KENDRIYA VIDYALAYA SANGATHAN

(BANGALURU REGION)

STUDY MATERIAL

SESSION 2024-25

CLASS -XII PHYSICS (042)

"Learning gives creativity, creativity leads to thinking, thinking provides knowledge, and knowledge makes you great."

PREFACE

This study material is the culmination of an extensive collaborative effort involving a dedicated team of educators and subject matter experts. With meticulous care, we have meticulously designed this resource to provide students with a succinct yet comprehensive tool for consolidating their knowledge.

Under the diligent guidance of our esteemed subject experts and the unwavering enthusiasm of our team, we have incorporated the entire curriculum and an extensive collection of practice questions spanning all chapters. Our paramount objective has been to ensure perfect alignment with the latest curriculum and examination patterns as set forth by the CBSE.

We firmly believe that this material will prove to be an invaluable resource, serving as a clear and concise repository of essential information for effective subject revision. It encompasses all the critical components necessary to assist in students' preparation and enhance their understanding of the subject matter.

Our aspiration is that this study material will emerge as a dependable aid for swift and efficient revision, instilling confidence in students and ultimately contributing to their academic success. We strongly encourage you to actively engage with the content, pose questions, and fully utilize this resource in your educational journey.

We extend our heartfelt best wishes for your studies and sincerely hope that this material becomes your trusted companion on the path to academic excellence.

KENDRIYA VIDYALAYA SANGATHAN

REGIONAL REGION

K. KAMARAJA ROAD

BENGALURU 560042

MESSAGE FROM THE DEPUTY COMMISSIONER

Dear students and teachers!

It is a matter of great pride and delight that KVS Bengaluru Region is putting forward the Students' Support Material (SSM) for class XIIth subject PHYSICS for the session 2024-25. I believe firmly that the subject experts have left no stone unturned to enable our students to add on more to their quality of performance by deep rooting more towards accessing required understating in the subject. Certainly, use of this SSM will help students in empowering themselves as one of the tools and will lead in bringing success.

With devotion, dedication & persistent hard work the team of experts has crafted out this SSM meticulously to complement the classroom learning experience of the students as well as to cope up with the Competency Based Questions as per the new pattern of examinations aligned with NEP-2020 and NCFSE-2023. This SSM, being well-structured and presented in a manner which makes it to be comprehended easily, will definitely serve as a precious supplement for self-study of students.

I am pleased to place on record my appreciation and commendation for the commitment and dedication of the team comprising of the subject experts in carving out such a useful edition of Students' Support Material for the students.

Wishing all the best!

(DHARMENDRA PATLE)
DEPUTY COMMISSIONER
KVS BENGALURU REGION

OUR PATRON

SHRI DHARMENDRA PATLE

DEPUTY COMMISSIONER, RO BENGALURU

SHRI P C RAJU

AC, RO BENGALURU

SHRI R PRAMOD

AC, RO BENGALURU

SMT HEMA K

AC, RO BENGALURU

MESSAGE FROM THE COORDINATOR

Dear Students,

I feel thrilled to commence on the study material for the Physics for class XII. My sincere appreciation and gratitude to the diligent team for the designing the practice material that caters to the revised pattern of CBSE. Congratulations to the committed team for their vital role in designing the practice material with inclusive competencies, analytical and critical reasoning questions summarizing all concepts.

I feel greatly honoured to be associated as a coordinator of diligent team in bringing out the Support Material for class XII Physics for the year 2024-25 and truly convinced that it would definitely help in learning and scoring high in exams.

Wishing success to all in the journey of learning.

I/C Principal,

PM SHRI K V Vijayapura, Karnataka

SHRI BANSHI LAL
I/C PRINCIPAL,PM SHRI KV VIJAYAPURA

MATERIAL PREPARED BY-

SLNO.	NAME OF THE TEACHER	NAME OF THE KV	CHAPTER / UNIT
1.	Sh. G. Gugan, PGT Physics	KV RWF Yelahanka	Reviewing committee members
2.	Sh. Satish Kumar Sivalanka, PGT Physics	KV Belagavi No.2 (Cantonment)	Reviewing committee members
3.	1. Mrs Nisha M Mohan 2. Mr A Jose Herbert Raj 3. Mrs. Neethu K	KV Hebbal	1. Electric Charges and Fields 2. Electrostatic Potential and Capacitance
4.	1. Mr. Rajendrnath U 2. Mrs. Rashmi K	KV MEG & Centre	3.Current Electricity
5.	1. Mr. Birender Singh 2. Mrs. Anupama Sharma 3. Mrs Lalithambika	KV Yelahanka - AFS	4. Moving Charges and Magnetism 5. Magnetism and Matter
6.	1. Mr. K Srihari 2. Dr Lalit Upadhyay	KV DRDO	6. Electromagnetic Induction 7. Alternating Current
7.	1. M. Govindan 2. Rajani C	KV IISc.	8. Electromagnetic Waves 9. Ray Optics and Optical
8.	Bheemarao M	KV Bidar - AFS	10. Wave Optics
9.	1. N Chandramouli 2. Mr. Boominathan B	KV Malleshwaram	11. Dual Nature of Radiation and Matter
10.	1. Mrs. Susmitha.LK 2. Mr. S N V Harinath Babu	KV Jalahalli No.2	12. Atoms 13. Nuclei
11.	1. Sarithan Swamy	KV Yelahanka- CRPF	14. Semiconductor Electronics: Materials, Devices and Simple Circuits
12.	Mr. Birender Singh	KV Yelahanka - AFS	SAMPLE PAPER WITH SOLUTION
13.	Mrs Lalithambika	KV Yelahanka - AFS	PRACTICE PAPER -01
14.	Mr. K. VEERABHADRAPPA	K V Bellari	PRACTICE PAPER -02

INDEX

1. ELECTRIC CHARGES AND FIELDS

	SYLLABUS
	Electric charges, Conservation of charge, Coulomb's law-force between two- point charges, forces between multiple charges; superposition principle and continuous charge distribution. Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric field. Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).
	GIST/FORMULAS/IMPORTANT DEFINITIONS/DIAGRAMS

ELECTRIC CHARGE

It is a scalar. SI unit is C.

METHODS OF CHARGING

- By friction
- By Induction
- By conduction

BASIC PROPERTIES OF ELECTRIC CHARGE

- Additivity of charges
- Charge is conserved
- Quantisation of charge

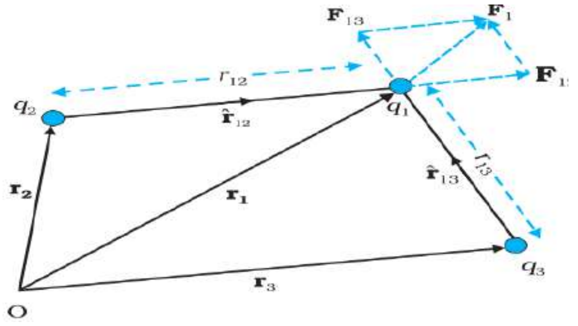
  q =ne

COULOMB'S LAW

$F = kq_1q_2/r^2$

$k = 1/4\pi\epsilon_0$, $\epsilon_0 = 8.854 \times 10^{-12}\ C^2\ N^{-1}m^{-2}$

FORCE BETWEEN MULTIPLE CHARGES



$$\mathbf{F}_1 = \mathbf{F}_{12} + \mathbf{F}_{13} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}^2}\hat{\mathbf{r}}_{12} + \frac{1}{4\pi\varepsilon_0}\frac{q_1q_3}{r_{13}^2}\hat{\mathbf{r}}_{13}$$

SUPERPOSITION PRINCIPLE

$$\mathbf{F}_1 = \mathbf{F}_{12} + \mathbf{F}_{13} + \ldots + \mathbf{F}_{1n} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{r_{12}^2}\hat{\mathbf{r}}_{12} + \frac{q_1q_3}{r_{13}^2}\hat{\mathbf{r}}_{13} + \ldots + \frac{q_1q_n}{r_{1n}^2}\hat{\mathbf{r}}_{1n}\right]$$

$$= \frac{q_1}{4\pi\varepsilon_0}\sum_{i=2}^{n}\frac{q_i}{r_{1i}^2}\hat{\mathbf{r}}_{1i} \quad ($$

CONTINUOUS CHARGE DISTRIBUTION

Linear charge density , $\lambda = q/l$

Surface charge density , $\sigma = q/A$

Volume charge density, $\rho = q/V$

ELECTRIC FIELD

$E = F/q_0$

SI unit = N/C, it is a vector .

ELECTRIC FIELD DUE TO A POINT CHARGE

$$\mathbf{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$$

The direction of E is on a radial line from q, pointing outward if q is positive and inward if q is negative.

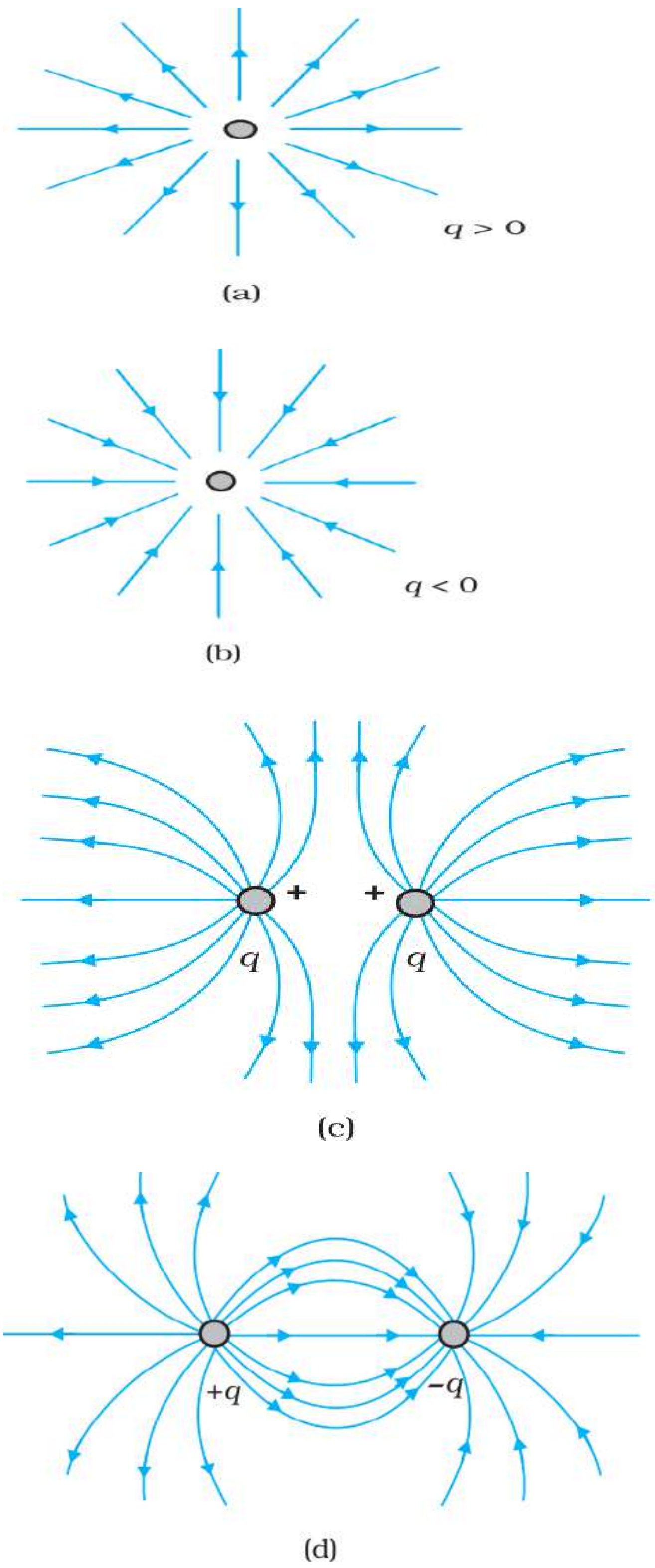
ELECTRIC FIELD LINES

A line of force is a curve drawn in a field such that the tangent at each point on the curve gives the direction of the field at that point.

PROPERTIES

i) Field lines start from positive charges and end at negative charges. If there is a single charge, they may start or end at infinity.
(ii) In a charge-free region, electric field lines can be taken to be continuous curves without any breaks.
(iii) Two field lines can never cross each other.
(iv) Electrostatic field lines do not form any closed loops.This follows from the conservative nature of electric field.

FIELD LINES DUE TO SOME SIMPLE CHARGE CONFIGURATIONS



ELECTRIC DIPOLE

An electric dipole is a pair of equal and opposite point charges q and –q, separated by a distance 2a.

ELECTRIC DIPOLE MOMENT (p)

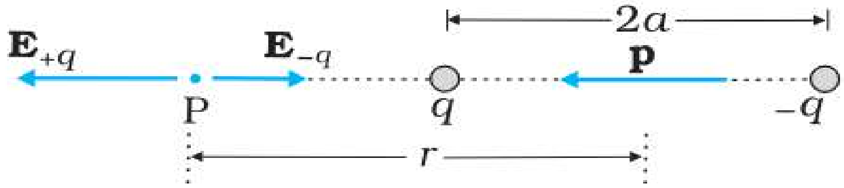
p = q x 2a

It is a vector whose direction is from –q to +q.

SI unit is Cm.

ELECTRIC FIELD DUE TO A DIPOLE

- FOR A POINT ON THE AXIS



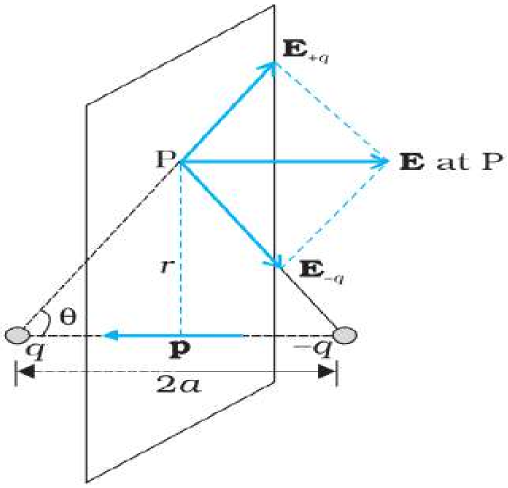
$$\mathbf{E} = \mathbf{E}_{+q} + \mathbf{E}_{-q} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{\mathbf{p}}$$

$$= \frac{q}{4\pi\varepsilon_o}\frac{4ar}{(r^2-a^2)^2}\hat{\mathbf{p}}$$

For $r >> a$

$$\mathbf{E} = \frac{4qa}{4\pi\varepsilon_0 r^3}\hat{\mathbf{p}} \qquad (r >> a)$$

- FOR POINTS ON THE EQUITORIAL PLANE



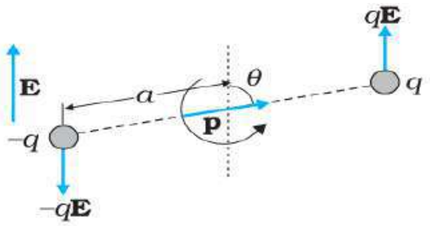
$$\mathbf{E} = -(E_{+q} + E_{-q})\cos\theta\ \hat{\mathbf{p}}$$

$$= -\frac{2qa}{4\pi\varepsilon_o(r^2+a^2)^{3/2}}\hat{\mathbf{p}}$$

At large distances ($r >> a$), this reduces to

$$\mathbf{E} = -\frac{2qa}{4\pi\varepsilon_o r^3}\hat{\mathbf{p}} \qquad (r >> a)$$

TORQUE ON A DIPOLE IN A UNIFORM ELECTRIC FIELD



Magnitude of torque $= qE \times 2a\sin\theta$
$= 2qaE\sin\theta$

$$\boldsymbol{\tau} = \mathbf{p} \times \mathbf{E}$$

ELECTRIC FLUX (φ)

The flux $\Delta\varphi$ of electric field through a small area element ΔS is given by

$\Delta\varphi = E.\ \Delta S$

It is a scalar.

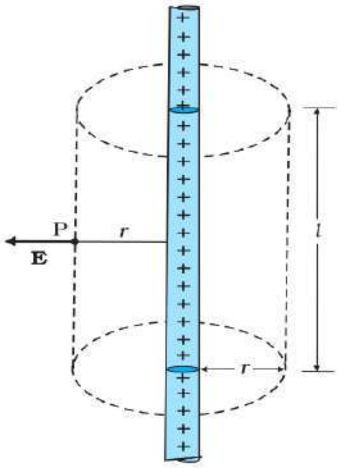
SI unit is Nm^2C^{-1}

GAUSS'S LAW

Gauss's law: The flux of electric field through any closed surface S is $1/\varepsilon_0$ times the total charge enclosed by surface.

$\Phi = q / \varepsilon_0$

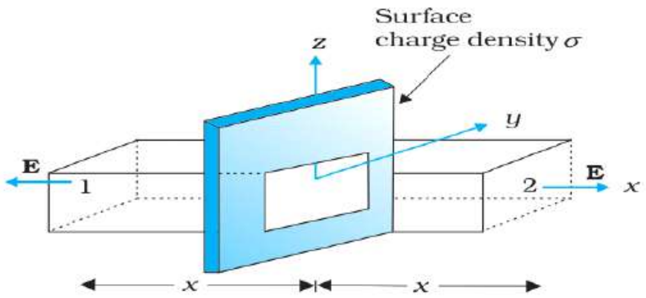
APPLICATIONS OF GAUSS'S LAW1). FIELD DUE TO AN INFINITELY LONG STRAIGHT UNIFORMLY CHARGED WIRE



$$\mathbf{E} = \frac{\lambda}{2\pi\varepsilon_0 r}\,\hat{\mathbf{n}}$$

where nˆ is the radial unit vector in the plane normal to the wire passing through the point. E is directed outward if λ is positive and inward if λ is negative.

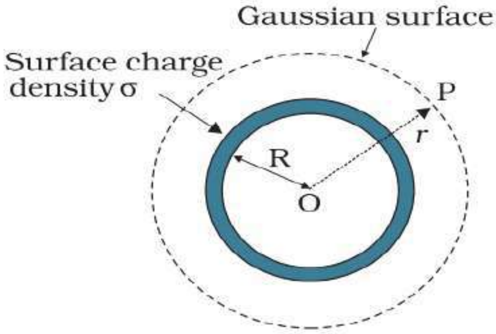
(ii)FIELD DUE TO A UNIFORMLY CHARGED INFINITE PLANE SHEET



$$\mathbf{E} = \frac{\sigma}{2\varepsilon_0}\,\hat{\mathbf{n}}$$

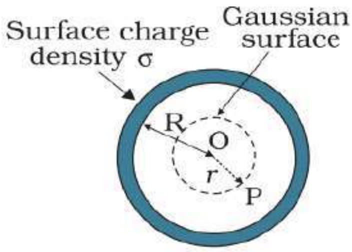
where nˆ is a unit vector normal to the plane and going away from it.

- FIELD DUE TO A UNIFORMLY CHARGED THIN SPHERICAL SHELL.
  - Field outside the shell



$$\mathbf{E} = \frac{q}{4\pi\varepsilon_0 r^2}\hat{\mathbf{r}}$$

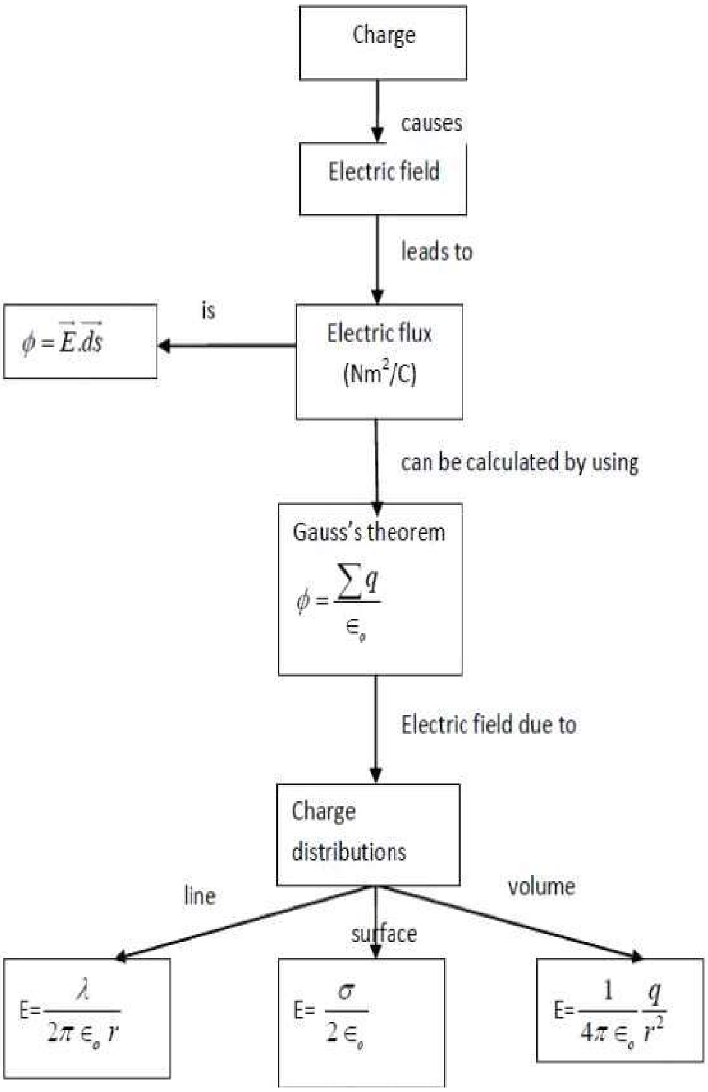
- Field inside the shell.

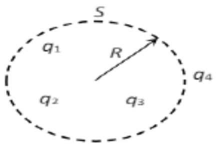


$$E \times 4\pi r^2 = 0$$

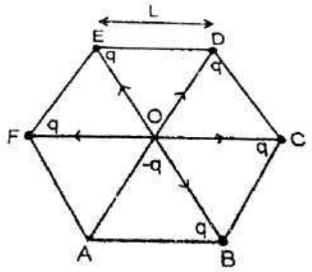
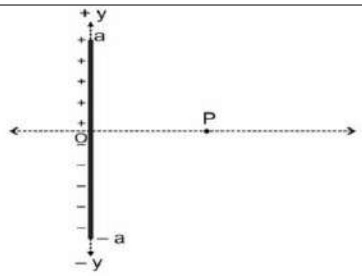
i.e., $E = 0 \qquad (r < R)$

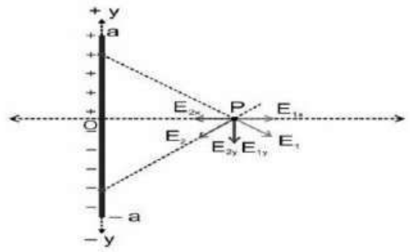
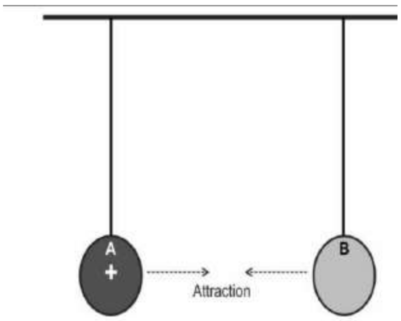
MIND MAP

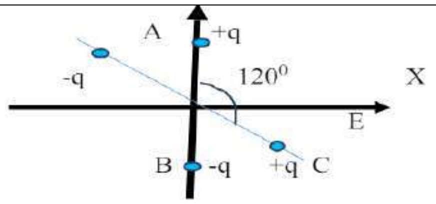
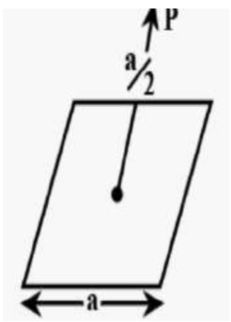

Charge
causes
Electric field
leads to
Electric flux
(Nm^2/C)
is
$\phi = \vec{E}.\vec{ds}$
can be calculated by using
Gauss's theorem
$\phi = \frac{\sum q}{\epsilon_o}$
Electric field due to
Charge distributions
line
surface
volume
E=$\frac{\lambda}{2\pi \epsilon_o r}$
E=$\frac{\sigma}{2 \epsilon_o}$
E=$\frac{1}{4\pi \epsilon_o}\frac{q}{r^2}$

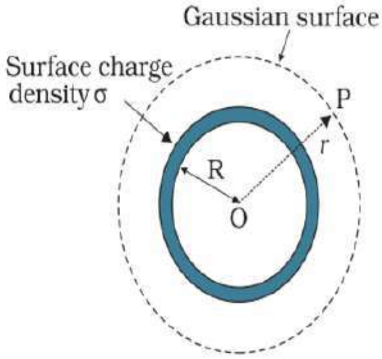
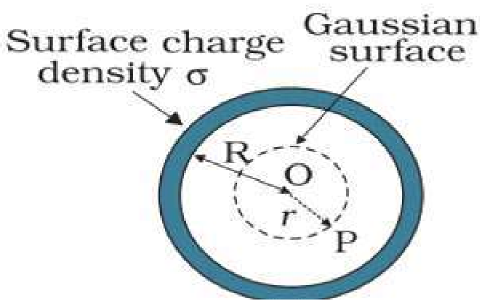
	COMPETENCY BASED QUESTIONS MCQ (1mark)
1.	Two positive ions each carrying a charge q are separated by a distance d. If F is the force of repulsion between the ions , the number of electrons missing from each ion (a) $\frac{4\pi\epsilon_0 F d^2}{e^2}$ (b) $\sqrt{\frac{4\pi\epsilon_0 F e^2}{d^2}}$ (c) $\sqrt{\frac{4\pi\epsilon_0 F d^2}{e^2}}$ (d) $\frac{4\pi\epsilon_0 F e^2}{d^2}$
2.	The total electric flux emanating from an alpha particle is (a) $2e/\varepsilon 0$ (b)$e/ \varepsilon 0$ (c) $4e/ \varepsilon 0$ (d) $e2 / \varepsilon 0$
3.	A charge Q is placed at each of the opposite corners of a sphere. A charge q is placed at each of the other corners .If the net electrical force on Q is zero then Q/q is equal to (a) $-2\sqrt{2}$ (b) -1 (c) 1 (d) $-1/\sqrt{2}$
4.	A cylinder of radius r and length l is placed in a uniform electric field parallel to the axis of the cylinder. The total flux for the surface of the cylinder is given by (a) zero (b) πr^2 (c) $\pi E r^2$ (d) $2E(\pi r^2)$
5.	q_1, q_2, q_3 and $q_4$are point charges located at points as shown in the figure and S is a spherical Gaussian surface of radius R. Which of the following is true according to the Gauss's law  (a) $\oint_s (\vec{E}_1 + \vec{E}_2 + \vec{E}_3).d\vec{s} = \frac{q_1+q_2+q_3}{2\varepsilon_0}$ (b) $\oint_s (\vec{E}_1 + \vec{E}_2 + \vec{E}_3).d\vec{s} = \frac{(q_1+q_2+q_3)}{\varepsilon_0}$ (c) $\oint_s (\vec{E}_1 + \vec{E}_2 + \vec{E}_3).d\vec{s} = \frac{(q_1+q_2+q_3+q_4)}{\varepsilon_0}$ (d) None of the above
6.	Seven charges of equal magnitude q are placed at the corners of a cube of side b. The force experienced by another charge Q placed at the center of the cube is (a) Zero (b) KQq/ 3b (c) 7KQq/3b (d) 2KQq/3b
7.	Electric charge is uniformly distributed along a long straight wire of radius 1mm. The charge per cm of the wire is Q coulomb. Another cylindrical surface of length L meter encloses the wire symmetrically, The total flux through the surface is (a) Q/ε_0 (b) LQ/ ε_0 (c) $QL/ 10^{-3}\varepsilon_0$ (d) $Q/L\ 10^{-3}\varepsilon_0$
8	A hemisphere is uniformly charged positively. The electric field at a point on the diameter away from the centre is directed (a) perpendicular to the diameter (b) parallel to the diameter. (c) at an angle tilted towards the diameter (d) zero

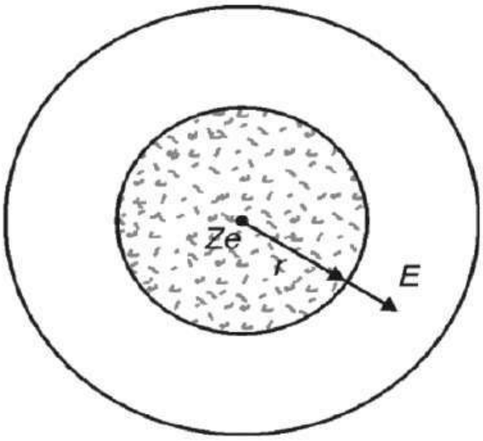
	ANSWERS 1.(a) 2. (a) 3. (a) 4. (a) 5.(b) 6. (d) 7. (b) 8. (a)
	COMPETENCY BASED QUESTIONS 2 MARKS QUESTIONS
1.	Calculate the electric field strength required to just support a water drop of mass 10^{-7} kg and having a charge $1.6x\ 10^{-19}$ C.
Ans.	Force on water drop due to electric field = Weight of water drop. qE =mg E $= 6.125x10^{12}$N/C
2.	A spherical rubber ballon carries some charge distributed uniformly over its surface. The balloon is blown up to increase in its size. How does the total electric flux coming out of the surface change?
Ans.	The total electric flux coming out of the surface of ballon remains unchanged. This is because total charge enclosed by the balloon is independent of size of the ballon.
3.	Two dipoles, made from charges and have equal dipole moments. Give the (i) Ratio between the separations of these two pairs of charges (ii) Angle between the dipole axes of these two dipoles
Ans.	As the two dipoles have equal dipole moments (i) Qx 2a' =q X 2a, 2a'/2a=q/Q (ιι) $\theta=0^o$
4.	The electrostatic force (F) acts between two point charges in a vacuum. If a brass plate is placed between the two charges. What would be the value of the electrostatic force?
Ans.	For any metal , K=∞, $F_{brass}=F_{vac}/K=F/\infty=0$
5.	A uniformly charged conducting sphere of diameter 24m has a surface charge density of 80μc/m2. Find the charge on the sphere and the total electric flux leaving the sphere.
	$Q = \sigma 4\pi r^2 = 80x\ 10^{-6}\ x\ 4x\ 3.14\ x\ (1.2)^2 = 1.45\ x\ 10^{-3}C$ $\Phi=Q/\epsilon_0 = 1.6\ x\ 10^8\ Nm^2C^{-1}$
6.	Two-point charges Q and -3Q are placed at some distance apart at some distance apart. If electric field at location of Q is E Find the field in the location of -3Q
Ans.	Field at -3Q due to Q is $E' = KQ/x^2$ away from Q E/E' = 3 Field at Q due to -3Q is $E = K.\ 3Q/x^2$ towards -3Q
7.	Why do the electrostatic field lines not form closed loops?

Ans.	Electric field lines do not form closed loops because the direction of an electric field is from positive to negative charge. So one can regard a line of force starting from a positive charge and ending on a negative charge. This indicates that electric field . lines do not form closed loops.
	COMPETENCY BASED QUESTIONS 3 MARKS QUESTIONS
1.	Five point charges, each of value +q are placed on five vertices of a regular hexagon of side Lm. What is the magnitude of the force on a point charge of value -q coulomb placed at the centre of the hexagon?
Ans.	If there had been a sixth charge +q at the remaining vertex of hexagon due to all the six charges on -q at O will be zero (as the forces due to individual charges will balance each other).  The resultant force , F = ($1/4\pi \varepsilon_0$) q/ L^2
2.	Given is a line of charge of uniform linear density. A charge +q is distributed uniformly between y = 0 and y = a and charge –q is distributed uniformly between y = 0 and y = -a. Explain how the direction of the resultant electric field at point P can be obtained. Represent using a vector diagram
Ans.	 The x-components of E1 and E2, due to two equidistant points on either side of O, cancel each other.The resultant electric field is due to the superposition of the y-components of E1 and E2.The direction of the net electric field is along the negative y-axis. This is true for all pairs of equidistant points on either side of O.

	
3.	A positively charged ball A hangs from a string. A non-conducting ball B is brought near ball A. Ball A is seen to be attracted to ball B.  (a) Give reason why it is NOT possible to determine whether ball B is negatively charged or neutral for sure from the above experiment alone. (b) Suggest any ONE additional experiment with ball B required to determine whether ball B is negatively charged or neutral for sure.
Ans.	(a) The attraction between A and B could be due to the following reasons: - B is negatively charged and hence A and B attract each other. - B is neutral. The two balls attract each other due to the polarization of molecules in neutral ball B. It is not possible to determine for sure that ball B is negative or neutral from this experiment alone. (b) Possible additional experiments: - A known neutral ball can be brought near ball B (without ball A nearby). If the neutral ball is attracted to ball B, then ball B is negatively charged for sure. If there is no interaction between the two balls, then ball B is neutral for sure.
4.	A spherical Gaussian surface encloses a positive charge q. Explain with a reason what happens to the net electric flux through the Gaussian surface if: (a) the charge is tripled (b) the volume of the sphere is tripled (c) the shape of the Gaussian surface is changed into a cuboid.

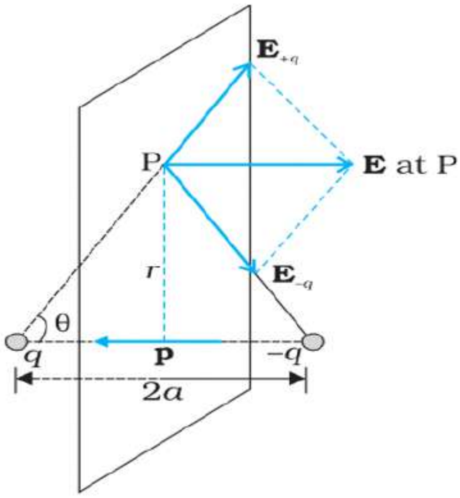
Ans.	(a) The net flux is also tripled because as per Gauss law the net flux is proportional to the net charge enclosed. (b) Regardless of the volume of the enclosed surface, if the net charge enclosed is the same, the net flux remains the same as per Gauss law. (c) No change in the net flux as it doesn't depend upon the shape of the closed surface.
5.	Two small identical electric dipoles AB and CD each of dipole moment P are kept at an angle 120^0 to each other in an electric field E pointing along the X axis. Find the dipole moment of the arrangement and the magnitude and direction of torque acting on it.
Ans.	 Dipole moment of AB is P **j** Dipole moment of CD = pcos30 **i** – pcos60 **j**= p√3/2 **i** -p/2 **j** Dipole moment of AB is P **j** Dipole moment of CD = pcos30 **i** – pcos60 **j**= p√3/2 **i** -p/2 **j** Net dipole moment = p√3/2 I + p/2 j | p| = P Directionθ = 30^0 Torque on dipole AB = (p **j** x E**i**) = pE **(-k)** Torque on CD = pE/2 (**k**) Net torque = pE/2 (**-k**)
	COMPETENCY BASED QUESTIONS 5 MARKS QUESTIONS
1.	a). Define electric flux. Is it a scalar or vector quantity? b).A point charge Q is placed at a distance a/2 above the centre of the square surface of edge a as shown in the figure. What is the electric flux through the square surface? c. If the point charge is now moved to a distance 'd' from the centre of the square and the side of the square is doubled, explain how the electric flux will be affected. 
Ans.	(a) No. of electric lines of force passing normal to the surface. It is a scalar quantity. (b) Draw an imaginary square enclosing that point charge at the centre.

	Then from gauss law, $\phi = Q/\epsilon o$ Electric flux through one face=1/6 ($Q/\epsilon o$) No change
2.	a). Derive an expression for electric field at a point outside and inside for a uniformly charged spherical shell b).An early model for an atom considered it to have a positively charged point nucleus of charge Ze, surrounded by a uniform density of negertive charge up to a radius R. The atom as a whole is neutral. For this model, what is the eletric field at a distance r from the nucleus?
Ans.	FIELD DUE TO A UNIFORMLY CHARGED THIN SPHERICAL SHELL. (a) Field outside the shell  $\mathbf{E} = \frac{q}{4\pi\varepsilon_0 r^2}\hat{\mathbf{r}}$ (b) Field inside the shell. 

	 $q_{in} = Ze - \frac{Ze}{\left(\frac{4}{3}\pi R^3\right)}\left(\frac{4}{3}\pi r^3\right)$ $q_{in} = Ze\left(1 - \frac{r^3}{R^3}\right)$ According to Gauss's law, $\oint \vec{E}.\vec{ds} = \frac{q_{in}}{\epsilon_0}$ $E(4\pi r^2) = \frac{Ze}{\epsilon_0}\left(1 - \frac{r^3}{R^3}\right)$ $\boxed{E = \frac{Ze}{4\pi\epsilon_0}\left(\frac{1}{r^2} - \frac{r}{R^3}\right)}$
3.	(a) Find the electric field due to an electric dipole on a point in an equatorial plane. (b) Two similar balls, each of mass m and charge q, are hung from a common point by two slik threads, each of length l. Prove that separation between the ball is $x = \left[\frac{q^2 l}{2\pi\varepsilon_0 mg}\right]^{1/3}$ if θ is small. Find the rate dq/dt with which the charge should leak off each sphere if thevelocity of approach varies as v=a/√x, where a is a constant.

Ans.

FOR POINTS ON THE EQUITORIAL PLANE

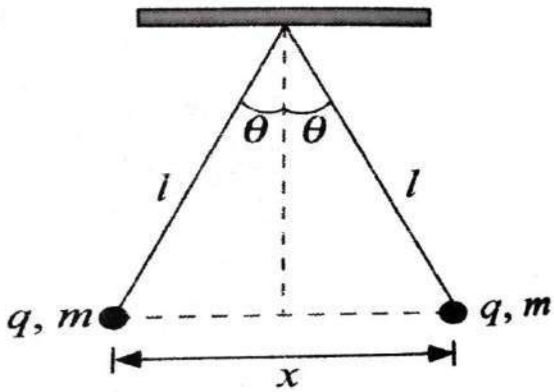


$$\mathbf{E} = -(E_{+q} + E_{-q})\cos\theta\ \hat{\mathbf{p}}$$

$$= -\frac{2qa}{4\pi\varepsilon_o (r^2 + a^2)^{3/2}}\hat{\mathbf{p}}$$

At large distances $(r >> a)$, this reduces to

$$\mathbf{E} = -\frac{2qa}{4\pi\varepsilon_o r^3}\hat{\mathbf{p}} \qquad (r >> a)$$



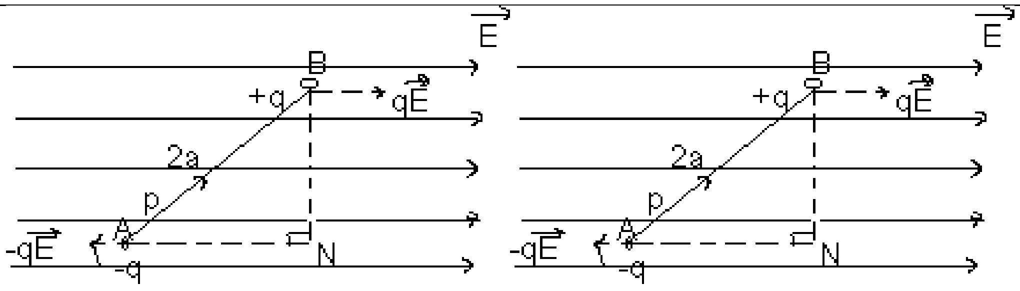
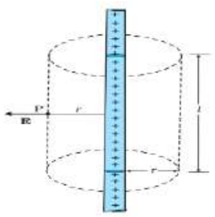
$$\tan\theta = \frac{F}{mg} = \frac{kq^2}{x^2 mg}$$

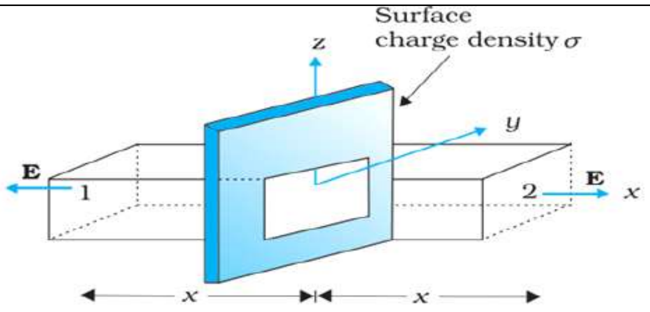
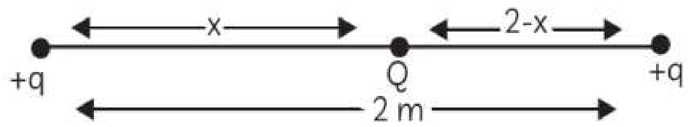
$$\frac{x}{21} = \frac{q^2}{4\pi\varepsilon_0 mg}$$

$$x = \left[\frac{q^2 l}{2\pi\varepsilon_0 mg}\right]^{1/3}$$. Hence proved.

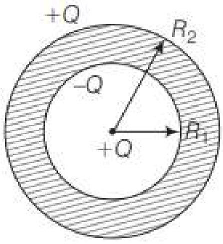
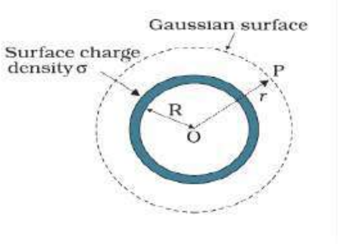
	1 MARK QUESTIONS
1.	Two charges q_1 and q_2 are placed at the centres of two spherical conducting shells of radius r_1 and r_2 respectively. The shells are arranged such that their centres are d [> (r_1+r_2)] distance apart. The force on q_2 due to q_1 is (a) $(1/4\Pi\varepsilon_0)\, q_1q_2/d^2$ (b) $(1/4\Pi\varepsilon_0)\, q_1q_2/(d - r_1)^2$ (c) Zero (d) $(1/4\Pi\varepsilon_0)\, q_1q_2/[d - (r_1 - r_2)]^2$
2.	When a negative charge (-Q) is brought near one face of a metal cube, the (a) cube becomes positively charged (b) cube becomes negatively charged. (c) face near the charge becomes positively charged and the opposite face becomes negatively charged. (d)face near the charge becomes negatively charged and the opposite face becomes positively charged.
3.	Let F1 be the magnitude of the force between two small spheres, charged to a constant potential in free space and F_2 be the magnitude of the force between them in a medium of dielectric constant K, Then F_1/F_2 is (a) 1/K (b) K (c) K^2 (d) 1/ K^2
4.	A charge Q is placed at the centre of the line joining two charges q and q. The system of the three charges will be in equilibrium if Q is (a) q/3 (b) – q/3 (c) q/4 (d) – q/4
5.	A point charge situated at a distance r from a short electric dipole on its axis, experience a force F. If the distance of the charge is 2r, the force on the charge will be (a) F/16 (b) F/8 (c) F/4 (d) F/2
6.	The magnitude of the electric field due to a point charge, object at a distance of 4m is 9 N/C. From the same charged object the electric field of magnitude, 16 N/C will be at a distance of (a) 1m (b) 2m (c) 3m (d) 6m
7.	An isolated point charge particle produces an electric field E at a point 3m away from it. The distance of the point at which the field is E/4 (a)2m (b) 3m (c) 4m (d) 6m
8.	Which one of the following is not a scalar quantity ? (a)Electric field (b) Voltage (c) Resistivity (d) Power
9.	An electric dipole of length 2cm is placed at an angle of 30˚ with an electric field of $2x10^5$ N/C. If the dipole experiences a torque of $8x10^{-3}$ Nm, the magnitude of either charge of the dipole , is (a) 4 µC (b) 7 µC (c) 8 mC (d) 2mC
10.	An electric dipole placed in a non-uniform electric field will experience

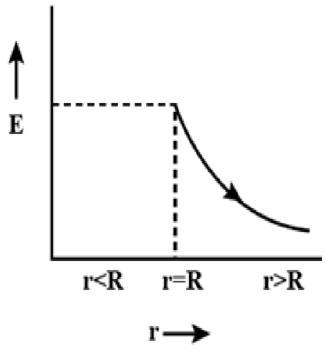
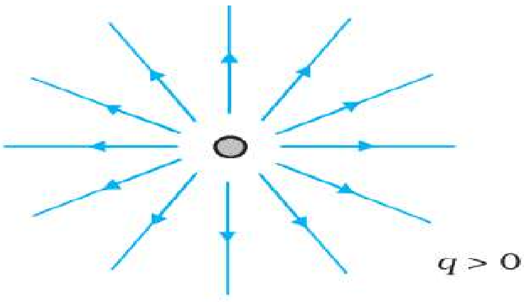
	(a) Only a force (b) only a torque (c) both force and torque (d) neither force nor torque
	ANSWER KEY
	(1) C (2) C (3) B (4) D (5) B (6) C (7) D (8) A (9) A (10) C
	ASSERSION- REASON QUESTIONS
	Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below A) Both A and R are true and R is the correct explanation of A B) Both A and R are true and R is NOT the correct explanation of A C) A is true but R is false D) A is false and R is also false.
1.	Assertion: The charge on anybody can be increased or decreased in terms of e. Reason: Quantization of charge means that the charge on a body is the integral multiple of e.
2.	Assertion : A Charge, which is less than charge of one electron is not possible Reason : Charge is quantized.
3.	Assertion: The properties that the force with which two charges attract or repel each other are not affected by the presence of a third charge. Reason: Force on any charge due to a number of other charges is the vector sum of all the forces on that charge due to other charges, taken one at a time.
4.	Assertion(A) : A metallic shield in the form of a hollow shell, can be built to block an electric field. Reason(R): In a hollow spherical metallic shell, electric field inside is zero at every point.
5.	Assertion: Coulomb force is the dominating force in the universe. Reason: Coulomb force is weaker than the gravitational force.
6.	Assertion (A): The range of gravitational force and coulomb force is infinity. Reason(R): The Coulomb force is stronger than the gravitational force.
7.	Assertion (A): The range of gravitational force and coulomb force is infinity. Reason(R): The Coulomb force is stronger than the gravitational force.
8.	Assertion (A): Positive electric flux indicates that electric lines of force are directed outwards Reason (R): Positive electric flux is due to a positive charge.
9.	Assertion (A): Electric field inside a metallic charged conductor is always zero whatever of amount of charge. Reason (R): Electric field lines are always perpendicular to surface of the metal.
10.	Assertion (A): Charge on a body is 2.3×10^{-19}C is not possible. Reason (R): Electric charge on a body is quantized and integral multiple of charge of an electron.
	ANSWER KEY

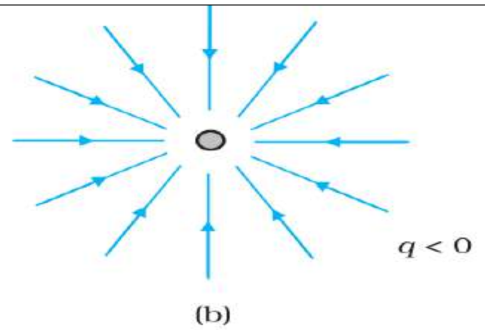
	(1) A (2) B (3) B (4) A (5) D (6) C (7) C (8) B (9) B (10) A
	2 MARKS QUESTIONS
1.	Derive the expression for the torque acting on an electric dipole, when it is held in a uniform electric field
Ans.	 Force on +q charge = + q E along the direction of E Force on –q charge = -q E opposite to the direction of E Net force on the dipole is F Net = +qE- qE =0 But the two force act at different point on the dipole. They form a couple and exerts torque. Torque = Force X perpendicular distance between lines of action of forces. τ = qE X 2a Sin θ τ = pE sin θ
2.	Use Gauss's law to obtain the expression for electric field due to an infinitely long straight uniformly charged wire
Ans.	The surface area of the curved part =$2\pi rl$ Flux through the Gaussian surface= $\varphi = E \times 2\pi rl$  From Gauss law $\Phi = q / \varepsilon_0$ $E \times 2\pi r l = \lambda l / \varepsilon_0$ $E = \lambda / 2\pi \varepsilon_0 r$ The direction of electric field is outward if charge is positive and inward if charge is negative.

3.	Use Gauss's law to obtain the expression for the elctric field due to a uniformly charged infinite plane thin sheet.
Ans.	 Let A be the cross section. As the electric field is parallel to the curved surface of the cylinder, the flux through the curved surface is zero. Total charge q = σ X A --(1) Flux through both surfaces = $\varphi = E\ X\ 2\ A$ ----------------------------(2) From Gauss Law, $\varphi = q/\ \epsilon_0$ --(3) $E \times 2A = \sigma$ X A ϵ_0 -----------------------(4) $E = \sigma/\ 2\epsilon_0$ If σ >0, the direction of E is outward. If σ<0, the direction of E is inward
4.	Two identical point charges, q each, are kept 2 m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q.
Ans.	Let x be the distance of Q from either charge. Let us assume the following figure:  First we need to figure out the sign of Q. Since, it has to be kept between the two positive charges, hence it has to be negative. This is so because if Q has positive charge, it will get repelled by both q charges and hence the system will not be in equilibrium. Now, the force on Q should be equal by both q and the equation will be given by: $\frac{Qq}{4\pi\varepsilon_0 x^2} = \frac{Qq}{4\pi\varepsilon_0 (2-x)^2}$ $x^2 = (2-x)^2$ $\Rightarrow x^2 = 4 + x^2 - 4x$ $x = 1\ \text{m}$
5.	Two identical conducting balls A and B have charges $-Q$ and $+3Q$ respectively. They are brought in contact with each other and then separated by a distance d apart. Find the nature of Coulomb force between them.

Ans.	The force between them is repulsive in nature. As the two balls are brought in contact with each other, they exchange their charges till they both attain the same charge which is, $[-Q+3Q]/2 = +Q$. Since, both acquire the same charge $+Q$, they repel each other.
6.	Two small identical conducting spheres carrying charge $10\mu C$ and $-20\mu C$ when separated by a distance of r, experience a force F each. If they are brought in contact and then separated to a distance of $r/2$, what is the new force between them in terms of F?
Ans.	Given, $q_1 = 10\mu C, q_2 = -20\mu C$ $r_1=r$, $r_2=r/2$ $F \alpha q_1 q_2$ and $F \alpha 1/r_2$ When two identical conductors having charges q_1 and q_2 are kept in contact and separated later then each has charge of $[q_1+q_2]/2$. Initial charges are $q1$ and $-q2$, then each has a final charge, $q' = [q1 + q2]/2$ $\therefore [10 + (-20)]/2 = -5\mu C$ So, $q'^2 = 25(\mu C)^2$ while $q_1 q_2 = (-200)(\mu C)^2$ So, $F'/F = [q'^2]/[r^2/4] \times r^2/q_1q_2$ $= [4 \times 25]/(-200) = -1/2$ $\Rightarrow F' = -F/2$ i.e., new force is repulsive and half of the initial force.
7.	A uniformly charged large plane sheet has charge density $\sigma = (1/18\pi) \times 10^{-15}$ C/m^2. Find the electric field at point A which is 50 cm from the sheet.
Ans.	$E = \frac{\sigma}{2\varepsilon_0}$ $\sigma = \left(\frac{1}{18\pi}\right) \times 10^{-15} C/m^2$ $E = \frac{\left(\frac{1}{18\pi}\right) \times 10^{-15} C/m^2}{2 \times 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}}$ On solving we get $E = 1 \times 10^{-6}$ N/C outwards. At point Q, because at 50 cm, the charge sheet acts as a finite sheet and thus the magnitude remains same towards the middle region of the plane sheet.
8.	A sphere encloses a charge of 8.85×10^{-8}C. (i) calculate the electric flux passing through the surface (ii) if the radius of the gaussian surface is tripled, how would the flux change.
Ans.	(i) Electric flux , $\varphi = q/\varepsilon_0$ $\Phi = 8.85 \times 10^{-8} / 8.85 \times 10^{-12}$ $\Phi = 10^4$ Nm^2/C (ii) Electric flux remains the same as the charge enclosed is same.

9.	A metallic spherical shell has an inner radius R1 and outer radius R2 . A charge Q is placed at the centre of the spherical cavity. What will be surface charge density on (i) the inner surface (ii) the outer surface? Here, the charge placed at the centre of the spherical cavity is positively charged. So, the charge created at the inner surface of the sphere, due to induction will be − Q and due to this charge created at outer surface of the sphere is + Q. 
Ans.	Now, surface charge density on the inner surface $= \frac{-Q}{4\pi R_1^2}$ and Surface charge density on the inner surface $= \frac{+Q}{4\pi R_2^2}$ Now, surface charge density on the inner surface $= \frac{-Q}{4\pi R_1^2}$ and Surface charge density on the inner surface $= \frac{+Q}{4\pi R_2^2}$
10.	What is the electric flux through one face of a cube enclosing a dipole of dipole moment $2x10^{-7}$ Cm? Justify your answer.
Ans.	Net charge of dipole is zero. Hence flux is zero.
	3 MARKS QUESTIONS
1.	Using Gauss's law, derive an expression for the electric field intensity at any point outside a uniformly charged thin spherical shell of radius R and charge density σ C/m². Draw the graph of electric field E versus distance r. Draw the field lines when the charge density of the sphere is (i)positive (ii) negative
Ans.	**Electric field outside the shell:** 

	Consider a point P outside the shell with the radial vector r. Let P be the point on the Gaussian surface to be a sphere of radius R with the centre O passing through P. The electric field at each point of Gaussian surface has the same magnitude E and is along the radius vector at each point. Thus E and ΔS at every point are parallel. Flux = E ΔS. The total flux over the Gaussian surface= $E * 4\pi r^2$ Charge $q = \sigma X 4 \pi R^2$,From Gauss Law, $\Phi = q / \varepsilon_0$ $E x 4 \Pi r^2 = \sigma x 4 \Pi R^2$ $E = \sigma R^2 / \varepsilon_0 r^2$ But charge $q = \sigma 4\pi R^2$, $E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$ The direction of the field is radially out ward, if the charge on the shell is +ve.  field lines when the charge density of the sphere is (i) Positive  (a) (ii) Negative

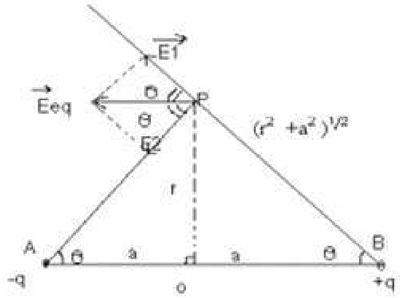


2. Derive the expression for electric field at a point on the equatorial plane of an electric dipole.

Ans. Consider an electric dipole consisting of charges –q and +q separated by a distance of 2a, placed in air. Let P be a point on the equatorial line of the dipole at a distance r from o.

Electric Field at point P due to charge +q = $E_1 = \frac{1}{4\pi\epsilon_0} \times \frac{q}{r^2+a^2}$ along BP

Electric field at point P due to charge –q = $E_2 = \frac{1}{4\pi\epsilon_0} \times \frac{-q}{r^2+a^2}$ along AP



The angle between two vectors E1 and E2 is 2θ.

The magnitude of the resultant vector E is given by

$E^2 = E1^2 + E2^2 + 2\,E1\,E2\cos 2\theta$. Since E1 = E2

The magnitude of the resultant field at P is E= 2 E1 Cosθ

= 2E1 Cosθ

$$E = 2 \times \frac{1}{4\pi\epsilon_0} \times \frac{q}{r^2+a^2} \times \frac{a}{\sqrt{r^2+a^2}}$$

Dipole moment p = 2a X q $\quad E = \frac{1}{4\pi\epsilon_0} \times \frac{p}{(r^2+a^2)^{3/2}}$

Assume that the distance between two charges is smaller than r

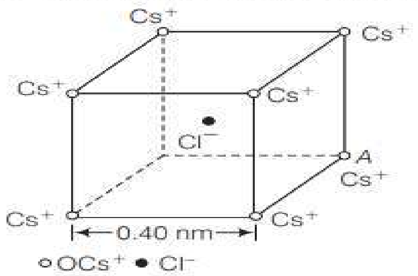
$$E = \frac{1}{4\pi\epsilon_0}\frac{p}{r^3}$$

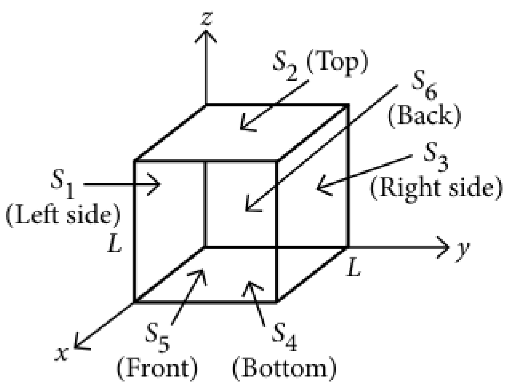
The direction of this resultant electric field is opposite to that of the dipole moment.

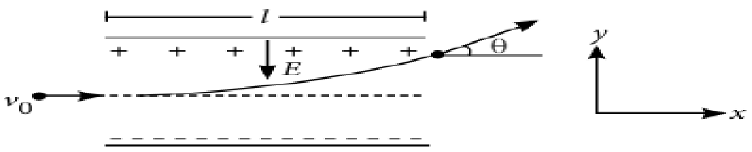
3. Figure represents a crystal unit of cesium chloride, CsCl. The cesium atoms, represented by open circles are situated at the corners of a cube of side 0.40nm, whereas a Cl atom is situated at the centre of the cube. The Cs atoms are deficient in one electron while the Cl atom carries an excess electron.

(i) What is the net electric field on the Cl atom due to eight Cs atoms?

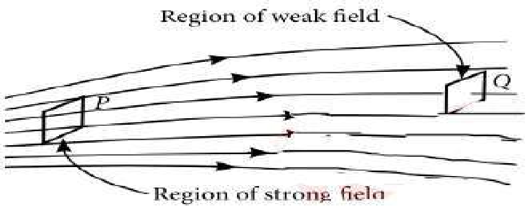
(ii) Suppose that the Cs atom at the corner *A* is missing. What is the net force now on the Cl atom due to seven remaining Cs atoms?



Ans.	(i) From the given figure, we can analyse that the chlorine atom is at the centre of the *i.e.*, at equal distance from all the eight corners of cube where cesium atom placed. Thus, due to symmetry the forces due to all Cs tons, on Cl atom will cancel Hence, $E = \frac{F}{q}$ where $F = 0$ $\therefore$ $E = 0$ (ii) Thus, net force on Cl atom at *A* would be, $F = \frac{e^2}{4\pi\varepsilon_0 r^2}$, where, r = distance between Cl ion and Cs ion. Applying Pythagorous theorem, we get $r = \sqrt{(0.20)^2 + (0.20)^2 + (0.20)^2} \times 10^{-9}$ m $= 0.346 \times 10^{-9}$ m Now, $F = \frac{q^2}{4\pi\varepsilon_0 r^2} = \frac{e^2}{4\pi\varepsilon_0 r_2}$ $= \frac{9\times 10^9 (1.6\times 10^{-19})^2}{(0.346\times 10^{-9})^2} = 1.92\times 10^{-9}$ N
	CASE STUDY QUESTIONS (4 MARKS EACH)
1.	Observe the figure, read the data given below and answer the following questions  The cube as shown in Fig. has sides of length L=10.0 cm. The electric field is uniform, has a magnitude $E=4.00\times10^3 NC^{-1}$, and is parallel to the xy−plane at an angle of 37° measured from the +x−axis towards the +y−axis.

	(i) Electric flux passing through surface S6 is (a) $-24\ Nm^2C^{-1}$ (b) $24\ Nm^2C^{-1}$ (c) $32\ Nm^2C^{-1}$ (d) $-32\ Nm^2C^{-1}$ (ii) The dimensional formula of surface integral $\int \mathbf{E} \cdot d\mathbf{S}$ of an electric field is (a) $[M\ L^2\ T^{-2}\ A^{-1}]$ (b) $[M\ L^3\ T^{-3}\ A^{-1}]$ (c) $[M^{-1}\ L^3\ T^{-3}\ A]$ (d) $[M\ L^{-3}\ T^{-3}\ A^{-1}]$ (iii) The surfaces that have zero flux are (a) S1 and S3 (b) S4 and S6 (c) S2 and S4 (d) S1 and S (iv) The total net electric flux through all faces of the cube is (a) $8\ N\ m^2C^{-1}$ (b) $-8\ N\ m^2C^{-1}$ (c) $24\ N\ m^2C^{-1}$ (d) zero
Ans.	(i) d (ii) b (iii) b (iv) d
2.	When a charged particle is placed in an electric field, it experiences an electrical force. If this is the only force on the particle, it must be the net force. The net force will cause the particle to accelerate according to Newton's second law. So, **F**=q**E**= m**a.**  If **E** is uniform, then **a** is constant and **a**= q **E** /m . If the particle has a positive charge, its acceleration is in the direction of the field. If the particle has a negative charge, its acceleration is in the direction opposite to the electric field. Since the acceleration is constant, the kinematic equations can be used. **(i)** An electron of mass m, charge e falls through a distance h metre in a uniform electric field E. then time of fall, (a) $t = \sqrt{\frac{2hm}{eE}}$ (b) $t = \frac{2hm}{eE}$ (c) $t = \sqrt{\frac{2eE}{hm}}$ (d) $t = \frac{2eE}{hm}$ (ii) The electric flux through a closed surface area S enclosing charge Q is f. If the surface area is doubled, then the flux is (a) 2ϕ (b) $\phi/2$ (c) $\phi/4$ (d) ϕ (iii)A Gaussian surface encloses a dipole. The electric flux through this surface is (a) $\frac{q}{\varepsilon_0}$ (b) $\frac{2q}{\varepsilon_0}$ (c) $\frac{q}{2\varepsilon_0}$ (d) zero (iv) In an electric field directed upwards, an electron will experience a force directed (a) Downward force of magnitude e E (b)Upward force of magnitude e E (c)Downward force of magnitude e/E (d)Upward force of magnitude e/E
Ans.	(i) a (ii) d (iii) d (iv) a

3. Electric field strength is proportional to the density of lines of force i.e., electric field strength at a point is proportional to the number of lines of force cutting a unit area element placed normal to the field at that point. As illustrated in the given figure, the electric field at P is stronger that at Q.



(i) Electric lines of force about a positive point charge are

(a) radially outwards

(b) circular clockwise

(c) radially inwards

(d) parallel straight lines.

(d) parallel straight lines.

(ii) Which of the following is false for electric lines of force?

(a) They always start from positive charges and terminate on negative charges.

(b) They are always perpendicular to the surface of a charged conductor.

(c) They always form closed loops.

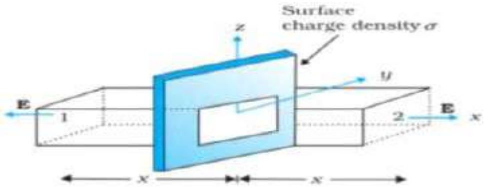
(d) They are parallel and equally spaced in a region of uniform electric field.

(iii) Which one of the following patterns of electric line of force in not possible in filed due to stationary charges?

(iv)The figure below shows the electric field lines due to two positive charges. The magnitudes EA, EB and EC of the electric fields at points A, B and C respectively are related as

(a) $E_A > E_B > E_C$ (b) $E_B > E_A > E_C$ (c) $E_A = E_B > E_C$ (d) $E_A > E_B = E_C$

Ans. (i) a (ii) c (iii) c (iv) a

	5 MARKS QUESTIONS
1.	**(i) Define electric flux and write its SI unit.** **(ii) Use Gauss' law to obtain the expression for the electric field due to a uniformly charged infinite plane sheet.** **(iii) A cube of side L is kept in space, as shown in the figure. An electric field $\vec{E} = (Ax + B)\,\hat{i}\ \frac{N}{C}$ exists in the region. Find the net charge enclosed by the cube.**
Ans.	(i) $\phi = \vec{E}.\vec{A}$ **Alternatively:** Electric flux is the number of electric field lines passing through an area normally. S.I. unit of electric flux Nm^2/C or V-m. (ii)  From Gauss's law:- $\phi = \oint \vec{E}\cdot\vec{dA} = \frac{q}{\varepsilon_o}$ $2EA = \frac{\sigma A}{\varepsilon_o}$ $E = \frac{\sigma}{2\varepsilon_o}$ (iii) $\phi_L = Eds\cos 180^o = -Eds$ $= -BL^2$ $\phi_R = Eds\cos 0^0 = Eds$ $= (AL+B)L^2 = AL^3 + BL^2$ Net flux $= \phi_L + \phi_R$ $= (AL^3 + BL^2) - BL^2$ Net flux $= AL^3 = \frac{q}{\epsilon_o}$ $\Rightarrow q = AL^3\,\epsilon_o$

2.

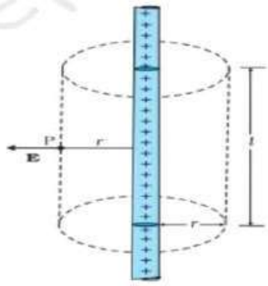
(i) Use Gauss' law to obtain an expression for the electric field due to an infinitely long thin straight wire with uniform linear charge density λ.

(ii) An infinitely long positively charged straight wire has a linear charge density λ. An electron is revolving in a circle with a constant speed v such that the wire passes through the centre, and is perpendicular to the plane, of the circle. Find the kinetic energy of the electron in terms of magnitudes of its charge and linear charge density λ on the wire.

(iii) Draw a graph of kinetic energy as a function of linear charge density λ.

Ans.

(i)



Flux through the Gaussian surface

$\emptyset = E.2\pi rl$

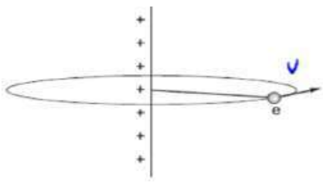
According to Gauss's law

$$E.2\pi rl = \frac{q}{\epsilon_0}$$

$\because \quad q = \lambda l$

$$E = \frac{\lambda}{2\pi \epsilon_0 r}$$

(i) $$E = \frac{\lambda}{2\pi \epsilon_0 r}$$



$$\frac{mv^2}{r} = eE$$

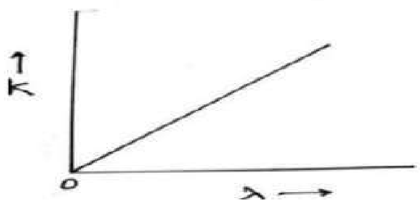
$\therefore$ Kinetic energy $K = \frac{1}{2}mv^2$

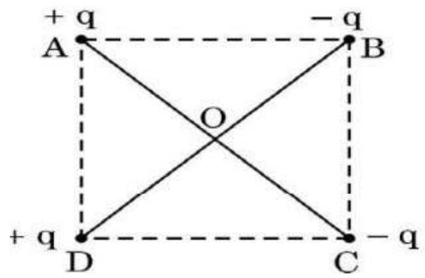
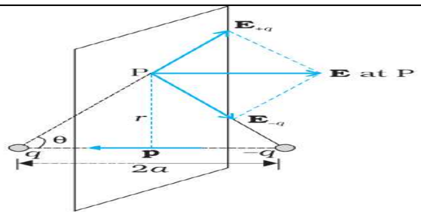
$$= \frac{1}{2}eEr$$

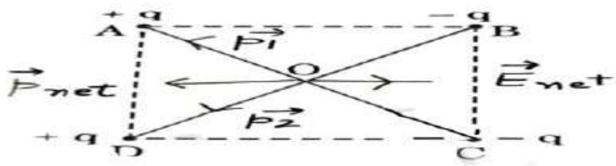
$$= \frac{1}{2}e\frac{\lambda.r}{2\pi \epsilon_0 r} = \frac{e\lambda}{4\pi \epsilon_0}$$

(ii) Kinetic energy $K = = \frac{e\lambda}{4\pi \epsilon_0}$

$\therefore \quad K \propto \lambda$



3.	(i) Derive an expression for the electric field at a point on the equatorial plane of an electric dipole consisting of charges q and − q separated by a distance 2a. (ii) The distance of a far off point on the equatorial plane of an electric dipole is halved. How will the electric field be affected for the dipole ? (iii) Two identical electric dipoles are placed along the diagonals of a square ABCD of side $\sqrt{2}$ m as shown in the figure. Obtain the magnitude and direction of the net electric field at the centre (O) of the square. 
Ans.	 $E_{+q} = \frac{q}{4\pi \epsilon_o} \times \frac{1}{r^2 + a^2}$ $E_{-q} = \frac{q}{4\pi \epsilon_o} \times \frac{1}{r^2 + a^2}$ The components normal to dipole axis cancel away. The components along the dipole axis add up. Total electric field is opposite to dipole moment. $\overline{E} = -(E_{+q} + E_{-q}) \cos\theta \hat{p}$ $= \frac{-2qa}{4\pi \epsilon_o (r^2 + a^2)^{3/2}} \hat{p}$ $= \frac{-\vec{p}}{4\pi \epsilon_o (r^2 + a^2)^{3/2}}$ Deduct ½ mark if the expression of electric field is not in vector form. ii) At far off point r >> a $\vec{E} = \frac{-\vec{p}}{4\pi \epsilon_o r^3}$ When distance is halved. $\vec{E} = \frac{-\vec{p}}{4\pi \epsilon_o (\frac{r}{2})^3}$ $= \frac{-8\vec{p}}{4\pi \epsilon_o r^3}$ $\vec{E}$ becomes 8 times

	iii.  p_1= q X 2 along OA p_2= q X 2 along OD $P_{net} = \sqrt{p_1^2 + p_2^2}$ $= 2\sqrt{2}\, q\, Cm$ Electric field at centre O $E = \frac{kp_{net}}{(r^2+a^2)^{3/2}}$ at point O, r = 0 , a = 1 m $E = \frac{k \times 2\sqrt{2}q}{1^3} = 2\sqrt{2}kq = \frac{2\sqrt{2}q}{4\pi \epsilon_o}$ Along DC
	ASSIGNMENTS
	2 MARKS QUESTIONS
1	An attractive force of 5N is acting between two charges of +2.0 μC & -2.0 μC placed at some distance. If the charges are mutually touched and placed again at the same distance, what will be the new force between them?
2.	A spherical balloon carries a charge that is uniformly distributed over its surface. As the balloon is blown up and increases in size, how does the total electric flux coming out of the surface change? Give reason
3.	Two point charges placed at a distance r in air exert a force F on each other. At what distance will these charges experience the same force F in a medium of dielectric constant k?
4.	A force F is acting between two charges placed some distance apart in vacuum. If a brass rod is placed between these charges, how does the force change?
5.	Define electric lines of force and give its two important properties
	3 MARKS QUESTIONS
1.	An electric dipole is held in a uniform electric field. (i)Using suitable diagram, show that it does not undergo any translator motion. (ii)Derive an expression for the torque acting on it and specify its direction.
2.	A charge is distributed uniformly over a ring of radius a. Obtain an expression for the electric intensity E a point on the axis of the ring. Hence show that for points at large distances from the ring, it behaves like a point charge.
3.	A long charged cylinder of linear charge density λ_1 is surrounded by a hollow co-axial conducting cylinder of linear charge density – λ_2 . Use Gauss's law to obtain expressions for the electric field at a point (i) In the space between the cylinders.

	(ii) Outside the larger cylinder.
4.	(a) State Gauss's law. Using this law, obtain the expression for the electric field due to an infinitely long straight conductor of linear charge density λ. (b)A wire AB of length L has linear charge density $\lambda = kx$ where x is measured from the end A of the wire. This wire is enclosed by a Gaussian hollow surface. Find the expression for the electric flux through the surface.
5.	Two large parallel thin metallic plates are placed close to each other. The plates have surface charge densities of opposite signs and of magnitude 20×10^{-12} C/ m^2. Calculate the electric field intensity (i) in the outer region of the plates (ii) in the interior region between the plates
	5 MARKS QUESTIONS
1.	(a) Derive an expression for the electric field at any point on the axial line of an electric dipole. (b)Two identical point charge q each are kept 2m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q.
2.	(a) Derive an expression for the electric field E due to a dipole of length '2a'at a point distant r from the centre of the dipole on the axial line (b) Draw a graph of E versus r for r>>a. (c) If this dipole were kept in a uniform external electric field E_o diagrammatically represent the position of the dipole in stable and unstable equilibrium and write the expressions for the torque acting on the dipole in both the cases.
3.	.(i) Use Gauss's law to obtain the expression for the electric field due to an infinitely long thin straight wire with uniform linear charge density λ. (ii)An infinitely long positively charged straight wire has a linear charge density λ. An electron is revolving in a circle with a constant speed v such that the wire passes through the centre, and is perpendicular to the plane, of the circle. Find the kinetic energy of the electron in terms of magnitudes of its charge and linear charge density λ on the wire. (iii) Draw a graph of kinetic energy as a function of linear charge density λ.

****

2. ELECTROSTATIC POTENTIAL AND CAPACITANCE

SYLLABUS: Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges; equipotential surfaces, electrical potential energy of a system of two-point charges and of electric dipole in an electrostatic field.

Conductors and insulators, free charges and bound charges inside a conductor. Dielectrics and electric polarization, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of a parallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor (no derivation, formulae only).

GIST

- **Electric potential difference.** The electric potential difference between two points in an electric field is defined as the amount of work done per unit positive test charge in moving the test charge from one point to the other against the electrostatic force due to the field.

Unit. Its SI unit is volt (V)

1 volt (V) = 1 joule /coulomb

Electric potential. The electric potential at a point in an electric field is defined as the amount of work done per unit positive test charge in moving the test charge from infinity to that point against the electrostatic force due to the field.

Mathematically - If W is work done in moving a small positive test charge from infinity to point A in the electrostatic field of charge q, then potential at point A,

V= WAB/q

- **Electric potential due to group of charges.** The electric potential at a point due to a group of charges is equal to the algebraic sum of the electric potentials due to individual charges at that point. It is because of the reason that electric potential is a scalar quantity.
- **Potential gradient.** The rate of change of potential with distance at a point is called potential gradient at that point.

The electric field at a point is equal to the negative of potential gradient at that point.

Mathematically E= - dV/dr

Unit. Its unit in SI is volt /metre (V/m).

- **Equipotential surface**. The surface inan electric field having same potential at all points is called equipotential surface. Two equipotential surfaces can never intersect each other.
- **Electrostatic potential energy of a system of charges**. The electric potential energy of a system of point charges is the work needed to bring the charges from an infinite separation to their final positions. Its SIunit is joule (J) or electron volt (eV). **1 eV =1.6 x 10^{-19}J**
- **Potential energy of an electric dipole in a uniform electric field.**

If the electric dipole is rotated from initial orientation making angle Θ_1, with the electric field to the final orientation making angle Θ_2 , with the field, then

$U = pE(\cos \Theta_2 - \cos \Theta_1)$

- **Behaviour of a charged conductor**

Charges reside only at the surface of the charged conductor.

The electric potential is constant at the surface and inside the conductor.

. The electric field is zero inside the conductor and just outside it, the electric field is normal to the surface.

- **Capacitor :**It is an arrangement for storing a very large amount of charge.
- **Electrical capacitance**. The ability of a conductor to store charge is called its electrical capacitance.

Mathematically $C = Q/V$ Its SI unit is farad (F).

1 farad (F) = 1 coulomb /volt (C/ V)

- **Capacitance of a spherical conductor**. $C = 4\pi\epsilon_0 r$,r is radius (in metre) of the spherical conductor.
- **Principle**. The capacitance of a conductor gets increased greatly, when an earth connected conductor is placed near it.
- **Parallel plate capacitor**

It consists of two flat, parallel metal plates separated by a small distance. The space between the plates may have vacuum or some other insulating material such as mica, glass or paper.

- **Energy stored in a capacitor**.

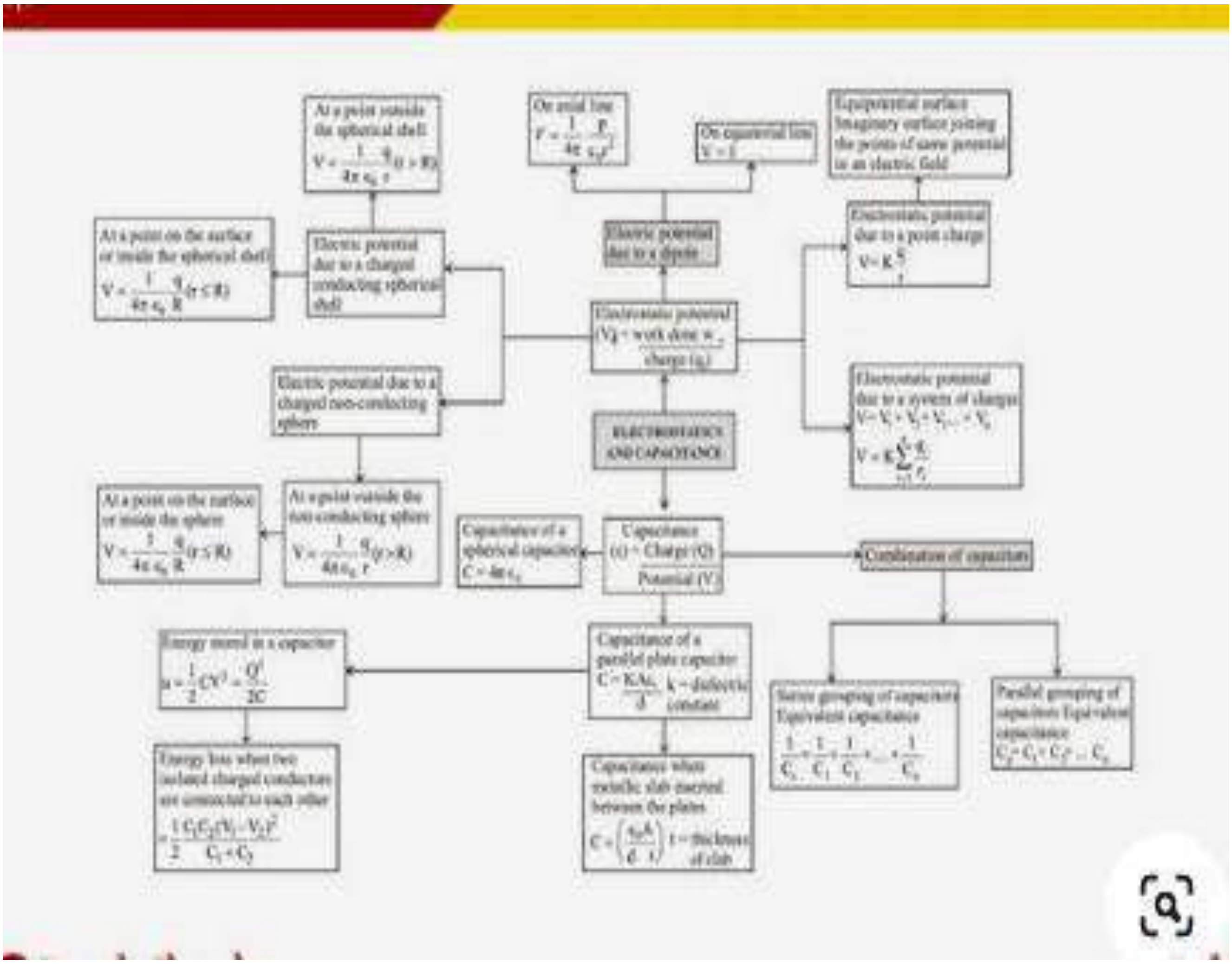
Work done in charging a capacitor gets stored in the capacitor in the form of its electrostatic potential energy.

- **Dielectric constant**. The ratio of the strength of the applied electric field to the strength of reduced value of electric field on inserting the dielectric slab between the plates of a capacitor is called the dielectric constant of the slab.
- **Dielectric strength**. The maximum value of electric field (or potential gradient) that can be applied to the dielectric without its electric breakdown is called dielectric strength of the dielectric. Its unit is V/m (same as that of electric field).
- **Effect of dielectric slab on the capacitance of a parallel plate capacitor.**

When a dielectric slab of dielectric constant K is introduced between the plates, then ,

$$C' = \frac{K\epsilon_0 A}{d} \qquad C' = KC_0.$$

MIND MAP



Electric Potential

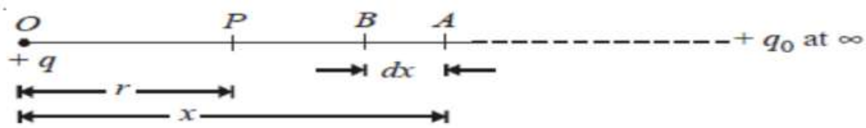
Electric potential *at a point in an electric field is equal to the* ***work done in bringing a unit positive charge (against electric field) from infinity to that point along any path.***

$$V = \frac{W}{q_0} = \frac{q}{4\pi\epsilon_0 r}$$

Unit- Volt (JC^{-1}).Scalar quantity.

ELECTRIC POTENTIAL DUE TO A SINGLE POINT CHARGE

Consider a point charge +*q* placed at point *O* in free space/air as shown in Fig. It is desired to find electric potential at *P* due to charge +*q*. Let *r* be the distance of point *P* from *O i.e,.OP = r*.



At point *A* at *a* distance *x* from charge +*q*, electric field intensity is

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}$$

Small amount of work done/C in moving positive test charge from *A* to *B* (where *AB* = *dx*) is

dW= – E dx

The negative sign is taken because *dx* is measured along the negative direction of *x*.

∴Total amount of work done/*C* in bringing a small positive test charge from infinity to *r* is

$$W = \int_{\infty}^{r} - E\,dx = \int_{\infty}^{r} - \frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}dx$$

$$= -\frac{q}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{1}{x^2}dx = \frac{-q}{4\pi\varepsilon_0}\left[-\frac{1}{x}\right]_{\infty}^{r}$$

$$= -\frac{q}{4\pi\varepsilon_0}\left[-\frac{1}{r}+\frac{1}{\infty}\right] = \frac{q}{4\pi\varepsilon_0 r}$$

Therefore, $V = \frac{q}{4\pi\epsilon_0 r}$

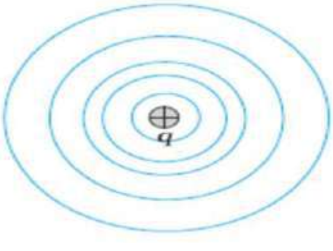
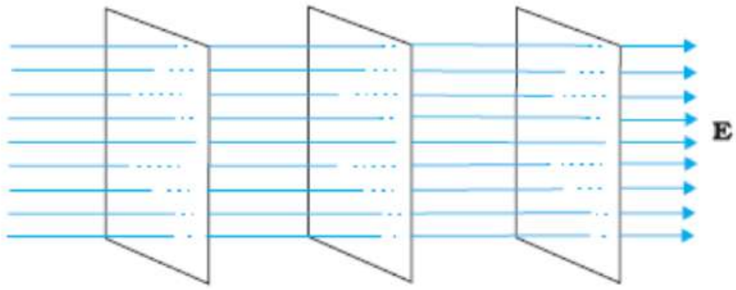
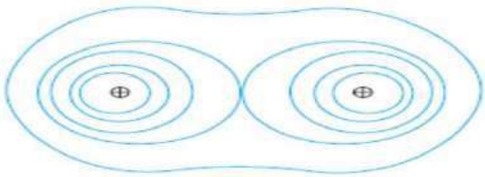
ELECTRIC FIELD INTENSITY AND POTENTIAL DIFFERENCE,

$$E = -\frac{dV}{dr}$$

EQUIPOTENTIAL SURFACE

Any surface over which the potential is constant is called an ***equipotential surface*****.**

Few equipotential surfaces

 Equipotential surface due to point charge	Equipotential surface due to a uniform field 
 Equipotential surface due to a dipole	 Equipotential surface due to equal charges

Properties of equipotential surfaces.

(i) ***Work done in moving a charge over an equipotential surface is zero***.

The work done in moving a test charge $+q_0$ from A to B is given by;

$W_{AB} = (V_B - V_A)\, q_0$

Since $V_B - V_A = 0$, $W_{AB} = 0$

Hence, no work is done in taking a charge from one point to another over an equipotential surface.

(ii) ***The electric field is always perpendicular to an equipotential surface.*** we have,

$$V_B - V_A = -\vec{E}.\overrightarrow{dr}$$

But

$$V_B - V_A = 0$$

Therefore,

$$-\vec{E}.\overrightarrow{dr} = 0$$

It implies that, E perpendicular to r.

(iii) ***Two equipotential surfaces can never intersect.*** If two equipotential surfaces could intersect, then at the point of intersection there would be two values of electric potential which is not possible.

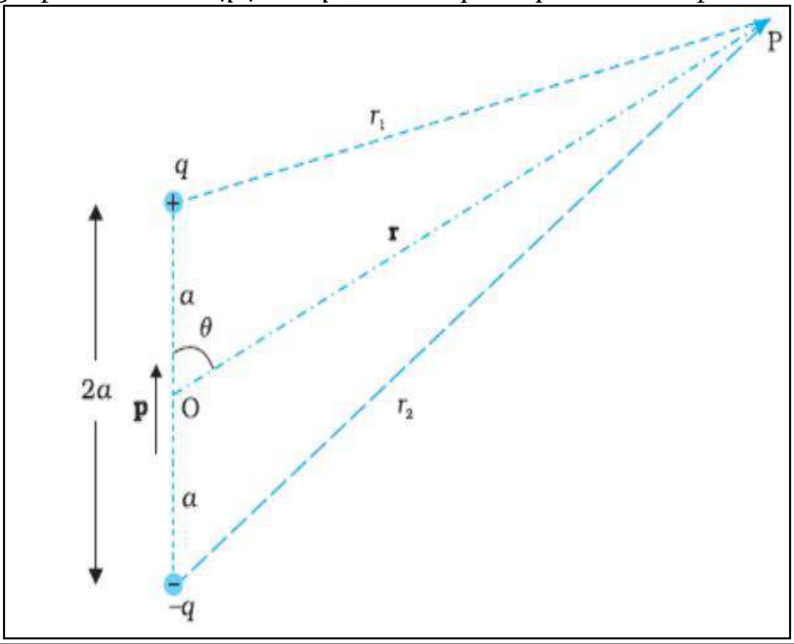
(*iv*) ***The spacing between equipotential surfaces enables us to identify regions of strong and weak fields.***

ELECTRIC POTENTIAL ENERGY

The electric potential energy of a system of point charges is the ***work needed to bring the charges from an infinite separation to their final positions.***

POTENTIAL DUE TO AN ELECTRIC DIPOLE

Consider an electric dipole $(\pm q, 2a)$ having dipole moment $|\vec{p}| = 2qa$, from –q to +q. Let P be a point at(r,θ)from the centre$O$ of the dipole (*i.e.*, OP = r). It is desired to find the Electric Potential at P due to the dipole as shown in fig.



$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r_1} - \frac{q}{r_2}\right)$$

Now, by geometry,

$$r_1^2 = r^2 + a^2 - 2ar\cos\theta$$

$$r_2^2 = r^2 + a^2 + 2ar\cos\theta$$

We take r much greater than a ($r >> a$) and retain terms only upto the first order in a/r

$$r_1^2 = r^2\left(1 - \frac{2a\cos\theta}{r} + \frac{a^2}{r^2}\right)$$

Similarly,

$$r_2^2 \cong r^2\left(1 + \frac{2a\cos\theta}{r}\right)$$

Using the Binomial theorem and retaining terms upto the first order in a/r ; we obtain,

$$\frac{1}{r_1} \cong \frac{1}{r}\left(1 - \frac{2a\cos\theta}{r}\right)^{-1/2} \cong \frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right)$$

$$\frac{1}{r_2} \cong \frac{1}{r}\left(1 + \frac{2a\cos\theta}{r}\right)^{-1/2} \cong \frac{1}{r}\left(1 - \frac{a}{r}\cos\theta\right)$$

Using Eqs. (2.9) and (2.13) and $p = 2qa$, we get

$$V = \frac{q}{4\pi\varepsilon_0}\frac{2a\cos\theta}{r^2} = \frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$$

Now, $p\cos\theta = \mathbf{p}\cdot\hat{\mathbf{r}}$

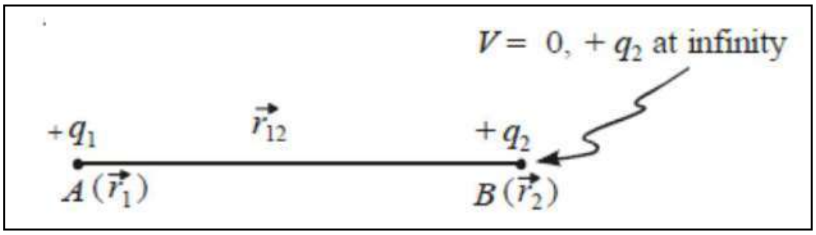
The electric potential of a dipole is then given by

$$V = \frac{1}{4\pi\varepsilon_0}\frac{\mathbf{p}\cdot\hat{\mathbf{r}}}{r^2}; \qquad (r >> a)$$

POTENTIAL ENERGY OF TWO-CHARGE SYSTEM

(*i*) First assume that the two charges $+q_1$ and $+q_2$ are infinite apart at rest. If we bring charge $+q_1$ from infinity to its original position *A*, no work is done because no electrostatic force acts on it due to any other charge.

(*ii*) When we bring charge $+q_2$ from infinity (where $V = 0$) to its original position *B*, work will have to be done due to the repulsive force of $+q_1$. This work done is equal to potential difference between *B* and ∞multiplied by charge $+q_2$, *i.e*.



$$W = (V_B - 0)\, q_2$$

$$V_B = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$

$$W = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$

By definition, this is the electric potential energy (*U*) of the two-charge system.

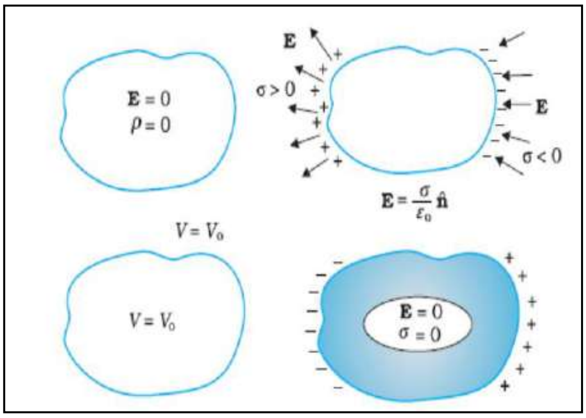
$$U = W = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$

Potential energy of a system of two charges in an external field

$$= q_1 V(\mathbf{r}_1) + q_2 V(\mathbf{r}_2) + \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$

Important electrostatic properties of a conductor

1. Inside a conductor, electrostatic field is zero.
2. At the surface of a charged conductor, electrostatic field must be normal to the surface at every point because surface of the conductor is an equipotential surface.
3. The interior of a conductor can have no excess charge in the static situation because E=0 and therefore ∑Q=0(from Gauss theorem)
4. Electrostatic potential is constant throughout the volume of the conductor and has the same value (as inside) on its surface because work done is zero from surface to inside as at surface E is perpendicular and inside E=0.
5. Electric field at the surface of a charged conductor $E = \frac{\sigma}{\epsilon_0}$



ELECTROSTATIC SHIELDING: *The phenomenon of protecting a certain region of space from external electric field is called* **electrostatic shielding.**

*Since, Electric field inside a conductor is zero therefore i*f we want to protect delicate instruments from external electric field, we enclose them in hollow conductors.

Dielectric Strength: The maximum electric field that a dielectric medium can withstand without its electrical break-down.
e.g. for air it is about 3×10^6 Vm^{-1}.

Capacitor

It consists of two metallic conductors electrically insulated from each other as well as their surroundings.

It is used to store electrical energy in the form of electric field lines. The total charge of the capacitor is zero.

Principle of Capacitor: The charge storing capacity of a conductor can be increased considerably by bringing an uncharged earthed conductor near it.

Capacitance(C): The ratio of charge of capacitor to the potential difference across its ends.

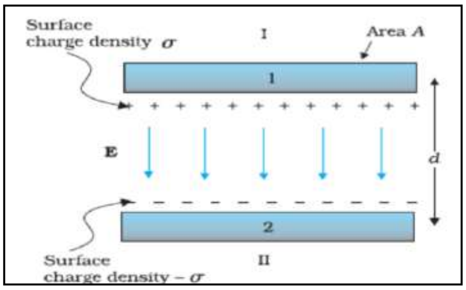
$$C = \frac{Q}{V}$$

SI unit of capacitance is 1 farad (=1 coulomb $volt^{-1}$) or 1 F = 1 C V^{-1}.

It does not depend on charge and potential. It depends only on the dimension of the capacitor.

Graph between Q and V is a straight line.

PARALLEL PLATE CAPACITOR : It consists of two flat, parallel metal plates separated by a small distance as shown in Fig. The space between the plates may have vacuum or some other insulating material such as mica, glass or paper.



CAPACITANCE OF PARALLEL PLATE CAPACITOR

Consider a parallel plate capacitor having air/vacuum in the space between the plates.

Let A = area of each plate, d = distance between the plates

V = p.d. across the plates, q = charge on each plate

σ = surface charge density on either plate = q/A

The electric field between the plates is uniform and its magnitude is given by

$$E = \frac{\sigma}{\varepsilon_0} = \frac{q}{A\varepsilon_0}$$

Also $$V = Ed = \frac{q}{A\varepsilon_0} d$$

or $$\frac{q}{V} = \frac{\varepsilon_0 A}{d}$$

But q/V is the capacitance of the parallel plate capacitor.

∴ $$C = \frac{\varepsilon_0 A}{d}$$

CAPACITANCE OF PARALLEL PLATE CAPACITOR WITH A DIELECTRIC SLAB

Consider a parallel plate capacitor having dielectric in the space between the plates.

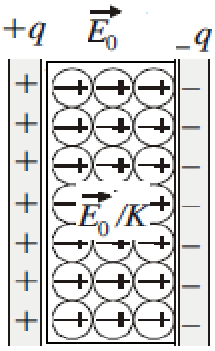
Let A = area of each plate

d = distance between the plates

V = p.d. across the plates

q = charge on each plate

σ = surface charge density on either plate = q/A



In the absence of dielectric, field between the plates

$$E_0 = \frac{\sigma}{\epsilon_0} = \frac{q}{A\epsilon_0}$$

The electric field due to the charged plates induces a net dipole moment in the dielectric. This effect, called polarization ,gives rise to a field in the opposite direction.

The net electric field inside the dielectric is thus reduced and given by

$$E' = \frac{E_0}{K} = \frac{q}{KA\epsilon_0}$$

Also, $$V' = E'd = \frac{q}{KA\epsilon_0}$$

$$\frac{q}{V'} = \frac{K\epsilon_0 A}{d}$$

But q/v' is the capacitance,therefore, $$C' = \frac{K\epsilon_0 A}{d} \Rightarrow C' = KC_0$$

RELATIVE PERMITTIVITY or DIELECTRIC CONSTANT

$$K = \frac{C_m}{C_{air}} = \frac{\text{Capacitance of capacitor with dielectric between the plates}}{\text{Capacitance of the same capacitor with air between the plates}}$$

Effect of introducing a dielectric of constant K between the plates of parallel plate capacitor

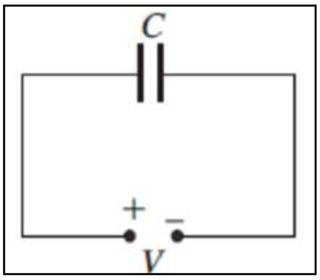
Physical Quantity	**When the capacitor connected**	**When the capacitor disconnected**
Capacitance	K times	K times
Charge	K times	Constant
Potential Difference	constant	$\frac{1}{K}$ times
Electric Field	$\frac{1}{K}$ times	$\frac{1}{K}$ times
Potential Energy	K times	$\frac{1}{K}$ times

Energy stored in a Capacitor

During charging a capacitor, transfer of electrons take place from one plate of the capacitor to the other . This work done by the battery in moving the electron is stored in the form of electric potential energy in the electric field between the plates. $U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$

ENERGY DENSITY

Consider a charged parallel plate capacitor of plate area A and plate separation $d$as shown in Fig.



$$\text{Energy stored} = \frac{1}{2}CV^2$$

Volume of space between plates $= A\,d$

$\therefore$ Energy density, $u = \frac{\text{Energy stored}}{\text{Volume}} = \frac{CV^2}{2Ad}$

We know that capacitance of a parallel plate capacitor is $C = \varepsilon_0 A/d$.

$\therefore$ $u = \frac{\varepsilon_0 A}{d} \times \frac{V^2}{2Ad} = \frac{1}{2}\varepsilon_0\left(\frac{V^2}{d}\right)$

But V/d is the electric field intensity (E) between the plates.

$\therefore$ Energy density, $u = \frac{1}{2}\varepsilon_0 E^2$

When two capacitors are connected then

(i) Common Potential, $V_C = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$

(ii) New charge on each capacitor, $q_1 = C_1V_C$, $q_2 = C_2V_C$

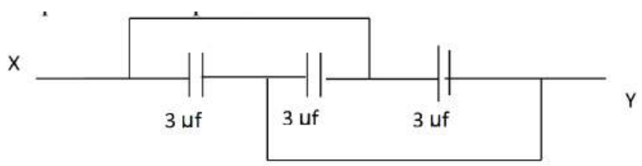
(iii) Energy loss, $\Delta E = \frac{1}{2}\frac{C_1C_2}{C_1+C_2}(V_1 - V_2)^2$

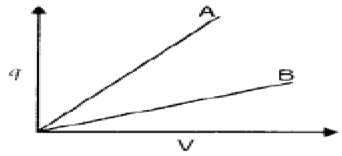
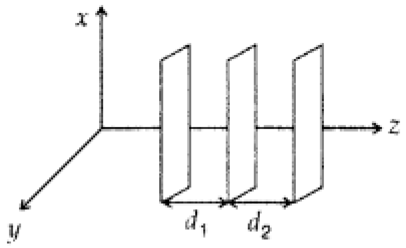
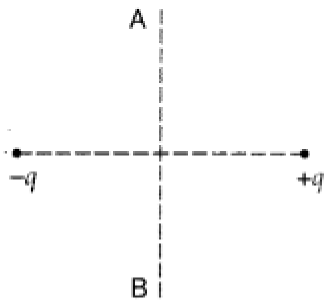
(iv) This energy is lost in the form of heat and electromagnetic radiation.

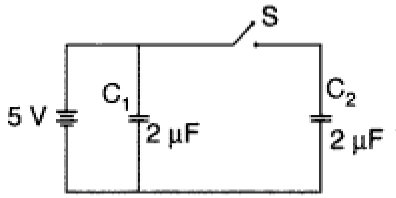
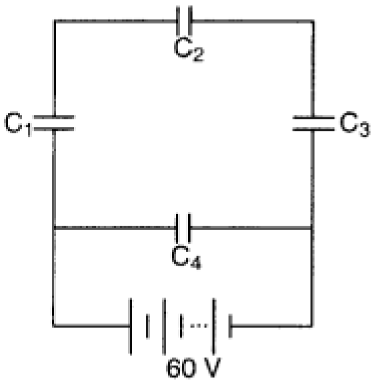
(v) For uncharged capacitor take V=0

COMPETENCY BASED QUESTIONS	
1	Consider a uniform electric field in the z-direction. The potential is a constant (a) for any x for a given z (b) for any y for a given z (c) on the x-y plane for a given z (d) all of these
ANS	**d**
2	In a parallel plate capacitor, the capacity increases if (a) area of the plate is decreased. (b) distance between the plates increases. (c) area of the plate is increased. (d) dielectric constant decreases
ANS	**c**

3	When two identical charges approaches each other then electric potential energy of the system (a) Increases (b) decreases (c) may increase or decrease (d) remains constant
ANS	**a**
4	Two charges + 3 μC and – 3 μC are placed at points A(0,0,4cm) and B(0,0,-4cm.) respectively. Work done to move a charge of 2 μC from point P (0,1cm,0) to point Q (2cm,0,0) will be (a) 2 mJ (b) Zero (c) 1 mJ (d) 4 mJ
ANS	b
5	Three capacitors each of capacitance 3 μF are first connected in series and then in parallel. Ratio of effective capacitance in series C_s and in parallel C_P is (a) 9 (b) 1/9 (c) 2/9 (d) 9/2
ANS	b
6	Two capacitors 3 μF and 6 μF are connected in series and connected to 100 V d.c. source. What is the ratio of energies stored in them (a) 1:2 (b) 1:3 (c) 2:1 (d) 3:1
ANS	c
7	SI unit of line integral of electric field is (a) J (b) N /C (c) N c^{-1} m^2 (d) J / C
ANS	d
8	Two parallel plate air capacitors A and B have plate separation in ratio 1:3 and plate area in ratio 2:3. Ratio of their capacitances (a) 1:2 (b) 1:3 (c) 2:1 (d) 3:1
ANS	c
9	To protect a given region from the effect of electric fields and charges (a) it should be enclosed in a non magnetic material (b) it should be enclosed in a metallic conductor (c) it should be enclosed in a magnetic material (d) it should be enclosed in an insulating material
ANS	b
10	Four capacitor each of capacitance 16μF areare given. Equivalent capacitance will be 4μF when (a) all are connected in parallel (b) three are connected in parallel and one in series with them (c) all are connected in series (d) three are connected in series and one in parallel with them
ANS	c

<u>ONE MARK QUESTIONS</u>	
1	A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. What is the potential at the centre of the sphere?
ANS	The electric field inside the shell is zero. This implies that potential is constant inside the shell (as no work is done in moving a charge inside the shell) and, therefore, equals its value at the surface, which is 10 V.
2	What is the work done in moving a test charge q through a distance of 1 cm along the equatorial axis of an electric dipole?
ANS	Zero
3	Why is electrostatic potential constant throughout the volume of the conductor and has the same value (as inside) on its surface?
ANS	$E = -\frac{dV}{dr} \Rightarrow \frac{dV}{dr} = 0 \quad \therefore \mathbf{V = constant}$
4	A point charge Q is placed at point O as shown. Is the potential difference ($V_A - V_B$) positive, negative or zero if Q is positive 
ANS	If q is positive charge, $V_A - V_B$ = negative
5	What will happen to the Capacitance when a dielectric slab is placed between the plates of the capacitor?
ANS	Increases
<u>2 MARKS QUESTIONS</u>	
1	Find the equivalence capacitance between X and Y. 
ANS	9 µ F
2	The given graph shows variation of charge 'q' versus potential difference 'V' for two capacitors C_1 and C_2. Both the capacitors have same plate seperation but plate area of C_2 is

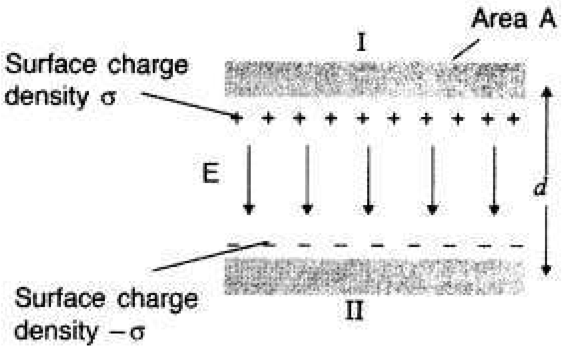
	greater than that of C_1. Which line (A or B) corresponds to C_1 and why? 
ANS	Line B corresponds to C_1 Reason: Since slope (qv) of 'B' is less than that of 'A'
3	. Draw 3 equipotential surfaces corresponding to a field that uniformly increases in magnitude but remains constant along Z-direction. How are these surfaces different from that of a constant electric field along Z-direction?
ANS	$d_2 < d_1$ for increasing field and $d_2 = d_1$ for uniform field. 
4	. i) Can two equipotential surfaces intersect each other? Give reasons. (ii) Two charges -q and + q are located at points A (0, 0, – a) and B (0, 0, +a) respectively. How much work is done in moving a test charge from point P (7, 0, 0) to Q (-3,0,0)?
ANS	i) No, if they intersect, there will be two different directions of electric field at that point which is not correct. If they intersect, then at the same point of intersection, there will be two values of potential. This is not possible and hence two equipotential surfaces cannot intersect. (ii) Since both the points P and Q are on the equatorial line of the dipole and V = 0 at every point on it, work done will be zero. Also the force on any charge is perpendicular to the equatorial line, so work done is zero
5	A charge 'q' is moved from a point A above a dipole of dipole movement 'p' to a point B below the dipole in equitorial plane without acceleration. Find the work done in the process. 
ANS	No work is done [W = q V_{AB} = q × 0 = 0, since potential remains constant]
3 MARKS QUESTIONS	
1	Figure shows two identical capacitors C_1 and C_2, each of 2 μF capacitance, connected to a battery of 5 V. Initially switch 'S' is left open and dielectric slabs of dielectric constant K = 5 are inserted to fill completely the space between the plates of the two capacitors. How will the

	charge and  (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted?
ANS	(i) When switch S is open and dielectric is introduced, charge on each capacitor will be $q_1 = C_1 V$, $q_2 = C_2 V$ $q_1 = 5CV$ $= 5 \times 2 \times 5 = 50\ \mu C$, $q_2 = 50\ \mu C$ Charge on each capacitor will become 5 times (ii) P.d. across C_1 is still 5V and across C_2, $q = (5C)\ V$ $V' = \frac{V}{5} = \frac{5}{5} = \mathbf{1V}$
2	..A network of four capacitors, each of capacitance 30 pF, is connected across a battery of 60 V as shown in the figure.Find the net capacitance and the energy stored in each capacitor. 

ANS	Answer: $\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ ...[∵ C_1, C_2 and C_3 are in series or $\frac{1}{C'} = \frac{1}{30} + \frac{1}{30} + \frac{1}{30} = \frac{3}{30} = \frac{1}{10}$ ∴ $C' = 10\,\mu F$ C_4 and C' are in parallel ∴ $C_{net} = C' + C_4 = 10 + 30 = \mathbf{40\,\mu F}$ Energy stored in C_1, C_2 and $C_3 = \frac{1}{2}C'V^2$ $= \frac{1}{2} \times 10 \times 10^{-6} \times 3600\ J = 18 \times 10^{-3}\ J$ Energy stored in each of the capacitor C_1, C_2 and C_3 = $\mathbf{6 \times 10^{-3}\ J}$ ∴ Energy stored in capacitor C_4 $= 1/2 \times (30 \times 10^{-6} \times 3600)\ J$ $= 54000 \times 10^{-6} = \mathbf{5.4 \times 10^{-2}\ J}$
3	Net capacitance of three identical capacitors in series is 1 pF. What will be their net capacitance if connected in parallel? Find the ratio of energy stored in the two configurations if they are both connected to the same source.
ANS	*When connected in series:* $C_S = \frac{C}{3} = 1\ \mu F$ ∴ $C = 3\ \mu F$ *When connected in parallel:* $C_p = C + C + C = 3 + 3 + 3 = 9\ \mu F$ Energy stored in capacitor $E = \frac{1}{2}CV^2$ ∴ $\frac{E_s}{E_p} = \frac{\frac{1}{2}C_sV^2}{\frac{1}{2}C_pV^2} = \frac{C_s}{C_p} = \frac{1}{9} = \mathbf{1:9}$
4	Two point charges q_1 and q_2 are located at $\vec{r1}$ and $\vec{r2}$ respectively in an external electric field $\vec{E}$ .Obtain the expression for the total work done in assembling this configuration
ANS	Work done in bringing the charge q_1 from infinity to position r_1 $W_1 = q_1V(r_1)$ Work done in bringing charge q_2 to the position r_2 $W_2 = q_2V(r_2) + \frac{q_1q_2}{4\pi\varepsilon_0 r_{12}}$ Hence, total work done in assembling the two charges

	w = $W_1 + W_2$ $= q_1V(r_1) + q_2V(r_2) + \frac{q_1q_2}{4\pi\varepsilon_0 r_{12}}$
5	An electric dipole of length 4 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of 4√3 Nm. Calculate the potential energy of the dipole, if it has charge ± 8 nC
ANS	1st method Given : $2a = 4$ cm $= 4 \times 10^{-2}$ m, $\theta = 60°$ $\tau = 4 \times \sqrt{3}$ Nm, $q = \pm 8$ nC $= \pm 8 \times 10^{-9}$ CP.E. = $\|p\|\ \|E\| \cos\theta$, $\tau = \|p\|\ \|E\| \sin\theta$ $\frac{P.E.}{\tau} = \frac{\|p\|\ \|E\|\cos\theta}{\|p\|\ \|E\|\sin\theta} = \cot\theta = \cot 60°$ $P.E. = \tau\cot\theta = 4 \times \sqrt{3} \times \frac{1}{\sqrt{3}}$ $\therefore$ **P.E. = −4 Joules** **2nd method** $\because\ \tau = pE\sin\theta$ $\therefore\ E = \frac{\tau}{p\sin\theta}$ $\qquad p = q \times 2a$ $\therefore\ E = \frac{4\times\sqrt{3}}{8\times10^{-9}\times4\times10^{-2}\times\frac{\sqrt{3}}{2}} = \frac{1}{4}\times10^{11}$ Now P.E. = $\|p\|\ \|E\|\cos\theta$ $= (q \times 2a)(E)\cos\theta$ $= (8\times10^{-9}\times4\times10^{-2})\times\left(\frac{1}{4}\times10^{11}\right)\times\frac{1}{2}$ $= -4$ Joules $\qquad [\because \cos 60° = \frac{1}{2}$
	5 Marks Questions
1	(a) Define the SI unit of capacitance. (b) Obtain the expression for the capacitance of a parallel plate capacitor. (c) Derive the expression for the affective capacitance of a series combination of n capacitors.
ANS	(a) When a charge of one coulomb produces a potential difference of one volt between the plates of capacitor, the capacitance is one farad. $Q = CV \Rightarrow C = \frac{Q}{V}$ When Q = 1 coulomb, V = 1 volt …[1 farad = $\frac{1\,\text{coulomb}}{1\,\text{volt}}$ (b) Capacity of a parallel plate capacitor. A parallel plate capacitor consists of two large plane parallel conducting plates separated by a small distance. We first take the intervening medium between the plates to be vaccum. Let A be the area of each plate and d the separation between them. The two plates have charges Q and – Q. Since d is

	much smaller than the linear dimension of the plates ($d^2 << A$), we can use the result on electric field by an infinite plane sheet of uniform surface charge density. Plate 1 has surface charge density σ = Q/A and Plate 2 has a surface charge density -σ, the electric field in different region



Outer region I (region above the plate 1),

$$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

Outer region II (region below the plate 2),

$$E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

In the inner region between the plates 1 and 2, the electric fields due to the two charged plates add up, giving

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A} \text{ or } V = Ed = \frac{1}{\varepsilon_0}\frac{Qd}{A}$$

The capacitance C of the parallel plate capacitor is then

$$C = \frac{Q}{V} = \frac{\varepsilon_0 A}{d}$$

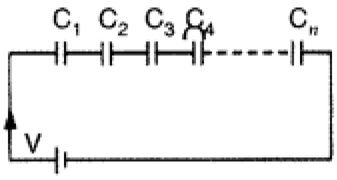
(c) In series combination, charge on each capacitor is same.

Let it be Q.

$$V_1 = \frac{Q}{C_1}$$

.
.
.

$$V_n = \frac{Q}{C_n}$$



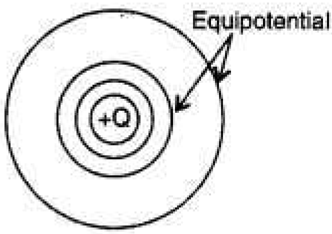
Total potential

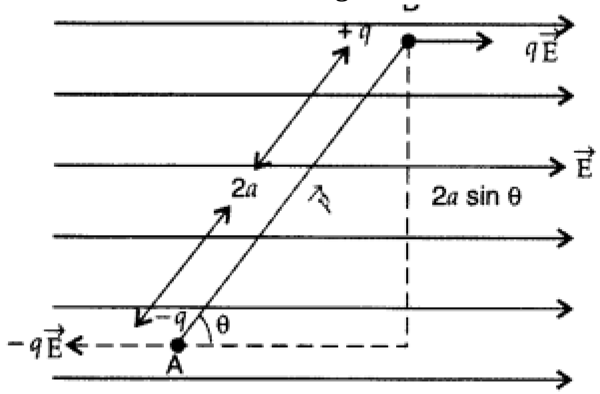
$$V = V_1 + V_2 + V_3 + \ldots + V_n$$

$$V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} + \ldots + \frac{Q}{C_n}$$

$$\frac{V}{Q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots + \frac{1}{C_n}$$

$$\Rightarrow \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots + \frac{1}{C_n}$$

2	A parallel plate capacitor is charged by a battery. After sometime the battery is disconnected and a dielectric slab with its thickness equal to the plate separation is inserted between the plates. How will (i) the capacitance of the capacitor, (ii) electric field between the plates and (iii) the energy stored in the capacitor be affected? Justify your answer in each case.
ANS	Let C be the capacitance and V be the potential difference. The charge on the capacitor plates will then be Q = CV. The electric field between the plates, E = Vd and the energy stored, $E_n = \frac{Q^2}{2C}$ or $\frac{1}{2}CV^2$ As the dielectric (K) is introduced after disconnecting the battery We have the new values of charge, Q' = Q Capacitance C' = KC Potential V' = QKC=VK (i) New capacitance is K times its original. (ii) New electric field $E = \frac{V'}{d} = \frac{V}{Kd} = \frac{E}{K}$ *i.e.* $\frac{1}{K}$ times the original field. (iii) New energy $= \frac{Q^2}{2C'} = \frac{Q^2}{2KC} = \frac{1}{K}(E_n)$ *i.e.* $\frac{1}{K}$ times the original energy.
3	a) Write two properties of equipotential surfaces. Depict equipotential surfaces due to an isolated point charge. Why do the equipotential surfaces get closer as the distance between the equipotential surface and the source charge decreases? (b) An electric dipole of dipole moment $\vec{p}$, is placed in a uniform electric field $\vec{E}$,. Deduce the expression for the torque 'x acting on it.
ANS	(a) Properties of equipotential surfaces: (i) No work is done in moving a test charge over an equipotential surface. (ii) No two equipotential surfaces can inter-sect each other. (iii) Equipotential surface due to an isolated point charge is spherical. (iv) The electric field at every point is normal to the equipotential surface passing through that point. (any two) As $E = \frac{-dV}{dr}$ or $dr = \frac{-dV}{E}$ For the same charge in the value, V, i.e., when dV = constant, we have dr ∝1E Hence, equipotential surface gets closer as the distance between the equipotential surface and the source charge decreases. 

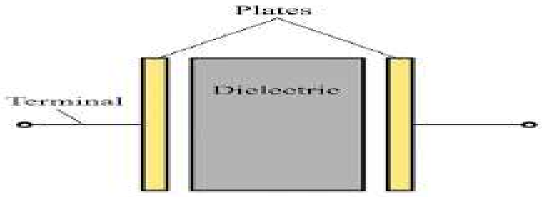
	Equipotential surface due to an isolated charge (b) Consider a dipole with charges +q and -q placed in a uniform electric field E→ such that AB = 2a as shown in the figure  Since the dipole experiences no net force in a uniform electric field but experiences a torque (τ) is given by $\vec{\tau} = \vec{p} \times \vec{E}$ $\therefore\ \tau = pE \sin\theta$ It tends to rotate the dipole in clockwise direction. To rotate the dipole anti-clock wise has to be done on the dipole. $W = \int_{\theta_1}^{\theta_2} \tau d\theta$ or $W = \int_{\theta_1}^{\theta_2} pE \sin\theta\, d\theta$ or $W = pE\,[-\cos\theta]_{\theta_1}^{\theta_2}$ $\therefore$ $\mathbf{W = -pE\,[\cos\theta_2 - \cos\theta_1]}$
	SELECT RESPONSE QUESTIONS (MCQ)
1	Which of the following options is correct? In a region of constant potential (a) the electric field is uniform. (b) The electric field is zero. (c) There can be charge inside the region. (d) The electric field shall necessarily change if a charge is placed outside the region.
ANS	**b**
2	The potential at a point due to an electric dipole will be maximum and minimum when the angles between the axis of the dipole and the line joining the point to the dipole are respectively (a) 90^0 and180^0 (b)0^0 and 90^0 (c)90^0 and0^0 (d)0^0 and 180^o
ANS	**d**
3	A parallel plate capacitor with dielectric slab (K= 2) in between the plates has a capacitance ‘C’. Without the slab capacitance of the capacitor is (a) C/ √2 (b)2C (c)C/2 (d) √2C

ANS	**c**
4	Dielectric constant for metal is (a)Zero (b) Infinite (c) 1 (d)Greater than 1
ANS	**b**
5	Two charged spheres of radii R_1 and R_2 are connected by a thin wire. No current will flow, if they have (a) The same charge on each (b) the same charge densities (c) The same potential energy (d) The same potential
ANS	**d**
6	The kinetic energy will be gained by an alpha particle in going from a point at $20V$ to another point at $10V$ (a) $20eV$ (b) $20keV$ (c) $20MeV$ (d) $20J$
ANS	**a**
7	The electric potential V is given as a function of distance x (metre) by $V = (x^2 + 2x - 9)volt$. Value of electric field at x = 1 is (a) $4\ V/m$ (b) $\frac{6V}{m}$ (c) $2V/m$ (d) 0
ANS	a
8	The capacity of a parallel plate condenser is C.Its capacitance when the separation between the plates is halved and dielectric slab of dielectric constant K=5 in inserted between the plates, will be
ANS	a
9	19 A $2\mu F$capacitor is charged to $100volt$ and then its plates are connected by a conducting wire resistance 2ohm. The heat produced is (a) $1\ J$ (b) $0.1\ J$ (c) $0.01\ J$ (d) $0.001\ J$
ANS	c

<u>CASE-STUDY BASED QUESTION</u>

CAPACITOR

A capacitor is a device used to store electrical energy. In it two identical surfaces are placed in front of each other, one of these plates is given charge and opposite nature of charge induces on the inner side of the other plate, outer side of which is grounded. This induced charge helps in reducing the potential of that plate which has been given charge, thus its capacity to hold charge increases. Capacity can also be increased by inserting dielectric slab in between the plates.



Q 1- If a capacitor is connected to a battery and a dielectric slab of dielectric constant K is introduced in between the plates and the distance between the plates is Doubled then its capacitance will

(a) Increases K times (b) Decreases K times (c) Increases K/2 Times (d) Decreases K/2 times

Q 2 - If a capacitor is connected to a battery and later on a dielectric slab of dielectric constant K is introduced in between the plates. On account of introducing the dielectric slab

(a) Electric field in between the plates will increase (b) Electric field in between the plates will decrease

(c) Electric charge on the plates will increase (d) Electric charge on the plates will decrease

Q 3 - If a capacitor is connected to a battery and later on a dielectric slab of dielectric constant K is introduced in between the plates. On account of introducing the dielectric slab

(a) Energy stored in between the plates will decrease K times

(b) Energy stored in between the plates will increase K times

(c) Energy stored in between the plates will decrease K/2 times

(d) No effect on the Energy stored

Q 4 - A technician has only two capacitors by using them either alone or in grouping he can obtain capacities 2, 3, 6 and 9 μf. The capacitors he has are

(a) 3 and 9 micro Farad (b) 3 and 6 micro Farad (c) 2 and 9 micro Farad (d) 2 and 3 micro Farad

Answer: (b) 3 and 6 micro Farad

OR

If a capacitor is charged by a battery and then disconnected after that the distance between its plates is doubled then

(a) Energy stored between the plates will be doubled

(b) Charge on the plates will be doubled

(c) Electric field between the plates will be doubled

(d) No change in any of the above quantities

CASE STUDY QUESTION-02

POTENTIAL ENERGY OF A SYSTEM OF CHARGES:-

For two charge system – Let the two charges are q_1 and q_2 and distance between them is r_{12}

$$U = Kq_1q_2/r_{12}$$

For three charge system – Let the third charge q3 is now in the electric field region of the charges q_1 and q_2 , distance of q_3 is r_{13} and r_{23} from the charges q_1 and q_2 respectively.

$$U_{123}= K(q_1q_2/r_{12} + q_1q_3/r_{13} + q_2q_3/r_{23})$$

The potential energy (for a system of charges) is characteristic of the present state of configuration.

$U= q_1 V r_1 + q_2 V r_2 + q_3Vr_3$

Now answer the following questions.

Q1 – Work done in bringing two charges each of magnitude 10 C, which are initially at a distance of 1 m to a distance of 50 cm, will be

(a) $9x10^{11}$ Joules (b) $9x10^{10}$ Joules (c) $9x10^{9}$ Joules (d) None of the above

Q 2 – If one charge from the above question is removed from the system, then the Energy of the remaining system will be

(a) $9x10^{12}$Joules (b) $27x10^{11}$Joules (c)) $27x10^{12}$Joules (d) None of the above

Q 3– If one more charge from the above question is removed from the system, then the Energy of the remaining system will be

(a) $9x10^{11}$Joules (b) $27x10^{11}$Joule (c)) $27x10^{12}$Joules (d) Zero
Hint:-as there will be only one charge which will not be in the Electric field region of any other charge.

OR

If three charges each of magnitude 10 C are at the vertices of an Equilateral triangle of side 10 cm, then the Energy of this system is

(a) $9x10^{11}$Joules (b) $27x10^{11}$Joules (c) $27x10^{12}$ Joules (d) None of the above

Q 4– If two charges each of 10 C are at the corners of an equilateral triangle of side 20 cm then the work done to bring the third charge also of 10 C at the third corner will be

(a) $9x10^{12}$Joules (b) 9 $x10^{11}$Joules (c)) 18 $x10^{12}$Joules (d) Zero

CASE STUDY QUESTION-03

CAPACITOR

A **capacitor** is a device that stores electrical energy in an electric field. It is a passive electronic component. The most common use for capacitors is energy storage, power conditioning, electronic noise filtering, remote sensing and signal coupling/decoupling. The capacitor was originally known as a **condenser** Most capacitors contain at least two electrical conductors often in the form of metallic plates or surfaces separated by a dielectric medium. Materials commonly used as dielectrics include glass, ceramic, plastic film, paper, mica, air, and oxide layers. Here by using dielectric medium we can change capacitance of given condenser

1. In which of the following forms is the energy stored in a capacitor?

(a) Charge (b) Potential (c) Capacitance (d) Electric field

2. When a metal slab is introduced between the plates of a parallel plate capacitor, its capacitance becomes

(a) Zero (b) Infinite (c) Less than one (d) None of these

3.Capacitors also known as in our daily life.

(a) Diode (b) Resistance (c) **Condenser** (d) Inductive coil

4.Dielectric medium used in capacitor-

(a) To increase capacitance (b) To decrease capacitance (c) To increase resistance (d) To decrease resistance

OR

The effective capacitance of a capacitor is reduced when capacitors are connected in

(a) Series (b) Parallel (c) Series-parallel combination (d) None of the above

ANSWERS

CASE BASE Q.1 CASE BASE Q.2 CASE BASE Q.3

1	2	3	4	1	2	3	4	1	2	3	4

ASSERTION-REASON TYPE QUESTIONS

Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A

b) Both A and R are true and R is NOT the correct explanation of A

c) A is true but R is false

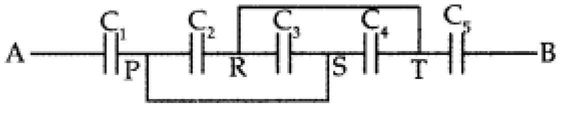
d) A is false and R is also false.

1	Assertion(A): The potential inside a hollow spherical charged conductor is zero. Reason(R): Inside the hollow spherical conductor electric field is constant
Answer	d

2	Assertion (A) -The work done by an electrostatic field in moving a charge from one point to another depends only on the initial and the final points. Reason (R)- Electrostatic force is a conservative fore.
Answer	a
3	Assertion (A)- For a uniform electric field E along the x -axis, the equipotential surfaces are planes parallel to the y-z plane. Reason (R)- Electric field lines are always perpendicular to equipotential surfaces.
Answer	a
4	Assertion (A)- A polar molecule is one in which the centres of positive and negative charges are separated. Reason (R)- A polar molecules have a permanent electric dipole moment.
Answer	b
5	Assertion (A)- When capacitors are connected in series net capacitance decreases. Reason (R)- In series combination, charges on the two plates are the same on each capacitor
Answer	b
6	Assertion (A)- When a charged capacitor is filled completely with a metallic slab, its capacitance decreases. Reason (R) -The dielectric constant for metal is zero.
Answer	d
7	Assertion(A): No work is done in moving a point charge Q around a circular arc of radius $'r'$ at the Centre of which another point charge $'q'$ is located. Reason(R): No work is done in moving a test charge from one point to another over an equipotential surface
Answer	c
8	Assertion(A): No work is done in moving a test charge from one point to another over an equipotential surface. Reason(R): Electric field is always normal to the equipotential surface at every point
Answer	b
9	Assertion(A)-Electric potential inside a hollow conductor is constant. Reason(R)– Electric field inside a hollow conductor is constant.
Answer	c
10	Assertion(A)–Work done to move a charge on an equipotential surface is always zero.

	Reason(R)– Electric field is zero at each point on an equipotential surface.
Answer	c

SELF TEST

1	1. In a parallel plate capacitor, the capacity increases if (a) area of the plate is decreased. (b) distance between the plates increases.(1) (c) area of the plate is increased. (d) dielectric constant decreases	1 M
2	2. A charge Q is given to a metallic conductor. Which is true? (a) Electric field inside it is same as on the surface. (b) Electric potential inside is zero. (c) Electric potential on the surface is zero (d) Electric potential inside it is constant.	1 M
3	**Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.** **a) Both A and R are true and R is the correct explanation of A** **b) Both A and R are true and R is NOT the correct explanation of A** **c) A is true but R is false** **d) A is false and R is also false** 1.Assertion(A): No work is done in moving a test charge from one point to another over an equipotential surface. Reason(R): Electric field is always normal to the equipotential surface at every point	1 M
4	Find equivalent capacitance between A and B in the combination given below. Each capacitor is of 2 μF capacitance 	2 M
5	a) Write two properties of equipotential surfaces. Depict equipotential surfaces due to an isolated point charge. Why do the equipotential surfaces get closer as the distance between the equipotential surface and the source charge decreases?	3 M

6	. A technician has only two capacitors by using them either alone or in grouping he can obtain capacities 2, 3, 6 and 9 μf. The capacitors he has are (a) 3 and 9 micro Farad (b) 3 and 6 micro Farad (c) 2 and 9 micro Farad (d) 2 and 3 micro Farad	2 M
7	Draw 3 equipotential surfaces corresponding to a field that uniformly increases in magnitude but remains constant along Z-direction. How are these surfaces different from that of a constant electric field along Z-direction?	2 M
8	. A parallel plate capacitor is charged by a battery. After sometime the battery is disconnected and a dielectric slab with its thickness equal to the plate separation is inserted between the plates. How will (i) the capacitance of the capacitor, (ii) electric field between the plates and (iii) the energy stored in the capacitor be affected? Justify your answer in each case	3 M

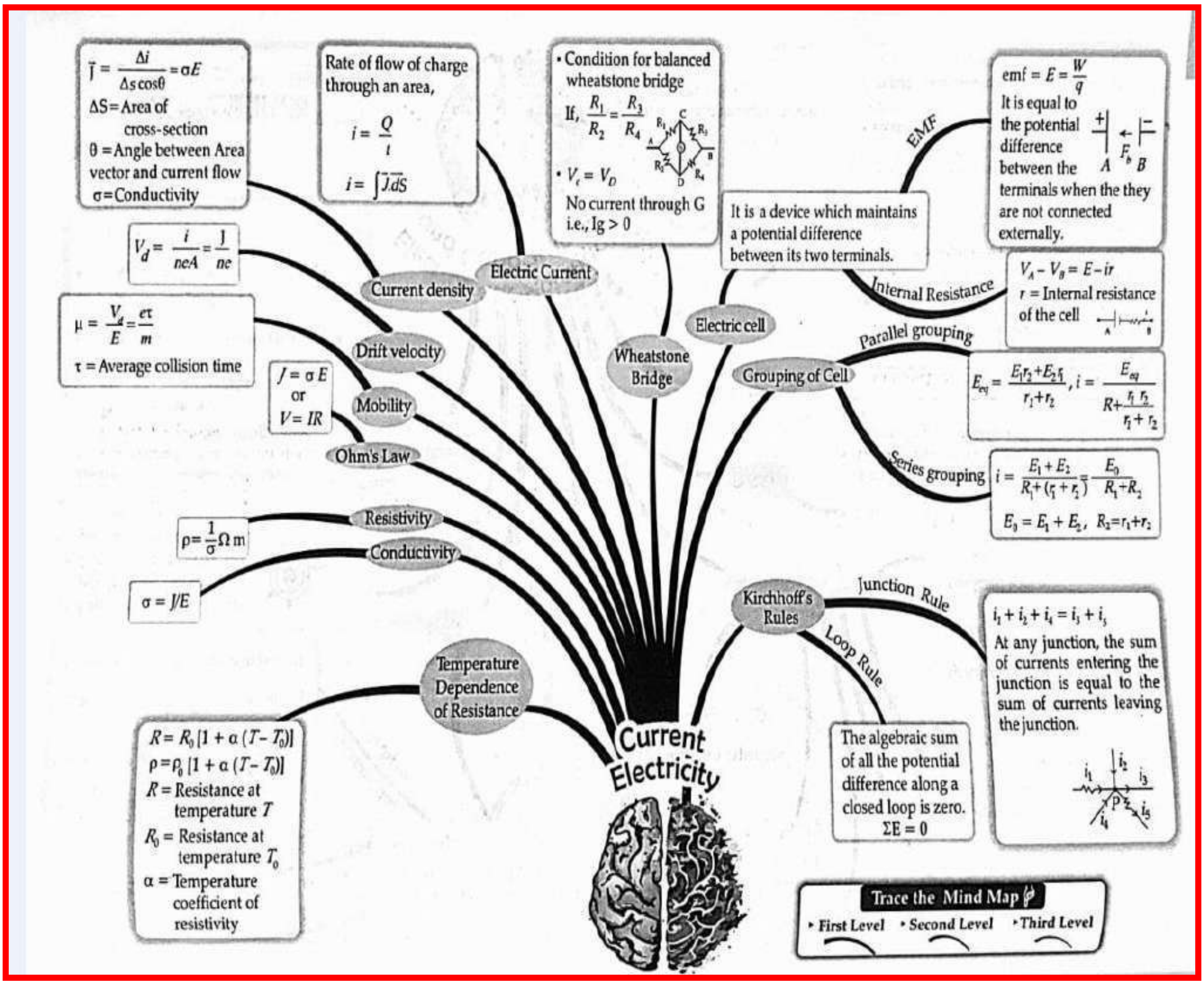
****

3. CURRENT ELECTRICITY

Syllabus

Electric current, flow of electric charges in a metallic conductor, drift velocity, mobility and their relation with electric current; Ohm's law, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity, temperature dependence of resistance, Internal resistance of a cell, potential difference and emf of a cell, combination of cells in series and in parallel, Kirchhoff's rules, Wheatstone bridge.

Mind Map



SUMMARY- IMPORTANT FORMULA AND DEFINITIONS

Electric current. It is the rate of flow of electric charge through a conductor.
Mathematically - I= Q/t
Unit. In SI, the unit of electric current is ampere

(A).1 ampere (A) = 1 coulomb per second (C S^{-1})

Ohm's law -It states that physical conditions remaining unchanged, the current flowing througha conductor is always directly proportional to the potential difference across its two ends.
Mathematically - V α I or V=RI
Here, R is called resistance of the conductor.Unit. The unit of resistance is ohm (Ω)
1 ohm (Ω) = 1 volt/ampere (V/A)
Resistance of a conductor. The resistance of a conductor of length l and area of cross-section A is given by R = ρ l/A

Here, ρ is resistivity of the material of the conductor.
Resistivity. The resistivity of the material of a conductor is the resistance offered by a wire of this material of unit length and unit area of cross-section. It is also known as specific resistanceof the material of the conductor. Unit. **The SI unit of resistivity is ohm metre (Ω m) Conductance.** The reciprocal of the resistance of a conductor is called its conductance (G).
Thus, G=1/ *R* **Unit. The SI unit of conductance is ohm^{-1} (Ω^{-1}) or siemen (S). ohm^{-1} is alsowritten as mho.**

Conductivity. The reciprocal of the resistivity of the material of a conductor is called itsconductivity. Thus, σ=1/ ρ
Unit. The SI unit of conductivity is siemen /metre (S/m). ohm^{-1} metre^{-1} is also written as mho /metre'.
Drift velocity. It is the velocity with which a free electron in the conductor gets drifted underthe influence of the applied external electric field.

Temperature coefficient of resistance. It is defined as the change in resistance per unitresistance per degree rise in temperature.

If resistance increases linearly up to temperature θ, then temperature coefficient
. The unit of temperature coefficient is °C^{-1}.

E.M.F. The work done per unit charge by the source in taking the charge from its one terminalto the other is called the electromotive force or e.m.f. of the source.
I= E/(R + r)
It is equal to the potential difference between the two terminals of the source, when no current isdrawn from it.
Internal resistance. The resistance offered by the electrolyte of the cell, when the electric currentflows through it, is known as internal resistance of the cell.
If V is potential difference across the two terminals of a cell, when a current I is drawn from it,then
V = E – Ir
Here, E is e.m.f. of the cell and R, the external resistance in the circuit.
Heat produced by electric current, H =I^2 Rt

Electric power, P = VI =I^2R = V^2 /R

Electric energy, W = Pt = Vit

Kirchhoff's Laws. These laws are used to analyseelectric circuits.

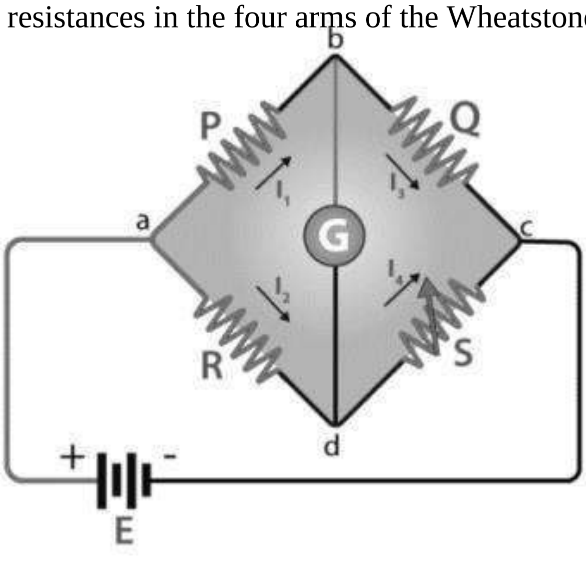
First law, It states that the algebraic sum of the currents meeting at a point (junction) in an electricalcircuit is always zero. $\Sigma I = 0$

Second law. It states that in any closed loop of an electrical circuit, the algebraic sum of the e.m.fs. isequal to the algebraic sum of the products of the resistances and the currents flowing through them. $\Sigma E = \Sigma IR$

Wheatstone bridge. It is an arrangement of fourresistances used to determine an unknown resistance.

In a balanced Wheatstone bridge, $P/Q = R/S$

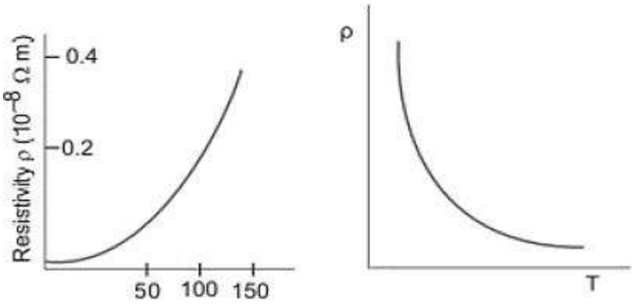
where P, Q, R and S are resistances in the four arms of the Wheatstone bridge.(3)



Competency based questions

Que. 1 Show, on a plot, variation of resistivity of (i) a conductor, and (ii) a typical semiconductor as a function of temperature. Using the expression for the resistivity in terms of number density and relaxation time between the collisions, explain how resistivityin the case of a conductor increases while it decreases in a semiconductor, with the rise of temperature.

Ans- We know that, $\rho = /\boldsymbol{ne2}\ r$ Where m is mass of electron, t = charge density, τ = relaxation time e = charge on the electron. In case of conductors with increase intemperature, relaxation time decreases, so resistivity increases. Incase of semiconductors with increase in temperature number density (n) of free electrons increases, hence resistivity decreases.



Out of 40 and 60 Watt bulb , which has greater resistance ?
(a) 60 Watt and 100 Watt bulbs are connected parallel to 220 Volt supply. Which bulb willglow more? (c) 100 Watt and 200 Watt bulbs are connected series to 220 Volt supply. Which bulb will glow more?

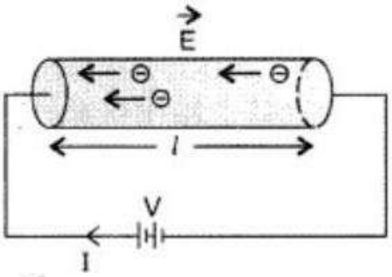
Ans. (a) 40 Watt has greater resistance because P a 1/R . (b) 100 Watt bulb will glow more.H $=V^2t/R$ & P a 1/R . (c) 100 Watt bulb will glow more. H= I^2 Rt & P a 1/R .

Q.2 (i)Why do the 'free electrons', in a metal wire, 'flowing by themselves', not causeany Current flowing in the wire? (ii)Explain the term 'drift velocity' of electrons in a conductor. Derive the expression of drift velocity Hence obtain the expression for the current through a conductor in terms of 'drift velocity'

(b) Use the above expression to show that the 'resistivity', of the material of a wire, isproportional to the Relaxation time

Answer: (a) (i) The free electrons, in a metal, (flowing bythemselves), have a random distribution of
their velocities. Hence the net charge crossing any crosssection in a unit time is zero.
(ii) The drift velocity equals the average (time dependent)velocity acquired by free electrons, under the action of anapplied (external) electric field.
Its unit is m/s and dimensions $[LT^{-1}]$
Let n be the number of free electrons per unit volume ofthe conductor. Acceleration= a= eE/m
$V_d = [(U_1 + a\tau_1) + (U_2 + \tau_2) + \ldots\ldots(U_n + a\tau_n)]/n$

$= [(U_1 + U_2 + \ldots + U_n]/n + [a(\tau_1 + \tau_2 + \ldots\ldots + \tau_n)]/n = 0 + a\tau$ $\quad V_d = eE\tau/m$



$t = \frac{l}{v_d}$ where $[v_d$ is drift velocity of electrons

$\therefore \quad I = \frac{Q}{t} = \frac{nAle}{\frac{l}{v_d}} = neAv_d \quad \therefore \boxed{I = neAv_d}$

(b) We know from above

$I = -neA\, v_d \qquad \ldots(i)$

Also we know, $v_d = \left(\frac{e\vec{E}}{m}\right)\tau \qquad \ldots(ii)$

Putting the value of v_d in equation (i) from equation (ii) we have

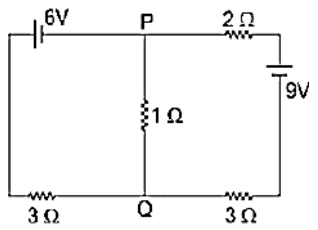
$I = -neA\frac{eE}{m}\tau \qquad \left[\because E = \frac{V}{l}\right.$

or $\frac{E}{I} = -\frac{m}{ne^2A\tau} \qquad \left[\because \rho = \frac{RA}{l}\right.$

$\rho = -\frac{m}{ne^2\tau}$

$\rho \propto \frac{1}{\tau}$

Q3 .Find the magnitude and direction of current in 1Ω resistor in the given circuit.



Answer

For the mesh *APQBA*

$$-6 - 1(I_2 - I_1) + 3I_1 = 0$$

or $\quad -I_2 + 4I_1 = 6 \qquad \ldots(i)$

For the mesh *PCDQP*

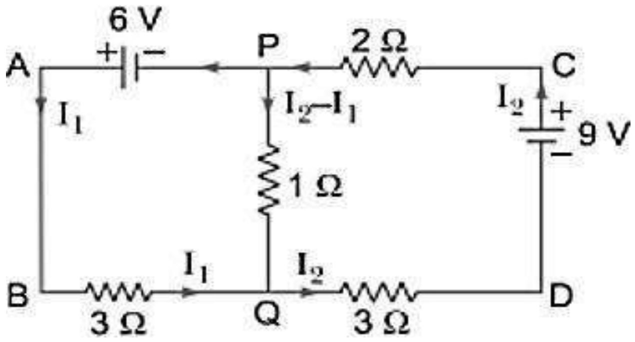
$$2I_2 - 9 + 3I_2 + 1(I_2 - I_1) = 0$$

or $\quad 6I_2 - I_1 = 9 \qquad \ldots(ii)$

Solving (*i*) and (*ii*), we get

$$I_1 = \frac{45}{23}\text{A} \quad \text{and} \quad I_2 = \frac{42}{23}\text{A}$$

$\therefore$ Current through the 1 Ω resistor $= (I_2 - I_1) = \mathbf{\frac{-3}{23}A}$



Q.4 Using the concept of free electrons in a conductor, derive the expression for the conductivity of a wirein terms of number density and relaxation time. Hence obtain the relationbetween current density and the applied electric field E.

The acceleration, $\vec{a} = -\frac{e}{m}\vec{E}$

The average drift velocity is given by, $v_d = -\frac{eE}{m}\tau$

(τ = average time between collisions or relaxation time)

If n is the number of free electrons per unit volume, the current I is given by

$$I = neA|v_d|$$

$$= \frac{e^2A}{m}\tau n|E|$$

But $I = |j|A$ (where j= current density)

Therefore, we get

$$|j| = \frac{ne^2}{m}\tau|E|.$$

The term $\frac{ne^2}{m}\tau$ is conductivity.

$$\therefore \sigma = \frac{ne^2\tau}{m}$$

$$\Rightarrow \quad J = \sigma E$$

Q.5 Make circuit diagram of Wheatstone Bridge and obtain condition for balance.

Ans.

Wheatstone Bridge:

Currents through the arms are assumed by applying Kirchhoff's Junction Rule.

Applying Kirchhoff's Loop Rule for:

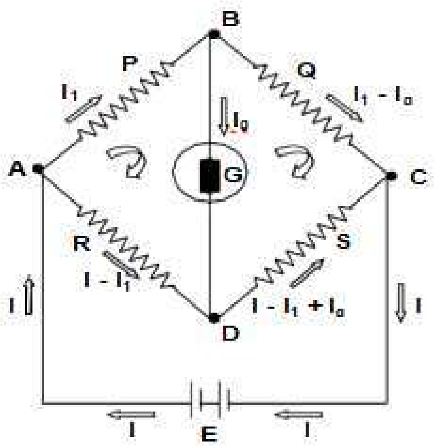
Loop ABDA:

$-I_1.P - I_g.G + (I - I_1).R = 0$

Loop BCDB:

$-(I_1 - I_g).Q + (I - I_1 + I_g).S + I_g.G = 0$

When $I_g = 0$, the bridge is said to balanced.

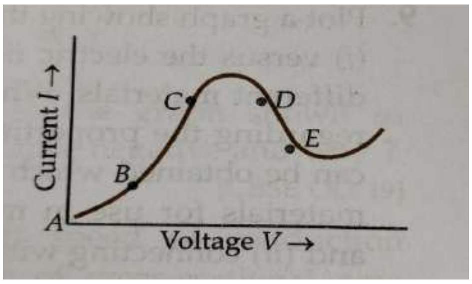


By manipulating the above equations, we get $\frac{P}{Q} = \frac{R}{S}$

GsQ.6 Graph showing the variation of current versus voltage for a material GaAs is shown in fig. Identify the region of

(i) Negative resistance

(ii) Where ohm's law is obeyed.



Ans) I) in the region DE,I decreases with increasing V.
Therefore +ve dv/-ve dv = -ve R.
ii) AB/BC is the region where ohm’s law is obeyed.

Q.7 Two metallic wires P1 and P2 of the same material and same length but different cross sectional areas, A1 and A2 are joined together and connected to a source of emf. Find the ratio of the drift velocities of free electrons in the two wires when they are connected (i) in seies and (ii) in parallel.

Ans) in series vd1/vd2 = A2/A1
In parallel vd1/vd2 = 1

Q.8 When 5 V potential difference is applied across a wire of length 0.1 m, the drift speed of electrons is 2.5×10^{-4} m/s if the electron density in the wire is 8×10^{28} m^{-3}, calculate the resistivity of the material of wire.

Ans) resistivity + 1.56×10^{-5} Ωm

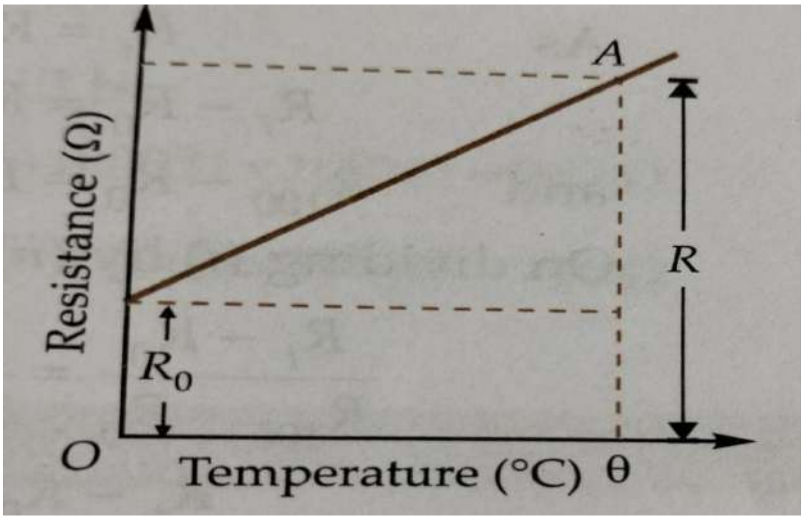
Q.9 The following table gives the length of three copper wires, their diameters, and the applied potential difference across their ends. Arrange the wires in increasing order according to the following :

(a) The magnitude of the electric field within them.
(b) The drift speed of electrons through them and
(c) The current density within them.

Wire no	Length	Diameter	Potential difference
1	l	3d	V
2	2l	d	V
3	3l	2d	2V
P162			

Ans) a) $E_2 < E_3 < E_1$
B) $V_{d2} < v_{d3} < v_{d1}$
C) $j_2 < j_3 < j_1$

Q.10 The variation of resistance of a metallic conductor with temperature is shown in fig.
(i) Calculate the temperature coefficient of resistance α from graph
(ii) State why the resistance of the conductor increases with the rise in temperature.



Ans) I) $\alpha = (R - R_0) / (R_0 \times \theta)$

Ii) The resistance of a conductor increases with the rise in temperature due to the increase in collision frequency of electrons with the positive metal ions.

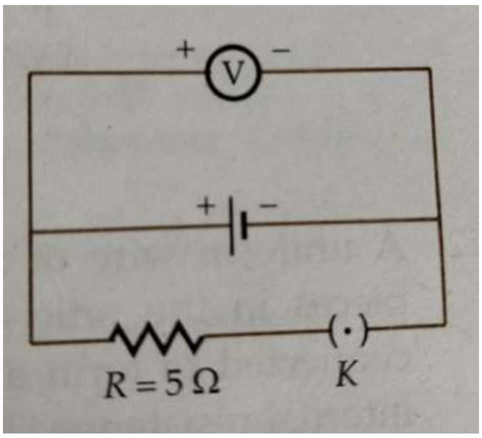
Q.11Two materials Si and Cu (or GaAs and Ag) are cooled from 300 K to 60 K. What will be the effect on their resistivity.

Ans) The resistivity of Si (a semiconductor) increases and that of Cu (a metallic conductor) decreases, when cooled from 300K to 60K.

Q.12.Two metallic rods each of length L area of cross section A1 and A2 having sensitivities ρ1 & ρ2 are connected parallel across a d.c battery. Obtain the expression for the effective resistivity of this combination.

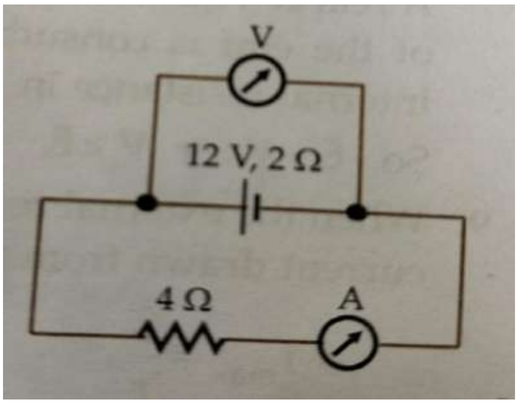
Ans) $\rho_{eff} = ((A1 + A2)\rho1\rho2) / (A1\rho1 + A2\rho2)$

Q.13 The reading of a high resistance voltmeter when a cell is connected across it is 2.2 V. when the terminals of the cell are also connected to a resistance of 5Ω, the voltmeter reading drops to 1.8 V. Find the internal resistance of the cell. P 180 fig 3.61



Ans) r = 1.1 Ω

Q.14 A battery of emf 12 V and internal resistance 2 Ω is connected to a 4 Ω resistor as shown in fig show that a voltmeter when placed across the cell and across the resistor, in turn, gives the same reading

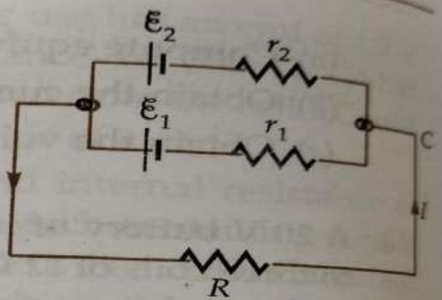


Ans) Potential difference across 4 Ω resistance = 4Ω x 2 A = 8 V, hence the voltmeter gives the same reading in the two cases.

Q.15 A student connects a cell, of emf E2 and internal resistance r2 with a cell of emf E1 and internal resistance r1 such that their combination has a net internal resistance less than r1.

This combination is then connected across a resistance R.
Draw a diagram of the set up and obtain an expression for the current flowing through the resistance R.

Ans) As the net internal resistance is less than r1 the two cells are connected in parallel as shown in figure.



$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

$$\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}$$

$$\varepsilon_{eq} = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right)\frac{r_1 r_2}{r_1 + r_2}$$

$$I = \frac{\varepsilon_{eq}}{R + r_{eq}} = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right)\frac{r_1 r_2}{r_1 + r_2} \cdot \frac{1}{R + \frac{r_1 r_2}{r_1 + r_2}}$$

$$= \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right)\frac{r_1 r_2}{R(r_1 + r_2) + r_1 r_2}.$$

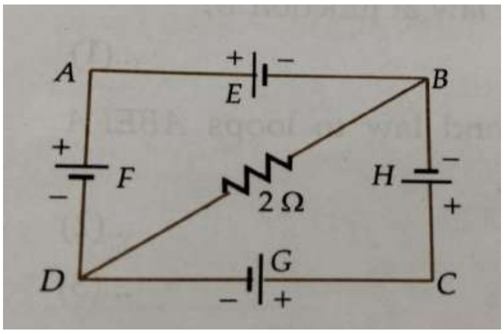
Q.16 Two wires A and B of the same material and having same length have their cross sectional area in the ratio 1:4. What would be the ratio of heat produced in these wires when same voltage is applied across each ?

Ans) 1 : 4

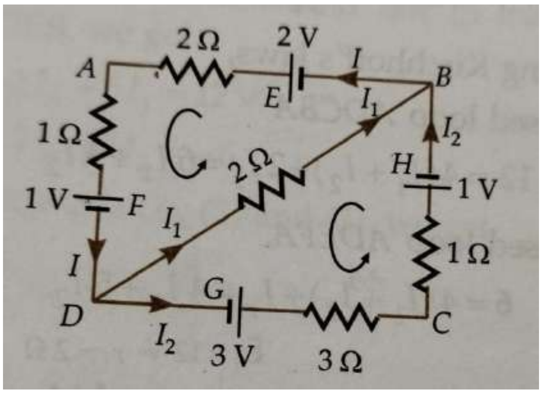
Q.17 Two 120 V light bulbs, of emf 25 W and other of 200 W were connected in series across a 240 V line. One bulb burnt out almost instantaneously which one was burnt and why ?

Ans) since $R = V^2/P$, so 25 watt bulb has more resistance. In the series ciruit same current flows through both the bulbs. The 25 W bulb develops more heat ($H = i_2 Rt$)and hence burns out almost instantaneously.

Q.18 In the circuit shown in fig E, F, G and H are cells of emf 2 V , 1 V, 3 V and 1 V and their internal resistances are 2, 1, 3 and 1 respectively. Calculate
(i) The potential difference between B and D.and
(ii) The potential differnce across the terminals of each of the cells G and H. fig



V1 = 2/13 v
V2 = 1.615 v
V3 = 1.46 v
Hint



MULTIPLE CHOICE QUESTIONS

Q1 A metal rod of length 10 cm and a rectangular cross-section of 1cm x ½ cm is connectedto a battery across opposite faces. The resistance will be
(a) Maximum when the battery is connected across 1cm x ½ cm faces.
(b) Maximum when the battery is connected across 10 cm x 1cm faces.
(c) Maximum when the battery is connected across 10 cm x ½ cm faces.
(d) Same irrespective of the three faces.
Ans-(a) Maximum when the battery is connected across 1cm x ½ cm faces.

2. Kirchhoff's II law for the electric network is based on:
(A)Law of conservation of charge(B)Law of conservation of energy
(C) Law of conservation of angular momentum(D)Law of conservation of Linear momentum. Ans. (B)Law of conservation of energy.

3. In a Whetstone's bridge, all the four arms have equal resistance R. If resistance of thegalvanometer arm is also R, then equivalent resistance of the combination is-
(A) R (B)2R
(C)R/2 (D)R/4
Ans. (A) R

4. Drift velocity vd varies with the intensity of electric field as per the relation **:**
(A) vd α E (B) vd α 1/ E
(C) vd = constant (D)vd α E^2
Ans. (A) vd α E

5. Two electric bulbs whose resistances are in the ratio of 1:2 are connected in parallel to aconstant voltage source the power dissipated in them have the ratio-
(A)1:2 (B)1:1
(C)2:1 (D)1:4
Ans. ©2:1

6. EMF of a cell depends:
(A) nature of electrolyte (B) metal of electrode
(C) both (A) and (B) (D) None
of theseAns.- (C) both (A) and (B)

7. A 12 cm wire is given shape of of a a right angled triangle PQR having sides PQ = 3 cm , QR= 4cm and RP= 5 cm. The resistance between two ends (PQ, QR, RP) of the respective sides are measured one by one by a multimeter. The resistances will be in the ratio
(A) 27:32:35 (B) 9:16:25 (C) 4:3:5 (D) 3:4:5
Ans. (A) 27:32:35

8. What is the effect on the product of resistivity and conductivity of a conductor when its temperature is increased?
(A) may increase or decrease. (B) increases (C) decreases. (D) remains constantAns. (D) remains constant

9. Specific resistance of a conductor increases with :–
(A) increase in temperature. (B) increase in cross–sectional area
(C) increase in cross–sectional area and decrease in length. (D) decrease in cross–sectionalAns. (A) increase in temperature.

10. The resistance of an ideal ammeter is
(a) Infinite (b) Very high (c) Small
(d) ZeroAns. (d) Zero

ASSERTION REASON TYPE QUESTIONS

The questions given below consist of an Assertion and a Reason. Use the following key tochoose the appropriate answer.

(a) If both Assertion and Reason are true and the reason is correct explanation of the Assertion.

(b) If both Assertion and reason are true, but Reason is not correct explanation ofthe Assertion.

(c) If Assertion is true, but the Reason is false.

(d) If Assertion is false, but the Reason is true.

1. Assertion: Electric appliances with metal body has three electrical connection but anelectrical bulb has two electrical connection.
Reason: Three pin connections reduce chance of electric shock.
Ans. (a) If both Assertion and Reason are true and the reason is correct explanation ofthe Assertion.

2. Assertion: EMF of battery increases with time. Reason: Internal resistance increases with time. Ans.(d) If Assertion is false, but the Reason is true.

3. Assertion : Voltmeter is connected in parallel with the circuit.Reason : Resistance of a voltmeter is very large.
Ans. (b) If both Assertion and reason are true, but Reason is not correct explanation ofthe Assertion.

4. Assertion: Kirchhoff's junction law follows from the conservation of charges.Reason: Kirchhoff's loop law follows from the conservation of energy.
Ans. (b) If both Assertion and reason are true, but Reason is not correct explanation ofthe Assertion.

5. Assertion : Though the direction of electric current is well defined, yet it is treated as ascalar.
Reason : Electric current does not follow the laws of vector addition.
Ans. (a) If both Assertion and Reason are true and the reason is correct explanation ofthe Assertion.

CASE BASED QUESTION

Q1**.** Read the passage given below and answer the following questions

Whenever an electric current is passed through a conductor, it becomes hot after some time. Thephenomenon of the production of heat in a resistor by the flow of an electric current through it iscalled heating effect of current or Joule heating. Thus, the electrical energy supplied by the source of emf is converted into heat. In purely resistive circuit, the energy expended by the source entirely appears as heat. But if the circuit has an active element like a motor, then a part of energy supplied by the source goes to do useful work and the rest appears as heat. Joule's lawof heating forms the basis of various electrical appliances such as electric bulb, electric furnace, electric press etc.

(i) Which of the following is correct statement?

(a) Heat produced in a conductor is independent of the current flowing.

(b) Heat produced in a conductor varies inversely as the current flowing.

(c) Heat produced in a conductor varies directly as the square of the current flowing.

(d) Heat produced in a conductor varies inversely as the square of the current flowing Ans. (c) Heat produced in a conductor varies directly as the square of the current flowing.

(ii) If the coil of a heater is cut to half, what would happen to heat produced?

(a) Doubled (b) Halved (c) Remains same (d) Becomes four times.

Ans. (a) Doubled

(iii)A 25 W and 100 W are joined in series and connected to the mains. Which bulb willglow brighter?

(a) 100 W (b) 25 W (c) Both bulbs will glow brighter (d) None will glow brighter

Ans.(b) 25 W

(iv)A rigid container with thermally insulated wall contains a coil of resistance 100 Ω,carrying 1A. Change in its internal energy after 5 min will be

(a) 0 Kj (b) 10 kJ (c)20 kJ (d) 30 kJAns. (d) 30 kJ

(v) The heat emitted by a bulb of 100 W in 1 min is

(a) 100 J (b) 1000 J (c) 600 J (d) 6000 J

Ans. (d) 6000 J

Q2 Read the passage given below and answer the following questions

An electrocardiogram records the electrical signals in your heart. It's a common and painless testused to quickly detect heart problems and monitor your heart's health. During an ECG, up to 12 sensors (electrodes) will be attached to your chest and limbs. The electrodes are sticky patches with wires that connect to a monitor. They record the electrical signals that make your heart beat. A computer records the information and displays it as waves on a monitor or on paper. It works on the principle that a contracting muscle generates a small electric current that can be detected and measured through electrodes suitably placed on the body. The voltage is in the range of 1mV ~ 5 mV. Using this information and concepts of current electricity, answer any four of the following questions:

(i). The voltage range in which an ECG works is

(a) 1-2 V (b) 1-10 V (c) 1-5 V (d) 1-5 mV

Ans. (d) 1-5 mV

(ii). What is the purpose of the probes connected to the human body while taking an ECG?

(a) They supply current to the heart. (b) They detect current when the heart muscles contract.
(c) Both a and b (d) None of these.

Ans. (b) They detect current when the heart muscles contract.**(iii). How much current can a human body withstand?**

(a) More than 10 mA (b) Less than 10 mA (c) More than 1A (d) Less than 100 mA

Ans. (b) Less than 10 mA

(iv). Drift velocity is of the order of
(b) about 10^{-6} ms^{-1} (b) about 10^{4} ms^{-1} (c) about 10^{-4}ms^{-1} (d) None of these

Ans. (c) about 10^{-4}ms^{-1}

(v). The resistance of a wet human body is
(a) 10 Ω (b) 100 Ω(c) 1000 Ω (d) 500 Ω
Ans. (c) 1000 Ω

SHORT ANSWER TYPE QUESTIONS (2 MARKS)

Q.1How does the mobility of electrons in a conductor change, if the potential difference appliedacross the conductor is doubled, keeping the length and temperature of the conductor constant? Ans. Mobility is defined as the magnitude of drift velocity per unit electric field.
At constant temperature and length, there is no change in relaxation time Also, it does not depend on potential difference. Hence, on changing the potential difference,there is no change in mobility of electrons.

Q.2 Plot a graph showing variation of current versus voltage for the material GaAs.
Ans- The variation of electric current with applied voltage forGaAs is a straight curve.

Q.3Two wires, one of copper and the other of manganin, have same resistance and equal thickness.Which wire is longer? Justify your answer.
Ans- Copper Reason: Let l1 and l2 be lengths of copper andmanganin wires having same resistance R and
thickness i.e., area of cross-section (A).

Nichrome wire gets heated up more.
Heat dissipated in a wire is given by

$$H = I^2Rt$$

$$H = I^2 \frac{\rho l}{A} t \quad \left(\because R = \frac{\rho l}{A}\right)$$

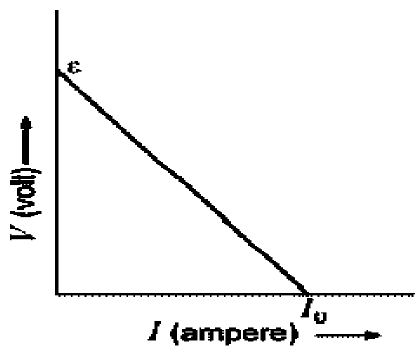
Here, radius is same, hence area (A) is same. Also, current (I) and length (l) are same.

$\therefore \quad H \propto \rho$

But $\quad \rho_{nichrome} > \rho_{copper}$

$\therefore \quad H_{nichrome} > H_{copper}$

Q.4Why are alloys used for making standardresistance coils?
Ans. Alloys have (i)low value of temperature coefficient and the resistance of the alloy does notvary much with rise in temperature. (ii) high resistivity, so even a smaller length of the materialis sufficient to design high standard resistance.



Q.5Plot a graph showing variation of voltage Vs the current drawn from the

cell. How can one get information from this plot about the emf of the celland its internal resistance?
Ans

$$V = \varepsilon - Ir \Rightarrow r = \frac{\varepsilon - V}{I}$$

At $I = 0, V = \varepsilon$

When $V = 0$, $I = I_0$, $r = \frac{\varepsilon}{I_0}$

The intercept on y-axis gives the emf of the cell. The slope of graph gives the internal resistance.

Q. 6 Two conducting wires X and Y of same diameter but different materials are joined in seriesacross a battery. If the number density of electrons in X is twice that in Y, find the ratio of drift velocity of electrons in the two wires.
Ans.

In series current is same,

So, $I_X = I_Y = I = neAv_d$

For same diameter, cross-sectional area is same

$A_X = A_Y = A$

$\therefore \quad I_X = I_Y \Rightarrow n_x eAv_x = n_y eAv_y$

Given $n_x = 2n_y \Rightarrow \frac{v_x}{v_y} = \frac{n_y}{n_x} = \frac{n_y}{2n_y} = \frac{1}{2}$

Q.7 A conductor of length 'l' is connected to a dc source of potential 'V'. If the length of the conductor is tripled by gradually stretching it, keeping 'V' constant, how will (i) drift speed ofelectrons and (ii) resistance of the conductor be affected? Justify your answer.

Ans.

(*i*) We know that $v_d = -\frac{eV\tau}{ml} \propto \frac{1}{l}$

When length is tripled, the drift velocity becomes one-third.

(*ii*) $R = \rho\frac{l}{A}$, $l' = 3l$

New resistance

$$R' = \rho\frac{l'}{A'} = \rho \times \frac{3l}{A/3} = 9R \Rightarrow R' = 9R$$

Hence, the new resistance will be 9 times the original.

LONG ANSWER TYPE QUESTIONS (3Marks)

Q.1. Define internal resistance of a cell. What are the factors those affect it?
Ans. The opposition offered by the electrolyte of the cell to the flow of

electric currentthrough it is called the internal resistance of the cell.

Factors affecting Internal Resistance of a cell:

Larger the separation between the electrodes of the cell, more the length of the electrolyte through which current has to flow and consequently a higher value of internal resistance. Greater the conductivity of the electrolyte, lesser is the internal resistance of the cell. i.e. internalresistance depends on the nature of the electrolyte. The internal resistance of a cell is inversely proportional to the common area of the electrodes dipping in the electrolyte. The internal resistance of a cell depends on the nature of the electrodes.

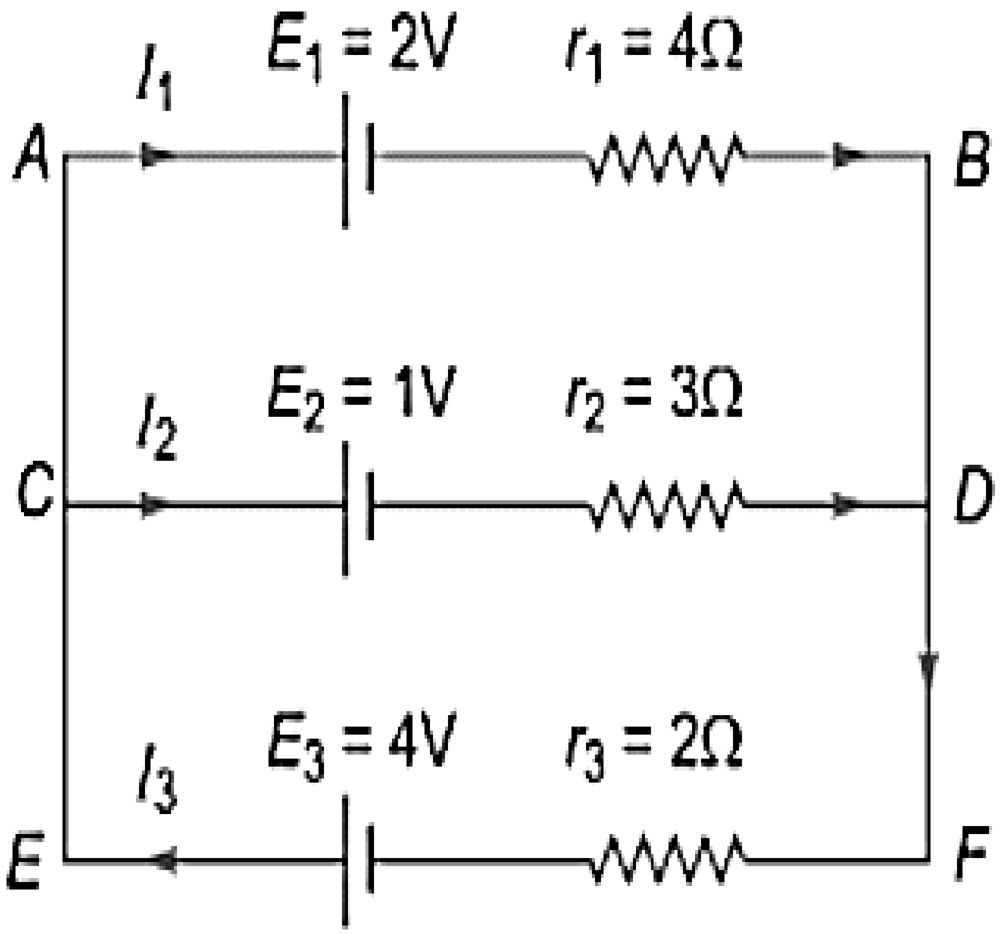
Q.2. Write Kirchoff's rules. What kind of conservation do they represent? Use these rulesto write the expressions for the currents I1, I2 and I3 in the circuit

diagram shown.

Ans. Kirchhoff's Rule:

Junction Rule:-The algebraic sum of currents meeting ata point is zero.It is in accordance with conservation of charge

ii) Loop rule:-The algebraic sum of potential differencearound a closed loop is zero.It is in accordance with conservation of energy.



Kirchhoff's Rules:

(*i*) The algebraic sum of currents meeting at any junction is zero, *i.e.*,

$$\sum I = 0$$

(*ii*) The algebraic sum of potential differences across circuit elements of a closed circuit is zero, *i.e.*, $\sum V = 0$

From Kirchhoff's first law

$I_3 = I_1 + I_2$ ...(*i*)

Applying Kirchhoff's second law to mesh *ABDCA*

$$-2 - 4I_1 + 3I_2 + 1 = 0$$

$\Rightarrow \quad 4I_1 - 3I_2 = -1$ ...(*ii*)

Applying Kirchoff's second law to mesh *ABFEA*

$$-2 - 4I_1 - 2I_3 + 4 = 0$$

$\Rightarrow \quad 4I_1 + 2I_3 = 2$ or $2I_1 + I_3 = 1$

Using (*i*) we get

$\Rightarrow \quad 2I_1 + (I_1 + I_2) = 1$

or $\quad 3I_1 + I_2 = 1$ ...(*iii*)

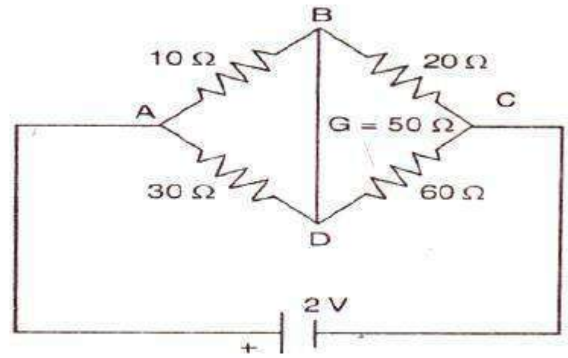
Solving (*ii*) and (*iii*), we get

$$I_1 = \frac{2}{13}\,\text{A}, I_2 = 1 - 3I_1 = \frac{7}{13}\,\text{A}$$

so, $\quad I_3 = I_1 + I_2 = \frac{9}{13}\,\text{A}$

NUMERICAL PROBLEMS ON CURRENT ELECTRICITY

1. What is the current flowing in the arm BD of this circuit?



2. A cylindrical metallic wire is stretched to increase its length by 5%. Calculate the percentage change in its resistance.

3. Two cells of EMF 1V, 2V and internal resistances 2Ω and 1Ω respectively are connected in (i) series, (ii) parallel. What should be the external resistance in the circuit so that the current through the resistance be the same in the two cases? In which case more heat is generated in the cells?

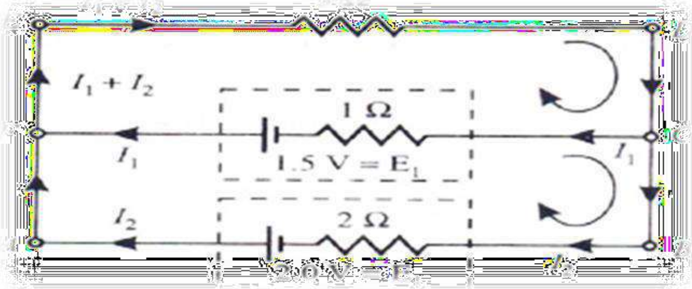
4. Calculate the temperature at which the resistance of a conductor becomes 20% more than its resistanceat 27^0C. The value of the temperature coefficient of resistance of the conductor is 2×10^{-4} / K.

5. Two metallic wires of the same material have the same length but cross sectional area is in the ratio of 1:2. They are connected (i) in series and (ii) in parallel. Compare the drift velocities of electrons in the two wires in both the cases.

6. Two wires X, Y have the same resistivity but their cross-sectional areas in the ratio 2:3 and lengths in the ratio 1:2. They are first connected in series and then in parallel to a dc source. Find out the ratio of the drift speeds of the electrons in the two wires for the two cases.

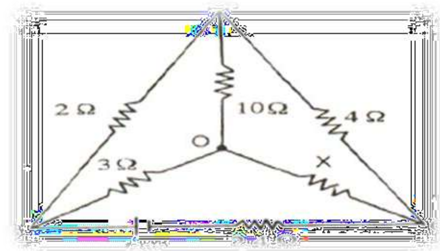
7. A room has AC run for 5 hours a day at a voltage of 220V. The wiring of the room consists of Cu of 1 mm radius and a length of 10m. Power consumption per day is 10 commercial units. What fraction of it goes in the joule heating in the wires? What would happen if the wiring is made of Al of the same dimensions? [$\rho_{Cu} = 1.7 \times 10^{-8}$ Ωm, $\rho_{Al} = 2.7 \times 10^{-8}$ Ωm]

8. Two cells of emf 1.5 V and 2V and internal resistance 1 Ω and 2 Ω are connected in parallel to pass a current in the same direction through an external resistance of 5 Ω. (a) Draw Circuit Diagram. (b) Using Kirchhoff's laws, calculate the current through each branch of the circuit and p.d. across the 5 Ω resistor.

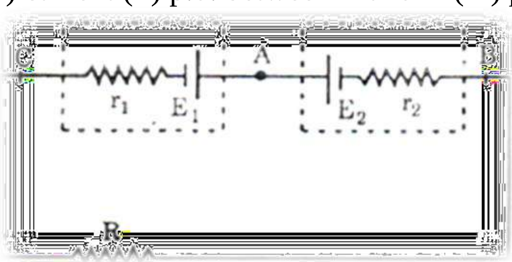


9. E2 =1.02V, PQ=1m. When switch S open, null position isobtained at a distance of 51 cm from P. Calculate
(i) Potential gradient
(ii) emf of the cell E1
(iii) When switch S is closed, will null point move towards P or
Give reason for your answer.

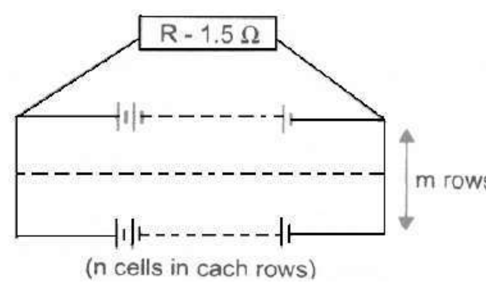
10. Find the value of the unknown resistance X in the circuit, if no current flows through the section AO. Also calculate the current drawn from the battery of emf 6V.



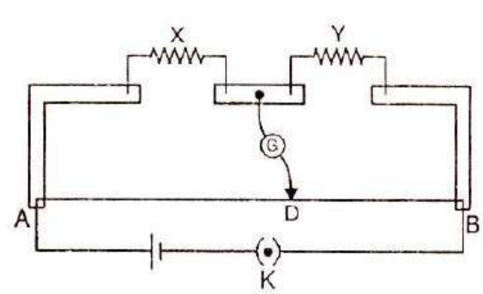
11. E1 = 2V, E2 = 4V, r1 = 1Ω, r2 = 2Ω, R = 5Ω
Calculate (i) current (ii) p.d. between B and A (iii) p.d. between A and C.



12. 12 cells, each of emf 1.5V and internal resistance 0.5Ω, arearranged in m rows each containing n cells connected in series, as shown. Calculate the values of n and m for which this combination would send maximum current through an external resistance of 1.5Ω

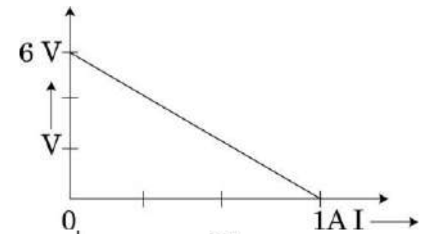
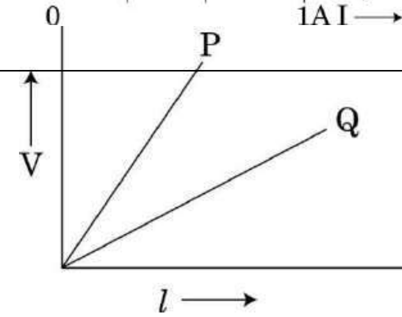
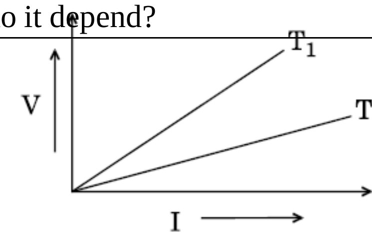
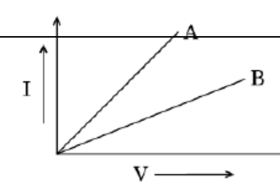
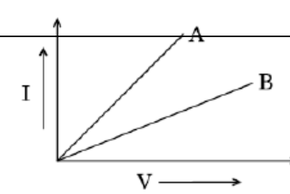
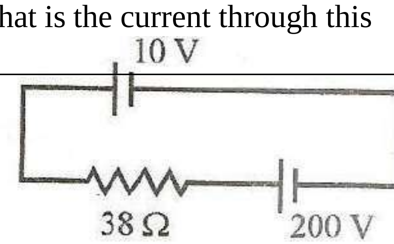


13. The given figure shows the experimental set up of a meter bridge. The null point is found to be 60cm away from the end A with X and Y in position as shown. When a resistance of 15Ω is connected in series with 'Y', the null point is found to shift by 10cm towards the end A of the wire. Find the position of null point if a resistance of 30Ω were connected in parallel with 'Y'.



14. A cell of unknown emf E and internal resistance r, two unknown resistances R1 and R2 (R2>R1) and aperfect ammeter are given. The current in the circuit is measured in five different situations:
(i) Without any external resistance in the circuit,
(ii) With resistance R1 only,
(iii) With resistance R2 only,
(iv) With both R1 and R2 used in series combination and
(v) With R1 and R2 used in parallel combination.
The current obtained in the five cases are 0.42A, 0.6A, 1.05A, 1.4A, and 4.2A, but not necessarily in that order. Identify the currents in the five cases listed above and calculate E, r and R2.

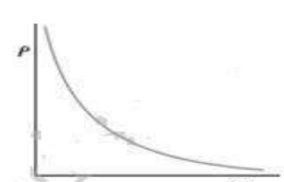
VERY SHORT ANSWER TYPE (CURRENT ELECTRICITY)1 MARKS

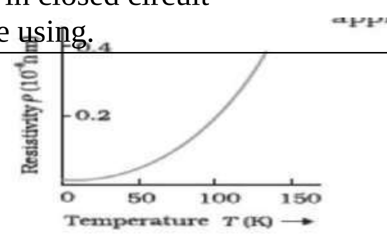
1	The plot of the variation of potential difference across the combination of three identical cells in series is shown in the figure: what is the emf and internal resistance of each cell. 	2016 D
2	The variation of potential difference V with length l for two potentiometrs P and Q are as shown , which one of the two will you prefer to comparing emf of two primary cells and why? 	2016 2006
3	Define the terms conductivity of a conductor?On what factors do it depend?	2016
4	V – I graph for a metallic wire at two different temperatures T1 and T2 is as shown in the figure. Which of the two temperatures is higher and why? 	2015
5	Two metallic resistors are connected first in series and then in parallel across a d.c. supply. Plot of I – V graph is shown for thetwo cases. Which one represents a parallel combination of theresistors and why? 	2015
6	I – V graph for two identical conductors of different materials A and B is shown in the figure. Which one of the two has higher resistivity? 	2015
7	State the underlying principle of the potentiometer?	2014
8	Two identical cells each of emf E having negligible internal resistance are connected in parallel with each other across an external resistance R, what is the current through this resistance?	2013 AI
9	A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance as shown in the figure find the value of current in the circuit. 	2013

10	When electrons drift in a metal from lower to higher potential, does it mean that all the free electrons of the metal are moving in the same direction?	2012
11	Show on a graph the variation of resistivity with temperature for a typical semiconductor?	2012 2006
12	Two wires, one of copper and the other of manganin, have same resistance and equalthickness. Which wire is longer? Justify your answer	2012 2009
13	A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor: Current, current density, drift speed, electric field?	2011
14	Two conducting wires *X* and *Y* of same diameter but different materials are joined in series across a battery. If the number density of electrons in *X* is twice that in *Y*, find the ratio of drift velocity of electrons in the two wires.	2010
15	A wire of resistance 8 *R* is bent in the form of a circle. What is the Effective resistance between the ends of a diameter *AB* ?	2010
16	Define the term 'mobility' of charge carriers. Write its S.I. unit.	2008
17	Distinguish between emf and terminal voltage of a cell.	2008
18	Show variation of resistivity of copper as a function of temperature in a graph.	2007

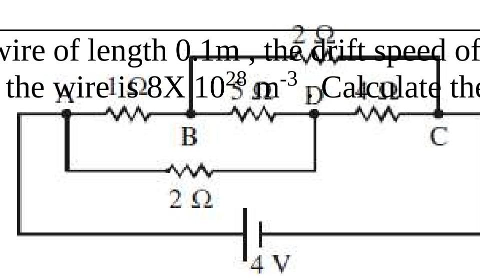
ANSWERS OF

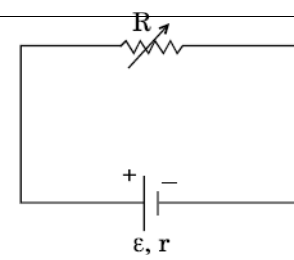
VERY SHORT ANSWER TYPE (CURRENT ELECTRICITY)1 MARKS

1	When I=0 emf of three identical cells in series is equal to 6V, hence E=2V,r=2Ω
2	As Potential Gradient k=V/l, Potentiometer Q will be preferred.
3	Conductivity is the reciprocal of resistivity,It depends upon no density of electrons and Average relaxation time.
4	For metallic wire R=V/I increases with temperature, hence T_1 will be higher.
5	In parallel combination less resistance will be the equivalent resistance, therefore A will represent parallel combination.
6	B will be of higher resistivity
7	The potential difference across any two points of uniform current carrying conductor is directly proportional to the length of the conductor between those two points.
8	I=E/R
9	I=200-10/38=190/38=5Amp.
10	No, Maximum no of electrons will drift opposite to the direction of higher potential
11	

12	$R = \frac{\rho l}{A} = \frac{ml}{ne^2 cA}$ As R and A are constant, ρl is a constant, Manganin is an alloy of higher resistivity, Copper wire will be longer.
13	Current and electric field will remain constant Current density will change with non-uniform area of cross section Drift velocity will change as area changes ($I = n e A V_d$)
14	As ($I = n e A V_d$),in series combination current remain same. In both X and Y,n V_d will be constant. Therefore the ratio will be $V_X/V_Y=1/2$
15	$\frac{1}{R} = \frac{1}{4R} + \frac{1}{4R}$ Effective resistance will be 2R.
16	$\mu = \frac{V_d}{E} = \frac{ec}{m}$, m^2 C/sJ
17	Emf is measured in open circuit ,p.d in closed circuit Emf is slightly greater than p d while using.
18	

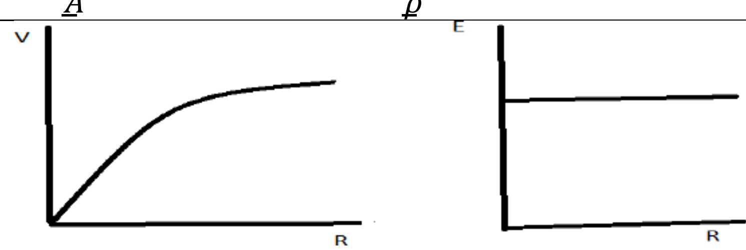
VERY SHORT ANSWER TYPE (ELECTRICITY)2 MARKS

1	Two electric bulbs P and Q have their resistances in the ratio of 1: 2. They are connected in series across a battery. Find the ratio of the power dissipation in these bulbs.	2018 2008C
2	In a potentiometer arrangement for determining the internal resistance of a cell, the balance point of the cell in open circuit is 350 cm. When a resistance of 9 Ω is used in the external circuit of the cell, the balance point shifts to 300 cm. Determine the internal resistance of the cell.	2018
3	Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time.	2016 2014
4	How does the drift velocity of free electrons in a metallic conductors change with the rise in temperature.	2009
5	When 5V potential difference is applied across a wire of length 0.1m , the drift speed of electrons is $2.5x10^{-4}$ m/s, if the electron density in the wire is $8X\ 10^{28}\ m^{-3}$, Calculate the  resistivity of the material of the wire.	2016N

6	Calculate the current drawn from the battery by the network of resistors shownin figure	2009, 2015
7	Using the concept of drift velocity of charge carriers in a conductor, deduce the relationship between current density and resistivity of the conductor.	2009
8	A variable resistor R is connected across a cell of emf E and internal resistance r as shown in the figure. Draw a plot showing the variation of (i) terminal voltage V and (ii) the current I, as a function of R. 	2011 2009

ANSWER OF

VERY SHORT ANSWER TYPE (CURRENT ELECTRICITY)2 MARKS

1	P = V^2/R hence the ratio will be 2:1
2	$r = (\frac{E}{V} - 1)R$ $r = (\frac{l1}{l2} - 1)R = (\frac{350}{300} - 1)9 = 1.5\Omega$
3	$I = n e A V_d$, $V_d = -\frac{e\tau}{m}E$
4	As the temperature of the conductor increases, average relaxation time will decrease, drift velocity will also decrease, resistivity increases.
5	Resitivity=$1.56\times10^{-5}\Omega m$
6	As the circuit is similar to a whaetstone bridge 5 Ω resistor can be removed ,then R=2Ω .Hence i=2 amp**.**
7	$j = \frac{I}{A} = n e V_d$ $j = \sigma E = \frac{1}{\rho}E$
8	

ASSERTION & REASONING TYPE (ELCETRICITY)

(4Q x 1M =4 Marks)

Directions : Each of these questions contain two statements, Assertion and Reason. Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select oneof the codes (a), (b), (c) and (d) given below.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.
(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion
(c) Assertion is correct, reason is incorrect
(d) Assertion is incorrect, reason is correct.

1. Assertion: Current is a vector quantity.
Reason: Current has magnitude as well as direction.

2.Assertion : A stream of positively charged particle produces an electric field E at a certain distance from it
Reason : A current currying conductor produces an electric field 2E at the same distance.

3.Assertion : Electric field outside the conducting wire which carries a constant current is zero.
Reason : Net charge on conducting wire is zero.

4.Assertion: The statement of Ohm's law is V = IR.
Reason: V = IR is the equation which defines resistance.

5.Assertion : A current flows in a conductor only when there is an electric field within the conductor.
Reason : The drift velocity of electron in presence of electric field decreases.

6.Assertion : Drift speed *vd* is the average speed between two successive collisions.
Reason : If Δ l is the average distance moved between two collision and Δ*t* is the corresponding time, then

$$v_d = \lim_{\Delta t \to 0} \frac{\Delta \ell}{\Delta t}.$$

electrons drift in the direction opposite to the current and so the number of free electrons in the wirecontinuously decrease.

7. Assertion : When a current is established in a wire, the free electrons drift in the direction opposite to the current and so the number of free electrons in the wire continuously decrease.
Reason : Charge is a conserved quantity.

8.Assertion : The electric bulb glows immediately when switch is on.
Reason : The drift velocity of electrons in a metallic wire is very high.

9. Assertion: $E=\rho j$ is the statement of Ohm's law.
Reason: If the resistivity of the conducting material is independent of the direction and magnitude of applied field then the material obeys Ohm's law.

10. Assertion: For a conductor resistivity increases with increase in temperature.
Reason: Since

$$\rho = \frac{m}{ne^2\tau},$$

when temperature increases the random motion of free electrons increases and vibration of ions increases which decreases relaxation time.

11. Assertion : The drift velocity of electrons in a metallic wire will decrease, if the temperature of the wire is increased.
Reason : On increasing temperature, conductivity of metallic wire decreases.

12. Assertion : Bending a wire does not effect electrical resistance.
Reason: Resistance of wire is proportional to resistivity of material.

13. Assertion : Two non ideal batteries are connected in parallel. The equivalent emf is smaller than either of the two emfs.
Reason : The equivalent internal resistance is smaller than either of the two internal resistances.

14. Assertion : Kirchoff's juction rule can be applied to a junction of several lines or a point in a line.
Reason : When steady current is flowing, there is no accumulation of charges at any junction or at any point in a line.

15. Assertion : Kirchoff's junction rule follows from conservation of charge.

Reason : Kirchoff's loop rule follows from conservation of momentum.

16. Assertion : In meter bridge experiment, a high resistance is always connected in series with a galvanometer.

Reason : As resistance increases current through the circuit increases.

17. Assertion : In a meter bridge experiment, null point for an unknown resistance is measured. Now, the unknown resistance is put inside an enclosure maintained at a higher temperature. The null point can be obtained at the same point as before by decreasing the value of the standard resistance.

Reason : Resistance of a metal increases with increase in temperature

18. Assertion : In meter bridge experiment, a high resistance is always connected in series with a galvanometer.

Reason : As resistance increase current more accurately then ammeter.

19. Assertion : The e.m.f of the driver cell in the potentiometer experiment should be greater that the e.m.f of the cell to be determined.

Reason : The fall of potential across the potentiometer wire should not be less than the e.m.f of the cell tobe determined.

20. Assertion : A potentiometer of longer length is used for accurate measurement.

Reason : The potential gradient for a potentiometer of longer length with a given source of e.m.f becomes small.

21. Assertion(A):

The wire of potentiometer is made by constantan and manganin.

Reason(R):Constantan and manganin are alloys and dependence of resistivity of alloys in temperature is negligible.

ANSWER:

ASSERTION & REASONING TYPE(ELECTRICITY)

1. (d) We call those quantities as vector quantities which have magnitude and direction and obey laws of vector addition. Though current has magnitude as well as direction but it does not obey laws of vector addition. Hence it is not a vector quantity.
2. (c) The net charge on current carrying conductor is zero, and so its electric field is also zero.
3. (a)
4. (d) A diode does not obey Ohm's law while a resistor obeys. But the equation $V = IR$ can be applied to both. In fact the equation $V = IR$ can be applied to all the conducting devices whether they obey Ohm's law or not. So $V = IR$ is directly proportional to I i.e.. $V \alpha I$. The proportionality sign is changed to equality sign in the equation $V = IR$ with R as constant of proportionality know as resistance of conductor. Thus the equation $V = IR$ defines resistance.
5. (c) Before the presence of electric field, the free electrons move randomly in the conductor, so their drift velocity is zero and therefore there is no current in the conductor. In the presence of electric field, each electron in the conductor experience a force in a direction opposite to the electric field. Now the free electrons are accelerated from negative and to the positive end of the conductor
and hence a current starts to flow from the conductor.
6. (c) Drift speed is the average speed between two successive collisions.
7. (d) The free electron density in any part of the conductor remains constant.
8. (c) The drift velocity of electrons in metals is order of 10–4 m/s.
9

(a) We know that $V = IR$

Since $R = \rho \dfrac{l}{A}$

Therefore $V = I\rho \dfrac{l}{A}$ ... (i)

Now $\dfrac{I}{A} = j$ is the current density.

Therefore eq. (i) becomes

$V = j\rho l$ or $\dfrac{V}{l} = j\rho$

Now $\dfrac{V}{l} = E$, where E is magnitude of electric field.

Therefore $E = j\rho$ ... (ii)

Current density $\vec{j}$ is also a vector which is directed along $\vec{E}$. Therefore the relation (ii) can also be written in vector form $\vec{E} = \rho\,\vec{j}$.

10. **(a)** When temperature increases the random motion of electrons and vibration of ions increases whichresults in more frequent collisions of electrons with the ions. Due to this the average time between the successive collisions, denoted by τ, decreases which increases ρ

11. b) On increasing temperature of wire the kinetic energy of free electrons increase and so they collide more rapidly with each other and hence their drift velocity decreases. Also when temperature increases, resistivity increases and resistivity is inversely
Proportional to conductivity of material.

12. (a) Resistance wire $R = \rho\, l/A$, where ρ is resistivity of material which does not depend on the geometryof wire. Since when wire is bent resistivity, length and area of cross-section do not change, therefore resistance of wire also remain same.

13. **(d)** The equivalent *emf* of the two batteries in parallel,

$$e = \left(\frac{e_1 r_2 + r_2 r_1}{r_1 + r_2}\right).\ e \text{ may be; } e_1 \le e \le e_2.$$

Internal resistance,

$$r = \left(\frac{r_1 r_2}{r_1 + r_2}\right).$$

This value is smaller than either of $r1$ and $r2$.

14. (a)

15. **(c)** Kirchoff 's loop rule follows from conservation of energy.

16. (c) The resistance of the galvanometer is fixed. In meter bride experiments, to protect the galvanometer from a high current, high resistance is connected to the galvanometer.

17. (d) With increase in temperature, resistance of metal wire increases, but balance conduction will not change.

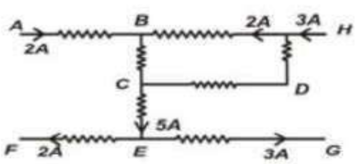
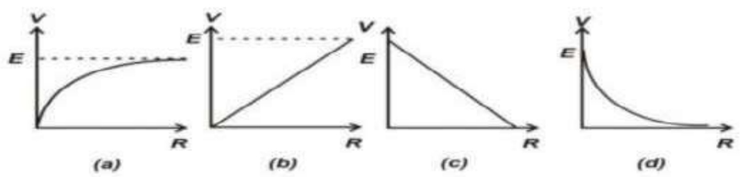
18. (c) The resistance of the galvanometer is flexed. In meter bridge experiments, to protect the galvanometer from a high current, high resistance is connected to the galvanometer in order to protect it from damage.

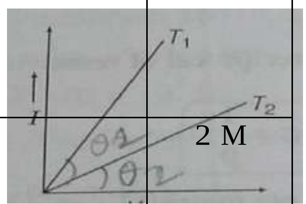
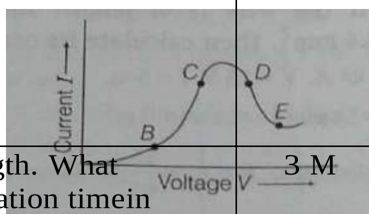
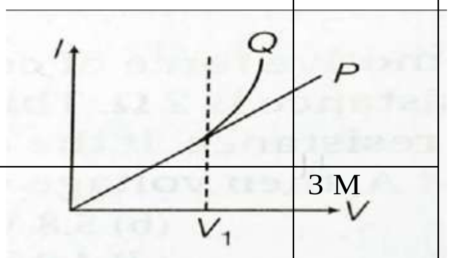
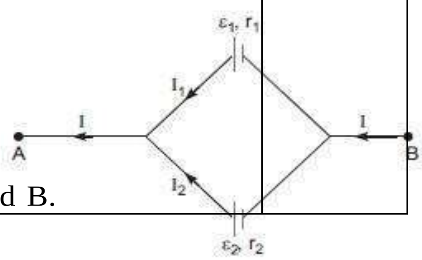
19. (a) If either e.m.f. of the driver cell or potential difference across the whole potentiometer wire is lesser than the e.m.f. of then experimental cell, then balance point will not obtained.

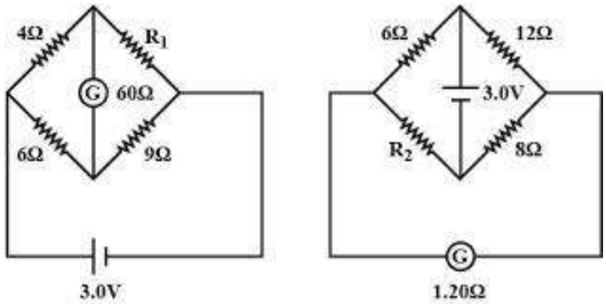
20. (a) Sensitivity α

21.a) (Length of wire)

TAKE A TRIAL – CURRENT ELECTRICITY

1	When electrons drift in a metal from lower to higher potential, does it mean that all the 'free' electrons of the metal are moving in the same direction?	1 M
2	A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor: current, current density, electric field, drift speed?	1 M
3	In the circuit diagram, calculate the electric current through branch BC:  (a) 4 amp (b) 2 amp (c) 5 amp (d) 10 amp	1 M
4	A cell of emf E and internal resistance r is connected across an external resistor R. The graph showing the variation of P.D. across R versus R 	1 M

5	In a Whetstone's bridge, all the four arms have equal resistance R. If resistance of the galvanometer arm is also R, thenequivalent resistance of the combination is (a) R (b) 2R (c) 2 R (d) 4 R	1 M
6	How much work is required to carry a 6 Cμ charge from thenegative to the positive terminal of a 9V battery? (a) 54×10^{-3} J (b) 54×10^{-6} J (c) 54×10^{-9} J (d) 54×10^{-12} J	1 M
7	For a cell, the terminal potential difference is 3.6 V, when the circuit is open. If the potential difference reduces to 3 V, when cell is connected to a resistance of 5 Ω , the internal resistance of cell is (a) 1 Ω (b) 2 Ω (c) 4 Ω (d) 8 Ω	1 M
8	Masses of three wires of copper are in the ratio of 1 : 3 : 5 andtheir lengths are in the ratio of 5 : 3 : 1. The ratio of their electrical resistances are (a) 1 : 3 : 5 (b) 5 : 3 : 1 (c) 1 : 15 : 125 (d) 125 : 15 : 1	1 M
9	Why are alloys used for making standard resistance coils	1 M
10	Is the motion of a charge across junction momentum conserving? why or why not?	1 M
11	I-V Graph for a metallic wire at two different temperatures T1 and T2 is as shown in the figure below which one of the two temperature is low and why? 	2 M
12	Graph showing the variation of current versus voltage for a material GaAs is shown in thefigure identify the region of a) negative resistance b) where Ohm's law is obeyed 	2 M
13	Wire of length L is stretched to the three times its length. What will be its new resistivity? In what manner do the relaxation timein good conductor change when its temperature increases?	3 M
14	Figure shows a plot of current versus voltage for two different materials P&Q. Which of the two materials satisfies ohms law? 	3 M
15	Two cells of emf E1 and E2 , and internal resistance r1 and r2 respectively are connected in parallel as shown. Deduce expressions for the equivalent emf of the combination, the equivalent resistance of the combination and the potential difference between the points A and B. 	3 M

16	Figure shoes two circuits each having a galvanometer and a battery of 3 Volt. When a galvanometer in each arrangement do not show any deflection obtain the ratio R1/R2. 	3 M

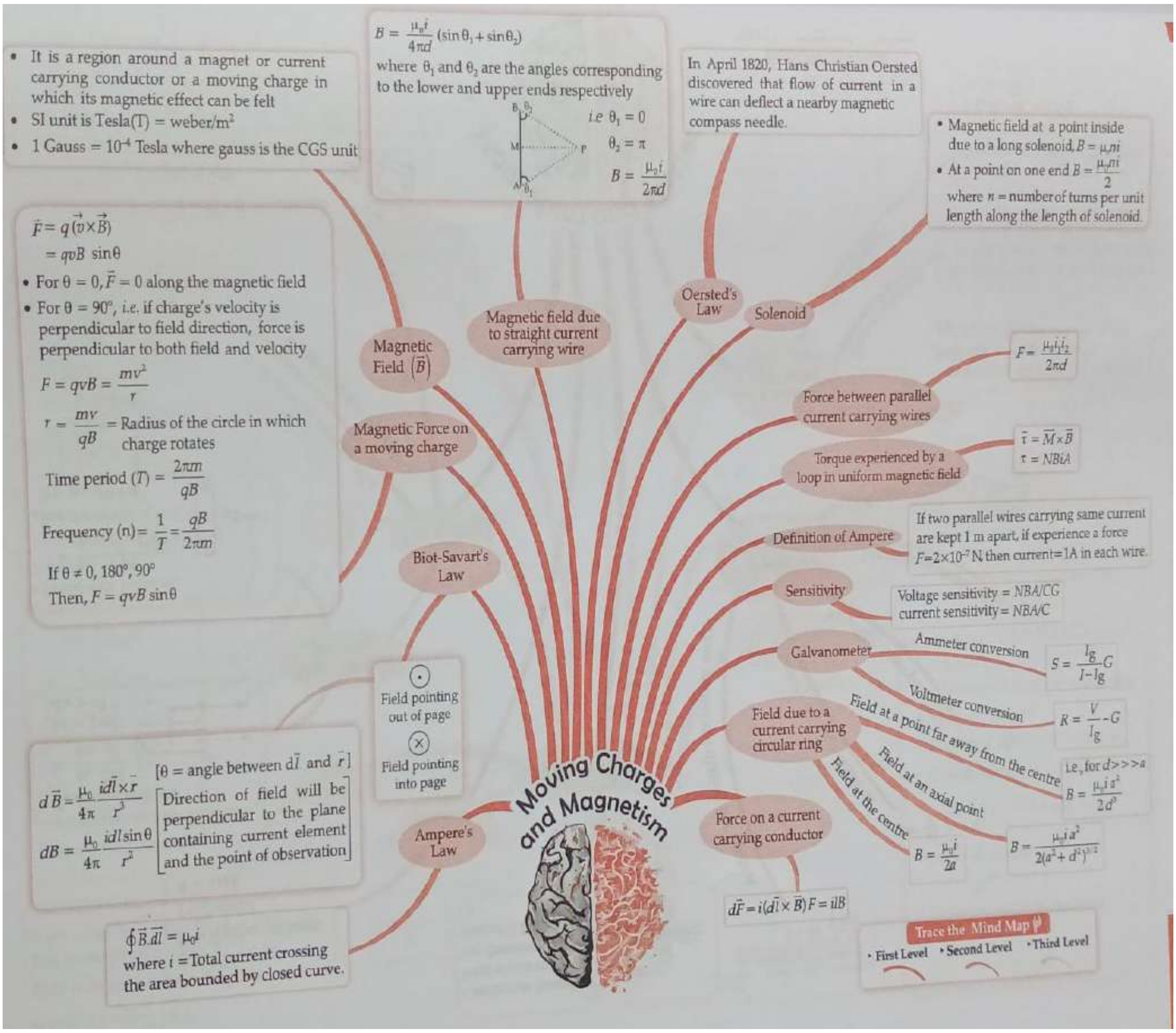
****

4. MOVING CHARGES & MAGNETISM

GIST OF THE CHAPTER:

- Concept of magnetic field
- Oersted's experiment.
- Biot - Savart law and its application to current carrying circular loop.
- Ampere's law and its applications to infinitely long straight wire. Straight solenoid (only qualitative treatment),
- Force on a moving charge in uniform magnetic and electric fields.
- Force on a current-carrying conductor in a uniform magnetic field,
- Force between two parallel current-carrying conductors-definition of ampere,
- Torque experienced by a current loop in uniform magnetic field;
- Current loop as a magnetic dipole and its magnetic dipole moment,
- Moving coil galvanometer- its current sensitivity and conversion to ammeter and voltmeter.

MIND MAP:



IMPORTANT DEFINITIONS:

1. **Magnetic Field: It is a region or space around a magnet or current carrying conductor or a moving charge, in which its magnetic effect can be felt. Magnetic field is a vector quantity,**

The S.I. unit of magnetic field is tesla (T) or weber/metre^2 (Wb/m^2).
The CGS unit of magnetic field is gauss (G).

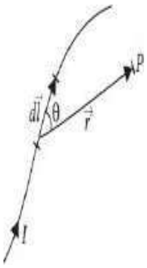
$$1 \text{ tesla} = 10^4 \text{ gauss}$$

2. **Lorentz Force: When a charged particle of charge *q* moving with velocity *v* is subjected to an electric field *E* and magnetic field B, the total force acting on the particle is**

$$\vec{F} = \vec{F}_e + \vec{F}_m = q\vec{E} + q(\vec{v} \times \vec{B}) = q(\vec{E} + \vec{v} \times \vec{B})$$

This force is known as Lorentz force.

3. **Biot Savart's Law: According to this law, the magnetic field at a point *P* due to a current element of length *dl*, carrying current *I*, at a distance *r* from the element is**
   (i) **directly proportional to current**
   (ii) **directly proportional to length of current element**
   (iii) **directly proportional to sine angle between current element and the distance**
   (iv) **inversely proportional to square of the distance between current element and point.**



$$dB = \frac{\mu_0}{4\pi} \frac{Idl \sin\theta}{r^2} \quad \text{or} \quad d\vec{B} = \frac{\mu_0}{4\pi} \frac{I(d\vec{l} \times \vec{r})}{r^3}$$

4. **Ampere's Circuital Law: The line integral of the magnetic field *B* around any closed loop is equal to μ₀ times the total current *I* threading through the loop.**

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$$

5. **Current Sensitivity: It is defined as the deflection produced in the galvanometer, when unit current flows through it. The unit of current sensitivity is rad A^{-1} or div A^{-1}.**

$$I_s = \frac{\theta}{I} = \frac{NAB}{k}.$$

6. **Voltage Sensitivity: It is defined as the deflection produced in the galvanometer when a unit voltage is applied across the two terminals of the galvanometer. The unit of voltage sensitivity is rad V^{-1} or div V^{-1}.**

$$V_s = \frac{\theta}{V} = \frac{\theta}{IR} = \frac{NAB}{kR} \qquad V_s = \frac{1}{R} I_s$$

7. **Magnetic Dipole: A magnetic dipole consists of two unlike poles of equal strength and separated by a small distance, *e.g.* a bar magnet, a compass needle etc. are magnetic dipoles.**

8. **Magnetic Dipole Moment: It is defined as the product of strength of either pole**

(*m*) and the magnetic length (2*l*) of the magnet. It is denoted by *M*. Magnetic dipole moment is a vector quantity and it is directed from south to north pole of the magnet. The SI unit of magnetic dipole moment is A m^2.

Magnetic dipole moment = strength of either pole × magnetic length

$$M = m\,(2l)$$

9. Gauss's Law for Magnetism: Gauss's law for magnetism states that the net magnetic flux through any closed surface is zero. This law establishes that isolated magnetic poles do not exist.

$$\phi = \sum_{\substack{\text{all area}\\ \text{elements}}} \vec{B}\cdot\Delta\vec{S} = 0$$

FORMULAES:

1. Force experienced by a charged particle moving in a magnetic field: $F = qvB\sin\theta$
2. Force experienced by a current carrying conductor placed in magnetic field: $F = ILB\sin\theta$
3. 1 gauss = 10^{-4} T
4. For a charged particle undergoing circular motion in an external magnetic field, $\frac{mv^2}{r} = qvB$ and angular frequency is $\omega = 2\pi f = \frac{qB}{m}$
5. For a charged particle undergoing helical motion in an external magnetic field, pitch = $v_{\parallel}T = \frac{2\pi m v_{\parallel}}{qB}$
6. Velocity selector, $v = E/B$
7. Cyclotron: $\frac{1}{2}mv^2 = \frac{q^2B^2R^2}{2m}$
8. Biot-Savart's (OR) Laplace's law: $dB = \frac{\mu_0}{4\pi}\frac{I\,dl\sin\theta}{r^2}$
9. Magnetic field at a point on the axis of circular coil carrying current: $B = \frac{\mu_0}{4\pi}\frac{2N\pi Ir^2}{(r^2+x^2)^{3/2}}$
10. Magnetic field at the centre of the circular coil carrying current: $B = \frac{\mu_0 NI}{2r}$
11. Ampere's circuital law: $BL = \mu_0 I_e$
12. Magnetic field at a point due to long straight conductor: $B = \frac{\mu_0 I}{2\pi r}$
13. Magnetic field at the centre inside a long solenoid and magnetic field inside the toroid is $B = \mu_0 nI$
    where n = N/L = number of turns per unit length.
14. Force between two straight parallel conductors carrying current:

15. Torque on a rectangular current loop in a uniform magnetic field is $\tau = mB\sin\theta$ and τ_{max} =NIAB where m = NIA

16. Conversion of G → A: Shunt resistance, $S = \frac{I_g G}{I - I_g}$

17. Conversion of G → V: $R = \frac{V}{I_g} - G$

18. Current sensitivity: $\frac{\theta}{I} = \frac{NBA}{k}$

19. Voltage sensitivity: $\frac{\theta}{V} = \frac{NBA}{Kr}$

A. COMPETENCY BASED QUESTIONS:

a. MCQ (HOTS):

1. An electron is moving along positive x-axis in a magnetic field which is parallel to the positive y-axis. In what direction will the magnetic force be acting on the electron?

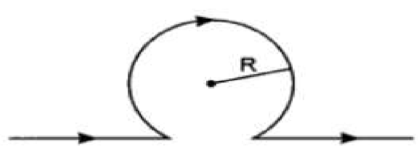
(a) Along -x axis (b) Along -z axis (c) Along +z axis (d) Along -y axis

2. A strong magnetic field is applied on a stationary electron. Then the electron

(a) Moves in the direction of the field. (b) remains stationary.

(c) Moves perpendicular to the direction of the field. (d) Moves opposite to the direction of the field.

3. The strength of magnetic field at the centre of the circular coil is:



(a) $\frac{\mu_0 I}{\pi R}$ (b) $\frac{\mu_0 I}{2\pi R}$ (c) $\frac{\mu_0 I}{2R}(1-\frac{1}{\pi})$ (d) $\frac{\mu_0 I}{2R}(1+\frac{1}{\pi})$

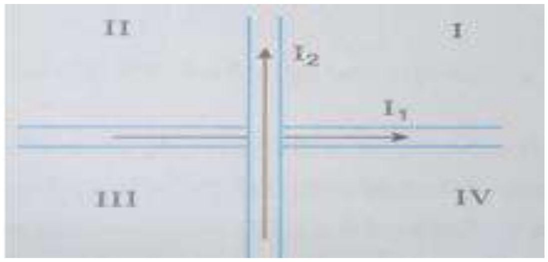
4. Two wires of same length are shaped into a square and a circle. If they carry the same current, ratio of magnetic moment is :

(a) 2 : π (b) π : 2 (c) 4 : π (d) π : 4

5.An electron of mass m kg and charge e Coulomb travels from rest through a potential difference of V volts. The final velocity of the electron is given by:

(a) $\frac{2eV}{m}$ (b) $\frac{2mV}{e}$ (c) $\sqrt{\frac{2eV}{m}}$ (d) $\sqrt{\frac{2mV}{e}}$

6. Two wires carrying currents I_1 and I_2 lie, one slightly above the other, in a horizontal plane as shown in figure.



The region of vertically upward strongest magnetic field is:

(a) I (b) III (c) II (d) IV

7. A solenoid of is made up of 500 turns per unit length. It carries a current of 5 A. If μ_0 is the permeability of free space, the magnitude of the magnetic field inside the solenoid is:

(a) $25\mu_0$ (b) $250\mu_0$ (c) $2500\mu_0$ (d) None of these

8. An ammeter of resistance 0.81 ohm reads up to 1 A. The value of the required shunt to increase the range to 10 A is

(a) 0.9 ohm (b) 0.09 ohm (c) 0.03 ohm (d) 0.3 ohm

9. A circular coil of 200 turns and radius 10 cm is placed in a uniform magnetic field of 0.5 T, normal to the plane of the coil. If the current in the coil is 3.0 A, the total torque on the coil is:

(a) 9.42 Nm (b) 94.2 Nm (c) 942 Nm (d)None of these

10. A galvanometer having a resistance of 20 Ω and 30 divisions on both sides has figure of merit 0.005 ampere/division. The resistance that should be connected in series such that it can be used as a voltmeter upto 15 volt is:

(a) 20 Ω (b) 40 Ω (c) 60 Ω (d) 80 Ω

b. <u>CASE BASED QUESTIONS:</u>

1. Both Electricity and Magnetism have been known for more than 2000 years. However, it was only about 200 years ago, in 1820, that it was realised that they were intimately related. The Danish physicist Hans Christian Oersted noticed that a current in a straight wire caused a noticeable deflection in a nearby magnetic compass needle. He investigated this phenomenon. He found that the alignment of the needle is tangential to an imaginary circle which has the straight wire as its centre and has its plane perpendicular to the wire. It is noticeable when the current is large and the needle sufficiently close to the wire. Reversing the direction of the current reverses the orientation of the needle. Iron filings sprinkled around the wire arrange themselves in concentric circles with the wire as the centre. Oersted concluded that moving charges or currents produced a magnetic field in the surrounding space.

(i) When a magnetic needle is placed near a current carrying wire,
(a) the wire moves away from the needle (b) the wire moves towards the needle
(c) the magnetic needle shows deflection (d) None of these

(ii) When a magnetic material is suspended freely, it points in the
(a) south-east direction (b) north- west direction
(c) north- south direction (d) None of these

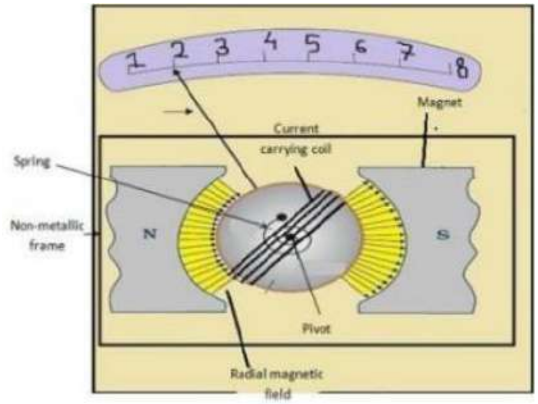
(iii) The direction of magnetic field around a straight conductor carrying current
(a) will be tangential to an imaginary line drawn around the conductor
(b) along the length of the conductor
(c) perpendicular to the conductor
(d) none of these

(iv) A magnetic field is produced due to:
(a) movement of charges (b) passage of electric current in a conductor
(c) both (a) and (b) (d) none of these

OR

The direction of magnetic field around a current carrying conductor is given by:
(a) Fleming's left hand rule (b) Right hand grip rule
(c) Fleming's right hand rule (d) Amperes circuital law

2. The galvanometer is a device used to detect the current flowing in a circuit or a small potential difference applied to it. It consists of a coil with many turns, free to rotate about a fixed axis, in a uniform radial magnetic field formed by using concave pole pieces of a magnet. When a current flows through the coil, a torque acts on it.



1. What is the principle of moving coil galvanometer?

(a) Torque acting on a current carrying coil placed in a uniform magnetic field.

(b) Torque acting on a current carrying coil placed in a non-uniform magnetic field.

(c) Potential difference developed in the current carrying coil.

(d) Mutual Induction.

2. If the field is radial, then the angle between magnetic moment of galvanometer Coil and the magnetic field will be

(a) 0° (b) 30° (c) 60° (d) 90°

3. Why are the pole pieces made concave in the moving coil galvanometer?

(a) To make the magnetic field radial. (b) To make the magnetic field uniform.

(c) To make the magnetic field non-uniform. (d) To make torque = 0.

4. What is the function of radial field in the moving coil galvanometer?

(a) To make the torque acting on the coil maximum. (b) To make the magnetic field strong.

(c) To make the current scale linear. (d) All the above.

OR

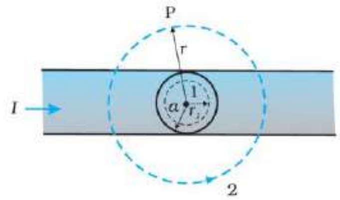
If the rectangular coil used in the moving coil galvanometer is made circular, then what will be the effect on the maximum torque acting on the coil in magnetic field for the same area of the coil?

(a) remains the same (b) becomes less in circular coil

(c) becomes greater in circular coil (d) depends on the orientation of the coil

c. TWO MARK QUESTIONS:

1. A long straight wire of a circular cross section of radius *a* carries a steady current *I* .



Apply Ampere's circuital law to calculate the magnetic field at a point '' *r''*, in the region for which r < a (ii) r > a

2. A proton and an α-particle enter a number magnetic field perpendicularly with the same speed. How many times in the time period of the α particle than that of the proton? Deduce an expression for the ratio of the radii of the circular path of the two particles.
3. Find the condition under which the charged particle moving with different speeds in the presence of electric and magnetic field vectors can be used to select charged particles of a particular speed.
4. What is the radius of the path of an electron (mass 9×10^{-31}kg and charge 1.6×10^{-19} C) moving at a speed of 3×10^{7} m/s in a magnetic field of 6×10^{-4} Tesla perpendicular to it?

5. (a)Write an expression for the force F acting on a particle of mass m and charge q moving with velocity V in a magnetic field B . Under what condition will it move in (i) a circular path (ii) a helical path?
(b) Show that kinetic energy of the particle moving in magnetic remains constant.

d. Assertion and Reason questions:

Instructions: Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not the correct explanation of A
(c) A is true but R is false
(d) A is false and R is also false

1. Assertion (A): If an electron and proton enter a magnetic field with equal momentum, then the paths of both of them will be equally curved.
Reason (R): The magnitude of charge on an electron is same as that on a proton.
2. Assertion (A): The voltage sensitivity may not necessarily increase on increasing the current sensitivity
Reason (R): Current sensitivity increases on increasing the number of turns of the coil.
3. Assertion (A): An electron projected parallel to the direction of magnetic field will experience a maximum force.
Reason (R): Magnetic force on a charge particle is given by F = I (L x B).
4. Assertion (A): Magnetic field due to an infinite straight conductor varies inversely as the distance from it
Reason (R): The magnetic field due to a straight conductor is in the form of concentric circles.
5. Assertion (A): The sensitivity of a moving coil galvanometer is increased by placing a suitable

magnetic material as a core inside the coil.
Reason(R): Soft iron has high magnetic permeability and cannot be easily magnetized or demagnetized.

B. SELECT RESPONSE TYPE QUESTIONS

a. MCQ (EASY):

1. The direction of magnetic force acting on a charged particle q, moving with a velocity v in a uniform magnetic field B is:

(a) normal to v alone (b) normal to B alone (c) normal to the plane of v and B (d) parallel to B

2. A planar loop carrying a current I, having N closely wound turns, and an area A. The magnetic moment possessed by the loop m is given by:

(a) IA (b) NIA (c) $A\ N$ (d) None of these

3. An electron with angular momentum L moving around the nucleus has a magnetic moment is given by:

(a) e L/ 2m (b) e L/3m (c) e L /4m (d) e L / m

4 Which of the following statements is true regarding the nature of parallel and anti-parallel currents in two conductors placed nearer to each other?

(a) parallel currents repel and antiparallel currents attract each other

(b) parallel currents attract and antiparallel currents repel each other

(c) both currents repel each other (d) both currents attract each other

5. A region has a uniform magnetic field in it. A proton enters into the region with velocity making an angle of 45° with the direction of the magnetic field, in this region the proton will move on a path having the shape of

(a) Helix (b) Circle (c) Spiral (d) Straight line

6. A circular coil of one turn with radius R carrying a current I has a dipole moment M. Now the coil is opened and rewound to have two turns without altering the current. The new dipole moment of the coil is

(a) M/2 (b) M (c) 2M (d) 4M

7. A 2 μC charge moving around a circle with a frequency of 6.25×10^{12} Hz produces a magnetic field 6.28 Tesla at the centre of the circle. The radius of the circle is:

(a) 2.25 m (b) 1.35 m (c) 1.25 m (d) 2.15 m

8. Under the influence of a uniform magnetic field, a charged particle moves with constant speed v in a circle of radius R. The time period of rotation of the particle:

(a) depends on R and not on v | (b) depends on v and not on R

(c) is independent of both v and R | (d) depends on v and not on R

9. The coil of a moving coil galvanometer is wound over a metal frame in order to :

(a) reduce hysteresis | (b) increase sensitivity

(c) increase moment of inertia | (d) provide electromagnetic damping

10. In a moving coil galvanometer, we use a radial magnetic field so that the galvanometer scale is:

(a) exponential (b) linear (c) algebraic (d) logarithmic

C. CONSTRUCTED RESPONSE QUESTIONS:

a. THREE MARK QUESTIONS:

1. State Biot- Savart law. Using this law derive expression for the magnetic field at an axis of current carrying circular loop.
2. Derive an expression for force between two parallel straight conductor carrying current in same direction hence define one ampere.
3. State Principle and construction of moving coil galvanometer. Define figure of merit, current and voltage sensitivity.
4. How a moving coil galvanometer can be converted to an ammeter and a voltmeter?

b. FIVE MARK QUESTION:

1. (a) Derive an expression for torque acting on a loop of 'N' turns area 'A' carrying current 'I' and held in a magnetic field 'B'.

(b)With the help of a circuit diagram show how a moving coil galvanometer can be converted into
ammeter of given range write the necessary mathematical formula.

2. A rectangular current carrying loop EFGH is kept in a uniform magnetic field what is the direction of magnetic moment of the current loop. When a torque acting on loop (i) maximum (ii) zero
3. State Biot - Savarts law.
   (a) Expressing it in vector form use it to obtain the magnetic field at an axial point distance r from the centre of a circular coil of radius 'r' carrying current 'I'.
   (b) Compare the magnitude of magnetic field of this coil at the centre and at axial point for which $x = \sqrt{3}r$. ($B_{centre} / B_{\sqrt{3}r} = 8$)

SELF ASSESSMENT:

1. Two concentric and coplanar circular loops P and Q have their radii in the ratio 2:3.

Loop Q carries a current 9 A in the anticlockwise direction. For the magnetic field to be zero at the common centre, loop P must carry

(i) 3 A in clockwise direction (ii) 9 A in clockwise direction

(iii) 6 A in anti-clockwise direction (iv) 6 A in the clockwise direction.

2. Currents of 10 A and 2 A are flowing in opposite directions through two parallel wires A and B respectively. If the wire A is infinitely long and wire B is 2 m long, then force on wire B which is situated at 10 cm from A, is

(a) 8×10^{-5} N (b) 6×10^{-5} N (c) 4×10^{-5} N (d) 5×10^{-5} N

Instructions: Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is not the correct explanation of A

(c) A is true but R is false

(d) A is false and R is also false

3. Assertion (A): An electron projected parallel to the direction of magnetic force will experience maximum force.

Reason (R): Magnetic force on a charge particle is given by F = (I L x B).

4. Assertion (A): Magnetic field due to an infinite straight conductor varies inversely as the distance from it.

Reason (R): The magnetic field due to a straight conductor is in the form of concentric circles

5. Two long parallel wires are hanging freely. if they are connected to a Battery (i) series (ii) parallel. what would be the effect on their position.?

6. Current flows through a circular loop. Depict the north and south pole of its equivalent magnetic dipole.

7. Why do we use a shunt to convert a galvanometer into an ammeter?

ANSWERS

A. (COMPETENCY BASED QUESTIONS):

a. MCQ (HOTS)

1.b	2.b	3.c	4.c	5. c
6. d	7.c	8.b	9.a	10.d

b. CASE BASED QUESTIONS:

1.	i. c	ii. c	iii. a	iv. c OR b
2.	i.a	ii. d	iii. a	Iv.d OR a

c. TWO MARK QUESTIONS:

Ans1. (i) Consider the case r > a. The Amperian loop, labelled 2, is a circle concentric with the cross-section. For this loop, L = 2 π r

Using Ampere circuital Law, we can write

$$B\,(2\pi r) = \mu_0 I, \qquad B = \frac{\mu_0 I}{2\pi r}, \qquad B \propto \frac{1}{r} \qquad (r > a)$$

(ii) Consider the case r < a. The Amperian loop is a circle labelled 1. For this loop, taking the radius of the circle to be r, L = 2 π r Now the current enclosed Ie is not I, but is less than this value. Since the current distribution is uniform, the current enclosed is,

$$I_e = I\left(\frac{\pi r^2}{\pi a^2}\right) = \frac{Ir^2}{a^2} \quad \text{Using Ampere's law, } B\,(2\pi r) = \mu_0 \frac{Ir^2}{a^2}$$

$$B = \left(\frac{\mu_0 I}{2\pi a^2}\right) r \qquad B \propto r \qquad (r < a)$$

Ans2.

$$T = \frac{2\pi m}{Bq}; \qquad \text{For proton } T = \frac{2\pi m}{Bq} \quad \& \qquad \text{For } \alpha \text{ particle } T = \frac{2\pi 4m}{B2q} = 2T_p$$

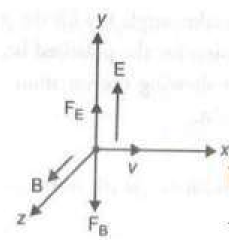
$$r = \frac{mv}{Bq} \quad \frac{rp}{r\alpha} = \frac{1}{2}$$

Ans3.

Ans: Condition

(i) For direction of $\vec{E}, \vec{B}, \vec{v}$

(ii) For magnitudes of $\vec{E}, \vec{B}, \vec{v}$



(i) The velocity $\vec{v}$, of the charged particles, and the $\vec{E}$ and $\vec{B}$ vectors, must be mutually perpendicular. Also the forces on q, due to $\vec{E}$ and $\vec{B}$, must be oppositely directed.
(ii) If magnetic force= electrostatic force
Fm=Fe
qvB = qE
v=E/B

Ans4.

Radius $r = \frac{mv}{qB} = \frac{9 \times 10^{-31} \times 3 \times 10^{7}}{1.6 \times 10^{-19} \times 6 \times 10^{-4}} = 26 \times 10^{-2}$ m

Ans5 (a). F =q (v ×B)

(i) When velocity of charge particle and magnetic field are perpendicular to each other.
(ii) when velocity is neither parallel nor perpendicular to the magnetic field.

(b) The force, experienced by the charged particle, is perpendicular to the instantaneous velocity v, at all instants. Hence, the magnetic force cannot bring any change in the speed of the charged particle. Since speed remains constant, the kinetic energy also stays constant

d. ASSERTION AND REASONING:

1. a	2. b	3. d	4. b	5. c

B. SELECT RESPONSE TYPE QUESTION

a. MCQ (EASY)

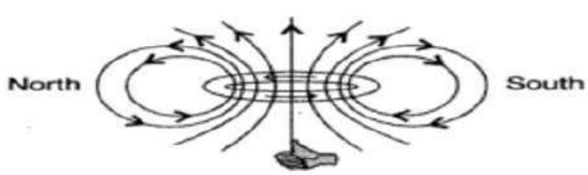
1.c	2.b	3.a	4.b	5. a
6. c	7.a	8.c	9.d	10.a

ANSWERS SELF ASSESSMENT:

1. (d) 2(a) 3(d) 4(b)

5.When connected in series I is in opposite direction therefore force of Repulsion. When connected with parallel I is in same direction force of attraction & they will move close to each other.

6.Direction of the magnetic field lines is given by right hand thumb rule.



Magnetic field lines

7.Since ammeter is an instrument used to measure the current in the circuit, so it has to be connected in series in the circuit to measure whole current. Hence its resistance makes it suitable for measuring current.

****

SELF TEST-2

1	A helium nucleus makes a full rotation in a circle of radius 0.8 meter in two second. The value of B (magnetic field) at the centre of the circle will be a) $\mu_0 \times 10^{-19}$T b) $\frac{10^{-19}}{\mu 0}$T c) 2×10^{-19}T d) $\frac{2\times10^{-19}T}{\mu 0}$	1 M
2	Draw the magnetic field lines of the field produced by a current carrying circular loop?	1 M
3	In a uniform magnetic field, an electron enters perpendicular to the field. The path of electron will be **A.** ellipse B. Circular C. Parabolic D. linear	1 M
4	A narrow beam of protons and neutrons, each having the same momentum, enters a region of uniform magnetic field directed perpendicular to their direction of momentum. What would be the ratio of the radii of the circular path described by them?	1 M
5	Current I is flowing in a coil of area A and number of turns is N, then magnetic moment of the coil is M equal to *A.*NIA B. NI/A C.NI/A D.N^2 AI	1 M
6	A galvanometer of resistance 25Ω gives full scale deflection for a current of 10 milliampere, is to be changed into a voltmeter of range 100 V by connecting a resistance of 'R' in series with galvanometer. The value of resistance R in Ω is ***A.*** 10000 ***B.*** 10025 ***C.*** 975 ***D.*** 9975	1 M
7	An electron is travelling horizontally towards East. A magnetic field is vertically downward direction exerts a force on the electron along A. East B. West C. North D. South	1 M
8	A circular loop of closely wound N turns and radius r carries a current I in the clockwise direction. Find- (i) the direction of field at its centre (ii) the magnitude of magnetic field at its centre.	2 M

9	Two identical circular loops P and Q each of radius R carrying 1A and √3 A respectively, are placed concentrically and perpendicular to each other lying in the XY and YZ planes. Find the magnitude and the direction of the net magnetic field at the centre of the coils.	2 M
10	Two long parallel wires carrying a current I , separated by a distance r are exerting a force F on each other. If the distance between them is increased to 2r and current in each wire is reduced from I to I/2 , then what will be the force between them?	2 M
11	A galvanometer gives full scale deflection with the current I_g . Can it be converted into an ammeter of range $I < I_g$?	2 M
12	A long straight solid metal wire of radius R carries a current I uniformly distributed over its circular cross section. Find the magnetic field at a distance *r* from the axis of wire(i) inside (ii) outside the wire.	3 M
13	State the principle of working of a galvanometer. A galvanometer of resistance G is converted into a voltmeter to measure up to V volts by connecting a resistance R_1 in series with the coil. If a resistance R_2 is connected in series with it, then it can measure up to v/2 volts. Find the resistance, in terms of R_1 and R_2, required to be connected to convert it into a voltmeter that can read up to 2V. Also , find the resistance G of the galvanometer in terms of R_1 and R_2.	3 M
14	A galvanometer having 30 divisions has a current sensitivity of 20 μA/div. It has a resistance of 25Ω. (i)How will you convert it into an ammeter of range 0-1A? (ii)How will you convert this ammeter into a voltmeter of range 0-1 V?	3 M
15	State Biot- Savert's law expressing it in the vector form. Use it to obtain the expression for the magnetic field at an axial point distance d from the centre of circular coil of radius a carrying current I . Also, Find the ratio of the magnitudes of the magnetic field of this coil at the centre and at an axial point for which d=a√3	5 M

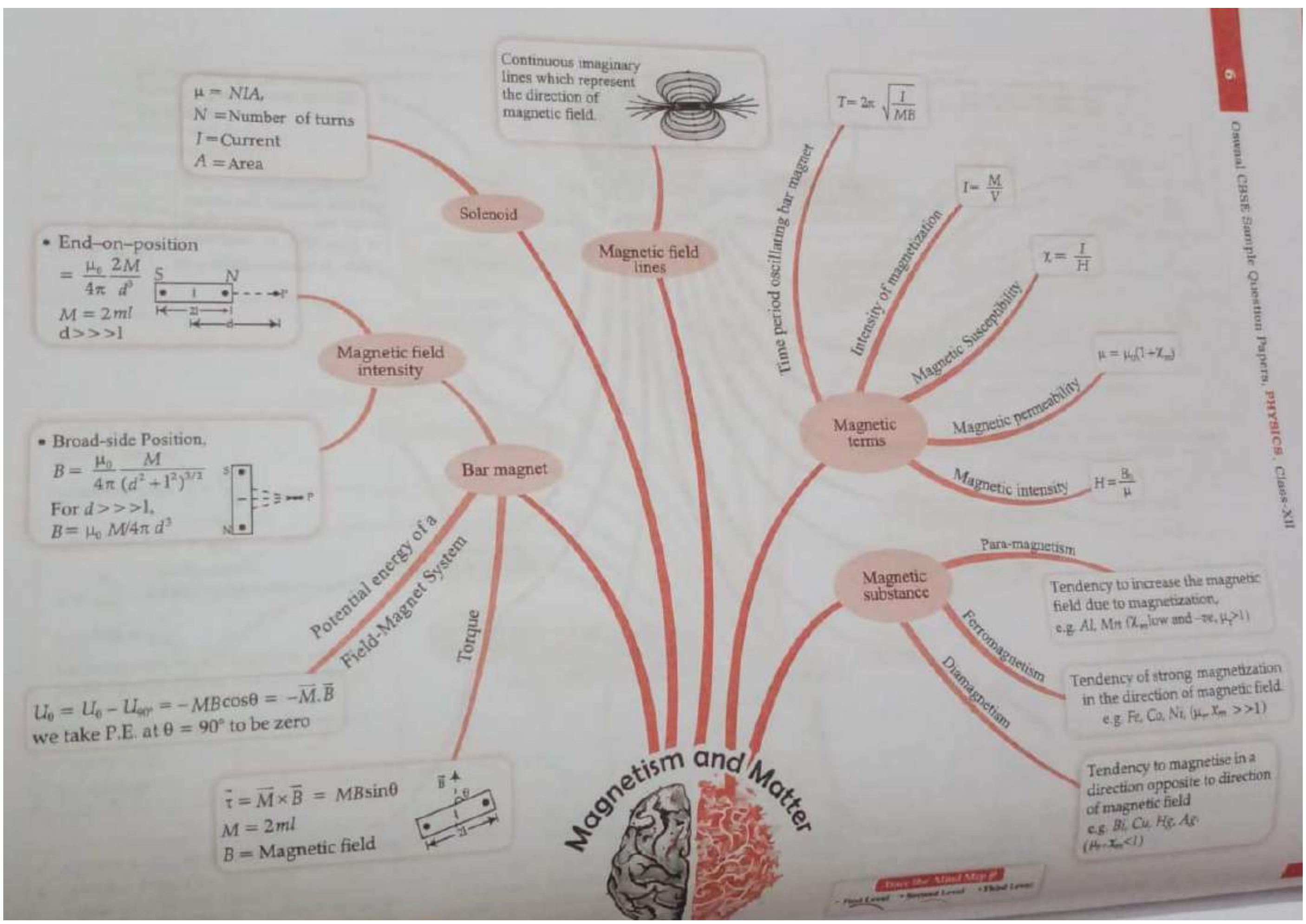
****

5. MAGNETISM and MATTER

GIST OF THE CHAPTER:

- Bar magnet, bar magnet as an equivalent solenoid (qualitative treatment only),
- Magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis (qualitative treatment only),
- Torque on a magnetic dipole (bar magnet) in a uniform magnetic field (qualitative treatment only),
- Magnetic field lines. Magnetic properties of materials- Para-, Dia- and ferro - magnetic substances with examples, Magnetization of materials,
- Effect of temperature on magnetic properties

MIND MAP :



IMPORTANT DEFINITIONS:

10. **Magnetic Intensity:** When a magnetic material is placed in a magnetic field, it becomes magnetised. The capability of the magnetic field to magnetise a material is expressed by means of a magnetic vector ***H***, called the magnetic intensity of the field. The relation between magnetic induction B and magnetising field ***H*** is

$$\boldsymbol{B} = \mathbf{m}\boldsymbol{H}$$

Where m is the permeability of medium.

11. **Intensity of Magnetisation:** It is defined as the magnetic moment per unit volume. The intensity of magnetisation is a vector quantity and its SI unit is

$$I = \frac{\text{Magnetic moment}}{\text{Volume}} = \frac{M}{V}$$

If A = uniform area of cross-section of the magnetised specimen (a rectangular bar)

$2l$ = magnetic length of the specimen

m = strength of each pole of the specimen, then

$$I = \frac{m \times 2l}{A \times 2l} = \frac{m}{A}$$

Am^{-1}.

12. **Magnetic Susceptibility:** It is defined as the ratio of the intensity of magnetisation (I) to the magnetising field (H). It is a scalar quantity with no units and dimensions. Physically, it represents the ease with which a magnetic material can be magnetised, *i.e.*, large value of χ_m implies that the material is more susceptible to the field and hence can be easily magnetised.

$$\chi_m = \frac{I}{H}$$

13. **Magnetic Permeability:** It is defined as the ratio of magnetic induction (B) to the magnetising field (H). It is a scalar quantity having unit H m^{-1}. It measures the degree to which a magnetic material can be penetrated by the magnetising field.

$$\mu = \frac{B}{H}$$

14. **Diamagnetic Substances:** Diamagnetic substances are those in which the individual atoms/molecules/ions do not posses any net magnetic moment of their

own. Eg: Bi, Cu, Pb, Si, N_2, Water, NaCl.

15. **Paramagnetic Substances:** Paramagnetic substances are those in which each individual atom/molecule/ion has a net non-zero magnetic moment of its own. Eg: Al, Na, Ca, O_2, $CuCl_2$.

16. **Ferromagnetic Substances:** Ferromagnetic substances are those in which each individual atom/molecule/ion has a non-zero magnetic moment, as in a paramagnetic substance. At high temperature, ferromagnetic becomes paramagnet. Eg: Fe, Ni, Co, Fe_2O_3.

17. **Curie Temperature (*TC*):** The temperature of transition from ferromagnetic to paramagnetic is known as Curie temperature (*TC*). The susceptibility above the Curie temperature *i.e.*, in the paramagnetic phase is given by

$$\chi_m = \frac{C}{T - T_C} \qquad (T > T_C)$$

This is known as Curie Weiss law.

FORMULAE:

1. Magnetic potential energy $U = mB(\cos\theta_1 - \cos\theta_2)$ (OR) $U = -mB\cos\theta$
2. Magnetic field on the equatorial line of bar magnet is $B = -\frac{\mu_0}{4\pi}\frac{m}{r^3}$
3. Magnetic field on the axial line of bar magnet is $B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$
4. Gauss law in magnetism: $\phi = 0$
5. Horizontal component of earth's magnetic field is $H_E = B_E \cos\theta$ and vertical component ofearth's magnetic field is $Z_E = B_E \sin\theta$
6. Earth's magnetic field: $B^2 = B_H^2 + B_V^2$ and $\theta = \tan^{-1}\left(\frac{B_V}{B_H}\right)$
7. Magnetization: $M = \frac{m_{net}}{V}$ and Magnetic intensity: $H = \frac{B_0}{\mu_0}$ where B_0 is external magnetic field.
8. $M = \chi H$ where χ is magnetic permeability.

12. $\mu_r = 1 + \chi$
13. Diamagnetic material: χ is negative and low
14. Superconductors: $\mu_r = 0$ and $\chi = -1$
15. Paramagnetic material: χ is positive and low
16. Ferromagnetic material: χ is positive and high

D. **COMPETENCY BASED QUESTIONS:**

e. **MCQ (HOTS):**

1. The resemblance of magnetic field lines for a bar magnet and a solenoid suggest that

(a) a bar magnet may be thought of as a large number of circulating currents in analogy with a solenoid

(b) cutting a bar magnet in half is like cutting a solenoid

(c) both (a) and (b) (d) neither (a) nor (b)

2. The resemblance of magnetic field lines for a bar magnet and a solenoid suggest that

(a) a bar magnet may be thought of as a large number of circulating currents in analogy with a Solenoid

(b) cutting a bar magnet in half is like cutting a solenoid

(c) both (a) and (b) (d) neither (a) nor (b)

3. A small bar magnet of moment M is placed in a uniform field B. If magnet makes an angle of 30° with field. The torque acting on the magnet is:-

(a) MB (b) MB/2 (c) MB/3 (d) MB/4

4. When a diamagnetic substance is placed near a magnet then it is

(a) Attracted (b) Repelled (c)No effect (d) None of these

5. Susceptibility is positive for

(a) Ferromagnetic material (b) Paramagnetic material
(c)Diamagnetic material (d) Option (a) and (b)

6. A magnetic needle is kept in a non-uniform magnetic field. It experiences
(a) a torque but not a force. (b) neither a force nor a torque.
(c) a force and a torque. (d) a force but not a torque.

7. Three needles N_1 N_2 and N_3 are made of a ferromagnetic, a paramagnetic and a diamagnetic substance respectively. A magnet, when brought close to them, will
(a) attract N_1 strongly, but repel N_2 and N_3 weakly. (b) attract all three of them.
(c) attract N_1 and N_2 strongly but repel N_3. (d) attract N_1 strongly, N_2 weakly and repel N_3 weakly.

8. A magnetic needle suspended parallel to a magnetic field requires /3 J of work to turn it through 60°. The torque needed to maintain the needle in this position will be

(a) $2\sqrt{3}$ J (b) 3 J
(c) $\sqrt{3}$ J (d) $\frac{3}{2}$ J

9. Two wires of same length are shaped into a square and a circle if they carry same current, ratio of magnetic moment is:

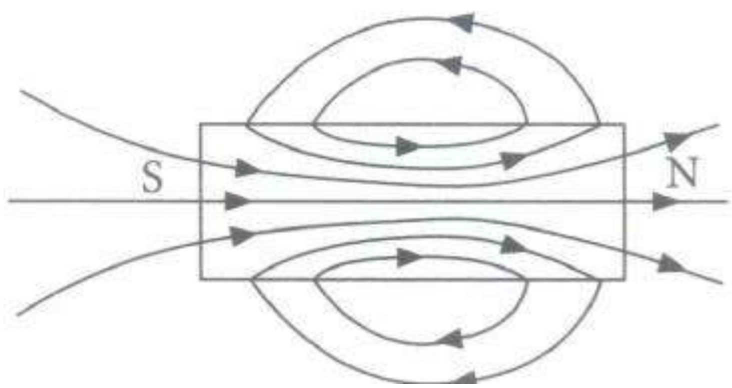
(a) 2 : π (b) π: 2 (c) π : 4 (d) 4 : π

10. A bar magnet is cut into two equal halves by a plane parallel to the magnetic axis. Of the following physical quantities, the one which remains unchanged is

(a) pole strength (b) magnetic moment (c) intensity of magnetisation (d) retentivity

f. CASE BASED QUESTIONS:

1. By analogy to Gauss's law of electrostatics, we can write Gauss's law of magnetism as $\oint \vec{B} \cdot \vec{ds} = \mu 0$ m_{inside} where $\oint \vec{B} \cdot \vec{ds}$ is the magnetic flux and m_{inside} is the net pole strength inside the closed surface.
   We do not have an isolated magnetic pole in nature. At least none has been found to exist till date. The smallest unit of the source of magnetic field is a magnetic dipole where the net magnetic pole is zero. Hence, the net magnetic pole enclosed by any closed surface is always zero. Correspondingly, the flux of the magnetic field through any closed surface is zero.



Consider the two idealised systems
(i) a parallel plate capacitor with large plates and small separation and
(ii) a long solenoid of length L >> R, radius of cross-section.

In (i) $\vec{E}$ is ideally treated as a constant between plates and zero outside.
In (ii) magnetic field is constant inside the solenoid and zero outside. These idealised assumptions, however, contradict fundamental laws as below

(a) case (i) contradicts Gauss's law for electrostatic fields
(b)case (ii) contradicts Gauss's aw for magnetic fields

(c) case (i) agrees with $\oint \vec{E} \cdot d\vec{l} = 0$.

(d) case (ii) contradicts $\oint \vec{H} \cdot \vec{dl} = I_{en}$

(ii) The net magnetic flux through any closed surface, kept in a magnetic field is

(a) zero (b) $\frac{\mu_0}{4\pi}$ (c) $4\pi\mu_0$ (d) $\frac{4\mu_0}{\pi}$

(iii) A closed surface S encloses a magnetic dipole of magnetic moment 2ml. The magnetic flux emerging from the surface is

(a) $\mu_0 m$ **(b) zero** (c) $2\mu_0 m$ (d) $\frac{2m}{\mu_0}$

(iv) Which of the following is not a consequence of Gauss's law?

(a) The magnetic poles always exist as unlike pairs of equal strength.

(b) If several magnetic lines of force enter in a closed surface, then an equal number of lines of force must leave that surface

(c) There are abundant sources or sinks of the magnetic field inside a closed surface

(d) Isolated magnetic poles do not exist

OR

The surface integral of a magnetic field over a surface
(a) is proportional to mass enclosed
(b) is proportional to charge enclosed
(c) is zero
(d) equal to its magnetic flux through that surface.

2. When the atomic dipoles are aligned partially or fully, there is a net magnetic moment in the direction of the field in any small volume of the material. The actual magnetic field inside material placed in magnetic field is the sum of the applied magnetic field and the magnetic field due to magnetisation. This field is called magnetic intensity (H).

$$H = \frac{B}{\mu_0} - M$$

where M is the magnetisation of the material, llo is the permittivity of vacuum and B is the total magnetic field. The measure that tells us how a magnetic material responds to an external field is given by a dimensionless quantity is appropriately called the magnetic susceptibility: for a certain class of magnetic materials, intensity of magnetisation is directly proportional to the magnetic intensity.

(i) Magnetization of a sample is
(a) volume of sample per unit magnetic moment (b) net magnetic moment per unit volume
(c) ratio of magnetic moment and pole strength (d) ratio of pole strength to magnetic moment
(ii) Identify the wrongly matched quantity and unit pair.

(a) Pole strength	Am
(b) Magnetic susceptibility	dimensionless number
(c) Intensity of magnetisation	A m^{-1}

(d) Magnetic permeability Henry m

(iii) A bar magnet has length- 3 cm, cross-sectional area 2 cm^2 and magnetic moment 3 A m^2. The intensity of magnetisation of bar magnet is

(a) 2×10^5 A/m (b) 3×10^5 A/m

(c) 4×10^5 A/m (d) 5×10^5 A/m

(iv) A solenoid has core of a material with relative permeability 500 and its windings carry a current of 1 A. The number of turns of the solenoid is 500 per metre. The magnetization of the material is nearly

(a) $2.5 \times 10^3 Am^{-1}$ (b) 2.5×10^5 A m^{-1}

(c) 2.0×10^3 A m^{-1} (d) 2.0×10^5 A m^{-1}

OR

The relative permeability of iron is 6000. Its magnetic susceptibility is

(a) 5999 (b) 6001

(c) 6000 x 10^{-7} (d) 6000 x 10^7

3. Before the 19th century, scientists believed that magnetic properties were confined to a few materials like iron, cobalt and nickel. But in 1846, Curie and Faraday discovered that all the materials in the universe are magnetic to some extent. These magnetic substances are categorised in two groups. Weak magnetic materials are called diamagnetic and para magnetic materials. Strong magnetic materials are called ferromagnetic materials. According to the modern theory of magnetism, the magnetic response of any material is due to circulating electrons in the atoms. Each such electron has a magnetic moment in a direction perpendicular to the plane of circulation. In magnetic materials all these magnetic moments due to the orbit and spin motion of all the electrons in any atom vectorially add up to a resultant magnetic moment. The magnitude and direction of these resultant magnetic moment is responsible for the behaviour of the materials. For diamagnetic materials χ is small and negative and for paramagnetic materials χ is small and positive. Ferromagnetic materials have a large χ and are characterised by non–linear relation between $\bar{B}$and H

(i) The universal (or inherent) property among all substance is

(a) Diamagnetism (b) Para magnetism

(c) Ferromagnetism (d) Both (a) and (b)

(ii) When a bar is placed near a strong magnetic field and it is repelled, then the material of the bar is

(a) Diamagnetic (b) Ferromagnetic
(c) Paramagnetic (d) Anti-ferromagnetic

(iii) Magnetic susceptibility of a diamagnetic substance

(a) Decreases with temperature (b) Is not affected by temperature
(c) Increases with temperature
(d) First increases then decreases with temperature

(iv) For a para magnetic material, the dependence of the magnetic susceptibility χ on the absolute temperature is given as

(a) $\chi \propto T$ (b) $\chi \propto 1/T^2$ (c) $\chi \propto 1/T$ (d) independent

g. TWO MARK QUESTIONS:

1. A circular coil of 'N' turns and radius 'R' carries a current 'I'. It is unwound and rewound to make another coil of radius 'R/2', current 'I' remaining the same. Calculate the ratio of the magnetic moments of the new coil and original coil.

2. Explain the following:

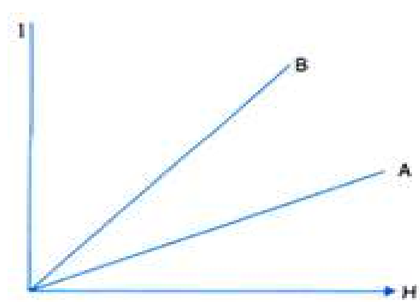
(i) Why do magnetic field lines from continuous closed loops?

(ii) Why are the field lines repelled when a diamagnetic material is placed in an external uniform magnetic field?

3. Write three points of difference between para-, dia- and ferro- magnetic materials, giving one example for each.

4. Deduce the expression for the magnetic dipole moment of an electron orbiting around central nucleus.

5. The following figure shows the variation of intensity of magnetization versus the applied magnetic field intensity H for two magnetic materials A and B.



(i) Identify the materials A and B .

(ii)Why does the material B have a largest susceptibility then A for a given field at constant temperature?

h. ASSERTION AND REASON QUESTIONS:

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

1. **Assertion :** We cannot think of a magnetic field configuration with three poles
   Reason : A bar magnet does exert a torque on itself due to its own field.
2. **Assertion :** Diamagnetic materials can exhibit magnetism.
   Reason : Diamagnetic materials have permanent magnetic dipole moment.
3. **Assertion :** Ferro-magnetic substances become paramagnetic above Curie temp.
   Reason : Domains are destroyed at high temperature.
4. **Assertion :** The poles of magnet can not be separated by breaking into two pieces.
   Reason : The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.
5. Assertion : Basic difference between an electric line and magnetic line of force is that former is discontinuous and the latter is continuous or endless.

Reason : No electric lines of forces exist inside a charged body but magnetic lines do exist inside a magnet.

E. SELECT RESPONSE TYPE QUESTIONS

b. MCQ (EASY):

1. The magnetic field lines of force inside a bar magnet:

a) From S pole to N pole of the magnet
b) Do not exist
c) From N pole to S pole of the magnet
d) Area of the cross-section of the magnet

2. The magnetic lines of force are:

(a) Closed curves
(b) Intersect far away from the poles
(c) Always intersect
(d)Do not pass through a vacuum

3. The magnetic dipole moment of a solenoid having N turns is given as -

(a) NIA^2 (b) NIA (c) NI^2A (d) NI^2A^2

4. A freely suspended magnet aligns in which direction?

(a) South-west (b)East-west (c) North-south (d) North-west

5. The SI unit of magnetic flux is

(a) Dyne (b) Tesla (c) Weber (d) Ohm

6. The materials with magnetic susceptibility negative and small are called as

(a) Paramagnetic (b) Diamagnetic (c) Ferromagnetic (d) None

7. Magnetic lines of force due to a bar magnet do not intersect because

(a) a point always has a single net magnetic field
(b) the lines have similar charges and so repel each other
(c) the lines always diverge from a single force
(d) the lines need magnetic lenses to be made to interest

8. If the magnetizing field on a ferromagnetic material is increased, its permeability
(a) Decreased (b) Increased (c) Is unaffected (d) May be increased or decreased

9. A circular loop carrying current I is replaced by a bar magnet of equivalent magnetic dipole moment. The point on the loop is lying _____.

(a) on equatorial plane of magnet
(b) on axis of the magnet
(c) A and B both
(d) except equatorial plane or axis of bar magnet

10. In non-uniform magnetic field, a diamagnetic substance experiences a resultant force

(a) which is zero
(b) perpendicular to the magnetic field.
(c) from the region of weak magnetic field to the region of strong magnetic field.
(d) from the region of strong magnetic field to the region of weak magnetic field.

F. CONSTRUCTED RESPONSE QUESTIONS:

a. THREE MARK QUESTIONS:

1. A bar magnet is placed in uniform magnetic field with its magnetic moment at angle θ with the magnetic field.
   i. Find expression for torque acting on the magnet.
   ii. Define magnetic moment.
2. Derive the expression for induced emf produced by changing the area of the rectangular coil placed in perpendicular magnetic field.

3. Differentiate between Diamagnetic, Paramagnetic and Ferromagnetic substances.
4. Show that the electron revolving around the nucleus in an orbit of radius 'r' with speed 'v' has magnetic moment evr/2. Hence using Bohr's postulate of angular momentum obtain the expression for magnetic moment of hydrogen atom in its ground state.

b. FIVE MARK QUESTIONS:

1.

(a) An iron ring of relative permeability 'μ' has windings of insulated copper wire of 'n' turns per metre. when the current in the winding is I, find the expression for magnetic field in the ring.
(b) The susceptibility of magnetic material is 0.9853. Identify the type of magnetic material draw the modification of field pattern on keeping a piece of this material in a uniform magnetic field.

2.
(a) Write the expression for equivalent magnetic moment of a planer current loop of area 'A', having 'N' turns and carrying current I use the expression to find the magnetic dipole moment of revolving electron.
(b) A circular loop of radius 'r', having 'N' turns and carrying current 'I' is kept in X Y plane. It is then subjected to uniform magnetic field $\mathbf{B = B_x i + B_y j + B_z k}$. Obtain expression for the magnetic potential energy of the coil - magnetic field system.

3.
(a) A long solenoid with air core has 'n' turns per unit length and carries a current 'I' using ampere circuital law derive an expression for magnetic field B at an interior point on its axis. Write an expression for magnetising field intensity 'H' in the interior of the solenoid.
(b) Small bar magnet off material having magnetic susceptibility 'χ', is now put along the axis and near the centre, of the solenoid which is carrying a dc current through its coils. After sometime the bar is taken out and suspended freely with an unspun thread. Will the bar orient itself in the magnetic meridian if (a) 'χ'< 0 (b) 'χ' > 1000?

SELF ASSESSMENT TEST:-

MCQ

1. A diamagnetic substance is brought near the north or south pole of a bar magnet. It will be :
(a) repelled by both the poles.
(b) attracted by both the poles.
(c) repelled by the north pole and attracted by the south pole.
(d) attracted by the north pole and repelled by the south pole.

2. In a permanent magnet at room temperature
(a) magnetic moment of each molecule is zero.
(b) the individual molecules have non-zero magnetic moment which are all perfectly aligned.
(c) domains are partially aligned.
(d) domains are all perfectly aligned.

ASSERTION BASED QUESTIONS:

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

3. Assertion (A) : When a bar of copper is placed in an external magnetic field, the field lines get concentrated inside the bar.
Reason (R) : Copper is a paramagnetic substance.

4.Assertion- diamagnetic materials can exhibit magnetism.
Reason-diamagnetic materials have permanent magnetic dipole moment. i
5.Assertion :When radius of a circular loop carrying current is doubled, its magnetic moment becomes four times.
Reason: Magnetic moment depends on the area of the loop.

6. Define magnetic susceptibility of a material. Name two elements, one having positive susceptibility and the other having negative susceptibility. What does negative susceptibility signify?
7. A circular coil of N turns and diameter 'd' carries a current 'I'. It is unwound and rewound to make another coil of diameter '2d', current T remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil.

ANSWERS

A. (COMPETENCY BASED QUESTIONS):

e. MCQ (HOTS):

1.c	2.b	3.d	4.b	5. (d) Option (a) and (b)
6. c	7.d	8.b	9.c	10.c

f. CASE BASED QUESTIONS:

1 .	i. b	ii. a	iii. b	iv. c OR d
2.	i. b	ii. d	iii. d	Iv. b OR a
3	i. a	ii. a	iii. b	iii. c

g. TWO MARK QUESTIONS:

1. As length of wire remains the

$$N_1 \times 2\pi R = N_2 \times 2\pi \frac{R}{2}$$

$$\therefore \qquad N_2 = 2N$$

Magnetic moment of a coil, m = NAI
For the coil of radius R, magnetic moment

$$m_1 = N_1 I A_1 = N_1 I \pi R^2$$

For the coil of radius $R/2$, magnetic moment

$$m_2 = N_2 I A_2 = \frac{2N_1 I \pi R^2}{4} = \frac{N_1 I \pi R^2}{2}$$

Now, m2/m1 = 1:2

2. (i) Magnetic lines of force form continuous closed loops because a magnet is always a dipole and as a result, the net magnetic flux of a magnet is always zero.

(ii) When a diamagnetic substance is placed in an external magnetic field, a feeble magnetism is induced in opposite direction. So, magnetic lines of force are repelled.

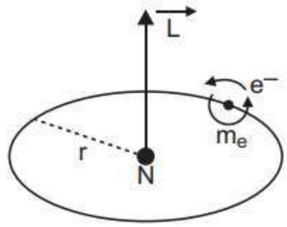
3.

1. Diamagnetic :
i) magnetic susceptibilty is independent of temperature.
ii) magnetic permeability has value less than 1.
iii) repelled by a strong magnet.

2. Paramagnetic:
i) magnetic susceptibility decreases with rise of temperature.
ii) magnetic permeabilty has value slightly greater than 1.
iii) attracted by a strong magnet.

3. Ferromagnetic:
i) magnetic susceptibility decreases with increase in temperature.
ii) magnetic permeabilty is very large.
iii) highly attracted by a strong magnet.

4. Consider an electron revolving around a nucleus (N) in circular path of radius r with speed v. The revolving electron is equivalent to electric current



I = e/T where T is period of revolution = 2πr/v

$$\therefore \quad I = \frac{e}{2\pi r / v} = \frac{ev}{2\pi r}$$

Area of current loop (electron orbit), A = πr2 Magnetic moment due to orbital motion,

$$M_l = IA = \frac{ev}{2\pi r}(\pi r^2) = \frac{evr}{2}$$

8. (i) Material A is Paramagnetic and Material B is Ferromagnetic.
(ii)Since paramagnetic substances have a tendency to pull in magnetic field lines when placed in a magnetic field.

h. ASSERTION AND REASONING:

9. d	10. c	11. a	12. b	13. a

B. (SELECT RESPONSE TYPE QUESTIONS):

a. MCQ (EASY):

1.a	2.a	3.b	4.c	5.c
6.b	7.a	8.a	9.a	10.d

SELF ASSESMENT:

1. a	2. c	3. c	4. c	5 . a

Ans 6. Sol: (i) Magnetic susceptibility (χm) : It is the property of a material which determines how easily it can be magnetised when kept in a magnetising field.

Also, it is the ratio of intensity of magnetisation (I) produced in the material to the intensity of magnetising field (H)

$$\chi_m = \frac{I}{H}$$

(ii) Positive susceptibility : para-magnetic material
Example: Al, Ca.
Negative susceptibility : diamagnetic material
Example: Bi, Cu.

Ans7. Magnetic moment of the coil is given by M = NIA

$$1^{st} \text{ case : } M_1 = N_1 I\pi \frac{d_1^2}{4},$$

$$2^{nd} \text{ case : } M_2 = N_2 I\pi \frac{d_2^2}{4}$$

But as given, I[st] coil is rewound to make new coil.

So, $N_1(2\pi r_1) = N_2(2\pi r_2)$ or $N_1 d_1 = N_2 d_2$

from given condition $d_2 = 2d_1$

$\Rightarrow \quad N_1 d_1 = N_2(2d_1) \quad \Rightarrow N_1 = 2N_2$

Ratio of M_1 and M_2 will be,

$$\frac{M_1}{M_2} = \frac{N_1 I\pi d_1^2 / 4}{N_2 I\pi d_2^2 / 4} = \frac{2N_2 \times d_1^2}{N_2 (2d)^2} = \frac{2}{4} = \frac{1}{2}$$

$\therefore \quad \mathbf{M_1 : M_2 = 1 : 2}$

****

6. ELECTROMAGNETIC INDUCTION

SYLLABUS: Electromagnetic induction; Faraday's laws, induced EMF and current; Lenz's Law, Self and mutual induction.

GIST

MAGNETIC FLUX:

The number of magnetic field lines crossing a surface normally is called magnetic flux (Φ_B) linked with the surface.

$$\Phi_B = \vec{B}.\vec{A} = BA\cos\theta$$

where B is the magnetic field, A is the area of the surface and θ is the angle, which the direction of the

magnetic field makes with normal to the surface.

The SI, unit of magnetic flux is **weber (Wb)**.

$$1 \text{ weber} = 10^8 \text{ maxwell}$$

ELECTROMAGNETIC INDUCTION

It is the phenomenon of production of e.m.f. in a coil, when the magnetic flux linked with the coil is changed. The e.m.f. so produced is called induced e.m.f. and the resulting current is called induced current.

FARADAY'S LAWS OF ELECTROMAGNETIC INDUCTION

1. Whenever magnetic flux linked with a circuit (a loop of wire or a coil or an electric circuit in general) changes, induced e.m.f. is produced.
2. The induced e.m.f. lasts as long as the change in the magnetic flux continues.

3. The magnitude of the induced e.m.f. is directly proportional to the rate of change of the magnetic flux.

Induced e.m.f., $\mathbf{e} = -\frac{d\phi}{dt} = \frac{\phi_2 - \phi_1}{t}$

LENZ'S LAW

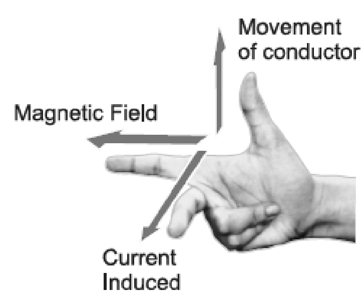
It states that the induced current produced in a circuit always flows in such a direction that it opposes the change or the cause that produces it. Lenz's law can be used to find the direction of the induced current.

MOTIONAL E.M.F

When a conductor of length *l* moves with a velocity v in a magnetic field B, so that magnetic field is perpendicular to both the length of the conductor and its direction of motion, the magnetic Lorentz force on the conductor gives rise to e.m.f. across the two ends of the conductor.

$$e = Blv$$

FLEMING'S RIGHT-HAND RULE



It is used to find the direction of flow of the induced current.

It states that if the thumb, forefinger and the central finger of the right hand are kept perpendicular to each other, so that the forefinger points in the direction of the field and the thumb in the direction of motion of the conductor, then the induced current flows in the direction of the central finger.

EDDY CURRENTS

The currents induced in the body of a conductor, when the magnetic flux linked with the conductor changes, are called eddy currents (or Foucault's currents). The direction of the eddy currents set up in the conductor can be found by applying Lenz's law or Fleming's right-hand rule.

SELF-INDUCTION

The phenomenon according to which an opposing induced e.m.f. is produced in a coil as a result of change in current or magnetic flux linked with it, is called self-induction.

COEFFICIENT OF SELF-INDUCTION

The coefficient of self-induction or simply self-inductance (L) of a coil is numerically equal to the magnetic flux (Φ) linked with the coil, when a unit current flows through it.

$$\Phi = LI$$

SELF-INDUCTANCE

The Self-Inductance of a coil is numerically equal to the induced e.m.f. produced in the coil, when the rate of change of current in the coil is unity.

$$e = -L\frac{dI}{dt}$$

The induced emf is also called back emf. Self-induction is also called inertia of electricity.

The SI unit of self-inductance is **Henry (H).**

The self-inductance of a coil is said to be one henry, if a rate of change of current of 1 ampere per second induces an e.m.f. of 1 volt in it.

ENERGY STORED IN AN INDUCTOR

When a current! flows through an inductor of self-inductance L, the energy stored in the inductor is given by

$$\mathbf{U = \frac{1}{2}LI^2}$$

The energy resides in the inductor in the form of magnetic field.

SELF-INDUCTANCE OF A LONG SOLENOID

The self-inductance of a long solenoid of length /, area of cross-section A and number of turns per unit length 1 is given by

$$L = \mu_0 n^2 l\ A$$

ENERGY STORED IN A SOLENOID

When a current is passed through a solenoid, the energy is stored inside it in the form of magnetic field. If the current builds up a magnetic field of induction B, then the energy stored in the solenoid is given by

$$U = \frac{1}{2\mu_0} B^2 A l$$

where / is length and A, the area of cross-section of the solenoid.

MUTUAL INDUCTION

The phenomenon according to which an opposing induced e.m.f. is produced in a coil as a result of change in current or magnetic flux linked with a neighbouring coil is called mutual induction.

COEFFICIENT OF MUTUAL INDUCTION

The coefficient of mutual induction or simply mutual inductance (M) of the two coils is numerically equal to the magnetic flux (p) linked with one coil, when a unit current flows through the neighbouring coil.

$$\Phi = MI$$

MUTUAL INDUCTANCE

The mutual inductance of two coils is also numerically equal to the induced e.m.f. produced in one coil, when the rate of change of current is unity in the other coil.

$$e = -M\frac{dI}{dt}$$

The SI unit of mutual inductance is **henry (H).**

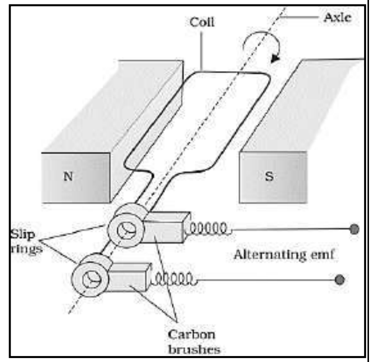
The mutual inductance of two coils is said to be one henry, if a rate of change of current of 1 ampere per second in one coil induces an e.m.f. of 1 volt in the neighbouring coil.

MUTUAL INDUCTANCE OF TWO LONG SOLENOIDS

When over a solenoid S_1, of length l, area of cross-section A and number of turns per unit length n_1, another solenoid S_2, of same length and number of turns per unit length n_2, is wound, then mutual inductance between the two solenoids is given by

$$M = \mu_0 n_1 n_2 \, l \, A$$

ALTERNATING CURRENT GENERATOR



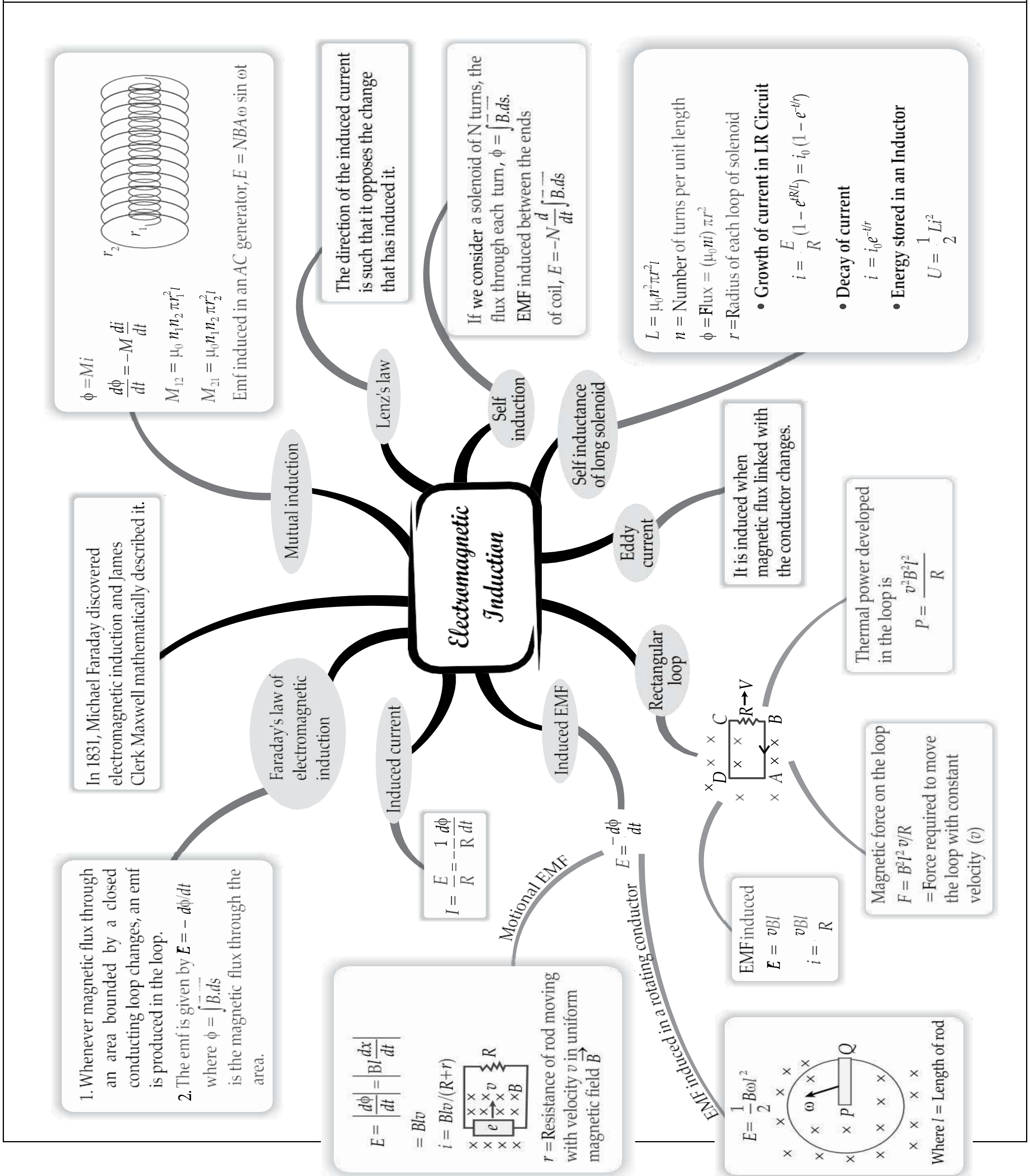
It is a device used to obtain a supply of alternating e.m.f. by converting mechanical energy into electrical energy. It is based on the phenomenon of electromagnetic induction.

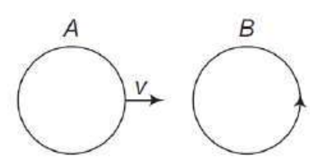
The instantaneous value of e.m.f. produced is given by

$$e = nBA\omega \sin \omega t$$

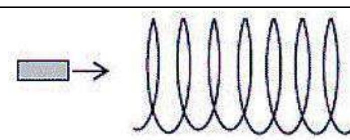
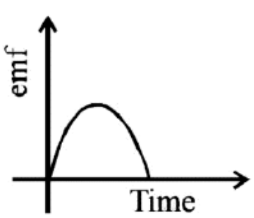
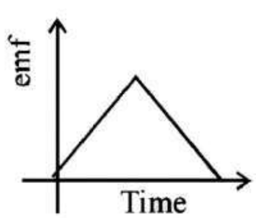
where n is number of turns of the coil, A is the area of coil and ω is angular frequency of rotation of the coil inside a magnetic field strength B.

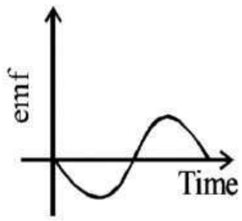
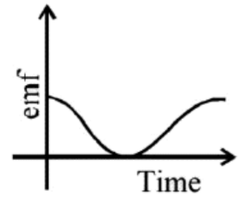
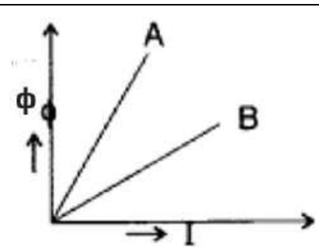
MIND MAP

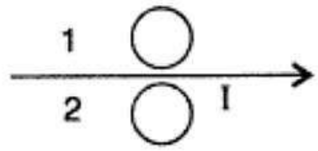
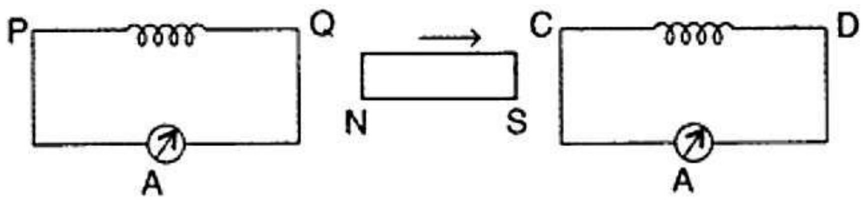

Electromagnetic Induction
Faraday's law of electromagnetic induction
1. Whenever magnetic flux through an area bounded by a closed conducting loop changes, an emf is produced in the loop.
2. The emf is given by E = – dϕ/dt where ϕ = ∫B.ds is the magnetic flux through the area.
In 1831, Michael Faraday discovered electromagnetic induction and James Clerk Maxwell mathematically described it.
Mutual induction
ϕ = Mi
dϕ/dt = –M di/dt
M12 = μ0 n1 n2 πr1² l
M21 = μ0 n1 n2 πr2² l
Emf induced in an AC generator, E = NBAω sin ωt
r2
r1
Lenz's law
The direction of the induced current is such that it opposes the change that has induced it.
Self induction
If we consider a solenoid of N turns, the flux through each turn, ϕ = ∫B.ds. EMF induced between the ends of coil, E = –N d/dt ∫B.ds
Self inductance of long solenoid
L = μ0 n² πr² l
n = Number of turns per unit length
ϕ = Flux = (μ0 ni) πr²
r = Radius of each loop of solenoid
• Growth of current in LR Circuit
i = E/R (1 – e^(tR/L)) = i0 (1 – e^(–t/τ))
• Decay of current
i = i0 e^(–t/τ)
• Energy stored in an Inductor
U = 1/2 Li²
Eddy current
It is induced when magnetic flux linked with the conductor changes.
Rectangular loop
D C A B R→V
Thermal power developed in the loop is
P = v²B²l²/R
Magnetic force on the loop
F = B²l² v/R
= Force required to move the loop with constant velocity (v)
EMF induced
E = vBl
i = vBl/R
Induced current
I = E/R = –1/R dϕ/dt
Induced EMF
E = –dϕ/dt
Motional EMF
E = |dϕ/dt| = |Bl dx/dt|
= Blv
i = Blv/(R+r)
e v R B
r = Resistance of rod moving with velocity v in uniform magnetic field B
EMF induced in a rotating conductor
E = 1/2 Bωl²
ω P Q
Where l = Length of rod

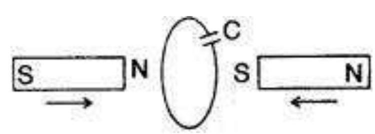
COMPETENCY BASED QUESTIONS	
1	A cylindrical bar magnet is rotated about its axis. A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then, (a) a direct current flows in the ammeter *A* (b) no current flows through the ammeter *A* (c) an alternating sinusoidal current flow through the ammeter *A* with a ti period $T = 2\pi/\omega$ (d) a time varying non-sinusoidal current flows through the ammeter *A.*
ANS	b
2	There are two coils A and B as shown in figure. A current start flowing in B as shown, whe is moved towards B and stops when A stops moving. The current in A is counter clockwise. B is kept stationary when A moves. We can infer that  (a) there is a constant current in the clockwise direction in A (b) there is a varying current in A (c) there is no current in A (d) there is a constant current in the counter clockwise direction in A
ans	d
3	The self-inductance L of a solenoid of length l and area of cross-section A, with a fixed number of turns N increases as

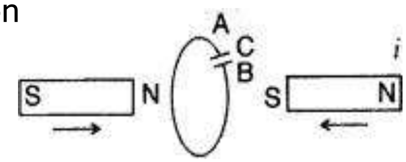
	(a) I and A increase (b) I decreases and A increases (c) I increases and A decreases (d) both I and A decrease
ANS	b
4	A metal plate is getting heated. It cannot be because (a) a direct current is passing through the plate (b) it is placed in a time varying magnetic field (c) it is placed in a space varying magnetic field, but does not vary with time (d) a current (either direct or alternating) is passing through the plate
ANS	c
5	emf is produced in a coil, which is not connected to an external voltage source. This cannot be due to (a) the coil being in a time varying magnetic field (b) the coil moving in a time varying magnetic field (c) the coil moving in a constant magnetic field (d) the coil is stationary in external spatially varying magnetic field, which does not change with time
ANS	d
6	A short-circuited coil is placed in a time-varying magnetic field. Electrical power is dissipated due to the current induced in the coil. If the number of

	turns were to be quadrupled and the wire radius halved, the electrical power dissipated would be (a) halved (b) the same (c) doubled (d) quadrupled
ANS	b
7	Two identical circular loops of metal wire are lying on a table without touching each other. Loop A carries a current which increases with time. In response the loop B (a) remains stationary (b) is attracted by loop A (c) is repelled by loop A (d) rotates about is CM with CM fixed
ANS	c
8	A small bar magnet is being slowly inserted with constant velocity inside a solenoid as shown in figure. Which graph best represents the relationship between emf induced with time  (a)  (b) 

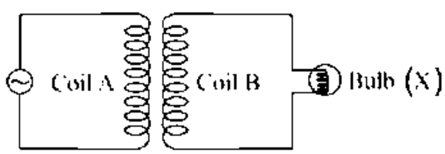
	(c)  (d) 
ANS	c
9	The coils in resistance boxes are made from doubled insulated wire to nullify the effect of (a) heating (b) magnetism (c) pressure (d) self-induced e.m.f.
ANS	d
10	The north pole of a long bar magnet was pushed slowly into a short solenoid connected to a short galvanometer. The magnet was held stationary for a few seconds with the north pole in the middle of the solenoid and then withdrawn rapidly. The maximum deflection of the galvanometer was observed when the magnet was (a) moving towards the solenoid (b) moving into the solenoid (c) at rest inside the solenoid (d) moving out of the solenoid
ANS	d
	<u>ONE MARK QUESTIONS</u>
1	 A plot of magnetic flux (ϕ) versus current (I) is shown in the figure for two inductors A and B. Which of the two has larger value of self-inductance?
ANS	Since $\phi = LI$ $\therefore$ L = ϕ /I= slope Slope of A is greater than slope of B $\therefore$ Inductor A has larger value of self-inductance than inductor B.

2	Predict the directions of induced currents in metal rings 1 and 2 lying in the same plane where current I in the wire is increasing steadily. 
ANS	In metal ring 1, the induced current flows in the clockwise direction. In metal ring 2, the induced current flows in the anticlockwise direction
3	A bar magnet is moved in the direction indicated by the arrow between two coils PQ and CD. Predict the directions of induced current in each coil. 
ANS	By Lenz's law, the ends of both the coils closer to the magnet behave as south pole. Hence the current induced in both the coils will flow clockwise when seen from the magnet side.
4	The motion of copper plates is damped when it is allowed to oscillate between the two poles of a magnet. If slots are cut in the plate, how will the damping be affected?
ANS	Eddy current will decrease due to which damping reduces
5	Two spherical bobs, one metallic and the other of glass, of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach earlier and why?
ANS	Glass bob would reach earlier because there would be a force acting upward due to eddy currents on metallic bob being conducting, due to earth's magnetic field. This will slow down the metallic bob.
2 MARKS QUESTIONS	
1	light metal disc on the top of an electromagnet is thrown up as the current is switched on. Why? Give reason.

ANS	A metal disc is placed on the top of a magnet, as the electric current flows through the coil, an induced current in the form of Eddies flows through the metal plate, the lower face attains the same polarity, and hence the metal disc is thrown up.
2	planar loop of rectangular shape is moved within the region of a uniform magnetic field acting perpendicular to its plane. What is the direction and magnitude of the current induced in it?
ANS	planar loop moves within the region of uniform magnetic field, there is no magnetic flux changes by loop so, no current will be induced in the loop. Hence no direction.
3	How does the mutual inductance of a pair of coils change when distance between the coils is increased and number of turns in the coils is increased?
ANS	(i) Mutual inductance decreases', because flux linked with the secondary coil decreases. (ii) $M=\mu_0 n_1 n_2 A/l$, so when n_1 and n_2 increase, mutual inductance (M) increases.
4	Two bar magnets are quickly moved towards a metallic loop connected across a capacitor 'C' as shown in the figure. Predict the polarity of the capacitor. 
ANS	When both magnets move towards loop, the A side plate of capacitor will be positive while the lower plate B is negative, making the induced current

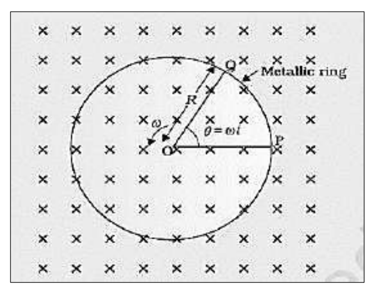
	in a clockwise direction 
5	A long straight current carrying wire passes normally through the centre of a circular loop. If the current through the wire increases, will there be an induced emf in the. loop? Justify.
ANS	No, As the magnetic field due to current carrying wire will be in the plane of the circular loop, so magnetic flux will remain zero.
3 MARKS QUESTIONS	
1	How is the mutual inductance of a pair of coils affected when (a) Separation between the coils is increased. (b) The number of turns of each coil is increased. (c) A thin iron sheet is placed between two coils, other factors remaining the same. Explain answer in each case.
ANS	(a) When the Separation between the coils is increased, the flux linked with the secondary coils decreases, hence mutual induction decreases. (b) Since mutual inductance **M =** $\mu_0 n_1 n_2\ l\ A$, , it increases when the number of turns of each coil (n_1 and n_2) is increased. (c) Mutual induction will increase because **M =** μ_r , (relative permeability of material)

2	State Lenz's law. Give one example to illustrate this law. "The Lenz's law is a consequence of the principle of conservation of energy." Justify this statement.
ANS	According to Lenz's law, the direction of induced current in a closed circuit is always such as to oppose the cause that produces it.  When the north pole of a coil is brought near a closed coil, the direction of current induced in the coil is such as to oppose the approach of north pole. For this the nearer face of coil behaves as north pole. This necessitates an anticlockwise current in the coil, when seen from the magnet side. Similarly, when north pole of the magnet is moved away from the coil, the direction of current in the coil will be such as to attract the magnet. For this the nearer face of coil behaves as south pole. This necessitates a clockwise current in the coil, when seen from the magnet side. Conservation of Energy in Lenz’s Law: In each of the above cases whenever there is a relative motion between a coil and the magnet, a force begins to act which opposes the relative motion. Therefore, to maintain the relative motion, a mechanical work must be done. This work appears in the form of electric energy of coil. Thus, Lenz’s law is based on conservation of energy.

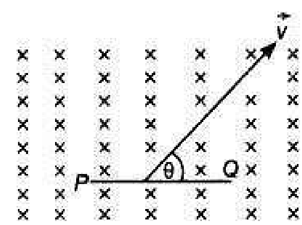
3	There are two coils A and B separated by some distance. If a current of 2A flows through A, a magnetic flux of 10^{-2} Wb passes through B (no current through B). If no current passes through A and a current of 1 A passes through B, what is the flux through A?
ANS	Applying the mutual inductance of coil A with respect to coil B $M_{21} = \frac{N_2\phi_2}{I_1}$ Therefore, we have Mutual inductance = 10^{-2} / 2 = 5mH Again, applying this formula for other case $N_1\ \phi_1 = M_{21} \times I_2$ = 5mH × 1A = 5mWb.
4	The figure given below shows an arrangement by which current flows through the bulb (X) connected with coil B, when a.c. is passed through coil Explain the following observation:  a) Bulb lights up. b) Bulb gets dimmer if the coil B is moved upwards c) If a copper sheet is inserted in the gap between the coils, how the brightness of the bulb would change?
ANS	a) Bulb lights up due to induced current setup in the coil B because of a.c. in coil A b) Bulb gets dimmer if the coil B is moved upwards as the flux linked with coil B decreases and induced current also decreases. c) When the copper sheet is inserted, eddy currents are set up in it which oppose the passage of magnetic flux. The induced emf in coil B decrease. This decreases the brightness of the bulb.
5	a) The motion of copper plate is damped when it is allowed to oscillate between the two poles of a magnet. What is the cause of this damping?

	b) A solenoid is connected to a battery so that a steady current flows through it. If an iron core is inserted into the solenoid, will the current increase or decrease? Explain.
ANS	a) We know that when a conductor is placed in a fluctuating magnetic field, Eddy currents form within the conductor. In this case as the plate oscillate, the changing magnetic flux through the plate produces a strong eddy current in the direction, which opposes the cause. Also, copper being diamagnetic substance, it gets magnetised in the opposite direction, so the plate motion gets damped. b) When the iron core is inserted in the current carrying solenoid, the magnetic field increase due to the magnetization of iron core and consequently the flux increases. According to Lenz's law, the emf produced must oppose this increase in flux, which can be done by making decrease in current. So, the current will decrease.
6	ımla peddles a stationary bicycle the pedals of the bicycle are attached to a 100-turn coil of area 0.10 m^2. The coil rotates at half a revolution per second and it is placed in a uniform magnetic field of 0.01 T perpendicular to the axis of rotation of the coil. What is the maximum voltage generated in the coil?
ANS	Here, f = 0.5 Hz; N =100, A = 0.1 m^2 and B = 0.01 T. The maximum value of the emf is, $\varepsilon_o = NBA\omega$ $= NBA\ (2\pi f)$ $= 100 \times 0.01 \times 0.1 \times 2 \times 3.14 \times 0.5$

	= 0.314 V
7	A 0.5 m long solenoid of 10 turns/cm has area of cross-section 1 cm^2. Calculate the voltage induced across its ends if the current in the solenoid is changed from 1A to 2A in 0.1s.
ANS	Here l = 0.5 m N= 10 turns/cm = 1000/m Change in current dI = (2-1) = 1 A, dt = 0.1 s The induced voltage, $\vert E \vert = L\frac{dI}{dt}$ $= \mu o n^2 l \; A\frac{dI}{dt}$ $= 4\pi \times 10^{-7} \times 1000^2 \times 10^{-4} \times 0.5 \times \frac{1}{0.1}$ $= 20\pi \times 10^{-5}$ = 0.628mV
8	/hat are eddy currents? Why are eddy currents called necessary evil?
ANS	Eddy currents are loops of electrical current induced within conductors by a changing magnetic field according to Faraday's law of induction. When a conductor is placed in a fluctuating magnetic field, these circular currents form within the conductor. Eddy currents have both positive and negative effects, that is why they are often considered as a necessary evil. It is a necessary evil in an arrangement as it can be used in applications like electric brakes, induction furnaces, dead-beat galvanometers etc. and brings loss of energy with heat production etc.
SELECT RESPONSE QUESTIONS (MCQ)	
1	Lenz's law of electromagnetic induction is as per law of conservation of a) energy b) angular momentum. c) charge. d) electromotive force.

ANS	a
2	Which of the following statements is not correct? a) Whenever the amount of magnetic flux linked with a circuit changes, an emf is induced in circuit. b) The induced emf lasts so long as the change in magnetic flux continues. c) The direction of induced emf is given by Lenz's law d) Lenz's law is a consequence of the law of conservation of momentum
ANS	d
3	Which of the following statements is wrong for magnetic flux a) Magnetic flux can be negative b) Magnetic flux can be positive c)Magnetic flux can be zero d) Magnetic flux is always positive or negative
ANS	**d**
4	A metallic rod of length ' L' is rotated with an angular frequency of 'ω', with one end hinged at the centre and the other end at the circumference of circular metallic ring of radius 'R', about an axis passing through the centre and perpendicular to the plane of the ring as shown in the figure. A constant and uniform magnetic field 'B' parallel to the axis is present everywhere. What is the emf between the centre and the metallic ring? 

	a) $\frac{B\omega R}{2}$ b) $\frac{B\omega^2 R}{2}$ c) $\frac{B\omega R^2}{2}$ d) $\frac{B^2\omega R}{2}$
ANS	**c**
5	In the given figure current from A to B in the straight wire is increasing. The direction of the induced current in the loop is  a) clockwise b) anticlockwise c) straight line d) no induced e.m.f. produced.
ANS	b
6	When current in a coil change from 5 A to 2 A in 0.1 s, average voltage of 50V is produced. The self-inductance of the coil is V is produced. The self-inductance of the coil will be. a) 1.67 H b) 6 H c) 3 H d) 0.67 H
ANS	a
7	If number of turns in primary and secondary coils is increased to two times each, the mutual induction a) becomes 4 times b) becomes 2 times c) becomes 8 times d) remains unchanged
ANS	

8	The polarity of the induced emf is given by a) Ampere' circuital law b) Bio- Savart Law c) Lenz's law d) Fleming's right-hand rule
ANS	c
9	Eddy currents produced in a conductor are responsible for: (a) damping (b) loss of energy (c) heating (d) All of the above
ANS	d
10	A rod PQ of length 'l' is moved in uniform magnetic field '**B**' as shown. If the rod is moving with a velocity 'v' making an angle 'θ' with magnetic field. What will be the emf induced in it?  a) B l v sin θ b) B l v cos θ c) B l v d) B l v tan θ
ANS	a

CASE-STUDY BASED QUESTION

CBQ-1

Faraday's law of electromagnetic induction, also known as Faraday's law is the basic law of electromagnetism which helps us to predict how a magnetic field would interact with an electric circuit to produce an electromotive force (EMF). This phenomenon is known as electromagnetic induction. Faraday's Experiment: Relationship Between Induced EMF and Flux.

In the first experiment, he proved that when the strength of the magnetic field is varied, only then-current is induced. An ammeter was connected to a loop of wire; the ammeter deflected when a magnet was moved towards the wire.

In the second experiment, he proved that passing a current through an iron rod would make it electromagnetic. He observed that when a relative motion exists between the magnet and the coil, an electromotive force will be induced. When the magnet was rotated about its axis, no electromotive force was observed, but when the magnet was rotated about its own axis then the induced electromotive force was produced. Thus, there was no deflection in the ammeter when the magnet was held stationary.

While conducting the third experiment, he recorded that the Galvanometer did not show any deflection and no induced current was produced in the coil when the coil was moved in a stationary magnetic field. The ammeter deflected in the opposite direction when the magnet was moved away from the loop

I) According to Faraday's law, EMF stands for

a) Electromagnetic field b) Electromagnetic force

c) Electromagnetic friction d) Electromotive force

II) As per Faraday's laws of electromagnetic induction, an e.m.f. is induced in a conductor whenever it

a) Lies perpendicular to the magnetic flux

b) Lies in a magnetic field

c) Cuts magnetic flux

d) Moves parallel to the direction of the magnetic field

III) For time varying currents, the field or waves will be

a) Electrostatic b) Magnetostatic c) Electromagnetic d) Electrical

IV) Find the displacement current when the flux density is given by t^3 at 2 seconds.

a) 3 b) 6 c) 12 d) 27

OR

Which of the following statements is true?

a) E is the cross product of v and B b) B is the cross product of v and E

c) E is the dot product of v and B d) B is the dot product of v and E

Answers: I) d II) c III) c IV) c OR a

CBQ-2

The migratory birds' patterns are one of the mysteries in the field of science. For example, every winter birds from Siberia fly unerringly to water spots in the Indian sub- continent. There has been a suggestion that electromagnetic induction may provide a clue to the migratory patterns. The earth's magnetic field has existed throughout evolutionary history. It would be of great benefit to migratory birds to use this field to determine the direction. As far as we know birds contains no ferromagnetic materials. So, electromagnetic induction seems to be the only reasonable mechanism to determine the direction. Consider the optimal case where the magnetic field B, the velocity of the bird v and two relevant points of its anatomy separated by a distance l, all three are mutually perpendicular. From the formula for motional emf i.e., ε=Blv

Certain kinds of fishes are able to detect small potential differences. However, in these fishes, special cells have been identified. Thus, the migration patterns of birds continue to remains a mystery.
I) An emf is produced in a coil, which is not connected to an external voltage source. This can be due to (a) the coil being in a time varying magnetic field (b) the coil moving in a time varying magnetic field (c) the coil moving out of constant magnetic field (d) All of the above
II) A circular coil expands radially in a region of magnetic field and no electromotive force is produced in the coil. This can be because (a) the magnetic field is in the same plane as the circular coil and it may or may not vary (b) the magnetic field has a perpendicular (to the plane of the coil) component whose magnitude is decreasing suitably. (c) there is constant magnetic field in the perpendicular (to the plane of their coil) direction. (d) Both (a) and (b)

III) A migratory Siberian bird is flying in the sky with a velocity of 10 m/s and the distance between two feathers is 2 cm. The earth's magnetic field B perpendicular to the feather is 4 x 10-5 T. Then emf generated between the two feathers is

(a) 4 μV (b) 6 μV (c) 8 μV (d) 10 μV

OR

An airplane having a wing span of 35 m flies due north with speed of 90 m/s, given B = 4 X 10^{-5} T, the potential difference between the tips of the wings will be

(a) 0.126 V (b) 1.26 V (c) 12.6 V (d) 0.013 V

IV) A moving conductor's coil produces an induced emf. This is in accordance with

(a) Lenz's Law (b) Coulomb's Law

(c) Faraday's Law (d) Ampere's Law

Answers: I) d II) d III) c OR a IV) c

ASSERTION-REASON TYPE QUESTIONS

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

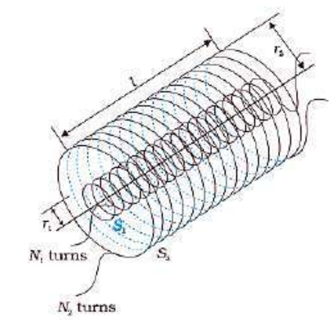
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion. (c) If the Assertion is correct but Reason is incorrect. (d) If both the Assertion and Reason are incorrect.	
1	Assertion: Magnetic flux linked to closed surface is zero. Reason: Direction of induced current due to change of magnetic flux is given by Faraday's Law.
ANS	c
2	Assertion: When two coils are wound on each other, the mutual induction between the coils is maximum. Reason: Mutual induction does not depend on the orientation of the coils.
ANS	c
3	Assertion: An induced current has a direction such that the magnetic field due to the current opposes the change in the magnetic flux that induces the current. Reason: Above statement is in accordance with conservation of energy.
ANS	b
4	**Assertion:** When number of turns in a coil is doubled, coefficient of self-inductance of the coil becomes 4 times. **Reason:** This is because self-inductance is directly proportional to the square of number of turns in a coil.
ANS	a

5	Assertion: Acceleration of a magnet falling through a long solenoid decrease. Reason: The induced current produced in a circuit always flow in such direction that it opposes the change to the cause that produced it.
ANS	a
6	Assertion: Faraday's laws are consequence of conservation of energy. Reason: In a purely resistive ac circuit, the current legs behind the emf in phase.
ANS	c
7	sertion: An emf can be induced by moving a conductor in a magnetic field. ason: An emf can be induced by changing the magnetic field.
ANS	b
8	sertion: An induced emf appears in any coil in which the current is changing. ason: Self-induction phenomenon obeys Faraday's law of induction.
ANS	b
9	ssertion: An induced emf appears in any coil in which the current is changing. eason: Self-induction phenomenon obeys Faraday's law of induction.
ANS	a
10	ssertion: Inductance coils are made of copper. eason: Induced current is more in wire having less resistance
ANS	a
LONG ANSWER (5 MARKS)	
1	Deduce an expression for the mutual inductance of two long coaxial solenoids but having different radii and different number of turns.

ANS

When a current I2 is set up through S2, it in turn sets up a magnetic flux through S1. Let us denote it by ϕ1. The corresponding flux linkage with solenoid S1 is



$N_1\Phi_1 = M_{12}I_2$ ………..(1)

M_{12} is called the mutual inductance of solenoid S1 with respect to solenoid S_2.

The magnetic field due to the current I2 in S2 is μ0n2I2. The resulting flux linkage with coil S_1 is,

$N_1\Phi_1= (n_1 /) (\pi r_1^2) (\mu_o n_2 I_2) =n_1 \ n_2 \ \pi r_1^2 /\mu_o I_2$ ……………….. (2)

where $n_1/$ is the total number of turns in solenoid S1. Thus, from Eq. 1 and Eq. 2

$$M_{12} = \mu_0 n_1 n_2 \pi r_1^2 / \text{……………………..(3)}$$

We now consider the reverse case. A current I_1 is passed through the solenoid S_1 and the flux linkage with coil S_2 is,

$$N_2\Phi_2 = M_{21} \ I_1 \text{ …………………… …(4)}$$

The flux due to the current I1 in S1 can be assumed to be confined solely inside S1 since the solenoids are very long. Thus, flux linkage with solenoid S_2 is

$$N_2\Phi_2= (n_2/) (\pi r_1^2) (\mu_o n_1 I_1) \text{ ……………………..(5)}$$

where $n_2/$ is the total number of turns of S_2.

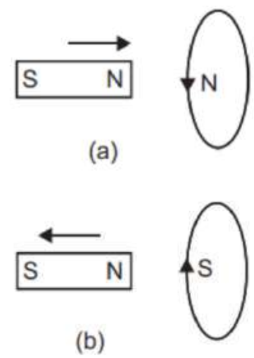
From equations 4 and 5

$$M_{21} = \mu_0 n_1 n_2 \pi r_1^2 / \text{ ……………………………..(6)}$$

Using Eq.3 and Eq. 6, we get

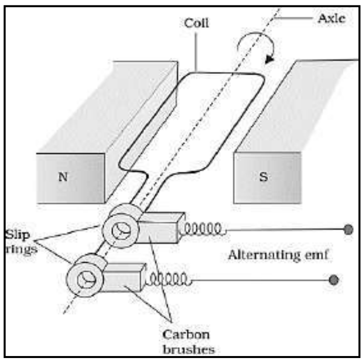
$$M_{12} = M_{21}= M \text{ (say)} = \mu_0 n_1 n_2 \pi r_1^2 /$$

2 a) State Lenz's law. Give one example to illustrate this law. "The Lenz's law is a consequence of the principle of conservation of energy." Justify

	this statement. b) A long solenoid with 15 turns per cm has a small loop of area 2.0 cm^2 placed inside the solenoid normal to its axis. If the current carried by the solenoid changes steadily from 2.0 A to 4.0 A in 0.1 s, what is the induced emf in the loop while the current is changing?
ANS	a) **Lenz's law:** According to this law "the direction of induced current in a closed circuit is always such as to oppose the cause that produces it." **Example:** When the north pole of a coil is brought near a closed coil, the direction of current induced in the coil is such as to oppose the approach of north pole. For this the nearer face of coil behaves as north pole. This necessitates an anticlockwise current in the coil, when seen from the magnet side (fig. a)  Similarly, when north pole of the magnet is moved away from the coil, the direction of current in the coil will be such as to attract the magnet. For this the nearer face of coil behaves as south pole. This necessitates a clockwise current in the coil, when seen from the magnet side (fig. b) **Conservation of Energy in Lenz's Law:** Thus, in each case whenever there is a relative motion between a coil and the magnet, a force begins to act which opposes the relative motion. Therefore, to maintain the

	relative motion, a mechanical work must be done. This work appears in the form of electric energy of coil. Thus, Lenz's law is based on conservation of energy. b) The magnetic field produced inside the solenoid, $B = \mu_o nI$ If is the area of the loop placed inside the solenoid, then magnetic flux linked with the loop, $\phi = BA = \mu_o nIA$ If e is the induced e.m.f. produced due to change in current through the solenoid, then $e = -\frac{d\phi}{dt}$ $= -\frac{d}{dt}(\mu_o nIA)$ $= -\mu_o nA\frac{dI}{dt}$ $= -2 \times 10^{-4} \times 4\pi \times 10^{-7} \times 1500 \times \frac{2}{0.1}$ $= -7.54 \times 10^{-6}$ V
3	Describe the construction, principle and working of an AC generator.
ANS	AC generator is a device used to obtain a supply of alternating e.m.f. by converting mechanical energy into electrical energy. <u>Principal:</u> It is based on the phenomenon of electromagnetic induction. A method to induce an emf or current in a loop is through a change in the loop's orientation or a change in its effective area. As the coil rotates in a

magnetic field B, the effective area of the loop (the face perpendicular to the field) is A cos θ, where θ is the angle between A and B. This method of producing a flux change is the principle of operation of a simple ac generator.

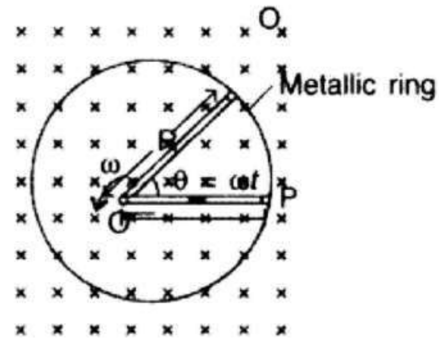


Construction: An Ac generator consists of two poles i.e. is the north pole and south pole of a magnet so that we can have a uniform magnetic field. There is also a coil which is rectangular in shape that is the armature. These coils are connected to the slip rings and attached to them are carbon brushes.

The slip rings are made of metal and are insulated from each other. The brushes are carbon brushes and one end of each brush connects to the ring and other connects to the circuit. The rectangular coils rotate about an axis which is perpendicular to the magnetic field. There is also a shaft which rotates rapidly.

Working: When the armature rotates between the poles of the magnet upon an axis perpendicular to the magnetic field, the flux which links with the armature changes continuously. Due to this, an emf is induced in the armature. This produces an electric current through the galvanometer and the slip rings and brushes.

The instantaneous value of e.m.f. produced is given by

	$$e = nBA\omega \sin \omega t$$ where n is number of turns of the coil, A is the area of coil and ω is angular frequency of rotation of the coil inside a magnetic field strength B.
4	a) A metallic rod of 'L' length is rotated with angular frequency of 'ω' with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius L, about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis is present everywhere. Deduce the expression for the emf between the centre and the metallic ring.  b) A wheel with 10 metallic spokes each 0.5 m long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of earth's magnetic field H_E at a place. If H_E = 0.4 G at the place, what is the induced emf between the axle and the rim of the wheel? ($1G = 10^{-4}$ T)
ANS	a) All points on the rod are moving perpendicular to the magnetic field. Hence, all elementary small elements of the rod induce a small potential difference and the net potential difference in the rod is the integration of the potential differences along the rod. Motional emf in a conductor moving perpendicular to the field is given by: $$\varepsilon = Bvl$$ The potential difference across a small element of rod dl, $$d\varepsilon = Bv(dl)$$ But $\quad v = \omega l$ $\Rightarrow \quad d\varepsilon = Bl\omega dl$

	Hence total emf produced across the rod, $\varepsilon = \int_0^L Bl\omega \; dl$ Hence $\varepsilon = \frac{1}{2} B\omega L^2$ b) Induced emf = $\frac{1}{2}\omega B R^2$ $= \frac{1}{2} \times 4\pi \times 0.4 \times 10^{-4} \times (0.5)^2$ $= 6.28 \times 10^{-5}$ V The number of spokes is immaterial because the emf's across the spokes are in parallel
5	Define the term self-inductance of a solenoid. Obtain the expression for the magnetic energy stored in an inductor of self-inductance L to build up a current I through it.
ANS	The phenomenon according to which an opposing induced e.m.f. is produced in a coil as a result of change in current or magnetic flux linked with it, is called self-induction and this property of the coil is the self-inductance (L) of the coil. The coefficient of self-induction or inductance (L) of a coil is numerically equal to the magnetic flux (Φ) linked with the coil, when a unit current flows through it. $N\Phi_B = LI$ Also, the Self-Inductance of a coil is numerically equal to the induced e.m.f. produced in the coil, when the rate of change of current in the coil is unity.

	$$\varepsilon = -L\frac{dI}{dt}$$ The SI unit of self-inductance is **henry (H).** <u>Self-inductance of a long solenoid</u> A long solenoid is one which length is very large as compared to its cross-section area. Let's consider of cross-sectional area *A* and length *l*, having *n* turns per unit length. The magnetic field due to a current *I* flowing in the solenoid is $B = \mu_o nI$ The total flux linked with the solenoid is, $$N\Phi_B = (nl)(\mu_o nI)(A)$$ $$= \mu_o n^2 Al\ I$$ where *nl* is the total number of turns. Thus, the self-inductance is, $L = \frac{N\phi_B}{I} = \mu_o n^2 Al$ The back emf opposes any change in the current in a circuit, so work needs to be done against the back emf (ε) in establishing the current. This work done is stored as magnetic potential energy. For the current *I* at an instant in a circuit, the rate of work done is $$\frac{dW}{dt} = \|\varepsilon\|I$$ $$\frac{dW}{dt} = L\,I\,\frac{dI}{dt}$$ Total amount of work done in establishing the current *I* is $$W = \int dW = \int_0^I L\,I\,dI = \frac{1}{2}LI^2$$

	This work done is in increasing the current flow through inductor is stored as potential energy (U)in the magnetic field of inductor. Therefore, potential energy (U) = $\frac{1}{2}$ LI^2

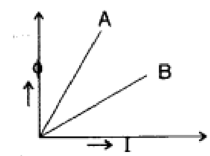
SELF TEST

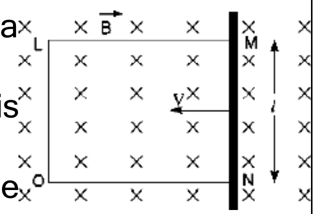
1	A coil of N turns and mean cross-sectional area A is rotating with uniform angular velocity ω about an axis at right angle to uniform magnetic field B. The induced emf in the coil will be (a) NBAsinωt (b) NBAsinωt (c) NB/Asinωt (d) NBAsinωt	1 M
2	The self-inductance of long solenoid cannot be increased by (a) increasing its area of cross section (b) increasing its length (c) changing the medium with grater permeability (d) Increasing the current through it.	1 M

3	Two currents loops are concentric and lie in the same plane. The current in the outer loop is anti-clockwise and increasing with time. The induced current in the inner loop is (a) Clockwise (b) Zero (c) Counter-clockwise (d) None of these	1 M
4	The magnetic flux linked with a coil is given by the equation $\Phi = 2t^2+2t+4$ weber. The magnitude of induced emf at time t=2s will be (a) 16 V (b) 10V (c) 12V (d) 8V	1 M
5	A conducting loop of area 5.0 cm^2 is placed in a magnetic field which varies sinusoidally with time as B=0.2 sin300t. The normal to the coil makes an angle of $60^o$with the field. The emf induced at $t=(\pi/900)$ s (a) 7.5 x 10^{-3} V (b) Zero (c) 15 x 10^{-3} V (d) 20 x 10^{-3} V	1 M
6	The magnetic flux linked with a coil is given by an equation = $5t^2 + 2t + 3$. The induced e.m.f. in the coil at the third second will be (a) 32 units (b) 54 units (c) 40 units (d) 65 units	1 M

7	An e.m.f is produced in a coil, which is not connected to an external voltage source. This can be due to (a) the coil being in a time varying magnetic field. (b) the coil moving in a time varying magnetic field. (c) the coil moving in a constant magnetic field. (d) the coil is stationary in external spatially varying magnetic field, which does not change with time.	1 M
8	which of the following application, eddy current has no role to play? (a) electric power meters (b) induction furnace (c) LED lights (d) magnetic brakes in trains	1 M
ASSERTION - REASON (Directions are as previous)		
9	*sertion:* If electric current, changes through a circuit, eddy currents are induced in nearby iron piece. *Reason:* Due to change of electric current, the magnetic flux through iron piece changes, so eddy currents are induced in the iron piece.	1 M
10	*Assertion:* An electric lamp is connected in series with a long solenoid of copper with air core and then connected to AC source. If an iron rod is inserted in solenoid the lamp will become dim.	1 M

	Reason: If an iron rod is inserted in solenoid, the inductance of solenoid increases.	
11	<u>Case Based Question:</u> When a current I flow through a coil, flux linked with it is Φ = LI, where L is a constant known as self- inductance of the coil. Any charge in current sets up an induced emf in the coil. Thus, self-inductance of a coil is the induced emf set up in it when the current passing through it changes at the unit rate. It is a measure of the opposition to the growth or the decay of current flowing through the coil. Also, value of self- inductance depends on the number of turns in the solenoid, its area of cross-section and the permeability of its core material. I)The inductance in a coil plays the same role as (a) inertia in mechanics b) energy in mechanics (c) momentum in mechanics (d) force in mechanics II) The inductance L of a solenoid depends upon its radius R as (a) $L \propto R$ (b) $L \propto 1/R$ (c) $L \propto R^2$ (d) $L \propto R^3$ III)The unit of self-inductance is (a) Weber ampere (b) Weber-1 ampere (c) Ohm second (d) Farad	4 M

	IV) The induced emf in a coil of 10 henry inductance in which current varies from 9 A to 4 A in 0.2second is (a)200 V (b) 250 V (c) 300 V (d) 350 V OR A current of 2.5 A flows through a coil of inductance 5 H. The magnetic flux linked with the coil is (a) 0.5 Wb (b) 12.5 Wb (c) zero (d) 2 Wb	
12	plot of magnetic flux (ϕ) versus current (I) is shown in the figure for two inductors A and B. Which of the two has larger value of self-inductance? 	2 M
13	100 mH coil carries a current of 1 A. Find the energy stored in the form of magnetic field.	2 M
14	ate the law that gives the polarity of the induced emf.	2 M
15	Two spherical bobs, one metallic and the other of glass, of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach earlier and why?	2 M
16	Current in a circuit falls from 5.0 A to 0.0 A in 0.1 s. If an average emf of 200 V is induced, calculate the self-induction of the circuit.	2 M

17	A rectangular conductor LMNO is placed in a uniform magnetic field of 0.5 T. The field is directed perpendicular to the plane of the conductor. When the arm MN of length of 20 cm is moved towards left with a velocity of 10 m/s. Calculate the emf induced in the arm. Given the resistance of the arm to be 5 Ω (assuming that other arms are of negligible resistance), find the value of the current in the arm. 	3 M
18	1.0 m long metallic rod is rotated with an angular frequency of 400 rad s−1 about an axis normal to the rod passing through its one end. The other end of the rod is in contact with a circular metallic ring. A constant and uniform magnetic field of 0.5 T parallel to the axis exists everywhere. Calculate the emf developed between the centre and the ring.	3 M
19	duce an expression for the mutual inductance of two long coaxial solenoids but having different radii and different number of turns.	5 M
20	scribe the construction, principle and working of an AC generator.	5 M

****

7. ALTERNATING CURRENT

SYLLABUS: Alternating currents, peak and RMS value of alternating current/voltage; reactance and impedance; LCR series circuit (phasors only), resonance, power in AC circuits, power factor, wattless current. AC generator, Transformer.

GIST

Alternating current is the one which changes in magnitude continuously and in direction periodically.

The maximum value of current is called current-amplitude or peak value of current.

It is expressed as, $I = I_o \sin \omega t$

Similarly alternating voltage (or emf) is $V = V_o \sin \omega t$

MEAN AND RMS VALUE OF ALTERNATING CURRENTS

The mean value of alternating current over complete cycle is zero.

$$(I_{mean})_{full\ cycle} = 0$$

While for half cycle it's value is given by

$$(I_{mean})_{half\ cycle} = \frac{2I_0}{\pi} = 0.636\ I_o$$

$$V_{av} = \frac{2V_0}{\pi} = 0.636\ V_o$$

An electronical device reads Root Mean Square value as

$$I_{rms} = \sqrt{(I^2)_{mean}} = \frac{I_0}{\sqrt{2}} = 0.707\ I_o$$

$$V_{rms} = \frac{V_0}{\sqrt{2}} = 0.707\ V_o$$

PHASE DIFFERENCE BETWEEN VOLTAGE AND CURRENT

In a circuit having a reactive component, there is always a phase difference between applied voltage and the alternating current.

If $E = E_o \sin \omega t$

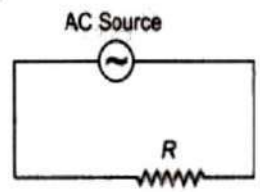
then current is $I = I_o \sin (\omega t + \Phi)$

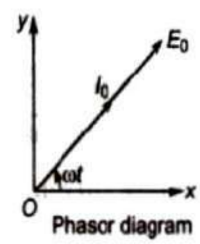
where Φ is the phase difference between voltage and current.

The average power loss over a complete cycle is given by, $P = E_v I_v \cos \Phi$

Term ***cos Φ*** *is called the* ***power factor.***

- In case of an AC circuit having pure resistance, alternating emf and alternating current both are in the same phase.





Alternating emf, $E = E_o \sin \omega t$

Alternating current, $I = I_o \sin \omega t$

Average power decay, $(P) = E_v . I_v$

Power factor, $\cos \Phi = 1$

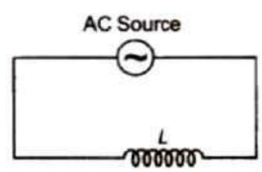
- In case of an AC circuit having pure inductance, current lags behind e.m.f. by a phase angle of 90°.

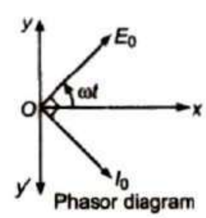
Alternating emf, $E = E_o \sin \omega t$

Alternating current, $I = I_o \sin (\omega t - \frac{\pi}{2})$

Inductive reactance, $X_L = \omega L = 2\pi f L$

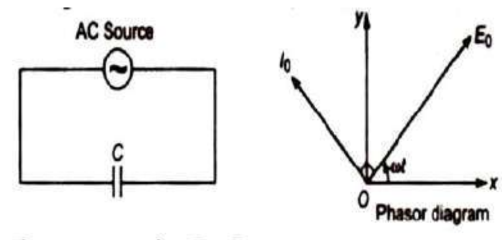
Average power decay, $(P) = 0$





Power factor, cos Φ = cos 90° = 0

❖ In case of an AC circuit having pure capacitance, current leads e.m.f. by a phase angle of 90°



Alternating emf, E = Eo sin ωt

Alternating current, I = Io sin $(\omega t + \frac{\pi}{2})$

Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

Average power decay, (P) = 0

Power factor, cos Φ = cos 90° = 0

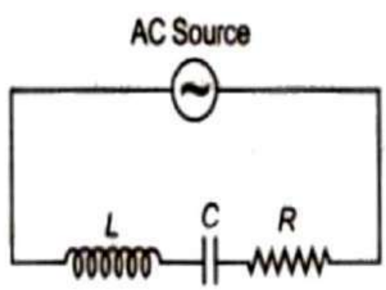
IMPEDANCE

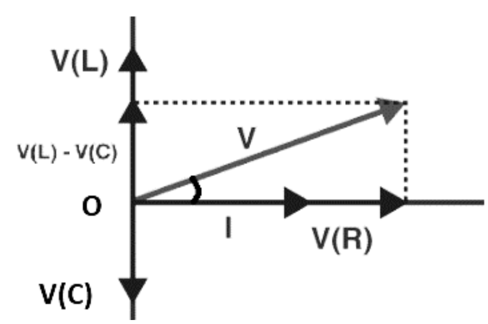
The opposition offered by an electric circuit to an alternating current is called impedance.

It is denoted as Z. Its unit is ohm.

$$Z = \frac{V}{I} = \frac{V_0}{I_0} = \frac{V_{rms}}{I_{rms}}$$

LCR SERIES CIRCUIT





Alternating emf, $E = E_0 \sin \omega t$

Alternating current, $I = I_0 \sin (\omega t \pm \Phi)$

Phase angle $\Phi = \tan^{-1} \frac{X_L - X_C}{R}$

Resultant voltage, $V = \sqrt{V_R^2 + (V_n - V_C)^2}$

Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

Power factor, $\cos \Phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$

Average power decay, $P = E_V I_V \cos \Phi$

Depending upon the values of X_L and X_C We have three possible conditions:

- ✓ If **$X_L > X_C$,** then $\tan \Phi > 0$ and the voltage leads the current and the circuit is said to be ***Inductive***
- ✓ If **$X_L < X_C$** , then $\tan \Phi < 0$ and the voltage lags the current and the circuit is said to be ***Capacitive***
- ✓ If **$X_L = X_C$,** then $\tan \Phi = 0$ and the voltage is in phase with the current and is known as ***Resonant circuit.***

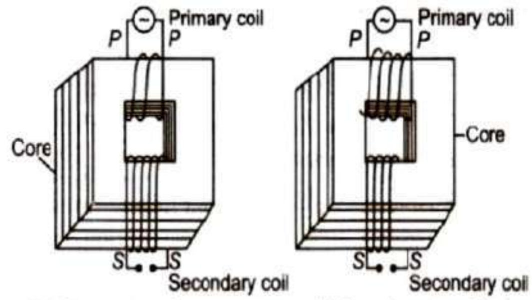
WATTLESS CURRENT

The current in an AC circuit when average power consumption in AC circuit is zero, is referred as wattless current or idle current. In case of L or C , Φ is 90^0. So $\cos 90^0 = 0$ or **$P_{av}=0$**

TRANSFORMER

It is a device which can change **a low voltage of high current into a high voltage of low current and vice-versa.**

Principle: M*utual induction*



(b) Step-up transformer (b) Step-down transformer

Types of transformers.

(i) **Step-up Transformer**

It converts a low voltage of high current into a high voltage of low current. In this transformer,

$N_s > N_P$, $E_s > E_P$ and $I_P > I_S$

(ii) Step-down Transformer

It converts a high voltage of low current into a low voltage of high current.

In this transformer, $N_P > N_S$, $E_P > E_S$ and $I_P < I_S$

Transformation Ratio

$$K = \frac{N_s}{N_P} = \frac{E_s}{E_P} = \frac{I_p}{I_s},$$ For step-up transformer, K > 1,

For step-down transformer, K <1

Energy Losses in a Transformer

1. Iron loss, 2. Copper loss , 3 Flux loss , 4.Hysteresis loss , 5.Humming loss

Important Points

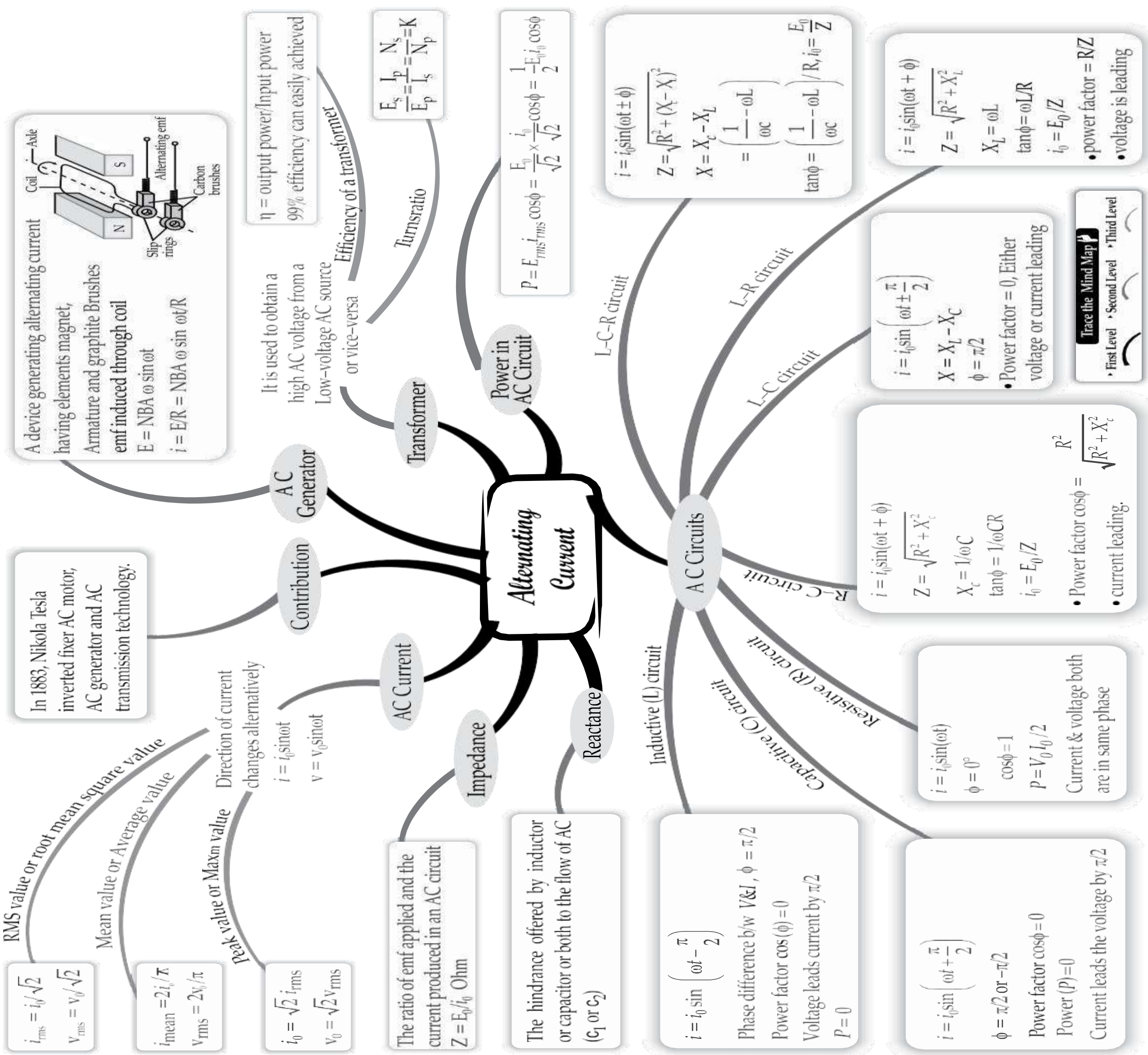
Transformer does not operate on direct current. It operates only on alternating voltages at input as well as at output.

Transformer does not amplify power as vacuum tube.

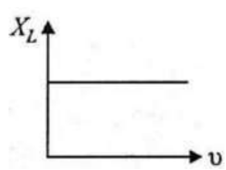
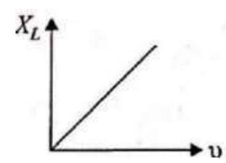
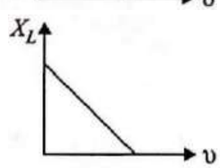
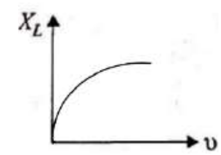
Efficiency of transformer, $\eta = \frac{Output\ power}{Input\ power}$

Generally, efficiency ranges from 70% to 90%.

MIND MAP



COMPETENCY BASED QUESTIONS

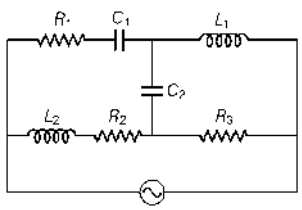
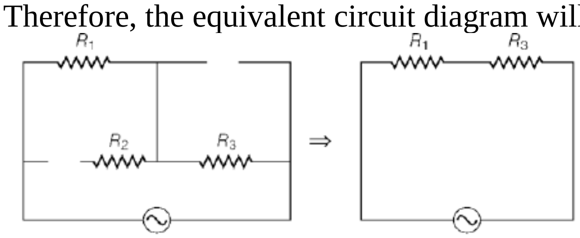
1	An alternating current generator has an internal resistance R_g and an internal reactance X_g. It is used to supply power to a passive load consisting of a resistance R_g and a reactance X_L. For maximum power to be delivered from the generator to the load, the value of X_L is equal to (a) zero (b) X_g (c) $-X_g$ (d) R_g
ANS	c
2	To reduce the resonant frequency in an L-C-R series circuit with a generator (a) the generator frequency should be reduced (b) another capacitor should be added in parallel to the first (c) the iron core of the inductor should be removed (d) dielectric in the capacitor should be removed
ANS	
3	Which of the following combinations should be selected for better tuning of an L-C-R circuit used for communication? (a) R = 20W, L =15H, C = 35μF (b) R = 25W, L = 25H, C = 45μF (c) R =15W, L = 35H, C = 30 μF (d) R = 25W, L =15H, C = 45μF
ANS	c
4	An inductor of reactance 1W and a resistor of 2W are connected in series to the terminals of a 6V (rms) AC source. The power dissipated in the circuit is (a) 8 W (b) 14.4 W (c) 12 W (d) 18 W
ANS	b
5	Electrical energy is transmitted over large distances at high alternating voltages. Which of the following statements is (are) correct? (a) For a given power level, there is a lower current (b) Lower current implies less power loss (c) Transmission lines can be made thinner (d) It is easy to reduce the voltage at the receiving end using step-down transformers
ANS	c
6	Which of the following graphs represent the correct variation of inductive reactance X_L with frequency υ a)  b)  c)  d) 
ANS	b
7	The variation of the instantaneous current (I) and the instantaneous emf(E) in a circuit is as shown in figure. Which of the following statements is correct?

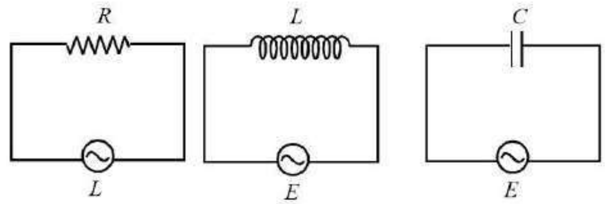
	a) The voltage leads the current by π/2 b) The voltage and the current are in phase c) The voltage leads the current by π d) The voltage lags behind the current by π/2
ANS	a
8	Using an A.C voltmeter the potential difference in the electrical line in a house is read to be 234 Volt. If the line frequency is known to be 50 cycles/second, the equation for the line voltage is a) V = 331 sin(100πt) b) V = 165 sin(100πt) c) V = 440 sin(100πt) d) V = 220 sin(100πt)
ANS	a
9	A capacitor: (a) offers easy path to a.c., but blocks d.c. (b) offers easy path to d.c. but blocks a.c. (c) offers easy path to both a.c. and d.c. (d) blocks a.c.
ANS	a
10	Can a.c. be used for electrolysis? Why? (a) yes, no fixed polarity (b) no, no fixed polarity (c) yes, fixed polarity (d) none of these.
ANS	b
ONE MARK QUESTIONS	
1	What is the power factor?
ANS	The power factor is defined as the cosine of the angle between voltage and current.
2	What is the operating principle of AC generators?
ANS	According to Faraday's law of electromagnetic induction, the electromotive force that is voltage or emf is induced in a current-carrying wire that cuts a uniform magnetic field, which serves as the foundation for AC generators.
3	Define the term 'wattless current'.
ANS	When simply an inductor or capacitor is connected to a circuit, the power consumption is zero and the current is known as wattless current, as it consumes no energy in the circuit.
4	Mention the two characteristic properties of the material suitable for making core of a transformer.
ANS	Characteristic properties of material suitable for core of a transformer: • It should have high permeability • It should have low hysteresis loss. • It should have low coercivity/retentivity. • It should have high resistivity. (Any two)
5	What is average value of a.c. for one cycle?

ANS	Zero
2 MARKS QUESTIONS	
1	Explain why current flows through an ideal capacitor when it is connected to an ac source but not when it is connected to a dc source in a steady state.
ANS	For ac source, circuit is complete due to the presence of displacement current in the capacitor. For steady dc, there is no displacement current, therefore, circuit is not complete. Mathematically, Capacitive reactance $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$ So, capacitor allows easy path for ac source. For dc, f = 0, so X_C = infinity, So capacitor blocks dc.
2	Both alternating current and direct current are measured in amperes. But how is the ampere defined for an alternating current?
ANS	An ac current changes direction with the source frequency and the attractive force would average to zero. Thus, the ac ampere must be defined in terms of some property that is independent of the direction of current. Joule's heating effect is such property and hence it is used to define rms value of ac.
3	If a L-C circuit is considered analogous to a harmonically oscillating springblock system, which energy of the L-C circuit would be analogous to potential energy and which one analogous to kinetic energy?
ANS	We consider a L-C circuit analogous to a harmonically oscillating springblock system. The electrostatic energy is analogous to potential energy and energy associated with moving charges (current) that is magnetic energy is analogous to kinetic energy.
4	When an ac source is connected to an ideal inductor show that the average power supplied by the source over a complete cycle is zero.
ANS	For an ideal inductor phase difference between current and applied voltage = $\pi/2$ ∴ Power, $P = V_{rms} I_{rms} \cos\varphi = V_{rms} I_{rms} \cos \pi/2 = 0$ Thus, the power consumed in a pure inductor is zero.
5	Why is the core of a transformer laminated?
ANS	The core of a transformer is laminated to minimize eddy currents in the iron core to reduce energy loss in the form of heat.

3 MARKS QUESTIONS	
1	Explain why the reactance offered by an inductor increases with increasing frequency of an alternating voltage.
ANS	An inductor opposes flow of current through it by developing a back emf according to Lenz's law. The induced voltage has a polarity so as to maintain the current at its present value. If the current is decreasing, the polarity of the induced emf will be so as to increase the current and vice -versa. Since, the induced emf is proportional to the rate of change of current, it will provide greater reactance to the flow of current if the rate of change is faster, i.e., if the frequency is higher. The reactance of an inductor, therefore, is proportional to the frequency. Mathematically, the reactance offered by the inductor is given by X L = ωL
2	State the underlying principle of a transformer. How is the large-scale transmission of electric energy over long distances done with the use of transformers?
ANS	The principle of transformer is based upon the principle of mutual induction which states that due to continuous change in the current in the primary coil an emf gets induced across the secondary coil. At the power generating station, the step-up transformers step up the output voltage which reduces the current through the cables and hence reduce resistive power loss. Then, at the consumer end, a step- down transformer steps down the voltage. Hence, the large-scale transmission of electric energy over long distances is done by stepping up the voltage at the generating station to minimize the power loss in the transmission cables.
3	An alternating voltage given by **V = 140 sin 314*t*** is connected across a pure resistor of 50 ohm. Find: (i) the frequency of the source (ii) the rms current through the resistor.
ANS	(i) V_o = 140 V, ω = 314 $2\pi f = 314$ Therefore, $f = 314/2\pi = 50$ Hz (ii) $I_{rms} = V_{rms}/R$ (where $V_{rms} = V_o/\sqrt{2}$) $= (V_o/\sqrt{2})/R$ $=V_o/\sqrt{2}\ R$ $= 140/(\sqrt{2} \times 50)$

	= 1.98 A
4	A series LCR circuit with R = 20 Ω, L = 1.5 H, and C = 35 μF is connected to a variable-frequency 200 V ac supply. When the frequency of the supply equals the natural frequency of the circuit, what is the average power transferred to the circuit in one complete cycle?
ANS	The supply frequency and the natural frequency are equal at resonance conditions in the circuit i.e. $X_L = X_C$ The given resistance of the resistor, R = 20 Ω An AC source with a voltage of V = 200 V is connected to the LCR circuit The impedance of the above combination is given by Z= $\sqrt{R^2 + (X_L - X_C)^2}$ = R (for $X_L = X_C$) ⇒ Z= 20 Ω Current, I = $\frac{V}{Z} = \frac{200}{20}$ = 10 A Therefore, the average power that is being transferred to the circuit in one full cycle: P = V I = 200 x 10 = 2000 W
5	A step-down transformer operated on a 2.5 kV line. It supplies a load with 20 A. The ratio of the primary winding to the secondary is 10:1. If the transformer is 90% efficient, calculate - (a) the power output, (b) the voltage, and (c) the current in the secondary.
ANS	Input Voltage V_P = 2.5 X 10^3 V Input Current I_P = 20 A Also, $\frac{N_P}{N_S} = \frac{10}{1}$ $\Rightarrow \frac{N_S}{N_P} = \frac{1}{10}$ a) Percentage efficiency = $\frac{\text{Output power}}{\text{Input power}}$ x 100 $\Rightarrow \frac{90}{100} = \frac{\text{Output power}}{V_p I_p}$ ⇒ Output power $= \frac{90}{100} \times V_p I_P$

	$= \frac{90}{100} \times 2.5 \times 10^3$ V x 20 A $= 4.5 \times 10^4$ W b) As $\frac{V_S}{V_P} = \frac{N_S}{N_P}$ $\Rightarrow V_S = \frac{N_S}{N_P} \times V_P = \frac{1}{10} \times 2.5 \times 10^3$ V = 250 V c) Output power $= V_S I_S = 4.5 \times 10^4$ W Current in the secondary, $I_S = \frac{4.5 \times 10^4}{250} = 180$ A
6	Why is the use of ac voltage preferred over dc voltage? Give three reasons.
ANS	(i)The generation of ac is more economical than dc. (ii) Alternating voltage can be stepped up or stepped down as per requirement during transmission from power generating station to the consumer. (iii) Alternating current in a circuit can be controlled by using wattless devices like the choke coil. (iv) Alternating voltages can be transmitted from one place to another, with much lower energy loss in the transmission line.
7	Draw the effective equivalent circuit of the circuit shown in figure, at very high frequencies and find the effective impedance. 
ANS	We know that inductive reactance, $X_L = \omega L = 2\pi f L$ and capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$ For very high frequencies $f \to \infty$ hence, $X_L \to \infty$ and $X_C \to 0$ So, C_1, C_2 can be taken as shorted (When reactance of a circuit is zero it will be considered as short circuited). and L_1, L_2 as opened (When reactance of a circuit is infinite it will be considered as open circuit). Therefore, the equivalent circuit diagram will be as,  So, effective impedance = $R_{eq} = R_1 + R_3$

8	The frequency of a.c. is being increased, explain the effect of current in each case 
ANS	i) In the case of resistance nothing will happen as its not the functional of frequency ii) In the case of an inductor ($X_L = \omega L = 2\pi f L$), when frequency will increase X_L increases which results in decrease of current and vice versa. iii) In the case of a capacitor $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$, when frequency will increase X_C decreases which results in increase of current and vice versa
SELECT RESPONSE QUESTIONS (MCQ)	
1	Reciprocal of impedance is called (a) Susceptance (b) Conductance (c) Admittance (d) Transconductance
ANS	**b**
2	The power factor varies between (a) 2 and 2.5 (b) 3.5 to 5 (c) 0 to 1 (d) 1 to 2
ANS	**c**
3	Why is the DC ammeter incapable of measuring alternating current? (a) AC is incompatible with DC ammeters. (b) AC modifies its course. (c) Zero is the average value of a whole cycle (d) AC is virtual
ANS	**c**
4	The core of a transformer is laminated because (a) ratio of voltage in primary and secondary may be increased (b) energy losses due to eddy currents may be minimized (c) the weight of the transformer may be reduced (d) rusting of the core may be prevented
ANS	**b**

5	In electric arc furnace Cu or Iron is melted due to variation of (a) current (b) magnetic field (c) voltage (d) electric field
ANS	b
6	In a purely resistive a.c. circuit, the current (a) is in phase with the e.m.f. (b) leads the e.m.f. by a difference of π radians phase (c) leads the e.m.f. by a phase difference of π /2 radians (d) lags behind the e.m.f. by phase difference of π /4 radians
ANS	a
7	An ac generator produced an output voltage, E = 170 sin377t where *t* is in seconds. The frequency of ac voltage is (a) 50 Hz (b) 110 Hz (c) 60 Hz (d) 230 Hz
ANS	
8	In an ac circuit, the power factor (a) Is zero when the circuit contains an ideal resistance only (b) Is unity when the circuit contains an ideal resistance only (c) Is zero when the circuit contains an ideal inductance and resistor only (d) Is unity when the circuit contains an ideal inductance only.
ANS	b
9	The ratio of primary and secondary windings of a transformer is 1:2. An a.c. source of 100 volts at 2 ampere is connected across the primary. Which of the following situations is correct in the given transformer? (a) the secondary voltage is 200 volts and current is 2 A

	(b) the secondary voltage is 200 volts and current is 1 A (c) the secondary voltage is 50 volts and current is 2 A (d) the secondary voltage is 50 volts and current is 4 A
ANS	b
10	The voltage of domestic ac is 220 volts. What does the represent a) Mean voltage b) Peak voltage c) Root mean voltage d) Root mean square voltage
ANS	d

CASE-STUDY BASED QUESTION

CBQ 1: A transformer is an electrical device which is used for changing A.C. voltages. It is based on the phenomenon of mutual induction. It consists of two coils wound on the same core. The alternating current passing through the primary creates a continuously changing flux through the core. This changing flux induces an alternating emf in the secondary. Depending on the number of turns in the primary and secondary coil the alternating voltage will increase and decreased.

It can be shown that $\frac{N_s}{N_P} = \frac{E_s}{E_P} = \frac{I_p}{I_s} =$ **K**, where K is transformation constant.

For a step-up transformer, K>1 and for a step-down transformer, K<1. The numbers of turns in the primary and secondary coils of a transformer are 2000 and 50 respectively. The primary coil is connected to main of 120 V and secondary to a night bulb of 0.6 ohm. The efficiency of transformer is 80%.

I) A transformer is used:

(a) to transform electric energy into mechanical energy.

(b) to obtain suitable DC voltage.

(c) to transform AC into DC.

(d) to obtain suitable AC voltage.

II) Which quantity is increased in step-down transformer?

(a) resistance (b) power (c) current (d) charge

III) In step-up transformer, relation between number of turns in primary (Np) and number of turns in secondary (Ns) is

(a) Ns > Np (b) Np > Ns (c) Ns = Np (d) Np = 2 Ns

IV) Voltage across the secondary of transformer is

(a) 120 V (b) 360 V (c) 40 V (d) 3 V

OR

Current in primary coil is

(a) 0.125 A (b) 2.52 A (c) 1.51 A (d) 3.52 A

Ans: I) d II) c III) a IV) d OR a

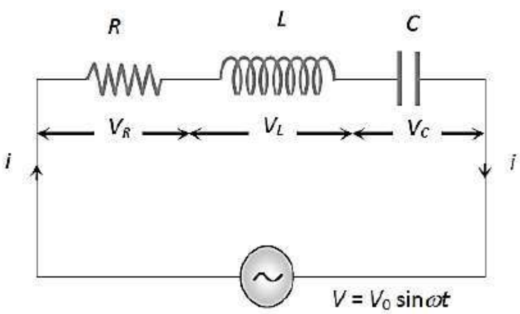
CBQ 2:

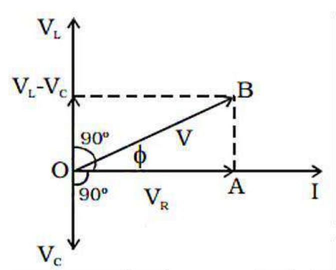
An interesting characteristics of the series LCR circuit is the phenomenon of resonance. The phenomenon of the resonance is common among systems that have tendency to oscillate at a particular frequency. This frequency is called the system natural frequency. If such system is driven by an energy source at a frequency that is near the natural frequency, the amplitude of the oscillation is found to be large.

Suppose a resonance R, inductance L and Capacitance C are connected in series and fed by an alternating source of voltage V, the frequency of alternating current source is f. This series LCR circuit is said to be resonance only if the frequency f of applied alternating source be such that the current flowing in circuit and voltage applied are in the same phase. At resonance in LCR series circuit impedance is minimum. For an LCR circuit the angular frequency is given by

$$\omega = \frac{1}{\sqrt{LC}}$$

At resonance frequency, the current amplitude is maximum.





I) At resonant condition-

(a) Impedance is maximum

(b) Impedance is minimum and equal to resistance R

(c) Impedance is zero

(d) Impedance is numerically equal to R/2

II) To reduce the resonance frequency in an LCR circuit with a generator

(a) The generator frequency should be reduced.

(b) Another capacitor should be added in parallel to the first one.

(c) The iron core of the inductor should be removed.

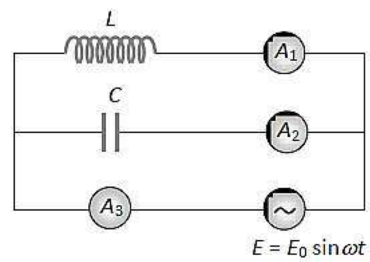
(d) Dielectric in the capacitor should be removed.

III) In a *LCR* circuit capacitance is changed from *C* to 2*C*. For the resonant frequency to remain unchanged, the inductance should be change from *L* to

(a) 4*L* (b) 2*L* (c) *L*/2 (d) *L*/4

OR

An inductor L and a capacitor C are connected in the circuit as shown in the figure. The frequency of the power supply is equal to the resonant frequency of the circuit. Which ammeter will read zero ampere?



(a) A_1 (b) A_2 (c) A_3 (d) None of these

IV) Power factor is maximum in an LCR circuit when

(a) $X_L = X_C$ (b) $R = 0$ (c) $X_L = 0$ (d) $X_C = 0$

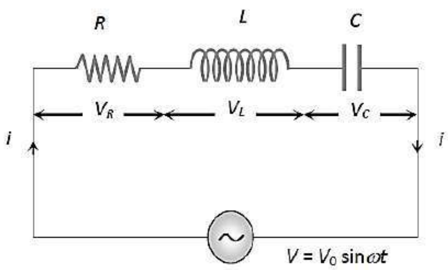
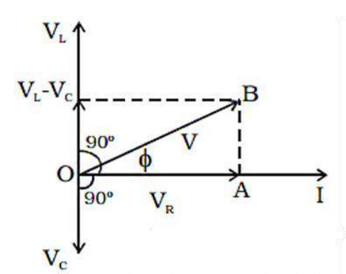
Ans: **I) b** **II) b** **III) c** **OR c** **IV) a**

ASSERTION-REASON TYPE QUESTIONS

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion. (c) If the Assertion is correct but Reason is incorrect. (d) If both the Assertion and Reason are incorrect.	
1	Assertion: The voltage across the secondary coil of a transformer depends upon the number turns in the primary and secondary coil. Reason: Transformer ratio is the ratio of number of turns in the secondary coil to the number of turns in the primary coil.
ANS	b
2	Assertion: Choke coil is preferred over a resistor to adjust current in an AC circuit Reason: Power factor for inductance is zero.
ANS	a
3	Assertion: A capacitor blocks direct current in the steady state. Reason: The capacitive reactance of the capacitor is inversely proportional to frequency f of the source of emf.
ANS	a
4	Assertion: AC is more dangerous than DC Reason: Frequency of ac is dangerous for human body.
ANS	a
5	Assertion (A): In an AC circuit, the instantaneous value of voltage and current can be represented by sine functions. Reason (R): The voltage and current in an AC circuit vary sinusoidally with time and can be expressed as $V(t) = V_m \sin(\omega t)$ and $I(t) = I_m \sin(\omega t + \Phi)$, respectively.
ANS	a
6	Assertion: In a purely inductive or capacitive circuit, the current is referred to as wattless current. Reason: No power is dissipated in a purely inductive or capacitive circuit even though a current is flowing in the circuit.
ANS	a

7	Assertion (A): Transformers work on the principle of electromagnetic induction. Reason (R): Transformers use two coils wound on a soft iron core, and the varying magnetic field in one coil induces an EMF in the other coil.
ANS	a
8	Assertion (A): An ideal inductor has zero resistance. Reason (R): An ideal inductor is a purely inductive element with no resistance, which means it does not dissipate power in the form of heat.
ANS	b
9	Assertion: If $X_c > X_L$, ϕ is positive and the circuit is predominantly capacitive, the current in the circuit leads the source voltage. Reason: If $X_c < X_L$, ϕ is negative and the circuit is predominantly inductive, the current in the circuit lags the source voltage.
ANS	b
10	Assertion - Soft iron is used as a core of transformer Reason - Area of hysteresis loop for soft iron is small.
ANS	a
LONG ANSWER (5 MARKS)	
1	A series L-C-R circuit is connected to an AC source having voltage $V = V_m \sin \omega t$ Derive the expression for the instantaneous current I and its phase relationship to the applied voltage. Obtain the condition for resonance to occur. Define power factor. State the conditions under which it is- (a) maximum (b) minimum.
ANS	Suppose resistance R, inductance L and capacitance C are connected in series and an alternating source of voltage $V = V_O \sin\omega t$ is applied across it.  

Being in series, the current (I) flowing through all of them is the same. Suppose the voltage across resistance is V_R, voltage across inductance is V_L and voltage across capacitance is V_C. The voltage V_R and current I are in the same phase, the voltage V_L will lead the current I by angle while the voltage will lag behind the current by 90° while the voltage V_C will lag behind the current I by 90°. Clearly V_L and V_C are in opposite directions, therefore their resultant potential difference = $V_L - V_C$ (if $V_L > V_C$)

Thus, V_R and $(V_L - V_C)$ are mutually perpendicular and the phase difference between them is 90°. As applied voltage across the circuit is V, the resultant of V_R and $(V_L - V_C)$ will also be V.

From phase diagram, $V^2 = V_R^2 + (V_L - V_C)^2$

$\Rightarrow \quad V = \sqrt{V_R^2 + (V_n - V_C)^2}$ .... (i)

But, $V_R = IR$, $V_L = I X_L$ and $V_C = I X_C$

Where, $X_L = \omega L = 2\pi f L$ = Inductive reactance and $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$ = Capacitive reactance

Impedance of the circuit, $Z = \frac{R}{Z} = \sqrt{R^2 + (X_L - X_C)^2}$ ....(ii)

Instantaneous current, $I = \frac{V_0 \sin(\omega t + \phi)}{\sqrt{R^2 + (x_L - x_c)^2}}$

The phase difference (Φ) between current and voltage V is given by

$$\Phi = \tan^{-1} \frac{x_L - x_c}{R}$$

Depending upon the values of X_L and X_C we have three possible conditions,

I) If $X_C > X_L$, Φ is positive and the circuit is predominantly capacitive. Consequently, the current in the circuit leads the source voltage.

II) If $X_C < X_L$, Φ is negative and the circuit is predominantly inductive. Consequently, the current in the circuit lags the source voltage.

III) If $X_L = X_c$, Φ = 0 then and the voltage is in phase with the current and is known as resonant circuit.

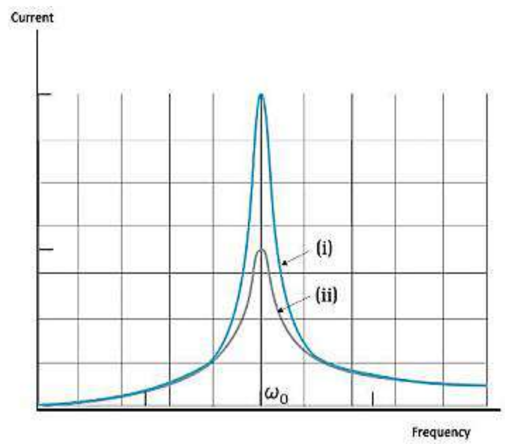
Power Factor: Power factor is defined as the cosine of the angle between voltage and current.

$$\text{Power factor} = \cos\Phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2+(X_L-X_C)^2}}$$

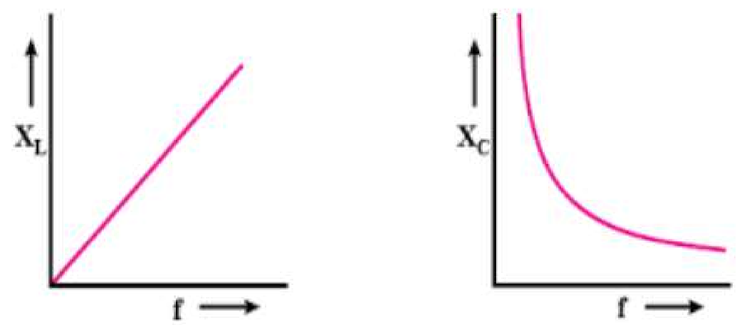
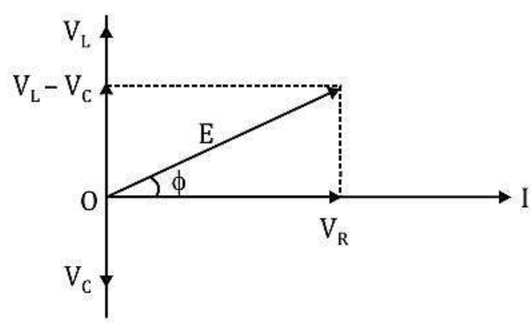
It is the measure of how effectively the incoming power is used in an electrical system. A high-power factor indicates that the power supplied to the electrical system is effectively used. A system with low power factor doesn't effectively consume the incoming electric supply and results in losses. In AC circuits, the value of power factor always lies between 0 and 1.

Maximum value of power factor: If the circuit contains only pure R, it is called resistive. In that cos Φ = 1. There is maximum power dissipation.

Minimum value of power factor: If the circuit contains only an inductor or capacitor, we know that the phase difference between voltage and current is π/2. Therefore, cos Φ = 0, and no power is dissipated even though a current is flowing in the circuit. This current is sometimes referred to as wattless current.

2	a) A series LCR circuit is connected to an ac source. Using the phasor diagram, derive the expression for the impedance of the circuit. b) Plot a graph to show the variation of current with frequency of the ac source , explaining the nature of its variation for two different resistances R_1 and R_2 ($R_1 < R_2$) at resonance
ANS	a) As previous question b) (i) for R_1 and the curve (ii) is for R_2 
3	A resistor of 200 W and a capacitor of 15.0 μF are connected in series to a 220 V, 50 Hz ac source. (a) Calculate the current in the circuit; (b) Calculate the voltage (rms) across the resistor and the capacitor. Is the algebraic sum of these voltages more than the source voltage? Justify.
ANS	(a) In order to calculate the current, we need the impedance of the circuit. It is $Z = \sqrt{R^2 + X_C{}^2}$ $= \sqrt{R^2 + (2\pi f C)^2}$

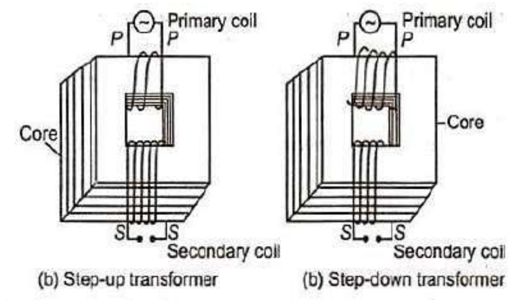
	$= \sqrt{200^2 + (2x\ 3.14\ x\ 50x\ 10^{-6})^2}$ $= 291.5\ \Omega$ Therefore, the current in the circuit is, $I = \frac{V}{Z}$ $= \frac{220V}{291.5\Omega} = 0.755\ A$ (b) Since the current is the same throughout the circuit, we have $V_R = I\ R$ $= (0.755\ A)\ (200\Omega) = 151\ V$ $V_C = I\ X_C$ $= (0.755\ A)\ (212.3\ \Omega) = 160.3\ V$ The algebraic sum of the two voltages, V_R and V_C is 311.3 V, which is more than the source voltage of 220 V. This is because the two voltages V_R and V_C are not in the same phase (are out of phase by ninety degrees). Therefore, they cannot be added like ordinary numbers. The total of these voltages must be $V_{R+C} = \sqrt{V_R^2 + V_c^2} = 220\ V$ = Source Voltage
4	a) Draw graphs showing the variations of inductive reactance and capacitive reactance with frequency of applied ac source. b) Draw the phasor diagram for a series LRC circuit connected to an AC source.

	c) When an alternating voltage of 220V is applied across a device X, a current of 0.25A flows which lags behind the applied voltage in phase by π/2 radian. If the same voltage is applied across another device Y, the same current flows but now it is in phase with the applied voltage. (i) Name the devices X and Y. (ii) Calculate the current flowing in the circuit when the same voltage is applied across the series combination of X and Y.
ANS	(a)  (b)  (c) i) In device X, Current lags behind the voltage by π /2, hence X is an inductor In device Y, Current in phase with the applied voltage, hence Y is a resistor (ii) We are given that $0.25=220/X_L$, $X_L = 880\Omega$, also $0.25=220/R$, $R = 880\Omega$ For the series combination of X and Y, equivalent impedance $Z = 880\sqrt{2}\ \Omega$, Hence I= 0.177 A

5	ate the main operating principle of a transformer. How is large scale transmission of electric energy over long distances done with the use of transformers?

ANS

A transformer is an electrical device used for converting an alternating current at a low voltage into a high voltage or vice versa. If the transformer increases the input voltage, then it is called as step-up transformer but if decreases the input voltage, then it is called as step-down transformer.



Principle: It operates upon the principle of mutual induction i.e., "The EMF induction on one coil when changing current is applied on another coil."

Working: As the ac flows through the primary, it produces an alternating magnetic flux in the core which also passes through the secondary. This changing flux will set up an induced emf in the secondary, and a self-induced emf in the primary. If there is no leakage of magnetic flux, then the flux linked with each and every turn of the primary will be equal to that linked with each turn of the secondary.

$$E_s = -N_s \frac{d\phi}{dt} \quad \text{and} \quad E_P = -N_P \frac{d\phi}{dt}$$

where, N_P and N_S are the number of turns in the primary and secondary respectively, and E_P and E_S are their respective voltages

$$\frac{E_s}{E_P} = \frac{N_s}{N_P} \quad \ldots\ldots\ldots\ldots\ldots(i)$$

This ratio, N_S:N_P is called the turns ratio (K)

Assuming the transformer as an ideal one, so that there are no energy losses, then

Input power = output power

$E_P . I_P = E_S I_S$………… *(ii)*

where I_P and I_S are the currents present in the primary and secondary coils respectively

From (i) and (ii), we get: $\frac{N_s}{N_P} = \frac{E_s}{E_P} = \frac{I_p}{I_s} = K$

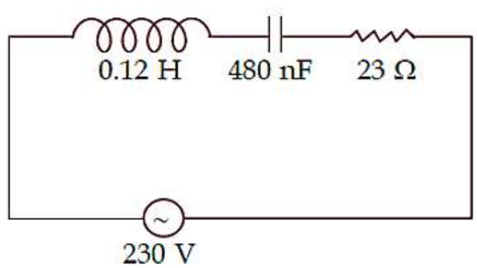
In the case of a step-up transformer, $N_S > N_P$ i.e., the turns ratio is greater than 1 and therefore $E_S > E_P$. The voltage which we get as output is greater than that of the input voltage.

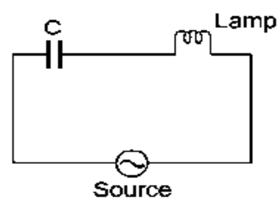
For step-up transformer, K > 1 and step-down transformer, K < 1

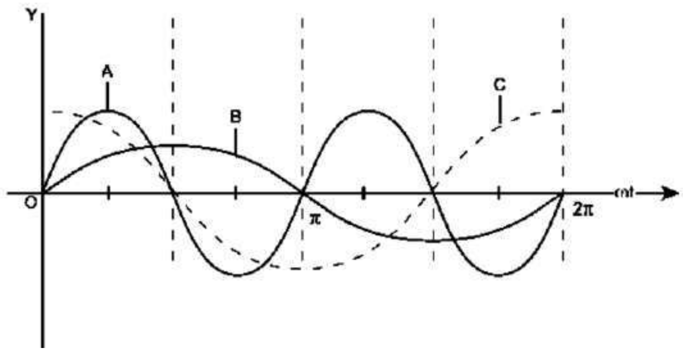
transmissions in long distances, the voltage output of the generator is stepped-up (but that current is reduced and consequently IR loss is also reduced). It is transmitted over long distances and is stepped- down at distributing substations at the consumer's end.

SELF TEST

1	In an LCR-series ac circuit, the voltage across each of the component L, C and R is 50 V. The voltage across the LC-combination will be (a) 50 V (b) 50√2 V (c) 100 V (d) zero	1 M
2	An ac circuit has a resistance of 12 ohm and an impedance of 15 ohm. The power factor of the circuit will be (a) 0.8 (b) 0.4 (c) 0.125 (d) 1.25	1 M
3	A transformer is used to light a 100 W lamp from 220 V mains. If the main current is 0.5 A, the efficiency of the transformer is **(a)**30% (b) 50% (c) 90% (d) 10%	1 M
4	What is the value of inductance L for which the current is maximum in a series LCR- circuit with C = 10 μF and ω = 1000 s^{-1}? (a) 100 mH (b) 1 mH (c) 10 mH (d) cannot be calculated unless R is known	1 M
5	Average power dissipated in an inductor connected to an a.c. source is (a) $\frac{1}{2}LI^2$ (b) LI^2 (c) zero (d) none of these	1 M
6	What happens to the inductive reactance when the frequency of the AC supply is increased? (a) Increases (b) Decreases (c)Remains the same (d) Decreases inversely	1 M
7	Energy is lost in the LCR circuit by: (a) L only (b) C only c) R only (d) All of the above	1 M

8	A 50 mH inductor is connected to a 200 V, 50 Hz AC supply. Determine the rms value of the current in the circuit. (a)12.74 A (b)13.57 A (c) 11.5 A (d) 9.53 A	1 M
ASSERTION - REASON (Directions are as previous)		
9	Assertion: Transformers work on the principle of electromagnetic induction. Reason: Transformers use two coils wound on a soft iron core, and the varying magnetic field in one coil induces an EMF in the other coil.	1 M
10	Assertion: Average value of ac over a complete cycle is always zero. Reason: Average value of ac is always defined over half cycle.	1 M
11	**Case Study based :** Resonant Series LCR Circuit. When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. We cannot have resonance in a RL or RC circuit. A series LCR circuit with L = 0.12 H, C = 480 nF, R = 23 Ω is Connect to a 230 V variable frequency supply.  Find the value of source for which current amplitude is maximum. (a) 222.32 Hz (b) 550.52 Hz (c) 663.48 Hz (d) 770 Hz) The value of maximum current is	4 M

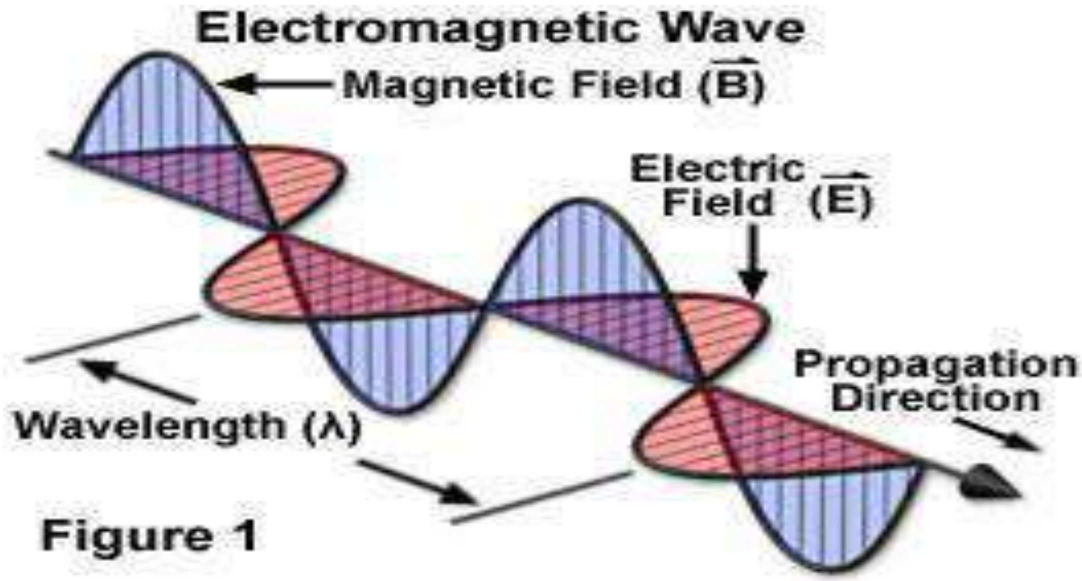
	(a) 14.14 A (b) 22.52 A (c) 50.25 A (d) 47.41 A I) The value of maximum power is (a) 2200 W (b) 2299.3 W (c) 5500 W (d) 4700 W OR What is the Q-factor of the given circuit? (a) 25 A (b) 42.21 A (c) 35.42 A (d) 21.74 A /) At resonance which of the following physical quantity is maximum? (a) Impedance (b) Current (c) Both (a) and (b) (d) Neither (a) nor (b)	
12	What is the operating principle of AC generators?	2 M
13	Why an inductor is an easy path for d.c. and resistive path for a.c.?	2 M
14	Give two advantages and disadvantages of AC over DC.	2 M
15	A coil of 0.01H inductance and 1W resistance is connected to 200 V, 50Hz AC supply. Find the impedance of the circuit and time lag between maximum alternating voltage and current	2 M
16	Explain why the reactance offered by an inductor increases with increasing frequency of an alternating voltage.	2 M
17	a) Define Power factor. What is the power factor of an LCR series circuit at resonance? b) The power factor of an A.C. circuit is 0.5. What is phase difference between voltage and current in the circuit?	3 M
18	An electric lamp connected in series with a capacitor and an ac source is glowing with of certain brightness. How does the brightness of the lamp change on reducing the  (i) capacitance and	3 M

	(ii) frequency?	
19	a) State the underlying principle of a transformer. Explain briefly any two energy losses in a transformer. b) How is the large-scale transmission of electric energy over long distances done with the use of transformers? c) Can a transformer be used to step up or step down a d.c. voltage? Justify your answer.	5 M
20	vice 'X' is connected to an ac source $V = V_o \sin \omega t$. The variation of voltage, current and power in one cycle is show in the following graph:  (a) Identify the device 'X'. (b) Which of the curves, A, B and C represent the voltage, current and the power consumed in the circuit? Justify your answer. (c) How does its impedance vary with frequency of the ac source? Show graphically. (d) Obtain an expression for the current in the circuit and its phase relation with ac voltage.	5 M

****

8. ELECTROMAGNETIC WAVES

SYLLABUS: Basic idea of displacement current, Electromagnetic waves, their characteristics, their transverse nature (qualitative idea only). Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.



GIST

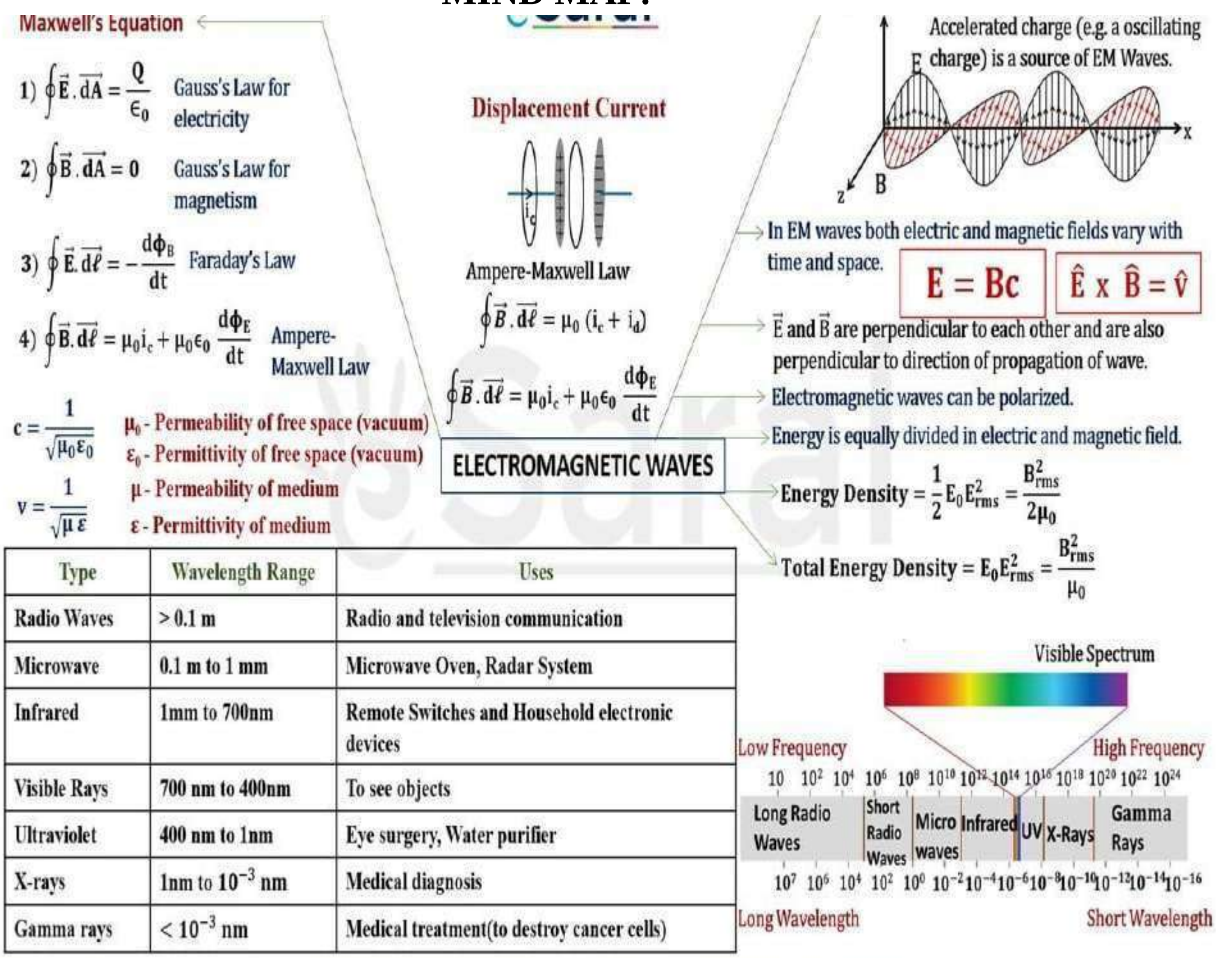
- Conduction current and displacement current together have the property of continuity.
- Conduction current & displacement current are precisely the same.
- Conduction current arises due to flow of electrons in the conductor. Displacement current arises due to electric flux changing with time.
- $\boldsymbol{I_D = \varepsilon_0 \frac{d\phi_E}{dt}}$
- Maxwell's equations
- **Gauss's Law in Electrostatics**
- $\oint \vec{E}.\overrightarrow{dS} = \frac{Q}{\varepsilon_0}$
- **Gauss's Law in Magnetism**
- $\oint \vec{B}.\overrightarrow{dS} = 0$
- **Ampere's – Maxwell law**

$\int \vec{B}\,.\overrightarrow{dl} = \mu_0 I + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$

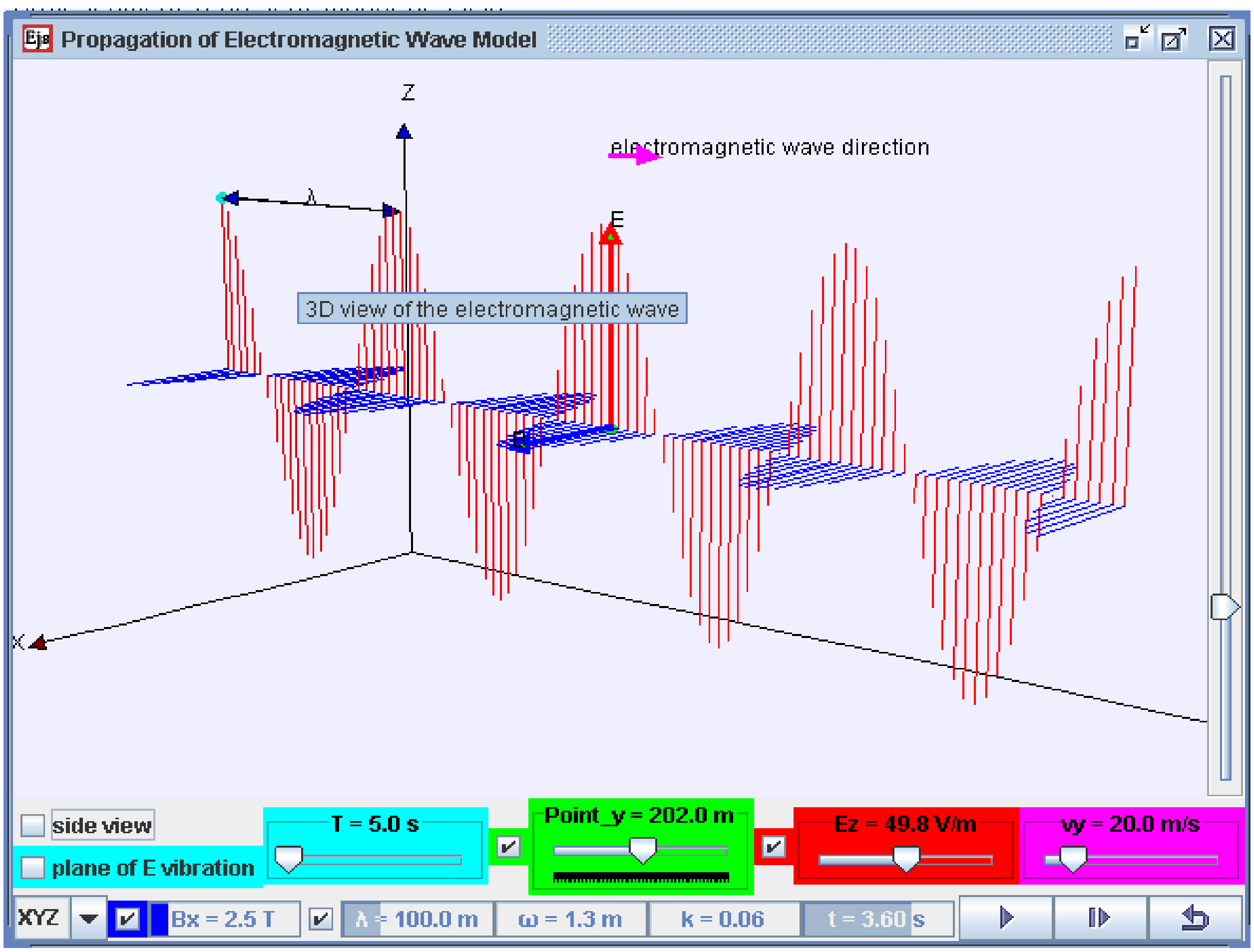
- **Electromagnetic Wave :-** The wave in which there are sinusoidal variation of electric and magnetic fields at right angles to each other as well as right angles to the direction of wave propagation.
- Velocity of EM waves in free space: $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ 3×10^8 m/s
- The Scientists associated with the study of EM waves are Hertz, Jagdish Chandra Bose & Marconi.

- EM wave is a transverse wave because of which it undergoes polarization effect.
- Electric vectors are only responsible for optical effects of EM waves.
- The amplitude of electric & magnetic fields are related by $\frac{E}{B} = c$
- Oscillating or accelerating charged particle produces EM waves.
- Orderly arrangement of electromagnetic radiation according to its frequency or wavelength is electromagnetic spectrum.
- **Hint to memorize the electromagnetic spectrum in decreasing order of its frequency.**
- ***G**andhiji's**X**-rays **U**sed **V**igorously In**M**edical**R**esearch*
- EM waves also carry energy, momentum and information

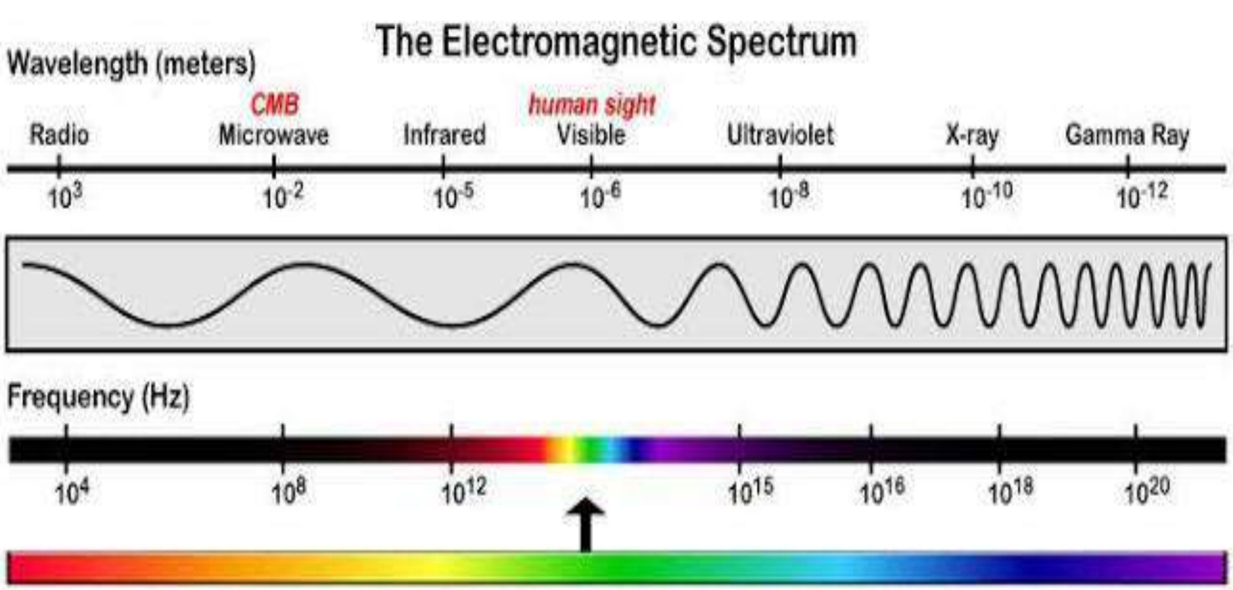
MIND MAP:



Type	Wavelength Range	Uses
Radio Waves	> 0.1 m	Radio and television communication
Microwave	0.1 m to 1 mm	Microwave Oven, Radar System
Infrared	1mm to 700nm	Remote Switches and Household electronic devices
Visible Rays	700 nm to 400nm	To see objects
Ultraviolet	400 nm to 1nm	Eye surgery, Water purifier
X-rays	1nm to 10^{-3} nm	Medical diagnosis
Gamma rays	< 10^{-3} nm	Medical treatment(to destroy cancer cells)


Propagation of Electromagnetic Wave Model
Z
electromagnetic wave direction
λ
E
3D view of the electromagnetic wave
X
side view
plane of E vibration
T = 5.0 s
Point_y = 202.0 m
Ez = 49.8 V/m
vy = 20.0 m/s
XYZ
Bx = 2.5 T
λ = 100.0 m
ω = 1.3 m
k = 0.06
t = 3.60 s

•


The Electromagnetic Spectrum
Wavelength (meters)
Radio
CMB
Microwave
Infrared
human sight
Visible
Ultraviolet
X-ray
Gamma Ray
10^3
10^-2
10^-5
10^-6
10^-8
10^-10
10^-12
Frequency (Hz)
10^4
10^8
10^12
10^15
10^16
10^18
10^20

ELECTROMAGNETIC WAVES

FORMULA

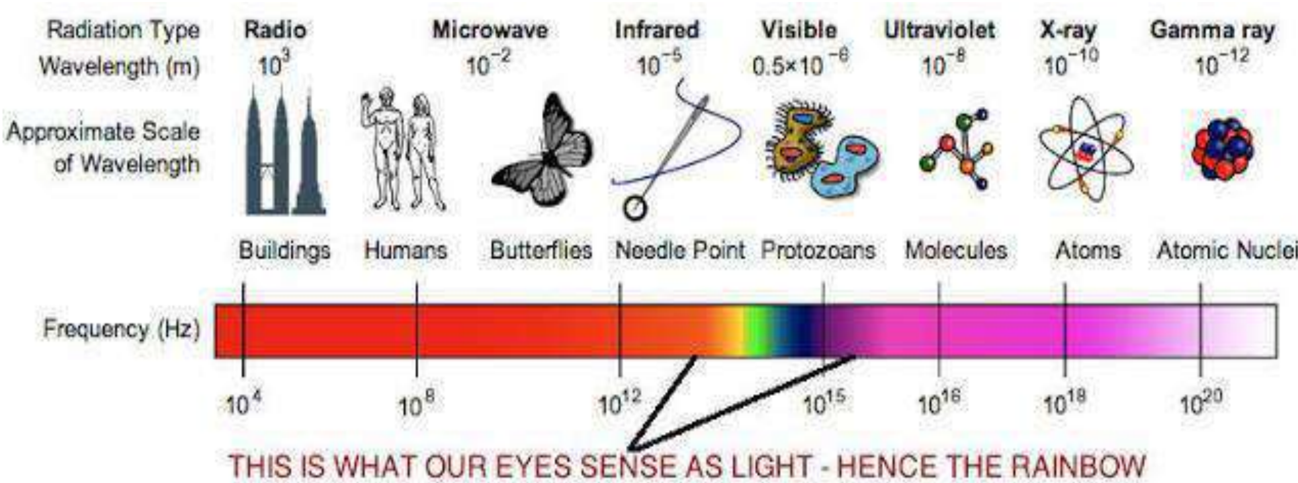
Equation for travelling electromagnetic waves along Z – axis

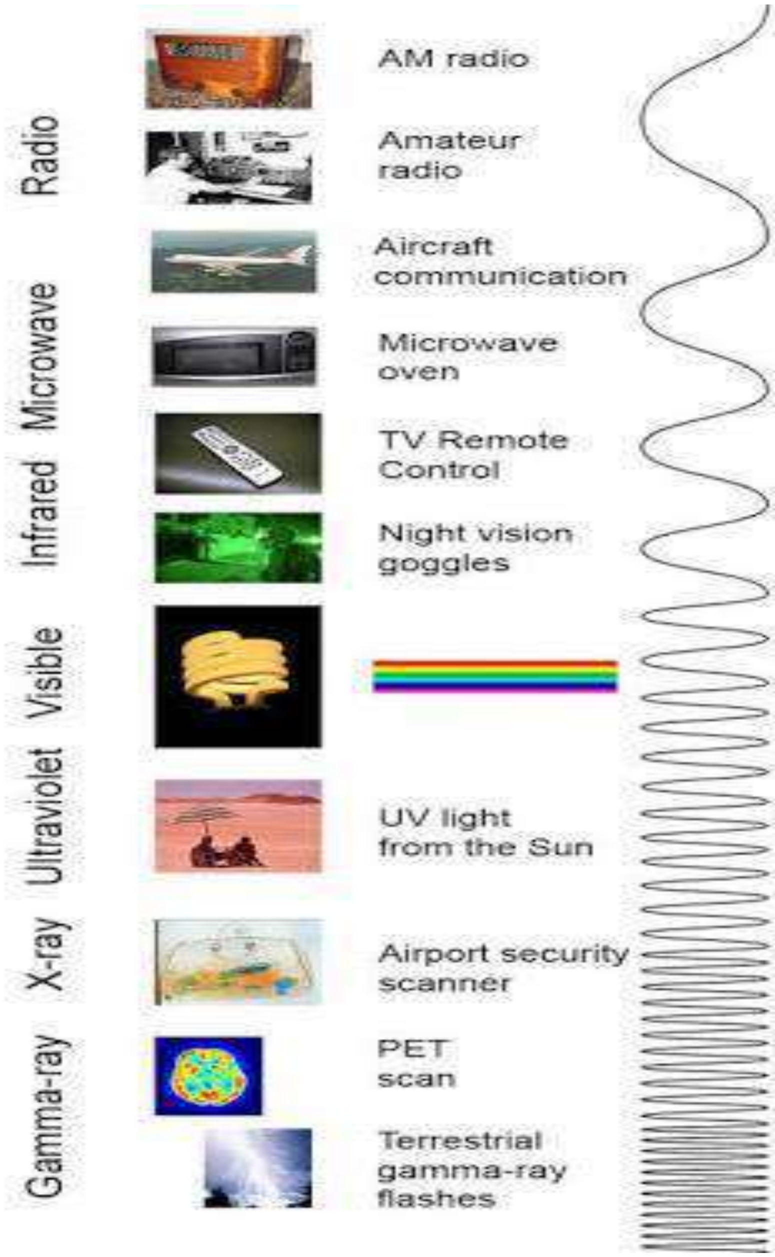
$E = E_X(t) = E_0 \sin(kz - \omega t)$

$B = B_y(t) = B_0 \sin(kz - \omega t)$

	Gamma rays	X-rays	UV rays	Visible Light	IR waves	Micro waves	Radio waves
Wave length range (m)	10^{-14} to 10^{-10}	10^{-13} to 10^{-8}	6×10^{-10} to 4×10^{-7}	4×10^{-7} to 7×10^{-7}	7×10^{-7} to 10^{-3}	10^{-3} to 10^{-1}	>0.1
Frequency (Hz)	10^{23} to 10^{18}	10^{21} to 10^{16}	10^{17} to 10^{14}	7×10^{14} to 4×10^{14}	10^{14} to 10^{11}	10^{12} to 10^{8}	10^{9} to 5×10^{5}
Production	Radioactive decay of the nucleus	Bombarding high energy electrons with heavy metal targets	1.High temperature bodies 2.Sun	Electrons in atoms of an object moves from higher to lower energy level	Vibrations of atoms and molecules of hot bodies	1.Klystrons 2.Magnetrons 3.Gunn diodes	Accelerated electrons in conducting wires
Detection	1.Photographic film 2.Geiger tube 3.Ionisation chamber	1.Photographic film 2.Geiger tube 3.Ionisat ion chamber	1.Photocell 2.Photographic film	1.Human eye 2.Photographic film 3.Photocell	1.Bolo meter 2.Thermopile 3.Photographic film	Point contact diodes	Receiver's aerial
Use	In medicine to kill the cancer cells	1.Medicine 2.Spectrscopy 3.industries	1.Eye surgery 2.Kill germs in water purifiers	Helps to view the objects	1.Earth satellites 2.Remote switches 3.Night vision cameras	1.RADAR system 2.Speed guns 3.Micro ovens	1.Radio 2.Television broadcasting 3.Communication system

•





•

COMPETENCY BASED QUESTIONS

1. The electric field associated with an electromagnetic wave in vacuum is given by $\vec{E}$ =40 cos (kz – 6×10^8t) î, where E, z and t are in volt/m, meter and seconds respectively. The value of wave vector K is

(a) 2 m^{-1}

(b) 0.5 m^{-1}

(c) 6 m^{-1}

(d) 3 m^{-1}

Answer: a
Explanation:
(a) Wave vector, $k=W/C=6\times10^8/3\times10^8=2m^{-1}$

2. Electromagnetic waves with wavelength λ are used by a FM radio station for broadcasting. Here λ belongs to
(a) radio waves
(b) VHF radio waves
(c) UHF radio waves
(d) microwaves

Answer: b

3. The oscillating magnetic field in a plane electromagnetic wave is given as $B_y = (8 \times 10^{-6}) \sin [2 \times 10^{11}t + 300\pi x]$ T, wavelength of the electromagnetic wave is
(a) 0.80 cm
(b) 1×10^3m
(c) 2×10^{-2}cm
(d) 0.67 cm

Answer: d
Explanation:
(d) wavelength $\lambda=2\pi/k=2\ \pi/\ 300\pi=1/150$m
= 0.67 cm

4. Maxwell in his famous equations of electromagnetism introduced the concept of
(a) ac current
(b) displacement current
(c) impedance
(d) reactance

Answer: b

5. The conduction current is same as displacement current when source is
(a) ac only
(b) dc only
(c) either ac or dc
(d) neither dc nor ac

Answer: c

6. If a variable frequency ac source is connected to a capacitor then with decrease in frequency the displacement current will
(a) increase

(b) decrease
(c) remains constant
(d) first decrease then increase

Answer: b

7. An electromagnetic wave can be produced, when charge is
(a) moving with a constant velocity
(b) moving in a circular orbit
(c) falling in an electric field
(d) both (b) and (c)

Answer: d

8. Which of the following statement is false for the properties of electromagnetic waves?
(a) Both electric and magnetic field vectors attain the maxima and minima at the same place and same time.
(b) The energy in electromagnetic waves is divided equally between electric and magnetic field vectors.
(c) Both electric and magnetic field vectors are parallel to each other and perpendicular to the direction of propagation of wave.
(d) These waves do not require any material medium for propagation.

Answer: c

9. Which of the following has/have zero average value in a plane electromagnetic wave?
(a) Both magnetic and electric fields
(b) Electric field only
(c) Magnetic field only
(d) None of these

Answer:a
10. A charged particle oscillates about its mean equilibrium position with a frequency of 10^9 Hz. The frequency of electromagnetic waves produced by the oscillator is
(a) 10^6 Hz
(b) 10^7 Hz
(c) 10^8 Hz
(d) 10^9 Hz

Answer: d

11. If E and B denote electric and magnetic fields respectively, which of the following is dimensionless?

(a) $\sqrt{\mu_0\varepsilon_0}\ \frac{E}{B}$ (b) $\mu_0\varepsilon_0 \frac{E}{B}$

(c) $\mu_0\varepsilon_0 \left(\frac{B}{E}\right)^2$ (d) $\frac{E}{\varepsilon_0}\frac{\mu_0}{B}$

Answer: a

12. The ultra high frequency band of radio waves in electromagnetic wave is used as in
(a) television waves
(b) cellular phone communication
(c) commercial FM radio
(d) both (a) and (c)

Answer: b

13. The waves used by artificial satellites for communication is
(a) microwaves
(b) infrared waves
(c) radio waves
(d) X-rays

Answer: a

14. Which of the following electromagnetic waves is used in medicine to destroy cancer cells?
(a) IR-rays
(b) Visible rays
(c) Gamma rays
(d) Ultraviolet rays

Answer: c

15. Light with an energy flux of 20 W/cm^2 falls on a non-reflecting surface at normal incidence. If the surface has an area of 30 cm^2, the total momentum delivered (for complete absorption) during 30 minutes is , [NCERT Exemplar]
(a) 36×10^{-5} kg m/s.
(b) 36×10^{-4} kg m/s.
(c) 108×10^{4} kgm/s.
(d) 1.08×10^{7}kg m/s.
Answer: b

16. The electric field intensity produced by the radiations coming from 100 W bulb at a 3 m distance is E. The electric field intensity produced by the radiations coming from 50 W bulbs at the same distance is [NCERT Exemplar]

(a) $\frac{E}{2}$ (b) $2E.$

(c) $\frac{E}{\sqrt{2}}$ (d) $\sqrt{2}E$

Answer: d

17. If E and B represent electric and magnetic field vectors of the electromagnetic wave, the direction of propagation of electromagnetic wave is along [NCERT Exemplar]

(a) $\vec{E}$

(b) $\vec{B}$

(c) $\vec{B} \times \vec{E}$.

(d) $\vec{E}$ x $\vec{B}$.

Answer: d

18. An EM wave radiates outwards from a dipole antenna, with E_0 as the amplitude of its electric field vector. The electric field E_0 which transports significant energy from the [NCERT Exemplar]

(a) $\frac{1}{r^3}$ (b) $\frac{1}{r^2}$

(c) $\frac{1}{r}$ (d) remains constant.

Answer: c

19. An electromagnetic wave travels in vacuum along z direction: E = (E_1^i + E_2^j) cos(kz – wt). Choose the correct options from the following:

(a) The associated magnetic field is given as

$$B = \frac{1}{c}(E_1\hat{i} - E_2\hat{j})\cos(kz - \omega t)$$

(b) The associated magnetic field is given as

$$B = \frac{1}{c}(E_1\hat{i} - E_2\hat{j})\cos(kz - \omega t)$$

(c) The given electromagnetic field is circularly polarised.

(d) The given electromagnetic wave is unpolarised.

Answer: a

20. An electromagnetic wave travelling along z-axis is given as-$E=E_0 \cos(kz - \omega t)$. Choose the incorrect option from the following;
(a) The associated magnetic field is given as $\vec{B}= 1/c\ \hat{k}\times \vec{E}= 1/\omega(\vec{B}\times \vec{E})$
(b) The electromagnetic field can be written in terms of the associated magnetic field as $\vec{E} = c(\vec{B}\times\hat{j})$
(c) $\hat{k}.\ \vec{E} = 0,\ \hat{k}.\vec{B}\neq 0$
(d) $\hat{k}\times\vec{E} = 0,\ \hat{k}\times\vec{B}= 0$.

Answer: d

21. A plane electromagnetic wave propagating along z direction can have the following pairs of E and B
(a) E_x, B_y.
(b) E_y, B_z.
(c) B_x, E_y.
(d) None of these

Answer: a

22. A charged particle oscillates about its mean equilibrium position with a frequency of 10^9 Hz. For producing electromagnetic waves which one is not true?
(a) They will have frequency of 10^9 Hz.
(b) They will have frequency of 2×10^9 Hz.
(c) They will have a wavelength of 0.3 m.
(d) They fall in the region of radio waves.

Answer: b

23. The source of electromagnetic waves can be a charge
(a) moving with a constant velocity.
(b) Moving in a circular orbit.
(c) at rest.
(d) Falling in a magnetic field.

Answer: b

24. One requires 11 eV of energy to dissociate a carbon monoxide molecule into carbon and oxygen atoms. The minimum frequency of the appropriate electromagnetic radiation to achieve the dissociation lies in [NCERT Exemplar]
(a) visible region.
(b) Infrared region.

(c) Ultraviolet region.
(d) Microwave region.

Answer: c

25. The ratio of contributions made by the electric field and magnetic field components to the intensity of an EM wave is [NCERT Exemplar]
(a) c : 1
(6) c^2 : 1
(c) 1 : 1
(d) √c : 1

Answer: c

26. An EM wave of intensity I falls on a surface kept in vacuum and exerts radiation pressure p on it. Which of the following is not true? [NCERT Exemplar]
(a) Radiation pressure is I/c if the wave is totally absorbed.
(b) Radiation pressure is I/c if the wave is totally reflected.
(c) Radiation pressure is 2I/c if the wave is totally reflected.
(d) Radiation pressure is in the range $I/c < p < 2I/c$ for real surfaces.

Answer: b

27. Speed of electromagnetic wave related to electric field and magnetic field vector in vacuum.
(a) $c = \frac{E_0}{B_0}$ (b) $c = \frac{B_0}{E_0}$
(c) $c = E_0 B_o$ (d) $c = \frac{1}{\sqrt{E_0 B_0}}$

Answer: a

28. Which of the following statement is false for the properties of em waves?
(a) The energy of em wave is divided equally between electric and magnetic fields.
(b) Both electric and magnetic field vectors are parallel to each and perpendicular to the direction of propagation of wave.
(c) These waves do not require any material medium for propagation.
(d) Both electric and magnetic field vectors attain the maximum and minimum at the same place and same time.

Answer: d
Explanation:

(b) Electric and magnetic field vectors are mutually perpendicular to each other directed along the propagation of wave.

29. An electromagnetic wave going through vacuum is described by $E=E_0 \sin (kx- \omega t)$. Which of the following is/are independent of the wave length?

(a) ω (b) ω (c) k/ω (d) $k\omega$

Answer : c

30. An electromagnetic wave going through vacuum is described by $E=E_0 \sin (kx-wt)$; $B=B_0 \sin (kx-\omega t)$. Which of the following equation is true?

(a) $E_0 k=B_0\omega$ (b) $E_0\omega =B_0k$

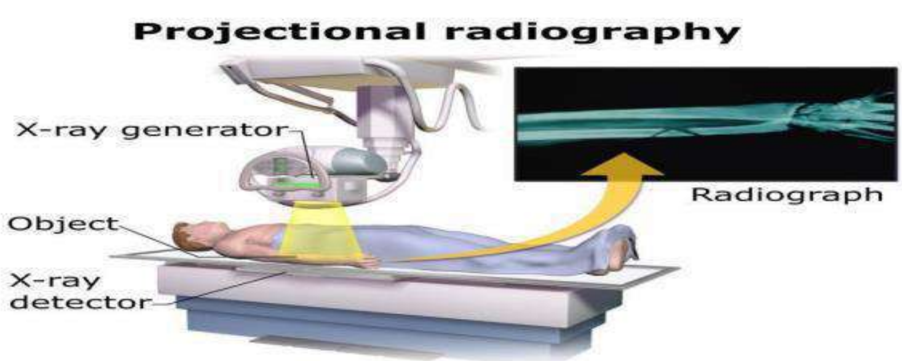
(c) $E_0B_0 = \omega k$ (d) none of these

Answer : a

CASE-STUDY BASED QUESTION

1. X- Rays

X-rays are a form of electromagnetic radiation, similar to visible light. Unlike light, however, x-rays have higher energy and can pass through most objects, including the body. Medical x-rays are used to generate images of tissues and structures inside the body



Q1. (A) What is the most common method of preparation of X rays?
a) Magnetron valve b) vibration of atoms and molecules
c) Bombardment of metal by high energy electrons d) radioactive decay of nucleus

OR

Q1). (B) Which of the following set of instrument /equipment can detect X- rays?

a) Photocells, photographic film
b) Thermopiles, bolometer
c) Photographic film, Geiger tube
d) Geiger tube, human eye

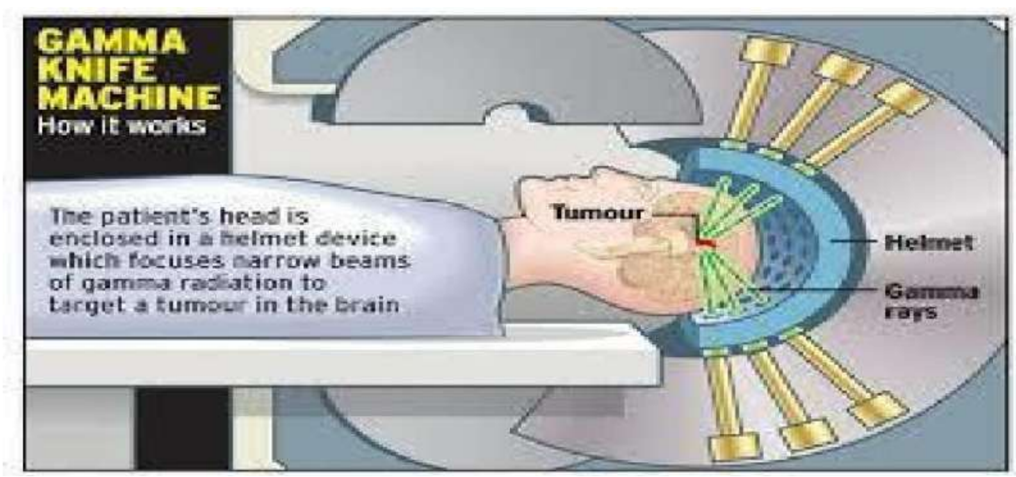
Q2). Where do X rays fall on the electromagnetic spectrum?
a) Between UV region and infrared region
b) Between gamma rays and UV region
c) Between infrared and microwaves
d) Between microwaves and radio waves

Q3) What is the use of rays lying beyond X ray region in electromagnetic spectrum
a) Used to kill microbes
b) Used to detect heat loss in insulated systems
c) Used in standard broadcast radio and television
d) Used In oncology, to kill cancerous cells.

Q4). Which of the following has the lowest frequency?
(a) microwaves
(b)ultra-violet
(c) X-rays
(d) None

ANSWER:
Q1. (A) c OR Q1. (B) c Q2. b Q3. d Q.4.a

2. GAMMA RAYS IN TREATMENT OF CANCER
Gamma rays are used in radiotherapy to Treat cancer. They are used to spot tumors. they kill the living cells and damage malignant tumor.



Q.1. what is the source of gamma rays?
a) Radioactive decay of nucleus
b) Accelerated motion of charges in conducting wire
c) Hot bodies and molecule
d) Klystron valve

Q.2. (A) How is wavelength of gamma rays
a) low b) high
c) infinite d) zero

OR

Q.2. (B) Which of the following is not a use of infrared waves
a) Used in treatment for certain forms of cancer
b) in military and civilian applications include target acquisition, surveillance, night vision, homing, and tracking.
c) to observe changing blood flow in the skin
d) In imaging cameras, used to detect heat loss in insulated systems

Q.3. What is other use of gamma rays?
a) used to change white topaz to blue topaz
b) used in aircraft navigation
(c)used in kill microbes
d) checking fractures of bone

Q.4.What is ratio of velocity of X rays and gamma rays in vaccum.
(a) 3:2 b) 2 :3
c) 1:1 d) none

ANSWER
1) a 2) (A) a OR 2) (B) a 3) a 4)c

3. Microwave oven:

The spectrum of electromagnetic radiation contains a part known as microwaves. These waves have frequency and energy smaller than visible light and wavelength larger than it. What is the principle of a microwave oven and how does it work ? Our objective is to cook food or warm it up. All food items such as fruit, vegetables, meat, cereals, etc., contain water as a constituent. Now, what does it mean when we say that a certain object has become warmer? When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies. The frequency of rotation of water molecules is about 2.45 gigahertz (GHz). If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food. One should use porcelain vessels and non metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get heaten up. Thus, the basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

Q 1. As compared to visible light microwave has frequency and energy:
(a) more than visible light.
(b) less than visible light.
(c) equal to visible light.
(d) Frequency is less but energy is more

2. (A) Microwaves are

(a) Transverse electromagnetic wave

(b) Longitudinal electromagnetic wave

(c) Stationary wave

(d) None of the above

OR

2. (B) Which of the following rays are not electromagnetic waves?

(a) γ-rays

(b) β-rays

(c) Microwaves

(d) Heat rays

Q.3. Why should one use porcelain vessels and nonmetal containers in a microwave oven?
(a) Because it will get too much hot.
(b) Because it may crack due to high frequency.
(b) Because it will prevent the food items to become hot.
(d) Because of the danger of getting a shock from accumulated electric charges

Q. 4. In the microwave oven,
(a) energy is directly delivered to water molecules which is shared by the entire food.
(b) the vessel gets heated first, and then the food grains inside.
(c) the vessel gets heated first and then the water molecules collect heat from the body of the vessel.
(d) energy is directly delivered to the food grains.

ANS.
1. (b) 2. (A) (a) OR 2. (B) (b) 3. (d) 4. (a)

4. ELECTROMAGNETIC (EM) SPECTRUM
The electromagnetic (EM) spectrum is the range of all types of EM radiation. Radiation is• energy that travels and spreads out as it goes – the visible light that comes from a lamp in your house and the radio waves that come from a radio station are two types of electromagnetic radiation. The other

types of EM radiation that make up the electromagnetic spectrum are microwaves, infrared light, ultraviolet rays, X- rays and gamma rays.

Q1. The classification of electromagnetic waves is roughly based on?
a) Wavelength and frequency of waves.
b) Production and detection of waves.
c) The way of travelling of waves.
d) Year discovered.

Q2. Which of the following is NOT a use of electromagnetic rays?
a) Radiotherapy (medicine). b) Checking fractures.
c) Sterilization. d) Explosives.

Q3. Identify the pair having highest frequency and highest wavelength in Electromagnetic waves.
a) UV rays and X- rays
b) Gamma rays and Microwaves.
c) Gamma rays and Radio waves.
d) Radio waves and UV rays.

Q4. (A) What physical quantity is the same for X rays of wavelength 10^{-10}m, red light of wavelength 6800 A^o and radiowaves of wavelength 500 m?
a) Speed in vacuum b) frequency
c) Wavelength d) Energy

OR

Q.4. (B) What is the ratio of velocity of electromagnetic waves having frequency 1MHz and 10MHz in air?
(a) 1:1 (b)2:1
(c) 1:2 (d)1:10

ANSWER KEY
1. a 2. D 3. C 4. (A) a OR (B) a

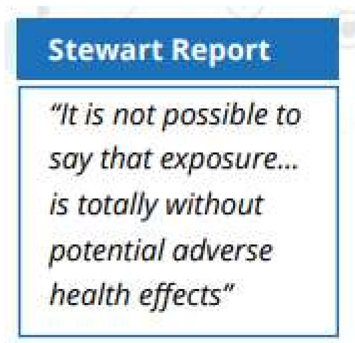
5. CHILD MOBILE PHONE WARNING

A major report into mobile phones and health advises limits on their use by children, the BBC understands.

Children may be advised to cut phone use

While the Stewart Report says that, as a precaution, children should limit their mobile phone use until more research has been completed. Some studies have suggested that children are more vulnerable to the effects of microwave radiation emissions because their nervous systems are not fully developed and their skull is thinner than adults, providing less protection.

Dr Alan Preece, from Bristol University, told the BBC that more research was needed: “I just can’t believe the explosion in mobile phone use in the last five years. “I think we really do need to research it to reassure the public that there are no long term effects.”Mary MacLeod, from the National Family and Parenting Institute said: “Parents need to have accurate information about health risks so that they can make judgments about their children using mobile phones. “A growing number of children have access to mobile phones, and they are a great source of comfort and security for parents, knowing they can find out where their children are and can keep in touch with them.” The radiation emitted by mobile phones is not X-ray radiation, but microwave radiation, and some scientists were concerned that it might actually be heating and damaging brain cells because the phone is held so close to the head.



1. (A) What type of electromagnetic waves do mobile phones emit?

(a) Heat waves

(b) X-rays

(c) UV rays

(d) Microwaves

OR

(B) The source of all electromagnetic waves is

(a) Magnetic Fields

(b) Heat

(c) Electric Fields

(d) Vibrating charges

2. Which of the following are fundamentally different from the others?

(a) Gamma rays

(b) Microwaves

(c) Sound waves

(d) Light waves

3. The main difference between microwaves and light waves is

(a) Speed

(b) Wavelength

(c) Nature

(d) None of the above

4. The domestic application of microwave used is

(a) Electrical induction

(b) Water heater

(c) TV

(d) Microwave oven

Answers:

1. (A) (d) OR (B)(d) 2. (c) 3. (b) 4. (d)

6. THEORY OF ELECTROMAGNETIC WAVES.

According to Maxwell's electromagnetic equations it has been proved that electric and magnetic field vectors are perpendicular to each other and also perpendicular to the direction of propagation as shown in the figure below. If Ex is the electric field along X axis, then by will be the direction of magnetic field along Y axis and both which are perpendicular to the Z axis showing direction of propagation. The light waves are also the electromagnetic waves and may travel through vacuum also. So, we can find the velocity of a light traveling through the material medium having permittivity 'e' and magnetic permeability 'u' as v = 1/Veu.

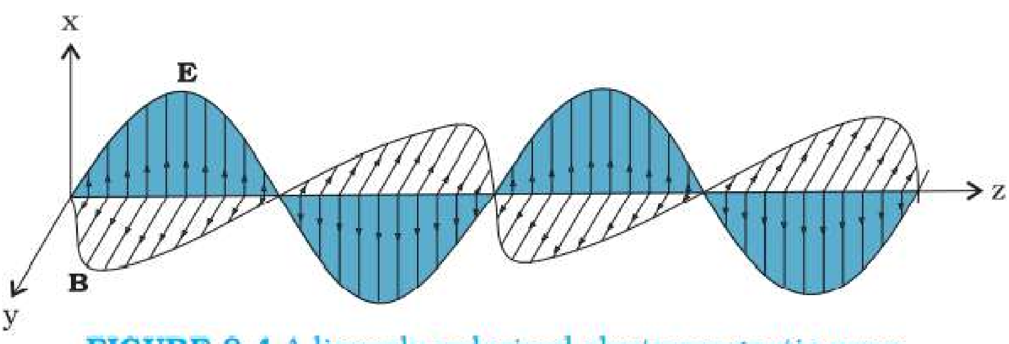


FIGURE 8.4 A linearly polarised electromagnetic wave, propagating in the *z*-direction with the oscillating electric field **E** along the *x*-direction and the oscillating magnetic field **B** along the *y*-direction.

In this way, we proved that velocity of light also depends on the electrical and magnetic properties of that medium through which it is traveling. The velocity of light which is constant everywhere is having value as 3 x 10 m/s. The most technological importance of EM waves is that they are having strong capacity to take energy from one place to another place. The best examples are radio waves, TV signals which also carry energy from their broadcasting stations. Also, life is possible on the earth only because of the sunlight coming from the sun to the earth which carries and it is nothing but the EM waves. Due to which Electro Magnetic waves are considered as the transverse waves.

1. The frequency of electromagnetic wave which is best suited to observe a particle of radius 3 x 10^{-4} cm is of the order of

(a) 10^{15} Hz

(b) 10^{13} Hz

(c) 10^{14} Hz

(d) 10^{12} Hz

2. The pressure exerted by the electromagnetic wave is called as

(a) Light pressure

(b) Electric pressure

(c) Magnetic pressure

(d) Radiation pressure

3. If we want to produce electromagnetic waves of wavelength 500 km by an oscillating charge; then frequency of oscillating charge must be

(a) 500 Hz

(b) 600 Hz

(c) 167 Hz

(d) 15 Hz

4. (A) Electromagnetic waves travelling in a medium having relative permeability 1.3 and relative permittivity 2.14. The speed of electromagnetic waves in medium must be

(a) 1.8 x 10^4 m / s

(b) 1.8 x 10^8 m / s

(c) 1.8 x 10^2 m ^ 3

(d) 1.8 x 10^6 m / s

OR

4. (B) Electromagnetic wave travelling in a medium has speed of 2 x 10^8 m/s. If the relative permeability is 1, then the relative permittivity of medium must be

(a) 2

(b) 2.5

(c) 2.25

(d) 1.5

Answers:

1. c 2. D 3. B 4. (A) b OR (B) c

7. ELECTROMAGNETIC SPECTRUM

The electromagnetic spectrum consists of visible light, x-rays, gamma rays, microwaves, ultraviolet rays, radio waves and infrared waves. The waves used in radio and television communication are the radio waves having frequency range 500 kHz to 1000MHz. In the ultrahigh frequency bands cellular phones uses th radio waves to transmit voice. Microwaves are the waves having short wavelength. In aircraft navigation, for the radar system microwaves are used due to their short wavelength. Infrared waves are also called as heat waves. Infrared radiation has most importance in maintaining earth's surface temperature through greenhouse effect. The infrared waves have vast application in real life such infrared detectors are used military purposes and also to see the growth of crops. The waves which are visible to human eye are the visible rays. Visible rays are having frequency range as 4 x10^{1}4 Hz to 7 x 10^{1} Hz. The huge source of ultraviolet light is the sun. Ultra violet rays have wavelength range from 4 x 10 m to 6 x 10m. X- rays are used destroy the living tissue and organisms medical field. Then gamma rays are the rays having wavelength range as 10 m to 10m which are the high frequency radiations mostly produced in nuclear reactions. Gamma rays are also used to destroy cancer cells in medical field.

1. (A) The TV waves range from which are the radio waves.

(a) 54 Hz to 890 Hz

(b) 54 MHz to 890 MHz

(c) 500 kHz to 1000 MHz

(d) 1000 Hz to 1000 KHz

OR

(B) The part of the electromagnetic spectrum which is detected by human eye is having wavelength as

(a) 900 – 400 nm

(b) 200-400 nm

(c) 700-600 nm

(d) 380-700 nm

2. An electromagnetic wave of frequency 3.0 MHz passes from vacuum into a dielectric medium with relative permittivity epsilon_{c} = 4 Then

(a) wavelength is doubled and frequency remains unchanged

(b) wavelength is doubled and frequency becomes half

(c) wavelength is halved and frequency remains unchanged

(d) wavelength and frequency both remains unchanged

3. The rms value of the electric field of light coming from the sun is 720 N/C. The average total energy density of the electromagnetic wave

(a) 6.37×10^{-9} Jm^{-3}

(b) 4.58×10^{-6} Jm^{-3}

(c) 81.35×10^{-12} Jm^{-3}

(d) 3.3×10^{-3} Jm^{-3}

4. A plane electromagnetic wave propagating along x direction can have the following pairs of E and B

(a) E_x, B_y

(b) E_x , B_z

(c) B_x ,E_y

(d) E_z , B_y

Answers:

1. **(A) b OR (B) d 2. D 3. B 4. D**

8. PROPERTIES OF ELECTROMAGNETIC WAVES

In an electromagnetic wave both the electric and magnetic fields are perpendicular to the direction of propagation, that is why electromagnetic waves are transverse in nature. Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields. Energy density of an electromagnetic wave is the energy in unit volume of the space through which the wave travels.

1. The electromagnetic waves propagated perpendicular to both E and B. The electromagnetic waves travel in the direction of

(i)$\vec{E}\,.\,\vec{B}$ $(ii)\vec{E}\ x\ \vec{B}$ $(iii)\vec{B}\ .\ \vec{E}$ $(iv)\vec{B}\ x\ \vec{E}$

2. The fundamental particle in an electromagnetic wave is

(a) Photon

(c) Electron

(b) Phonon

(d) Proton

3. Electromagnetic waves are transverse in nature is evident by

(a) Polarisation

(c) Interference

(b) Reflection

(d) diffraction

4. (A) For a wave propagating in a medium, identify the property that is independent of the others.

(a) Velocity

(c) Frequency

(b) Wavelength

(d) All these depend on each other

OR

(B) The electric and magnetic fields of an electromagnetic waves are

(a) in opposite phase and perpendicular to each other

(b) In opposite phase and parallel to each other

(c) In phase and perpendicular to each other.

(d) In phase and parallel to each other.

Answer:

1. b 2. a3. a4.(A) c OR (B) c

9. ELECTROMAGNETIC WAVES

The beauty of a coral reef, the warm radiance of sunshine, the sting of sunburn, the X-ray revealing a broken bone, even microwave popcorn- all are brought to us by electromagnetic waves. It is worth noting at the outset that the general phenomenon of electromagnetic waves was predicted by theory before it was realized that light is a form of electromagnetic wave. The prediction was made by James Clerk Maxwell in the mid-19th century when he formulated a single theory combining all the electric and magnetic effects known by scientists at that time. "Electromagnetic waves" was the name he gave to the phenomena his theory predicted.

An electromagnetic wave has a frequency 'ν' and a wavelength 'λ' associated with it and travels at the speed of light 'c'. The relationship among these wave characteristics is

$$c = \nu\lambda$$

Thus, for all electromagnetic waves, the greater the frequency, the smaller the wavelength.

1. Which of the following electromagnetic radiations have the longest wavelength?

(a) X-rays

(b) γ-rays

(c) Microwaves

(d) Radiowaves

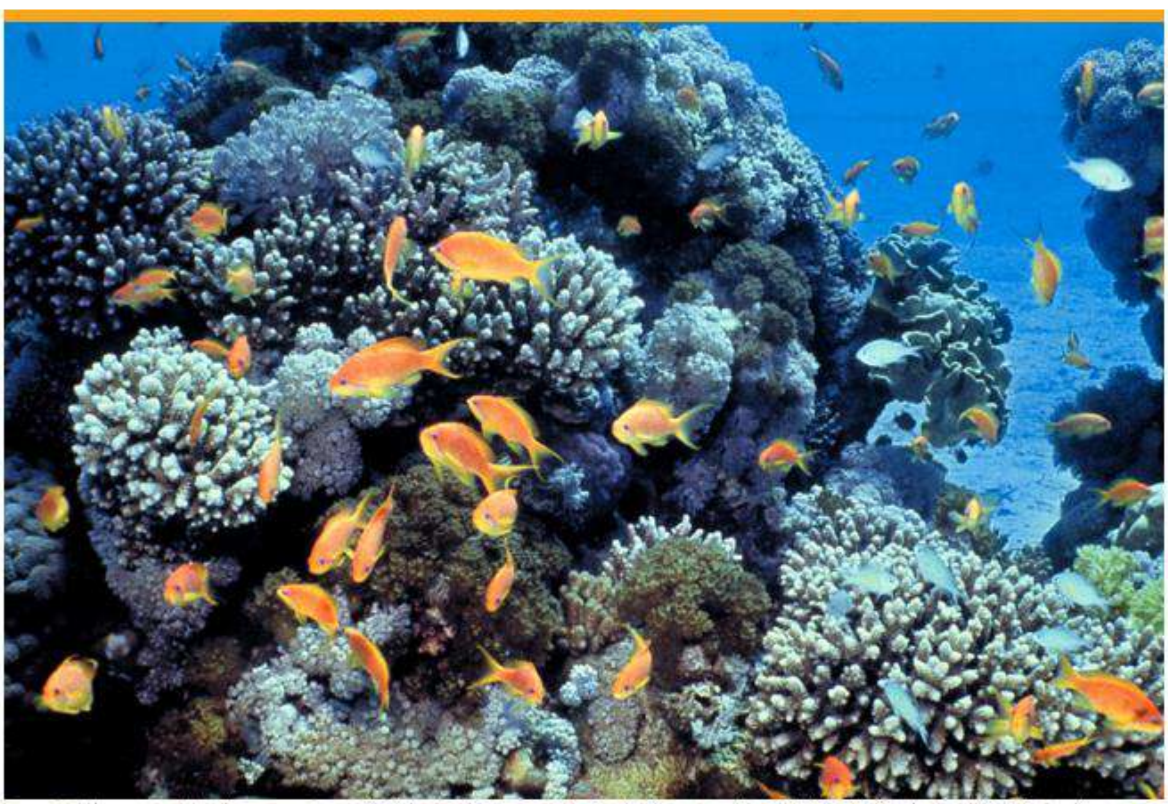


Figure 24.1 Human eyes detect these orange "sea goldie" fish swimming over a coral reef in the blue waters of the Gulf of Eilat (Red Sea) using visible light. (credit: Daviddarom, Wikimedia Commons)

2. If a source is transmitting electromagnetic waves of frequency 8.2×10^6 Hz, the wavelength of electro-magnetic wave transmitted from the source the source is

(a) 36.6 m

(b) 18.8 m

(c) 42.8 m

(d) 58 m

3. Light can travel in vacuum due to its

(a) Transverse nature

(b) Electromagnetic nature

(c) Longitudinal nature

(d) Both (a) and (c)

4. (A) Which of the following is the best method for production of infrared waves?
a) Bombardment of metal by high energy electrons
b) Radioactive decay of nucleus
c) Magnetron valve
d) Vibration of atoms and molecules

OR

(B) Wavelength of infrared radiations is

(a) Shorter (b) longer
(c) Infinite (d) zero

Answers;

1. **d**
2. **a**
3. **b**
4. **(A) a**

OR

(B) b

10. ELECTROMAGNETIC WAVES

Electromagnetic waves are classified into categories such as radio, infrared, ultraviolet, and so on, so that we can understand some of their similarities as well as some of their differences.

Table Electromagnetic Waves

Type of EM wave	Production	Applications	Life sciences aspect	Issues
Radio & TV	Accelerating charges	Communications Remote controls	MRI	Requires controls for band use
Microwaves	Accelerating charges & thermal agitation	Communications Ovens Radar	Deep heating	Cell phone use
Infrared	Thermal agitations & electronic transitions	Thermal imaging Heating	Absorbed by atmosphere	Greenhouse effect
Visible light	Thermal agitations & electronic transitions	All pervasive	Photosynthesis Human vision	
Ultraviolet	Thermal agitations & electronic transitions	Sterilization Cancer control	Vitamin D production	Ozone depletion Cancer causing
X-rays	Inner electronic transitions and fast collisions	Medical Security	Medical diagnosis Cancer therapy	Cancer causing
Gamma rays	Nuclear decay	Nuclear medicineSecurity	Medical diagnosis Cancer therapy	Cancer causing Radiation damage

1. Which of the following electromagnetic radiations have the longest wavelength?

(a) X-rays

(b) γ-rays

(c) Microwaves

(d) Radio waves.

2. (A) Why does a microwave oven heat up a food item containing water molecules most efficiently?

(a) Microwaves are heat waves, so always produce heating

(b) Infrared waves produce heating in a microwave oven

(c) Energy from the microwaves is transferred efficiently to the kinetic energy of water molecules at their resonant frequency.

(d) The frequency of microwaves has no relation with natural frequency of water molecules.

OR

(B). Microwaves are used in

(a) Radar system for aircraft navigation

(b) Long-distance communication systems via geostationary satellites

(c) Microwave ovens

(d) All of the above

3. The magnetic field in a plane electromagnetic wave is given by $B_y = 2 \times 10^{-7} \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)$. This electromagnetic wave is

(a) A visible light

(b) An infrared wave

(c) A microwave

(d) A radio wave

4. Consider the following types of electromagnetic radiation radiowaves, infra-red, visible light. Which of the following statements are correct?

(1) Only radio waves can be used to transmit audio information.

(ii) Only infrared radiation is emitted by very hot object.

(iii) Only visible light can be detected by humans.

(a) Only (i) is correct

(b) Only (ii) is correct

(c) Only (iii) is correct

(d) None of the above is correct

Answers:

1. (d)

2. (A) (c)

OR

(B) (d)

3. (c)

4. (d)

ONE MARK QUESTIONS

1. Name the part of the electromagnetic spectrum whose wave length lies in the range 10^{-10}m and give its one use..

Answer: X rays, diagnostic tool in medicine.

2. What is the frequency of electromagnetic waves produced by oscillating charge of frequency ν=10^5Hz and also name the electromagnetic wave?

Ans. Radio waves, 10^4Hz – 10^8Hz

3. Write two uses of microwaves.

Ans. (i) In Radar Communication (ii) In analysis of molecular and atomic structure

4. How are infrared waves produced? What is the range of their wavelength?

Ans. Hot objects and molecules, $7X10^{-7}$ m to 10^{-3} m

5. Which part of electromagnetic spectrum is used in RADAR systems? [Delhi 2010]
Ans. Micro Waves

6. Which part of electromagnetic spectrum has largest penetrating power?
Ans : Y- rays have highest frequency range and highest penetrating power .

7. Arrange the following in descending order of wavelength. X-rays, radiowaves, blue light, infrared light. [All India 2010]
Ans. Radiowaves> Infrared> Blue light > X-Ray

8. Which of the following has the shortest wavelength? Microwaves, ultraviolet rays, X-rays
Ans . X- ray has shortest wavelength.

9. Express the velocity of propagation of an electromagnetic waves in terms of the peak value of the electric and magnetic fields.
Ans. Velocity of propagation of EM wave in terms of peak values of electric and magnetic field vectors, $c = E_0 / B_0$

10.Write the following radiations in ascending order in respect of their frequencies X-rays, microwaves, ultraviolet rays and radio waves.
Ans.radiowaves.<microwaves< ultraviolet rays < X-Rays

11..Name the electromagnetic radiation which can be produced by a klystron or a magnetron valve.
Ans. Micro waves

12. State the reason why microwaves are best suited for long distance transmission of signals.
Ans. Due to Shorter wavelength is suitable for long distance transmission

13. Why is ozone layer on top of the stratosphere crucial for human survival?
Ans. Protect from U-V Rays

14. Write the SI unit of displacement current?
Ans. Ampere

15. What physical quantity is same for X-rays of wavelength 10^{-10} m, red light of wavelength 6800 Å and radio wave of wavelength 500 m?
Ans. Velocity in vacuum

16. Name the electromagnetic waves which
(i) maintain the earth's warmth and (ii) are used in aircraft navigation.

Ans. (i) infrared (ii) microwave

17. What is the relationship between magnitude of magnetic field and electric field in case of electromagnetic waves from Maxwell's equations?

Answer: E/B = c

ASSERTION-REASON TYPE QUESTIONS

In the following questions, mark the correct choice as:

(a) Both assertion and reason are true and the reason is a correct explanation of the assertion.

(b) Both assertion and reason are true but the reason is not a correct explanation of the assertion.

(c) Assertion is true but the reason is false.

(d) Both assertion and reason are false.

1. A: Different electromagnetic waves differ considerably in their mode of interaction with matter.
R: Different electromagnetic waves have different wavelength or frequency

Answer: (b)

2. A: All electromagnetic waves travel through vacuum with same speed but they have different wavelength or frequency.
R: The wavelength of the electromagnetic waves is often correlated with the characteristic size of the system that produces and radiates them.

Answer: (a)

3. A: High frequency electromagnetic waves are detected by some means based on the physical effects they produce on interacting with matter.
R: The oscillating fields of an electromagnetic wave can accelerate charges and can produce oscillating currents therefore, an apparatus designed to detected waves is based on this fact.

Answer: (a)

4. A: Infrared waves are often called heat waves.
R: Infrared waves vibrate not only the electrons, but entire atoms or molecules of a substance which increases the internal energy and temperature of the substance.

Answer: (a)

5. A: Optical and radio telescopes are built on the ground but X-ray astronomy is possible only from satellites orbiting the earth.
R: Atmosphere absorbs X-rays, while visible and radio waves can penetrate it.
Answer: (a)

6. A: In an EM wave the magnitude of the electric field vector is more than the magnitude of the Magnetic field vector.
R: Energy of the EM wave is shared equally between the electric and magnetic fields.

Answer: (b)

7. A: When cooking in microwave ovens, metal containers are used.
R: Energy of the microwaves can be easily transferred to the food through metal.
Answer: (d)

8. A: Food is cooked faster by microwaves than by conventional gas burner.
R: Microwaves have more energy than heat waves.
Answer: (c)

9. A: Microwaves are commonly used in radar to locate flying objects.
R: Microwaves have smaller wavelength than radio waves.
Answer: (a)

10. A: A: In an electromagnetic wave the energy density in electric field is equal to energy density in magnetic field.
R: Electromagnetic waves are transverse in nature.
Answer: (b)

11. A: In an electromagnetic wave the energy density in electric field is equal to energy density in magnetic field.
R: Electromagnetic waves are transverse in nature.
Answer: (b)

12. Assertion. Dipole oscillations produce electro- magnetic waves.

Reason. Accelerated charge produces electromagnetic waves. [AIIMS 2007]
Answer: (a)

13. Assertion. A charge moving in a circular orbit can produce electromagnetic wave.

Reason. The source of electro- magnetic wave should be in accelerated motion.
Answer: (a)

14. Assertion. Electromagnetic waves are transverse in nature.

Reason. The electric and magnetic fields of an em. wave are perpendicular to each other and also perpendicular to the direction of wave propagation. [AIIMS 2010]
Answer: (a)

15. Assertion. Electromagnetic radiations exert pressure.

Reason. Electromagnetic waves carry both momentum [AIIMS 13] and energy.
Answer : (a)

16. Assertion. When a charged particle moves in a circular path, it produces electromagnetic wave.

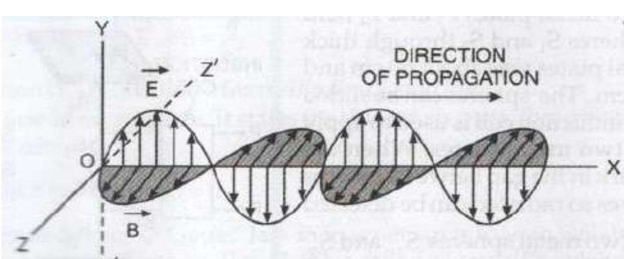
Reason. Charged particle has acceleration. [AIIMS 16]
Answer :(a)

2 MARKS QUESTIONS

1.(a) How does oscillating charge produce electromagnetic waves?
(b) Sketch a schematic diagram depicting oscillating electric and magnetic fields of an EM wave propagating along positive X-direction.

Ans. (a) The oscillating charge produces electric field and oscillating electric field produces magnetic fields which is then produces an oscillating emf. A changing electric field produces a magnetic field produces and changing magnetic field produces a electric field, the result is a wave of electric and magnetic fields that can propagate through space. This propagating field are called EMW.

(b) EMW



2.(i) How are electromagnetic waves produced?
(ii) How do you convince yourself that electromagnetic waves carry energy and momentum?

Ans (i) The oscillating charge produces electric field and oscillating electric field produces magnetic fields which is then produces an oscillating emf. A changing electric field produces a magnetic field produces and changing magnetic field produces a electric field, the result is a wave of electric and magnetic fields that can propagate through space. This propagating field are called EMW.

(ii)according to quantum theory electromagnetic radiation is a made up of mass less particles called photon. Momentum of photon is expressed

P = E / C

Thus I convinced that electromagnetic radiation can carry energy and momentum.

3. **(i)**The charging current for a capacitor is 0.25 A. what is the displacement current across its plates?
(ii) A variable frequency a.c source is connected to a capacitor. Will the displacement current increase or decrease with increasing frequency?

Ans.(i) 0.25 Amp
(ii) Increases

4.(i) Name the Maxwell's equation among the four which shows that the magnetic monopole does not exist?
(ii) Give reason for decrease or increase in velocity of light, when it moves from air to glass or glass to air respectively?

Ans. (i) Gauss's theorem of Magnetism
(ii) The velocity of light depends on ε & μ of the medium.

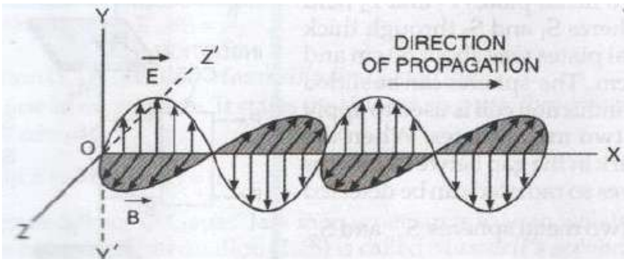
5.A parallel plate capacitor is being charged by a time varying current. Explain briefly how amperes circuital law is generalized to incorporate the effect due to the displacement current.

Ans:- Let us consider that a capacitor is being charged, There is a conduction current I in to plate , but out of A no there is no Conduction current. Similarly there is no conduction current in to B. Therefore Kirchhoff's law seems to fail; as it is a series circuit so current must be same in all parts of the circuit. Maxwell resolved this problem by stating that as the capacitor charges, a changing electric field (hence electric flux) is set-up between the plates of the capacitor. This changing electric field is equivalent to an electric current, known as displacement current (I_D).we know the electric field between the plates

$$\oint B.dl = \mu_0 \left(I + \varepsilon_0 \frac{d\phi_E}{dt} \right)$$

6. What is meant by transverse nature of electromagnetic wave? Draw a diagram showing the propagation of an electromagnetic wave along the x direction, indicating clearly the directions of the oscillating electric and magnetic fields associated with it. (CBSE-2010,2008)

Ans:-



E.M. waves are transverse in nature i,e, $\vec{E}$ & $\vec{B}$ are perpendicular to each other as well as perpendicular to the direction of propagation of the wave. E & B are related as follows -

$\frac{E_0}{B_0} = c$,or $\frac{E}{B} = c$

7.Optical and radio telescopes are built on the ground while X- ray astronomy is possible only from satellites orbiting the Earth. Why?

Ans.The earth's atmosphere is transparent to visible light and radio waves but absorbs X-rays. Satellites orbiting the earth at a height of 36000 km, where atmosphere is very thin and X-rays are not absorbed.

8.The small ozone layer on top of the stratosphere is crucial for human survival. Why?

Ans.Ozone layer absorbs ultraviolet radiation from the sun and prevent these radiations from reaching the earth which causes cancer.

9. The oscillating magnetic field in a plane electromagnetic wave is given by

$$B_Y = 8 \text{ X } 10^{-6} \sin (2 \text{ x } 10^{11} t + 300\pi x)] \text{ T}$$

(a) Calculate the wavelength of electromagnetic wave?
(b) Write down the expression for the oscillating electric field.

Ans. a. $\lambda = \frac{2}{3} c$m,

b. $E_Z = 2400 \sin (2 \text{ x } 10^{11} t + 300\pi x)$

10. In an electromagnetic wave propagating along x- direction, the magnetic field oscillates at a frequency of $3X10^{10}$ H_Z and has an amplitude of 10^{-7} Tesla acting along the y-direction.

(i) what is the wavelength of electromagnetic wave ?
(ii) write the expression representing the corresponding oscillating electric field.

Ans. (i) $\lambda = 10^{-2}$ m
(ii) $E_z = 30 \sin (6\pi \text{ x } 10^{10} t - 2\pi \text{ x } 10^2 x)$

11. What is the missing term in ampere Circuital law?

Ans. This is the **missing term in Ampere's circuital law** and known as displacement current , The source of a magnetic field is not just the conduction electric current due to flowing charges, but also the time rate of change of electric field.

12.Is displacement current real?

Ans. The **displacement current** is not a “**real**” **current**, in the sense that it does not describe charges flowing through some region. However, it acts just like a **real current.**

13. What is the direction of displacement current?

Ans. The direction of the displacement current I_d is in the direction of change of electric field. So for a charging capacitor, for which the magnitude of E is increasing, the direction of Id is in the direction of the **increase** of field.

14. Why infrared waves are also called as heat waves?

Answer: Infrared radiations get readily absorbed by water molecules in most materials. This increases their thermal motion and heats them up. That is why infrared radiations are often referred to as heat waves.

3 MARKS QUESTIONS

1.a) Which of the following if any, can act as a source of electromagnetic waves?
(i) A charge moving with constant velocity.
(ii) A charge moving in circular orbit. (iii)A charge at rest. Give reason
(b) Identify the part of electromagnetic spectrum to which the waves of frequency
(i) 10^{20} Hz (ii) 10^{9} Hz belong

Ans. a) can’t produce EM waves because no acceleration.
(ii) It is accelerated motion - can produce EM. Waves.
(iii)Can’t produce EM waves because no acceleration.
b) (i) Gamma rays.
(ii) Micro waves

2. Electromagnetic waves with wavelength,
(i) $\lambda_1$are used to treat muscular strain.
(ii) λ_2 are used by a FM radio station for broadcasting
(iii) λ_3 are produced by bombarding metal target by high speed electrons
Identify and name the part of electromagnetic spectrum to which these radiation belong.
Arrange these wave lengths, in decreasing order of magnitude.
Ans.(i) λ_1- Infra-red radiation.
(ii) λ_2 - VHF / Radio waves
(iii) λ_3 - X – rays

3.The electric field of a plane electromagnetic wave in vacuum is represented by

$E_X = 0 \quad E_Y = 0.5\cos[2\pi \times 10^8 (t - x/c)], \quad E_Z = 0$

(i) What is the direction of propagation of electromagnetic wave?
(ii) Determine the wavelength of the wave.
(iii) compute the component of oscillating magnetic field.

Ans.(i) + x-direction
(ii) $\lambda = 3.0$ m
(iii) $B_Z = 10^{-8}\cos[2\pi \times 10^8 (t - x/c)]$

4.A parallel plate capacitor made of circular 2 plates each of radius 10 cm has a capacitance 200pF. The capacitor is connected to a 200V ac supply with an angular frequency of 200 rad/s.

a) What is the rms value of conduction current
b) Is the conduction current equal to displacement current
c) Peak value of displacement current
d) Determine the amplitude of magnetic field at a point 2cm from the axis between the plates

Ans. a) $I_{rms} = 8\mu A$
b) $I_c = I_d$
c) $I_0 = 11.312 \times 10^{-6}$ A
d) $B = 4.525 \times 10^{-12}$ T

5. Write the order of frequency range and one use of the following e. m radiations.

(i) Microwaves ii) Ultra-violet rays iii) gamma rays

Ans: (i) Microwaves :- 10^8 to 10^{12} Hz approx used in radars/microwave ovens ii) Ultra violet rays:- 10^{15} to 10^{18} Hz approx. sterilizing the medical instruments

iii) Gamma rays:- 10^{18} to 10^{22} Hz in radio therapy, treating cancer and tumors.

6. How the following e.m radiations are produced? Mention one use of them.

(i) radio waves

(ii) Infra red rays

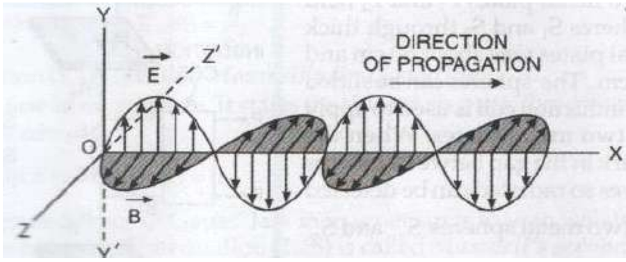
(iii) x rays

i) radio waves produced by oscillating circuits having inductor and capacitor. Used in radio and TV communication.

ii) infra red rays: produced by all hot bodies treating muscular strains/ solar appliances etc.,

(iii) X rays: produced when high energy electrons bombards metals. To detect fracture in bones/ study crystal structure

7. Draw a sketch showing the propagation of the electromagnetic wave, including the direction of the oscillating electric and magnetic fields., when its travelling in x-direction. How are the magnitudes of the electric and magnetic fields related to the velocity of the E M wave?

Answer: 

E/B=c

8. A capacitor of capacitance C is being charged by connecting it across a DC source along with an ammeter. Will the ammeter show a momentary deflection during the process of charging? If so, how would you explain the momentary deflection and resulting continuity of current in the circuit? Write the expression for the current inside the capacitor.

Answer: Yes the ammeter will show a momentary deflection. The momentary deflection is due to the flow of electrons in the circuit during the charging process. During this process the electric field between the capacitor plates is changing and hence a displacement current flows in the gap. Hence we can say that there is a continuity of current in the circuit.

9. Name the electromagnetic waves with their wavelength range which are used for

(i) FM radio broadcast
(ii) Detection of fracture in bones
(iii) Treatment of muscular strain

Answer: Electromagnetic waves	Wavelength range
(i) Radio waves	> 0.1m
(ii) X-rays	1 nm – 10^{-3} nm
(iii) Infrared waves	1 mm – 700 nm

10. An EM wave travelling through a medium has electric field vector. Ey= $4 \times 10^5 \cos(3.14 \times 10^8 t - 1.57 x)$ N/C. Here x is in m and t in s. Then find:

(i) Wavelength
(ii) Frequency
(iii) Direction of propagation
(iv) Speed of wave
(v) Refractive index of medium
(vi) Amplitude of magnetic field vector.

Answer: $E_Y = 4\times10^5 \cos(3.14 \times 10^8 t - 1.57 x)$ N/C

(i) $\nu = 5\times10^7$ Hz
(ii) $\lambda = 4$m
(iii) Along y axis
(iv) $V = 3\times10^8$ m/s
(v) $\mu = 1$
(vi) $B_0 = 1.34\times10^{-3}$ T

SELECT RESPONSE TYPE QUESTIONS

MCQ's(DIRECT &EASY)

1. Which of the following has minimum wavelength?
   (a) Blue light
   (b) γ-rays
   (c) infrared rays
   (d) microwave

Answer: b

Explanation:

(b) γ-rays have maximum frequency so minimum wavelength among electromagnetic waves.

2. Which of the following has maximum penetrating power?
   (a) Ultraviolet radiation
   (b) Microwaves
   (c) γ-rays
   (d) Radio waves

Answer: c

Explanation:

(c) γ-rays have maximum frequency and energy of proton, therefore maximum penetrating power.

3. Electromagnetic waves travelling in a medium having relative permeability μ_r = 1.3 and relative permittivity E_r = 2.14. The speed of electromagnetic waves in medium must be
   (a) 1.8×10^8 ms^{-1}
   (b) $1.8 \times 10^4 ms^1$
   (c) $1.8 \times 10^6 ms^1$
   (d) 1.8×10^2 ms^{-1}

Answer: a

Explanation: (a) speed of electromagnetic waves

$$v = \frac{c}{\sqrt{\mu_r \varepsilon_r}} = \frac{3 \times 10^8}{\sqrt{2.14 \times 1.3}}$$

$$= 1.8 \times 10^8 ms^{-1}$$

4. In electromagnetic waves the phase difference between electric and magnetic field vectors are
(a) zero
(b) π4
(c) π2
(d) π

Answer: a
Explanation: (a) Electric and magnetic field vectors always vary in same phase.

5. The quantity $1/\sqrt{\mu_0\varepsilon_0}$ represents
(a) speed of sound
(b) speed of light in vacuum
(c) speed of electromagnetic wave in medium
(d) inverse of speed of light in vacuum

Answer: b
Explanation: (b) Speed of light in vacuum, $c=1/\sqrt{\varepsilon_0\mu_0}$

6. In electromagnetic wave if u_e and u_m are mean electric and magnetic energy densities respectively, then

(a) $u_e = u_m$ (b) $u_e > u_m$

(c) $u_e < u_m$ (d) $u_e^2 = \frac{1}{2}u_m^2$

Answer: a
Explanation: (a) Energy is equally distributed among electric field and magnetic field

7. Which of the following is called heat radiation?
(a) X-rays
(b) γ-rays
(c) Infrared radiation
(d) Microwave

Answer: c

8. From Maxwell's hypothesis, a changing electric field gives rise to
(a) an electric field.
(b) an induced emf.
(c) a magnetic field.
(d) a magnetic dipole.

Answer: c
Explanation: (c) A changing electric field gives rise to a magnetic field.

9. Electromagnetic waves are transverse in nature is evident by
(a) polarization.
(b) Interference,

(c) reflection.
(d) Diffraction.

Answer: a
Explanation: (a) Only transverse waves can be polarised.

10. Which of the following are not electromagnetic waves?
(a) Cosmic rays
(b) γ-rays
(c) β-rays
(d) X-rays

Answer: c
Explanation: (c) β-rays consist of electrons which are not electromagnetic nature.

11. 10 cm is a wavelength corresponding to the spectrum of
ia) infrared rays
(b) ultraviolet rays
(c) microwaves
(d) X-rays

Answer: c
Explanation: (c) Microwaves have wavelength around 10 cm.

12. If $\vec{E}$ and $\vec{B}$ represent electric and magnetic field vector of the electromagnetic waves then the direction of propagation of the electromagnetic wave is that of

(a) $\vec{E} \cdot \vec{B}$ (b) $\vec{B} \cdot \vec{E}$

(c) $\vec{E} \times \vec{B}$ (d) $\vec{B} \times \vec{E}$

Answer: c
Explanation: (c) $\vec{E} \times \vec{B}$

13. The structure of solids is investigated by using
(a) cosmic rays
(b) X-rays
(c) γ-rays
(d) infrared rays

Answer: b
Explanation: (b) X-rays are used to investigate structure of solids.

14. The condition under which a microwave over heats up a food item containing water molecules most efficiently is
(a) The frequency of the microwaves must match the resonant frequency of the water molecules.
(b) The frequency of the microwaves has no relation with natural frequency of the water molecules.
(c) Microwaves are heat waves, so always produce heating.
(d) Infrared waves produce heating in a microwave oven.

Answer: a
Explanation:
(a) When frequency of microwave matches with frequency of water molecules i.e., resonant condition. Maximum energy is transferred to water molecules as their K.E. energy.

15. Which radiations are used in treatment of muscle ache?
(a) Infrared
(b) Ultraviolet
(c) Microwave
(d) X-rays

Answer: a
Explanation:
(a) Infrared radiations are used in the treatment of muscle ache.

16. The correct option, if speeds of gamma rays, X-rays and microwave are V_g, V_x and V_m respectively will be.
(a) $V_g > V_x > V_m$
(b) $V_g < V_x < V_m$
(c) $V_g > V_x > V_m$
(d) $V_g = V_x = V_m$

Answer: d
Explanation: (d) All electromagnetic waves travel with the speed of light in space.

17. Waves in decreasing order of their wavelength are
(a) X-rays, infrared rays, visible rays, radio waves
(b) radio waves, visible rays, infrared rays, X-rays.
(c) Radio waves, infrared rays, visible rays, X-rays.
(d) Radio waves, ultraviolet rays, visible rays, X-rays.

Answer: c

18.To which part of the electromagnetic spectrum does a wave of frequency 5×10^{19} Hz belong?

(a) β-rays (b)Y- Rays (c) Radio waves (d) x rays

Ans. Y- Rays

19.To which part of the electromagnetic spectrum does a wave of frequency 3 x 10^{13} Hz belong?

(a) Infra-red waves (b)Y- Rays (c) Radio waves (d) x rays

Ans. Infra-red waves

20.Write the condition under which an electron will move undeflected in the presence of crossed electric and magnetic fields.

(a) v = B/E (b) v = E ε_0 (c) v = B/ε_0 (d) v = E/B

Ans.v = E / B

21. A magnetic field can be produced by

(a) moving charge (b)a changing electric field

(c) none of them (d) both of them

22. Dimensions of $1/\sqrt{u_e \varepsilon_0}$ is

(a)L/T (b) T/L (c) L^2/T^2 (d) T^2/L^2

Answer : a

23. Electromagnetic waves are produced by

(a) a static charge (b)a moving charge (c)an accelerating charge (d) charge less particles

(a) moving charge (b)a changing electric field (c) none of them (d) both of them

24. Name the part of the electromagnetic spectrum whose wave length lies in the range 10^{-10}m.

(a) Micro waves (b) X rays (c) Y rays (d) UV rays

Answer : b

25. A plane electromagnetic wave is incident on a material surface. The wave delivers momentum p and energy E.

(a) p=0,E=0 (b) p≠0 E=0 (c) p≠0,E≠0 (d)p=0,E ≠0

Answer :c

26. Which of the following laws was modified by Maxwell by introducing the displacement current?

(a) Gauss's Law (b) Amperes law

(c) Biot-Savarts law (d) Coulombs law

Answer : b

27. Choose the wave relevant to telecommunication

(a)Ultra Violet (b) Infrared

(c) Micro wave (d) Visible light

Answer: c

28. Which of the following E M Wave has the highest wave length?

(a) X-ray (b) UV rays

(c) Infrared (d) Micro waves

Answer: d

SELF ASSESSEMENT PAPER
SUBJECT: PHYSICS THEORY
ELECTRO MAGNETIC WAVES

Time allowed:3 hours Maximum marks:55

General Instructions:

(i) The Question paper contains 42 questions. All questions are compulsory.

(ii) The question paper is divided in to 6sections: Section A, B,C,D,E ,F and G.

(iii) Section A –Question numbers 1 to 16 are Multiple Choice (MCQ) type questions. Each question carries 1 mark.

(iv)Section B- Question numbers 17 to 19 are Very Short Answer type questions. Each question carries 2 marks.
(v)Section C- Question numbers 20 to 24 are Very Short Answer type questions. Each question carries 1 mark.
(vi)Section D- Question numbers 25 and 26 are Case Based type questions. Each question carries 4 marks.
(vii) Section E -Question numbers 27 and 28 are Short Answer type questions. Each question carries 3 mark.
(viii) Section F-Question numbers 29 to 42 are Multiple Choice (MCQ) type questions. Each question carries 1 mark.
(ix) As per CBSE Curriculum no 5 marks questions for chapter Electro Magnetic Waves.
(x)There is no overall choice. However, an internal choice has been provided in few questions in all sections except Section A and Section F .
(xi) Use of calculator is NOT allowed.

SECTION A

1. The phase difference between electric field E and magnetic field B in an electromagnetic wave propagating along z-axis is

(a) zero (b) π
(c) $\frac{\pi}{2}$ (d) $\frac{\pi}{4}$

2. Wavelength of infrared radiations is

a) shorter (b) longer
(c) infinite (d) zero

3.Light with an energy flux of 20 W/cm² falls on a non-reflecting surface at normal incidence. If the surface has an area of 30 cm^2 the total momentum delivered (for complete absorption) during 30 minutes is

(a) 36 x 10 $^{-5}$ kg m/s

(b) 108 x 10^4 kg m/s

(c) 36 x 10 $^{-4}$ kg m/s

(d) 1.08 x 10^7 kg m/s

4 . If we want to produce electromagnetic waves of wavelength 500 km by an oscillating charge; then frequency of oscillating charge must be

(a)167 Hz

(b) 500 Hz

(c) 600 Hz

(d) 15 Hz

5. A plane electromagnetic wave propagating along x direction can have the following pairs of $\vec{E}$ and $\vec{B}$

(a) E_y, B_x

(b) E_x, B_y

(c) E_y, B_z

(d) E_z, B_x

6. A plane electromagnetic wave of energy U is reflected from the surface. Then the momentum transferred by electromagnetic wave to the surface is

(a) 0

(b)2U/c

(c) U/c

(d)U/2c

7. An electromagnetic wave radiates outwards from a dipole antenna, with E, as the amplitude of its electric field vector E, which transports significant energy from the source falls off as

(a) $1/r^2$

(b)1/r

(c)$1/r^3$

(d) remains constant

8. An electromagnetic wave of frequency 3.0 MHz passes from vacuum into a dielectric medium with relative permittivity = 4 .Then

(a) Wavelength is doubled and frequency remains unchanged

(b) Wavelength is doubled and frequency becomes half

(c) Wavelength is halved and frequency remains unchanged

(d) Wavelength and frequency both remains unchanged

9. The pressure exerted by the electromagnetic wave is called as

(a) Light pressure

(b) Electric pressure

(c) Magnetic pressure

(d) Radiation pressure

10.The part of the electromagnetic spectrum which is detected by human eye is having wavelength as

(a) 380-700 nm

(b) 200-400 nm

(c) 600-400 nm

(d) 700-800 nm

11. The current which comes into play in the region, whenever the electric field and hence the electric flux is changing with time is called

(a) Displacement current

(b) Conduction current

(c) Transient current

(d None of these

12. The magnetic field in a plane electromagnetic wave is given by $B = 2 \times 10^{-7} \sin (0.5 \times 10^{3} x + 1.5 \times 10^{11} t)$.This electromagnetic wave is

(a) a visible light

(b) An infrared wave

(c) a microwave

(d) a radio wave

For questions number 13 to 16, two statements are given one labeled Assertion (A) and the do 16 labeled Reason (R). Select the correct answer to these questions from the codes (A), (B), (C) and (D) as given below:

(A) If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

(B) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(C) If Assertion (A) is true and Reason (R) is false.

(D) If both Assertion (A) and Reason (R) are false.

13. A: In an EM wave the magnitude of the electric field vector is more than the magnitude of the magnetic field vector.
R: Energy of the EM wave is shared equally between the electric and magnetic fields.
14. A: When cooking in microwave ovens, metal containers are used.R: Energy of the microwaves can be easily transferred to the food through metal.
15. A: In an EM wave the magnitude of the electric field vector is more than the magnitude of the magnetic field vector.
R: Energy of the EM wave is shared equally between the electric and magnetic fields.

16. Assertion. Electromagnetic radiations exert pressure.
Reason. Electromagnetic waves carry both momentum and energy.

SECTION B

17. What is meant by displacement current? How is this current different from the conduction current? A capacitor is being charged by a source of emf. Justify the continuity of current circuit.

18. Find the wavelength of electromagnetic waves of frequency $5x10^{19}$ Hz in free space. Give its two applications by identifying the waves.

19. Write the order of frequency range and one use of the following e. m radiations.

i) Microwaves ii) Ultra-violet rays

SECTION C

20. How are radio waves produced? Mention one use of it.

21. Why infrared waves are also called as heat waves?

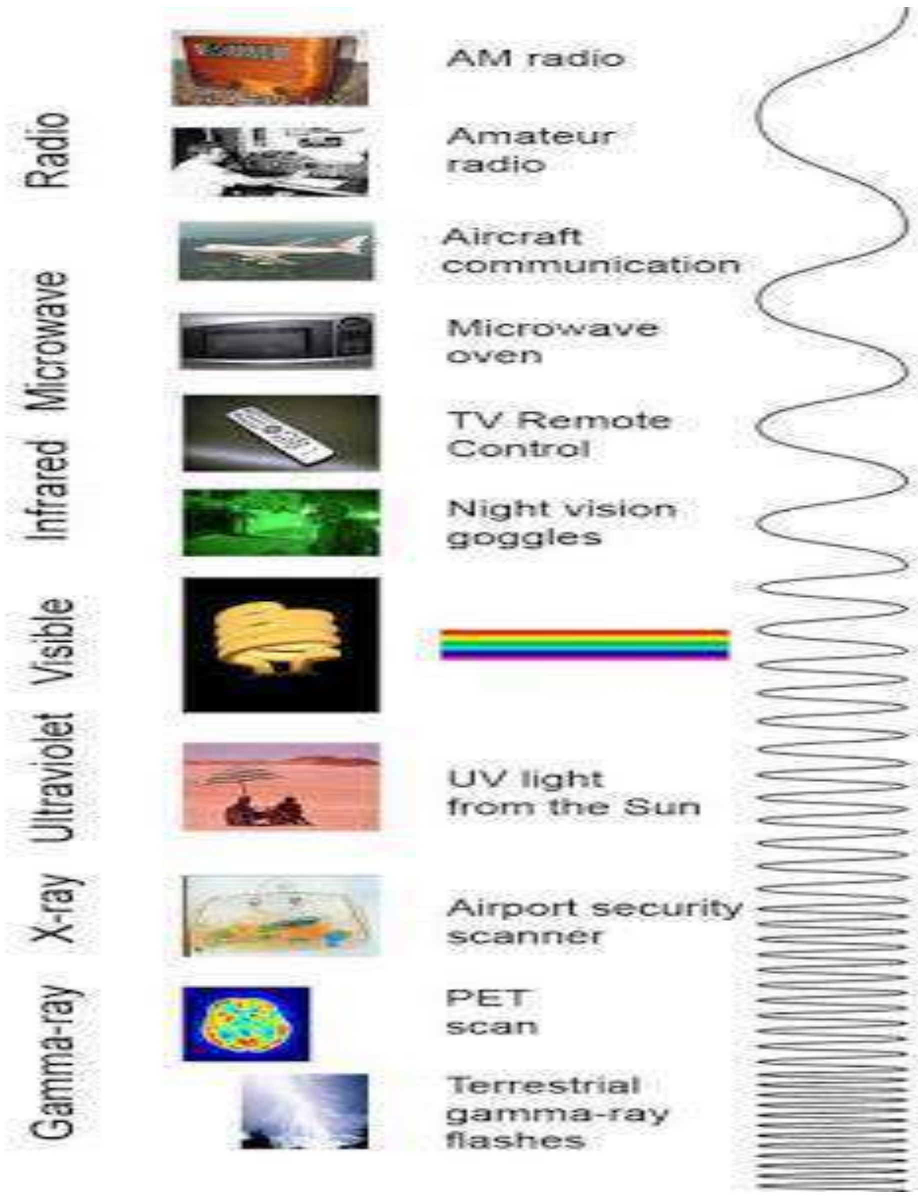
22. State two properties of electromagnetic wave.

23. Find the wavelength of electro- magnetic waves of frequency 4×10^{9} Hz in free space.

24. A plane electromagnetic wave of frequency 25 MHz travels in free space along the x-direction. At a particular point in space and time, $\vec{E} = 6.3\,\hat{j}\ Vm^{-1}$. What is $\vec{B}$ at this point?

SECTION D

25.



1. Name the type of radiation that has used in luggage security checks at airports.

(a)γ-rays

(b) X-rays

(c) Microwaves

(d) Infrared rays

2. Some γ-rays emitted from a radioactive source has wavelength1.0x 10^{-12}m.Calculate the frequency of the γ-rays

(a) 3x 10^{20}Hz

(b) 2x 10^{12}Hz

(c) 2.5x 10^{5}Hz

(d) 3.3x 10^{12} Hz

3. Why does a microwave oven heat up a food item containing water molecules most efficiently?

(a) Microwaves are heat waves, so always produce heating

(b) Infrared waves produce heating in a microwave oven

(c) Energy from the microwaves is transferred efficiently to the kinetic energy of water molecules at their resonant frequency.

(d) The frequency of microwaves has no relation with natural frequency of water molecules.

4. (A) Which of the following electromagnetic radiations have the longest wavelength?

(a) X-rays

(b) γ-rays

(c) Microwaves

(d) Radio waves.

OR

(B). If conducting current is 2A through a circuit the displacement current will be

(a) 1A

(b) 2A

(c) 3A

(d) 4A

26. According to Maxwell, an accelerating charge produces electromagnetic waves. Consider a charge oscillating harmonically with time. This is an example of an accelerating charge. This charge produces an oscillating electric field in its neighborhood. This field, in turn, produces an oscillating magnetic field in its neighborhood. The process continues because the oscillating electric and magnetic fields set as sources of each other. Hence an electromagnetic wave originates from the oscillating charge. The frequency of the electromagnetic wave is equal to the frequency of oscillation of the charge. The energy carried by the wave comes from the source which makes the charge oscillating. An electric dipole is a basic source of electromagnetic waves. An LC-circuit containing inductance L and capacitance C produces electromagnetic waves of frequency, $v = 1/2\pi/LC$.

1. Electromagnetic waves are produced by

(a) Accelerated charged particle

(b) Charge at rest

(c) Charge in uniform motion

(d) None of these.

2. Light can travel in vacuum due to its

(a) Transverse nature

(b) Electromagnetic nature

(c) Longitudinal nature

(d) Both (a) and (c).

3. If a source is transmitting electromagnetic waves of frequency 8.2×10^6 Hz, the wavelength of electro- magnetic wave transmitted from the source is

(a) 36.6 m

(b) 18.8 m

(c) 42.8 m

(d) 58 m

Q4. (A) Wavelength of infrared radiations is

(a) shorter (b) longer
(c) infinite (d) zero

OR

(B) The quantity $1/\sqrt{\mu_0 \varepsilon_0}$ represents
(a) speed of sound
(b) speed of light in vacuum
(c) speed of electromagnetic wave in medium
(d) inverse of speed of light in vacuum

SECTION F

27. Name the parts of electromagnetic spectrum which is

(a) Suitable for radar systems
(b) Used to treat muscular strain
(c) Used as diagnostic tool in medicine.
Write in brief how the above waves can be produced.

(OR)

Identify the type of waves which are produced by the following way and write one application for each.
(a) Radioactive decay of the nucleus
(b) Rapid acceleration and deceleration of electrons in aerials.
(c) Bombarding a metal target by high energy electrons.
(d)

28. An Electromagnetic waves travelling through a medium has electric field vector.

$E_y = 4 \times 10^5 \cos(3.14 \times 10^8 t - 1.57\, x)$ N/C. Here *x* is in *m* and *t*

in s. Then find:

(i) Wavelength

(ii) Frequency

(iii) Direction of propagation

(iv) Speed of wave

(v) Refractive index of medium

(vi) Amplitude of magnetic field vector.

SECTION G

29. Which of the following is the best method for production of infrared waves?
a) Bombardment of metal by high energy electrons
b) Radioactive decay of nucleus
c) Magnetron valve

d) Vibration of atoms and molecule

30. An Electromagnetic wave of wavelength $\lambda = 10^{-3}$ m is used for satellite communication. The wavelength of the electromagnetic wave belongs to
(A)Ultra violet radiation.
(B) Infra-red radiation.
(C) Micro wave radiation.
(D) Radio wave.

31. The Amplitude of the magnetic field of a harmonic electromagnetic wave in vacuum is B_o = = 500 μ T. The amplitude of the electric field part of the wave is
(A)153 x 10^{4} N/C
(B) 150 x 10^{3} N/C
(C) 500 x 10^{-3} N/C
(D) 150 x 10^{-3} N/C

32. In an experiment, a tiny light ball is suspended in a transparent vacuum chamber freely by shinning a Laser beam on it. The Property of Electromagnetic waves exhibited is
(A) Electromagnetic waves exert pressure.
(B) Transverse nature of the radiation.
(C) the wave nature of the Light
(D) Electromagnetic wave can travel in vacuum.

33. Samridhi fractured her leg by chance while playing. Her parents took to a doctor for treatment. The doctor advised that an X-ray of leg is needed to be done for diagnosing the problem. The Property of X-rays make it suitable for use in diagnosing and identifying the fracture in bones is
(A) X-ray has longer wave length.
(B) Can pass through bones.
(C) Cannot pass through bones.
(D) Easily available for diagnosis.

34. The correct option, if speeds of Gamma rays , X rays and microwaves are v_g, v_x and v_m respectively will be
(a) $v_g > v_x > v_m$
(b) $v_g < v_x < v_m$
(c) $v_g > v_m > v_x$
(d) $v_g = v_x = v_m$

35. In the order of increasing frequency, the electromagnetic spectrum may be arranged as
a) Gamma rays ,X rays, visible light ,radio waves

b) X rays, Gamma rays ,visible light, radio waves
c) Radio waves ,visible light, X rays, gamma rays
d) Radio waves, visible light ,Gamma rays, X-rays

36. The energy of photon of electromagnetic radiation of wavelength = 2000 A^0 is :
(A) 1.76 x 10^{-18} J
(B) 0.99 x 10^{-18} J
(C) 0.54 x 10^{-18} J
(D) 0.63 x 10^{-18} J

37. The speed of light in air if an electromagnetic wave is travelling in air whose dielectric constant is k = 1.006, will be :
(A) 3 x 10^8 m/s
(B) 3.88 x 10^8 m/s
(C) 2.5 x 10^8 m/s
(D) 4.6 xl0^8 m/s

38. The electromagnetic radiations used for water purification and eye surgery is
a) Infrared
b) Microwave
c) X-rays
d) None of the above

39. Name the physical quantity which remains same for micro waves of wave length one mm and UV radiations of 1600Å in vacuum?
(A) Speed
(B) Frequency
(C) Wavelength
(D) Refractive Index

40. A plane electromagnetic wave travels in vacuum along z-direction. What can you say about the direction of electric and magnetic field vector?
(A) The direction of electric and magnetic field vectors are along x-axis and y-axis respectively.
(B) The direction of electric and magnetic field vectors are along z-axis and y-axis respectively.
(C) The direction of electric and magnetic field vectors are along x-axis and z-axis respectively.
(D) The direction of electric and magnetic field vectors are along y-axis and z-axis respectively

41. The electromagnetic wave which lies in the wavelength range of 0.1m to 1mm is
(A) Radio wave
(B) Microwave
(C) Infrared
(D)Visible light

42. A plane electromagnetic wave of frequency 25 MHz travels in free space along the x direction. At a particular point in space and time the electric vector =5.2 V/m $\hat{j}$. The magnetic field B at this point is
(A) 2.1 x 10^{-8} T
(B)3.2 x 10^{-8} T
(C) 1.7 x 10^{-8} T
(D) 4.1 x 10^{-8} T

ANSWERS OF SELF ASSESSMENT PAPER

ELECTROMAGNETIC WAVES

1. (a) ZERO
2. (b) longer
3. (c) 36 x 10^{-4} kg m/s
4. (c) 600 Hz
5. (c) E_y, B_z
6. (b)2U/c
7. (b)1/r
8. (c) wavelength is halved and frequency remains unchanged
9. (d) Radiation pressure
10. (a) 380-700 nm
11. (a) Displacement current
12. (c) a microwave
13. (b)
14. (d)
15. (b)
16. (a)

17. Displacement current is the current which arises due to rate of change of electric field. Displacement current is due to varying electric field. Conduction current is due to motion of electrons in the presence of electric field. When the capacitor is being charged by a source of emf, the electric field between the plates of capacitor changes with time. It produces a displacement current is whose magnitude is equal to conduction current i,. Therefore the current is continuous.

18. $\lambda = \frac{c}{\nu} = \frac{3x10^8}{5x10^{19}} = 6\ x\ 10^{-12}$ m = 0.06 A° (X rays)

X rays are used as diagnostic tool and to study crystal structure.

19. (i) 10^9 to 10^{12}Hz (ii)10^{16}to10Hz
20. Oscillating circuits, wireless communication like radio broadcasting, televisions, cellular phones.
21. Infrared radiations get readily absorbed by water molecules in most materials. This increases their thermal motion and heats them up. That is why infrared radiations are often referred to as heat waves.
22. (i) The electromagnetic waves are produced by accelerated charges and do not require any material medium for their propagation.

(ii) The directions of oscillations of Electric and Magnetic fields are perpendicular to each other as well as perpendicular to the direction of propagation of the wave. So the electromagnetic waves are transverse in nature.

23. Wavelength, λ=c/ ν= 0.075 m
24. E/c=B=2.18x10^{-8} T
25. (1) (d) Infrared rays

(2) (a) 3x 10^{20}Hz

(3) (c) Energy from the microwaves is transferred efficiently to the kinetic energy of water molecules at their resonant frequency.

(4) (A) (d) Radio waves

OR

(B) (b) 2A

26. (1) (a) Accelerated charged particle

(2) (b) Electromagnetic nature

(3) (a) 36.6 m

(4) (A) (b) longer

OR

(B) (a) speed of sound

27. (i) Microwave Production: klystron, magnetron, gun diode.

ii.) IR Production: Hot bodies, vibrations of atoms and molecules.

iii.) X-Ray Production: Bombarding high energy electrons on metal targets, X-Ray tube.

(Or)

i.) Gamma rays- Treatment of tumors.

ii.) Radio waves- Radio and TV communication.

ii.) X-Ray- Study of Crystals.

28. $E_Y = 4x10^5 \cos(3.14 \times 10^8 t - 1.57\, x)$ N/C
    (vii) $\nu = 5x10^7$Hz
    (viii) $\lambda = 4$m
    (ix) Along y axis
    (x) $V = 3x10^8$m/s
    (xi) $\mu = 1$
    (xii) $B_{0} = 1.34X10^{-3}$T
29. (d) Vibration of atoms and molecules
30. (C) Micro wave radiation.
31. (B) 150 x 10^3 N/C
32. (A) Electromagnetic waves exert pressure.
33. (C) Cannot pass through bones.
34. (d) $v_g = v_x = v_m$
35. (c) Radio waves ,visible light, X rays, gamma rays
36. (B) 0.99 x 10^{-18} J
37. (A) 3 x 10^8 m/s
38. d) None of the above
39. (A) Speed
40. (A) The direction of electric and magnetic field vectors are along x-axis and y-axis respectively.
41. (B) Microwave
42. (C) 1.7 x 10^{-8} T

****

9. RAY OPTICS AND OPTICAL INSTRUMENTS

SYLLABUS: **Ray Optics:** Reflection of light, spherical mirrors, mirror formula, refraction of light, total internal reflection and optical fibers, refraction at spherical surfaces, lenses, thin lens formula, lens maker's formula, magnification, power of a lens, combination of thin lenses in contact, refraction of light through a prism.
Optical instruments: Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers.

GIST

1. Reflection of Light

Reflection. When light travelling in a medium strikes a reflecting surface, it goes back into the same medium obeying certain laws. This phenomenon is known as reflection of light.

Laws of reflection. 1. The incident ray, the normal to the reflecting surface at the point of incidence and the reflected ray all lie in the same plane.
2. The angle of incidence (i) is always equal to the angle of reflection (r).

Spherical mirror. The portion of a reflecting surface, which forms part of a sphere, is called a spherical mirror.

Concave spherical mirror. A spherical mirror, whose reflecting surface is towards the centre of the sphere, of which the mirror forms a part is called concave spherical mirror.

Convex spherical mirror. A spherical mirror, whose reflecting surface is away from the centre of the sphere of which the mirror forms a part is called convex spherical mirror.

Relation between f and R: $f = \frac{R}{2}$

According to new cartesian sign conventions, both f and R, are taken as negative for a concave mirror and positive for a convex mirror.

Mirror formula: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

Where **u** and **v** denote the object and image distances from the pole of the mirror. According to new Cartesian sign conventions, the distances of the real objects and real images (both lie in front of the mirror) are taken as negative, while those of virtual objects and virtual images (both lie behind the mirror) are taken as positive.

Linear magnification. The ratio of the size of the image (formed by the mirror) to the size of the object is called linear magnification produced by the mirror.

Mathematically- **m** = $\frac{I}{O}$= $\frac{-v}{u}$= =$\frac{f}{f-u}$= $\frac{f-v}{f}$

According to new Cartesian sign conventions, when the image formed is real (inverted), the magnification produced by the mirror is negative and when the image formed is virtual (erect), the magnification produced by the mirror is positive.

Spherical aberration. The inability of a spherical mirror of large aperture to bring all the rays in a wide beam of light falling on it to focus at a single point is called spherical aberration.

2. Refraction of Light

Refraction. The phenomenon of change in the path of light as it goes from one medium to another is called refraction.

Laws of refraction.

1. The incident ray, the normal to the refracting surface at the point of incidence and the refracted ray all lie in the same plane.
2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for any two- given media. It is called Snell's law.

Mathematically- $\mathbf{sin}\boldsymbol{i}/\mathbf{sin}\boldsymbol{r}$= μ_b^a

Absolute retractive index ($\boldsymbol{\mu}$).1 he absolute refractive index of a medium is defined as the ratio of the velocity of light in vacuum (c) to the velocity of light in that medium (v).

Real and apparent depth. When an object is placed in an optically denser medium, the apparent depth of the object is always less than its real depth.

Mathematically-:$\boldsymbol{Realdepth}/\boldsymbol{Apparentdepth}$ =μ_b^a

Total internal reflection. The phenomenon of reflection of light that takes place when a ray of light travelling in a denser medium gets incident at the interface of the two media at an angle greater than the critical angle for that pair of media.

Mathematically μ_b^a**=** $\mathbf{1}/\boldsymbol{sinC}$

μ_b^a is refractive index of the denser medium b w.r.t. the rarer medium a and C is the critical angle.

Spherical refracting surface. The portion of a refracting medium, whose curved surface forms the part of a sphere, is called spherical refracting surface.

When object is situated in the rarer medium, the relation is as follows

- $\boldsymbol{\mu}\mathbf{1}/\boldsymbol{u}$ + $\boldsymbol{\mu}_{2}/\boldsymbol{v}$ = $(\boldsymbol{\mu}\mathbf{2}-\boldsymbol{\mu}\mathbf{1})/\boldsymbol{R}$

When the object is situated in denser medium, the relation is as follows

- $\boldsymbol{\mu}/\boldsymbol{u}$ + $\boldsymbol{\mu}\mathbf{1}/\boldsymbol{v}$ =$(\boldsymbol{\mu}\mathbf{1}-\boldsymbol{\mu})/\boldsymbol{R}$

Power of spherical refracting surface: P= $(\boldsymbol{\mu}\mathbf{2}-\boldsymbol{\mu}\mathbf{1})/\boldsymbol{R}$

Here, R is measured in meter.

Lens maker's formula. The relation connecting the focal length of the lens with the radii of curvature of its two surfaces and the refractive index of the material of the lens is called lens maker's formula.

Mathematically- $\mathbf{1/f = (\mu - 1)(1/R1 - 1/R2)}$

The focal length of a convex lens is taken as positive, while that of concave lens is taken as negative.

Lens formula/equation. The relation between the focal length, the object and image distances is called lens equation.

Mathematically- $\mathbf{1/v - 1/u = 1/f}$

Linear magnification. The ratio of the size of the image (formed by the lens) to the size of the object is called linear magnification produced by the lens.

Mathematically- **m =** $\boldsymbol{I/O = -v/u = f/f + u = -v/f}$

Power of a lens. It is defined as the reciprocal of the focal length of the lens in metre.

Mathematically **P =** $\mathbf{1/f = (\mu - 1)(1/R1 - 1/R2)}$

Two thin lenses placed in contact. When two lenses of focal lengths $f1$ and $f2$are placed in contact, the focal length of the combination is given by $\mathbf{1/f = 1/f1 + 1/f2}$

Power of the equivalent lens: P =P1 +P2

Magnification produced by equivalent lens: m = $\boldsymbol{m_1 x m_2}$

Spherical aberration. The inability of a lens of large aperture to bring all the rays in a wide beam of light falling on it to focus at a single point is called spherical aberration.

DISPERSION OF LIGHT

Refraction through a prism. A prism is the portion of a transparent refracting medium bound by two plane surfaces meeting each other along a straight edge. When a ray of light is incident on one face of a prism having angle of prism equal to A at an angle of incidence i, it suffers successive refractions at the two surfaces (angles of refraction at the two surfaces are r, and ry respectively) and then emerges out of it making an angle of emergence equal to e. Due to refraction at the two surfaces, the incident ray deviates from its path through an angle 6, called angle of deviation.

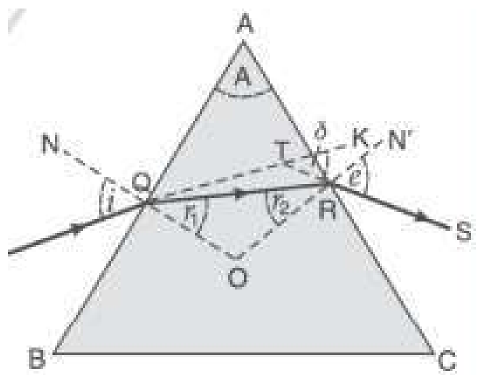
Mathematically-

A = $r_1 + r_2$

A + δ = I + e

$\mu = \sin((A+\delta m)/2)/\sin A/2$ (when the prism is placed in minimum deviation position)

δ=A (μ-1) (when angle of prism is small)



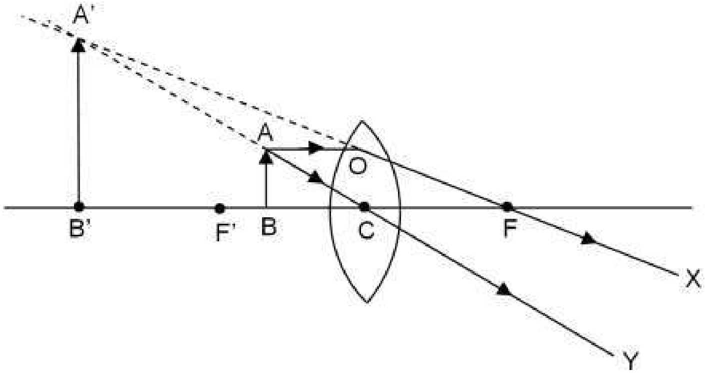
Dispersion. The phenomenon of splitting up of white light into its constituent colours is called dispersion.

Spectrum. The band of seven colours obtained on the screen is called spectrum.Pure spectrum. A spectrum, in which the constituent colours have sharp boundaries and are distinctly visible, is called the pure spectrum.

Chromatic aberration. The inability of a lens to bring the light of different colours to focus at a single point is called chromatic aberration.

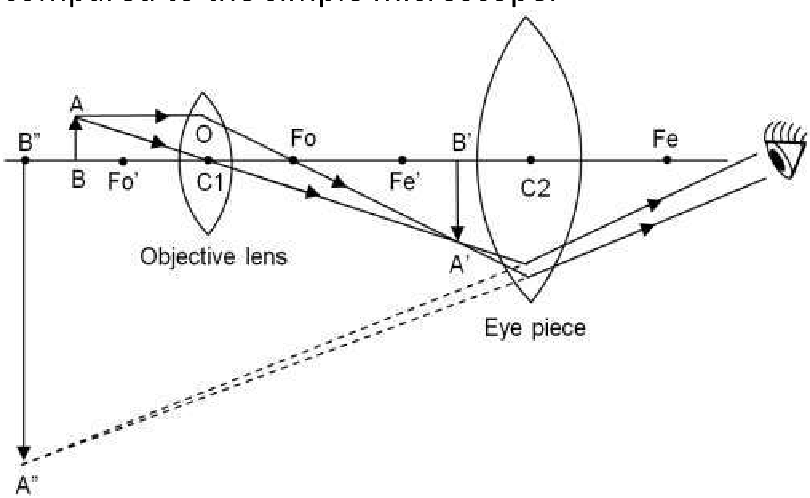
Rayleigh's law of scattering. It states that the intensity of the light of wavelength A in the scattered light varies inversely as the fourth power of its wavelength. **I $\alpha 1/\lambda 4$**

Simple microscope. A convex lens of small focal length is called a simple microscope or a magnifying glass. The magnifying power of a microscope is defined as the ratio of the angle subtended by the image at the eye to the angle subtended by the object seen directly, when both lie at the least distance of distinct vision.



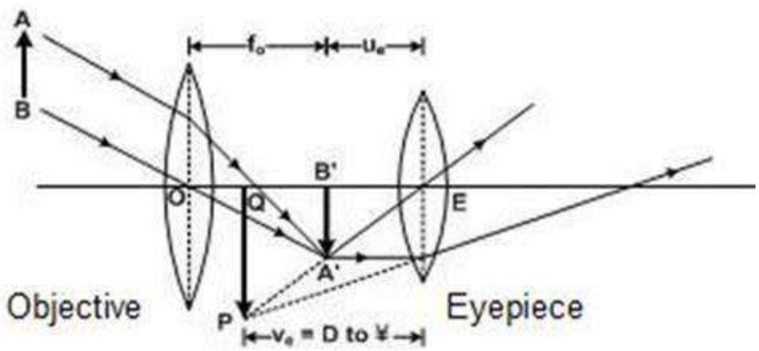
M = 1 + $\boldsymbol{D/f}$

Compound microscope. A compound microscope is a two-lens system (object lens and eye lens of focal lengths f, and f,). Its magnifying power is very large, as compared to the simple microscope.



Mathematically- **M =** $\boldsymbol{vo/uo\ (1+ D/fe) = - Lofo\ (1+ D/fe)}$

Astronomical telescope. It is a two-lens system and is used to observe distant heavenly objects. It is called refracting type astronomical telescope.
Normal adjustment. When the final image is formed at infinity, the telescope is said to be in normal adjustment. **M = -** $f o/f e$



When the final image is formed at the least distance of distinct vision, magnifying power of the telescope,
M = - $\boldsymbol{fo}/\boldsymbol{fe}\ (\mathbf{1}+ \boldsymbol{fe}/\boldsymbol{D})$

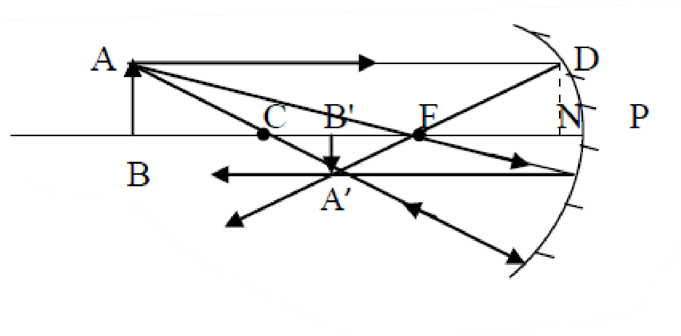
IMPORTANT 3 and 5 MARKS DERIVATIONS

1. Derive the mirror formula for concave mirror.

Let, P = pole and F=principal focus. Object AB is place beyond C and the real image formed by it is A'B' between F and C.

From similar triangles A'B'C and ABC

$\frac{AB}{A'B'} = \frac{BC}{B'C}$.... (1)



From similar triangles A'B'F and DNF

$\frac{DN}{A'B'} = \frac{FN}{B'F}Or\frac{AB}{A'B'} = \frac{FN}{B'F}$..... (2)

From (1) and (2)

$\frac{BC}{B'C} = \frac{FN}{B'F} = \frac{FP}{B'F}$=

Or,$\frac{PB-PC}{PC-PB'} = \frac{FP}{PB'-PF}$(∵ the aperture is small, FN=FP)

Using sign convention, the above equation can be written as

$$\frac{-u-2f}{-2f-(-v)} = \frac{-f}{-v-(-f)}$$

Or,$2f^2 - vf = -uf + 2f^2 - 2fv$

Or, f v + u f = u v

Dividing both sides by uvf, we get

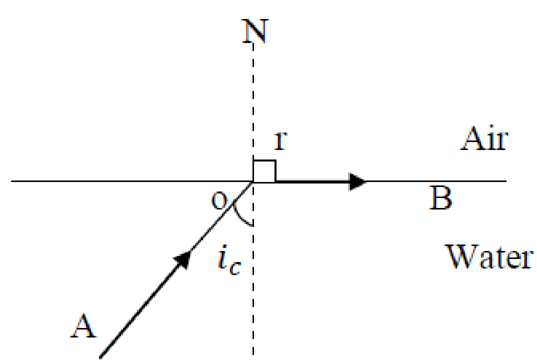
$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

which is the required formula.

2. Show that refractive index = real depth/apparent depth.

'O' is the object lying at the bottom of a tank containing water. A B O' is its virtual image.

From Snell's law, $n_a^w = \frac{\sin i}{\sin r} = \frac{AB/BO}{AB/BO'} = \frac{BO'}{BO}$



Since the aperture of the eye is very small, the two rays

from A and B will enter the eye, only if B lies very close i

to A. Then, BO'≃AO' and BO≃AO.

$$n_w^a = 1/\, n_a^w = \frac{AO}{AO'} = \frac{Realdepth}{Apparentdepth}$$

3. Derive the relation between critical angle and refractive index of the medium.

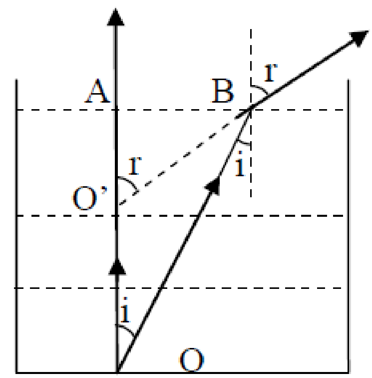
When a ray of light passes through denser (water to a rarer (air) medium, then, according to Snell's N law,

$n_a^w = \frac{\sin i}{\sin r}$

when, i = i_e , r = 90°

$\therefore n_a^w = \frac{\sin i}{\sin r} = \frac{\sin i_c}{\sin 90^0} = \sin i_c$

Or, $n_w^a = \frac{1}{\sin i_c}$



4. Obtain lens formula for a thin convex lens when the image is real.

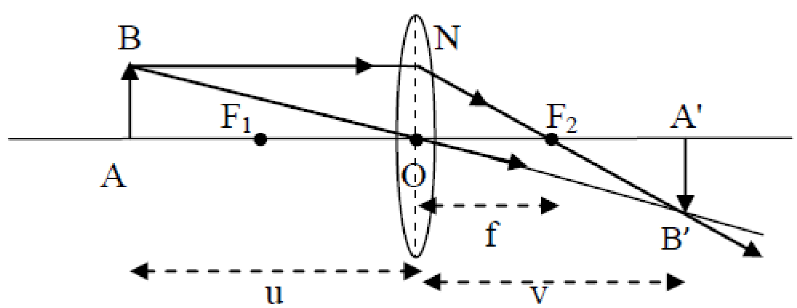
Let, O = optic centre, F_1 and F_2 be the principal focii. Object AB is place beyond F_2 and the real image formed by it is A'B' beyond F_2.

From similar triangles A'B' F_2 and ONF_2

$\frac{A'B'}{ON} = \frac{F2A'}{OF2} or \frac{A'B'}{AB} = \frac{F2A'}{OF2}$ ... ...(1)

From similar triangles A'B'O and ABO

$\frac{A'B'}{AB} = \frac{OA'}{OA}$….. (2)



From (1) and (2)

.. $\frac{F2A'}{OF2} = \frac{OA'}{OA}$

Or, $\frac{OA'-OF2}{OF2} = \frac{OA'}{OA}$

Using sign convention, the above equation can be written as

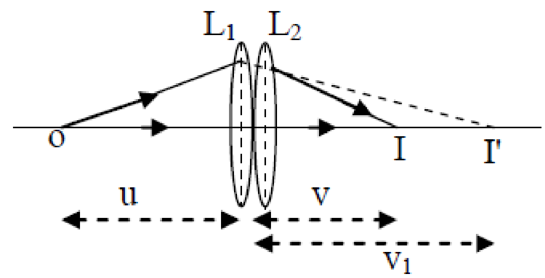
.. $\frac{v-f}{f} = \frac{v}{-u}$

On cross-multiplying, we get, v f = - u v + u f

Dividing both sides by uvf, we get, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ which is the required formula.

5. Two thin convex lenses of focal lengths f1 and f2 are kept in contact with each other coaxially. Deduce an expression for the effective focal length of the combination.

Let a point object ‘O’ is placed on the common principal axis. f1 and f2 be the focal lengths of lenses L1 and L2 .



In the absence of L2, the image formed by L1 will be at I1.

So, $\frac{1}{f1} = \frac{1}{v1} - \frac{1}{u}$ … (1)

In the presence of second lens L2, I1 will be the virtual

object and the final image will be formed at I.

So, $\frac{1}{f2} = \frac{1}{v} - \frac{1}{v1}$… (2)

Adding equations (1) and (2), we get v1

$\frac{1}{f1} + \frac{1}{f2} = \frac{1}{v} - \frac{1}{u}$… (3)

Now, if the lens combination is replaced by a single lens of focal length ‘ f ’ , then

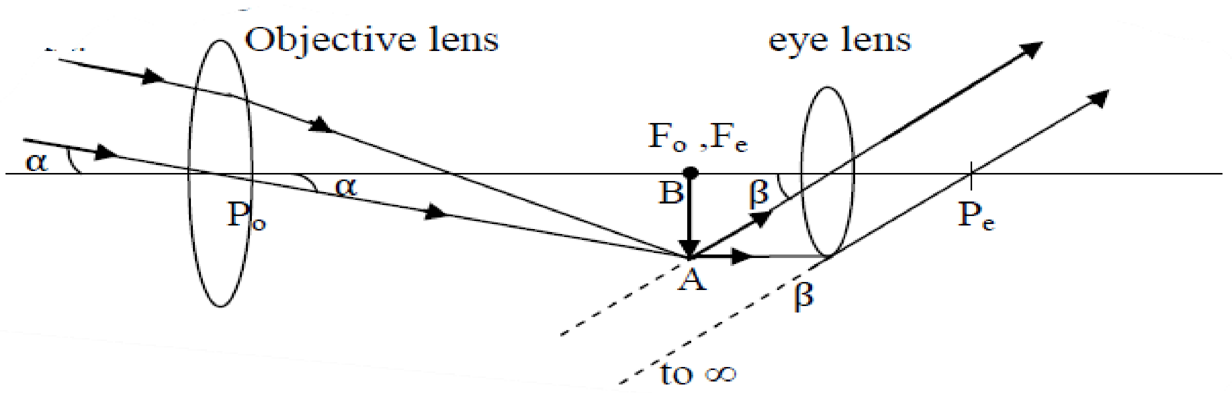
$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$… (4)

From equations (3) and (4), $\frac{1}{f} = \frac{1}{f1} + \frac{1}{f2}$This is the required relation.

6. What is meant by 'normal adjustment' in case of an astronomical telescope? With the help of a neat and labeled ray diagram, obtain an expression for the magnifying power of the telescope in (i) normal adjustment (ii)distance of distinct vision

(i) Definition: - When the final image is formed by the telescope at infinity, then the telescope is said to be in normal adjustment.

Focal length of the objective is much greater than that of the eyepiece. Aperture of the



objective is also large to allow more light to pass throughtit.

Magnifying power $= \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha} = \frac{\frac{h}{f_e}}{\frac{h}{f_o}} = \frac{f_o}{f_e}$which is the required relation.

(ii) When final image is formed at least distance of distinct vision.

$m = -\frac{f_o}{f_e}\left(1 + \frac{f_o}{D}\right)$and $L = f_o + |u_e|$

7. Derive an expression for the refractive index of the material of prism.

Diagram shows section ABC of a prism taken by a vertical plane perpendicular to the edge. BC is base of the prism and AB & AC are its two refracting surfaces. PQ is incident ray, QR is refracted ray and RS is emergent ray.

In quadrilateral AQN_2R, $\angle AQN_2 + \angle ARN_2 = 180^o$ …. (1)

$\angle A + \angle QN_2R = 180^o$

In Δ QRN2, $\angle r_1 + \angle r_2 + \angle QN_2R = 180^o$ …. (2)

From equations (1) and (2), $\angle A = \angle r_1 + \angle r_2$….. (3)

In Δ XQR, $\angle XQR = \angle i - \angle r$ & $\angle XRQ = \angle e - \angle r_2$

Since exterior $\angle TXR$ = interior $\angle XQR$ + interior $\angle XRQ$ Q R

$\therefore \angle \delta = (\angle i - \angle r_1) + (\angle e - \angle r_2)$ r_1 r2

$= (\angle i + \angle e) \angle A$

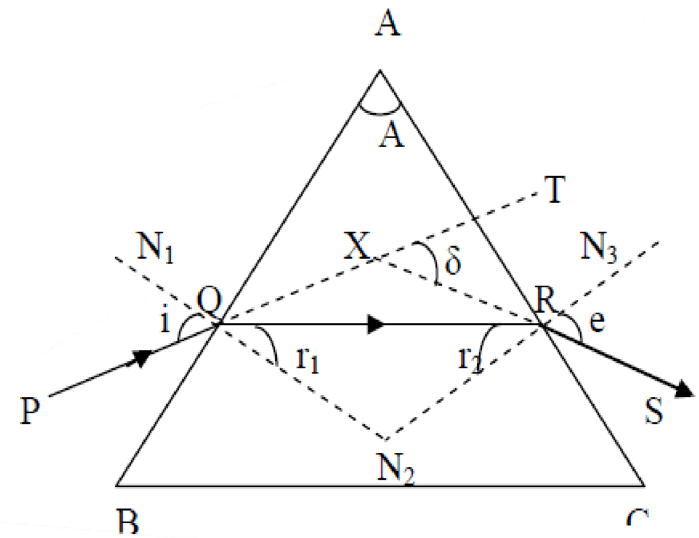
Or,$\angle A + \angle \delta = \angle i + \angle e$ …. (4)

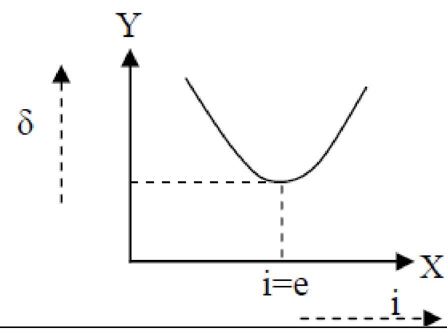
A graph between $\angle i$ and $\angle\delta$ shows that, B C

$\angle\delta$ is more when $\angle i$ is either small or large.

∠δ is minimum for some intermediate value of ∠i.
From graph, when $\angle\delta = \angle\delta_m$, then ∠i = ∠e & $\angle r_1 = \angle r_2$
Now, from equations (3) and (4), we get, δ_m
∠A = 2 r ⇒ r = ∠A/2 & $\angle A + \angle\delta_m = \angle i + \angle i \Rightarrow \angle i = \frac{<A+\delta_m}{2}$

From Snell's law, $n = \frac{\sin(\frac{<A+\delta m}{2})}{\sin(\frac{<A}{2})}$ This is the required expression.





8. With the help of a ray diagram, show the formation of image of a point object by refraction of light at a convex spherical (convex) surface separating two media of refractive indices n1 and n2 (n2> n1) respectively. Using this diagram, derive the relation $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ Also write the sign conventions used and assumptions.

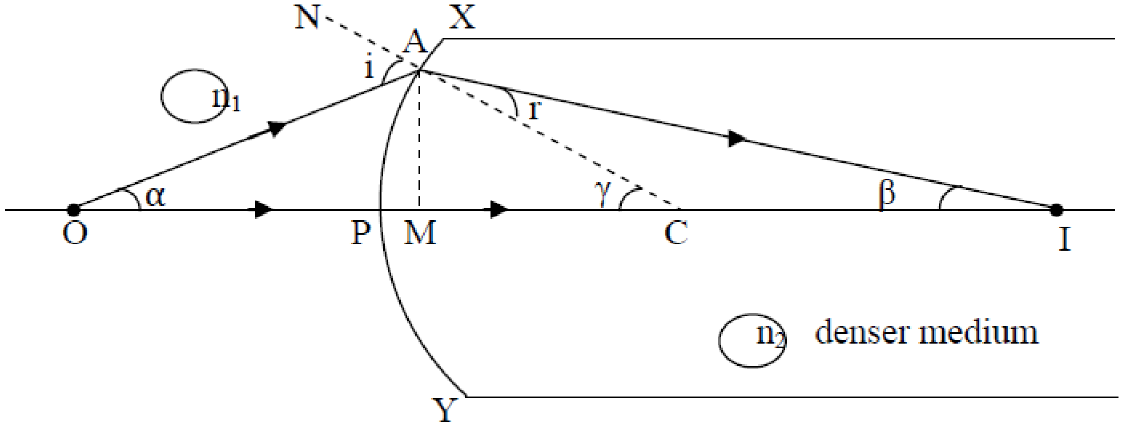
Sign Convention used:-

a) All the distances are measured from the pole.
b) The distances measured in the direction of incident light are taken as positive.
c) The distances measured in the direction opposite to the direction of light are taken as negative.

Assumptions:-

a) The aperture of the spherical refracting surface is small.
b) The object is a point object and lies on the principal axis.
c) The incident ray, the refracted ray and the normal to the spherical surface make small angles with the principal axis.

Let XPY = convex spherical refracting surface
O = point object in rarer medium
I = real image in denser medium



From ray diagram, from ΔAOC, i = α + γ
From ΔAIC, γ = r + β ⇒ r = γ – β
According to Snell's law, $\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$ ⇒ $n_1 \sin i = n_2 \sin r$
Since the angles are small, ∴ n_1 i = n_2 r or, = $n_1 \tan i = n_2 \tan r$
Substituting for & , in the above equation, we get
$n_1 \tan(\alpha + \gamma) = n_2 \tan(\gamma - \beta)$
Or, $n_1\{\tan\alpha + \tan\gamma\} = n_2\{\tan\gamma + \tan\beta\}$
Or, $n_1\{AM/PO + AM/MC\} = n_2\{AM/MC – AM/MI\}$
Since the aperture is small, ∴ MC = PC, MI = PI
∴ $\{n_1/PO + n_1/PC\} = \{n_2/PC – n_2/PI\}$
According to sign convention, PO = -u, PC = R, PI = v
∴ $\{\frac{n_1}{-u} + \frac{n_1}{R}\} = \{\frac{n_2}{R} - \frac{n_2}{v}\}$
Or, $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ This is the required equation.

9. Derive lens maker's formula.

It is a relation between the focal length of a lens to the refractive index of its material and the radii of curvature of its two surfaces. It is so called because it is used by lens manufacturers to make lenses of particular power from the glass of give refractive index.

Assumptions:

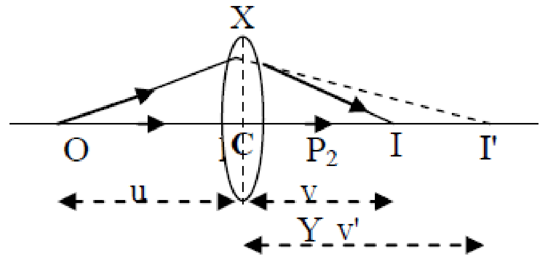
a) The lens is thin so that the distance measured from the poles of the two surfaces of the lens can be taken to be equal to the distances measured from the optical centre.
b) The object is a point object which is situated on the principal axis.
c) The aperture of the lens is small.
d) The incident as well as refracted ray makes small angle with the principal axis.

Consider a thin convex lens made of a material of absolute refractive index n_2 placed in a rarer medium of absolute refractive index n_1. Also, n = n_2/n_1 be the refractive index of the material of the lens w.r.t. the medium surrounding it. R_1 and R_2 are the radii of curvature of surfaces XP_1Y and XP_2Y respectively.

For refraction at surface XP_1Y:

'O' is the object and I' is its real image. Using the formula $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ we get,

$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R1}$........ (i)



For refraction at surface XP_2Y :

I' is the virtual object and I is its real image (final image). Using the formula $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$

we get, $\frac{n_1}{v} - \frac{n_2}{v'} = \frac{n_1 - n_2}{R2}$ .... (ii)

Adding equations (i) and (ii), we get

$n_1(\frac{1}{v} - \frac{1}{u}) = (n_2 - n_1)\{\frac{1}{R1} - \frac{1}{R2}\}$

Or, $\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2 - n_1}{n_1}\right)\left\{\frac{1}{R1} - \frac{1}{R2}\right\}$

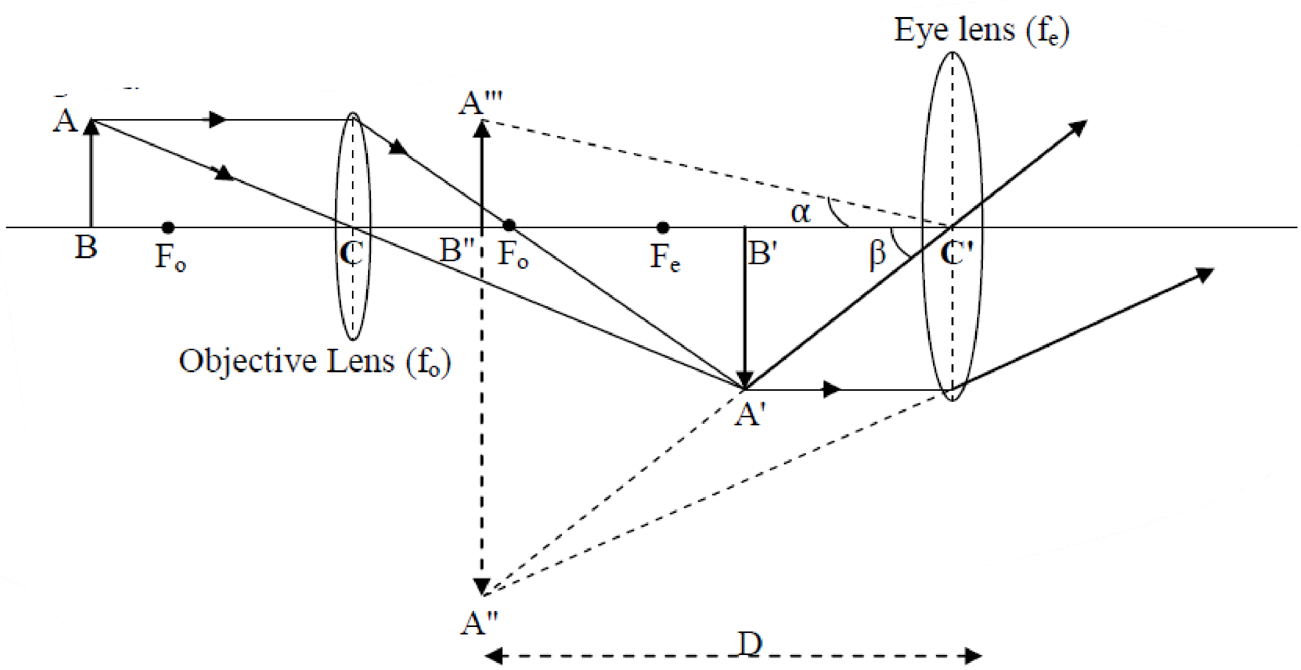
Or, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left\{\frac{1}{R1} - \frac{1}{R2}\right\}$

Or, $\mathbf{P} = \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = (n - 1)\left\{\frac{1}{R1} - \frac{1}{R2}\right\}$ This is called lens maker's formula.

10. With the help of a neat and labeled ray diagram, explain the working of a compound microscope. Also derive an expression for its magnifying power.

A compound microscope is used to see very small objects. Eye lens (fe)

Ray diagram



Working: - A compound microscope consists of two converging lenses (fe>fo). The object to be magnified is placed just beyond the focus of the objective lens which forms a real, inverted image. This image is either at the focus or within the focus of the eye lens.

The eye lens acts as a simple microscope and forms final image that is virtual, erect and magnified (at D).

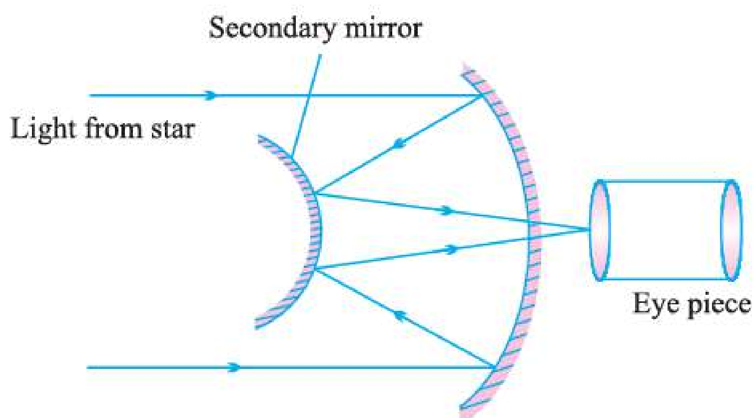
Expression for magnifying power (M):

$$M = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha} = \frac{\frac{A''B''}{C'B''}}{\frac{A'''B''}{C'B''}} = \frac{A''B''}{A'''B''} = \left\{\frac{A''B''}{A'B'}\right\}\left\{\frac{A'B'}{A'''B''}\right\} = \left\{\frac{A''B''}{A'B'}\right\}\left\{\frac{A'B'}{AB}\right\} = M_e M_o = M_o M_e$$

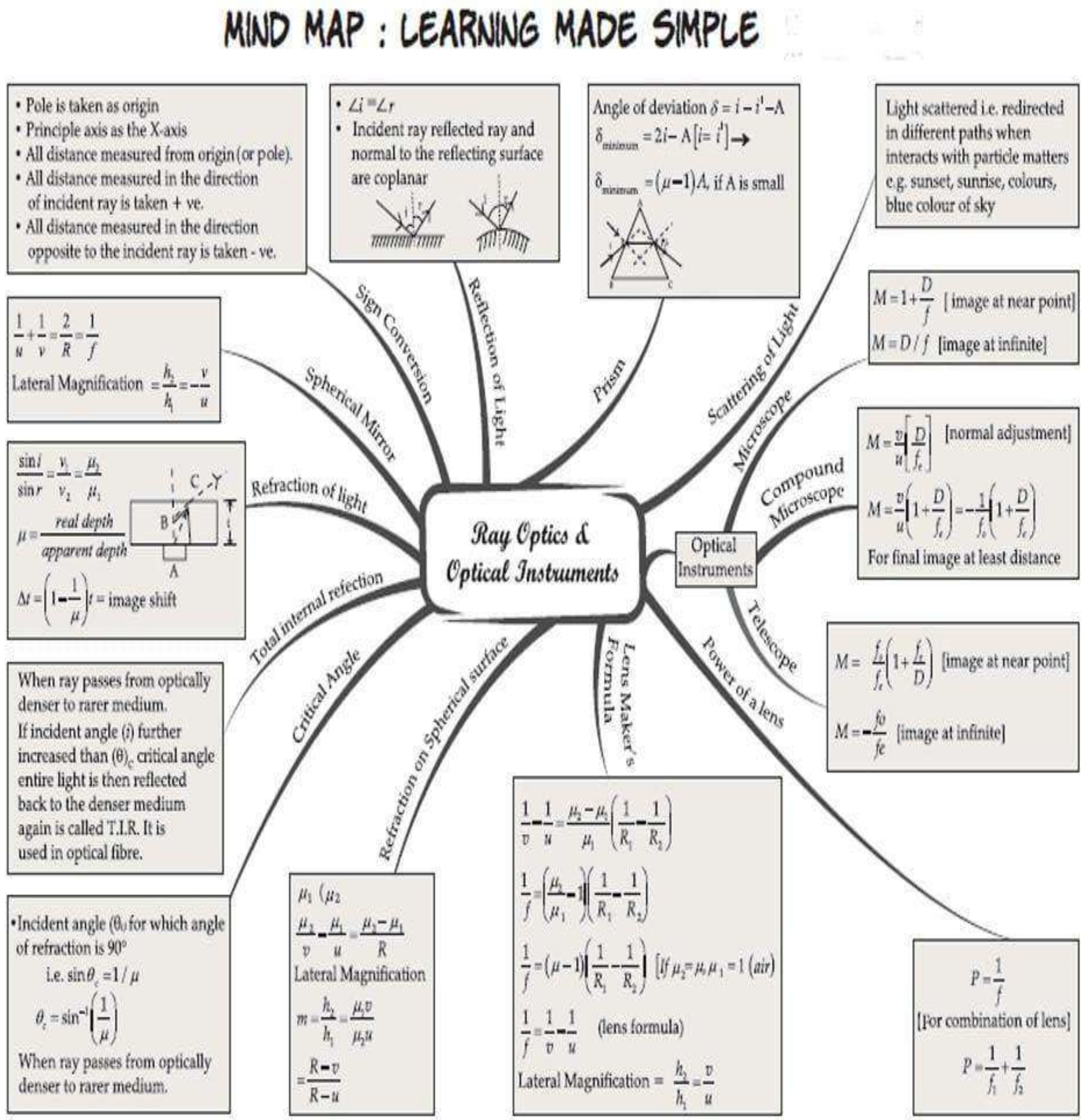
But, $M_o = -\frac{v_o}{u_0}$ *and* $M_e = 1 + \frac{D}{f_e}$

$\therefore \mathbf{M} = -\frac{\boldsymbol{v_o}}{\boldsymbol{u_o}}\left\{\mathbf{1} + \frac{\boldsymbol{D}}{\boldsymbol{f_e}}\right\}$ This is the required relation.

11. **Cassegrain telescope**



RAY OPTICS


MIND MAP : LEARNING MADE SIMPLE
Ray Optics & Optical Instruments
Sign Conversion
• Pole is taken as origin
• Principle axis as the X-axis
• All distance measured from origin (or pole).
• All distance measured in the direction of incident ray is taken + ve.
• All distance measured in the direction opposite to the incident ray is taken - ve.
Reflection of Light
• $\angle i = \angle r$
• Incident ray reflected ray and normal to the reflecting surface are coplanar
Prism
Angle of deviation $\delta = i - i' - A$
$\delta_{minimum} = 2i - A\ [i = i'] \rightarrow$
$\delta_{minimum} = (\mu - 1)A$, if A is small
Scattering of Light
Light scattered i.e. redirected in different paths when interacts with particle matters e.g. sunset, sunrise, colours, blue colour of sky
Spherical Mirror
$\frac{1}{u} + \frac{1}{v} = \frac{2}{R} = \frac{1}{f}$
Lateral Magnification $= \frac{h_2}{h_1} = -\frac{v}{u}$
Refraction of light
$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\mu_2}{\mu_1}$
$\mu = \frac{real\ depth}{apparent\ depth}$
$\Delta t = \left(1 - \frac{1}{\mu}\right)t$ = image shift
Optical Instruments
Microscope
$M = 1 + \frac{D}{f}$ [image at near point]
$M = D/f$ [image at infinite]
Compound Microscope
$M = \frac{v}{u}\left[\frac{D}{f_e}\right]$ [normal adjustment]
$M = \frac{v}{u}\left(1 + \frac{D}{f_e}\right) = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$
For final image at least distance
Telescope
$M = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$ [image at near point]
$M = -\frac{fo}{fe}$ [image at infinite]
Total internal refection
When ray passes from optically denser to rarer medium. If incident angle (i) further increased than $(\theta)_c$ critical angle entire light is then reflected back to the denser medium again is called T.I.R. It is used in optical fibre.
Critical Angle
•Incident angle (θ) for which angle of refraction is 90°
i.e. $\sin\theta_c = 1/\mu$
$\theta_c = \sin^{-1}\left(\frac{1}{\mu}\right)$
When ray passes from optically denser to rarer medium.
Refraction on Spherical surface
$\mu_1 (\mu_2$
$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$
Lateral Magnification
$m = \frac{h_2}{h_1} = \frac{\mu_1 v}{\mu_2 u}$
$= \frac{R - v}{R - u}$
Lens Maker's Formula
$\frac{1}{v} - \frac{1}{u} = \frac{\mu_2 - \mu_1}{\mu_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
$\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ [If $\mu_2 = \mu, \mu_1 = 1$ (air)
$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ (lens formula)
Lateral Magnification $= \frac{h_2}{h_1} = \frac{v}{u}$
Power of a lens
$P = \frac{1}{f}$
[For combination of lens]
$P = \frac{1}{f_1} + \frac{1}{f_2}$

1. Refractive index	$n_{21} = \frac{\sin i}{\sin r} = \frac{n_2}{n_1}$ $n_{21} = \frac{Realdepth}{Apparentdepth} = \frac{t}{t_{app}}$
2. Apparent shift	$x = t - \frac{t}{n}$
3. Relation between critical angle and refractive index	$n_{12} = \frac{1}{\sin C}$
4. Refraction at spherical surface	$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$
5. Lens formula	$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$
6. Lens makers formula	$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
7. Magnification	$(m) = I/O = v/u$
8. Power of lens	$P = \frac{1}{f}$
9. Combination of lens	$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ $P = P_1 + P_2$ $m = m_1 \times m_2$
10. Relation between i, e and δ_m	$\delta_m = 2i - A$
11. Prism formula	$n_{21} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$
12. Magnifying power of simple microscope	(final image at D) $m = 1 + D/f$
	(final image at infinity) $m = D/f$

COMPETENCY BASED QUESTIONS

1. A glass lens is immersed in water. What will be the effect on the power of lens?
(A) increase (B) decrease
(C) constant (D) not depends

2. How does the magnifying power of a telescope change on increasing the linear diameter of its objective?
(A) Power increases on increases diameter
(B) Power decreases on decreases diameter
(C) Power remain constant on increases diameter
(D) Power doesn't depends on diameter

3. An astronomical telescope has a large aperture to
(A) increase span of observation
(B) have low dispersion
(C) reduce spherical aberration
(D) have high resolution

4. Two lenses of focal lengths 20 cm and - 40cm are held in contact. If an object lies at infinity, image formed by the lens combination will be a
(A) infinity
(B) 20cm
(C) 40cm
(D) 60cm

5. The characteristic feature of light which remains unaffected on refraction is
(A) speed
(B) frequency
(C) wavelength
(D) velocity of light

6. The air bubble inside water shine due to
(A) Reflection
(B) Refraction
(C) Total internal reflection
(D) None of these

7. How does the focal length of a convex lens changes if mono chromatic red light is used instead of violet light?
(A)) Focal length is increased when red light is used
(B) Focal length is decreased when red light is used
(C) Focal length is remain same when red light is used
(D) Not depends on color of light.

8. When a convex lens placed inside a transparent medium of refracting index greater than that of its own material
(A) It behave as concave lens
(B) It behave as convex lens
(C) It behave as a glass slab
(D) It behave as a glass prism

9. The deviation of a ray on passing through a prism is $(\mu-1)A$ FOR
(A) All conditions
(B) small angle A
(C)) Large angle A
(D) In minimum angle of deviation case.

10. A thin prism of 12° angle gives a deviation of 6°. The refracting index of a material of the prism
(A) 3/2
(B) 4/3
(C) 8/9
(D)9/8

11. The radius of curvature of the convex surface of a plano- convex lens ,whose focal length Is 0.3m & the refractive index of material is 1.5 is
(A) 1.5m
(B) 0.15m
(C)0.5m
(D)1 .25m

12. The magnifying power of an astronomical telescope in the normal adjustment position Is 100.The distance between objective & the eyepiece is 101cm.what is the focal length of objective.
(A) 100cm
(B) 1cm
(C) 50 cm
(D) 11cm

13. A Tank is filled with water to a height of 12.5cm.The apparent depth of a needle lying at Bottom of tank is measured by a microscope to be 9.4cm.What is the refractive of water ? (A) 1.33 (B) 1.5 (C) 1.13 (D) 1.45
14. Two thin lenses of focal lengths 20 cm and 25 cm are placed in contact. The effective power of the combination is: (A) 45 D (B) 9 D (C) 19 D (D)6 D
15. The angle of deviation for a prism is greatest for: (A) violet (B) red. (C) orange (D) yellow
16. An astronomical refractive telescope has an objective of focal length 20 m and an eyepiece of focal length 2 cm. Then (i) the magnification is 1000 (ii) the length of the telescope tube is 20.02 m (iii) the image formed of inverted (iv) all of these
17. An astronomical refractive telescope has an objective of focal length 20 m and an eyepiece of focal length 2 cm. Which one of the following is not possible? (i) The length of the telescope tube is 20.02 m. (ii) The magnification is 1000. (iii) The image formed is inverted. (iv) An objective of a larger aperture will increase the brightness and reduce chromatic aberration of the image.
18. A concave mirror is held in water. What should be the change in the focal length of the mirror? (i) Halved (ii) Doubled (iii) Remains the same (iv) Increases exponentially

19. A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will
(i) become zero
(ii) become infinite
(iii) become small, but non-zero
(iv) remain unchanged

20. Which of-the following is not a property of light?
(i) It can travel through vacuum
(ii) It has a finite speed
(iii) It requires a material medium for its propagation
(iv) It involve transportation energy

21. Two concave mirrors have the same focal length but the aperture of one is larger than that of the other. Which mirror forms the sharper image ?
(i) Plane (ii) Concave
(iii) Convex (iv) Prism

22. An object is placed at a distance of 40 cm from a concave mirror of focal length 15 cm. If the object is displaced through a distance of 20 cm towards the mirror, the displacement of the image will be:
(i) 30 cm away from the mirror
(ii) 36 cm away from the mirror
(iii) 30 cm towards the mirror
(iv) 36 cm towards the mirror

23. A man stands in front of a mirror of special shape. He finds that his image has a very small head, a fat body, and legs of normal size. What can we say about the shapes of the three parts of the mirror?
(i) Convex, Concave, Plane
(ii) The plane, Concave, Convex
(iii) Concave, Convex, Plane
(iv) Convex, Plane, Concave

24. The refractive indices (R.I.) of glass and water with respect to air are 3/2 and 4/3 respectively. The R.I. of glass w.r. to water is:
(i) 8/9 (ii) 9/8
(iii) 7/6 (iv) 2

25. Which of the following colour of white light deviated most when passes through a prism?
(i) Red light
(ii) Violet light
(iii) Yellow light
(iv) Both (i) and (ii)

26. Two lenses of focal lengths 20 cm and – 40 cm are held in contact. The image of an object at infinity will be formed by the combination at (i) 10 cm (ii) 20 cm (iii) 40 cm (iv) infinity
27. A convergent lens will become less convergent in : (i) oil (ii) water (iii) both of (i) and (ii) (iv) none of these
28. Two beams of red and violet color are made to pass separately through a prism (angle of the prism is 60°). In the position of minimum deviation, the angle of refraction will be (i) 30° for both the colors (ii) greater for the violet color (iii) greater for the red color (iv) equal but not 30° for both the colors
29. When light is refracted into a medium, (i) its wavelength and frequency both increase (ii) its wavelength increases but frequency remains unchanged (iii) its wavelength decreases but frequency remains unchanged (iv) its wavelength and frequency both decrease
30. A ray of light incident at an angle θ on a refracting face of a prism emerges from the other face normally. If the angle of the prism is 5° and the prism is made of a material of refractive index 1.5, the angle of incidence is (a) 7.5° (b) 5° (c) 15° (d) 2.5°
31. Digital movie projectors work on the principle of (1) Reflection from micromirrors (2) Refraction from thin lenses (3) Dispersion from thin prisms (4) Total internal reflection from optical fibres
32. Day and night settings for rearview mirrors uses (1) Thin mirrors (2) Thick wedge-shaped mirrors (3) Convex mirrors (4) Concave mirrors
33. When a beam of light is incident on a plane mirror, it is found that a real image is formed. The incident beam must be (1) Converging (2) Diverging (3) Parallel (4) Formation of real image by a plane mirror is impossible
34. An object is placed symmetrically between two plane mirrors, inclined at an angle of 72°, then the total number of images observed is (1) 5 (2) 4 (3) 2 (4) Infinite

35. A person 1.6 m tall is standing at the centre between two walls three metre high. What is the minimum size of a plane mirror fixed on the wall in front of him, if he is to see the full height of the wall behind him?
(1) 0.8 m (2) 1 m
(3) 1.5 m (4) 2.3 m

36. While capturing solar energy for commercial purposes we use
(1) Parabolic mirrors (2) Plane mirrors
(3) Convex mirrors (4) Concave mirrors

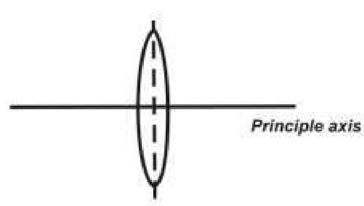
37. A convex mirror is used to form an image of a real object. Then mark the wrong statement
(1) The image lies between the pole and focus
(2) The image is diminished in size
(3) The image is erect
(4) The image is real

38. A convex mirror has a focal length f. A real object is placed at a distance f in front of it, from the pole. It produces an image at
(1) Infinity (2) f
(3) f/2 (4) 2f

39. An object placed in front of a concave mirror of focal length 0.15 m produces a virtual image, which is twice the size of the object. The position of the object with respect to the mirror is
(1) –5.5 cm (2) –6.5 cm
(3) –7.5 cm (4) –8.5 cm

40. When a light ray from a rarer medium is refracted into a denser medium, its
(1) Speed increases, wavelength increases
(2) Speed decreases, wavelength increases
(3) Speed increases, wavelength decreases
(4) Speed decreases, wavelength decreases

41. An equiconvex lens of focal length 15 cm is cut into two halves as shown in figure. Find the focal length of each part?



a) -30cm (b) -20cm (c) 30cm (d) -15cm

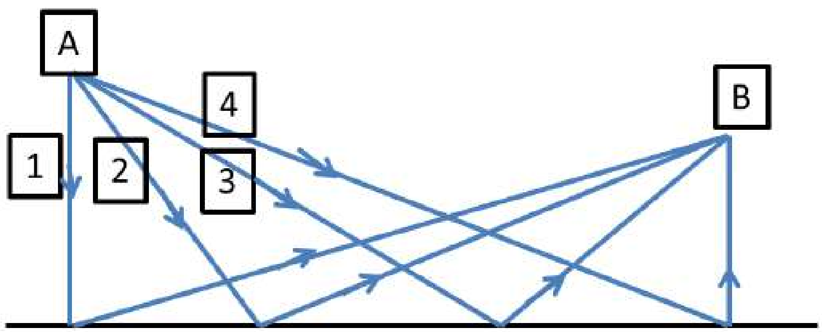
42. A glass lens is immersed in water. What will be the effect on the power of lens?
a)increase (b) decrease
(c) constant (d) not depends

43. How does the magnifying power of a telescope change on increasing the linear diameter of its objective? a. Power increases on increases diameter b. Power decreases on decreases diameter c. Power remain constant on increases diameter d. Power doesn't depend on diameter
44. An astronomical telescope has a large aperture to: (a) increase span of observation (b) have low dispersion (c) reduce spherical aberration (d) have high resolution
45. Two lenses of focal lengths 20 cm and - 40cm are held in contact. If an object lies at infinity, image formed by the lens combination will be at a. infinity b. 20cm c. 40cm d. 60cm
46. In the minimum deviation position, the refracted ray in the prism is 1. Parallel to the base of prism. 2. Perpendicular to the base of prism. 3. Parallel to the any side of prism 4. None of the above
47. Due to refraction, the depth of an optically denser medium appears to be a. less than its real depth. b. more than its real depth. c. Equal than its real depth. d. Not related to its real depth.
48. A convergent lens made of crown glass (refractive index 1.5) has focal length 20cm in air. If it is immersed in a liquid of refractive index 1.60, its focal length will be (a)160 cm (b)80 cm (c)-160 cm (d)-80 cm
49. A man runs towards a mirror at a rate of 6 m/s if we assume the mirror to be at rest, the image will have velocity - a. +12 m/s b. -12 m/s c. +6 m/s d. -6 m/s

50. Refractive index of water is 5/3. A light source is placed in water at a depth of 4 m. Then what must be the maximum radius of disc placed on water surface so that the light of source can be stopped ?
A. 3 m
B. 4m
C. 5m
D. Infinity

51. A short linear object of length b lies along the axis of a concave mirror of focal length f at a distance u from the pole of the mirror. The size of image is approximately equal to
A. b ((u-f)/f)1/2
B. b ((f)/u-f)1/2
C. b ((u-f)/f)
D. b ((f)/u-f)2

52. A ray of light travels from the point A to B with a uniform speed. On its way, it is reflected by the surface XX'. The path followed by the ray to take least time is



A. 1
B. 2
C. 3
D. 4

53. A Convex mirror of focal length f produces an image magnified m times. The distance of the object from the mirror is
A. (m-1)f/m
B. (m+1)f/m
C. (m-1)f
D. (m+1)f

54. A Thin lens of focal length f and its aperture has diameter d. it forms an image of intensity 3. Now the central part of aperture upto diameter d/2 is blocked by an opaque paper. The focal lenght and image intensity would change to
A. f/2, I/2
B. f, I/4
C. 3f/4, I/2
D. F, 3I/4

55. When a light ray from a rarer medium is refracted into a denser medium, its
(1) Speed increases, wavelength increases
(2) Speed decreases, wavelength increases
(3) Speed increases, wavelength decreases
(4) Speed decreases, wavelength decreases

56. Which of the following is possible application of fibre optics?
(1) Endoscopy
(2) High speed internet traffic
(3) Radio, TV & Telephone signals
(4) All of these

57. Two transparent media A and B are separated by a plane boundary. The speed of light in medium A is 2.0 x 108 ms-1 and in medium B is 2.5 × 108 ms-1. The critical angle for which a ray of light going from A to B suffers total internal reflection is
(1) $\sin^{-1}$ 1/2
(3) $\sin^{-1}$ 4/5
(2) $\sin^{-1}$ 2/5
(4) $\sin^{-1}$ ¾

58. An object is placed at a distance of f/2 from a convex lens. The image will be
(1) At one of the foci, virtual and double its size
(2) At 3f/2, real and inverted
(3) At 2f, virtual and erect
(4) At f, real and inverted

59. A glass concave lens is placed in a liquid in which it behaves like a convergent lens. The refractive index of glass is
1. Greater than the refractive index of the liquid
2. Less than the refractive index of the liquid
3. Cannot be decided
4 None of the above.

60. The radii of curvatures of each of the surfaces of a convex lens (refractive index of the material is 1.5) is 20 cm. The focal length of the lens in air is
1. 20 cm
2. -20 cm
3. 40 cm
4. 10 cm

61. A glass lens is immersed in water. Its power will
1. Decrease
2. Increase
3. Remains same
4. None of the above

62. A thin equiconvex glass lens of refractive index 1.5 has power of 5D. When the lens is immersed in a liquid of refractive index μ, it acts as a divergent lens of focal length 100 cm. The value of μ of liquid is (1) 4/3 (2) 3/4 (3) 5/3 (4) 8/3
63. At the minimum deviation of condition in a prism 1. The refracted ray is parallel to the base of the prism. 2. The incident angle is equal to the angle of emergence. 3. Angle of refraction is half of the angle of prism 4. All of the above
64. Focal length of the objective and eyepiece of a telescope are respectively 50 cm and 5 cm. The magnifying power of the telescope in its normal adjustment is 1. 0.1 2. 10 3. 11 4. 1.1
65. The equivalent focal length of a combination of a convex and a concave length is 1. Positive 2. Negative 3. May be positive or negative 4. None of the above.
66. Two convex lenses are separated by a distance equal to the sum of their focal lengths. A beam of light parallel to the principal axis incidence on one of the lenses. They will emerge from the second lens as 1. A beam of parallel rays 2. As a beam of diverging rays 3. As a beam of converging ray 4. None of the above
67. When a telescope is adjusted for normal vision, the distance of the objective from the eye-piece is found to be 80 cm. The magnifying power of the telescope is 19. What are the focal lengths of the lenses? (1) 61 cm, 19 cm (2) 40 cm, 40 cm (3) 76 cm, 4 cm (4) 50 cm, 30 cm
68. While measuring refractive index of glass using a glass slab of thickness 3 cm and a travelling microscope a student observes that he needed to shift the microscope by 1 cm to refocus the mark on the base of the travelling microscope when the slab is kept on it. The refractive index of the material of the glass slab is 1. 2/3 2. 1/3 3. 3/2 4. 1.8

69. Total internal reflection occurs when 1. Light travels from a denser to rarer medium 2. Light travels from a denser to rarer medium. and the angle of incidence is less than the critical angle 3. Light travels from a rarer to denser medium. and the angle of reflection is less than the critical angle 4. Light travels from a denser to rarer medium. and the angle of incidence is greater than the critical angle
70. Objects are visible in light due to : a. Scattering b) Refraction c) Absorption d) Fluorescence
71. Even in absolutely clear water ,a diver cannot see very clearly : a. Because rays of light get diffused b. Because velocity of light is reduced in water c. Because a ray of light passing through the water makes it turbid d. Because the focal length of the eye lens in water gets changed and the imge is no longer focused sharply on the retina
72. A lens behaves as a converging lens in air and as a diverging lens in water. The refractive index of the material is : a. Equal to unity b. Equal to 1.33 c. Between unity and 1.33 d. Greater than 1.33
73. When a thin convex lens is put in contact with a thin concave lens of the same focal length , the resultant combination had focal length equal to : a. f/2 b. 2f c. Zero d. Infinity
74. A concave lens of focal length f produces an image $1/\mu$ times the size of the object. The distance of the object from the lens is : a. $(\mu - 1)f$ b. $(\mu - 1)f/\mu$ c. $(\mu + 1)f/\mu$ d. $(\mu + 1)f$
75. When length of a microscope tube increases, its magnifying power : a. Decreases b. Increases c. Does not change d. May increase or decrease

76. A microscope has an objective of 5mm focal length and eye piece of 30 mm focal length and the distance between them is 150 mm . The magnification is : a. 50 b. 100 c. 200 d. 250
77. The magnifying power of an astronomical telescope can be increased if we : a. Increase the focal length of the objective b. Increase the focal length of the eye piece c. decrease the focal length of the objective d. decrease the focal length of the objective and at the same time increase the focal length of the eye piece
78. Two convex lenses of focal lengths 0.3 m and 0.05 m are used to make a telescope. The distance kept between them is equal to : a. 0.35 m b. 0.25 m c. 0.175 m d. 0.15 m
79. When a ray of light goes from a rarer medium into a denser medium , then : a. Speed of light is reduced b. Frequency of light is increased c. Wavelength of light is increased d. None of the above effects will be observed.
80. A ray of light can suffer total internal reflection when it goes from : a. Air to water b. Water to glass c. Glass to air d. Air to glass
81. If refractive indices for water and glass are 4/3 and 5/3 respectively and light is tending to go from glass to water, the critical angle is : a. Sin-1 (4/3) b. Sin-1 (5/3) c. Sin-1 (4/5) d. Sin-1 (5/4)
82. Optical fibres use the phenomenon of : a. Refraction b. Total internal reflection c. Polarisation d. Interference

83. In a glass prism : a. Blue light is dispersed more than red light b. Red light is dispersed more than blue light c. Both red light and blue light are equally dispersed d. Orange light is dispersed more than blue light
84. The angle of minimum deviation for a hollow prism filled with a liquid is 30 degree . A ray of light falling on the prism is refracted at 30 degree. The refractive index of the liquid is : a) 1.414 b) 1.732 c) 0.866 d) 1.500
85. In an experiment for determination of refractive index of glass of a prism by i-δ,plot,it was found that a ray incident at angle 35°,suffers deviation of 40° and that it emerges an angle 79°.In that case which of the following is closest to the maximum possible value of refractive index? (A)1.5 (B)1.6 (C)1.7 (D)1.8
86. An object 2.4m Infront of a lens form a sharp image on a film 12 cm behind the lens. A glass plate 1 cm thick, of refractive index 1.50 is interposed between lens and film with its plane faces parallel to film. At what distance (from lens) should object shifted to be in sharp focus on film? (A)7.2m (B)2.4m (C)3.2m (D)5.6m
87. A green light is incident from the water to the air-water interface at the critical angle (θ). Select the correct statement (A) The spectrum of visible light whose frequency is more than that of green light will come out to the air medium (B) The entire spectrum of visible light will come out of the water at various angles to the normal (C) The entire spectrum of visible light will come out of the water at an angle of 90° to the normal (D) The spectrum of visible light whose frequency is less than that of green light will come out to the air medium
88. The focal length of plano-convex lens, the convex surface of which is slivered is .3m, if μ of the lens is 7/4, the radius of curvature of the convex surface is (A)0.45m (B)1.05m (C)3m (D)0.9m

89. The magnification of a compound microscope is 30 and the focal length of its eye piece is 5m. Calculate the magnification produce by the objective , when the image is to be formed at least distance of distinct vision (25 cm).
(A) 5
(B) 6
(C) 8
(D) 10

90. A convergent double of separated lens, corrected for spherical aberration ,are separated by 2 m and has an equivalent focal length of 10 cm. Calculate the focal length of its component lenses.
(A) f1=18 cm,f2=10 cm.
(B) f1=20 cm,f2=28 cm.
(C) f1=20 cm,f2=18 cm.
(D) f1=24 cm,f2=18cm.

91. Calculate the time taken by the light to travel a distance of 500 m in water of reflective index of4/3. (Given the velocity of light in vacuum =3 X 10^{10}cm/s)
(A) 3X10^{-10}s
(B) 2.22 X 10^{-6}s
(C) 4.3 X 10^{-5}s
(D) 3 X 10^{-6}s

92. A telescope consist of two lenses of focal lengths 10 cm and 1 cm. Calculate the length of telescope, when an object is kept at distance of 60 cm from the objective, and the final image is formed is at least distance of distinct vision.
(A) 15.05 cm
(B) 12.96 cm
(C) 13.63 cm
(D) 14.44 cm

93. An equilateral prism deviates a ray through 45º for the two angle of incidence differing by 20º. The angle of incidence is
(A)60º
(B)40º
(C)120º
(D)None of these

94. A compound microscope has an eyepiece of focal length 10m and an objective of focal length 4cm. Calculate the magnification if an object is kept at a distance of 5cm from the objective, then the final image is formed at the least distance of distinct vision.
(A)10
(B)11
(C)12
(D)13

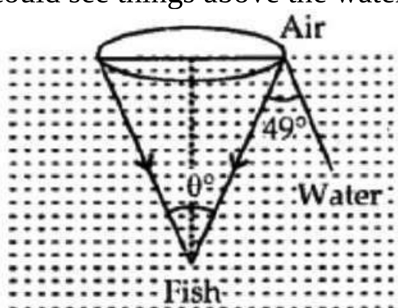
95. An object approaches a convergent lens from the left of the lens with uniform speed 5m/s and stops at the focus. The image (A)moves away from the lens with a uniform speed 5m/s (B)moves away from the lens with uniform acceleration (C) moves away from the lens with non-uniform acceleration (D)moves towards the lens with non-uniform acceleration
96. Find the change in the focal length of the lens, if a convex lens of focal length 20cm and refractive index 1.5, is emerged in water having refractive index 1.33. (A)62.2cm (B)5.82cm (C)58.2cm (D)6.22cm
97. Find the position of 1cm tall object which is placed 8cm in front of convex mirror of radius of curvature 24cm. (A)24cm (B)25cm (C)26cm (D)27cm
98. If two mirrors are inclined at some angle an object is placed between the mirrors and there are seven images formed for an object. Then, what is an angle between the mirrors? (A)54^o (B)50^o (C)60^o (D)64^o
99. The shortest height of a vertical mirror required to see the entire image of a man will be A) One third of the man's height (B)Half the man's height (C)Two third of the man's height (D)Data insufficient
100. A beam of monochromatic blue light of wavelength 4200 Å in air travels in water (4 / 3) . Its wavelength in water will be (a) 2800 Å (b) 5600 Å (c) 3150 Å (d) 4000 Å
101. The ratio of thickness of plates of two transparent mediums A and B is 6 : 4. If light takes equal time in passing through them, then refractive index of B with respect to A will be (a) 1.4 (b) 1.5 (c) 1.75 (d) 1.33
102. The wavelength of light in two liquids 'x' and 'y' is 3500 Å and 7000 Å, then the critical angle of x relative to y will be (a) 60^0(b) 45^0 (c) 30^0(d) 15^0

103. A convex lens of focal length 40 cm is an contact with a concave lens of focal length 25 cm.
The power of combination is
(a) – 1.5 D (b) – 6.5 D
(c) + 6.5 D (d) + 6.67 D

104. If the refractive indices of crown glass for red, yellow and violet colours are 1.5140, 1.5170 and 1.5318 respectively and for flint glass these are 1.6434, 1.6499 and 1.6852 respectively, then the dispersive powers for crown and flint glass are respectively
(a) 0.034 and 0.064 (b) 0.064 and 0.034
(c) 1.00 and 0.064 (d) 0.034 and 1.0

105. The focal length of objective and eye-piece of a microscope are 1 cm and 5 cm respectively. If the magnifying power for relaxed eye is 45, then length of the tube is
(a)6 cm (b) 9 cm
(c) 12 cm (d) 15 cm

106. A fish is a little away below the surface of a lake. If the critical angle is 49°, the fish could see things above the water surface within an angular range of θ°, where



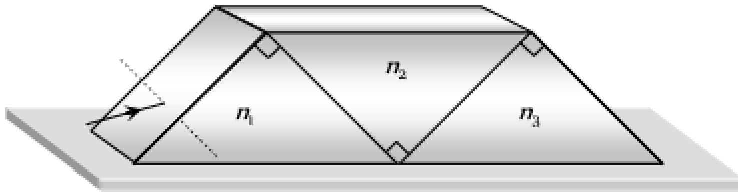
(a)49° (b)θ–98°
(c)90° (d)24.5°

107. A double convex thin lens, made of glass (μ = 1.5) has both radii of curvature of magnitude 20 cm. Incident light rays parallel to principal axis of the lens will converge at a distance L such that:
(a)20cm (b) 10 cm
(c) 15 cm (d) 19 cm

108. A spherical surface of radius of curvature R separated air (RI 1.0) from glass (RI 1.5). The center of curvature in the glass a point object P in air found to have a real image Q in the glass. The line PQ cuts the surface at a point O, and PO=OQ. The distance is equal to
a.5R b. 3R
c. 2R d. 1.5 R

109. The focal length of an object of a telescope is 3 m and diameter 15 cm. Assuming for a normal eye, the diameter of pupil 3mm for its complete use the focal eye piece must be
(a) 6 cm (b) 6.3 cm
(c) 20 cm (d) 60 cm

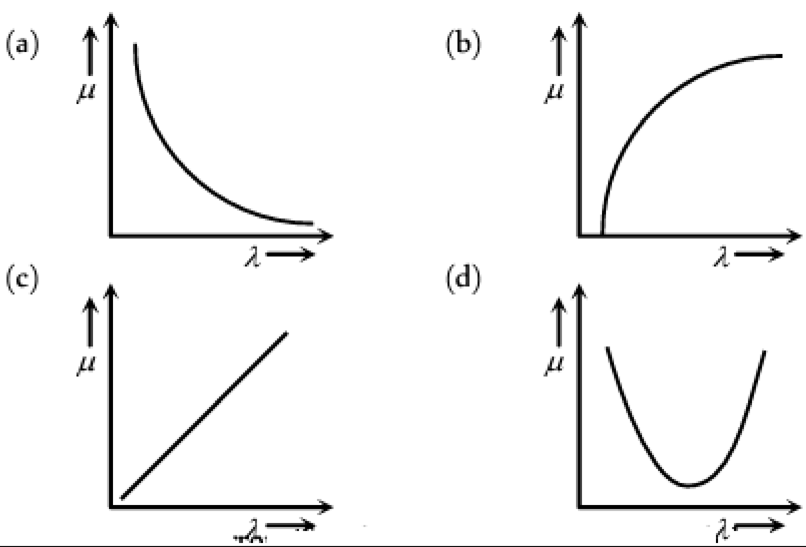
110. Three right angled prisms of refractive indices n1, n2 and n3 are fixed together using an optical glue as shown in figure. If a ray passes through the prisms without suffering any deviation, then



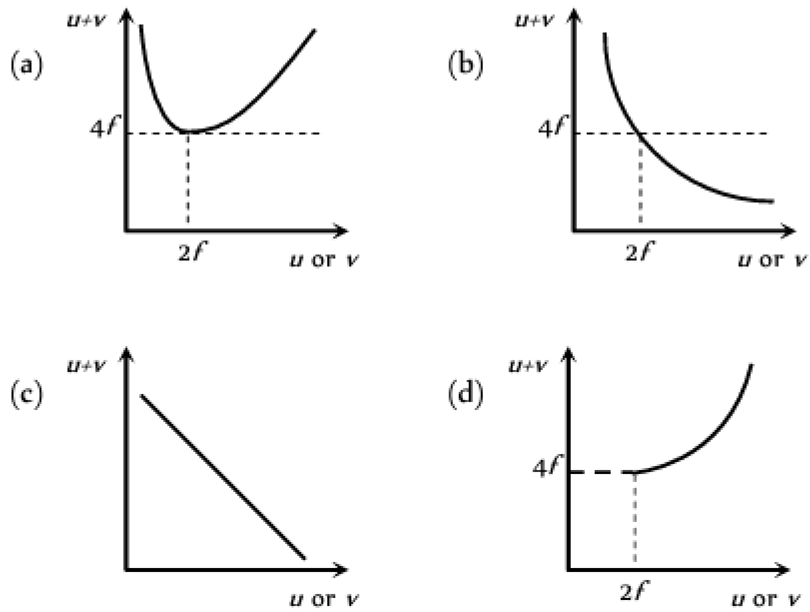
(a) $n_1 = n_2 = n_3$ (b) $n_1 = n_2 \neq n_3$

(c) $1 + n_1 = n_2 + n_3$ (d) $1 + n_2^2 = n_1^2 + n_3^2$

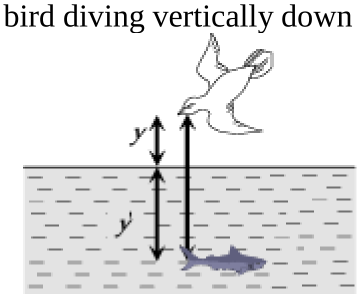
111. Which of the following graphs shows appropriate variation of refractive index μ with wavelength λ



112. For a convex lens, if real image is formed the graph between (u + v) and u or v is as follows a



113. A fish rising vertically up towards the surface of water with speed 3 ms–1 observes a bird diving vertically down towards it with speed 9 ms–1. The actual velocity of bird is



(a) 4.5 ms–1 (b) 5. ms–1
(c) 3.0 ms–1 (d) 3.4 ms–1

114. Two-point light sources are 24 cm apart. Where should a convex lens of focal length 9 cm be put in between them from one source so that the images of both the sources are formed at the same place
(a) 6 cm (b) 9 cm
(c) 12 cm (d) 15 cm

115. If *m*1 and *m*2 be the linear magnifications of the objective and eyepiece of a compound microscope, then the magnifying power of the compound microscope is
(A) *m*1 + *m*2 (B) *m*1 – *m*2
(C) *m*1 × *m*2 (D) (*m*1+*m*2)/2

116. The magnifying power of a telescope is M. If the focal length of the eyepiece is halved, the magnifying power will become
(A) M/2 (B) 4M
(C) M/4 (D) 2M

117. Light cannot easily escape a diamond without multiple internal reflections. This is because:
A. its critical angle with reference to air is too large.
B. its critical angle with reference to air is too small.
C. the diamond is transparent.
D. rays always enter at angle greater than critical angle.

118. If the focal length of objective lens is increased, then the magnifying power of
a. Microscope will increase but that of telescope decrease
b. Microscope will decrease but that of telescope increase
c. Microscope and Telescope, both will increase
d. Microscope and Telescope, both will increase

119. An Astronomical telescope has Objective and eyepiece of focal lengths 40cm and 4cm respectively. To view an object 200cm from the objective, the lenses must be separated by a distance of
a. 46.0cm b. 50cm
c. 54.0 cm d. 37.3cm

120. A spherical surface of radius of curvature R separates air (refractive index 1.0) from glass (refractive index 1.5). The center of curvature is in glass. A point object P placed When a glass lens is immersed in water, then the power of the lens will
a. Increase b. decrease
c. constant d. not depends

121. The deviation of a ray on passing through a prism of small angle A is
a. μ-1A b. Aμ-1
c. (μ-1)Ad. none

122. An object approaches a convergent lens from the left of the lens with a uniform speed 5m/s and stops at the focus. The image
a. Moves away from the lens with uniform speed 5m/s
b. Moves away from the lens with uniform acceleration
c. Moves away from the lens with non-uniform acceleration
d. Moves towards the lens with non-uniform acceleration

123. A converging lens of focal length 50cm is placed co-axially in contact with another lens of unknown focal length. If the combination behaves like a diverging lens of focal length 50cm. The power of lens is
a. 4D b. 2D
c. -4D d. -2D

124. A ray of light passes through an equilateral glass prism such that angle of incidence is equal to angle of emergence. If the angle of emergence is ¾ times the angle of prism, the angle of deviation is
a. 300 b. 450
c. 600 d. 400

125. A small object is place at a distance of 15cm from two coaxial thin lenses in contact. The focal length of each lens is 25cm. the distance between object and image when both the lenses are concave is
a. 6.8cm b. 75cm
c. 8.2cm d. 90cm

126. The radius of curvature of convex surface of a Plano convex lens, whose focal length is 0.3m and μ=1.5 is a. 5cm b. 10 m c. 12cm d. 15cm
127. One diopter is the power of lens of focal length a.1cm b. 1m c. -1cm d. -1m
128. An object is seen through a simple microscope of focal length 10cm. The angular magnification produced if the image is formed at the near point of the eye which is 20cm away from it is a. 2 b. 3 c. 6 d. 4
129. A biconvex lens has a focal length 2/3 times the radius of curvature of either surface. The refractive index of the lens material is a. 1.25 b. 1.30 c. 1.5 d.1.75
130. When light is passed through a prism, the colour which deviates least is: A. Red B. Blue C. Green D. Violet
131. The principal behind optical fibre communication is: A. Total internal reflection B. Both Total external reflection and Total internal reflection C. Refraction D. Total internal Reflection and Refraction
132. How does the power of a convex lens vary, if the incident red light is replaced by violet light? A. Increases B. Decreases C. No effect D. First increases and then decreases
133. Two lenses of focal lengths 20 cm and - 40cm are held in contact. If an object lies at infinity, image formed by the lens combination will be at A. infinity B. 20cm C. 40cm D. 60cm
134. A short pulse of white light incident from air to glass slab at normal incidence. After travelling through the slab the first colour to emerge is A. violet B. blue C. green D. red

135. A glass lens is immersed in water. What will be the effect on the power of lens?
(a) increase
(b) decrease
(c) constant
(d) not depends

136. An equiconvex lens of focal length 15 cm is cut into two halves along principal axis. Find the focal length of each part?
A. -30cm
B. -20cm
C. 30cm
D. 15cm

137. Name the device used to observe magnified image of microscopic objects.
A. Telescope
B. microscope
C. Periscope
D. Kaleidoscope

138. Name the device used to observe distinct image of long distance objects.
A. Telescope
B. microscope
C. Periscope
(D) Kaleidoscope

139. An equiconvex lens of focal length 15 cm is cut into two halves along aperture. What is the focal length of each part?
A. -30cm
B. -20cm
C. 30cm
D. -15cm

140. In construction how compound microscope differs from simple microscope?
A. Compound microscope has two convex lenses where simple microscope has three convex lens,
B. Objective has smaller focal length & smaller aperture compared to eyepiece.
C. Objective has greater focal length & greater aperture compared to eyepiece,
D. None of these.

141. How does objective differ from eyepiece in case of telescope?
A. Objective has greater focal length & greater aperture compared to eyepiece,
B. Objective has smaller focal length & smaller aperture compared to eyepiece
C. Objective and eyepiece have same focal length and aperture
D. None of these

142. Why is the focal length of objective greater than focal length of eyepiece telescope?
A. To increase magnification
B. To decrease magnification
C. To form image at D
D. To form image at ∞

143. Why in microscope we prefer to form image at least distance of distinct vision compare to image at infinity.
A. For Higher magnification
B. To decrease magnification
C. To reduce aberration
D. None of these

144. With increase in angle of incidence, What happens to angle of deviation?
A. Angle of deviation first decreases, then increases
B. Angle of deviation first increases, then decreases
C. Angle of deviation first decreases, then becomes constant.
D. Angle of deviation first remains constant, then increases

145. Human eye is most sensitive to visible light of wavelength
a)6050Å
b)5500 Å
c)4500 Å
d)7500 Å

146. Distance of distinct vision is 25cm. Focal length of convex lens is 5cm,it can act as a magnifier of magnifying power
a) <5 D
b) 5 D
c)6 D
d) Not more than 7 D.

147. Consider the following statement, a compound microscope is better than a single lens microscope because,
i) it can produce larger magnification.
ii) it has better resolution
iii) it produces an image free from all defects.
Of the above statements
a) 1,2&3 are correct.
b) 1 & 2 are correct.
c) 2 &3 are correct.
d)1 &3 are correct.

148. A microscope has an objective of 3mm focal length and eyepiece of 30mm focal length and distance between them is 152 mm. the magnification is
a) 90 x
b) 150 x
c) 180 x
d)35 x

149. A ray of light passes through a prism of angle 600 and refractive index 1.414. the angle of minimum deviation will be
a) 15o
b) 300
c) 450
d) 600

150. Radii of curvature of both the surfaces of a lens are equal(R) and it is made of material of refractive index 1.5. Its focal length will be
a)±R
b)±2R
c)± R/2
d) Zero

151. When a light wave get refracted into a denser medium the speed of propagation
a) Increases but the wavelength decreases.
b) Decreases but the wavelength increases
c) as well as wavelength increases
d) as well as wavelength decreases.

152. A concave lens of focal length 20cm is kept in contact with a convex lens of focal length 10cm .the combination will have a focal length of
a)10cm
b) -10cm
c) 20 cm
d) -20cm

153. A concave mirror is held in water .what would be the change in the focal length of the mirror?
a) Halved
b) Doubled
c) Remain the same
d) Increase exponentially

154. A man stand in front of a mirror of special shape .he finds that his image has a very small head , a fat body and legs of normal size . What can we say about the shape of three parts of the mirror
a) Convex, concave ,plane
b) Plane, concave, convex
c) Concave, convex, plane
d)convex, plane ,concave

155. Two beams of red and violet are made to pass separately through a prism (angle of prism 60). In the position of minimum deviation, the angle of refraction will be.
a) 30 for both colors
b) Greater for violet color
c) Greater for red color
d) Equal but not 30 for both color.

156. What are the factors affecting the power of a lens?
(i) Refractive index of lens material.
(ii) Refractive index of the surrounding.
(iii) Radii of curvature.
(iv). Wavelength of light
(a) (iii) & (iv)
(b) (i) ,(iii) &(iv)
(c) (iii) & (i)
(d) (i),(ii),(iii) &(iv)

157.A converging and a diverging lens of equal focal length f are placed coaxially in contact. What will be the power of this combination? (a) 2f (b) 0 (c) Infinity (d) < f
158 . A ray of light strikes a transparent rectangular slab of refractive index √2 at an angle of incidence 45°. The angle between reflected and refracted ray is (a) 75 (b) 90 (c)105 (d)120
159. Two identical glass ($\mu = 3/2$) equiconvex lenses of focal length f are kept in contact. The space between two lenses is filled with water ($\mu = 4/3$) the focal length o the combination is (a) f (b) f/2 (c) 4f/3 (d) 3f/4
160. A given convex lens of glass having refractive index $\mu = 32$ can behave as concave when it is held in a medium of μ equal to A. 1 B. 32 C. 23 D. 74
161. Refractive index of a medium depends upon A. Nature of the medium B. Wavelength of the medium C. Temperature D. All of these
162. A convex lens of focal length 25 cm is placed coaxially in contact with a concave lens of focal length 20 cm. The system will be A. Converging in nature B. Diverging in nature C. Can be converging or diverging D. None of the above
163. Which of the following is not due to total internal reflection ? A. Working of optical fibre B. Difference between apparent and real depth C. Mirage on hot summer days D. Brilliance of diamond

164. An air bubble is formed inside water. What change will be observed? A. It acts as converging lens B. It acts as diverging lens C. It acts as a plain glass sheet D. Cannot say with certainty
165. A ray of light is incident on an equilateral glass prism μ = 3 moves parallel to the base of the prism inside it. What is the angle of incidence of this ray ? A. 300 B. 450 C. 600 D. 900
166. Two lenses of power +15D and -5D are kept in contact with each other forming a combination lens. The effective power and focal length of the combination is A. 10D, 10 cm B. 5D, 5cm C. -10D, 20cm D. -5D, -10 cm
167. A convex lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen, A. Half of the image will disappear B. Complete image will formed with same intensity C. Complete image will formed with increase intensity D. Complete image will formed with decrease intensity
168. The image formed by an objective of a compound microscope is A. Virtual and diminished B. Real and enlarged C. Real and diminished D. Virtual and enlarged
169. A short pulse of white light is incident from air to glass slab at normal incidence. After travelling through the slab, the first colour to emerge is A. Violet B. Blue C. Red D. Green
170. The focal length of convex lens when incident by violet rays of light is f cm. When the incident violet light is replaced by red light, the new focal length will be A. Less than f cm B. Greater than f cm C. Equal to f cm D. Equal to zero

171. If the value of critical angle is 300 for total internal reflection from given optical fibre, then the speed of light in that fibre is

A. 3x108m/s

B. 1.5x108m/s

C. 6x108m/s

D. 4.5x108m/s

172. The magnifying power of a compound microscope increases with

A. The focal length of objective lens is increased and that of eye lens is decreased

B. The focal length of objective lens is decreased and that of eye lens is increased

C. Focal length of both object and eye piece are increased

D. Focal length of both object and eye piece are decreased

173. An equi -convex lens of focal length ‘f’ is cut into two identical plano convex lenses. The new focal length and power of the plano-convex lens are

(A) focal length = 2f, power = half of original power

(B) focal length = f, power = double of original power

(C) focal length = 2f, power = original power

(D) focal length = f, power = triple of original power

174. An object approaches a convergent lens from the left of the lens with a uniform speed 5m/s and stops at focus. The image

A. Moves away from the lens with a uniform speed 5m/s

B. Moves away from the lens with a uniform acceleration

C. Moves away from the lens with non-uniform acceleration

D. Moves towards the lens with non-uniform acceleration

ANSWERS:

1.	B	21.	(ii)	41.	c	61.	1
2.	D	22.	(ii)	42.	b	62.	3
3.	D	23.	(i)	43.	d	63.	4
4.	C	24.	(ii)	44.	d	64.	2
5.	B	25.	(ii)	45.	c	65.	3
6.	C	26.	(iii)	46.	1	66.	1
7.	A	27.	(ii)	47.	a	67.	4
8.	A	28.	(i)	48.	c	68.	3
9.	B	29.	(ii)	49.	d	69.	4
10.	A	30.	(a)	50.	a	70.	a
11.	B	31.	1	51.	d	71.	d
12.	A	32.	2	52.	d	72.	c
13.	A	33.	1	53.	3	73.	d
14.	B	34.	2	54.	a	74.	a
15.	A	35.	2	55.	4	75.	c
16.	(iv)	36.	1	56.	4	76.	d
17.	(iv)	37.	4	57.	4	77.	a
18.	(iii)	38.	3	58.	1	78.	c
19.	ii)	39.	3	59.	2	79.	a
20.	(iii)	40.	4	60.	1	80.	c

81.	c	101.	b	121.	c	141.	A	161.	D
82.	B	102.	c	122.	c	142.	A	162.	B
83.	A	103.	a	123.	c	143.	A	163.	B
84.	A	104.	a	124.	a	144.	A	164.	B
85.	A	105.	c	125.	c	145.	B	165.	C
86.	D	106.	b	126.	d	146.	C	166.	A
87.	D	107.	a	127.	b	147.	B	167.	D
88.	B	108.	a	128.	b	148.	B	168.	B
89.	A	109.	a	129.	d	149.	B	169.	C
90.	A	110.	d	130.	A	150.	A	170.	B
91.	B	111.	a	131.	A	151.	D	171.	B
92.	B	112.	a	132.	A	152.	C	172.	D
93.	A	113.	a	133.	C	153.	C	173.	A
94.	C	114.	a	134.	D	154.	A	174.	C
95.	C	115.	c	135.	B	155.	A		
96.	C	116.	d	136.	D	156.	D		
97.	A	117.	b	137.	B	157.	C		
98.	B	118.	b	138.	A	158.	C		
99.	B	119.	c	139.	C	159.	D		
100.	b	120.	b	140.	B	160.	D		

ASSERTION AND REASON QUESTIONS

Two statements are given one labeled Assertion (A) and the otherlabeled Reason (R). Select the correct answer to these questions from the codes (A), (B), (C) and (D) as given below: **(A) If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).** **(B) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).** **(C) If Assertion (A) is true and Reason (R) is false.** **(D) If both Assertion (A) and Reason (R) are false**.
1. Assertion(A) : The height of an object is always considered positive.
Reason (R) : An object is always placed above the principal axis in the upward direction.
2. Assertion(A): Virtual images are always erect.
Reason (R) : Virtual images are formed by diverging lenses only.
3. Assertion(A) : Refractive index has no units.
Reason (R) : The refractive index is a ratio of two similar quantities.
4. Assertion (A): Air bubbles shine in water.
Reason (R): Air bubbles shine in water due to total internal reflection of light.
5. Assertion (A): A diamond of refractive index $\sqrt{6}$ is immersed in a liquid of refractive index $\sqrt{3}$. If light travels from diamond to liquid, total internal reflection will take place when angle of incidence is 30°.
Reason (R): $\mu = 1/\sin C$, where μ is the refractive index of diamond with respect to the liquid
6. Assertion : Assertion : The resolving power of a telescope is more if the diameter of the objective lens is more.
Reason : Objective lens of large diameter collects more light.
7. Assertion : Assertion : The optical instruments are used to increase the size of the image of the object.
Reason : The optical instruments are used to increase the visual angle.
8. Assertion :- Assertion : An object is placed at a distance of f from a convex mirror of focal length f its image will form at infinity.
Reason : The distance of image in convex mirror can never be infinity .
9. Assertion:- The focal length of an equiconvex lens of radius of curvature R made of material of refractive index $\mu = 1.5$, is R.
Reason : The focal length of the lens will be R/2.
10. Assertion : The focal length of the convex mirror will increase, if the mirror is placed in water.
Reason : The focal length of a convex mirror of radius R is equal to , f = R/2.
11. Assertion : Plane mirror may form real image.
Reason : Plane mirror forms virtual image, if object is real.
12. Assertion : The focal length of the convex mirror will increase, if the mirror is placed in water.
Reason : The focal length of a convex mirror of radius R is equal to , f = R/2.
13. Assertion : The image formed by a concave mirror is certainly real if the object is virtual.
Reason : The image formed by a concave mirror is certainly virtual if the object is real.
14. Assertion : The image of an extended object placed perpendicular to the principal axis of a mirror, will be erect if the object is real but the image is virtual.
Reason : The image of an extended object, placed perpendicular to the principal axis of a mirror, will be erect if the object is virtual but the image is real.

15. Assertion : An object is placed at a distance of f from a convex mirror of focal length f its image will form at infinity.
Reason : The distance of image in convex mirror can never be infinity
17. Assertion: The focal length of an equiconvex lens of radius of curvature R made of material of refractive index $\mu = 1.5$, is R.
Reason : The focal length of the lens will be R/2.
18.Assertion : If the rays are diverging after emerging from a lens; the lens must be concave.
Reason : The convex lens can give diverging rays.
19.Assertion : The resolving power of a telescope is more if the diameter of the objective lens is more.
Reason : Objective lens of large diameter collects more light.
20.Assertion : The optical instruments are used to increase the size of the image of the object.
Reason : The optical instruments are used to increase the visual angle.
21. Assertion: The refractive index of a prism depends only on the kind of glass of which it is made of and the colour of light.
Reason: The refractive index of a prism depends upon the refracting angle of the prism and the angle of minimum deviation.
22. Assertion: If the angles of the base of the prism are equal, then in the position of minimum deviation, the refracted ray will pass parallel to the base of prism.
Reason: In the case of minimum deviation, the angle of incidence is equal to the angle of emergence.
23. Assertion: A convex mirror cannot form real images.
Reason : Convex mirror converges the parallel rays that are incident on it.
24. Assertion: A convex lens of focal length 30 cm can't be used as a simple microscope in normal setting.
Reason: For normal setting, the angular magnification of simple microscope is M=D/f
25. Assertion : The resolving power of a telescope is more if the diameter of the objective lens is more.
Reason : Objective lens of large diameter collects more light.
26. Assertion: The focal length of the convex lens will increase, if it is placed in water.
Reason: The focal length of a convex lens depends upon the refractive index of the surrounding medium.
27. Assertion: If the rays are diverging after emerging from a lens; the lens must be concave. Reason: The convex lens can give diverging rays.
28. Assertion: Chromatic aberration is observed in lenses.
Reason: Different colour has different wavelength.
29. Assertion: Objective of a telescope has a large focal length and aperture.
Reason: Resolving power of a lens of large focal length is more.
30. Assertion: Light passing through a prism split into seven colours.
Reason: Light has seven constituent colours
31. Assertion : When a light wave travels from a rarer to a denser medium, it loses speed. The reduction in speed implies a reduction in energy carried by the light wave. Reason : The energy of a wave is proportional to velocity of wave
32. Assertion (A): An object placed in form of convex lens from the image of same size.
Reason (R): Object is placed between optical center and focus.

33.Assertion (A): A spherical lens as two foci, whereas spherical mirrors only have one.
Reason (R): A spherical lens causes refraction of light while spherical mirror causes reflection of light.
34.Assertion(A): A convex lens of focal length 30 cm can't be used as a simple microscope in normal setting.
Reason (R): For normal setting, the angular magnification of simple microscope is M=D/f
35. Assertion – Thin prisms do not deviate light much.
Reason – Thin prism have small angle A and hence, Dm(minimum deviation) is also very small as Dm = [(1n2 – 1)A], where 1n2 is the refractive index of prism w.r.t. medium 1.
36. Assertion: Critical angle of light passing from glass to air is minimum for violet colour. Reason: The wavelength of blue light is greater than the light of other colours .
37. Assertion: the images formed by total internal reflection are much brighter than those formed by mirror or lenses
Reason: There is no loss of intensity in total internal reflection.
38. Assertion: The frequencies of incident, reflected beam of monochromatic light incident from one medium to another are same
Reason: The incident, reflected and reflected rays are coplanar
39. Assertion: if the angle of the base of the prism are equal, then in the position of minimum deviation the reflected ray will pass parallel to the base of prism.
Reason: In the case of minimum deviation, the angle of incidences is equal to the angle of emergence.
40. Assertion: The focal length of lens does not change when red light of lens does not change when red light is replaced by blue light.
Reason: The focal length of lens does not depend on colour of light used.
41. Assertion : Spherical aberration occur in lenses of larger aperture.
Reason : The two rays, paraxial and marginal rays focus at different points.
42. Assertion : The refractive index of a prism depends only on the kind of glass of which it is made of and the colour of light.
Reason : The refractive index of a prism depends upon the refracting angle of the prism and the angle of minimum deviation.
43. Assertion : Diamond glitters brilliantly.
Reason : Diamond does not absorb sunlight.
44. Assertion : Just before setting, the sun may appear to be elliptical. This happens due to refraction.
Reason : Refraction of light ray through the atmosphere may cause different magnification in mutually perpendicular directions.
45. Assertion : Critical angle of light passing from glass to air is minimum for violet colours.
Reason : The wavelength of blue light is greater than the light of other colours.
46.Assertion: out of blue and red light, blue color is deviated more by a prism.
Reason: The refractive index of the glass of a prism is different for different wavelengths of light
47.Assertion: There is no dispersion when light passes through a rectangular slab
Reason: net deviation produced by first face for a given color is neutralized by the second face in a glass slab.
48. Assertion: flat bottom of water tank appears concave.
Reason: Apparent depth decreases with increasing obliquity

49.Assertion: Power of objective lens of a telescope is kept as small as possible.
Reason: small power implies small magnifying power of the telescope.
50.Assertion: The air bubble shines in water
Reason: air bubble in water shines due to refraction of light
51. Assertion(A): A ray of light entering from glass to air suffers change in
frequency.
Reason(R): Velocity of light in glass is more than that in air.
52.Assertion (A): Nature of lens can be changed by placing the lens in a medium of refractive index more than that of the lens.
Reason (R): Focal length of a lens depends on refractive index of medium in which it will be immersed.
53.Assertion (A): A convex lens can form real and virtual images both.
Reason (R): Depending on the position of object from the lens.
54.Assertion: The air bubble shines in water.
Reason : Air bubble in water shines due to refraction of light.
55.Assertion: If the angles of the base of the prism are equal, then in the position of minimum deviation, the refracted ray will pass parallel to the base of prism.
Reason: In the case of minimum deviation, the angle of incidence is equal to the angle of emergence.
56. Assertion- The eyepiece as well as objective of a telescope consist of combination of two lenses
Reason - combination of lenses are used to minimize spherical aberration.
57. Assertion - The clouds are generally of white color.
Reason - The clouds areconsist of particles having size greater than wavelength of light, hence Rayleigh law is not applicable.
58. Assertion - An object placed at the focus of a focus of a convex mirror will have its image at infinity.
Reason- The distance of image a convex mirror can never be infinity.
59. Assertion - the focal length of an equiconvex lens of radius of curvature R made up of a material of refractive index 1.5 is R.
Reason - The formula for focal length of a lens is f = R/2(Applying)
60. Assertion - the brightness of the image produced by a lens which is half painted black .
Reason - Intensity of image is directly proportional to the (aperture)2
61. Assertion (A): A convex lens of glass (μ =1.5) behaves as diverging lens when immersed in carbon disulphide of higher refractive index (μ = 1.65)
REASON (R) : A divergent lens is thinner in the middle and thicker at the edges
62. Assertion (A): If the objective and eye lenses of a microscope are interchanged, then it can work as telescope.
REASON (R) :The objective lens of telescope has small focal length.
63. Assertion (A): A total reflecting prism is used to erect the inverted image without deviation.
Reason (R) : Rays of light incident parallel to the base of prism emerges out as parallel rays.
64. Assertion (A): Endoscopy involves use of optical fibres to study internal organs
Reason (R): Optical fibreare based on the phenomena of total internal reflection
65. Assertion (A): A single lens produces a coloured image of an object illuminated by white light.

Reason (R):The refractive index of the material of lens is different for different wavelengths of light.

ANSWERS:

1.	A	21.	B	41.	A	61.	B
2.	C	22.	A	42.	A	62.	D
3.	A	23.	C	43.	B	63.	A
4.	A	24.	C	44.	A	64.	A
5.	D	25.	A	45.	C	65.	A
6.	B	26.	A	46.	B	66.	
7.	D	27.	B	47.	A	67.	
8.	C	28.	A	48.	A	68.	
9.	B	29.	A	49.	C	69.	
10.	B	30.	D	50.	C	70.	
11.	B	31.	C	51.	D	71.	
12.	D	32.	D	52.	A	72.	
13.	C	33.	A	53.	A	73.	
14.	B	34.	A	54.	C	74.	
15.	D	35.	A	55.	A	75.	
16.	C	36.	C	56.	A	76.	
17.	C	37.	A	57.	B	77.	
18.	D	38.	B	58.	D	78.	
19.	A	39.	A	59.	B	79.	
20.	D	40.	D	60.	A	80.	

CASE BASED QUESTIONS

1. The lenses forms different types of images when object placed at different locations. When a ray is incident parallel to the principal axis, then after refraction, it passes through the focus or appears to come from the focus.
When a ray goes through the optical centre of the lens, it passes without any deviation. If the object is placed between focus and optical center of the convex lens, erect and magnified image is formed.
As the object is brought closer to the convex lens from infinity to focus, the image moves away from the convex lens from focus to infinity. Also the size of image goes on increasing and the image is always real and inverted.
A concave lens always gives a virtual, erect and diminished image irrespective to the position of the object.

(i) The location of image formed by a convex lens when the object is placed at infinity is
(a) at focus (b) at 2F
(c) at optical center (d) between Fand 2F

(ii) When the object is placed at the focus of concave lens, the image formed is
(a) real and smaller (b) virtual and inverted
(c) virtual and smaller (d) real and erect

(iii) The size of image formed by a convex lens when the object is placed at the focus of convex lens is
(a) small (b) point in size
(c) highly magnified (d) same as that of object

(iv) When the object is placed at 2F in front of convex lens, the location of image is
(a) at F (b) at 2 F on the other side
(c) at infinity (d) between F and optical center

(v) At which location of object in front of concave lens, the image is formed between focus and optical centre
(a) anywhere between opticalcentre and infinity (b) at F
(c) at 2F (d) infinity

Answers:

i.	ii.	iii.	iv.	v.
A	B	c	B	A

2. Telescope

An instrument used to view distant objects clearly.

It consists of:- (a) Objective lens (b) Eyepiece

The telescope is used to provide angular magnification of distant objects. The objective has a large focal length and a much larger aperture than the eyepiece because object is very far away.

Light from a distant object enters the objective and a real and inverted image is formed at its second focal point.

This image acts as an object for the eyepiece; it magnifies this image producing a final inverted image.

Magnification

The magnifying power m is the ratio of the angle β subtended at the eye by the final image to the angle α which the object subtends at the lens or the eye.

Therefore, $m \approx (\beta / \alpha) \approx (h/f_e) \times (f_o/h) = (f_o/f_e)$.

In this case, the length of the telescope tube is $(f_o + f_e)$.

In addition, a pair of inverting lenses to make the final image erect.

Refracting telescopes can be used both for terrestrial and astronomical observations.

i)A small telescope has an objective lens of focal length 144cm and an eyepiece of focal length 6 cm.What is the magnifying power of the telescope?

A)240 B)24

C)2.4 D)0.042

ii)What is the separation between the objective and eye piece

A)144cm B)6cm

C)150cm D)138cm

iii)What is the nature of the final image formed in an astronomical telescope

A)virtual,magnified and erect w.r.t the object

B) virtual,magnified and inverted w.r.t the object

C) Real,magnified and inverted w.r.t the object

D) virtual,diminishedand inverted w.r.t the object

iv) Three lenses of focal length 5cm ,50cm and 60cm are to be used for making a telescope ,which lens will you use for objective

A)5cm B)50cm

c) either one of these D)60cm

v)What do you mean by normal adjustment of telescope?

A)when image is formed at least distance of distinct vision

B) when image is formed at a distance less than least distance of distinct vision

C)) when image is formed a infinite.

D)Both B and C

Answer:

i	ii	iii	iv	v
B	C	D	B	C

3. A compound microscope is an optical instrument used for observing highly magnified images of tiny objects. Magnifying power of a compound microscope is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye by the object, when both the final image and the object are situated at the least distance of distinct vision from the eye. It can be given that, $m=m_e \times m_o$ where m_e is magnification produced by eye lens and m_o is magnification produced by objective lens.

Consider a compound microscope that consists of an objective lens of focal length 2.0 cm and an eyepiece of focal length 6.25 cm separated by a distance of 15 cm.

(i)The object distance for eye-piece, so that final image is formed at the least distance of distinct vision, will be

(a) 3.45 cm
(b) 5 cm
(c) 1.29 cm
(d) 2.59 cm

ii) What is the magnifying power of the microscope in case of least distinct vision?

(a) 20
(b) 30
(c) 40
(d) 50

(iii) Magnification at least distance of distinct vision of a simple microscope of focal length 5 cm is

(a) 2
(b) 5
(c) 4
(d) 6

(iv) Magnification of a compound microscope is 30. Focal length of eyepiece is 5 cm and the image is formed at a distance of distinct vision of 25 cm. The magnification of the objective lens is

(4) 6
(b) 5
(c) 7.5
(d) 10

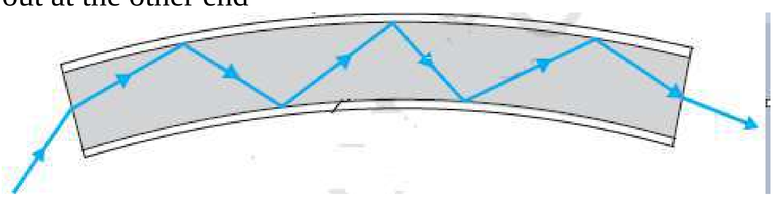
(v) In a simple microscope, if the final image is located at 25 cm from the eye placed close to the lens, then magnifying power is

(a) 25/f
(b) 1 + 25/f
(c) f/25
(d) f/25 + 1

Answer:

i	ii	iii	iv	v
B	A	D	B	B

4. Nowadays optical fibres are extensively used for transmitting audio and video signals through long distances. Optical fibres too make use of the phenomenon of total internal reflection. Optical fibres are fabricated with high quality composite glass/quartz fibres. Each fibre consists of a core (Inner) and cladding (outer).
When a signal in the form of light is directed at one end of the fibre at a suitable
angle, it undergoes repeated total internal reflections along the length of the fibre and finally comes out at the other end



Since light undergoes total internal reflection at each stage, there is no appreciable loss in the intensity of the light signal. Optical fibres are fabricated such that light reflected at one side of inner surface strikes the other at an angle larger than the critical angle. Even if the fibre is bent, light can easily travel along its length. Thus, an opticalfibre can be used to act as an optical pipe.

1. Light cannot escape an opticalfibre due to refraction. This is because:
a) Critical angle for core with reference to cladding is too large
b) Its critical angle for core with reference to cladding is too small
c) The core is transparent
d) Rays always enter at angle greater than critical angle.

2. For total internal reflection to take place
(a) the ray must go from rarer to denser medium.
(b) angle of incidence should be less than critical angle.
(c) the ray must go from denser to rarer medium.
(d) angle of incidence should be zero.

3. In optical fibre
(a) refractive index of core is kept less than that of cladding
(b) refractive index of core is kept more than that of cladding
(c) refractive index of core is equal to that of cladding
(d) refractive index of core is 1

4. If critical angle for core with reference to cladding is 60°. The refractive index of core with respect to cladding will be.
(a)23
(b) 32
(c) 2
(d) 12

5. If angle of incidence is greater than critical angle than
(a) very small amount of light refract to cladding.

(b) small amount of light gets reflected in core.
(c) total light is refracted into cladding
d) total light gets reflected in core.
Answer:

i.	ii.	iii.	iv.	v.
d	C	b	A	D

5. Astronomical Telescope

Astronomical telescope is made up of two lenses: objective lens and eyepiece separated by a certain distance to see heavenly bodies. The focal length of the objective lens of astronomical telescope is 80 cm and that of eye piece is 4 cm. The diameter of the moon is 3.0x105 km and the distance of of the moon from the Earth is 3.75x108 km.

(i) The final image formed by the astronomical telescope is:
(a) Real and inverted (b) Virtual and inverted
(c) Real and erect. (d) Virtual and erect

(ii) Magnifying power of the telescope is:
(a) 5 (b) 10
(c) 15 (d) 20

(iii) The length of the tube of the telescope is:
(a) 76 cm. (b) 86 cm
(c) 7.6 m. (d) 84 cm

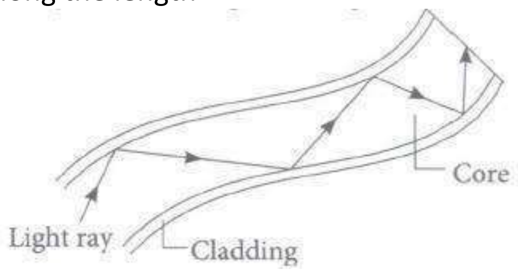
(iv) Angular size of the image of the moon is:
(a) 0.05 ° (b) 0.01°
(c) 0.1°. (d) 1°

(v) The magnifying power of telescope can be increased by using:
(a) Objective of large focal length.
(b) Objective of small focal length
(c) Eye lens of large focal length.
(d) All the above

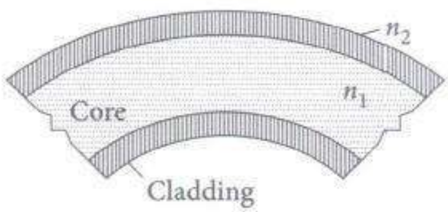
Answer:

i	ii	iii	iv	v
b	d	d	a	a

6. An optical fibre is a thin tube of transparent material that allows light to pass through, without being refracted into the air or another external medium. It make use of total internal reflection. These fibres are fabricated in such a way that light reflected at one side of the inner surface strikes the other at an angle larger than critical angle. Even, if fibre is bent, light can easily travel along the length



(i) Which of the following is based on the phenomenon of total internal reflection of light?
(a) Sparkling of diamond
(b) Optical fibre communication
(c) Instrument used by doctors for endoscopy
(d) All of these
(ii) A ray of light will undergo total internal reflection inside the optical fiber, if it
(a) goes from rarer medium to denser medium
(b) is incident at an angle less than the critical angle
(c) strikes the interface normally
(d) is incident at an angle greater than the critical angle
(iii) If in core, angle of incidence is equal to critical angle, then angle of refraction will be
(a) 0° (b) 45°
(c) 90^0(d) 180°
(iv) In an optical fibre (shown), correct relation for refractive indices of core and cladding is



(a) n1 = n2 (b) n1 > n2
(c) n1 < n2 (d) n1 + n2 = 2
(v) If the value of critical angle is 30° for total internal reflection from given optical fibre, then speed of light in that fibre is
(a) 3 x 108 m s^{-1}(b) 1.5 x 108 m s^{-1}
(c) 6 x 108 m s^{-1}(d) 4.5 x 108 m s^{-1}
Answer:

i	ii	iii	iv	v
d	d	c	b	b

7. A compound microscope is an optical instrument used for observing highly magnified images of tiny objects.Magnifying power of a compound microscope is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye by the object, when both the final image and the object are situated at the least distance of distinct vision from the eye. It can be given that:m=me×mo=me×mo where me is magnification produced by eye lens and mo is magnification produced by objective lens. Consider a compound microscope that consists of an objective lens of focal length 2.0 cm and an eyepiece of focal length 6.25 cm separated by a distance of 15 cm.

(i) The object distance for eye-piece, so that final image is formed at the least distance of distinct vision, will be
(a) 3.45 cm (b) 5.cm
(c) 1.29 cm (d) 2.59 cm

(ii) How far from the objective should an object be placed in order to obtain the condition described in part(i)?
(a) 4.5 cm (b) 2.5 cm
(c) 1.5 cm (d) 3.0 cm

(iii) What is the magnifying power of the microscope in case of least distinct vision?
(a) 20 (b) 30
(c) 40 (d) 10

(iv) The intermediate image formed by the objective of a compound microscope is
(a) real, inverted and magnified (b) real, erect, and magnified
(c) virtual, erect and magnified (d) virtual, inverted and magnified

(v) The magnifying power of a compound microscope increases with
(a) the focal length of objective lens is increased and that of eye lens is decreased
(b) the focal length of eye lens is increased and that of objective lens is decreased
(c) focal lengths of both objects and eyepiece are increased
(d) focal lengths of both objects and eyepieces are decreased.

Answer:

i	ii	iii	iv	v
b	b	a	a	b

8. Power (P) of a lens is given by reciprocal of the focal length (f) of the lens i.e., P= 1/f, where f is in meter and power is in diopter. Power a convex lens, power is positive and for a concave lens, power is negative. When a number of thin lenses of power P1, P2,P3,……. are held in contact with each other, the power of the combination is given by the algebraic sum of the power of all the lenses (P = P1+ P2+P3+…….).

1. Two convex lenses are separated by distance d and kept co-axially and then kept in contact co-axially with each other. The focal length of the combination
a) remains the same b) different
c) decreases d) none

2. If two lens of power +1.5D and +1.0D are place in contact, then the effective power of combination will be
a) 2.5 D b) 1.5 D
c) 0.5 d) 3.25 D

3. If the power of a lens is + 5D diopter, what is the focal length of the lens?
a) 10 cm b) 20 cm
c) 15 cm d) 5 cm

4. Two thin lenses of focal +10 cm and -5 cm are kept in contact. The power of the combination is
a) -10D b) -20D
c) 10 D d) 15 D

5. A convex lens of focal length 25 cm is place co-axially in contact with a concave lens of focal length 20 cm. The system will be
a) Converging in nature b) diverging in nature
c) a or b d) none

answer:

i.	ii.	iii.	iv.	v.
b	A	b	C	B

9. Total internal reflection is the phenomenon of reflation of light in denser medium at the interface of medium with a rarer medium. For this phenomenon to occur necessary condition is that light must travel from denser to rarer and angle of incidence is denser medium must be greater than critical angle (C) for the pair of media in contact. Critical angle depends on nature of medium and wavelength of light. We can show that $\mu = 1 / \sin(C)$.

1. Critical angle for glass air interface is……(where μ of glass is 3/2).
a) 41.8 deg b) 60 deg
c) 30 deg d) 15 deg

2. Critical angle for water air interface is 48.6 deg. What is the RI of water?
a) 1 b) 1.5
c) 1.3 d) 0.75

3. Critical angle for air water interface for violet colour is 49 deg. Its value for red colour would be
a) 49 deg b) 50 deg
c) 48 deg d) can not say

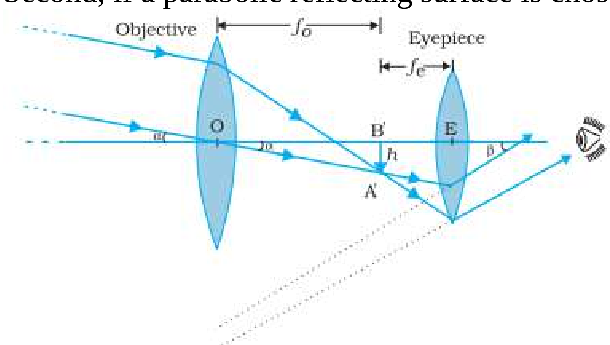
4. Which of the following is not due to total internal reflection?
a)Working of optical fiber
b) Difference between apparent and real depth of a pond.
c) Mirage on the hot summer days.
d) Brilliance of diamond.

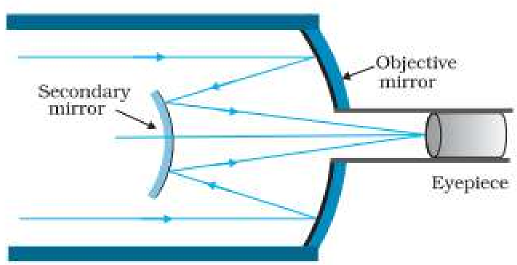
5. Critical angle of glass is θ_1 and that water θ_2. The critical angle for water and glass surface would be (μ_g =1.5 &μ_w = 1.3).
a) Less than θ_1 b) greater than θ_2
c) between θ_1 and θ_2 d) none

answer:

i.	ii.	iii.	iv.	v.
a	C	c	B	C

10. The telescope is used to provide angular magnification of distant objects. It also has an objective and an eyepiece. But here, the objective has a large focal length and a much larger aperture than the eyepiece. Light from a distant object enters the objective and a real image is formed in the tube at its second focal point. The eyepiece magnifies this image producing a final inverted image. The magnifying power m is the ratio of the angle β subtended at the eye by the final image to the angle α which the object subtends at the lens or the eye. The main considerations with an astronomical telescope are its light gathering power and its resolution or resolving power. The former clearly depends on the area of the objective. With larger diameters, fainter objects can be observed. The resolving power, or the ability to observe two objects distinctly, which are in very nearly the same direction, also depends on the diameter of the objective. So, the desirable aim in optical telescopes is to make them with objective of large diameter. Further, it is rather difficult and expensive to make such large sized lenses which form images that are free from any kind of chromatic aberration and distortions. For these reasons, modern telescopes use a concave mirror rather than a lens for the objective. Telescopes with mirror objectives are called reflecting telescopes. They have several advantages. First, there is no chromatic aberration in a mirror. Second, if a parabolic reflecting surface is chosen, spherical aberration is also removed.





i. An astronomical telescope consists of thin lenses,36cm apart and has a magnifying power 8. The focal lengths of objective and eyepiece are
a. Focal length of objective is 32cm and that of eyepiece is 4cm
b. Focal length of objective is 4 cm and that of eyepiece is 32cm
c. Focal length of objective is 8cm and that of eyepiece is 4cm
d. Focal length of objective is 4 cm and that of eyepiece is 8cm

ii. Two stars have an actual separation of one minute of arc. If the magnifying power of the telescope is 8 then the angle of separation as seen through telescope is
a. 1.65’ b. 1.85’
c. 4’ d. 8’

iii. The final image formed in an astronomical telescope with respect to the object is o
a. real, inverted
b. real, erect
c. virtual, erect
d. virtual, inverted

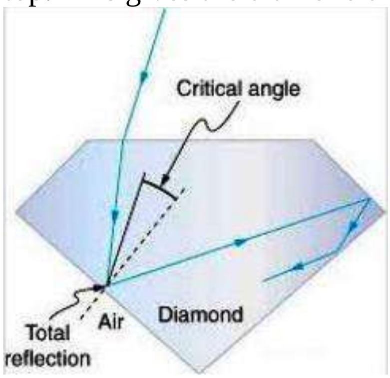
iv. The characteristic feature of light which remains unaffected on refraction is
a. Speed
b. Frequency
c. Wavelength
d. Velocity of light

v. An astronomical refracting telescope will have larger angular magnification and high angular resolution, when it has an objective lens of
a. Large focal length and large diameter
b. Large focal length and small diameter
c. small focal length and large diameter
d. Small focal length and small diameter

Answer:

a.	ii.	iii.	iv.	v.
a	D	d	B	A

11. Sparking Brilliance of Diamond: The total internal reflection of the light is used in polishing diamonds to create a sparking brilliance. By polishing the diamond with specific cuts, it is adjusted the most of the light rays approaching the surface are incident with an angle of incidence more than critical angle. Hence, they suffer multiple reflections and ultimately come out of diamond from the top. This gives the diamond a sparking brilliance.



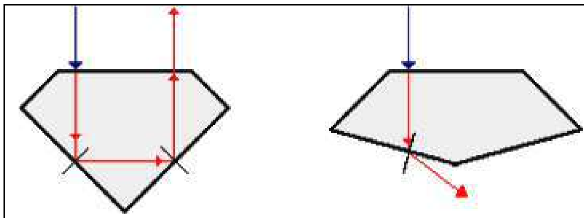
i. Light cannot easily escape a diamond without multiple internal reflections. This is because:
a) Its critical angle with reference to air is too large
b) Its critical angle with reference to air is too small
c) The diamond is transparent
d) Rays always enter at angle greater than critical angle

ii. The critical angle for a diamond is 24.4o. Then its refractive index is
a) 2.42
b) 0.413
c) 1
d) 1.413

iii. The basic reason for the extraordinary sparkle of suitably cut diamond is that
a) It has low refractive index
b) It has high transparency
c) It has high refractive index
d) It is very hard

iv. A diamond is immersed in a liquid with a refractive index greater than water. Then the critical angle for total internal reflection will
a) will depend on the nature of the liquid
b) decrease
c) remains the same
d) increase

v. The following diagram shows same diamond cut in two different shapes. The brilliance of diamond in the second diamond will be:



a) less than the first
b) greater than first
c) same as first
d) will depend on the intensity of light

Answer:

i.	ii.	iii.	iv.	v.
b	A	c	D	A

12.Optical fibres: Now-a-days optical fibres are extensively used for transmitting audio and video signals through long distances. Optical fibres too make use of the phenomenon of total internal reflection. Optical fibres are fabricated with high quality composite glass/quartz fibres and its refractive index about 1.7. Each fibre consists of a core and cladding. The refractive index of the material of the core is higher than that of the cladding. An optical fibre is a hair-thin long stand of quality glass or quartz surrounded by a glass coating of slightly lower refractive index. It is used as a guided medium for transmitting an optical signal from one place to another.

(i) Optical fibres are used for transmitting audio and video signals through long distances because ________

A. it is cheap
B. it is light weight
C. it is made by quartz
D. very little loss of energy.

(ii) The device which convert one form of energy into another is called ______
A. Rectifier
B. Diode
C. Oscillator
D. Transducer

(iii) The property of light that allows the functionality of an endoscope is ____
A. conservation of energy
B. conservation of momentum
C. light travel in straight path
D. Total internal reflection

(iv) Optical fibres are not useful for ______
A. Computer Networking
B. Surgery and dentistry
C. Internet
D. Haze Photography

(v) The outer concentric shell in fiber optic is called ________
A. cladding
B. core
C. coat
D. mantle

Answer

i.	ii.	iii.	iv.	v.
d	d	d	D	A

13. A compound microscope consists of two convex lenses-one acts as magnifying lens and is known as objective lens and another lens is called eyepiece. The two lenses work independently. Objective lens produces a magnified image of a tiny object O. This image is further modified by an eyepiece and the final image is magnified by an eyepiece and is seen at least distance of distinct vision or at infinity that depends on the position of object with respect to eyepiece.

Q1. What type of image is produced by an objective?
A. erect, virtual &diminished
B. Real, inverted &magnified
C. Real, inverted &diminished
D. virtual ,inverted& magnified

Q2. Where would the first image have to be produced by the objective lens relative to eyepiece such that second magnified image is formed at infinity?
A. At focus of Objective lens
B. At focus of eyepiece lens
C. Between focus and eyepiece
D. Between focus and objective lens

Q3. Where would the first image have to be produced by the objective lens relative to eyepiece such that second magnified image is formed on the same side of the eyepiece as the first image?
A. At focus of Objective lens
B. At focus of eyepiece lens
C. Between focus and eyepiece
D. Between focus and objective lens

Q4. What is the expression for magnifying power in normal adjustment position?
A. Dv_0/u_0f_e
B. $- Dv_0 /u_0f_e$
C. $1+ Dv_0 /u_0f_e$
D. $–v_0/u_0(1+D/f_e)$

Q5. What is the expression for magnifying power, when the image is formed at least distance of distinct vision (D)?
A. Dv_0 /u_0f_e
B. $- Dv_0 /u_0f_e$
C. $1+ Dv_0 /u_0f_e$
D. $–v_0 /u_0 (1+D/f_e)$

Answer:

i.	ii.	iii.	iv.	v.
b	b	c	B	D

14. the formula or equation giving relationship between the focal length (f) of lens ,refractive index of material of the lens (n) and radius of its surfaces (R1 & R2) is known as lens formula

$1/f = (n-1)/(1/R1 - 1/R2)$

i. The lens maker formula is based upon the assumption (analyzing ,evaluating and creating)
A. The aperture of the lens is small
B. The object is a point object and lies on the principal axis
C. The angle made by the incident ray & reflected ray with the principal axis.
a. (A)&(B)
b. (A)&(C)
c. (B)&(c)
d. (A),(B)& (C)

ii. A double concave lens of refractive index 1.6 has radii of curvature 40cm and 60cm.what will be its focal length. (Applying)
a. -40cm
b. +40cm
c. +60cm
d. -60cm

iii. A given convex lens of glass (n= 3/2) can behave as concave if it is held in a medium of refractive index n equals to(Applying)
a. 1
b. 3/2
c. 2/3
d. 7/4

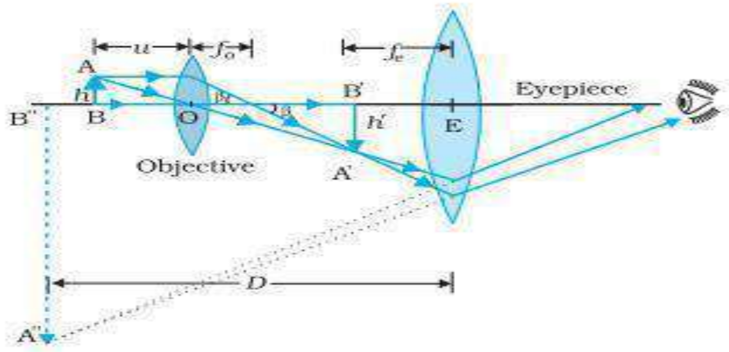
iv. Radius of curvature of a plano convex lens is 15cm and refractive index of the material of the lens is 1.4.the power of the lens in diopter is(Applying)
a. 1.6
b. 1.566
c. 2.4
d. 2.66

(v) An object is placed at the focus of concave lens having focal length f. What is the magnification and distance of the image from the optical centre of the lens?
(a) 1
(b) 1/4, f/4
(c) 1/2, f/2
(d) very high,

Answer:

i	ii	iii	iv	v
d	a	d	d	c

15. In order to have large magnifications compound microscope is used.



The lens nearest the object, called the objective, forms a real, inverted, magnified image of the object. This serves as the object for the second lens, the eyepiece, which functions essentially like a simple microscope or magnifier, produces the final image, which is enlarged and virtual.
The first inverted image is thus near (at or within) the focal plane of the eyepiece, at a distance appropriate for final image formation at infinity, or a little closer for image formation at the near point.
Clearly, the final image is inverted with respect to the original object.
Using tanβ = (h/f0) = (h'/L)
Magnification (mo) due to objective = (h'/h) =(L/f0)

i. The focal lengths of the objective and eye-lens of a microscope are 1 cm and 5 cm respectively. If the magnifying power for the relaxed eye is 45, then the length of the tube is (Applying)
a. 30cm
b. 25cm
c. 15cm
d. 12cm

ii. In a compound microscope magnification will be large, if the focal length of the eye piece is(analyzing ,evaluating and creating)
a. Large
b. Small
c. Greater than objective
d. Smaller than objective

iii. Microscope is an optical instrument which(Remembering& understanding)
a. Enlarges the object
b. Increases the visual angle formed by the object at the eye
c. Decreases the visual angle formed by the object at the eye
d. Brings the object nearer

iv. If in compound microscope m1 and m2 be the linear magnification of the objective lens and eye lens respectively, then magnifying power of the compound microscope will be (analyzing ,evaluating and creating)

a. m 1 – m 2

b. m 1 x m2

c. (m 1 + m 2) /2

d. (m 1 + m 2)1/2

(v) For compound microscope f_o = 1cm andf_e = 2.5cm . An object is placed at distance 1.2 cm from objective lens. What should be length of microscope for normal adjustment?

(4) 8.5 cm

(b) 8.3 cm

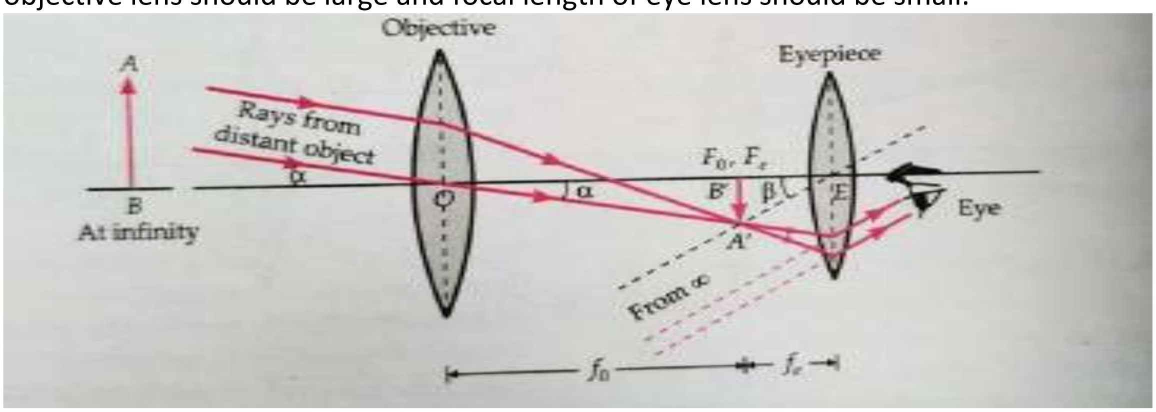
(c) 6.5 cm

(d) 6.3 cm

Answer:

i	ii	iii	iv	v
c	b	b	d	a

16. An astronomical telescope is an optical instrument which is used for observing distinct images of heavenly bodies like stars , planets etc. It consist of two lenses. In normal adjustment of telescope, the final image is formed at infinity. Magnifying power of an astronomical telescope in normal adjustment is defined as the ratio of the angle subtended at the eye by the final image as seen through the telescope to the angle subtended at the eye by the object seen directly, when both the object and the image are at infinity. The magnifying power is given by m =f0/fe. To increase magnifying power of an astronomical telescope in normal adjustment, focal length of objective lens should be large and focal length of eye lens should be small.



i. The magnifying power of an astronomical telescope in normal adjustment is 100. The distance between the objective and eye piece is 101cm. The focal length of the objective and eye piece are

A. 100 cm, 1 cm

B. 1 cm, 100 cm

C. 50 cm, 1 cm

D. 1 cm , 50 cm

ii. An astronomical telescope has magnifying power of 10.In normal adjustment position the distance between the objective and eye piece is 22cm. The focal length of the objective lens is
A. 10cm
B. 15cm
C. 20cm
D. 25cm

iii. To see distant object distinctly we used
A. Simple microscope
B. Compound microscope
C. Telescope
D. Endoscope

iv. In Astronomical telescope compare to eye piece, objective lens has
A. Small focal length
B. Large focal length
C. Negative focal length
D. Zero focal length

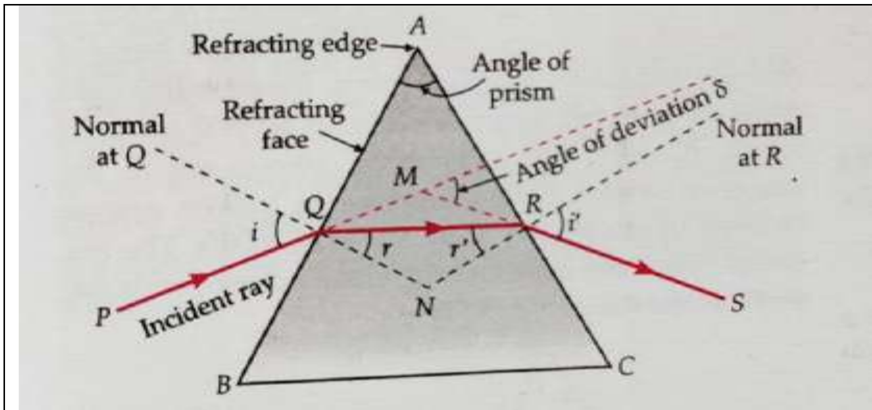
v. For large magnifying power of astronomical telescope
A. F0 <<fe
B. F0 = fe
C. F0 >>fe
D. None of these

Answer:

i.	ii.	iii.	iv.	v.
A	C	C	B	C

17. A prism is a transparent refracting body bounded by plane faces which are inclined to each other at a particular angle called angle of prism denoted by A . When a ray of light passes through a prism, it suffers refraction twice and hence the ray deviates through a certain angle from its original path. The angle between the incident ray and emergent ray is called angle of deviation D and is related as (i +e =A + D) where I = angle of incidence and e =angle of emergence. The angle of deviation is also related as D = (μ-1)A, where μ is refractive index of the material of prism. The refractive index of the material of the prism is also given by

μ == Sin (A+Dm)/2Sin A/2



i. When light passes through a prism, the angle of deviation will be minimum if

A. i = e

B. Angle of refraction , r = r'

C. Refracted ray inside the prism is parallel to the base of prism

D. All the above

ii. For which colourthe angle of deviation is minimum?

A. Red

B. Blue

C. Violet

D. Yellow

iii. The deviation through the prism is maximum when angle of incidence is

A. 45^0

B. 70^0

C. 90^0

D. 60^0

iv. The refractive index of the material of an equilateral prism for which the angle of minimum deviation $60^0$is

A. 1

B. 2

C. 3

D. 2

v. A ray of light incident on an equilateral glass prism shows minimum deviation of 30^0. The speed of light in that prism is

A. 3x108 m/s

B. 2.12x108 m/s

C. 2x108 m/s

D. 1.5x108 m/s

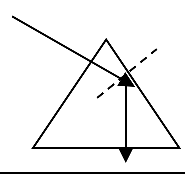
ANSWER:

i.	ii.	iii.	iv.	v.
D	A	C	C	B

ONE MARK QUESTIONS
1. How does the power of a convex lens vary, if the incident red light is replaced by violet light?
2. Define critical angle for total internal reflection.
3. You are provided with four lenses of focal lengths 1cm, 3cm, 10cm and 100cm. Which two would you prefer for a microscope and which two for a telescope?
4. An object is placed at the focus of concave lens. Where will its image be formed?
5. A ray of light is normally incident on one face of an equilateral prism. Trace the course of the ray through the prism and emerging from it.
6. One half of the reflecting surface of a concave mirror is coated with black paint. How will the image be affected?
7. Why a concave mirror is preferred for shaving?
8. Mirrors in search lights are parabolic and not spherical. Why?
9. An object is placed at the principal focus of a concave lens of focal length f. Where will its image be formed?
10. A prism of angle 60° gives a minimum deviation of 30°. What is the refractive index of the material of the prism?
11. An equi-convex lens has refractive index 1.5. Write its focal length in terms of radius of curvature R?
12. A mirror is turned through 15°. Through what angle will the reflected ray turn?
13. Velocity of light in a liquid is 1.5×10^{8} m/s and in air, it is 3×10^{8} m/s. If a ray of light passes from liquid into the air, calculate the value of critical angle.
14. Why does a convex lens of glass of refractive index 1.5 behave as a diverging lens when immersed in carbon disulphide of refractive index 1.65?
15. A ray if light is incident on a concave mirror after passing through its center of curvature. What is the value of angle of reflection?
16. A man stands in front of a mirror of special shape. He finds that his image has a very small head, a fat body and legs of normal size. What can we say about the shapes of the three arts of the mirror?
17. In which direction relative to the normal, does a ray of light bend, when it enters obliquely a medium in which its speed is increased?

18. For the same angle of incidence, the angles of refraction in three different media A,B and C are 15° ,25° and 35°,respectively. In which medium will the velocity of light be minimum?
19. For what angle of incidence, the lateral shift produced by a parallel sided galss slab is maximum?
20. If a plane glass slab is placed on letters of different colours, the red coloured letters appear more raised up. Why?
21. Does refraction in a water tank make apparent depth same throughout?
22. The critical angle for glass-air interface is ic. Will the critical angle for glass-water interface be greater than or less than ic?
23. An air bubble in a jar of water shines brightly. Why?
24. What happens to the shining of diamond if it is dipped in a transparent oil?
25. What type of a lens is a tumbler filled with water?
26. What type of a lens is an air bubble inside water? Give reason also.
27. A lens immersed in a transparent liquid is not visible. Under what condition can this happen?
28. A lens whose radii of curvature are different is forming the image of an object placed on its axis. If the lens is placed with its faces reversed, will the position of the image change?
29. What happens to focal length of a convex lens, when it is immersed in water ?
30. How does the focal length of a convex lens change if monochromatic red light is used instead of violet light?
31. The radii of curvature of both the surfaces of a lens are equal. If one of the surfaces is made plane by grounding, how will the focal length and power change?
32. A glass prism is held in water. How is the angle of minimum deviation affected?
33. A ray of light is normally incident on one face of an equilateral prism.Trace the course of the ray through the prism and emerging from it.

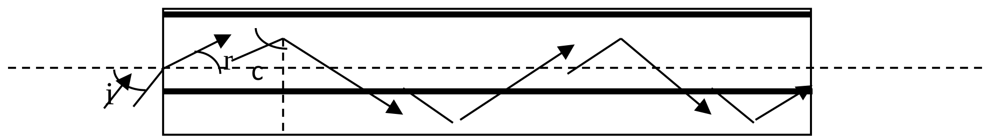
ANSWERS FOR ONE MARK QUESTIONS:

1. Power of lens increases.
2. Correct definition.
3. For microscope 1cm and 3cm; for telescope 100cm and 1cm.
4. At infinity.
5. 
6. Brightness decreases
7. Enlarged VIRTUAL
8. Produce intense parallel beam) eliminating spherical aberration
9. Given: u = -f, and for a concave lens f = - f,   v = ?
   a. Calculations: From lens formula, $\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$
   b. On substituting the values and on simplifying, we get, v = -f/2
   c. That is image will be formed between optical centre and focus of lens: towards the side of the object.

10. Given: A=60°, δ_m=30°, n = ?   a. Calculations: Use the formula, $n = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$ to get n = 1.41
11. Using the formula, $\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ we get, $\frac{1}{f} = (1.5-1)\left[\frac{1}{R} - \frac{1}{-R}\right] = \frac{1}{R}$ a. ∴ f = R
12. 30°, as the reflected ray turns through twice the angle through which mirror is turned.
13. n=c/v = 1/sinC , therefore, sinC = v/c =1.5 x 10^8 / 3 x 10^8 = 0.5   a. Now, C = $\sin^{-1}$ (0.5) = 30°
14. This is because $n = \frac{n_g}{n_c} = \frac{1.5}{1.65} < 1$ a. From lens maker's formula, 'f ' becomes negative. Therefore, the lens behaves as a diverging lens.
15. 0°. A ray of through center of curvature is incident normal to the surface of the mirror.
16. (i) The upper part of the mirror is convex.   ) The middle part of the mirror is concave.   .) The lower part of the mirror is plane.
17. The ray of light bends away from the normal.
18. As m = sini/sinr = c/v or v = sinr/sini *c   r a given angle of incidence, v ∝sinr, vA∝sin15° ,vB∝ sin25° , vC∝ sin35°   ıt sin15° < sin25°< sin35°.   A<vB<vC .   . the velocity of light is minimum in medium A.
19. For i = 90°, lateral shift is maximum and is equal to the thickness of the slab.   = t sin(i – r)/ cos r   ıax = t sin(90°- r)/cos r = t cos r/cos r = t.
20. The apparent shift caused by a slab of thickness 't' is given by   = t(1 -1/μ)   the refractive index of the galass is maximum for red light, so red coloured letters are more raised up.
21. No Apparent depth is maximum for that part of the bottom of the tank which is observed normally. Apparent depth decreases with increasing obliquity. Due to this unequal refraction, the flat bottom of the tank appears concave.
22. For glass-air interface, sin ic = 1/aμg   e critical angle i'c for glass water interface is given by   ı i'c = 1/ wμg   ɔw wμg<aμg   ı i'c> Sin ic or i'c>ic
23. Light entering water is totally reflected from the air bubble. For the observer, this light appears to come from the buble. So it shines.
24. As the critical angle for diamond-oil interface is greater than that for the diamond – air interface, so the shining of diamond reduces when it is dipped in a transparent oil.
25. It behaves like a biconvex lens.

26. Air bubble has spherical surface and is surrounded by medium (water) of higher refractive index. When light passes from water to air it gets diverged. So air bubble behaves as a concave lens.
27. When the refractive index of the liquid is same as the lens material, no light will be reflected by the lens and hence it will not be visible. μ
28. No, the image will be formed at the same position.From lens maker's formula, 1/f = (μ -1) [1/R1 –1/R2] , it is clear that when we interchangeR1 and R2, the magnitude of'f' remains the same
29. focal length'f' of a convex lens is related to its refractive index as : 1/(μ -1) wμg<aμg , so focal length of a convex lens will increase when it is immersed in water.
30. Focal length, f ∝ 1/(μ -1) As μR<μV , so the focal length of a convex lens will increase when red light is used.
31. For the original lens: R1 = +R and R2 = -R, so we can write = (μ -1) [1/R +1/R] = 2(μ -1)/R. hen one surface is made plane by grounding, we have R1 = +R and R2 = -∞ erefore, 1/f ' = (μ -1) [1/R +1/∞] =(μ -1)/R ' / f = 2 or f ' = 2f us the focal length becomes double and power becomes one –half.
32. When the prism is held in water, ıg = Sin (A + dm/2) /SinA/2 wμg<aμg , so the angle of minimum deviation decreases in water.
33. Total internal reflection.

TWO MARK QUESTIONS
1. An astronomical telescope uses two lenses of powers 10D and 1D. What is its magnifying power in normal adjustment?
2. Draw a ray diagram to show the formation of the image of an object by a compound microscope.
3. An illuminated object and a screen are placed 90cm apart. Determine the focal length and nature of the lens required to produce a clear image on the screen, twice the size of the object.
4. The near vision of an average person is 25cm. To view an object with an angular magnification of 10, what should be the power of the microscope?
5. An object is placed at a distance of 36cm from a convex mirror. A plane mirror is placed in a. between so that the two virtual images so formed coincide. If the plane mirror is at a distance b. of 24cm from the object, find the radius of curvature of the convex mirror.
6. Draw a ray diagram to show the formation of the image of an object by a compound microscope.
7. Derive an expression for the magnifying power of the telescope in normal adjustment.

8. Figure shows a cross-section of a 'light pipe' made of a glass fibre of refractive index 1.68. The outer covering of the pipe is made of a material of refractive index 1.44. What is the range of the angles of incident rays with the axis of the pipe for which total reflections inside the pipe take place as shown. 
9. A dentist uses a small concave mirror of focal length 16mm to view a cavity in the tooth of a patient by holding the mirror at a distance of 8mm from the cavity. Calculate the magnification.
10. Show that for a concave mirror, a virtual object forms a real image which is always diminished.
11. A point source of light is placed at the bottom of a lake with refractive index 4/3. Show that only 17% light can emerge out of the water surface.
12. Why does violet colour deviate more than red in prism?
13. Why is the focal length of an objective in compound microscope little shorter than the focal length of the eyepiece?
14. You are provided with four lenses of focal length 1 cm, 3cm, 10cm and 100cm. Which two would you prefer for a microscope and which two for a telescope?
15. Can we increase the range of a telescope by increasing the diameter of its objective?
16. A telescope has been adjusted for the relaxed eye. You are asked to adjust it for the least distance of distinct vision, then how will you change the distance between the two lenses?
17. The distances of an object and its real image, measured from the focus of a concave mirror, are a and b respectively. Show that f2 = ab.
18. A ray of light goes from medium 1 to medium 2. velocities of light in the two media are c1 and c2 respectively. For an angle of incidence q in medium 1, the corresponding angle of refraction in medium 2 is q/2. i. Which of the two media is optically denser and why? ii. Establish the relationship between q, c1 and c2.
19. A microscope is focused on a dot at the bottom of a beaker. Some oil is poured into the beaker to a height of y cm and it is found necessary to raise the microscope through a vertical distance of x cm to bring the dot again into focus. Express refractive index of oil in terms of x and y.
20. A ray of light while traveling from a denser to a rarer medium undergoes total reflection. Derive the expression for the critical angle in terms of the speed of light in the respective media.
21. Explain the twinkling of stars. Why do the planets not show twinkling effect?
22. Only the stars near the horizon twinkle while those overhead do not twinkle. Why?
23. Show that a convex lens produces an N times magnified image when the objet distances, from the lens, have magnitudes (f ± f / N). Here f is the magnitude of the focal length of the lens. Hence find the two values of object distance, for which a convex lens, of power 2.5D, will produce am image that is four times as large as the object?

24. Use the lens equation to deduce algebraically what you know otherwise from explicit ray diagrams. (a) An object placed within the focus of a convex lens produce a virtual and enlarged image. (b) A concave lens produces a virtual and diminished image independent of the location of the object.
25. A beam of white light on passing through a hollow prism gives no spectrum. Why?

ANSWERS FOR TWO MARK QUESTIONS

1. M = - $\frac{f_o}{f_e}$ = - $\frac{P_e}{P_o} = \frac{-10}{1} = -10$

2. Draw neat labelled diagram.

3. Given: u + v = 90cm ….. (i)
= |v| / |u| = 2 or |v| = 2 |u| ….. (ii)
om (i) and (ii), |u| = 30cm, |v| = 60cm
sign convention, u = - 30cm, v = 60cm
bstituting the values in equation $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ and after simplification we get,
20cm (convex lens)

4. Given: D = 25cm, M=10 , P =?
lculations: Using the formula, M = D / f , we get, f = D/M = 25/10 cm = 0.025m
w, P = 1 / f (in m) = 1 / 0.025m = 40D

5. The image formed by plane mirror should be at 24cm behind the mirror or 12cm behind the convex mirror. For no parallax between the images formed by the two mirrors, the image formed by the convex mirror should also be at I. Therefore, for convex mirror
-36cm, v =12cm. So, f = 18 cm and R = 36cm

6. Neat and labeled diagram.

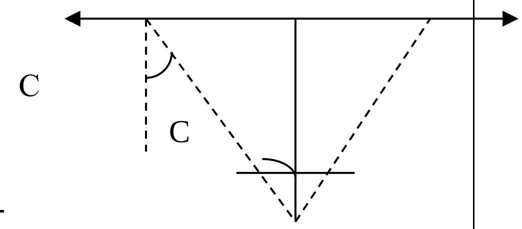
7. Correct ray diagram and derivation of the equation M = - f_o / f_e

8. Given: n_2 =1.68 , n_1 =1.44, i_{max} = ?
lculations: As n = $\frac{n_2}{n_1} = \frac{1}{sinC}$∴ sin C = $\frac{n_1}{n_2} = \frac{1.44}{1.68}$ = 0.8571 So, C = sin $^{-1}$ (0.8571) =59°
tal internal reflection would take place when i> C i.e., i>59° or when r<r_{max} , where
x= 90°- C = 90° - 59° = 31°
$\frac{Sin\,(i)_{max}}{Sin\,(r)_{max}} = 1.68$∴$Sin\,(i)_{max} = 1.68\,Sin\,(r)_{max}$ = 1.68 x sin 31° = 1.68 x 0.5156= 0.8662
$_{max}$ = sin $^{-1}$ (0.8662) = 60°

9. Given: u = -8mm, f = - 16mm, m = ?
lculations: $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-16} - \frac{1}{-8} = \frac{1}{16}$∴ v = 16 mm
w, |m| = v /u = 16/8 = 2

10. $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$. Here, 'u' is positive, 'f ' is negative, v =?
ving signs to u, v and f, we have $\frac{1}{v} + \frac{1}{u} = \frac{1}{-f}$ or v = $-\{\frac{f\,u}{f+u}\}$ which is negative.
so, |m| = |v /u| = $\frac{1}{\left[\frac{u}{f}+1\right]}$< 1 Hence, the image is diminished.

11. The fraction of light energy that can escape is the fraction
the solid angle which allows it to pass without total
ernal reflection.



t the critical angle be C, so that, $\sin C = \frac{1}{n}$ where 'n' is
the refractive index of water.

Fraction of solid angle $= \frac{2\pi}{4\pi}(1 - \cos C) = \frac{1}{2} - \frac{1}{2}\sqrt{1 - \sin^2 C}$

$= \frac{1}{2} - \frac{1}{2n}\sqrt{n^2 - 1} = \frac{1}{2} - \frac{1\times 3}{2\times 4}\sqrt{\left(\frac{4}{3}\right)^2 - 1}$ = 0.17= 17%

12. For a prism, $\delta = (n - 1)A$ and $n = a + \frac{b}{\lambda^2} + \frac{c}{\lambda^4} + \cdots$

13. This is done so that the objective lens forms image within the focal length of the eyepiece.

14. (i) We should take f0 =1 cm and fe = 3cm for a microscope.
) We should take f0 = 100 cm and fe = 1 cm for a telescope.

15. Yes, because the light gathering power of objective will increase and even faint objects will become visible.

16. For relaxed eye,
= f0 + fe (normal adjustment)
r least distance of distinct vision,
= f0 + ue ,ue<fe
erefore, L' < L. so that distance between the two lenses should be decreased.

17. Here u = - (f+a), v = -(f+b), f = -f
1/f = 1/u +1/v
= uv/ u + v
-f = [-(f+a)] x [-(f+b)] / -(f+a) – f(a+b)
2 + af +bf +ab / -(2f+a+b)
2 f2 + af +bf = f2 + af +bf +ab
f2 = ab

18. (i) Angle of refraction (θ/2) in medium 2 is less than the angle of incidence (θ) in medoum 1 i.e. the ray bends towards the normal in medium 2. so medium 2 is optically denser than medium 1.
) From Snell's law,
= sin i/sin r = sin θ/ sin θ/2 = 2sin θ/2 cos θ/2 /sin θ/2 = 2 cos θ/2
so μ = c1 / c2
nce 2 cos θ/2 = c1 /c2 or θ = 2cos-1(c1 / 2c2) .

19. Real depth = y cm
parent depth = y- x cm
fractive index of oil,
= real depth/ apparent depth = y / y-x

20. Using Snell's Law for refraction from glass to air, n i/sin r = gμa = v / c here c is the speed of light in air and v is the speed of light in glass, In the consition of critical incidence, we have ic and r = 900 Sin ic/ sin 900 = v / c or Sin ic = v / c ic = sin -1 (v / c)
21. Twinkling of stars. The light from stars undergoes refraction continuously before it reaches earth. So the apparent position of the stars is slightly different than its actual position. Due to variation in atmosphere conditions, like change in temperature, density etc., and this apparent position keeps on changing. The amount of light entering our eyes from a particular star increases and decreases randomly with time. Sometimes, the star appears brighter andother times, it appears fainter. This gives rise to the twinkling effect of stars. The planets do not show twinkling effect. As the planets are much closer to the earth, the greater and the fluctuations caused in the amount of light due to atmospheric refraction are negligible as compared to the amount of light received from them.
22. Ans. Light from the stars near the horizon reaches the earth obliquely through the atmosphere. Its path changes due to refraction. Frequent atmospheric disturbances change the path of light and cause twinkling of stars. Light from the stars overhead reaches the earth normally. It does not suffer refraction. There is no change in its path. Hence there is no Twinkling effect
23. Magnification produced by any lens, = v/u = f / f + u ven m = ± N ±N = f / f + u f + u = ± f / N or u = - f ± f / N nce magnitude of object distances, = f ± f / N ven P = 1/f = + 2.5 D 1/ 2.5 = 0.4 m = 40 cm so N = 4 = 40 ± 40/4 = 40 ± 10 = 50 cm or 30 cm.

24. (a) for a convex lens, f>>0 and for an object on left, u<0. when the object is placed within the focus of a convex lens,

$< |u| < f$ or $0 < 1/|u| > 1/f$

$= 1/f + 1/u = 1/f - 1/|u| < 0$

. v < 0 so a virtual image is formed on left.

w as u<0 and v<0, so $1/v = 1/f + 1/u$

$1/|v| = 1/f - 1/|u|$ or $1/|u| - 1/|v| = 1/f$

$f > 0$

$u| - 1/|v| > 0$ or $1/|u| > 1/|v|$ or $|u| < |v|$

. $|v| > |u|$ $|m| = |v/u| > 1$

nce image is enlarged.

) For a concave lens f<0 and for an object on left, u<0

$= 1/f + 1/u = 1/|f| - 1/|u|$

$[1/|f| + 1/|u|] < 0$ for all u.

. v<0 for all values of u. hence a virtual image is formed on the left.

so $1/|v| = 1/|f| + 1/|u|$ $1/|v| > 1/|u|$

$|v| < |u|$ $|m| = |v/u| < 1$

. the image is diminished in size.

25. A hollow prism contains air which does not cause dispersion. The faes AB and AC of the hollow prism behave like parallel sides of glass plates. The beam is laterally deviated at each of the two refracting faces. However, the rays of different colours emerge parallel to each other. So there is no dispersion.

3 MARK QUESTIONS

1.	Derive an expression for the magnifying power of the telescope in normal adjustment.
2.	Obtain an expression for the effective focal length of two thin lenses placed in contact coaxially with each other.
3.	A ray of light is incident at an angle of incidence 'i' on one surface of a prism of small angle 'A' and it is found to emerge normally from the opposite surface. If the refractive index of the material of the prism is 'n' , calculate the angle of incidence.
4.	The bottom of a container is a 4.0 cm thick glass. (m=1.5) slab. The container contains two immiscible liquids And B of depths 6.0 cm and 8.0 cm respectively. What is the apparent position of a scratch on the outer surface of the bottom of the glass slab when viewed through the container? Refractive indices of A and B are 1.4 and 1.3 respectively.
5.	The refractive index of water is 4/3. Obtain the value of the semivertical angle of the cone within which the entire outside view would be confined for a fish under water. Draw an appropriate ray diagram.
6.	A lens forms a real image of an object. The distance of the object to the lens is 4 cm and the distance of the image from the lens is v cm. The given graph shows the variation of v with u. (i) What is the nature of the lens? (ii) Using this graph, find the focal length of this lens.

7. A ray of light passes through an equilateral glass prism, such that the angle of incidence is equal to the angle of emergence. If the angle of emergence is ¾ times the angle of the prism, Calculate the refractive index of the glass prism.

8. Obtain an expression for the effective focal length of two thin lenses placed in contact coaxially with each other.

9. Using the data given below, state which two of the given lenses willbe preferred to construct a (i) telescope (ii) Microscope. Also indicatewhich is to be used as objective and as eyepiece in each case.

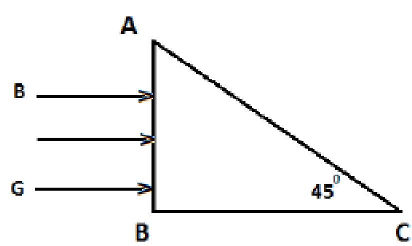
nses	Power (p)	Apetune (A)
	6 D	1 cm
	3 D	8 cm
	10 D	1 cm

10. A ray of light incident on the horizontal surface of a glass slab at 70° justgrazes the adjacent vertical surface after refraction. Compute the criticalangle and refractive index of glass.

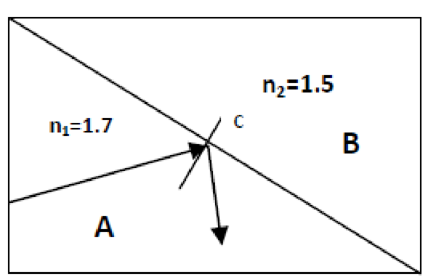
11. A convex and a concave mirror each of radius 10cm, are placed facing eachother and 15cm apart, as shown in figure. A point object is placed midwaybetween them. Find the position of the final image if the reflection takesplace first at the concave mirror and then at the convex mirror.

12. Explain with reason, how the resolving power of a compoundmicroscope will change when (i) frequency of theincident light on the objective lens isincreased. (ii) focal length of the objectivelens is increased. (iii) aperture of objectivelens is increased.

13. Three rays of light red (R) green (G) and blue (B) are incidenton the surface of a right angled prism as shown in figure.The refractive indices for the material of the prism for redgreen and blue are 1.39, 1.43 and 1.47 respectively. Tracethe path of the rays through the prism. How will thesituation change if the rays were falling normally on one ofthe faces of an equilateral prism?



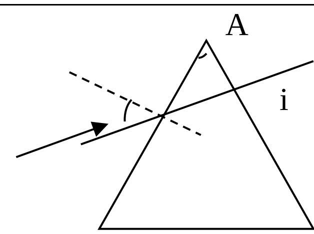
14. In the given diagram, a ray of light undergoes total internalreflection at the point C which is on the interface of twodifferent media A and B with refractive indices1.7 and 1.5respectively. What is the minimum value of angle ofincidence? Can you expect the ray of light to undergo totalinternal reflection when it falls at C at the same angle ofincidence while entering from B to A. Justify your answer?



15. For the same angle of incidence, the angles of refraction in three differentmedia A,B and C are 15° ,25° and 35°,respectively. In which medium will thevelocity of light be minimum?
16. A microscope is focused on a dot at the bottom of a beaker. Some oil is poured into the beaker to a height of y cm and it is found necessary to raise the microscope through a vertical distance of x cm to bring the dot again into focus. Express refractive index of oil in terms of x and y.

<u>ANSWERS OF 3 MARK QUESTIONS:</u>

1. **Labelled ray diagram and derivation.(Refer section important 3 & 5 marks derivations).**
2. Labelled ray diagram and derivation(Refer section important 3 & 5 marks derivations).
3. 3. For refraction through a prism: we have
    a. $\angle i + \angle e = \angle A + \angle \delta$
    b. But, $\angle e = 0$
    c. $\therefore \angle i = \angle A + \angle \delta$
    d. Also, $\delta = (n - 1)A$
    e. $\therefore \angle i = A + (n - 1)A = n A$
    C



4. The total apparent shift in the position of the image due to all the three media is
/en by
= t1[1-1/(μ1)+ t2[1-1/(μ2)+ t3[1-1/(μ3)
ven t1 = 4.0 cm,t2=6.0 cm , t3 =8.0 cm
= 1.5 , μ2=1.4 , μ3 =1.3 cm
4.0(1-1/1.5)+6.0(1-1/1.4)+8.0(1-1/1.3)
l.33 + 1.71 + 1.85 = 4.89 cm

5. Clearly , the fish can see the outside view of the cone with semi vertical angle,
t m = 1 / sin ic
1/3 = 1 / sin ic
sin ic = ¾ = 0.75
2 = ic = sin-1 (0.75) = 48.60

6. (i) As the lens forms a real iamge, it must be a convex lens.
) From the graph, when u=20 cm , we have v = 20 cm.
r the convex lens forming a real iamge, u is negative and v and f are positive.
= -20 cm v = +20cm
ing this lens formula,
' = 1/v – 1/u = 1/20 – 1/-20 = 1/10 or f = + 10 cm

7. $A=60^0$,$\delta m=30^0$
e = ¾ A = 45^0 ,
A + δ = i + e
\+ δ = 45 + 45
$\delta = 30^0$
fractive index,
= sin a+δm /2 /sin A/2 = sin 60^0+30^0/2 / sin 60^0/2
in 45^0/sin30^0 = 1/√2 / ½ = √2 = 1.414

8. refer important derivations for 3 & 5 marks

9. For telescope, lens L2 is chosen as objective as it aperture is largest,L3 is chosen as eyepiece as its focal length is smaller.For microscope lens L3 is chosen as objective because of its small focallength and lens L1, serve as eye piece because its focal length is notlarges.

10. From figure, for total internal reflection at B,

C = 90° , r = 90° - C

cording to Snell's law

= sin i/sin r = sin 70^0/sin (70^0 – C) = sin 70^0/cos C

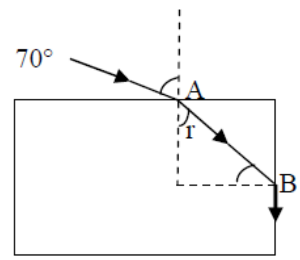
so, n = 1/sin C

, sin 70^0/cos C = 1/sin C or sin C/cos C = 1/ sin 70^0

tan C = 1/0.9397 = 1.0642

C = $\tan^{-1}$(1.0642) = $46^0 47'$

so n = 1/sin C = 1/ $46^0 47'$ = 1/0.7288 = 1.372



11. For the concave mirror

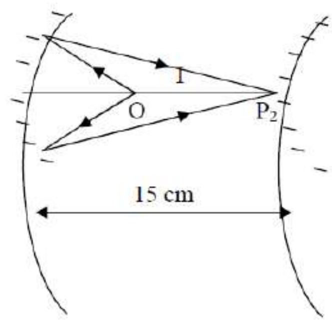
f = -10/2 = -5 cm, u=P_1O= -7.5cm

From mirror formula,

1/v = 1/f – 1/u = 1/-5 + 1/7.5 = - 1/15

Or v = -15cm, which is P_1I

Thus image of object is formed by concave mirror at the pole of convex mirror. Hence, final image is formed at the pole of convex 15 cm mirror, just behind P_2.



12. Resolving power (RP) of a compound microscope

(i) When frequency v increases, R.P. increases

(ii) R.P. does not change with change in focal length ofobjective lens.

(iii) When aperture increases, increases R.P. increases

13. Calculate the critical angle for each n=1/sinc, n increases cdecreases,diagram,blue light.

14. Use sin C = n_r /n_d = 0.88 and C=61.

so i=$61.8^{0.}$

no for TIR ray of light musttravel from denser to rarer from B to A

15. As m = sini/sinr = c/v or v = sinr/sini x c

For a given angle of incidence, v ∝ sinr, vA∝ sin15° , vB ∝sin25° , vC ∝ sin35°

But sin15° < sin25°< sin35°.

vA < vB < vC .

i.e. the velocity of light is minimum in medium A.

16. Real depth = y cm

Apparent depth = y- x cm

Refractive index of oil,

μ = real depth/ apparent depth = y / y-x

5 MARK QUESTIONS
1. Derive the relation between distance of object, distance of image and radius of curvature of a convex spherical surface, when refraction takes place from a rater medium of refractive index to a denser medium of refractive index and the image produced is real. State assumptions and convention of signs used.
2. (a)With the help of a neat labelled ray diagram derive anexpression for the refractive index of the material of prism.) A ray of light passes through an equilateral glass prism, such that the angle ofincidence is equal to the angle of emergence. If the angle of emergence is ¾ timesthe angle of the prism, Calculate the refractive index of the glass prism.
3. (a) With the help of a ray diagram, show the formation of image of apoint object by refraction of light at a convex spherical (convex)surface separating two media of refractive indices n1 and n2(n2> n1)respectively. Using this diagram, derive the relationAlso write the sign conventions used and assumptions. small object is placed 45 cm from a convex refracting surface of radius ofcurvature 15 cm. If the surface separates air from glass of refractive index 1.5,find the position of the image. Also, determine the first and second principalfocal lengths.
4. (a) With the help of a neat labelled ray diagram derive lens maker'sformula.) A ray of light goes from medium 1 to medium 2. velocities of light in the two media are v1 and v2respectively. For an angle of incidence q in medium 1, the corresponding angle of refraction in medium 2 is ɵ/2.(i) Which of the two media is optically denser and why?) Establish the relationship between ɵ, v1 and v2.
5. (a) With the help of a neat and labeled ray diagram, explain theworking of a compound microscope. Also derive an expression for itsmagnifying power.) Why is the focal length of an objective in compound microscope little shorter than the focal length of theeyepiece?
6. (a) Draw ray diagram for astronomical telescope with image at nearpoint. Derive expression for magnification.) A ray of light goes from medium 1 to medium 2. velocities of light in the two media are v1 and v2 respectively.For an angle of incidence q in medium 1, the corresponding angle of refraction in medium 2 is ɵ/2. Which of the two media is optically denser and why?) Establish the relationship between ɵ, v1 and v2.

ANSWERS TO 5 MARK QUESTIONS
1. Labelled ray diagram and derivation. (Refer section important 3 & 5 marks derivations).

2. (a)Labelled ray diagram and derivation. (Refer section important 3 & 5 marks derivations).

) $A=60^0$,$\delta m=30^0$

e = ¾ A = 45^0

A + δ = i + e

\+ δ = 45 + 45

$\delta = 30^0$

fractive index,

= sin a+δm /2 /sin A/2 = sin $60^0+30^0/2$ / sin $60^0/2$

in $45^0/\sin 30^0$ = 1/√2 / ½ = √2 = 1.414

3. (a) Labelled ray diagram and derivation. (Refer section important 3 & 5 marks derivations).

) Distance of object, u = -45 cm

dius of curvature, R = +15 cm

= 1.5

= 1

the object lies in the rarer medium

/v – μ1/u = μ2 – μ1/ R

5/v] – [1/(-45)] = 0.5/15

l/30

5/v = 1/30 – 1/45

5/v = 1/90

= 135 cm

erefore position of the image would be at 135 cm.

rst principal focal length is given by

= - μ1R/[μ2–μ1]

\- (1×15)/0.5

-30 cm

cond principal focal length is given by

= - μ2R/[μ2–μ1]

\- (1.5×15)/0.5

-45 cm

om the above observation we conclude that, the first focal length would be at distance -30 cm

d second focal length would be at distance -45 cm.

4. (a)Labelled ray diagram and derivation. (Refer section important 3 & 5 marks derivations).
se (i): When the image is real,
= -4
, v/u = -4 or v = -4u
ɔw, 1/f = 1/v – 1/u
, 1/20 = – (1/4u) – (1/u)
- (1/u) [1+(1/4)]
, 1/20 = – (5/4u)
, u = (-20)× (5/4)
-25 cm
ɔm the above observation we conclude that, the distance of the object if the image
tained is magnified 4 times would be -25 cm.
se (ii): When the image is virtual, m = +4
, v/u = +4 or v = +4u
gain, 1/f = 1/v – 1/u
(1/4u) – (1/u)
, 1/20 = (1/u) [(1/4) – 1]
20 = -(3/4u)
, u = (-20) (3/4) = -15 cm
ɔm the above observation we conclude that, the distance of the object if the image
tained is magnified 4 times would be -15 cm.

5. (a)Labelled ray diagram and derivation. (Refer section important 3 & 5 marks derivations).
). This is done so that the objective lens forms image within the focal length of the eyepiece.

6. (a)Labelled ray diagram and derivation. (Refer section important 3 & 5 marks derivations).
). (i) Angle of refraction (θ/2) in medium 2 is less than the angle of incidence (θ) in medoum 1 i.e. the ray bends towards the normal in medium 2. so medium 2 is optically denser than medium 1.
) From Snell's law,
= sin i/sin r = sin θ/ sin θ/2 = 2sin θ/2 cos θ/2 /sin θ/2 = 2 cos θ/2
so μ = c1 / c2
nce 2 cos θ/2 = c1 /c2 or θ = 2cos-1(v1 / 2v2) .

SELF ASSESSMENT PAPER

SUBJECT:PHYSICS THEORY

Ray optics and Optical instruments

Maximum marks:70 **Time allowed:3 hours**

General Instructions:

(i) The Question paper contains 45 questions. All questions are compulsory.

(ii) The question paper is divided in to 7 sections: Section A, B,C,D,E ,F and G.

(iii) Section A–Question numbers 1 to 16 are Multiple Choice (MCQ) type questions. Each question carries 1 mark.

(iv)Section B-Question numbers 17 to 19 are Very Short Answer type questions. Each question carries 2 marks.

(v)Section C-Question numbers 20 to 24 areVery Short Answer type questions. Each question carries 1 mark.

(vi)Section D-Question numbers 25 and 26 are Case Based type questions. Each question carries 4 marks.

(vii)Section E -Question numbers 27 and 28 are Short Answer type questions. Each question carries 3 mark.

(viii)Section F-Question numbers 29 to 42 are Multiple Choice (MCQ) type questions. Each question carries 1 mark.

(ix)Section G-Question numbers 43 to 45 areLong Answer type questions. Each question carries 5marks.

(x)There is no overall choice. However, an internal choice has been provided in few questions in all sections except Section A and Section F.

(xi) Use of calculator is NOT allowed.

Section A

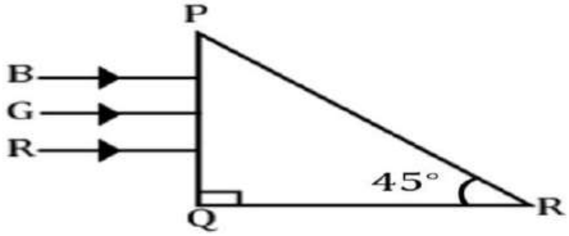
1. In order to increase the angular magnification of a simple microscope, one should increase
(i) The object size
(b) The aperture of the lens
(c) The focal length of the lens
(d) The power of the lens

2. A converging lens of focal length f is used as simple microscope. If the least distance of distinct vision of the observer is Dand the lens is held close to the eye, the magnifying power of the lens is
(a) D / 2 f
(b) f/D
(c)(D/f)-1
(d)D/f

3. Magnification of a compound microscope is 30. Focal length of eyepiece is 5 cm and the image is formed at a distance of distinct vision of 25 cm. The magnification of the objective lens is
(a) 6
(b) 5
(c) 7.5
(d) 10

4.The wavelength of sodium light in air is 5890 Å The velocity of light in air 3 x10^8 m /s .The wavelength of light in a glass of refractive index 1.6 would be close to a) 5890^0 A. (b) 3681^0 Á (c) 9424^0 À (d) 1507^0 Å
5. What will be the magnifying power and length of an astronomical telescope whose objective is of 3 m focal length and eyepiece is of 1.25 cm focal length? (a) 240 and 120 cm (b) 240 and 301.25 cm (c) 301.25 and 240 cm (d) 240 and 150 cm
6. If an object is placed at a distance of 10 cm in front of a concave mirror of focal length20 cm, the image formed will be (a)real and 20cm in front of the mirror (b) real and6.67cm in front of the mirror © virtualand 20cm in behind the mirror (d) virtualand 6.67cm in behind the mirror
7. The magnifying power of a telescope is 9. When it is adjusted for parallel rays, the distance between the objective and the eyepiece is found to be 20 cm. The focal length of lenses is (a) 18 cm. 2 cm. (c) 10 cm, 10 cm (b) 11 cm, 9.cm (d) 15 cm, 5 cm
8. An astronomical telescope of tenfold angular magnification has a length of 44 cm. The focal length of the objective lens is (a) 4 cm (6) 44 cm (c) 40 cm (d) 440 cm
9. A telescope with objective of focal length 60 cm and eyepiece of focal length 5 cm is focused on a far of distance object such that parallel rays emerge from the eyepiece. If object subtends an angle of 2^0 on the objective, angular width of the image will be (4) 10° (b) 30° (c) 24° (d) 60
10. A ray of light is incident on the surface of separation of a medium with velocity of light at an angle 45^0 and is refracted in the medium at an angle $30^{0.}$ What will be the velocity of light in the medium? (a) 1.96 x10^{3} m / s (b) 3.18 x10^{8}m / s (c) 2.12 x 10^8 m / s (d) 3.3 x 10^{8} m / s

11. Three rays of light, namely red (R), green (G) and blue (B) are incident on the face PQ of a right angled prism PQR as shown in the figure. The refractive indices of the material the prism for red,



green, blue wavelengths are 1.27, 1.42 and 1.49, respectively. The color of the ray(s) emerging out of the face PR is
(a) blue
b) red
(c) green
(d) blue and green

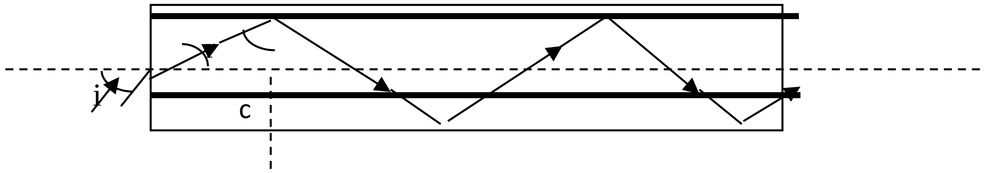
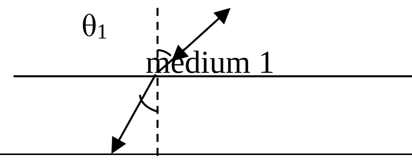
12. A convex lens is making full image of an object. If half of lens is covered by an opaque object, then
(a) half image is not seen
(b) full image of same intensity is seen
(c) half image of same intensity is seen
(d) full image of decreased intensity is seen.

For questions number 13 to 16, wo statements are given one labeled Assertion (A) and the do 16 labeled Reason (R). Select the correct answer to these questions from the codes (A), (B), (C) and (D) as given below:
(A) If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(B) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).
(C) If Assertion (A) is true and Reason (R) is false.
(D) If both Assertion (A) and Reason (R) are false.

13.Assertion. The edges of the images of white object formed by a concave mirror on the screen appear white.
Reason. Concave mirror does not suffer from chromatic aberration.
14. Assertion: A total reflecting prism is used to erect the inverted image without deviation.
Reason:Rays of light incident parallel to base of prism emerge out as parallel rays.
15. Assertion: If objective and eye lenses of a microscope are interchanged, then it can work as telescope.
Reason: The objective lens of a telescope has small focal length
16.Assertion : The refractive index of diamond is $\sqrt{6}$ and that of liquid is $\sqrt{3}$. If the light travels from diamond to the liquid, it will totally reflect when the angle of incidence is 30^0.
Reason: $\mu = 1/\sin C$ where μ is the refractive index of diamond with respect to liquid.

SECTION B

17.An illuminated object and a screen are placed 90cm apart. Determine the focal length and nature of the lens required to produce a clear image on the screen, twice the size of the object.

18.Figure shows a cross-section of a 'light pipe' made of a glass fibre of refractive index 1.68. The outer covering of the pipe is made of a material of refractive index 1.44. What is the range of the angles of incident rays with the axis of the pipe for which total reflections  OR Light of wavelength $\lambda_1$propagates from medium 1 incident at angle θ_1. The angle inside medium 2 is θ_2 . What is its wavelength in medium 2? 
19.(a) A prism of angle 60° gives a minimum deviation of 30°. What is the refractive index of the material of the prism?
(b).An equi-convex lens has refractive index 1.5. Write its focal length in terms of radius of curvature .
SECTION C
20. An object is placed at the principal focus of a concave lens of focal length f. Where will its image be formed?
21.A concave lens of refractive index 1.5 is immersed in a medium of refractive index 1.65.What is the nature of the lens? OR When light travels from an optically denser medium to a rarer medium, why does the critical angle of incidence depend on the colour of light ?
22.The focal length of an equiconvex lens is equal to the radius of curvature of either face. What is the refractive index of the material of the lens ?
23.An astronomical telescope uses two lenses of powers 10D and 1D. What is its magnifying power in normal adjustment?
24. Draw a ray diagram for the formation of image of an object by a convex mirror.
SECTION D
CASE BASED QUESTIONS

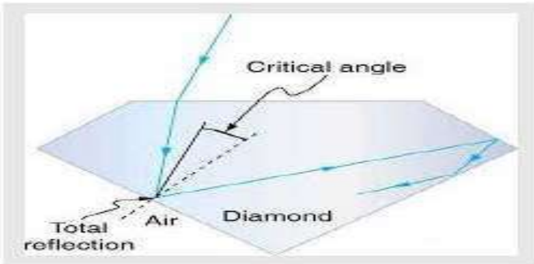
25.

Visible light consists of different colors, specially the colors of the rainbow, and these colors together constitute white. Each color has certain wavelength and frequency.Starting with violet that has the lowest wavelength(higher frequency) to red with highest wavelength(lowest frequency).When light enters a

medium it bends (refracts)-in letter L we explained why light refracts-so when light enters a glass, each wavelength of light refracts with certain angle.Because different wavelengths of light travel through a medium at different speeds. In which short wavelength light travels more slowly and bends with greater angle compared to long wavelengths.

(i) A light wave of frequency ‘ν’ and wavelength ’λ’ travels from air to glass. Then,
(a) ‘ν’ changes.
(b) ‘ν’ does not change, ‘λ’ changes.
(c) ‘λ’ does not change.
(d) ‘ν’ and ‘λ’ change.
(ii) A beam of monochromatic light is refracted from vaccum into a medium of refractive index 1.5. The wavelength of refracted light will be
(a) same
(b) dependent on intensity of refracted light
(c) larger
(d) smaller
(iii)How does the frequency of a beam of ultraviolet light change when it goes from air into glass prism?
(a)increases(b)decreases
(c)remains same (d)none of the above
(iv).A glass prism is held in water. How is the angle of minimum deviation affected?
(a) Decreases (b) increases
(c) remains same (d) none of the above.
OR
iv) The angle of prism is 60^0 and angle of deviation is 30^0. In the position of minimum deviation, the angle of incidence ‘i’ and angle of emergence ‘e’ are
(a) $i=45^0, e=50^0$ (b) $i=30^0, e=45^0$
(c) $i=45^0, e=45^0$ (d) $i=30^0, e=30^0$.

26.



The total internal reflection of the light is used in polishing diamonds to create a sparking brilliance. By polishing the diamond with specific cuts, it is adjusted the most of the light rays approaching the surface are incident with an angle of incidence more than critical angle. Hence, they suffer multiple reflections and ultimately come out of diamond from the top. This gives the diamond a sparking brilliance.

1. Light cannot easily escape a diamond without multiple internal reflections. This is because:
a) Its critical angle with reference to air is too large
b) Its critical angle with reference to air is too small
c) The diamond is transparent
d) Rays always enter at angle greater than critical angle

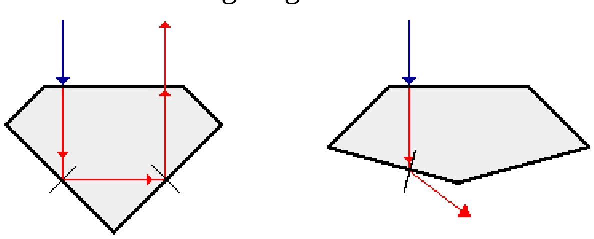
2. The critical angle for a diamond is 24.4o. Then its refractive index is-
a) 2.42
b) 0.413
c) 1
d) 1.413

3. The basic reason for the extraordinary sparkle of **suitably cut** diamond is that
a) It has low refractive index
b) It has high transparency
c) It has high refractive index
d) It is very hard

4. A diamond is immersed in a liquid with a refractive index greater than water. Then the critical angle for total internal reflection will
a) will depend on the nature of the liquid
b) decrease
c) remains the same
d) increase

OR

4. B The following diagram shows same diamond cut in two different shapes.



Velocity of light in diamond, glass and water decreases in the following order
(a) Water > glass > diamond

(b) Diamond > glass > water
(c) Diamond water > glass
(d) Water > diamond > glass

SECTION E

27.A small illuminated bulb is at the bottom of a tank, containing a liquid of refractive index up to a height H. Find the expression for the diameter of an opaque disc, floating symmetrically on the liquid surface in order to cut-off the light from the bulb.
OR
Define Total internal reflection. What are the conditions for the total internal reflection to take place?

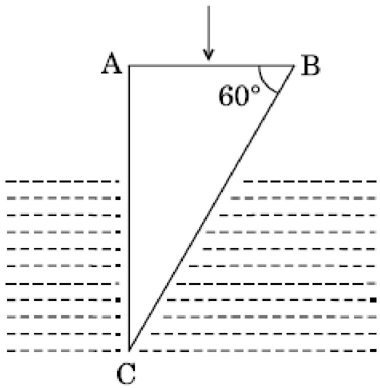
28. Draw a graph to show the angle of deviation d with the angle of incidence i for a monochromatic ray of light passing through a prism of refracting angle A. Deduce the relation
OR
Obtain an expression for the effective focal length of two thin lenses placed in contact coaxially with each other.

SECTION F

29.(a) With the help of a neat labeled ray diagram derive lens marker's formula.
(b) A small object is placed 45cm from a convex refracting surface of radius of curvature 15cm. If the surface separates air from glass of refractive index 1.5, find the position of the image.
OR
(a) With the help of a neat and labelled ray diagram, explain the working of a compound microscope. Also derive an expression for magnifying power.
(b) The magnifying power of an astronomical telescope in normal adjustment is 100 and distance between objective and eye lens in 101cm. Find the focal length of objective and eye piece.

30.

(a) A ray of light is incident normally on the face AB of a right-angled glass prism of refractive index $_a\mu_g = 1.5$. The prism is partly immersed in a liquid of unknown refractive index. Find the value of refractive index of the liquid so that the ray grazes along the face BC after refraction through the prism.



(b) Trace the path of the rays if it were incident normally on the face AC.

(c) Double-convex lenses are to be manufactured from a glass of refractive index 1.55, with both faces of the same radius of curvature. What is the radius of curvature required if the focal length of the lens is to be 20 cm?

OR

a) State two main considerations taken into account while choosing the objective of astronomical telescope.

b) Draw a ray diagram of reflecting type telescope. State its magnifying power.

c) State the advantages of reflecting type telescope over the refracting type?

31.a)Derive the relation between distance of object, distance of image and radius of curvature of a Convex spherical surface, when refraction takes place from a rarer medium of refractive index to a denser medium of refractive index and the image produced is real. State assumptions and convention of signs used.

b)A thin converging lens of focal length 10 cm and thin diverging lens of focal length 20 cm are place coaxially in contact. The power of the combination is

OR

(a)Derive an expression for the magnifying power of the telescope in normal adjustment.

(b)You are provided with four lenses of focal lengths 1cm, 3cm, 10cm and 100cm. Which two would you prefer for a microscope and which two for a telescope ?

SECTION G

32. What is the focal length f of the convex lens in the liquid whose refractive index is equal to refractive index of lens? a) f=0 b) f=infinity c) f=100 cm d) f=1/1.47 cm
33. What is the refractive index of the material of the lens? a)1.33 b)1.47 c)1/1.47 d) 1.003
34. How does the power of the lens vary, if the incident red light is replaced by violet light? a) decreases b) increases c) remains same . d) slightly decreases
35. A converging lens is placed in contact with another diverging lens of same focal length. What is the focal length of the combination? a) 2f b) f/2 c) 0 d) infinity
36. When light passes from air to the lens, what happens to the frequency of the light ? a) Increases b) Decreases c) Remains the same. d) In some media frequency increases and in some other media decreases.
37. The refractive index of a converging lens is 1.4. What will be the focal length of this lens if it is placed in a medium of same refractive index? (Assume the radii of curvature of the faces of lens are R_1 and R_2respectively). (a) $(R_1R_2)/(R_1 - R_2)$ (b) zero (c) 1 d) infinite

38. For a given lens, the magnification was found to be twice as large as when the object was 0.15 m distant from it as when the distance was 0.2 m. The power of the lens is
(a) 1.5D
(b) 20D
(c) 10 D
(d) 15D

39. The astronomical telescope consists of objective and eyepiece. The focal length of the objective is
(a) equal to that of the eyepiece
(b) shorter than that of the eyepiece
(c) greater than that of the eyepiece
(d) five times shorter than that of eyepiece

40. Magnification at least distance of distinct vision of a simple microscope of focal length 5 cm is
(a) 2
(b) 5
(c) 4
(d) 6

41. A good plane mirror reflects 95% of light. What percentage of light reflected when passed through a totally internally reflecting prism?
(a)100% (b)95%
(c)90% (d)0%

42. In a simple microscope, if the final image is located at 25 cm from the eye placed close to the lens, then magnifying power is
a)25/f
b)1+(25/f)
c)f/25
d) 25/f+1

43.For the same angle of incidence, the angles of refraction in three different media A, B and C are 15^0,$25^0$and 35^0respectively. In which medium will the velocity of light be minimum?
a) A
b) B
c) C
d) None of these

44. For compound microscope f_0=1 cm, f_e =2.5 cm. An object is placed at distance 1.2 cm from objective lens. What should be length of microscope for normal adjustment?
a) 8.3 cm
(b) 8.5 cm
(c) 6.5 cm
(d) 6.3 cm

(45) The focal length of the objective and eyepiece of a telescope are respectively 100 cm and 2 cm. The moon subtends angle of 0.5°, the angle subtended by the moon's image will be
(a) 10^0
(b) 25^0
(c) 100^0
(d) 75°

SELF ASSESSEMENT PAPER – MARKING SCHEME RAY OPTICS AND OPTICAL INSTRUMENTS

1.c
2.d
3.a
4.b
5.b
6.c
7.a
8.c
9.c
10.b
11.b
I3.a
14.c
15.a
16.d

17. Given: u + v = 90cm ….. (i)
m = |v| / |u| = 2 or |v| = 2 |u| ….. (ii)
From (i) and (ii), |u| = 30cm, |v| = 60cm
By sign convention, u = - 30cm, v = 60cm
Substituting the values in equation $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ and after simplification we get f = 20cm (convex lens)

18. Given: n_2=1.68 , n_1 =1.44, i_{max} = ?

lculations: As $\mu = \mu\ \frac{\mu_2}{\mu 1} = \frac{1}{sinC} \therefore sinC = \frac{n_1}{n_2} = \frac{1.44}{1.68}$ = 0.8571 So, C = $\sin^{-1}$ (0.8571) =59°

tal internal reflection would take place when i> C i.e., i>59° or when r <r_{max} , where

$_x$ = 90°- C = 90° - 59° = 31°

$\frac{Sin\ (i)_{max}}{Sin\ (r)_{max}} = 1.68 \therefore Sin\ (i)_{max} = 1.68\ Sin\ (r)_{max}$ = 1.68 x sin 31° = 1.68 x 0.5156= 0.8662

$_{nax}$ = $\sin^{-1}$ (0.8662) = 60°

OR

18. Snell's law says, $v_2 \sin\theta_1 = v_1 \sin\theta_2$

e ratio of wavelengths is equal to the ratio of the speeds of light.

$\therefore \lambda_1/\lambda_2 = v_1/v_2$

velength in medium 2, $\lambda_2 = (\sin\theta_2 / \sin\theta_1)\ \lambda_1$

---

19. (a) n = sin(A + D) / 2 / (sin(A / 2)) where n is the refractive index at a wavelength A, D is the angle of minimum deviation, and A is the internal angle of the prism in question given that

A = 60^0 . D = 30^0

n = sin 45^0 / (sin 30^0)

= 1 / √2 / 1 / 2

= 2 / √2

n = √2

(b) f = R

---

20. Infinity

---

21. Diverging lens

OR

Different colors have different wavelength.

22.1/f = μ − 1 /(1/ R1 − 1/R2) Ans:μ = 1.

---

23. M = - 10

---

24. draw neat labelled diagram

25i)b

ii)d

iii)c

iv) A. a

OR

iv) B. c

---

26 i) b

(ii)a

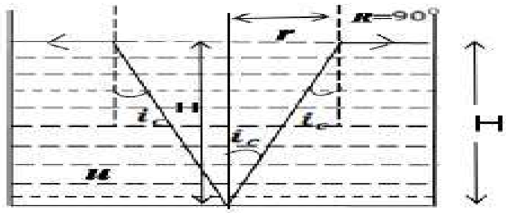
iii)c

iv) A. d

OR

iv) B. a

27



is only the light coming out from a cone of semi
rtical angle i_c ($i_c = \sin^{-1}\frac{1}{\mu}$ = critical angle) that
eds to be stopped by the opaque disc

Now $\sin i_c = \frac{1}{\mu}$

$\therefore \cos i_c = \sqrt{1 - \frac{1}{\mu^2}}$

Also $\tan i_c = \frac{r}{H}$

$$\Rightarrow r = H \tan i_c = H \frac{\sin i_c}{\cos i_c}$$

$$= H.\frac{\frac{1}{\mu}}{\sqrt{1 - \frac{1}{\mu^2}}}$$

$$r = \frac{H}{\sqrt{\mu^2 - 1}}$$

Diameter of the opaque disc $= 2r$

$$= \frac{2H}{\sqrt{\mu^2 - 1}}$$

OR

Definition, write two conditions.

28. Draw neat labeled diagram and derivation.

OR

Draw neat labeled diagram and derivation.

29. (a) Draw neat labeled diagram and derivation.

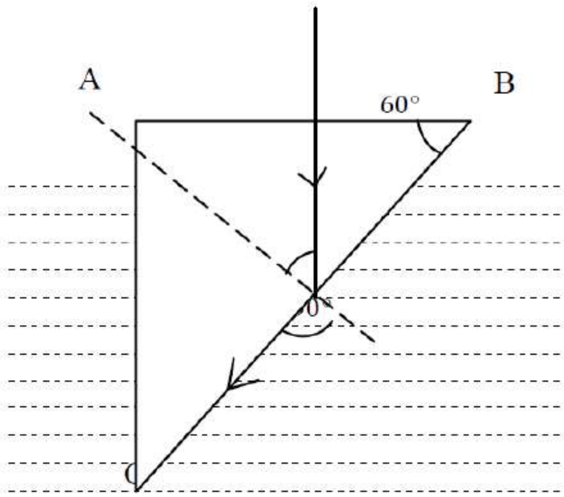
(b) v = 135cm.

OR

a) Draw neat labeled diagram and derivation

b)f=1cm

a)



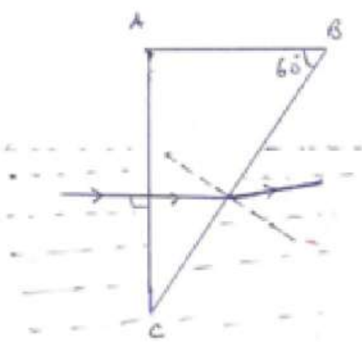
$$sini_c = \frac{1}{\mu_{mg}} = \frac{\mu_m}{\mu_g}$$

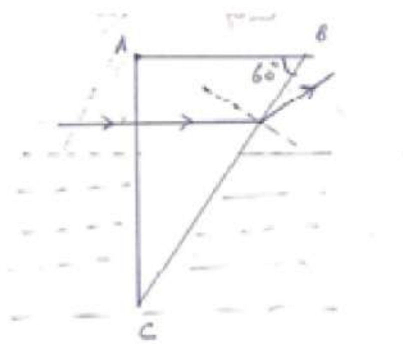
⇨ $\mu_m = \mu_g sini_c$

$=1.5 \times \frac{\sqrt{3}}{2} \quad (i_c = 60°)$

$= 1.299 \simeq 1.3$

(b)





Alternatively

30.
(c) f_1 = 30 cm
OR
a)Two considerations, neat labeled diagram& differences

31. (a) Draw neat labeled diagram and derivation.
(b) P = +5D
OR
(a) Draw neat labeled diagram and derivation.
(b) For microscope 1cm and 3cm; for telescope 100cm and 1cm.

32. b

33. b
34. b
35. d
36.c
37. d
38. c
39. c
40 .d
41. a
42.b
43. a
44. b
45. b

****

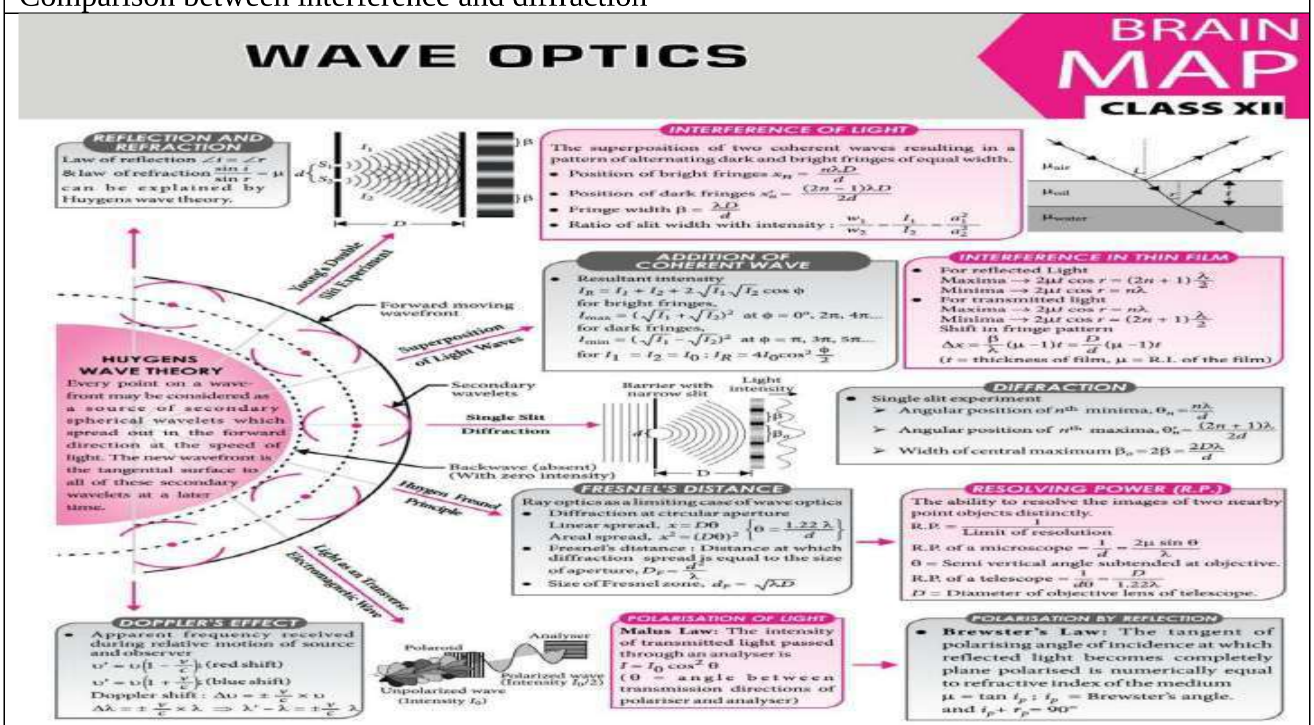
10. WAVE OPTICS

Contents:

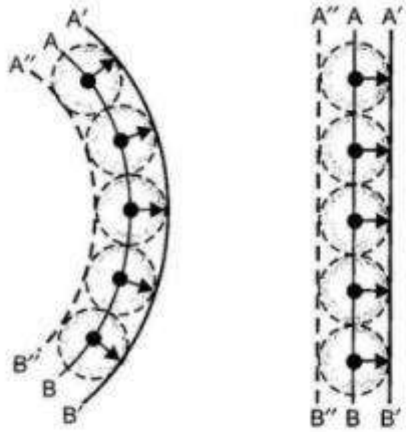
Huygen's theory of Wavefront
Reflection and Refraction by Huygen's theory
Behaviour of light waves with respect to Mirrors, lenses and prism
Superposition principle of light waves
Young's double slit experiment(YDSE)
Diffraction of light by double sit

Gist of the lesson :

Wavefront, Huygen's explanation of wavefronts
Reflection of light waves proving reflection properties by wave theory
Refraction of light, explanation by using Huygen's theory
Interference of light
Superposition principle
YDSE, Experiment explanation of YDSE with mathematical analysis
Different conditions that effect fringe width in YDSE and its justification with graphical representation
Diffraction
Single slit
Mathematical explanation of diffraction
Comparison between interference and diffraction

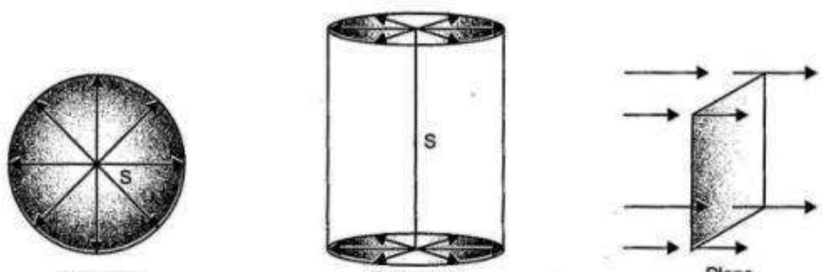


1. Wave Optics: Describes the connection between waves and rays of light. According to wave theory of light, light is a form of energy which travels through a medium in the form of transverse wave.
2. Wave front: The locus of all those particles which are vibrating in the same phase at any instant is called wave front. Thus, wave front is a surface having same phase of vibrating particles at any instant at every point on it.
3. Phase Speed: Phase speed is the speed with which wave front moves and it is equal to wave speed.
4. The shape of wavefront due to a (i) point source is spherical (ii) line source is cylindrical (iii) source at infinity is a plane.
5. A line perpendicular to a wave front is called a ray. The direction of rays are always perpendicular to the wave front along the direction of propagation of wave.
UYGEN'S WAVE THEORY :
stulates:
1. Light travels in a medium in the form of wavefronts i.e., the locus of all the particles of the medium which are vibrating in the same phase.
2. Every point on a given wavefront called primary wavefront acts as a new source of disturbance called as secondary wavelet which travels in all directions with the velocity of light in that medium.
3. A surface touching these secondary wavelets tangentially in forward direction given the new wavefront called as secondary wavefront.



4. Types of wavefronts:

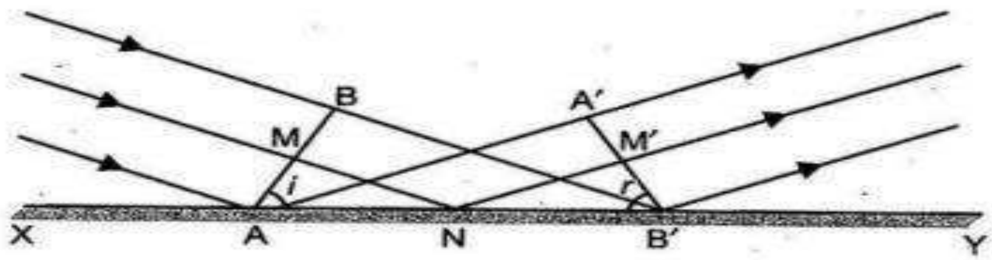
1. Spherical wavefront: When the source of light is a point source, the wavefront is a sphere with source at centre.
2. Cylindrical wavefront: When the source of light is linear, then all the points equidistant from source will form a cylindrical wavefront.
3. Plane wavefront : When the point source or the linear source of light is at very large distance then a small portion of spherical or cylindrical wavefront appears to be plane such a wavefront is called as a plane wavefront.



Spherical wavefront (a) Cylindrical wavefront (b) Plane wavefront (c)

Reflection by Huygen's principle:

Let a plane wavefront ABC is incident on a plane mirror M_1M_2 at angle of incidence I . The normal rays on the wavefront will show the direction of its propagation. According to Huygen's principle, every point of the wavefront will be a source of secondary wavelets. Initially (at t= 0), a wavelet originates from 'A' and travel in the medium with a velocity 'v'. When the last point C of the wavefront reaches at the surface after a time of 't' seconds, then the wavelet originated from A has travelled a distance 'vt'. In the meantime, each point on the surface will be a source of secondary wavelets. The envelope/locus of all the secondary wavelets will be the reflected wavefront.



Consider

Δ ABB' and Δ A A' B

A B' = A B'

B B' = A A' = vt

$\angle ABB' = \angle AAB' = 90^0$

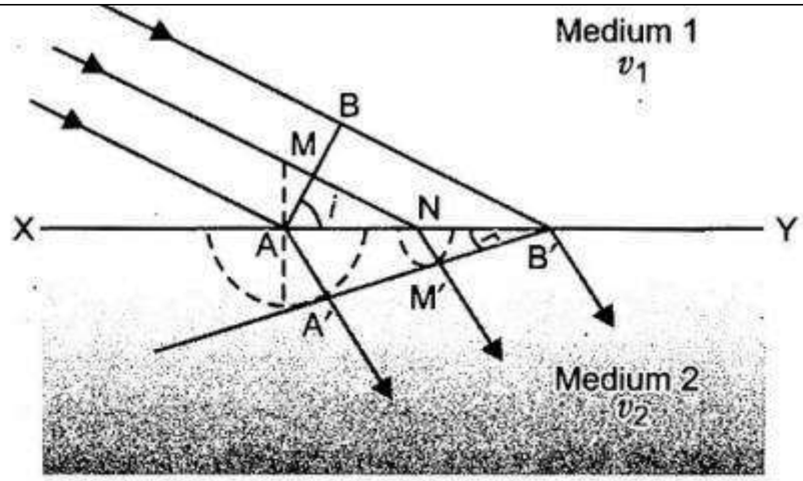
$\therefore \Delta ABB' = \Delta AA'B'$

$\therefore \angle BAB' = \angle A'B'A$

$\therefore \angle i = \angle r$

Refraction on the basis of Wave theory:

Let us consider a plane wavefront AMB travelling from rarer to denser medium. If v_1 is the speed in the rarer medium and v_2 in the denser medium, then $v_2 < v_1$. Let this wavefront strike the surface at an angle i. According to Huygen's principle , every point of the wavefront AMB will be a source of secondary wavelets. Initially, at t = 0, a wavelet originates from A and will travel with the speed v_2 in the denser medium. If the time taken by the point B of the incident wavefront to reach the surface is t seconds, then $BB^I = v_1t$ and $AA^I = v_2t$. In the meantime, each point of the surface will be a source of secondary wavelets and the envelope of all the secondary wavelets will be the refracted wavefront and angle of refraction 'r'.



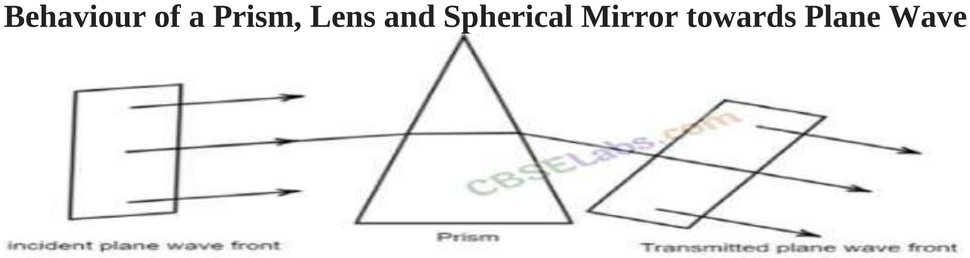
$\frac{\sin i}{\sin r}$ = constant = $_1\mu_2$

$$\frac{\frac{BB^I}{AB^I}}{\frac{AA}{AB^I}} = \frac{V_1\, t}{v_2 t}$$

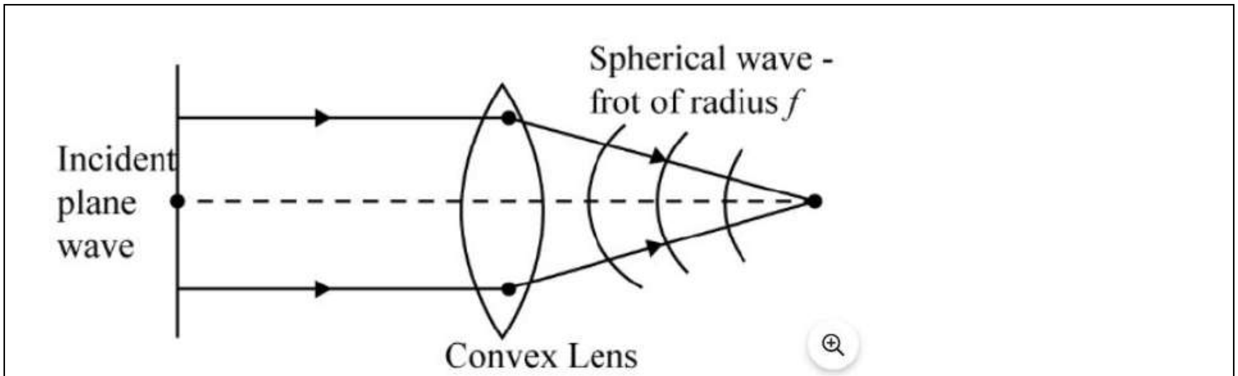
$\therefore \frac{\sin i}{\sin r} = \frac{V_1}{v_2}$ = constant = $_1\mu_2$

1. The laws of reflection and refraction can be verified using Huygens' wave theory.
2. Huygens' wave theory successfully explains the phenomenon of interference, diffraction and polarisation.
3. As, frequency v is characteristic of the source, therefore v = 1/T remains the same as light travels from one medium to another.
4. Wavelength is inversely proportional to refractive index (μ) of the medium i.e. λ' = λ/μ

Behaviour of a Prism, Lens and Spherical Mirror towards Plane Wave front



a) A plane wave front passing through prism



Interference : The phenomenon of interference takes place when two waves of same /different amplitude, same frequency and travelling in the same direction with a constant phase difference superimpose on each other, then alternate maximas and minimas are observed on a screen.

Principle of superposition: When two or more waves travelling in a medium reach at a point at the same time, then the resultant displacement at that point is the vector sum of individual displacements. $\vec{y} = \vec{y_1} + \vec{y_2} + \cdots \dots\dots\dots + \vec{y_n}$

Coherent Sources: The sources of light which emit light waves of same wavelength, same frequency and in the same phase difference are called coherent sources.
The necessary conditions for the interference to take place is that the two sources should be coherent. Two independent sources of light can't be coherent because a constant phase difference can't be maintained in two different sources.
Therefore the coherent sources are those which are produced from the same source so that the phase difference will always remain zero.

$Y_1 = A_1 \sin(\omega t)$ (initial phase zero)

$Y_2 = A_2 \sin(\omega t+\phi)$ (initial phase ϕ)

Phase difference = ϕ

According to principle of superposition $y = y_1 + y_2$

$Y = A_1 \sin(\omega t) + A_2 \sin(\omega t+\phi)$

$Y = A_1 \sin(\omega t) + A_2 \sin(\omega t) \cos\phi + A_2 \cos(\omega t) \sin\phi$

$Y = \sin(\omega t)[A_1 + A_2 \cos\phi] + A_2 \cos(\omega t) \sin\phi$

Let $[A_1 + A_2 \cos\phi] = A\cos\Theta$ …………………(1)

and $A_2 \sin\phi = A \sin\Theta$ ……………………………..(2)

$Y = A \sin(\omega t)\cos\Theta + A\cos(\omega t)\sin\Theta$

$Y = A \sin(\omega t + \Theta)$

Squaring and adding (1) and (2)

$$A_1^2 + A_2^2\cos^2\phi + 2A_1A_2\cos\phi + A_2^2\sin^2\phi = A^2$$

$A_1^2 + A_2^2 + 2A_1A_2\cos\phi = A^2$……………………………(3)

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2cos\phi}$$

Divide (2) by (1)

$\frac{A_2 sin\phi}{A_1 + A_2 cos\phi}$ = tanΘ, Θ being the phase difference

Maxima (constructive interference)

Amplitude A should be maximum when

$\cos\phi = +1$

$\cos\phi = \cos 0, \cos 2\pi, \cos 4\pi, \ldots\ldots$

$\cos\phi = \cos 2n\pi$ (phase difference $\phi = 2n\pi$)

Minima (Destructive interference)

$\cos\phi = -1$

$\cos\phi = \cos\pi, \cos 3\pi, \cos 5\pi \ldots\ldots$

$\cos\phi = \cos(2n+1)\pi$ (phase difference $\phi = (2n+1)\pi$)

$A_{max} = A_1 + A_2$ and $A_{min} = A_1 - A_2$

Intensity $_{max} \propto (A_1+A_2)^2$ and Intensity $_{min} \propto (A_1-A_2)^2$

$$\frac{I_{max}}{I_{min}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2}$$

For wave having same amplitude

$A_{max} = 2A$ and $A_{min} = 0$

As intensity is proportional to the square of amplitude equation (3) turns out to be

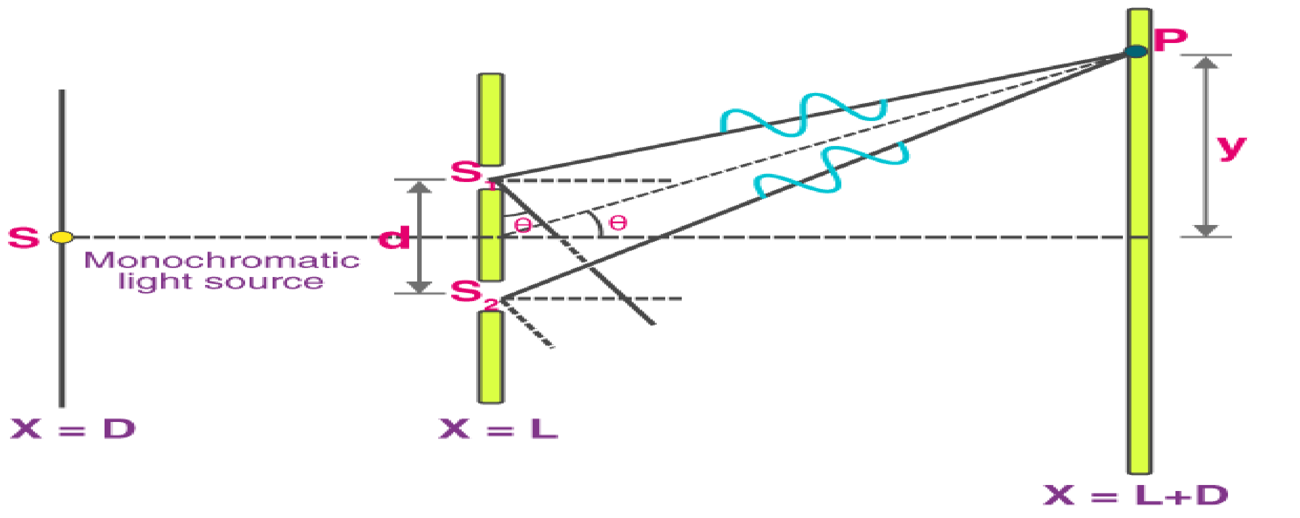
$I_{net} = I_1 + I_2 + 2\sqrt{I_1 I_2}\, cos\phi$, if phase difference $\phi = 0$ then $I_{net} = I_1 + I_2$

$\phi = 90^0$ then $I_{net} = I_1 - I_2$

Young's double slit experiment: (YDSE)

Consider a monochromatic light source 'S' kept at a considerable distance from two slits: s_1 and s_2. S is equidistant from s_1 and s_2. s_1 and s_2 behave as two coherent sources as both are derived from S. The light passes through these slits and falls on a screen which is at a distance 'D' from the position of slits s_1 and s_2. 'd' is the separation between two slits.

If s_1 is open and s_2 is closed, the screen opposite to s_1 is closed, and only the screen opposite to s_2 is illuminated. The interference patterns appear only when both slits s_1 and s_2 are open.



When the slit separation (d) and the screen distance (D) are kept unchanged, to reach P, the light waves from s_1 and s_2 must travel different distances. It implies that there is a path difference in Young's double slit experiment between the two light waves from s_1 and s_2.

Approximations in Young's double slit experiment

- **Approximation 1:D > > d:** Since D > > d, the two light rays are assumed to be parallel.
- **Approximation 2: d/λ >> 1:** Often, d is a fraction of a millimetre, and λ is a fraction of a micrometre for visible light.

Under these conditions, θ is small. Thus, we can use the approximation $\sin\theta = \tan\theta \approx \theta = \lambda/d$.

∴ path difference, $\Delta z = \lambda/d$

This is the path difference between two waves meeting at a point on the screen. Due to this path difference in Young's double slit experiment, some points on the screen are bright, and some points are dark.

Now, we will discuss the position of these light and dark fringes and fringe width.

Position of Fringes in Young's Double Slit Experiment

Position of Bright Fringes

For maximum intensity or bright fringe to be formed at P,

Path difference, $\Delta z = n\lambda$ (n = 0, ±1, ±2, ...)

i.e., $xd/D = n\lambda$ (or) $x = n\lambda D/d$

The distance of the n^{th} bright fringe from the centre is

$x_n = n\lambda D/d$

Similarly, the distance of the $(n-1)^{th}$ bright fringe from the centre is

$x_{(n-1)} = (n-1)\lambda D/d$

Fringe width, $\beta = x_n - x_{(n-1)} = n\lambda D/d - (n-1)\lambda D/d = \lambda D/d$, $(n = 0, \pm1, \pm2, \ldots)$

Position of Dark Fringes

For minimum intensity or dark fringe to be formed at P,

Path difference, $\Delta z = (2n + 1)(\lambda/2)$ $(n = 0, \pm1, \pm2, \ldots)$

i.e., $x = (2n+1)\lambda D/2d$

The distance of the n^{th} dark fringe from the centre is

$x_n = (2n+1)\lambda D/2d$

Similarly, the distance of the $(n-1)^{th}$ bright fringe from the centre is

$x_{(n-1)} = (2(n-1)+1)\lambda D/2d$

Fringe width, $\beta = x_n - x_{(n-1)} = (2n + 1)\lambda D/2d - (2(n-1) + 1)\lambda D/2d = \lambda D/d$

$(n = 0, \pm1, \pm2, \ldots)$

Fringe Width

The distance between two adjacent bright (or dark) fringes is called the fringe width.

$\beta = \lambda D/d$

If the apparatus of Young's double slit experiment is immersed in a liquid of refractive index (μ), then the wavelength of light and fringe width decreases 'μ' times.

$\beta_1 = \frac{\beta}{\mu}$

If white light is used in place of monochromatic light, then coloured fringes are obtained on the screen, with red fringes larger in size than violet.

Angular Width of Fringes

Let the angular position of n^{th} bright fringe is θ_n, and because of its small value, $\tan\theta_n \approx \theta_n$

$\tan\theta_n = \frac{n\lambda}{d}$ and $\theta_n = \frac{n\lambda}{d}$

Similarly, the angular position of $(n+1)^{th}$ bright fringe is θ_{n+1}, then $\theta_{n+1} = \frac{(n+1)\lambda}{d}$

∴ The angular width of a fringe in Young's double slit experiment is given by,

$\Theta = \theta_{n+1} - \theta_n = \frac{(n+1)\lambda}{d} - \frac{n\lambda}{d} -= \frac{\lambda}{d}$

Hence $\Theta = \frac{\lambda}{d}$

We know that $\beta = \lambda D/d$

Therefore $\Theta = = \frac{\beta}{D}$

Angular width is independent of 'n', i.e., the angular width of all fringes is the same.

Maximum Order of Interference Fringes

The position of n^{th} order maxima on the screen is

$Y = \frac{n\lambda D}{d}$, n=0,±1,±2,..

But 'n' values cannot take infinitely large values as it would violate the 2^{nd} approximation.

i.e., θ is small (or) y < < D

$\frac{Y}{D} = \frac{n\lambda}{d} << 1$

Hence, the above formula for interference maxima is applicable when

$n << \frac{d}{\lambda}$

When the 'n' value becomes comparable to d/λ, path difference can no longer be given by dγ/D.

Hence for maxima, path difference = nλ

⇒ d sinΘ = nλ

⇒ $n = \frac{d \sin\theta}{\lambda}$

$n_{max} = (\frac{d}{\lambda})$

The above represents the box function or greatest integer function.

Similarly, the highest order of interference minima

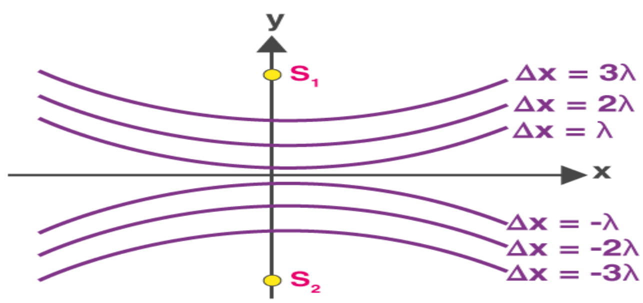
$n_{min} = (\frac{d}{\lambda} + \frac{1}{2})$

The Shape of Interference Fringes in YDSE

From the given YDSE diagram, the path difference between the two slits is given by

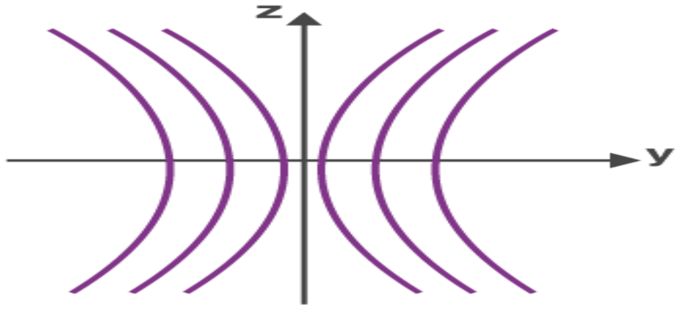
$S_2P \approx S_1P = d \sin\Theta$

The above equation represents a **hyperbola** with its two foci as, s_1 and s_2

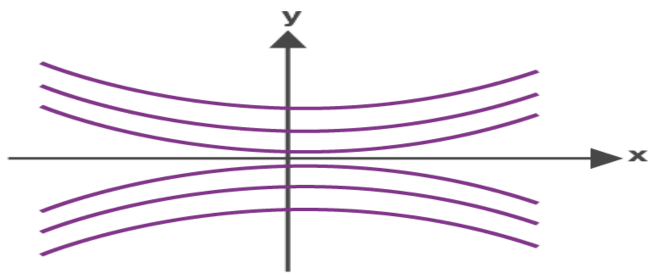


The interference pattern we get on the screen is a section of a hyperbola when **we** revolve the hyperbola about the axis s_1s_2.

If the screen is a yz plane, fringes are hyperbolic with a straight central section.



If the screen is xy plane, the fringes are hyperbolic with a straight central section.



The Intensity of Fringes in Young's Double Slit Experiment

For two coherent sources, s_1 and s_2, the resultant intensity at point *p* is given by

$I = I_1 + I_2 + 2\sqrt{(I_1 . I_2)}\cos\varphi$

Putting $I_1 = I_2 = I_0$ (Since, d<<<D)

$I = I_0 + I_0 + 2\sqrt{(I_0.I_0)}\cos\varphi$

$I = 2I_0 + 2(I_0)\cos\varphi$

$I = 2I_0(1 + \cos\varphi)$

$I = 4I_0\cos^2(\frac{\phi}{2})$

For maximum intensity

$\cos(\frac{\phi}{2}) = \pm1$; $(\frac{\phi}{2}) = n\pi$, $n = \pm1, \pm2, \pm3, \pm4$…………..

or $\varphi = 2n\pi$

phase difference $\varphi = 2n\pi$

Then, **path difference**

$\Delta x = \frac{\lambda}{2\pi}(2n\pi)$

$= n\lambda$

The intensity of bright points is maximum and given by

$I_{max} = 4I_0$

For minimum intensity

$\cos(\frac{\phi}{2}) = 0$

$(\frac{\phi}{2}) = (n - \frac{1}{2})\ \pi, where (n = \pm1, \pm2, \pm3, \ldots..)$

$\varphi = (2n - 1)\ \pi$

Phase difference $\varphi = (2n - 1)\pi$, $\frac{2\pi}{\lambda}\Delta x = (2n-1)\pi$

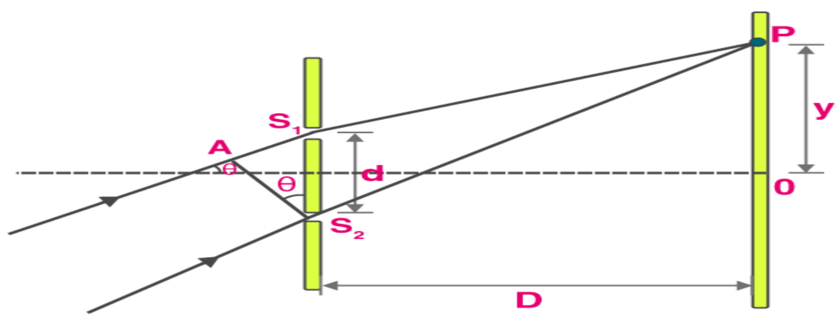
$$\Delta x = (2n-1)\frac{\lambda}{2}$$

Thus, the **intensity of minima** is given by

$I_{min} = 0$

If $I_1 \neq I_2$, $I_{min} \neq 0$.

Special Cases: Rays Not Parallel to Principal Axis:



From the above diagram,

Path difference $\Delta x = (AS_1 + S_1P) - S_2P$

$\Delta x = AS_1 - (S_1P - - S_2P)$

$\Delta x = d\ sin\theta - (\frac{4d}{D})$

For maxima

$\Delta x = n\lambda$

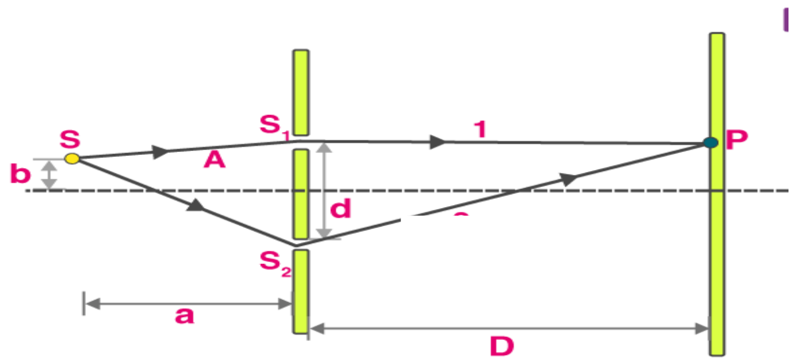
For minima

$\Delta x = (2n-1)\frac{\lambda}{2}$

Using this, we can calculate different positions of maxima and minima.

Source Placed beyond the Central Line:

If the source is placed a little above or below this centre line, the wave interaction with S_1 and S_2 has a path difference at point *P* on the screen.



Δ x= (distance of ray 2) – (distance of ray 1)

$=(SS_2+S_2P)-(SS_1+S_1P)$

$=(SS_2 - SS_1) + (S_2P - S_1P)$

$= bd/a + yd/D \rightarrow (*)$ We know $\Delta x = n\lambda$ for maximum

$\Delta x = (2n - 1)\lambda/2$ for minimum

By knowing the value of Δx from (*), we can calculate different positions of maxima and minima.

Constructive and Destructive Interference

For constructive interference, the path difference must be an integral multiple of the wavelength. Thus, for a bright fringe to be at 'y',

$n\lambda = y\, d/D$

Or, $y = n\lambda D/d$

Where $n = \pm 0,1,2,3\ldots\ldots$

The 0th fringe represents the central bright fringe.

Similarly, the expression for a dark fringe in Young's double slit experiment can be found by setting the path difference as

$\Delta l = (2n+1)\lambda/2$

This simplifies to

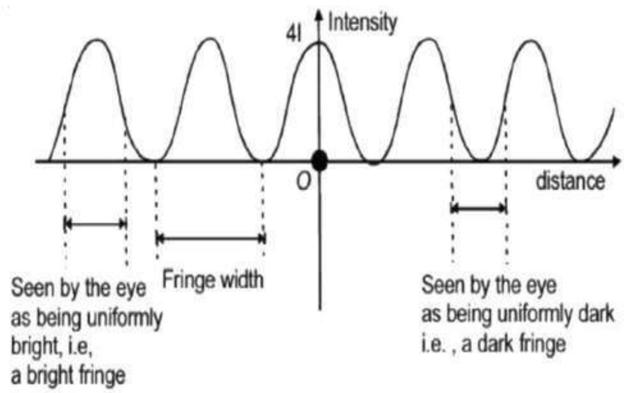
$(2n+1)\lambda/2 = y\, d/D$

$y = (2n+1)\lambda D/2d$

Young's double slit experiment was a watershed moment in scientific history because it firmly established that light behaved like a wave.

The double slit experiment was later conducted using electrons , and to everyone's surprise, the pattern generated was similar as expected with light. This would forever change our understanding of matter and particles, forcing us to accept that matter, like light, also behaves like a wave.

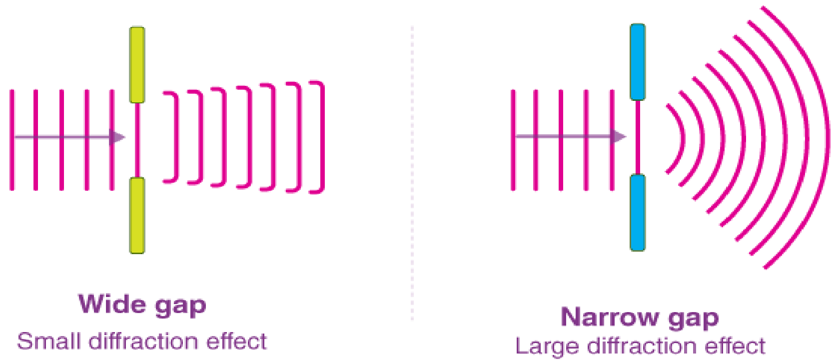
The variation in light intensity along the screen near the centre O is shown below:



Diffraction of light through single slit:

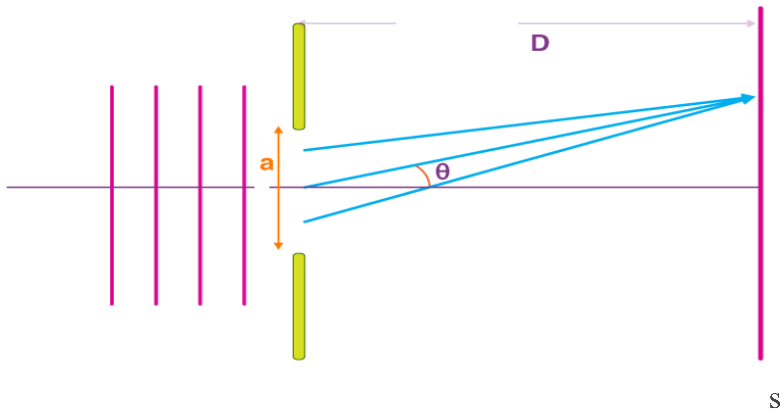
Diffraction of light is defined as the bending of light around corners such that it spreads out and illuminates areas where a shadow is expected. In general, it is hard to separate diffraction from interference since both occur simultaneously. The silver lining which we witness in the sky is caused due to diffraction of light. When the sunlight passes through or encounters the cloud, a silver lining is seen in the sky.When the double-slit in Young's experiment is replaced by a single narrow slit, a broad pattern with a bright region at the centre is seen. On both sides of the centre, there are alternating dark and bright regions. The intensity becomes weaker away from the centre. In this article, we discuss the single slit diffraction of light in a detailed manner.

In the single-slit diffraction experiment, we can observe the bending phenomenon of light or diffraction that causes light from a coherent source to interfere with itself and produce a distinctive pattern on the screen called the diffraction pattern. Diffraction is evident when the sources are small enough that they are relatively the size of the wavelength of light. You can see this effect in the diagram below. For large slits, the spreading out is small and generall noticeable.

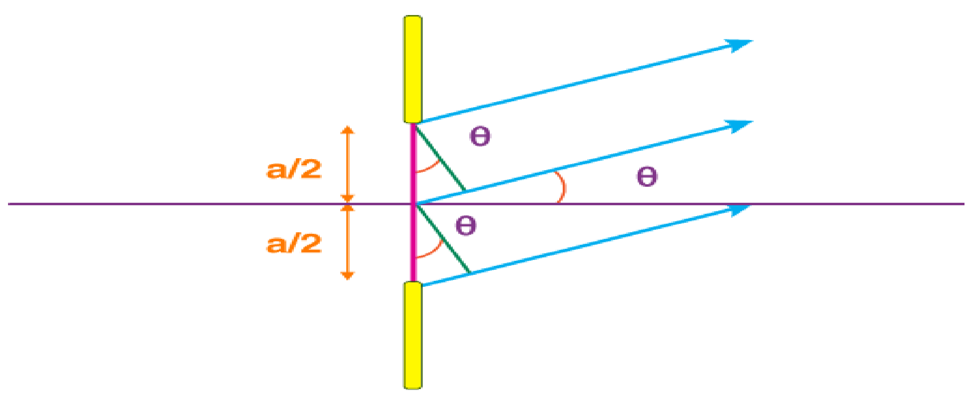


Single Slit Diffraction Formula:

We shall assume the slit width a << D. D is the separation between slit and source.



We shall identify the angular position of any point on the screen by θ measured from the slit centre which divides the slit by a/2 lengths. To describe the pattern, we shall first see the condition for dark fringes. Also, let us divide the slit into zones of equal widths a/2. Let us consider a pair of rays that emanate from distances a/2 from each other as shown below.



The path difference exhibited by the top two rays shown is:

$$\Delta L = (\frac{a}{2}) sin\,\Theta$$

Remember that this is a calculation valid only if D is very large. For more details about the approximation check out our article on the Young's Double Slit experiment.

We can consider any number of ray pairings that start from a distance a/2 from one another such as the bottom two rays in the diagram. Any arbitrary pair of rays at a distance of a/2 can be considered. We shall see the importance of this trick in a moment.

For a dark fringe, the path difference must cause destructive interference; the path difference must be out of phase by λ/2. (λ is the wavelength)

For the first fringe,

$$\Delta L = \frac{\lambda}{2} = \left(\frac{a}{2}\right) sin\Theta$$

λ= a sinΘ

For a ray emanating from any point in the slit, there exists another ray at a distance of a/2 that can cause destructive interference.

Thus, at **$\theta = \sin^{-1}(\lambda a)$** , there is destructive interference as any ray emanating from a point has a counterpart that causes destructive intesrference. Hence, a dark fringe is obtained.

For the next fringe, we can divide the slit into 4 equal parts of a/4 and apply the same logic. Thus, for the second minima:

$$\frac{\lambda}{2} = \frac{a}{4}\, sin\,\Theta$$

Similarly, for the **nth fringe**, we can divide the slit into 2n parts and use this condition as: nλ= a sinΘ

The Central Maximum:

The maxima lie between the minima and the width of the central maximum is simply the distance between the 1st order minima from the centre of the screen on both sides of the centre.

The position of the minima given by y (measured from the centre of the screen) is:

For small θ,

sin θ≈θ

⇒ **λ** = a sin θ≈aθ

⇒ **θ** = y/D = λ/a

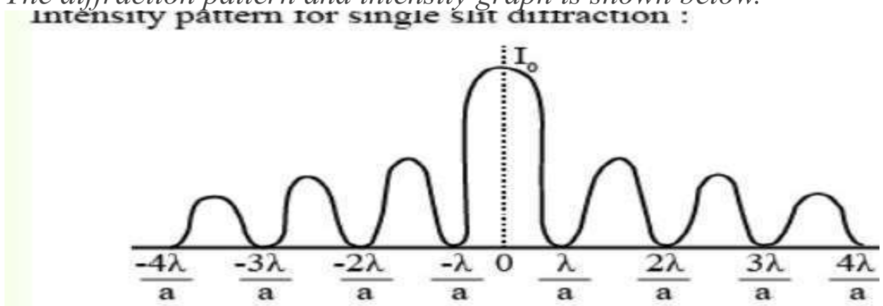
⇒ **y** = λD/a

The width of the central maximum is simply twice this value

⇒ **Width of central maximum** = 2λD/a

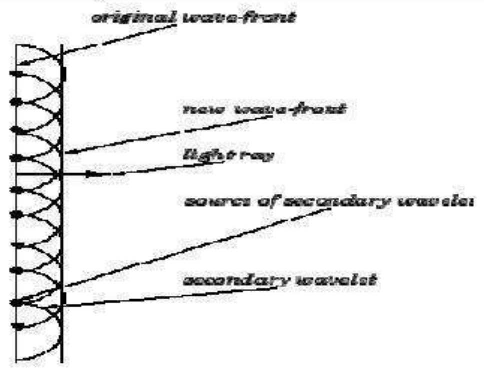
⇒ **Angular width of central maximum** = 2θ = 2λ/a

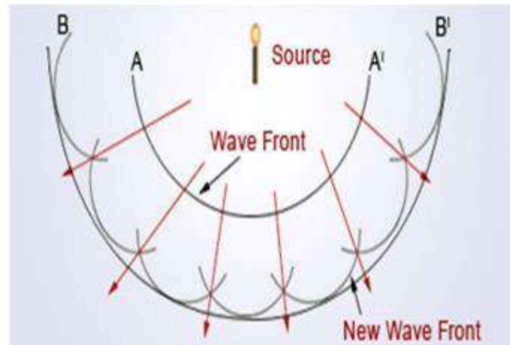
The diffraction pattern and intensity graph is shown below.



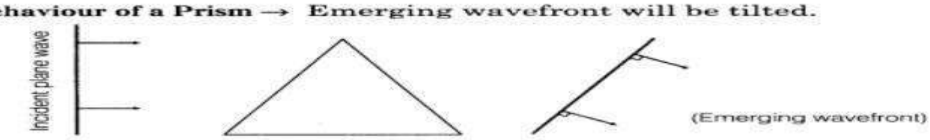
9. WAVE 0PTICS

S.No	Application	Formula	Term/Unit Figure
1	Huygen's principle	1. Each point of wave acts as a source secondary wavelets. 2. The tangential envelop touching all the points of secondary wavelets give the position of next wavefront. 3. The secondary wavelets spread forward in all directions at the speed of light.	

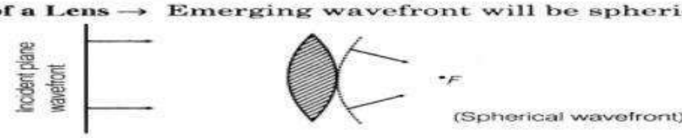




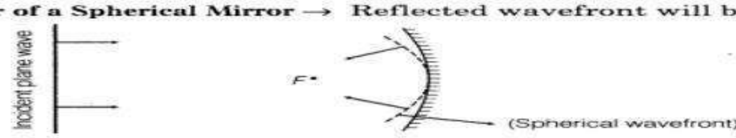
(i) **Behaviour of a Prism** → Emerging wavefront will be tilted.



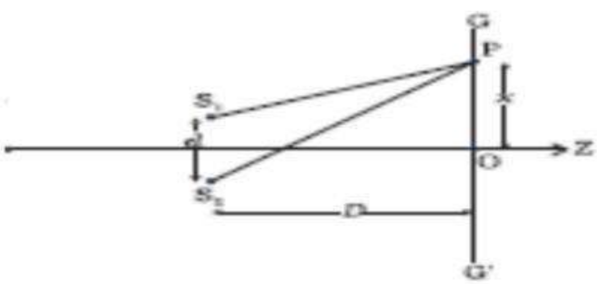
(ii) **Behaviour of a Lens** → Emerging wavefront will be spherical.



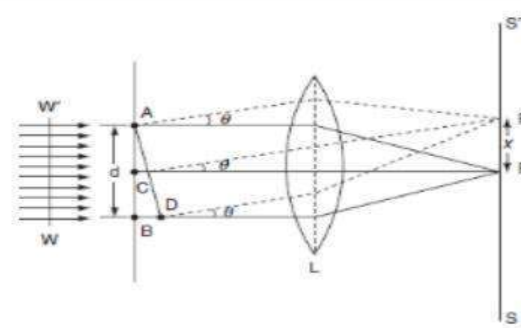
(iii) **Behaviour of a Spherical Mirror** → Reflected wavefront will be spherical.

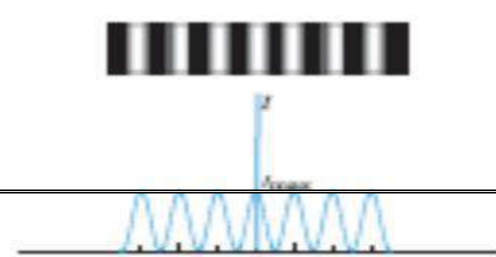


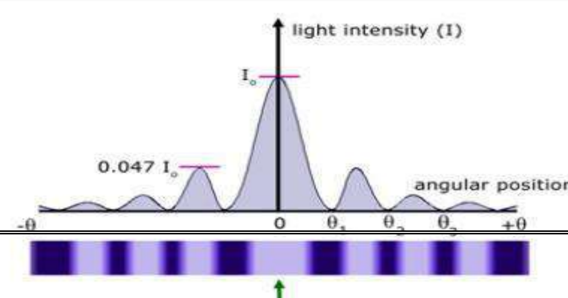
Interference of light	Diffraction of light

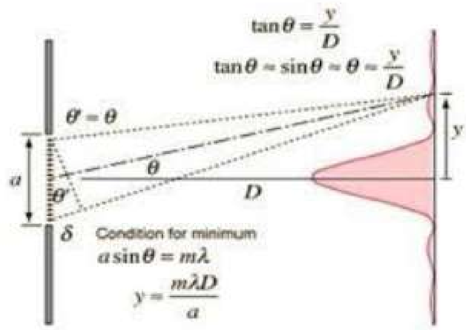


Young's double slit experiment







2	Resultant amplitude	$a = \sqrt{a_1 + a_2 + 2a_1a_2Cos\phi}$ Where a_1 and a_2 are amplitude	Condition for nth secondary minima is $d\ \sin\theta = n\lambda$; $Where\ n = 1,2,3 \ldots\ldots$
3	Resultant intensity	$I = I_1 + I_2 + 2\sqrt{I_1I_2}\ Cos\phi$ Where I_1 and I_2 are intensity of light	Condition for nth secondary maxima is $d\ \sin\theta = (n + \frac{1}{2})\lambda$; $Where\ n = 1,2,3 \ldots\ldots$
4		When $I_1 = I_1 = I_0\ then$ $I = 2I_0(1 + Cos\phi) = 4I_0Cos^2\frac{\phi}{2}$	
5		$\frac{W_1}{W_2} = \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2}$ W_1 and W_2 are width of slit	
6	Intensity at maxima	I_{max} α $(a_1 + a_2)^2$	
7	Intensity at minima	I_{max} α $(a_1 - a_2)^2$	
8	Ratio of maxima and minimum intensity	$\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \left(\frac{r+1}{r-1}\right)^2$ $Where\ r = \frac{a_1}{a_2} = \sqrt{\frac{I_1}{I_2}}$	I_1 and I_2 are intensity of light a_1 and a_2 are amplitude
9	Path difference	Path difference for bright fringe = P = n λ ; Where $n = 0, \pm 1, \pm 2, \pm 3, \ldots$ Path difference for dark fringe = $P = \left(n + \frac{1}{2}\right)\lambda$ $Where\ n = 0, \pm 1, \pm 2, \pm 3, \ldots$	Path difference for nth minima = P = n λ
10	Phase difference	Phase difference for bright fringe = $\phi = 2n\pi$; $n = 0, \pm 1, \pm 2, \pm \cdots$ Phase difference for dark fringe = $\phi = (2n + 1)\pi$; $Where\ n = 0, \pm 1, \pm 2, \pm \cdots$	
11	Linear Potion of nth bright fringe position	$y_b = \frac{n\lambda D}{d}$ $Where\ n = 0, \pm 1, \pm 2, \pm 3, \ldots$	$y_b = \left(n + \frac{1}{2}\right)\frac{\lambda D}{d}$ $Where\ n = \pm 1, \pm 2, \pm 3, \ldots$
12	Linear Potion of nth dark fringe position	$y_d = \left(n + \frac{1}{2}\right)\frac{\lambda D}{d}$ $Where\ n = 0, \pm 1, \pm 2, \pm 3, \ldots$	$y_d = \frac{n\lambda D}{d}$ $Where\ n = \pm 1, \pm 2, \pm 3, \ldots$

14	Angular Position of nth dark fringe position	$\theta_d = \left(n + \frac{1}{2}\right)\frac{\lambda}{d}$ $Where\ n = 0, \pm 1, \pm 2, \pm 3, \ldots$	$\theta_d = \frac{n\lambda}{d}$ $Where\ n = \pm 1, \pm 2, \pm 3, \ldots$
15	Fringe width	$Fringe\ Width = \beta = \frac{\lambda D}{d}$	1. Linear $Width\ of\ central\ maximum =$ $\beta_c = 2\beta = \frac{2\lambda D}{d}$ 2. Angular width of central maximum = $\theta_c = \frac{2\lambda}{d}$
16	Fresnel distance	$D_F = \frac{d^2}{\lambda}$	D_F = Fresnel distance d= width of slit λ= wavelength of light
17	Size of Fresnel zone	$d_F = \sqrt{\lambda D}$	d_F = Fresnel zone

MULTIPLE CHOICE QUESTIONS (1 MARK)

1. Monochromatic yellow light is replaced with red light. The liner width of central bright fringe in diffraction at a single slit
a) Increases because $\lambda_{red} < \lambda_{yellow}$ (b) Decreases because $\lambda red > \lambda yellow$
c) Increases because $\lambda red > \lambda yellow$ (d) Decreases because $\lambda red < \lambda_{yellow}$

2. To demonstrate the phenomenon of interference we require two sources which emit radiation of
(a) Nearly same frequency (b) The same frequency
(c)Different wavelength (d) The same frequency and having definite phase relationships

3. Which of the following cannot be explained on the basics of wave nature of light?
(a) Polarisation (b) Diffraction (c) Photoelectric effect (d) Interference

4. The wave front of distant source of unknown shape is approximately
(a) Spherical (b) Cylindrical (c)Elliptical (d) plane

5. In young's double slit experiment the slit separation is 0.2cm, the distance between the screen and the slit is 1m, wavelength of light used is $5000A^0$. The fringe width in mm is a) 0.25 (b) 0.26 (c) 0.27 (d) 0.28

6. If young's double slit experiment of light is performed in water which of the following is correct
(a) Fringe width will decrease (b)Fringe width will increase (c)There will be no fringe (d)Fringe width will remain unchanged

7. A beam of light of wavelength 600nm from a distance source fall on a single slit 1mm wide and the resulting diffraction pattern is observed on a screen 2m away. The distance between the 1st dark fringes on either side of the central bright fringe is
(a) 1.2cm (b) 1.2mm (c) 2.4cm (d) 2.4 mm

8. Ratio of intensities of two waves are given by 4:1. Then ration of the amplitude of the two wave is
(a) 2:1 (b)1:2 (c) 4:1 (d) 1:4

9. The locus of all particles in a medium vibrating in the same phase is called
(a) Fringe (b) Wavelet (c)Wavefront (d) All the above

10. Which of the following factor does the intensity of light depend on?
(a) Frequency (b) Wavelength (c)Amplitude (d)Velocity

11. What happens to the interference pattern; the two slits S_1 and S_2 in young's double slit experiment are illuminated by two independent but identical sources?
(a) The intensity of the bright fringe doubled.
(b) The intensity of the bright fringes becomes 4 times.
(c)Two sets of interference fringes overlap
(d) No interference pattern is observed

12. A diffraction pattern is obtained by using a beam of red light. What will happen if the red light is replaced by blue light
a) Bands disappear (b)Bands become broader and farther apart
(c)No change will take place (d) Diffraction bands become narrower and crowded

13. Two coherent sources are used to obtain interference pattern on the screen D m away from the slit separated by distance d. A maximum is obtained when the path difference between the interfering wave is
(a) $n\lambda$ (b) $n\lambda/2$ (c) $(2n+1)\ \lambda/2$ (d) $(2n-1)\ \lambda/4$

14. A minimum is obtained when the phase difference of the superposition waves is
a) $n\pi$ (b) $(n+1/2)\ \pi$ (c) $(2n+1)\ \pi$ (d) Zero

15. The fringe width β of a diffraction pattern and the slit width d are related as
(a) $\beta \propto$ d (b) $\beta \propto 1/d$ (c) $\beta \propto \sqrt{d}$ (d) $\beta \propto 1/d^2$

16. A phase difference of 5π corresponds to a path difference of (in terms of λ)
(a) $5\ \lambda$ $(b)10\ \lambda$ (c)$5\ \lambda/2$ $(d)2\ \lambda$

17. A monochromatic light is refracted from air to a glass of refractive index μ. The ratio of the wavelength of the incident and the refracted wave is
(a) $1: \mu$ (b) $1: \mu^2$ (c) $\mu: 1$ (d) $\mu^2 : 1$

18. Huygens's principle of secondary wavelet may be used to
(a) Find the velocity of the light in vacuum (b) Explain the particles behaviour of light
(c)Find the new position of a waveform (d) Explain photoelectric effects

19. In the phenomenon of interference energy is
(a) Destroyed at destructive interference (b) Created at constructive interference
(c)Conserved but it is redistributed (d)Same at all points

20. The reason of interference is
(a)Phase difference (b)Change of amplitude (c)Change of velocity (d)Intensity

21. From a single slit the first diffraction minima is obtained at 300 for a light of $6500A^0$ Wavelength. The width of the slit is
(a) $3250A^0$ (b)$1.3\ \mu m$ (c) $5.4 X 10^{-4}$ km (d) $1.2X 10^{-2}$ cm

22. Two disturbances arriving at a point on the screen kept at a distance D from two coherent source have a phase difference of /2 . The intensity at this point is (assume that intensity of each

source id Io.
(a) 4 I_o (b) 2 I_o (C)1/2 I_o (d)1/4 I_o

23. The ratio of intensities of two points P and Q on a screen in Young's double slit experiment when waves from sources S1 and S2 have phase difference of $\pi/3$ and $\pi/2$ is
(a) 3:1 (b)2:1 (c)3/2:1 (d)3:2

24. Light waves from two coherent sources arrive at two points P and Q on a screen with path difference of 0 and $\lambda/2$ the ratio of intensities at the point I_P:I_Q is
(a) 2:1 (b) 4:0 (c) 1:2 (d) 0:1/2

25. The phase difference between two light waves reaching a point is $\pi/2$. The resultant amplitude if the individual amplitude are 3mm and 4mm is
(a) 7mm (b)5mm (c)1mm (d)None of the above

26. In a Young's double slit experiment, the source is white light. One of the holes is covered by a red filter and another by a blue filter. In this case
(a) there shall be alternate interference patterns of red and blue.
(b) there shall be an interference pattern for red distinct from that for blue.
(c) there shall be no interference fringes.
(d) there shall be an interference pattern for red mixing with one for blue.

27. Two light sources are said to be coherent when both the sources of light emit light of
(a) The same amplitude and phase (b) The same intensity and wavelength
(c)The same speed s(d) The same wavelength and constant phase difference

s28. In Young's double slit experiment, the distance between the slits is reduced to half and the distance between the slits and the screen is doubled. The fringe width
(a) Will be double. (b) will be half. (c) will remain same. (d) will be four times.

Answers :1-c,2-d,3-c,4-d,5-a, 6-a,7-d,8-a,9-c,10-c,11-d, 12-d,13-a,14-c,15-b,16-c,17-c,18-c,19-c, 20-a,21-b,22-b,23-d,24-b, 25-b, 26-c, 27-d,28-d

ASSERTION AND REASONS

Follow the instructions and answer the given questions
(a) Both are correct and reason is correct explanation of assertion.
(b) Both are correct but reason is not the correct explanation of assertion.
(c) Reason is wrong.
(d) Both are wrong.

1.**Assertion**: No interference pattern is detected when two coherent sources are infinitely close to each other.
Reason: The fringe width is inversely proportional to the distance between the two sources.

2. **Assertion**: Interference pattern is made by using yellow light instead of red light, the fringes become narrower.
Reason: In Young's double experiment slit fringe width is given by $\beta=\lambda D/d$.

3.**Assertion**: Coloured spectrum is seen when we look through a muslin cloth.
Reason: It is due the diffraction of white light on passing through fine slits.

4. Assertion: Diffraction takes place for all types of waves mechanical or non-mechanical, transverse or longitudinal.
Reason: Diffraction's effect are perceptible only if wavelength of wave is comparable to dimensions of diffracting device.

5.**Assertion** (A): Interference obeys the law of conservation of energy.
Reason(R): The energy is redistributed in case of interference.

6. **Assertion (A):** Diffraction is common in sound but not common in light waves.
Reason (R): Wavelength of light is more than the wavelength of sound.

7**. Assertion (A)**: We cannot get diffraction pattern from a wide slit illuminated by monochromatic light.
Reason (R): In diffraction pattern, all the bright bands are not of the same intensity.

8**. Assertion (A)** : The maximum intensity in interference pattern is four times the intensity due to each slit.
Reason (R): Intensity is directly proportional to square of amplitude.

9.**Assertion**: In Young's experiment, the fringe width for dark fringes is different from that for white fringes.
Reason: In Young's double slit experiment the fringes are performed with a source of white light then only black and bright fringes are observed.

10. **Assertion** (A) : One of the condition for interference is that the two source should be very narrow.
Reason (R) : One broad source is equal to large number of narrow source.

Answers : 1-a,2-a,3-a,4-b,5-a,6-c,7-b, 8-a, 9-d, 10 –a.

2 marks Questions

1. **In** a YDSE , the separation between the slits is 'd' and the distance of the screen from the slits is 1000d. If the first minima falls at a distance 'd' from the central maximum then find the relation between d and λ. 2M

Solution: The condition for the first minima in a double slit experiment is given by d sinθ = mλ, where m is the order of the minima (m = 1 for the first minima), d is the separation between the slits, θ is the angle of the minima from the central maximum, and λ is the wavelength of the light. For the first minima, this can be approximated as d θ = λ when the angle is small (sinθ ≈ θ). The angle θ is related to the distance on the screen by θ ≈ y/x, where y is the distance from the central maximum to the first minima, and x is the distance from the slits to the screen. Substituting y with d and x with 1000d, we get θ = d/1000d = 1/1000. Plugging this into the formula, we get d (1/1000) = λ, which simplifies to the wavelength λ = d/1000.

2. How does the fringe width in Young's double-slit experiment change when the distance of separation between the slits and screen is doubled? 2M

Solution: The fringe width is β = λD/d
sIf D (distance between slits and screen) is doubled, then fringe width will be doubled

3. In a single slit diffraction experiment, the width of the slit is reduced to half its original width. How would this affect the size and intensity of the central maximum? 2M

Solution : Width of central maximum is, =2β=2λD/a

Where a is the width of the slit and D is the distance between the screen and slit.
⇒β∝D and β∝1/a
When the width of the slit is reduced by half, the width of central maximum is doubled. So, in order to keep the width of the central maximum unchanged, we have to reduce the distance between the screen and slit by half.
∴ New width of central maximum is, $=2\beta'=2\lambda(D/2)/(a/2)=2\lambda D/a=2\beta$

4. A narrow slit is illuminated by a parallel beam of monochromatic light of wavelength λ equal to 6000 Å and the angular width of the central maximum in the resulting diffraction pattern is measured. When the slit is next illuminated by light of wavelength λ’, the angular width decreases by 30%. Calculate the value of the wavelength λ’. 2M

Solution: Angular width 2Θ = 2λ/d Given λ = 6000 Å In Case of new λ (assumed λ’ here), angular width decreases by 30%

$$= \left(\frac{100-30}{100}\right)2\,\Theta$$

$$= 0.70\ (2\,\Theta)$$

2 λ’/d = 0.70 X (2 λ/d) ∴ λ’= 4200 A^0

5. A parallel beam of light of 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Calculate the width of the slit. 2M

Given, $\lambda = 500\ \text{nm} = 500 \times 10^{-9}\ \text{m}$, $D = 1$

$x_n = 2.5\ \text{mm} = 2.5 \times 10^{-3}\ \text{m}$ $n = 1$

$$\frac{x_m d}{D} = n\lambda$$

$$d = \frac{n\lambda D}{x_n}$$

$$d = 1 \times (500 \times 10^{-9}) \times \frac{1}{2.5 \times 10^{-3}} = 2 \times 10^{-4}\ \text{m}$$

6. In a single slit diffraction experiment, a slit of width ‘d’ is illuminated by red light of wavelength 650 nm. For what value of ‘d’ will (i) the first minimum fall at an angle of diffraction of 30°, and (ii) the first maximum fall at an angle of diffraction of 30°? (b) Why does the intensity of the secondary maximum become less as compared to the central maximum?
2M

Solution:

(*i*) I minimum at 30° satisfies the condition,

$$d \sin\theta = \lambda$$

$$d = \frac{\lambda}{\sin 30^\circ} = 2 \times \lambda = \mathbf{1300\ nm}$$

(*ii*) I maxima at 30° satisfies the condition,

$$d \sin\theta = \frac{3\lambda}{2}$$

$$\therefore \quad d = 3 \times \frac{\lambda}{2 \sin 30^\circ} \Rightarrow 3\lambda = 2d \sin 30^\circ$$

$$\Rightarrow \quad 3 \times 650 = 2d \sin 30^\circ$$

$$\Rightarrow \quad 2d \times \frac{1}{2} = 1950$$

$$\therefore \quad d = \mathbf{1950 \times 10^{-9}\ nm}$$

7. In young’s double slit experiment how is the fringe width change when 2 M

a. Light of smaller frequency is used b. Distance between the slits is decreased?

Solution: We know, fringe width could be expressed as,

a) $\beta = D\lambda/d$. If light of smaller frequency, in other words, higher wavelength is used, the fringe width would increase.

b) We know that, fringe width is inversely proportional to the distance between the slits, that is, $\beta \propto 1/d$
So, if distance between the slits is decreased, the fringe width will increase.

3 marks Questions

8. In a Young's double slit experiment the width of fringes obtained with light of wavelength 6000Å is 2.0 mm. What will be the fringe width if the entire apparatus is immersed in a liquid of refractive index 1.33? 3M

Solution: We know that,

Fringe width, $\beta = \frac{\lambda D}{d}$, where λ is the wavelength, D is the distance between slits and the screen and 'd' is distance between slits.

When immersed in water, the wavelength becomes, $\lambda_1 = \frac{\lambda}{\mu}$, μ is the Refractive index and λ_1 is the new wavelength

, $\lambda_1 = \frac{6000}{1.33}$ = 4511.27 A^0

We know that, , $\beta = \frac{\lambda D}{d}$

2 mm = $\frac{6000\ D}{d}$s

$\frac{D}{d} = \frac{2\ mm}{6000}$

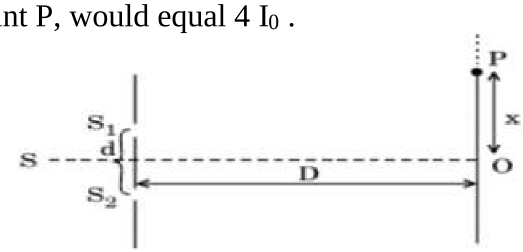
$\beta new = \frac{\lambda 1 D}{d}$, Where, βnew is the new fringe width.

Substituting the values, we get

$\beta new = (4511.27)\frac{2\ mm}{6000\ A^0}$, $\beta new = 1.5\ mm$

Hence, In Young's double slit experiment, the fringe width is found to be 2 mm, when the light of wavelength 6000 A^0 is used then the change in fringe width if the whole apparatus is immersed in water of refractive index 1.33 is. 1.5 mms

9 . (a) The intensity at the central maximum (O) in a Young's double slit experimental setup shown in the figure is I_0. If the distance OP equals one-third of the fringe width of the pattern, show that the intensity at point P, would equal 4 I_0 . 3 M



Solution:
Fringe width β = λD/d ; y = β/3 = λD/3d

$$\text{Path diff } (\Delta p) = \frac{yd}{D} \Rightarrow \Delta p = \frac{\lambda D}{3d} \cdot \frac{d}{D} = \frac{\lambda}{3}$$

$$\Delta\phi = \frac{2\pi}{\lambda} \cdot \Delta p = \frac{2\pi}{\lambda} \cdot \frac{\pi}{3} = \frac{2\pi}{3}$$

$$\text{Intensity at point } P = I_0 \cos^2 \Delta\phi$$

$$= I_0 \left[\cos \frac{2\pi}{3}\right]^2$$

$$= I_0 \left(\frac{1}{2}\right)^2$$

$$= \frac{I_0}{4}$$

(b) Two Sources of Intensity I and 4I are used in an interference experiment. Find the intensity at points where the waves from two sources superimpose with a phase difference (i) zero (ii) $\pi/2$ (iii) π.

10. a) Can white light produce interference? What is the nature? 3M

b) The refractive index of glass is 1.5. What is the speed of light in glass? Speed of light in vacuum is $3.0\times10^{8}ms^{-1}$.

Solution : (a) White light would produce interference. But because of different colours present in white light, the interference pattern overlaps the central bright fringe for all the colours at the position, so its colour is found to be white. The white central bright fringe is seen to be surrounded by few coloured rings.

(b) Given refractive index of glass, μ=1.5μ=1.5

Speed of light, c = $3\times10^{8} m/s$

Now, we have the speed of light in glass is given by the relation,

$v = c/\lambda$

Substituting the given values,

$\Rightarrow v=3\times10^{8}/1.5$

$\therefore v=2\times10^{8} m/s$

Hence, the speed of light in glass is found to be $2\times10^{8} m/s$

11. In deriving the single slit diffraction pattern, it was stated that the intensity is zero at angles of nλ $/a$. Justify this by suitably dividing the slit to bring out the cancellations 3M

Solution:

Consider that a single slit of width dd is divided into nn smaller slits.

That is, width of each slit, $d=d/n$

Angle of diffraction is given by the relation,

$$\theta=d/d\lambda/d=\lambda/d$$

Now, each of these infinitesimally small slits send zero intensity in direction θθ. Thus, the combination of these slits will give zero intensity.

12. a) When a low flying aircraft passes overhead, we sometimes notice a slight shaking of the picture on our TV screen. Suggest a possible explanation. 3M

b) As you have learnt in the text, the principle of linear superposition of wave displacement is basic to understanding intensity distributions in diffraction and interference patterns. What is the justification of this principle?

Solution:

(a) We know that weak radar signals are sent by a low flying aircraft and this can interfere with the TV signals received by the antenna. As a result of this, the TV signals might get distorted. Hence, when a low flying aircraft passes overhead, we could sometimes notice a slight shaking of the picture on our TV screen

(b) For our understanding of intensity distributions and interference patterns, the principle of linear superposition of wave displacement is essential. This is because superposition follows from the linear character of a differential equation that is known to govern wave motion. Let y_1 and y_2 are the solutions of the second order wave equation, then any linear combination of y_1 and y_2 might also be the solution of the wave equation.

13. a) How is a wave front defined? Using Huygens construction draw a figure showing the propagation of a plane wave reflecting at the interface of the two media. Show that the angle of incidence is equal to the angle of reflection.

13. b) In Young's double slit experiment, monochromatic light of wavelength 630 nm illuminates the pair of slits and produces an interference pattern in which two consecutive bright fringes are separated by 8.1 mm. Another source of monochromatic light produces the interference pattern in which the two consecutive bright fringes are separated by 7.2 mm. Find the wavelength of light from the second source. What is the effect on the interference fringes if the monochromatic source is replaced by a source of white light? 5 M

$$\beta_1 = \frac{\lambda_1 D}{d} \quad \ldots(1)$$

$$\beta_2 = \frac{\lambda_2 D}{d} \quad \ldots(2)$$

$$\therefore \quad \frac{\beta_2}{\beta_1} = \frac{\lambda_2}{\lambda_1}$$

$$\Rightarrow \quad \lambda_2 = \frac{\beta_2}{\beta_1}\lambda_1$$

Given $\beta_1 = 8 \cdot 1$ mm, $\beta_2 = 7 \cdot 2$ mm, $\lambda_1 = 630$ mm

$$\therefore \quad \lambda_2 = \left(\frac{7 \cdot 2\text{ mm}}{8 \cdot 1\text{ mm}}\right) \times 630\text{ mm}$$

$$= \mathbf{560\ mm}$$

Use of white light: When white light is used to illuminate the slit, we obtain an interference pattern consisting of a central white fringe having on both sides symmetrically a few coloured fringes and then uniform illumination.

14.(a) State Huygen's principle. Using this principle explain how a diffraction pattern is obtained on a screen due to a narrow slit on which a narrow beam coming from a monochromatic source of light is incident normally. 5 M

(b) Show that the angular width of the first diffraction fringe is half of that of the central fringe.

Solution:

We know that,

Ø=+λ/a and Ø= − λ/a Which means, Angular width of central bright fringe is 2Ø=2λ/a Therefore, first diffraction lies between Ø=λ/a and Ø=2λ/a Furthermore, 2λ/a−λ/a = λ/a ∴ It is proved that the angular width of the first diffraction fringe is half that of the central fringe.
(c) If a monochromatic source of light is replaced by white light, what change would you observe in the diffraction pattern?
Solution: When a monochromatic source is replaced by a white light, the diffracted image of the slit will get dispersed into constituent colors of white light. The central maxima will be white, and all other fringes will be of the constituent colors $I_1 = I, I_2 = 4I$ $I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$ (a) $\phi = 0, I_R = I + 4I + 2\sqrt{I.4I}\cos 0 = 9I = I_{\max}$ (b) $\phi = \frac{\pi}{2}, I_R = I + 4I + 2\sqrt{I.4I}\cos(\pi/2) = 5I$ (c) $\phi = \pi, I_R = I + 4I + 2\sqrt{I.4I}\cos(\pi) = I = I_{\min}$
15. (a) Two coherent monochromatic light beams of intensities I and 4 I superpose each other. Find the ratio of maximum and minimum intensities in the resulting beam. 5M $I_{\max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 = \left(\sqrt{4I} + \sqrt{I}\right)^2 = 9I$ $I_{\min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2 = \left(\sqrt{4I} - \sqrt{I}\right)^2 = I$ (b) In Young's double slit experiment, the two slits are separated by a distance equal to 100 times the wavelength of light that passes through the slits. Calculate : (1) the angular separation in radians between the central maximum and the adjacent maximum. (2) the distance between these two maxima on a screen 50 cm from the slits. d = 100λ, D = 50.0 cm
Solution: The condition for maximum intensity in Young's experiment is, d sin θ = nλ, n = 0, 1, 2...., The angle between the central maximum and its adjacent maximum can be determined by setting n equal to 1, ∴ d sin θ = λ $\theta = \sin^{-1}(\frac{\lambda}{d})$ $\Rightarrow \theta = \sin^{-1}(\frac{\lambda}{100\lambda})$ $\Rightarrow \theta = \sin^{-1}(\frac{1}{100})$ $\Rightarrow \theta = 0.9' = 0.01571\, rad$ 2)The distance between these maxima on the screen is D sin θ = D (λ/ d) = (50.0 cm) (λ /100 λ) = 0.50 cm

16. (a) Two harmonic waves of monochromatic light $\boldsymbol{y_1 = a\cos\omega t}$ and $\boldsymbol{y_1 = a\cos(\omega t + \phi)}$, are superimposed on each other. Show that the maximum intensity in interference pattern is four times the intensity due to each slit. 5M

(b) Also write the condition for constructive and destructive interference in terms of the phase angle ϕ.

17. (a) Using Huygens's principle draw a diagram to show how a plane wave front incident at the interface of the two media gets refracted when it propagates from a rarer to a denser medium. Hence Verify Snell's law of refraction. 5M

(b) Two coherent sources have intensities in the ratio 25 : 16. Find the ratio of intensities of maxima to minima after interference of light occurs.

Solution : $I_1 = a_1^2 = 25$, $a_1 = 5$

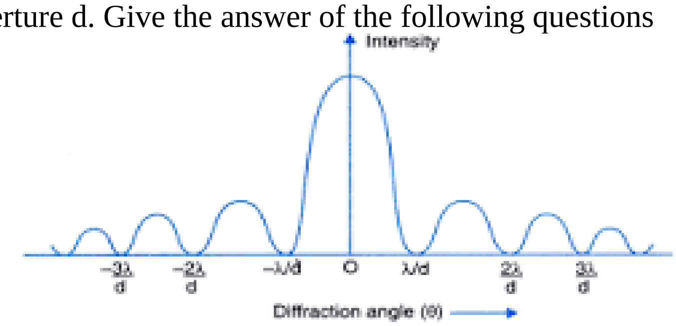
$I_2 = a_2^2 = 16$: $a_2 = 4$

Maximum intensity $I_{max} = (a_1 + a_2)^2 = (5 + 4)^2 = 81$

Minimum intensity $I_{min} = (5 - 4)^2 = 1$

CASE BASED QUESTIONS

1. The experiment produces a bright central maximum that is flanked on both sides by secondary maxima, with the intensity of each succeeding secondary maximum decreasing as the distance from the center increases. Figure 4 illustrates this point with a plot of beam intensity versus diffraction radius. Note that the minima occurring between secondary maxima are located in multiples of π.
This experiment was first explained by Augustin Fresnel who, along with Thomas Young, produced important evidence confirming that light travels in waves. From the figures above, we see how a coherent, monochromatic light emitted from point is diffracted by aperture d. Give the answer of the following questions



(i) Which one of the following is most essential for observing diffraction of light___________
(a) monochromatic light (b) white light (c) a very narrow slit or obstacle (d) two coherent sources

(ii) A diffraction pattern is obtained using a beam of red light. What happens if red light is replaced by the blue light_________
(a) bands disappear (b) diffraction bands become narrow and crowded together
(c) diffraction bands become broader and farther apart (d) no change in diffraction pattern

(iii) The angular width of the central maxima of a diffraction pattern due to a single slit does not depend upon the_____

(a) distance between slit and source
(b) width of the slit
s(c) wavelength of light used
(d) frequency of light used

(iv) The phenomenon of diffraction may be considered as interference, where the number of coherent sources are___
(a) one (b) zero (c) less than 5 (d) infinite

(v) Diffraction pattern of a single slit is observed with red light the source is then replaced with that of blue light. If the positions of the diffraction minima on the screen are to remain the same as before__________

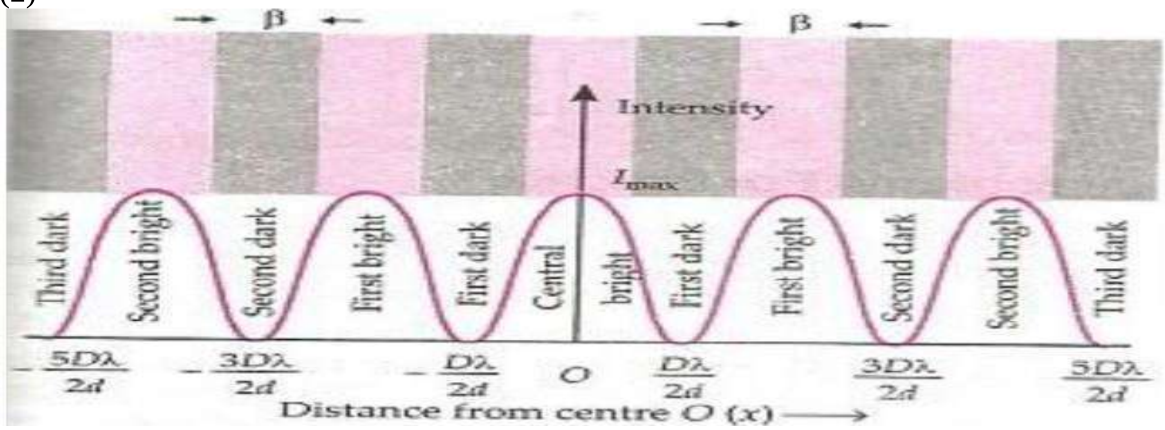
(a) the slit width must be decreased
(b) the slit width must be increased
(c) the lens-screen combination must be moved away from the slit
(d) the lens-source combination must be moved away from the slit

2. Young's double slit experiment uses two coherent sources of light placed at a small distance apart. The light from these slits falls on a screen which is at a distance D from the position of slits S_1 and S_2 ,d is the separation between the two slits. Interference pattern appears on the screen. The waves from a S_1 and S_2 travel equal distance to reach the point O the central point which is equidistant from S_1 and S_2. The path difference for these waves is zero. There will be a central bright fringe at O. but as we move from O upwards or downwards, alternate bright and dark fringe are formed. Fringe width β is the separation between two successive bright or dark fringes. β is independent of the order of fringe (n). In case of light λ is extremely small. D should be much larger than d so that the fringe width β may be appreciable.

1) State the principle of superposition of waves.
2) Draw the graph showing the variation of intensity in the interference pattern in young's double slit experiment with the distance from the centre O (y).
3) What will be the effect on the interference fringes in young's double slit experiment when (a) Separation between the slits is increased. (b) Monochromatic source is replaced by source of white light. (OR)
(a) Two waves from S_1 and S_2 have a phase difference ϕ. If Δx is the path difference between the two waves, write the relation between phase difference and the path difference.
(b) Obtain the ration of the interference fringe width β_1 and β_2 obtained with monochromatic red light of λ_1 = 660 nm and ultraviolet light of λ_2 = 330 nm

Answers:
(1) When a number of waves travelling through a medium superpose on each other the resultant displacement at any point at a given instant is equal to the vector sum of the displacements due to the individual waves at that point.

(2)



(3) (a) Fringe width $\beta = \lambda D/d$

$\beta \; \alpha \; 1/d$ β decreases when d increases

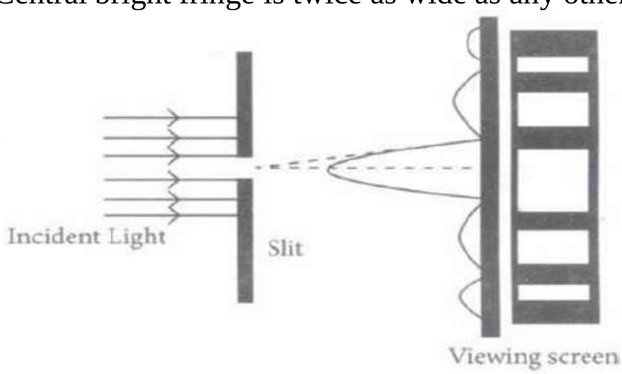
(b) central bright fringe is white .The closest fringe on either side of white fringe is violet (smallest wavelength).Farthest fringe is red.

(a) $\emptyset = (2\pi/\lambda)\,\Delta x$

(b) $\beta_1/\beta_2 = \lambda_1/\lambda_2$ = 660 :330 = 2 : 1

3. When light from a monochromatic source is incident on a single narrow slit, it gets diffracted and a pattern of alternate bright and dark fringes is obtained on screen, called "Diffraction Pattern" of single slit. In diffraction pattern of single slit, it is found that Central bright fringe is ·of maximum intensity and the intensity of any secondarybright fringe decreases with increase in its order. When light from a monochromatic source is incident on a single narrow slit, it getsdiffracted and a pattern of alternate bright and dark fringes is obtained on screen, called "Diffraction Pattern" of single slit. In diffraction pattern of single slit, it is found that

- Central bright fringe is ·of maximum intensity and the intensity of any secondarybright fringe decreases with increase in its order.
- Central bright fringe is twice as wide as any other secondary bright or dark fringe



1. A single slit of width 0.1 mm is illuminated by a parallel beam of light of wavelength 6000 A and diffraction bands are observed on a screen 0.5 m from the slit.The distance of the third dark band from the central bright band is

(a) 3 mm (b) 1.5 mm (c) 9 mm (d) 4.5 mm

2. In Fraunhofer diffraction pattern, slit width is 0.2 mm and screen is at 2 m away from the lens. If wavelength of light used is 5000 λ then the distance between the firstminimum on either side the central maximum is

(a) 10^{-1} m (b) 10^{-2} m (c) 2 x 10^{-2} m (d) 2 x 10^{-1} m

3. Light of wavelength 600 nm is incident normally on a slit of width 0.2 mm. Theangular width of central maxima in the diffraction pattern is (measured from minimum to minimum)

(a) 6 x 10^{-3} rad (b) 4 x 10^{-3} rad (c) 2.4 x 10^{-3} rad (d) 4.5 x 10^{-3} rad

4. A diffraction pattern is obtained by using a beam of red light. What will happen,if the red light is replaced by the blue light?

a) bands disappear (b) bands become broader and farther apart

c) no change will take place (d) diffraction bands become narrower and crowded together.

HOTS

1. On a hot summer night, the refractive index of air is smallest near the ground and increases with height from the ground. When a light beam is directed horizontally, the Huygen's principle leads us to conclude that as it travels, the light beam……..

(a) Becomes narrower (b) goes horizontally without any deflection

(c) bends downwards (d) bends upwards

2. To demonstrate the phenomenon of interference, we require two sources, which emit radiation of

(a) Nearly the same frequency (b) the same frequency

(c) different wavelength (d) The same frequency and having definite phase relationship

3. A Young's double slit experiment uses a monochromatic source. The shape of the interference fringes formed on a screen is……….

(a) Hyperbola (b) circle (c) straight line (d) parabola

4. In a YDSE, light of 500 nm is used to produce an interference pattern. When the distance between the slits is 0.05 mm, the angular width (in degree) of the fringes formed on the distant screen is close to …...

(a) 0.17^0 (b) 1.7^0 (c) 0.57^0 (d) 0.07^0

5 . If I_0 is the intensity of the principal maximum in the single slit diffraction pattern, then what will be its intensity when the slit width is doubled?

(a) 2 I_0 (b) 4 I_0 (c) I_0 (d) $I_0/2$

6. In a double slit experiment, green light (5303 A^0) falls on a double slit having a separation of 19.44 micro meter and a width of 4.05 micro meter. The number of bright fringes between the first and the second diffraction minima is

(a) 09 (b) 10 (c) 04 (d) 05

7. Visible light of wavelength 6000 x 10^{-8} cm falls normally on a single slit and produces a diffraction pattern. It is found that the second diffraction minimum is at 60^0 from the central maximum. If the first minimum is produced at Θ_1, then Θ_1 is close to

(a) 45^0 (b) 20^0 (c) 30^0 (d) 25^0

8. In a double slit experiment, when light of wavelength 400 nm was used, the angular width of the first minima formed on a screen placed 1 m away, was found to be 0.2^0. What will be the angular width of the first minima, if the entire experiment apparatus is immersed in water ($\mu_{water} = 4/3$)

(a) 0.15^0 (b) 0.05^0 (c) 0.1^0 (d) 0.266^0

9. A linear aperture whose width is 0.02 cm is placed immediately in front of lens of focal length 60 cm. The aperture is illuminated normally by a parallel beam of wavelength 5×10^{-5} cm. The distance of the first dark band of the diffraction pattern from the centre of the screen is

(a) 0.20 cm (b) 0.15 cm (c) 0.10 cm (d) 0.25 cm

10. The YDSE is performed with blue and with green light of wavelength 4360 A^0 and 5460 A^0 respectively. If x is the distance of 4th maximum from the central one, then

(a) x (blue) = x (green) (b) x (blue) > x (green)

(c) x (blue) < x (green) (d) $\frac{x\ (blue)}{x(green)} = \frac{5460}{4360}$

Answers:

1. d 2. d 3. a 4. c 5. c 6. d 7. d 8. a 9. b 10. c

****

11. DUAL NATURE OF RADIATION AND MATTER

SYLLABUS: Dual nature of radiation, Photo electric effect, Hertz and Lenard's observations, Einstein's photo electric equation, particle nature of light, Experimental study of photo electric effect. Matter waves, wave nature of particles, de-Broglie equation.

GIST

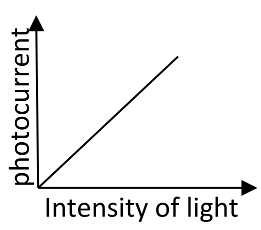
Particle nature of light

- **Work function ($\emptyset_0$):** The minimum energy required by an electron to escape from a metal surface.
- **Photo electric effect:** The phenomenon was discovered by Heinrich Hertz. When UV/visible radiations of suitable energy fall on some material surfaces, electrons are emitted from it. Hallwachs' and Lenard conducted detailed experiments.

S No	Name of the em radiations	Material(s) that emit electrons
1	UV radiations	Zinc, cadmium, magnesium, Selenium, copper etc.
2	Visible light	Lithium, Sodium, Potassium, caesium, rubidium

Experimental study and observations of photo electric effect

- **Factors on which photo electric current depends upon:**
- Intensity of the incident radiations
- Frequency of the incident radiations
- Potential difference between the electrodes of a photocell
- Nature of the material used
- **Intensity:** It refers to the number of photoelectrons of a particular energy emitted per unit area per sec. It is inversely proportional to the square of the distance (d) of a source from the photosensitive material. $\left(I \propto \frac{1}{d^2}\right)$
- **Intensity** and **photo electric current** are **directly proportional** to each other.

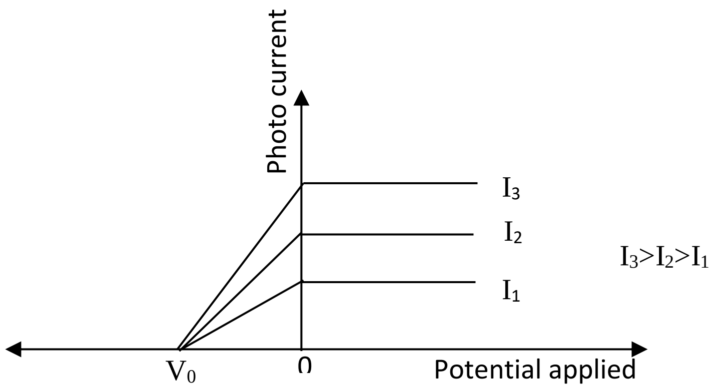


- **VARIATION OF POTENTIAL DIFFERENCE AND CURRENT**

Potential difference applied between the electrodes and photoelectric current.
Higher the positive potential to the collector plate implies current is saturated.

When the potential is slowly decreased and increased towards the negative potential, the photo electric current starts falling and reaches zero at a particular potential.

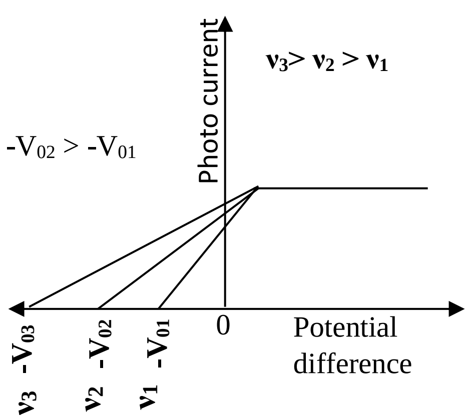
- **This negative retarding potential is independent of the intensity of the incident radiations for a given frequency of the incident radiations.**
- **Cut-off or stopping potential(V_0):** The retarding potential for which the photoelectric current is zero is also called as cut-off or stopping potential. At the cut-off potential, the maximum kinetic energy of the photo electrons becomes equal to the potential energy of the electrons. $K_{max} = eV_0 = \emptyset_0$



Variation of photo electric current with potential applied

- **Variation of the Photo electric current with the frequency of the incident radiations (on cut-off or stopping potential):**

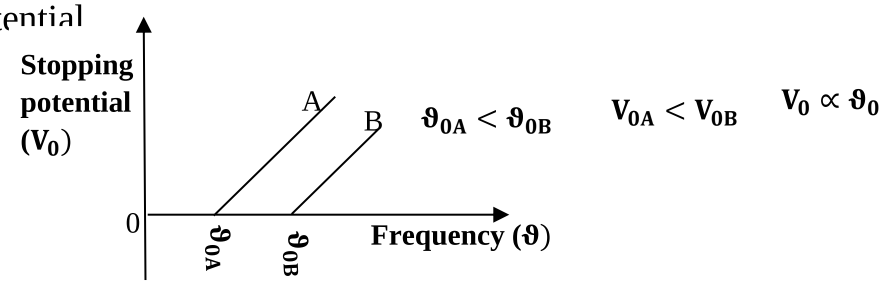
For a given intensity of the incident radiations, saturation current remains same but the cut-off or stopping potential would be different for different frequencies of the incident radiations. Greater the frequency, greater is the stopping or cut-off potential.



Variation of photo current and potential difference but same intensity

- **Variation of stopping or cut-off potential [hence kinetic energy] with frequency of the incident radiations.:**

The cut-off or stopping potential is directly proportional to the frequency of the incident radiations for two metals A, B. Greater the frequency, greater is the stopping or cut-off potential



Variation of stopping potential with frequency of the incident radiation

- **Cut-off or threshold frequency(ϑ_0):** The minimum frequency of the incident radiations below which no photo electric emission is possible is called cut-off or threshold frequency. It is independent of the incident radiations. This threshold frequency is also directly proportional to the stopping potential.

$$\vartheta_0 \propto V_0$$

- **Einstein's photo electric equation and laws of photo electric emission:**

$K_{max} = \frac{1}{2}mv_{max}^2 = h\vartheta - \emptyset_0$; as $\emptyset_0 = h\vartheta_0$

$K_{max} = h[\vartheta - \vartheta_0]$ or $K_{max} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$ or

$h[\vartheta - \vartheta_0] = eV_0 = \frac{1}{2}mv_{max}^2$

$v_{max}^2 = \frac{2h}{m}[\vartheta - \vartheta_0]$ or $V_0 = \left(\frac{h}{e}\right)\vartheta - \left(\frac{\emptyset_0}{e}\right)$

For photo electric emission to take place, $\vartheta \geq \vartheta_0$ or $\lambda \leq \lambda_0$.

Laws of photoelectric emission

- Photo electric emission is an instantaneous process.
- The frequency of the incident radiations should be greater than the threshold frequency for a given photosensitive material.
- Photoelectric current is directly proportional to the intensity of the incident radiations, provided the frequency of the incident radiations is greater than the threshold frequency.
- The stopping or cut-off potential for a given material is directly proportional to the threshold frequency but independent of the intensity of the incident radiations.

Power of a bulb [P] is equated with number of photons N of given energy E per unit time as $\mathbf{P = E \times N}$

Wave nature of matter

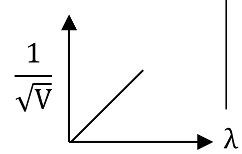
Nature loves symmetry. Waves can behave as particles and particles can behave as waves.

Wave theory of light shows the phenomenon of reflection, refraction, interference, diffraction and polarization. Particle theory [photons] of light proves photoelectric effect.

Wave nature of particle was theoretically proposed by **Louis Victor de Broglie.** He called the waves associated with matter in motion as matter waves and also proposed the equation for the wavelength of such waves as $\boldsymbol{\lambda = \frac{h}{mv}}$, where mv is the momentum of the matter in motion and for a photon, the wavelength is given by $\boldsymbol{\lambda = \frac{c}{\vartheta}}$

For charged particles accelerated by a **potential difference V** and having **kinetic energy K**, the **wavelength λ** associated is given by

$$\boldsymbol{\lambda = \frac{h}{\sqrt{2mqV}} = \frac{h}{\sqrt{2mK}}}$$



Wavelength of an electron accelerated by a potential V is given by

$\boldsymbol{\lambda = \frac{1.227}{\sqrt{V}}}$ **nm, for a charged particle the graph is as shown.**

For a potential difference of about 120V, the wavelength of electron is **0.112 nm** which is roughly the **wavelength of X rays.**

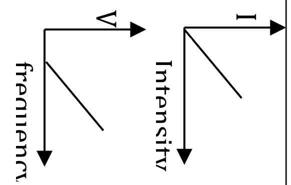
De Broglie wavelength of electrons are determined experimentally in **Davisson-Germer experiment** and paved the way for the **construction of electron microscope** having high resolutions while viewing bacteria and virus.

DUAL NATURE OF RADIATION AND MATTER

MIND

PARTICLE NATURE OF RADIATION

Photo electric effect observed by Hertz and Lenards. Emission of electrons by some photo sensitive materials, when the frequency of light is above the threshold value



Laws of photo electric Emission: [graphs shown here]

- Instantaneous process
- No of electrons depends directly on intensity
- Stopping potential is directly proportional to frequency
- Requires threshold frequency ϑ_0

Einstein's equation

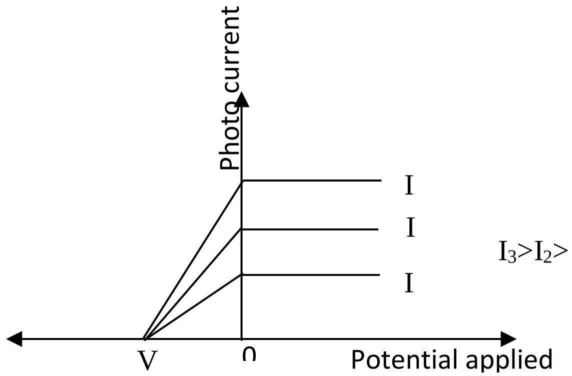
Work function. $K_{max} = h\vartheta - h\vartheta_0$ is the minimum energy of

WAVE NATURE OF MATTER

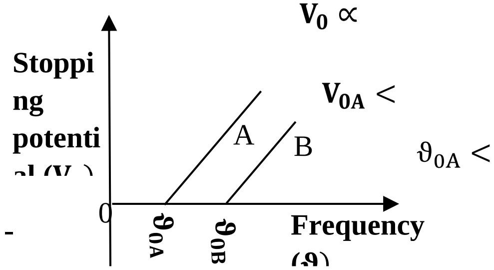
MATTER WAVES: De Broglie Waves:
Wave length $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mqV}} = \frac{h}{\sqrt{2mK}}$
[charged particles]

For electrons $\lambda = \frac{h}{\sqrt{2mqV}} = 1.67\dot{A}, V = 54\ V$

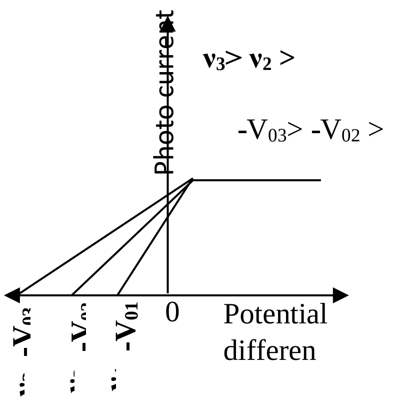
Braggs law: $n\lambda = 2d\sin\theta$, $\lambda == 1.65\dot{A}$[X Rays]



Variation of photo electric current with potential applied



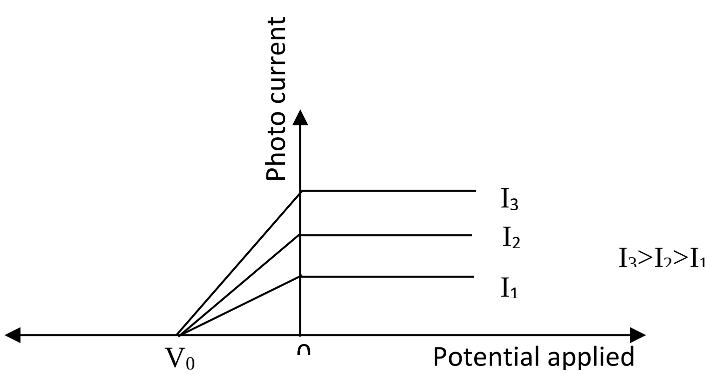
Variation of stopping potential with frequency of the incident radiation



Variation of photo current and potential difference but same intensity

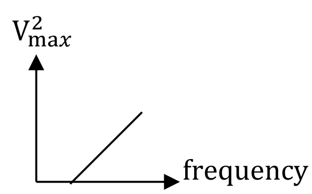
COMPETENCY BASED QUESTIONS	
1	The phenomenon of photo electric effect proves the **a. Quantum theory of light** **b. Wave theory of light** **c. Both the quantum theory and wave theory** **d. None of the above.**
ANS	A
2	The wave length of light falling on a photosensitive material is λ while the threshold wavelength for the material is λ_0. The photoelectric effect would take place only if **a. $\lambda > \lambda_0$** **b. $\lambda < \lambda_0$** **c. Either of the above** **d. Photoelectric effect is independent of the wave length of the light**
ANS	
3	If the distance between the light source and the photosensitive material is doubled, the intensity of the light falling on it changes **a. Two times** **b. Four times** **c. Half times** **d. One fourth times**
ANS	D Explanation: $I \propto \frac{1}{d^2} \Rightarrow \frac{1}{4}$
4	When blue light of a given intensity falls on a photo sensitive material, photoelectrons of some energy are ejected out of it. If it is replaced by red light of same intensity, then **a. Photoelectrons will not be emitted from the material** **b. Photoelectrons emitted will have higher energy** **c. Photoelectrons emitted will have smaller energy** **d. Photoelectrons emitted will have same energy.**
ANS	A EXPLANATION: FREQUENCY OF RED IS SMALLER THAN THAT OF BLUE COLOUR
5	The theory of wave nature of particle is motion was put forward by **a. Einstein**

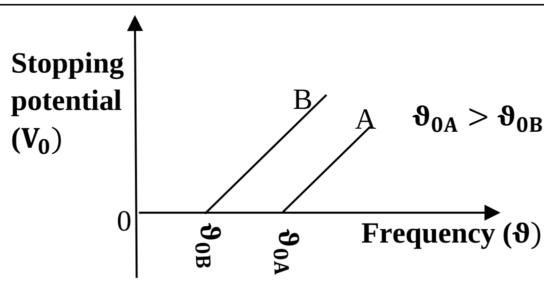
	b. Bohr **c. Louis Victor De Broglie** **d. J J Thomson**
ANS	C
6	The stopping potential for a photosensitive material is -5V. Then the work function for the material is **a. +5 J b. -5 J c. +5 eV d. -0.5 eV**
ANS	C
7	The stopping potential and the threshold frequency for a given photosensitive material is related as **a. Directly proportional to each other** **b. Inversely proportional to each other** **c. Equal to each other** **d. There is no such relation between the two quantities**
ANS	A
8	The De Broglie wavelength associated an electron accelerated by a potential difference of 100 V would approximately equal to be **a. 0.1227 nm** **b. 12.27 nm** **c. 0.01227 nm** **d. 1.227 nm**
ANS	A Explanation $\lambda = \frac{1.227}{\sqrt{V}}$ **nm**
9	The equation for momentum of a photon would be **a. h/λ** **b. h/ν** **c. λ/h** **d. ν/h**
ANS	A

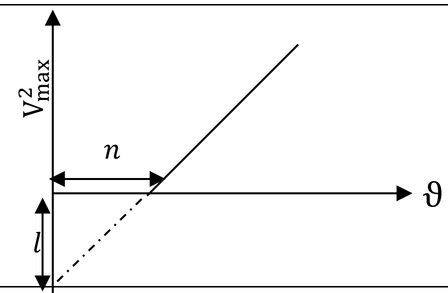
10	Two charged particles A, B of masses m_A, m_B ($m_A>m_B$) move with same kinetic energy. Then the De Broglie wavelength of the two particles would be given by **a.** $\lambda_A > \lambda_B$ **b.** $\lambda_A < \lambda_B$ **c.** $\lambda_A = \lambda_B$ **d. None of the above.**
ANS	B Explanation $\boldsymbol{\lambda} \propto \frac{1}{\sqrt{m}}$
11	The quantum nature of light explains the observations on photoelectric effect as- **a. There is a minimum frequency of incident radiation below which no electrons are emitted.** **b. The maximum kinetic energy of the photoelectrons depends only on the frequency of the incident radiations** **c. When the metal surface is illuminated, electrons are ejected from the surface of the material after some time.** **d. The photoelectric current is independent of the intensity of the incident radiations.**
ANS	A
12	Draw graph showing the variation of photoelectric current with the applied voltage for two incident radiations of equal frequency and different intensities. Mark the graph for the radiation of higher intensity
ANS	
3	Are the matter waves similar to electromagnetic waves? Why?

ANS	No, they are not same. Wavelength, frequency are not related to speed in matter waves.
4	What is the advantage of finding wavelength of a moving electron?
ANS	It helped in the construction of electron microscope used for high resolution picture of virus, etc.
5	**How is the intensity of the incident radiations related to the stopping potential for a photosensitive material?**
ANS	They are independent of each other
	2 MARKS QUESTIONS
1	If light of wavelength 412.5 nm is incident on each of the following materials given below, which one will show photo electric emission? Why? Metal: Na, K, Ca, Mo Work function(eV): 1.92, 2.15, 3.20, 4.17
ANS	Using $E = \frac{hc}{e\times\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times412.5\times10^{-9}} = 3eV > W_{Na}, W_K$ So, Na, K will emit photo electrons.
2	In wave picture of light, intensity of light is determined by the square of the amplitude of light. What determines the intensity in photon picture of light?
ANS	Intensity is determined by the number of photons of a given energy per unit area/time.
3.	A proton and an alpha particle are accelerated by the same potential difference. Which of them will possess (i) higher de-Broglie wavelength; (ii) less kinetic energy. Justify your answers
ANS	(i) High de-Broglie wavelength for proton because $\boldsymbol{\lambda \propto \frac{1}{\sqrt{mq}}},\ (\mathbf{mq})_{\mathbf{alpha}} > (\mathbf{mq})_{\mathbf{proton}}$ (ii) Proton has less kinetic energy because $\mathbf{Vq = KE};\ \mathbf{q_{alpha} > q_{proton}}$
4	Explain the reasons why the wave theory of light is not able to explain the observed effects of photoelectric effect?

Metal	Na	K	Ca	Mo
Work function(eV)	1.92	2.15	3.20	4.17

ANS	(i) By wave theory, one cannot prove the instantaneous process of photo electric emission. (ii) Threshold frequency does not exist as per the wave theory. (iii) As per wave theory, intensity of the incident light and the kinetic energy of photoelectrons should be directly proportional to each other. This is also against the observations made.
5	The ratio of de Broglie wavelengths of a proton and a deuteron accelerated by potential V_p and V_d respectively, $\left(\frac{\lambda_p}{\lambda_d}\right) = \frac{1}{2}$. Find the ratio between V_p and V_d.
ANS	$\boldsymbol{\lambda \propto \frac{1}{\sqrt{mqV}}}$, $\boldsymbol{(mq)_{deuteron}(=2) > (mq)_{proton}(=1) \therefore \frac{V_p}{V_d} = 4:1}$
3 MARKS QUESTIONS	
1	State the laws of photoelectric emission. Also draw a graph between the v_{max}^2 and frequency of the incident radiation, where the V_{max} refers to the maximum velocity of photoelectrons.
ANS	• Photo electric emission is an instantaneous process. • The frequency of the incident radiations should be greater than the threshold frequency for a given photosensitive material. • Photoelectric current is directly proportional to the intensity of the incident radiations, provided the frequency of the incident radiations is greater than the threshold frequency. • The stopping or cut-off potential for a given material is directly proportional to the threshold frequency but independent of the intensity of the incident radiations. 
2	A beam of monochromatic radiations is incident on a photosensitive surface. Answer the following, giving reasons. (i) Do the emitted photoelectrons have the same kinetic energy? (ii) Does the kinetic energy of the electron emitted depends on the intensity of the incident radiations? (iii) On what factors does the number of photoelectrons emitted depend upon?

ANS	(i) No, all the electrons are bound with different layers of the metal. So, the more tightly bound electrons will come out with less kinetic energy. KE of electrons are not same. (ii) No, kinetic energy of electrons does not depend on the intensity but the frequency [should be greater than the threshold frequency] of the incident radiations. (iii) It depends on the intensity of the incident radiations whose energy should be greater than the work function of the material.
3	Define the term work function of a metal. The threshold frequency for a material is f_0. When light of frequency $2f_0$ is made to fall on the plate, the velocity of electrons emitted is v_1 and when light of frequency $5f_0$ is made to fall on it, the velocity of electrons is found to be v_2. Calculate the ratio of v_1 and v_2.
ANS	**Work function ($\emptyset_0$):** The minimum energy required by an electron to escape from a metal surface. $\mathbf{v_{max}^2 = \frac{2h}{m}[f - f_0] \Rightarrow v_1^2 \propto f_0 \& v_2^2 \propto 4f_0 \Rightarrow \frac{V_1}{V_2} = 1:2}$
4	Sketch the graph showing the variation of stopping potential with frequency of the incident radiations for two photosensitive materials A, B having threshold frequency of A>B. In which of the case, the stopping potential is more and why? Does the slope depend on the nature of the material used? Explain
ANS	 $\boldsymbol{\vartheta_{0A} > \vartheta_{0B}}$ $\mathbf{V_{0A} > V_{0B}}$ $\mathbf{V_0 \propto \vartheta_0}$ **Variation of stopping potential with frequency of the incident radiation** $\mathbf{V_0 = \left(\frac{h}{e}\right)\vartheta - \left(\frac{\emptyset_0}{e}\right)}$**; the slope** $\mathbf{\left(\frac{h}{e}\right)}$**is a universal constant which is independent of the nature of the material used**
5	From the plot of the graph between the frequency of the incident radiations and the square of the maximum velocity of the electrons from the surface of a photosensitive material, find the values of the Planck's constant and work function in terms of the x, y intercepts and mass (m) of the electron

	
ANS	$\frac{\mathbf{v^2_{max}}}{\boldsymbol{\vartheta}} = \frac{\boldsymbol{l}}{\boldsymbol{n}} = \boldsymbol{slope\ of\ the\ graph}$ $\mathbf{v^2_{max}} = \frac{\mathbf{2h}}{\mathbf{m}}[\vartheta - \mathrm{n}]$ $\boldsymbol{Planck's constant[h]} = \frac{m}{2} \times \frac{l}{n}$; **work function**= $h \times n = \frac{m \times l}{2}$

<u>CASE-STUDY BASED QUESTION</u>

1. The work function of metal **A is 3.6 eV** and another metal **B is 13.6 eV.** Light of energy E is made to fall on these surfaces. It is found that maximum kinetic energy of the electrons emitted from A is twice that of the electrons emitted by B.

Based on the above passage, answer the following questions.

(i) The value of E is

a. 20.8 eV b. 23.8 eV c. 24.6 eV d. 32.2 eV

(ii) The difference in maximum kinetic energy of the photoelectrons from A and B

a. Increases with increase in E
b. Decreases with increase in E
c. First increases and then decreases with increase in E
d. Remains constant

(iii) The threshold wavelength of A and B are related to each other as:

a. $\boldsymbol{\lambda_A = 2\lambda_B}$ **b.** $\boldsymbol{\lambda_B = 2\lambda_A}$ **c.** $\boldsymbol{\lambda_A = 4\lambda_B}$ **d.** $\boldsymbol{\lambda_B = 4\lambda_A}$

(iv) The number of photoelectrons emitted from the surfaces will depend upon

a. Distance of the source from the photosensitive material
b. Frequency of the incident radiations.
c. Colour of light falling on it.
d. All the above.

(i)	(ii)	(iii)	(iv)
B	D	D	A

Radiations have dual nature., wave and particle. The nature of the experiment determines whether the wave or particle description is best suited for understanding the experimental result. Reasoning that radiation and matter should be symmetrical in nature, Louis Victor de Broglie attributed a wave like character to matter. The waves associated with moving matter are called as matter waves or de Broglie waves.

Based on the above, answer the following questions.

(i) The momentum of electrons having kinetic energy of 120 eV would be

- a. $5.92 \times 10^{-24}\,\mathrm{kgm/s}$
- b. $5.20 \times 10^{-24}\,\mathrm{kgm/s}$
- c. $4.92 \times 10^{-24}\,\mathrm{kgm/s}$
- d. $4.20 \times 10^{-24}\,\mathrm{kgm/s}$

(ii) The nature of matter waves is

- a. **Similar to that of em waves**
- b. **Different from that of em waves**
- c. **Sometimes similar to that of em waves and other times different from that of em waves.**
- d. **Similar to that of sound waves.**

(iii) The wave nature of electrons is confirmed by

- a. **Davisson-Germer Experiment**
- b. **Millikan's oil drop experiment**
- c. **Alpha particle scattering experiment**
- d. **Cavendish experiment**

(iv) The de Broglie wavelength of an accelerated charged particle will be

- a. **Directly proportional to its kinetic energy**
- b. **Inversely proportional to its kinetic energy**
- c. **Independent of its kinetic energy**
- d. **Inversely proportional to the square root of its kinetic energy.**

ANSWERS FOR CBQ			
1	**2**	**3**	**4**
A	**B**	**A**	**D**

ASSERTION-REASON TYPE QUESTIONS

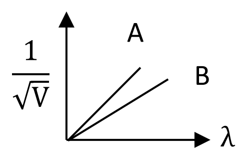
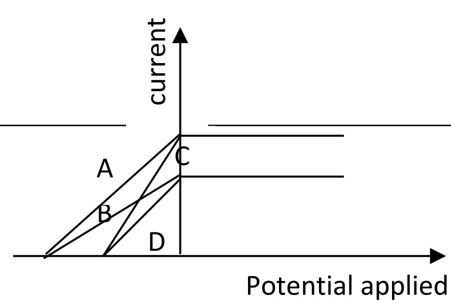
In the following questions, mark the correct choice as:

(a) Both assertion and reason are true and the reason is a correct explanation of the assertion.

(b) Both assertion and reason are true but the reason is not a correct explanation of the assertion. **(c) Assertion is true but the reason is false.** **(d) Both assertion and reason are false.**	
1	**ASSERTION:** Electrons are emitted from the surface of zinc when irradiated by yellow light **REASON:** Energy associated with a photon of yellow light is more than the work function of Zinc.
ANS	D [Zinc responds to ultra violet radiations only]
2	**ASSERTION:** The number of photoelectrons emitted by a photosensitive material depends on the intensity of light falling on the surface of the material. **REASON:** The intensity of the light falling is independent of the nature of the material.
ANS	A
3	**ASSERTION:** Light of frequency greater than that of threshold frequency for a material, then electrons would be emitted from the surface of the material. **REASON:** For given materials A, B the threshold frequency is such that $\nu_A > \nu_B$. If the light falling on them has frequency greater than their threshold frequency, then the kinetic energy of the electrons emitted by A would be smaller than that of B.
ANS	A
4	**ASSERTION:** When a proton and an alpha particle are accelerated by a similar potential difference, the wavelength for proton is greater than that for alpha particle. **REASON:** Wavelength of the waves for these particles are inversely proportional to the square root of product of their masses and charges.
ANS	A
5	**ASSERTION:** Wavelength of electrons is of the order of that of X rays when accelerated by a potential difference of about 54 V **REASON:** Electron microscopes are having high resolving power as the wavelength and resolving power are inversely proportional to each other
ANS	B

SELF TEST

1	Two metal surfaces have work function $\emptyset_A, \emptyset_B$. $[\emptyset_A > \emptyset_B]$They are exposed to visible radiation of frequency ϑ which is greater than the threshold frequency of both A, B. Which of these metals will emit electrons of higher kinetic energy?	1 M
2	Is it possible to make the electrons to be emitted from a metal surface by increasing the intensity, with frequency less than its threshold value?	1 M
3	Draw graph showing the variation of de-Broglie wavelength and $\frac{1}{\sqrt{V}}$ where Vis the accelerating potential.	1 M
4	X ray microscope cannot be constructed whereas, electron microscope are constructed though both X rays and electrons accelerated by a potential of 54 V has similar wavelengths. Why?	1 M
5	An electron and an alpha particle have same de-Broglie wave length. Compare their kinetic energies.	1 M
6	A laser lamp with power 5 mW emits light. Find the number of photons of energy 1.5 eV emitted by it per unit time.	1 M
7	The maximum velocity of photo electrons emitted by an ideal metal surface when exposed to a light of given frequency is v. Find the maximum velocity of the electrons, if the frequency of the incident light is increased by 4 times.	1 M
8	hich of the following represents Einstein's equation? a. $\mathbf{V_0} = \left(\frac{\mathbf{h}}{\mathbf{e}}\right)\boldsymbol{\vartheta} - \left(\frac{\emptyset_0}{\mathbf{e}}\right)$ b. $\mathbf{V_0} = \left(\frac{\mathbf{h}}{\mathbf{e}}\right)\boldsymbol{\vartheta} + \left(\frac{\emptyset_0}{\mathbf{e}}\right)$ c. $\mathbf{K_{max}} = \mathbf{h}\boldsymbol{\vartheta} + \emptyset$ d. $\mathbf{V_0} = -\left(\frac{\mathbf{h}}{\mathbf{e}}\right)\boldsymbol{\vartheta} + \left(\frac{\emptyset_0}{\mathbf{e}}\right)$	1 M
9	The work function of caesium is 2.14 eV. Then its threshold frequency would be a. 5.16×10^{14}Hz b. 5.45×10^{14}Hz c. 6.16×10^{14}Hz d. None	1 M
10	The ratio of wavelength of a photon and of an electron of same kinetic energy would be a. $\frac{1}{c}\sqrt{\frac{2m}{E}}$ b. $c\sqrt{\frac{2m}{E}}$ c. $\sqrt{\frac{2m}{E}}$ d. $\sqrt{\frac{m}{E}}$	1 M

11	**ASSERTION:** Photoelectric effect demonstrates particle nature of light. **REASON:** The number of photons emitted depends on frequency of the light falling on a given metal surface	1 M
12	**ASSERTION:** The work function of different metals are different **EASON:** The electrons emitted by a given metal surface have single kinetic energy.	1 M
13	**ASSERTION:** A photon and a charged particle accelerated by a given potential can have same de-Broglie wavelength **REASON:** The energy of the photon and the kinetic energy of the charged particle will also be same.	1 M
14	Two particles have same charge are accelerated by a given potential difference V. From the graph shown, find which one has more mass? Justify the same.  	2 M
15	A proton and an electron have same velocity. Which one will have higher de-Broglie wave length? Why?	2 M
16	The work function for Na is 2.75 eV and that for Mo is 4.175 eV. Which of these will not be able to emit photo electrons when exposed to a wavelength of 330 nm? Why? If the source is brought closer, what will be the effect on kinetic energy of the electrons emitted?	2 M
17	Draw graph to show the variation of stopping potential with the frequency of the incident radiations falling on a metal surface. Which quantity is measured by the slope of this graph experimentally? How does the slope vary with change of metal?	3 M
18	The graph shows the variation of photoelectric current for two different materials for two different intensities of radiations. Identify and explain using Einstein's photo electric equation for the pair of curves that correspond to (i) different materials but same intensity; (ii) different intensities but same material. (iii) Which of these will emit photo electrons of more kinetic energy?  	3 M

19	(i) Write two characteristic features observed in photoelectric effect based on photon theory. (ii) Draw a graph between the kinetic energy of the electrons emitted and the frequency of the incident radiations. (iii) Hence explain how will you determine the Planck's constant and work function of a photosensitive material.	3 M
20	(i) Write the expression for de-Broglie wavelength of a charged particle and neutron. (ii) The first two isotopes of hydrogen have same kinetic energy. Which of them will have more de-Broglie wavelength? (iii) Draw a schematic diagram of a localized wave describing the wave nature of an electron.	3 M
21	**<u>CASE BASED QUESTIONS</u>** The de-Broglie wavelength (λ) associated with a moving particle is related to its momentum by the equation $\lambda = \frac{h}{mv}$. The dualism of matter is inherent in the above equation. The de-Broglie wavelength is independent of charge and nature of the particle. It is significantly measurable only in sub atomic particles like electrons, protons etc., However it is indeed small, quite beyond measurement in case of macroscopic objects, commonly encountered in daily life situations. Based on the above answer the following questions: 1. Why do we say that dual nature of radiation and matter exist? a. Because they show particle character. b. Because they show the wave character. c. Because they show both particle and wave character d. None of the above. 2. The de-Broglie wavelength of a foot ball of mass 1 kg moving with a speed of 1 m/s would approximately be a. 10^{-34}m b. 10^{-33}m c. 10^{-35}m d. 1m 3. Write the expression for the de-Broglie wavelength of a neutron. 4. Does the de-Broglie hypothesis of matter waves support the Bohr's concept of stationary orbits? [OR]	4 M

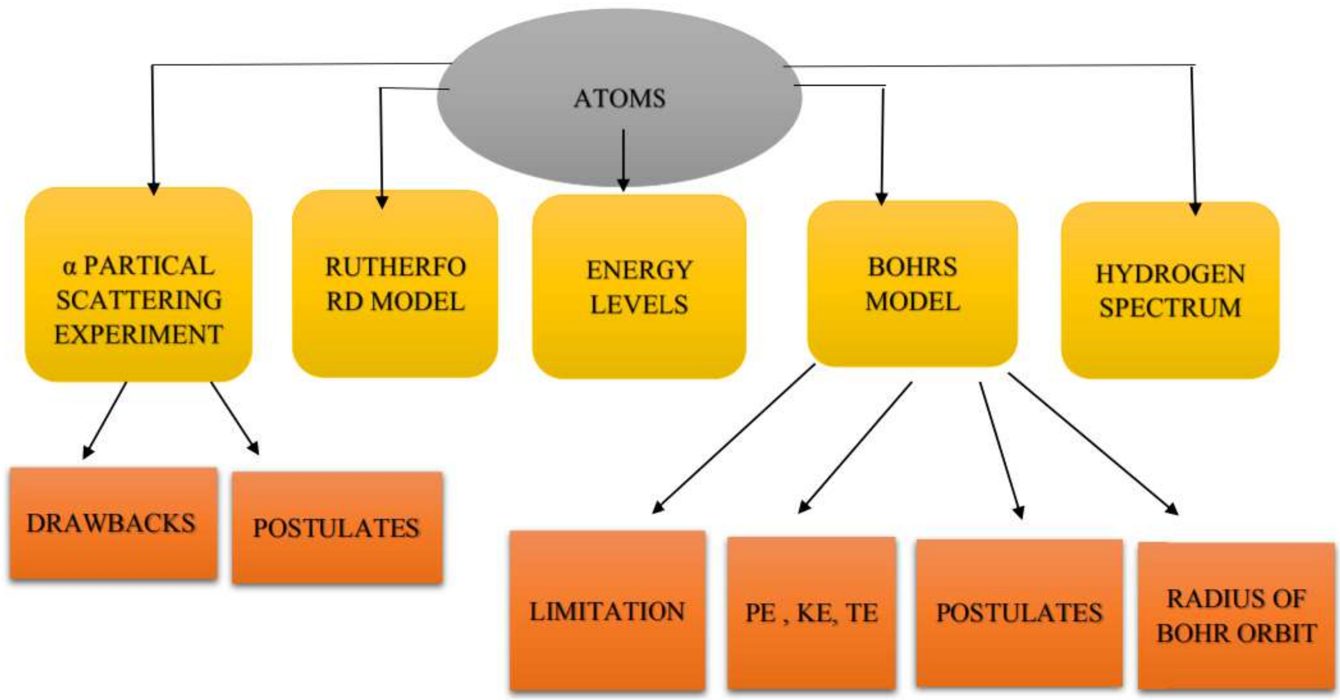
	How is Heisenberg's uncertainty principle accounted for using de-Broglie hypothesis	

****

12. ATOMS

SYLLABUS: Alpha-particle scattering experiment; Rutherford's model of atom; Bohr model of hydrogen atom, Expression for radius of nth possible orbit, velocity and energy of electron in nth orbit, hydrogen line spectra (qualitative treatment only)

MIND MAP



GIST OF THE LESSON

- Every element is made up of tiny, invisible particles known as atoms.
- Every atom is a sphere with a radius of 10^{-10} m in which the entire mass is uniformly distributed and the nucleus is surrounded by negatively charged electrons.
- Experimental setup for the α-scattering experiment (Geiger- Marsden experiment).

Conclusions of α-scattering experiment (Geiger- Marsden experiment)

- (i) The existence of a positively charged nucleus in an atom.
- (ii) Most of the α-particles pass straight, so most of the space in the atom is empty.
- (iii) Very few α-particles suffer large angle scattering > 90°. The large angle scattering indicates that most of the mass and entire positive charge of the atom are concentrated in a very small volume of the atom, called nucleus.

Impact parameter

- The impact parameter is the perpendicular distance between the velocity vector of a particle and the central line of the nucleus of the atom.

Basic Assumptions of Rutherford's Atomic Model

- Atoms are made up of a small central core known as the atomic nucleus, which is thought to contain all of the mass and positive charge.
- Electrons surround the nucleus, making the atom electrically neutral.
- The nucleus is surrounded by electrons, and the centripetal force is electrostatic.

- **Distance of Closest Approach:**

  The KE of a α-particle converts to electrostatic potential energy at a distance r_0 from the nucleus, and the -particle can no longer approach the nucleus; this distance (r_0) is known as the distance of closest approach.

- **Angle of Scattering:**
- Angle of scattering is the angle by which a particle deviates from its original path around the nucleus.

Limitations of Rutherford's Model

- (i) It was unable to clearly explain the stability of an atom.
- (ii) Line spectrum cannot be explained.

Bohr's Theory of the Hydrogen Atom

- Electrons revolve around the nucleus in stable orbits without emission of radiant energy.
- The electrons revolves around the nucleus only in those orbits for which the angular momentum is an integral multiple of $\frac{h}{2\pi}$.
- An electron emits or absorbs energy when it jumps from one orbit or energy level to another.

Bohr's Model Limitations

- (i) Only applies to hydrogen-like atoms.
- (ii) Does not account for the fine structure of H-atom spectral lines.
- (iii) The shape of the orbit is not explained.

Energy Level:

- When an atom's electron is revolving in the orbit closest to the nucleus, n = 1, the energy of the atom is the lowest.
- The ground state of an atom is the lowest and most energy-dense state of the atom. This state has an energy of -13.6 eV for hydrogen atom.
- Spectral emission occurs when an electron transitions, or jumps, from a higher energy state to a lower energy state.
- The spectral series of hydrogen are Lyman, Balmer, Paschen, Bracket and Pfund series.

IMPORTANT FORMULA

1) Distance of closest approach, $r_0 = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{KE}$

2) Impact parameter $b = \frac{Ze^2 \cot\frac{\theta}{2}}{4\pi\varepsilon_0\, KE}$

3) Angular momentum of electron = mvr = $\frac{nh}{2\pi}$

4) Radius of electron orbits in hydrogen atom $r_n = \frac{\varepsilon_0}{\pi}\frac{n^2}{m}\frac{h^2}{e^2}$

5) Velocity of electron in hydrogen atom $v_n = \frac{e^2}{2\varepsilon_0 nh}$

6) Total Energy of electron in hydrogen atom = $-\frac{1}{8\pi\varepsilon_0}\frac{e^2}{r}$

7) Kinetic Energy of electron in hydrogen atom = $\frac{1}{8\pi\varepsilon_0}\frac{e^2}{r}$

8) Potential Energy of electron in hydrogen atom = $-\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$

9) KE = - Total Energy of electron in hydrogen atom

10) PE = 2 X Total Energy of electron in hydrogen atom

11) Energy of electron in hydrogen atom, $E_n = -\frac{13.6}{n^2}$ eV

12) Energy emitted when electron jumps from one energy level to another,

$$h\nu = \frac{hc}{\lambda} = E_i - E_f$$

13) Energy emitted when electron jumps from one energy level to another,

$E = 13.6 \left(\frac{1}{n^2{}_f} - \frac{1}{n^2{}_i}\right)$ eV

14) Rydberg's formula, $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

A. COMPETENCY BASED QUESTIONS

(a) MULTIPLE CHOICE QUESTIONS (HOTS)

1) In an experiment on scattering of α-particles by a gold nucleus, the closest distance of approach is 30 fermi. If the velocity of the α-particle is doubled, the closest distance of approach will

(A) remain unaltered (B) double

(C) reduce to a value half of the original value (D) reduce to (1/4)th the original value

2) α-particles of energy 400 KeV are bombarded on nucleus of $_{82}Pb$. In scattering of α-particles, its minimum distance from nucleus will be

(A) 0.59 nm (B) 0.59 Å (C) 0.59 µm (D) 0.59 pm

3) α-particles are projected towards the nuclei of the following metals with the same kinetic energy. The distance of closest approach is minimum for

(A) Cu (Z = 29) (B) Ag (Z = 47) (C) Au (Z = 79) (D) Pd (Z = 46).

4) In the Bohr's model of a hydrogen atom, the centripetal force is furnished by the Coulomb attraction between the proton and the electron. If r_0 is the radius of the ground state orbit, m is the mass and e is the charge on the electron and ε_0 is the permittivity of vacuum, the speed of the electron is

(A) $\frac{2e}{\sqrt{\pi\varepsilon_0 r_0 m}}$ (B) $\frac{e}{\sqrt{\pi\varepsilon_0 r_0 m}}$ (C) $\frac{e}{\sqrt{4\pi\varepsilon_0 r_0 m}}$ (D) $\frac{4e}{\sqrt{\pi\varepsilon_0 r_0 m}}$

5) The ratio of time taken by the electron to go once round the nucleus in the orbits of radii R and 4R of hydrogen atom is

(A) 1 : 4 (B) 1 : 8 (C) 1 : 64 (D) 64 : 1.

6) For an electron revolving in a H-like atom, the radii of the first three orbits are r_1, r_2 and r_3 and the corresponding period of revolution are T_1, T_2 and T_3, Then,

(A) $r_1 : r_2 : r_3$ .....1: 2 :3.....and $T_1 : T_2 : T_3$ ......1: 4 :9

(B) $r_1 : r_2 : r_3$ .....1: 4 :9.....and $T_1 : T_2 : T_3$ ......1: 4 :9

(C) $r_1 : r_2 : r_3$ ....1: 2 :3.....and $T_1 : T_2 : T_3$ 1:8: 27

(D) $r_1 : r_2 : r_3$ .....1: 4 :9.....and $T_1 : T_2 : T_3$ 1:8: 27

7) The diameter of the Bohr orbit in hydrogen atom is 1.06×10^{-10} m. The diameter of the second orbit will be

(A) 4.24×10^{-10} m (B) 2.12×10^{-10} m (C) 8.48×10^{-10} m (D) 1.06×10^{-10} m

8) An electron in a hydrogen atom makes a transition from $n = n_1$ to $n = n_2$. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are

(A) $n_1 = 8, n_2 = 1$ (B) $n_1 = 8, n_2 = 2$ (C) $n_1 = 4, n_2 = 2$ (D) $n_1 = 5, n_2 = 3$

9) In the Bohr model of the hydrogen atom, let R, v and E represent the radius of the orbit, the speed of electron and the total energy of the electron respectively. The quantity that is proportional to the quantum number n is

(A) Rv (B) RE (C) Ev (D) $\frac{E}{R}$

10) A hydrogen atom is excited from its ground state to the state with n = 4. The energy absorbed by the atom is

(A) 0.85 eV (B) 1.51 eV (C) 13.6 eV (D) 12.75 eV

11) The kinetic energy of the electron in an orbit of radius r in a hydrogen atom is related to electron charge (e) as

(A) $\frac{e^2}{r^2}$ (B) $\frac{e}{r}$ (C) $\frac{e^2}{r}$ (D) $\frac{e^2}{r^3}$

12) According to the Bohr theory of H-atom, the speed of the electron, its energy and the radius of its orbit varies with the principal quantum number n, respectively as

(A) $\frac{1}{n}, \frac{-1}{n^2}, n^2$ (B) $\frac{1}{n}, n^2, \frac{1}{n^2}$ (C) $\frac{1}{n}, \frac{1}{n^2}, n^2$ (D) $n, \frac{-1}{n^2}, n^2$

13) If R is the Rydberg constant for hydrogen, the wave length of the first line in the Lyman series is

(A) $\frac{4}{R}$ (B) $\frac{4}{3R}$ (C) $\frac{2}{3R}$ (D) $\frac{1}{3R}$

14) The ratio of the maximum to the minimum wavelengths in Balmer series of H spectrum is

(A) 9 : 5 (B) 36 : 5 (C) 27 : 15 (D) 144 : 7

15) The ratio of the shortest wavelength of the Balmer series to the shortest wavelength of the Lyman series is

(A) 4 : 1 (B) 4 : 3 (C) 4 : 9 (D) 5 : 9.

16) The wavelength of first line of Balmer series is 6563 Å. The wavelength of first line of Lyman series will be

(A) 1215 Å (B) 2500 Å (C) 7500 Å (D) 600 Å

17) If λ_1 and λ_2 are the wavelengths members of the first line of Lyman and Paschen series respectively, then $\lambda_1 : \lambda_2$ is

(A) 1 : 3 (B) 1 : 30 (C) 7 : 50 (D) 7 : 108

18) Of the following transitions in the Hydrogen atom, the one which gives an emission line of the highest frequency is

(A) n = 3 to n = 1 (B) n = 4 to n = 1 (C) n = 3 to n = 2 (D) n = 2 to n = 1.

19) According to Bohr's theory (assuming infinite mass of the nucleus), the frequency of the second line of the Balmer series is

(A) 6.16×10^{14} Hz (B) 6.16×10^{13} Hz (C) 6.16×10^{15} Hz (D) 6.16×10^{16} Hz.

20) If the wavelength of the first line of the Balmer series of hydrogen is 6561 Å, the wavelength of the second line of this series should be

(A) 13122 Å (B) 3280 Å (C) 4860 Å (D) 2187 Å.

21) Frequency of the series limit of Balmer series of hydrogen atom in term of Rydberg constant R and velocity of light c is

(A) $\frac{4}{Rc}$ (B) $4Rc$ (C) $\frac{Rc}{4}$ (D) Rc

22) The largest wavelength in the ultraviolet region of the hydrogen spectrum is 122 nm. The smallest wavelength in the infrared region of the hydrogen spectrum (to the nearest integer) is

(A) 802 nm (B) 823 nm (C) 1882 nm (D) 1648 nm.

ANSWERS

(1) D (2)D (3)A (4)C (5)B (6)D (7)A (8)C (9)A (10)D (11)C (12)A (13)B (14)A (15)A (16)A (17)D (18)B (19)A (20)C (21)C (22)B

b. CASE STUDY BASED QUESTIONS

I. Rutherford's Atom model

The Rutherford model was devised by Ernest Rutherford to describe an atom. Rutherford directed the Geiger–Marsden experiment in 1909, which suggested, upon Rutherford's analysis, that J. J. Thomson's plum pudding model of the atom was incorrect. Rutherford's new model for the atom, based on the experimental results, contained new features of a relatively high central charge concentrated into a very small volume in comparison to the rest of the atom and with this central volume containing most of the atom's mass; this region would be known as the atomic nucleus.

Rutherford overturned Thomson's model in 1911 with his well-known gold foil experiment in which he demonstrated that the atom has a tiny and heavy nucleus. Rutherford designed an experiment to use the alpha particles emitted by a radioactive element as probes to the unseen world of atomic structure. If Thomson was correct, the beam would go straight through the gold foil. Most of the beams went through the foil, but a few were deflected.

Rutherford presented his own physical model for subatomic structure, as an interpretation for the unexpected experimental results. In it, the atom is made up of a central charge (this is the modern atomic nucleus, though Rutherford did not use the term "nucleus" in his paper) surrounded by a cloud of orbiting electrons.

(i) When a narrow accelerated beam of α - particles is allowed to fall on a thin gold foil, most of the α - particles pass straight through the foil or suffer only small deflections. This is because -

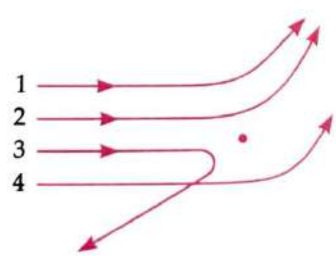
(A) α - particles are positively charged.

(B) α - particles are much massive than electrons.

(C) Most of the space within the atoms is empty.

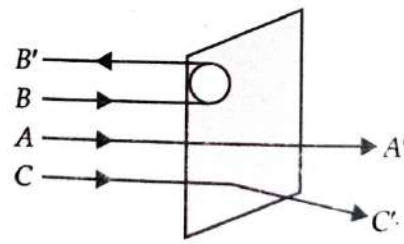
(D) α - particles move with high velocity.

(ii) The given figure show the path of four α - particles of the same energy being scattered by the nucleus of an atom simultaneously. Which of these are/is not physically possible?



(A) 3 and 4 (B) 2 and 3 (C)1 and 4 (D)4 only

(iii) A beam of fast moving α - particles was directed towards a thin foil of gold. The parts A', B' and C' of the transmitted and reflected beams corresponding to parts A, B and C of the beam are shown in the figure. The number of α - particles in



(A) B' will be maximum and in C' maximum.

(B) A' will be maximum and in B' minimum

(C) A' will be minimum and in B' maximum

(D) C' will be minimum and in B' minimum

(iv) Choose the correct option from the following options given below

(A) In the ground state of Rutherford's model electrons are in stable equilibrium while in Thomson's model electrons always experience a net-force.

(B) An atom has a nearly continuous mass distribution in a Rutherford's model but has a highly non-uniform mass distribution in Thomson's model.

(C) A classical atom based on Rutherford's model is doomed to collapse.

(D) The positively charged part of the atom possesses most of the mass in Rutherford's model but not in Thomson's model.

ANSWERS

(i) C (ii)D (iii)B (iv) C

II. <u>Rutherford's alpha particle scattering experiment</u>

Ernst Rutherford, a former research student of J J Thompson, proposed a classical experiment of alpha particles by atoms to investigate the atomic structure.The nucleus was postulated as small and dense to account for the scattering of alpha particles from thin gold foil, as observed in a series of experiments performed by undergraduate Ernest Marsden under the direction of Rutherford and German physicist Hans Geiger in 1909. A radioactive source emitting alpha particles (i.e., positively charged particles, identical to the helium atom nucleus and 7,000 times more massive than electrons) was enclosed within a protective lead shield. The radiation was focused into a narrow beam after passing through a slit in a lead screen. A thin section of gold foil was placed in front of the slit, and a screen coated with zinc sulfide to render it fluorescent served as a counter to detect alpha particles. As each alpha particle struck the fluorescent screen, it produced a burst of light called a scintillation, which was visible through a viewing microscope attached to the back of the screen. The screen itself was movable, allowing Rutherford and his associates to determine whether or not any alpha particles were being deflected by the gold foil.

From the experiment, Rutherford presented his own physical model for subatomic structure, as the atom is made up of a central positive charge surrounded by a cloud of orbiting electrons.

(i) The existence of positively charged nucleus in an atom was first established by

(A) Bohr's theory of hydrogen atom

(B) Positive rays analysis

(C) α - particles scattering experiment

(D) Thomson's model of atom

(ii) When alpha particles are sent through a thin gold foil, most of them go straight through the foil, because

(A) Alpha particles are positively charged

(B) The mass of an alpha particle is more than the mass of an electron

(C) Most of the part of an atom is empty space

(D) Alpha particles move with high velocity

(iii) In a Rutherford scattering experiment when a projectile of charge z_1 and mass m_1 approaches a target nucleus of charge z_2 and mass m_2, the distance of closest approach is r_0. The energy of the projectile is

(A) Directly proportional to z_1z_2

(B) Inversely proportional to z_1

(C) Directly proportional to mass m_1

(D) Directly proportional to m_1m_2

(iv) When a α - particle of mass m moving with velocity v bombards on a heavy nucleus of charge 'Ze', its distance of closest approach from the nucleus depends on m as

(A) $\frac{1}{m}$ (B) $\frac{1}{\sqrt{m}}$ (C) $\frac{1}{m^2}$ (D) m

ANSWERS

(i) C (ii)C (iii)A (iv) A

III. Bohr Model of Atom

In the year 1913, Niels Bohr proposed an atomic structure model, describing an atom as a small, positively charged nucleus surrounded by electrons that travel in circular orbits around the positively charged nucleus like planets around the sun in our solar system, with attraction provided by electrostatic forces, popularly known as Bohr's atomic model. It was basically an improved version of Rutherford's atomic model overcoming its limitations. On most of the points, he is in agreement with him, like concepts of nucleus and electrons orbiting it. Salient features of Niels Bohr atomic model are:

- Electrons revolve around the nucleus in stable orbits without emission of radiant energy.
- The electrons revolves around the nucleus only in those orbits for which the angular momentum is an integral multiple of $\frac{h}{2\pi}$.
- An electron emits or absorbs energy when it jumps from one orbit or energy level to another.

(i) Bohr's atom model assumes

(A) The nucleus is of infinite mass and is at rest

(B) Electrons in a quantized orbit will not radiate energy

(C) Mass of electrons remains constant

(D) All the above conditions

(ii) $\frac{h}{2\pi}$ has the dimensions of

(A) Velocity (B) Momentum (C) Energy (D) Angular momentum

(iii)The ratio between the first three Bohr radii is

(A) 1:2:3 (B) 2:4:6 (C) 1:4:9 (D) 1:3:5

(iv)Energy E of a hydrogen atom with principal quantum number n is given by $E = -\frac{13.6}{n^2}$ eV

The energy of a photon ejected when the electron jumps from n= 3 state to n = 2 state of hydrogen, is approximately

(A) 1.5 eV (B) 0.85 eV (C) 3.4 eV (D) 1.9 eV

ANSWERS

(i) D (ii)D (iii)C (iv) D

IV. Hydrogen spectral series

A hydrogen atom consists of an electron orbiting its nucleus. The electromagnetic force between the electron and the nuclear proton leads to a set of quantum states for the electron, each with its own energy. These states were visualized by the Bohr model of the hydrogen atom as being distinct orbits around the nucleus. The Bohr model was later replaced by quantum mechanics in which the electron occupies an atomic orbital rather than an orbit, but the allowed energy levels of the hydrogen atom remained the same as in the earlier theory.

Spectral emission occurs when an electron transitions, or jumps, from a higher energy state to a lower energy state. The energy of an emitted photon corresponds to the energy difference between the two states. Because the energy of each state is fixed, the energy difference between them is fixed, and the transition will always produce a photon with the same energy.

Spectral series of the Hydrogen atom were identified in the course of spectroscopic investigations and are known as the Lyman, Balmer, Paschen, Brackett and Pfund series.

(i) If ground state ionisation energy of H-atom is 13.6eV, the energy required to ionize a H-atom from second excited state is

(A) 1.51eV (B) 3.4eV (C) 13.6eV (D) 12.1eV

(ii) The atomic hydrogen emits a line spectrum consisting of various series. Which series of hydrogen atomic spectra is lying in the visible region?

(A) Balmer series (B) Brackett series (C) Lyman series (D) Paschen series

(iii) A gas of monoatomic hydrogen is bombarded with a stream of electrons that have been accelerated from rest through a potential difference of 12.75 V. In the emission spectrum one cannot observe any line of

(A) Lyman series (B) Balmer series (C) Paschen series (D) Pfund series

(iv) The ratio of maximum frequency and minimum frequency of light emitted in Balmer series of hydrogen spectrum, in Bohr's model is

(A) 11/9 (B) 9/5 (C) 11/7 (D) 16/7

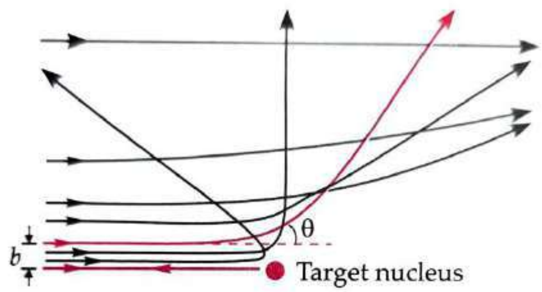
ANSWERS

(i) A (ii)A (iii)D (iv) B

c. 1 m, 2m & 3m questions (HOTS)

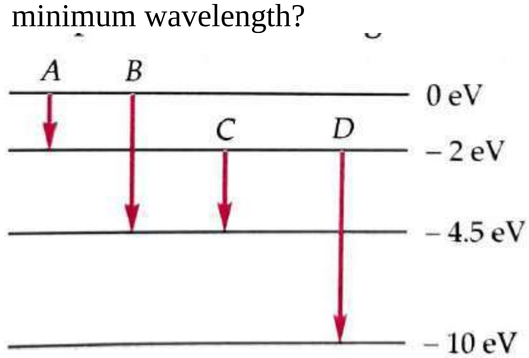
1) The KE of alpha particle incident on gold foil doubled. How does the distance of closest approach change?
2) In the Rutherford experiment, the distance of closest approach for an alpha particle is d_0. If alpha particle is replaced by a proton, how much KE in comparison to alpha particle will it require to have the same distance of closest approach d_0?
3) Find the ratio of energies of photons produced due to transition of an electron of hydrogen atom from its (i) second permitted energy level to the first level (ii) the highest permitted energy level to the first permitted level.
4) The trajectories, traced by different alpha particles, in Geiger- Marsden experiment were observed as shown.

What names are given to the symbols b and θ ?
What can we say about the values of b for (i) $\theta = 0$ and (ii) $\theta = \Pi$

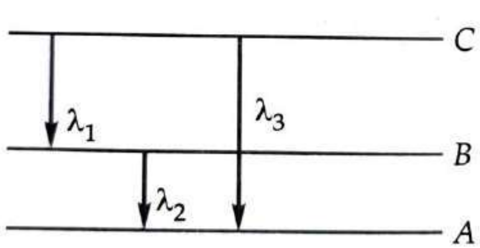


5) (a) The energy levels of an atom are as shown below. Which of them will result in the transition of a photon of wavelength 275 nm?

(b) Which transition corresponds to emission of radiation of (i) maximum wavelength and (ii) minimum wavelength?

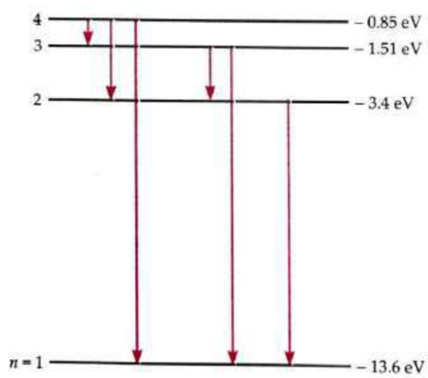


6) Find the relation between the three wavelengths λ_1, λ_2 and λ_3 from the energy level diagram.



7) The ground state energy of an atom is -13.6 eV. The photon emitted during the transition of electron from n=3 to n=1 state, is incident on a photosensitive material of unknown work function. Photoelectrons are emitted from the material with a maximum KE of 9 eV. Calculate the threshold wavelength of the material used.
8) The ground state energy of hydrogen atom is -13.6 ev.
   (i) What is the KE of an electron in the 2 nd excited state?
   (ii) What is the PE of an electron in the 3 rd excited state?
   (iii) If the electron jumps to the ground state from the 3 rd excited state, calculate the wavelength of the photon emitted?
9) The energy of the electron in the hydrogen atom is given by En= $-13.6\ ev/n^2$

Use this expression to show that the
   (i) Electron in the hydrogen atom cannot have an energy -6.8 ev.
   (ii) Spacing between the lines with in the given set of the observed hydrogen spectrum decreases as n increases.
10) From the energy level diagram
   (i) Find out the transition which results in the emission of a photon of wavelength 496 nm.
   (ii) Which transition corresponds to the emission of radiation of maximum wavelength? Justify.



11) Calculate the shortest wavelength in the Balmer series of hydrogen atom. In which region of hydrogen spectrum does this wavelength lie?
12) When is Hα line of the Balmer series in the emission spectrum of hydrogen atom obtained? Calculate the frequency of the photon emitted during the transition.
13) A 12.9 eV beam of electrons is used to bombard gaseous hydrogen at room temperature. Up to which energy level would the hydrogen atoms be excited?
14) The short wavelength for the Lyman series of the hydrogen spectrum is 913.4 A^0. Calculate the short wavelength limit for Balmer series of hydrogen spectrum.
15) Find the relation between the wavelengths of the most energetic spectral lines in the Balmer and Paschen series of hydrogen spectrum.

ANSWERS

1) Kinetic energy is inversely proportional to the distance of closest approach. Hence, if the kinetic energy is doubled, the distance of closest approach will be halved.

2) KE = $\frac{1}{4\pi\varepsilon_0}\frac{q1\,q2}{d}$

$KE_\alpha = \frac{1}{4\pi\varepsilon_0}\frac{Zex2e}{d}$

$KE_{proton} = \frac{1}{4\pi\varepsilon_0}\frac{Zexe}{d}$

For same d, $KE_{proton} = \frac{KE\alpha}{2}$

3) $E = 13.6(\frac{1}{n^2{}_f} - \frac{1}{n^2{}_i})$ eV

$\frac{E_1}{E_2} = \frac{1}{1^2} - \frac{1}{2^2} : \frac{1}{1^2} - \frac{1}{\alpha^2} = 3{:}4$

4) b - impact parameter

θ - scattering angle

(i) b is large

(ii) b=0

5) (a) $E = \frac{hc}{\lambda}$

Substituting the values

E = 4.5 eV

Transition B

(b) (i) Transition A (ii) Transition D

6) $E_C - E_B = \frac{hc}{\lambda_1}$

$E_B - E_A = \frac{hc}{\lambda_2}$

$E_C - E_A = \frac{hc}{\lambda_3}$

$\frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} = \frac{hc}{\lambda_3}$

$\frac{1}{\lambda_1} + \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$

7) E = hν = $13.6(\frac{1}{n^2{}_f} - \frac{1}{n^2{}_i})$ eV

$= 13.6(\frac{1}{1^2} - \frac{1}{3^2})$ eV = 12.1 eV

$h\nu = KE_{max} + W_0$

$W_0 = h\nu_0 = 3.1$ eV

$\lambda_0 = 4 \times 10^{-7}$ m

8) $E_n = -\frac{13.6}{n^2}$ eV

(i) $E_3 = -\frac{13.6}{3^2}$ eV = -1.51 eV

$KE_3 = -E_3 = 1.51$ eV

(ii) $E_4 = -\frac{13.6}{4^2}$ eV = -0.85 eV

$PE_4 = 2E_4 = -1.7$ eV

(iii) $h\nu = \frac{hc}{\lambda} = E_i - E_f$

= -0.85 -(-13.6) eV = 12.75 eV

λ = 970 A^0

9) $E_n = -\frac{13.6}{n^2}$ eV

$E_n = -\frac{13.6}{1^2}$ eV =-13.6 eV

$E_n = -\frac{13.6}{2^2}$ eV = -3.4 eV

$E_n = -\frac{13.6}{3^2}$ eV = -1.51 eV

$E_n = -\frac{13.6}{4^2}$ eV =-0.85 eV

(i) Hence an electron can not have energy of -6.8 eV

(ii) As the value of n increases, the energy difference between two consecutive energy levels decreases

10) (i) $E = \frac{hc}{\lambda} = 2.5$ eV

The transition is from n=4 to n=2

(ii) The transition is from n=4 to n=3

11) The transition is from n=infinity to n=2

$\frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{\alpha^2})$

$\lambda = 3637\ A^0$

Visible region

12) Hα line of Balmer series is obtained for the transition from n=3 to n=2

$E = h\nu = 13.6(\frac{1}{n^2{}_f} - \frac{1}{n^2{}_i})$ eV

$E = h\nu = 13.6(\frac{1}{4} - \frac{1}{9})$ eV

$\nu = 4.6 \times 10^{14}$ Hz

13) $E_4 - E_1 = 12.75$ eV

Hence hydrogen atom can be excited to n =4

14) For Lyman series $\frac{1}{\lambda} = R(\frac{1}{1^2} - \frac{1}{\alpha^2})$

$\lambda_L = \frac{1}{R}$

For Balmer series $\frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{\alpha^2})$

$\lambda_B = \frac{4}{R}$

$\lambda_B = 4\lambda_L = 3654 A^0$

15) For Balmer series $\frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{\alpha^2})$

$\lambda_B = \frac{4}{R}$

For Paschen series $\frac{1}{\lambda} = R(\frac{1}{3^2} - \frac{1}{\alpha^2})$

$\lambda_P = \frac{9}{R}$

$\frac{\lambda_B}{\lambda_P}$ = 4: 9

d.ASSERTION REASONING QUESTIONS

Directions: Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A

b) Both A and R are true and R is NOT the correct explanation of A

c) A is true but R is false

d) A is false and R is also false

1) **ASSERTION:** Both the Thomson's as well as the Rutherford's models constitute an unstable system.

REASON: Thomson's model is unstable electro-statically while Rutherford's model is unstable because of electromagnetic radiation of orbiting electrons.

2) **ASSERTION:** Bohr's orbits are regions where the electron may be found with large probability.

REASON: The orbital picture in Bohr's model of the hydrogen atom was inconsistent with the uncertainty principle.

3) **ASSERTION:** Bohr's model with its planet-like electron is not applicable to many electron atoms.

REASON: Unlike the situation in the solar system, where planet-planet gravitational forces are very small as compared to the gravitational force of the sun on each planet, the electron-electron electric force interaction is comparable in magnitude to the electron nucleus electric force.

4) **ASSERTION:** In Bohr model, the frequency of revolution of an electron in its orbit is not connected to the frequency of spectral line for smaller principal quantum number n.

REASON: For transitions between large quantum number the frequency of revolution of an electron in its orbit is connected to the frequency of spectral line.

5) **ASSERTION:** Total energy of an electron in a hydrogen atom is negative.

REASON: Electron is bounded to the nucleus.

6) **ASSERTION:** According to Bohr’s atomic model the ratio of angular momenta of an electron in first excited state and in ground state is 2:1.

REASON: In a Bohr’s atom the angular momentum of the electron is directly proportional to the principal quantum number.

7) **ASSERTION:** If a beam of photons of energy 10.0 eV each, is incident on a sample of hydrogen gas containing all atoms in the ground state, then the beam of the photons is completely transmitted through the gas without absorption.

REASON: The minimum energy required by an electron to make a transition to an excited state is 10.2 eV.

8) **ASSERTION:** Balmer series lies, in the visible region of electromagnetic spectrum.

REASON: Balmer series if formed when the electron jumps from any higher excited state to first excited state.

9) **ASSERTION:** Bohr had to postulate that the electrons in stationary orbits around the nucleus do not radiate.

REASON: According to classical physics all accelerating electrons radiate.

10) **ASSERTION:** It is essential that all the lines available in the emission spectrum will also be available in the absorption spectrum.

REASON: The spectrum of hydrogen atom is only absorption spectrum.

11) **ASSERTION:** Electrons in an atom are held by Coulombian forces.

REASON: The atom is stable because the centripetal force due to Coulomb's law is balanced by the centrifugal force.

12) **ASSERTION:** The force of repulsion between atomic nucleus and alpha particle varies with distance according to inverse square law.

REASON: Rutherford did alpha particle scattering experiment.

13) **ASSERTION:** The positively charged nucleus of an atom has a radius of almost 10^{-15} m

REASON: In alpha-particle scattering experiment, the distance of closest approach for alpha particles is approximately 10^{-15} m.

14) **ASSERTION: For** the scattering of alpha-particles at a large angle, only the nucleus of the atom is responsible.

REASON: Nucleus is very heavy and all the positive charges are concentrated inside it.

15) **ASSERTION:** Bohr postulated that the electrons in stationary orbits around the nucleus do not radiate.

REASON: According to classical physics all moving electrons radiate.

ANSWERS

(1) A (2)A (3)A (4)B (5) A (6)A (7)A (8)B (9)B (10)D (11) C (12) B (13) A (14) A (15) B

B. SELECT RESPONSE TYPE QUESTIONS

MULTIPLE CHOICE QUESTIONS

1) According to classical theory, the Rutherford's model of an atom is

(A) stable (B) semi stable (C) meta stable (D) unstable.

2) Rutherford's experiment on α−particle scattering has proved that

(A) the positive charges in the atom are uniformly distributed

(B) most of the space in an atom is empty

(C) atoms contain electrons

(D) the atom is electrically neutral.

3) Bohr's atomic model gained importance over previous atomic models because it

(A) is based on the quantum principles only

(B) explained the hydrogen spectrum quite satisfactorily

(C) explained the constitution of atom

(D) is partly based on quantum principles and partly on classical mechanics.

4) According to Bohr's model of hydrogen atom

(A) the linear velocity of the electron is quantised

(B) the angular velocity of the electron is quantised

(C) the linear momentum of the electron is quantised

(D) the angular momentum of the electron is quantised

5) For the electron to revolve round the nucleus without radiating energy in the orbit, the electron orbit should be

(A) circular

(B) elliptic

(C) having angular momentum equal to integral multiple of the Planck's constant

(D) consisting of only one electron in its orbit.

6) In the lowest energy level of hydrogen atom, the angular momentum of electron is

(A) $\frac{h}{\pi}$ (B) 0 (C) $\frac{h}{2\pi}$ (D) $\frac{2h}{\pi}$

7) The radius of hydrogen atom, when it is in its second excited state, becomes ------ times that in the ground state

(A) half (B) double (C) four times (D) nine times

8) According to Bohr's theory of the hydrogen atom, the radii r_n of stationary electron orbits are related to the principal quantum number n as

(A) $r_n \propto n^2$ (B) $r_n \propto \frac{1}{n^2}$ (C) $r_n \propto n$ (D) $r_n \propto \frac{1}{n}$

9) The angular speed of the electron in the n^{th} orbit of Bohr's hydrogen atom is

(A) inversely proportional to n (B) inversely proportional to $\sqrt{n}$

(C) inversely proportional to n^2 (D) inversely proportional to n^3

10) When a hydrogen atom is raised from the ground state to an excited state, its

(A) potential energy increases and kinetic energy decreases.

(B) potential energy decreases and kinetic energy increases.

(C) potential energy and kinetic energy, both decrease.

(D) potential energy and kinetic energy, both increase.

11) The total energy of the electron in the hydrogen atom in its ground state is −13.6 eV. The kinetic energy of this electron is

(A) 0 (B) −13.6 eV (C) 6.8 eV (D) 13.6 eV

12) The ground state energy of hydrogen atom is –13.6 eV. The potential energy of the electron in this state is

(A) 0 eV (B) – 27.2 eV (C) –13.6 eV (D) 13.6 eV

13) As the principal quantum number increases, the difference of energy between consecutive energy levels

(A) increases (B) decreases

(C) remains the same (D) sometimes increases and sometimes decreases

14) The spectral lines are emitted when the electrons

(A) jump from lower energy orbit to higher energy orbits

(B) jump from higher energy orbit to lower energy orbits

(C) revolve in the circular orbit

(D) vibrate about their mean position.

15) When the electron in a hydrogen atom jumps from n = 4 to n = 2 state, the spectral line emitted in the Balmer series is called

(A) Hα line (B) Hβ line (C) Hγ line (D) Hδ line

16) For ground state of hydrogen atom the value of principal quantum number is___

(A) n = 2 (B) n = 0 (C) n = 1 (D) n = infinity

17) The minimum energy required to remove the electron from the ground state of the hydrogen atom is called as___

(A) excitation energy (B) ionisation energy (C) ground state energy (D) excited state energy

18) The Lyman series of hydrogen lies in the region

(A) microwave (B) infrared (C) visible (D) ultraviolet.

ANSWERS

(1)D (2)B (3)B (4)D (5)C (6)C (7)D (8)A (9)D (10)A (11)D (12)B (13)B (14)B (15)B (16)C (17)B (18)B

C. CONSTRUCTED RESPONSE QUESTIONS

SHORT ANSWER QUESTIONS (2m & 3m QUESTIONS)

1) Briefly explain Geiger-Marsden experiment. Show the variation of the number of particles scattered (N) with scattering angle (θ) in this experiment. What is the main conclusion that can be inferred from this plot ?

2) (a) Draw the graph showing the variation of the number (N) of scattered alpha particles with scattering angle (θ) in Geiger-Marsden experiment.

(b) Why is it that a very small fraction of the particles is scattered at θ > 90° ?

(c) Discuss briefly two observations that can be drawn from this graph and how they lead to the discovery of nucleus in an atom.

3) (a) An α-particle having kinetic energy K approaches a nucleus of atomic number Z. It gets close to the nucleus and then approaches a distance (d_o) and reverses its direction. Obtain an expression for the distance of closest approach (d_o) in terms of kinetic energy of the a-particle.

(b) A proton and an alpha particle approach a target nucleus in head-on position, with equal velocities. Find the ratio of their distances of closest approach to the target nucleus.

4) (a) Differentiate between 'distance of closest approach' and 'impact parameter'.

(b) Determine the distance of closest approach when an alpha particle of kinetic energy 7.2 MeV approaches a nucleus of Z = 80, stops and reverses its directions.

5. (a) State three postulates of Bohr's theory of hydrogen atom.

(b) Find the angular momentum of an electron revolving in the second orbit in Bohr's hydrogen atom.

6. State Bohr's postulate to explain stable orbits in a hydrogen atom. Prove that the speed with which the electron revolves in n^{th} orbit is proportional to (1/n)

7) Using Bohr's postulates, obtain the expressions for (i) kinetic energy and (ii) potential energy of the electron in stationary state of hydrogen atom.

Draw the energy level diagram showing how the transitions between energy levels result in the appearance of Lyman series.

8) An electron in a hydrogen atom makes transitions from orbits of higher energies to orbits of lower energies.

(i) When will such transitions result in (a) Lyman (b) Balmer series ?

9) (a) Using Bohr's postulates, obtain the expression for total energy of the electron in the nth orbit of hydrogen atom.

(b) What is the significance of negative sign in the expression for the energy ?

10) (a) Write Rydberg's formula for wavelengths of the spectral lines of hydrogen atom spectrum. Mention to which series in the emission spectrum of hydrogen, Hα line belongs.

(b) Identify the transition of electron in Bohr model which gives rise to (i) the maximum, and (ii) the minimum wavelength in Balmer series of hydrogen spectrum.

11) (a)Show that the radius of orbit in hydrogen atom, varies as n^2, where n is the principal quantum number of the atom.

(b)Draw the graph of radius of orbit (r) in hydrogen atom as a function of orbit number (n).

12) Write shortcomings of Rutherford atomic model. Explain how these were overcome by the postulates of Bohr's atomic model.

13) What is impact parameter. How does it influence the trajectory of an α particle scattered by heavy nucleus ? What is the value of impact parameter for a head on collision ?

14) When an electron in hydrogen atom jumps from the third excited state to the ground state, how would the de Broglie wavelength associated with the electron change? Justify your answer.

15) A hydrogen atom is in its third excited state.

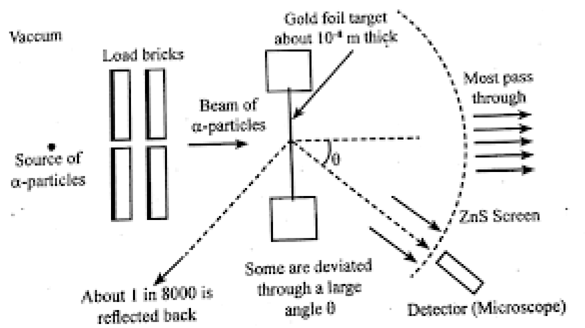
(a) How many spectral lines can be emitted by it before coming to the ground state? Show these transitions in the energy level diagram.

(b) In which of the above transitions will the spectral line of shortest wavelength be emitted ?

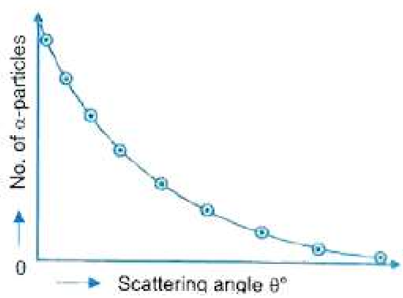
16) Use Bohr's model of hydrogen atom to obtain the relationship between the angular momentum and the magnetic moment of the revolving electron.

ANSWERS

1)

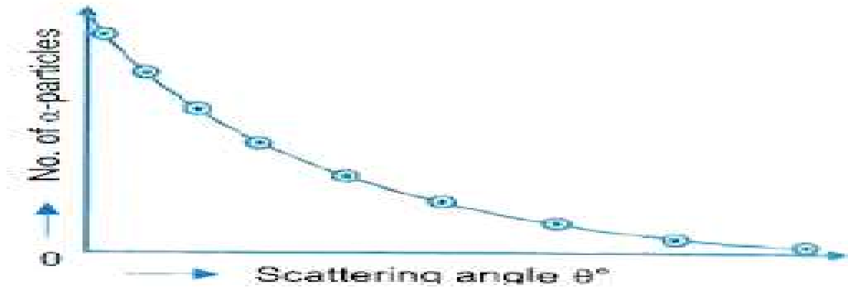


α-particles from a radioactive source are allowed to fall on a thin gold foil of thickness 10^{-7}m. The scattered a-particles fall on ZnS screen and produce light flashes or scientillations. With the help of rotatable detector, these flashes are counted at different angles (0) from the direction of the incident beam.



Conclusions. (i) The existence of a positively charged nucleus in an atom.

(ii)The nuclear radius is about $\frac{1}{10000}$ of the atomic nucleus.

2) (a) 

(b)The size of the nucleus is very small, about 1/10000 of the atomic size. So a very small fraction of the incident a-particles is scattered at 0 > 90° by the atomic nucleus.

(c) Observations. (i) Most of the a-particles pass straight, so most of the space in the atom is empty. (ii) Very few a-particles suffer large angle scattering > 90°.

Conclusions. The large angle scattering indicates that most of the mass and entire positive charge of the atom are concentrated in a very small volume of the atom, called nucleus.

3) (a) At distance of closest approach,

KE of α particle = Electrostatic PE

Electrostatic PE = $\frac{1}{4\pi\epsilon_0}\frac{2e\ xZe}{d}$

$$\frac{1}{4\pi\epsilon_0}\frac{2e\ xZe}{d} = K$$

$$d = \frac{1}{4\pi\epsilon_0}\frac{2Ze^2}{K}$$

(b)For bombarding particle of mass m and charge q

$$d = \frac{1}{4\pi\epsilon_0}\frac{qxZe}{K}$$

$$d\ \alpha\ \frac{q}{m}$$

$$\frac{d_p}{d_\alpha} = \frac{q_p}{q_\alpha} \text{ x } \frac{m_\alpha}{m_p} = 2:1$$

4) (a) Distance of closest approach is the distance between the centre of the nucleus and the point from which an a-particle approaching directly to the nucleus returns and at which its entire kinetic energy gets converted into electrostatic P.E.

Impact parameter is the perpendicular distance of the velocity vector of the a-particle from the central line of the nucleus, when the particle is far away from the atom.

(b) $d = \frac{1}{4\pi\epsilon_0}\frac{qxZe}{K}$

$= 5.12 \times 10^{-14}$ m

5) (a) 1.Electrons revolve around the nucleus in stable orbits without emission of radiant energy.

2.The electrons revolves around the nucleus only in those orbits for which the angular momentum is an integral multiple of $\frac{h}{2\pi}$.

3.An electron emits or absorbs energy when it jumps from one orbit or energy level to another.

(b) $L = \frac{nh}{2\pi} = \frac{2h}{2\pi} = \frac{h}{\pi} = 2.1 \times 10^{-34}$ Js

6) 1.Electrons revolve around the nucleus in stable orbits without emission of radiant energy.

2.The electrons revolves around the nucleus only in those orbits for which the angular momentum is an integral multiple of $\frac{h}{2\pi}$.

3.An electron emits or absorbs energy when it jumps from one orbit or energy level to another.

Centripetal force = Electrostatic force

$$\frac{mv^2}{r} = \frac{kZe^2}{r^2}$$

$$mv^2r = ke^2$$

From Bohr's postulates

Angular momentum of electron = mvr = $\frac{nh}{2\pi}$

Velocity of electron in hydrogen atom, $v_n = \frac{e^2}{2\varepsilon_0 nh}$

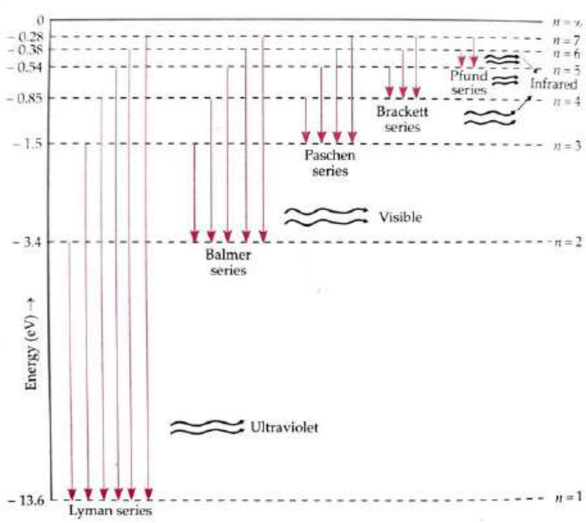
7) Centripetal force = Electrostatic force

$$\frac{mv^2}{r} = \frac{ke^2}{r^2}$$

$$mv^2 = \frac{ke^2}{r}$$

$\therefore$ KE = $\frac{1}{2}$ mv^2 = $\frac{ke^2}{2r}$

PE = k $\frac{q_1 q_2}{r}$ = - $\frac{ke^2}{r}$



8) Lyman series is obtained for transition from n = 2,3,4 …….. to n = 1

Balmer series is obtained for transition from n = 3,4,5 …….. to n = 2

9) Electrostatic attraction between nucleus and an electron provides the necessary centripetal force to keep the electron in dynamically stable orbit.

Centripetal force = Electrostatic force

$$\frac{mv^2}{r} = \frac{ke^2}{r^2}$$

$$mv^2 = \frac{ke^2}{r}$$

$\therefore$ KE = $\frac{1}{2}$ mv^2 = $\frac{ke^2}{2r}$

PE = k $\frac{q_1 q_2}{r}$ = - $\frac{ke^2}{r}$

TE = PE + KE = - $\frac{ke^2}{2r}$

Negative sign shows that electrons are bound to the nucleus.

10) (a)Rudberg formula $\frac{1}{\lambda} = R(\frac{1}{n_f^2} - \frac{1}{n_i^2})$

Hα line belongs to Balmer series

(c) (i) n=3 to n=2

(iii) n=infinity to n=2

11) Centripetal force = Electrostatic force

$$\frac{mv^2}{r} = \frac{kZe^2}{r^2} \quad \text{(i)}$$

$mv^2r = ke^2$

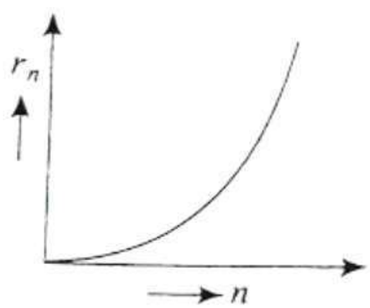
From Bohr's postulates

Angular momentum of electron = mvr = $\frac{nh}{2\pi}$

ie. v = $\frac{nh}{2\pi\pi mr}$

Substituting v in eq. (i)

r = $\frac{\varepsilon_0 n^2 h^2}{\pi m e^2}$



12) (a) Shortcomings of Rutherford's atomic model,

(i) An electron revolving around the nucleus is continuously accelerated. So it continuously loses energy and finally spirals into the nucleus.

(ii) It must emit a continuous spectrum.

According to Bohr's model of hydrogen atom, (i) While revolving in a permissible orbit, an electron does not radiate energy.

(ii)Energy is released/absorbed only, when an electron jumps from one stable orbit to another. This results in a discrete spectrum.

13) Impact parameter is the perpendicular distance of the velocity vector of the a-particle from the central line of the nucleus, when the particle is far away from the atom.

For most of the a-particles, the impact parameter is large, hence they suffer very small repulsion due to the nucleus and go straight through the foil.

The impact para- meter decides the shape of the trajectory of an a-particle scattered from a heavy nucleus.

Also, it gives an estimate of the size of the nucleus.

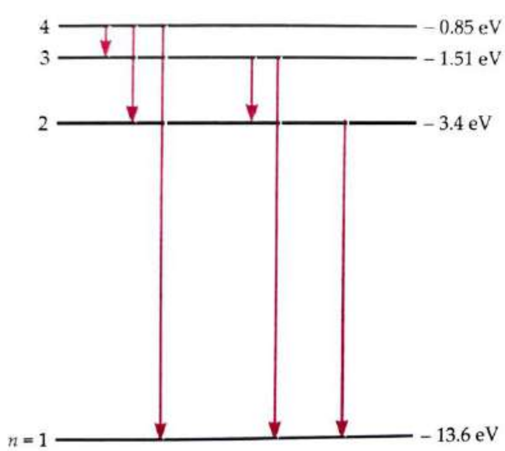
impact parameter for a head on collision = 0

14) $E_4 = \frac{E_1}{4^2} = \frac{E_1}{16}$

$\frac{E_4}{E_1} = \frac{1}{16}$

$\frac{\lambda_4}{\lambda_1} = \sqrt{\frac{E_1}{E_4}} = \sqrt{\frac{16}{1}} = 4$

15) No of spectral lines =6



Transition from n=4 to n=1 will have shortest wavelength.

16) The equivalent current due to the revolving electron, $I = \frac{ev}{2\pi r}$

Magnetic moment, $\mu = IA = \frac{evr}{2}$

By Bohr's postulates , $L = mvr = \frac{nh}{2\pi}$

$\therefore\ \mu = \frac{e}{2m} \times L$

LONG ANSWER QUESTIONS (5m QUESTIONS)

1. Draw a labelled diagram for α-particle scattering experiment. Give Rutherford's observations and discuss the significance of this experiment. Obtain the expression which helps us to get an idea of the size of the nucleus, using these observations.

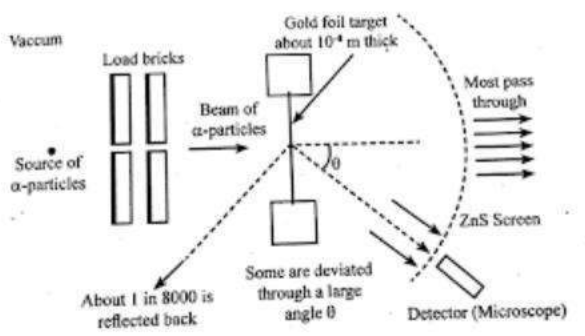
2. (a) Draw a schematic arrangement of Geiger- Marsden experiment showing the scattering of a-particles by a thin foil of gold. Why is it that most of the a-particles go straight through the foil and only a small fraction gets scattered at large angles ?

Draw the trajectory of the α-particle in the Coulomb field of a nucleus. What is the significance of impact parameter and what information can be obtained regarding the size of the nucleus ?

(b) Estimate the distance of closest approach to the nucleus of atomic number Z if an α-particle of kinetic energy K comes momentarily to rest and reverses its direction.

ANSWERS

1)



Observations. (i) Most of the a-particles pass straight, so most of the space in the atom is empty. (ii) Very few a-particles suffer large angle scattering > 90°.

Conclusions. The large angle scattering indicates that most of the mass and entire positive charge of the atom are concentrated in a very small volume of the atom, called nucleus.

At distance of closest approach,

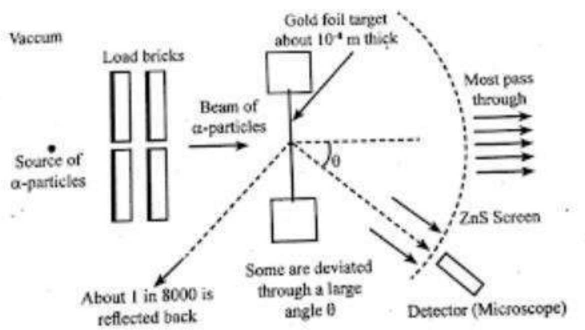
KE of α particle = Electrostatic PE

Electrostatic PE = $\frac{1}{4\pi\epsilon_0}\frac{2e\,xZe}{d}$

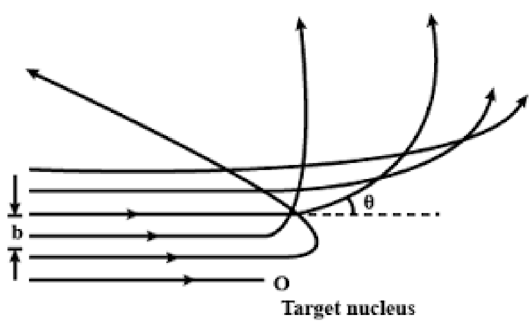
$\frac{1}{4\pi\epsilon_0}\frac{2e\,xZe}{d}$ = K

d = $\frac{1}{4\pi\epsilon_0}\frac{2Ze^2}{K}$

2)



For most of the a-particles, the impact parameter is large, hence they suffer very small repulsion due to the nucleus and go straight through the foil.



The impact para- meter decides the shape of the trajectory of an a-particle scattered from a heavy nucleus. Also, it gives an estimate of the size of the nucleus.

At distance of closest approach,

KE of α particle = Electrostatic PE

Electrostatic PE = $\frac{1}{4\pi\epsilon_0}\frac{2e\,xZe}{d}$

$$\frac{1}{4\pi\epsilon_0}\frac{2e\,xZe}{d} = K$$

$$d = \frac{1}{4\pi\epsilon_0}\frac{2Ze^2}{K}$$

SELF ASSESSMENT

MULTIPLE CHOICE QUESTIONS

1) Name the spectral series of hydrogen atom lying in visible region?

(a) Paschen series (b)Pfund series (c)Bracket series (d) Balmer series

2) What is the angle of scattering for zero impact parameter?

(a) 0 (b) 90 (c) 180 (d) None of these

3) Rutherford model of atom was unstable because

(a)nuclei will break down (b)electron move in circular orbit

(c)orbiting electrons radiate energy (d) electrons are repelled by the nucleus

4) Bohr's atomic model is applicable for

(a) All types of atoms (b) Only for hydrogen atom

(c) For hydrogen like atoms (d) For helium atom

5) The cause of rejection of Rutherford atomic model was

(a) It was totally wrong (b) It could not justify its stability

(c) Rutherford was unable to explain it (d) none of the above.

ASSERTION REASONING QUESTIONS

Directions: Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A

b) Both A and R are true and R is NOT the correct explanation of A

c) A is true but R is false

d) A is false and R is also false

6) Assertion**:** Hydrogen atom consists of only one electron but its emission spectrum has many lines.

Reason: Only Lyman series is found in the absorption spectrum of hydrogen atom whereas in the emission spectrum, all the series are found.

7)Assertion: Total energy of revolving electron in any stationary orbit is negative

Reason: Energy is a scalar quantity. It can have only positive value.

SHORT ANSSWER QUESTIONS

8. Write two drawbacks of Ruherford's atomic model.

9. Find the shortest wavelength of Balmer series in Hydrogen atom.

10. Define distance of closest approach and impact parameter.

11. Show that the radius of the orbit in hydrogen atom varies as n^2 , where n is the principal quantum number of the atom.

12. The total energy of electron in the first excited state of hydrogen atom is -3.4eV.

(a) What is kinetic energy of electron in this state?

(b) What is potential energy of electron in this state?

(c) Which of the answers above would change if the choice of zero of potential energy is changed?

13. By using Rutherford's atomic model, derive expression for the Kinetic energy, potential energy and total energy of an electron revolving in hydrogen atom.

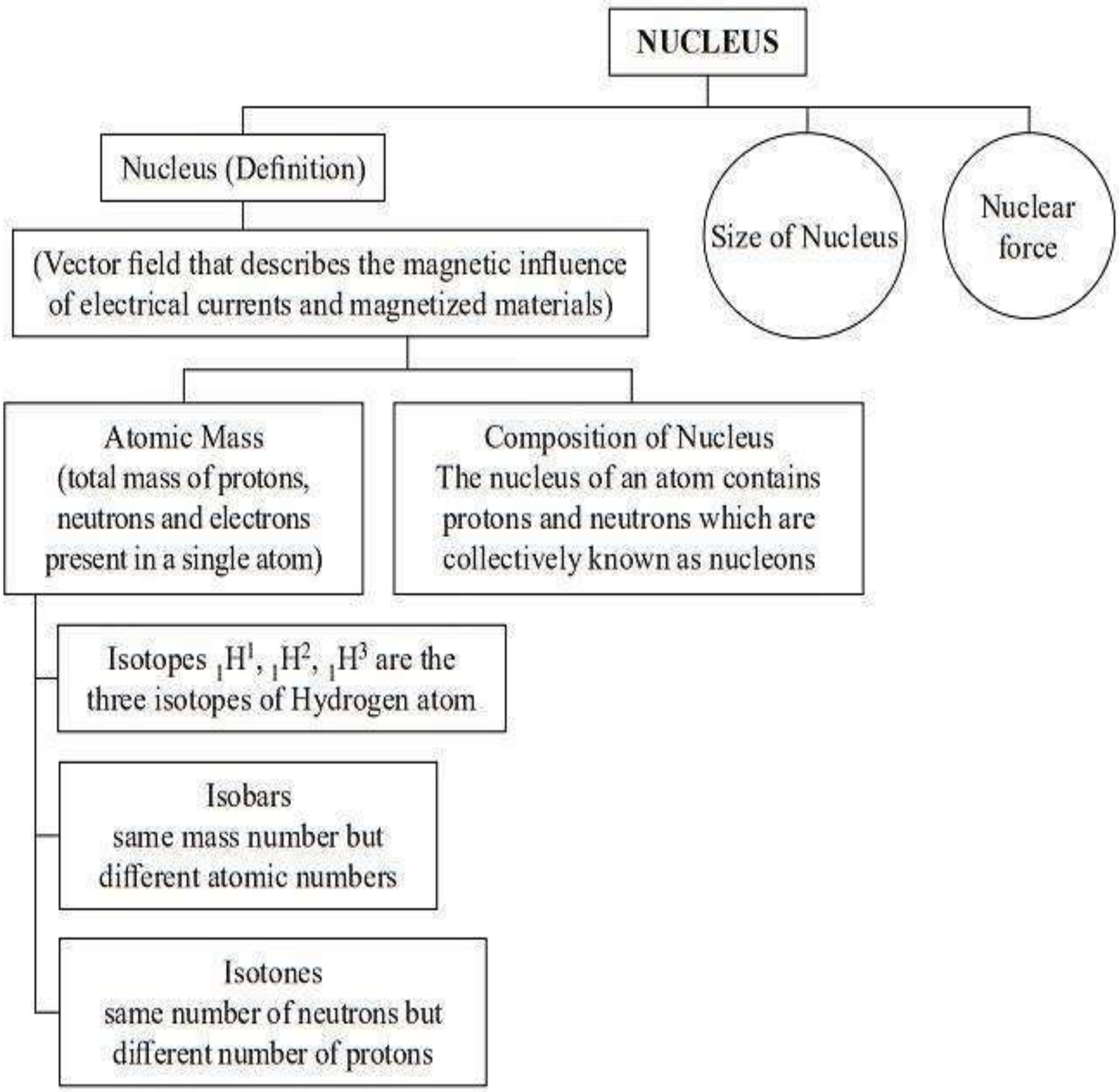
14. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. Up to which energy level the the hydrogen atom would be excited? Calculate the wavelength of the first member of Lyman and the first member of Balmer series.

****

13. NUCLEI

Syllabus :-Composition and size of nucleus, nuclear force Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

MIND MAP



SIZE OF NUCLEUS

Mass Energy

Mass defect
The difference in mass of a nucleus and its constituents is known as the mass defect
$$\Delta m = Zm_p + (A - Z)m_n - M(Z, A)$$

Packing fraction
Mass defect per nucleon is called packing fraction
Formula: $f = \frac{\Delta m}{A} = \frac{M - A}{A}$

Nuclear Binding Energy

The energy equivalent to that of mass defect is called the binding energy of the nucleus.
Formula: Binding energy = Δmc^2

Binding Energy per nucleon
$$\text{B.E./nucleon} = \frac{\text{Total Binding Energy}}{\text{Mass Number}} = \frac{\Delta m \times 931}{A}$$

NUCLEAR FORCE

Nuclear Reaction

$$X + a \rightarrow Y + b + Q$$

Nuclear Fusion and Fission

Nuclear Fission
The breaking of a heavy nucleus into two or more fragments of comparable masses, with the release of tremendous amount of energy is called as nuclear fission

Nuclear Fusion
The combination of lighter nuclei to form the heavy nucleus with the release of energy is called nuclear fusion.

GIST OF LESSON:

Nuclear Physics: - Branch of physics dealing with the study of nucleus is called nuclear Physics.

- The word nucleus is from 1704, meaning kernel of a nut. In 1844, Michael Faraday used nucleus to describe the central point of an atom.
- The nucleus is the centre of an atom. It is made up of nucleons called (protons and neutrons) and is surrounded by the electron cloud.
- Almost all of the mass in an atom is made up from the protons and neutrons in the nucleus with a very small contribution from the orbiting electrons.
- Neutrons have no charge and protons are positively charged. Because the nucleus is only made up of protons and neutrons it is positively charged. Things that have the same charge repel each other: this repulsion is part of what is called electromagnetic force.

Atomic Mass

- Atomic mass is defined as the total mass of protons, neutrons and electrons present in a single atom.
- Atomic masses are conventionally expressed in atomic mass units.
- The mass of an atom is very small, compared to a kilogram. Accurate measurement of atomic masses is carried out with a mass spectrometer

Atomic mass unit: It is defined as $\frac{1}{12}$th the mass of carbon atom, it is abbreviated as a.m.u and often denoted as u.

$$1\text{ amu} = \frac{1}{12} \times \frac{12\ kg}{6.02\times10^{26}} = 1.66 \times 10^{-27} Kg$$

Mass of electron $m_e = 9.1 \times 10^{-31} Kg = 0.000548\ amu$

Mass of proton $m_p = 1.6027 \times 10^{-27} Kg = 1.00727\ amu$

Mass of neutron $m_n = 1.675 \times 10^{-27} Kg = 1.00865\ amu$

Composition of Nucleus

Nucleus: A small positively charged tiny central core, at which almost the entire mass of the atom is concentrated is called as nucleus.

- The number of protons in a nucleus is called the atomic number and is denoted by Z. The total number of protons and neutrons in a nucleus is called its mass number of the element and is denoted by A.
- Number of protons in an atom = Z
- Number of electrons in an atom = Z
- Number of nucleons in an atom = A

- Number of neutrons in an atom = N = A − Z

Nuclide

- It is a specific nucleus of an atom which is characterized by its atomic number Z and mass number A. It is represented by $_ZX^A$ where X is the chemical symbol of the element.

Nuclear Radius:

- Nuclear radius $R = R_0 A^{1/3}$. Where $R_0 = 1.2\times10^{-15}$ m
- Nuclear radius is measured in fermi 1 fm = 10^{-15} m.
- **Volume of the nucleus: -** $V = \left(\frac{4}{3}\right)\pi\left(R_0 A^{\frac{1}{3}}\right)^3 = \left(\frac{4}{3}\right)\pi {R_0}^3 A$

Nuclear Density:

$$nuclear\ density = \frac{mass}{volume} = \frac{A}{(\frac{4}{3})\pi {R_0}^3 A} = \frac{1\ amu}{(\frac{4}{3})\pi {R_0}^3} = \frac{1.66\times10^{-27}}{(\frac{4}{3})\pi(1.2\times10^{-15})^3} = 1.2\times10^{17}\ Kg/m^3$$

- Nuclear density is independent of A and is order of the 10^{17} kgm^{-3}

Mass Energy

- The energy corresponding to the mass defect is the nuclear binding energy, the amount of energy released when a nucleus forms from its component particles.
- **Mass-Energy Relation:** According to Einstein, mass and energy are interconvertible. If a particle of rest mass m_0 is completely converted into energy, then the energy E released is given by,

$E = m_0 c^2$

- The energy equivalent to 1 amu is given by,

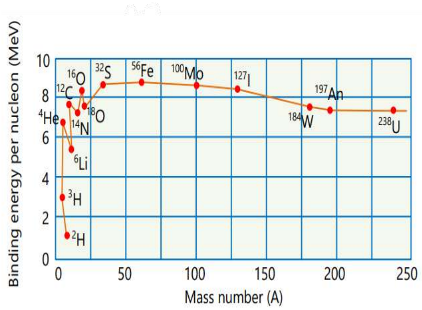
$E = m_0 c^2 = 1.66\text{x}10^{-27} \text{ x } (3\text{x}10^8)^2 = 1.494\text{x}10^{-10}$ J

$E = \frac{1.484\times10^{-10}}{1.6\times10^{-19}}\ eV \approx 931.5\ MeV$

- **Mass Defect:** It is the difference between the rest mass of the nucleus and the sum of the masses of the nucleons composing a nucleus is known as mass defect and is denoted as
- If the mass of the nucleus $_zX^A$ is M, then the mass defect, ΔM
- $\Delta M = [Zm_p + (A\text{-}Z)\, m_n - M]$ Here, m_p and m_n are the masses of the proton and neutron respectively.
- This mass defect is in form of energy and is responsible for binding the nucleons together.

Nuclear Binding Energy:

- The energy equivalent to that of mass defect is called the binding energy of the nucleus.
- Binding energy B.E = $\Delta mc^2 = [Zm_p + (A\text{-}Z)m_n - M]c^2$ = Δm x 931.5 MeV



Binding energy per nucleon:

- The average energy required to release a nucleon from the nucleus is called binding energy per nucleon (B.E./ nucleon).
- B.E./nucleon= $\frac{Total\ BE}{Mass\ number} = \frac{\Delta m \times 931.5}{A}$

Unit: MeV/Nucleon in SI system.
B.E./nucleon ∝ stability of nucleus.

Binding Energy curve: It is the graph between binding energy per nucleon and the total number of nucleons (i.e., mass number A).

Some nuclei with mass number A < 20 have large binding energy per nucleon than their neighbouring nuclei. Examples: ${}_4Be^8$, ${}_6C^{12}$, and ${}_8O^{16}$. These nuclei are more stable than their neighbours.

Importance of Binding Energy curve:

The very small nuclei tend to fuse together to form the heavier more stable nuclei.
The larger nuclides (like ${}_{92}U^{238}$) have a tendency to split into two smaller nuclei (fission) and the process requires some kind of trigger.
Larger nuclides show the phenomenon of radioactivity

Nature of nuclear force: - The protons and neutrons are held together by the strong attractive forces inside the nucleus. These forces are called as nuclear forces.

Properties of Nuclear force

- ✓ Nuclear forces are attractive in nature.
- ✓ Nuclear forces are charge independent.
- ✓ These are short range forces.
- ✓ Nuclear forces decrease very quickly with distance between two nucleons.
- ✓ Nuclear forces are spin dependent.

Nuclear Fission and Fusion:

Nuclear Fission: The breaking of a heavy nucleus into two or more fragments of comparable masses, with the release of tremendous amount of energy is called as nuclear fission.

The most typical fission reaction occurs when slow moving neutrons strike ${}_{92}U^{235}$.

$$U_{92}^{235} + n_0^1 \rightarrow Ba_{56}^{141} + Kr_{36}^{92} + 3(n_0^1) + 200MeV$$

If the number of fissions in a given interval of time goes on increasing continuously, then a condition of explosion is created. In such cases, the chain reaction is known as uncontrolled chain reaction. This forms the basis of atomic bomb.

In a chain reaction, the fast-moving neutrons are absorbed by certain substances known as moderators (like heavy water), then the number of fissions can be controlled and the chain reaction in such case is known as controlled chain reaction. This forms the basis of a nuclear reactor.

Nuclear Fusion: The combination of lighter nuclei to form the heavy nucleus with the release of energy is called nuclear fusion.

Like a fission reaction, the sum of masses before the fusion (i.e. of light nuclei) is more than the sum of masses after the fusion (i.e. of bigger nucleus) and this difference appears as the fission energy. The most typical fission reaction is the fusion of two deuterium nuclei into helium.

Energy Source of Sun: Proton – Proton Cycle:

$${}_1H^1 + {}_1H^1 \rightarrow {}_1H^2 + e^+ + \nu + 0.42 \text{ MeV}$$

$$e^+ + e^- \rightarrow \gamma + \gamma + 1.02 \text{ MeV}$$

$${}_1H^2 + {}_1H^1 \rightarrow {}_2He^3 + {}_1H^1 + {}_1H^1 + 12.86 \text{ MeV}$$

For the fourth reaction to occur, the first three reactions must occur twice, in which case two light helium nuclei unite to form ordinary helium nucleus.

$$4{}_1H^1 + 2e^- \rightarrow {}_2He^4 + 2\nu + 6\gamma + 26.7 \text{ MeV}$$

Thus, four hydrogen atoms combine to form an ${}_2He^4$ atom with a release of 26.7 MeV of energy.

FORMULAE:

- Number of neutrons in an atom = N = A − Z
- Nuclear radius $R = R_0 A^{1/3}$. Where $R_0 = 1.2\times10^{-15}$ m
- $\Delta M = [Zm_p + (A-Z)\, m_n – M]$
- Binding energy B.E $= \Delta mc^2 = [Zm_p + (A-Z)m_n – M]c^2 = \Delta m \times 931.5$ MeV

A. COMPETENCY BASED QUESTIONS

a. MULTIPLE CHOICE QUESTIONS - HOTS

1) When a microgram of matter is converted to energy, the amount of energy released will be:

(a) 9×10^{10} J (b) 9×10^{7} J (c) 3×10^{4} J (d) 9×10^{17} J

2) If in a nuclear fusion reaction, mass defect is 0.3% then energy released in fusion of 1 kg mass:

(a) 27×10^{12} J (b) 27×10^{13} J (c) 27×10^{10} J (d) 27×10^{11} J

3) The binding energy per nucleon of $_8O^{16}$ is 7.97 MeV and that of $_8O^{17}$ is 7.75 MeV. The energy (in MeV) required to remove a neutron from $_8O^{17}$ is :

(a) 0.42 MeV (b) 7.86 MeV (c) 4.23 MeV (d) 3.64 MeV

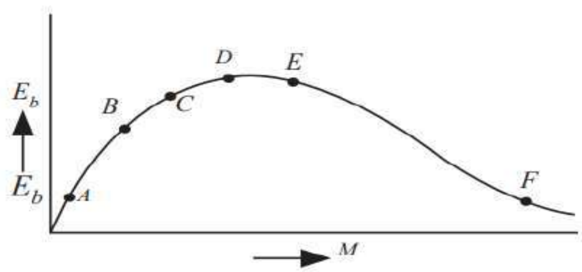
4) Two nuclei have their mass numbers in the ratio of 1: 27.What is the ratio of their nuclear densities ?

(a) 1 : 27 (b) 1 : 1 (c) 1 : 9 (d) 1 : 3

5) A nucleus with mass number 220 initially at rest emits an α-particle. If the Q value of the reaction is 5.5 MeV, the kinetic energy of the α-particle is**:**

(a) 6.5 MeV (b) 5.6 MeV (c) 5.4 MeV (d) 4.4 MeV

6) Given figure shows a plot of binding energy per nucleon E_b against the nuclear mass M. A, B, C, D, E, F correspond to different nuclei. Consider four reactions



(i) A + B → C + ε (ii) C → A + B + ε

(iii) D + E → F + ε (iv) F → D + E + ε

In which reactions is ε positive? Where ε is the energy released.

(a) (i) and (iv) (b) (ii) and (iv) (c) (ii) and (iii) (d) (i) and (ii)

7) A nucleus ruptures into two nuclear parts which have their velocity ratio equal to 2 : 1. What will be the ratio of their nuclear size (nuclear radius)

(a) $2^{1/3} : 1$ (b) $1 : 2^{1/3}$ (c) $3^{1/2} : 1$ (d) $1 : 3^{1/2}$

8) In nuclear fusion, one gram hydrogen is converted into 0. 993gm.If the efficiency of the generator be 5%, then the energy obtained in KWH is

a) 8.75 x10^3 b) 4.75 x10^3 c) 5.75 × x10^3 d) 3.73x x10^3

9) The atomic mass of $_7N^{15}$ is 15.000108 amu and that of $_8O^{16}$ is 15.994915 amu. The minimum energy required to remove the least tightly bound proton is (mass of proton is 1.007825 amu)

a) 0.013018 amu b) 12.13 MeV c) 13.018 meV d) 12.13 eV

10) R1 and r2 are the radii of atomic nuclei of mass numbers 64 and 27 respectively. The ratio (r1 / r2) is

a) 64 / 27 b) 27 / 64 c) 4 / 3 d) 1

ANSWERS:

1) **(b)**

Hint: As we know that, $E = m_0 c^2 = 10^{-9} \times (3\times10^8)^2 = 9 \times 10^7$ J

2) **(b)**

Hint: Δm = 0.3% of 1 kg = $\frac{0.3}{100} X 1 = 3 \times 10^{-3}$ kg

$E = \Delta m\, c^2 = 3 \times 10^{--3} \times (3\times10^8)^2 = 27 \times 10^{13}$ J

3) **Answer: (c) 4.23 MeV**

Hint: Energy = (17 x 7.75) – (16 x 7.79) = 4.23 MeV

4) **(b)**

Hint: Nuclear density does not depend on mass number

5) **(c)**

Hint: $K = \frac{(A-4)}{A} Q$ A = 220 , Q = 5.5 MeV

$K = \frac{(220-4)}{220}$ 5.5 = 5.4 MeV

6) **(a)**

Hint: Energy (ε) is released when lighter nuclei fuse to form a heavier nucleus, such as in

(i) A +B + →C + ε

Again, energy is released when a heavy nucleus splits into lighter nuclei, such as in

(iv) F → D + E + ε

7) **(b)**

Hint: $m_1 v_1 = m_2 v_2$

$\frac{m_1}{m_2} = \frac{v_2}{v_1} = \frac{1}{2}$

$\frac{R_1}{R_2} = \left(\frac{m_1}{m_2}\right)^{1/3} = \left(\frac{1}{2}\right)^{1/3} = 1 : 2^{1/3}$

8) **(a)**

Hint: Output = efficiency% x Δmc^2 = 0.05 x (1-0.993)x$(3\times10^8)^2$ /(3.6×10^6) = 8.75×10^3 KWH

9) **(b)**

Hint: $\Delta m = m_p + m_n - m_o$ =1.007825 + 15.000108 - 15.994915 = 0.013018 a.m.u

Energy = $\Delta m \times$ 931.5 Mev = 0.013018 x 931.5 = 12.13 Mev

10) **(c)**

Hint: $\frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{64}{27}\right)^{1/3} = 4 : 3$

b. CASE-BASED QUESTIONS

1) **Read the passage given below and answer the following questions:**

Neutrons and protons are identical particle in the sense that their masses are nearly the same and the force, called nuclear force, does into distinguish them. Nuclear force is the strongest force. Stability of nucleus is determined by the neutron proton ratio or mass defect or packing fraction. Shape of nucleus is calculated by quadrupole moment and spin of nucleus depends on even and odd mass number. Volume of nucleus depends on the mass number. Whole mass of the atom (nearly 99%) is centred at the nucleus.

(i) The correct statements about the nuclear force is/are

(a) charge independent
(b) short range force
(c) non-conservative force
(d) all of these.

(ii) The range of nuclear force is the order of

(a) 2×10^{-10} m (b) 1.5×10^{-20} m (c) 1.2×10^{-4} m (d) 1.4×10^{-15} m

(iii) A force between two protons is same as the force between proton and neutron. The nature of the force is

(a) electrical force
(b) weak nuclear force
(c) gravitational force
(d) strong nuclear force

(iv) two protons are kept at a separation of 40 A^0 . F_n is the nuclear force and F_e is the electrostatic force between them. Then

(a) Fn <<Fe
(b) Fn= Fe
(c) Fn >> Fe
(d) Fn ≈ Fe

(v) All the nucleons in an atom are held by

(a) nuclear forces
(b) vander waal's forces
(c) tensor forces
(d) coulomb forces

2) **Read the passage given below and answer the following questions:**

Nuclear Holocaust: A nuclear holocaust, nuclear apocalypse or atomic holocaust is a theoretical scenario where the mass detonation of nuclear weapons causes globally widespread destruction and radioactive fall out. Under such scenario, large parts of the earth are made uninhabitable by nuclear arfare,
potentially causing the collapse of civilization.

In a single uranium fission about 0.9 x 235 MeV (= 200 MeV)
of energy is liberated. If each nucleus of about 50 kg of $^{235}U_{92}$ undergoes fission, the amount of energy involved is about 4 x 10^{15} J. This energy is equivalent to about 20,000 tons of TNT, enough for a super explosion. Uncontrolled release of large nuclear energy is called an atomic explosion.

(i) In a nuclear reactor, moderators slow down the neutrons which comes out in a fission process.

The moderator used have light nuclei. Heavy nuclei will not serve the purpose because

(a) substance with heavy nuclei do not occur in liquid or gaseous state at room temperature
(b) the net weight of the reaction would be unbearably high
(c) elastic collision of neutrons with heavy nuclei will not slow down the neutrons
(d) they will break up

(ii) In an atomic bomb, the energy is released due to

(a) chain reaction of neutrons and $_{92}U^{240}$
(b) chain reaction of neutrons and $_{92}U^{238}$
(c) chain reaction of neutrons and $_{92}U^{236}$
(d) chain reaction of neutrons and $_{92}U^{235}$

(iii) Energy released in nuclear fission is due to

(a) total binding energy of fragments is more than the binding energy of parental element
(b) total binding energy of fragments is less than the binding energy of parental element
(c) total binding energy of fragments is equal to the binding energy of parental element
(d) some mass is converted into energy

(iv) Solar energy is mainly caused due to

(a) gravitational contraction
(b) fusion of proton during synthesis of heavier elements
(c) fission of uranium present in the sun
(d) burning of hydrogen in the oxygen

OR

Heavy stable nuclei have more neutrons than protons. This is because of the fact that

(a) electrostatic force between protons are repulsive
(b) neutrons decay into protons through beta decay
(c) nuclear forces between neutrons are weaker than that between protons
(d) neutrons are heavier than protons

3) **Read the passage given below and answer the following questions:**

The Nucleus of an atom consists of a tightly packed arrangement of protons and neutrons. These are the two heavy particles in an atom and hence 99.9% of the mass is concentrated in the nucleus. Of the two, the protons possess a net positive charge and hence the nucleus of an atom is positively charged on the whole and the negatively charged electrons revolve around the central nucleus. Since the mass concentration at the nucleus of an atom is immense the nuclear forces holding the protons and the neutrons together are also large.

(i) The density of a nucleus is of the order of
(a) 10^{15} kg m^{-3} (b) 10^{18} kg m^{-3} (c) 10^{17} kg m^{-3} (d) 10^{16} kg m^{-3}

(ii) Nuclear force is:
(a) strong, short range and charge independent force
(b) charge independent, attractive and long range force
(c) strong, charge dependent and short range attractive force
(d) long range, change dependent and attractive force

(iii) The mass no. of a nucleus is M and its atomic no. is Z. The number of neutrons in the nucleus is
(a) (M – Z)/M
(b) M
(c) Z
(d) M + Z

(iv) The atomic mass number is equivalent to which of the following?
(a) The number of neutrons in the atom.
(b) The number of proton in the atom.
(c) The number of nucleons in the atom.
(d) The number of alpha particles in the atom.

Answers:

1)	(i) d	(ii) d	(iii) d	(iv) a	(v) a
2)	(i) c	(ii) d	(iii) a	(iv) b (OR) a	
3)	(i) c	(ii) a	(iii) a	(iv) c	

c. 2M & 1M questions

1) Why do stable nuclei never have more protons than neutrons?

2) Nuclei have the same mass number. Do they have the same binding energy?

3) Define the term, mass defect. How is it related to stability of the nucleus ?

4) Calculate the binding energy of 17Cl35 if mass of 17Cl35 nucleus is 34.98 amu, mass of neutron is 1.008665 amu and mass of proton is 1.007277 amu.

5) Which one of the following cannot emit radiation and why? Excited nucleus, excited electron.

6) A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy per nucleon in Y and Z is 8.5 MeV per nucleon. Calculate the energy Q released per fission in MeV

ANSWERS

1) **Answer:** A stable nuclei never have more protons than neutrons because protons are charged particles and they repel each other. The repulsion is so much that excess neutrons only produce attractive forces and this is sufficient enough to build stability

2) **Answer:** ${}_2He^3$ and ${}_1He^3$ have the same mass number but the binding energy of these two nuclei is different.

The binding energy of the ${}_1He^3$ is greater than the ${}_2He^3$ because the number of protons and neutrons present in both the nuclei are different. ${}_1He^3$ has one proton and two neutrons while, ${}_2He^3$ has two protons and one neutron

3) **Answer:** Mass defect is the difference between the actual mass of the nucleus and the sum of the masses of its nucleons. Greater the mass defect, greater will be the binding energy and the nucleus will be more stable

4) **Answer:** $\Delta m = (17 \times 1.007277) + (18 \times 1.008665) - 34.98$

$\Delta m = 0.299679$amu

$E = 0.299679 \times 931.478$ MeV

$E = 279.001149$ MeV

$E = 279$ MeV

5) **Answer:** Excited electron cannot emit radiation. This is because energy of electronic energy levels is in the range of eV only not in MeV and γ–radiation has energy in MeV.

6) Answer:

Energy released $Q = (M_Y + M_Z)\, c^2 - M_X\, c^2$

$= 8.5\,(110+130)$ MeV $- 7.6 \times 240$ MeV

$= (8.5 - 7.6) \times 240$ MeV $= 0.9 \times 240$ MeV $= 216$ MeV

ASSERTION AND REASON QUESTIONS

Select the most appropriate Answer from the options given below:

(a) Assertion is true, reason is true; reason is a correct explanation for assertion.
(b) Assertion is true, reason is true; reason is not a correct explanation for assertion
(c) Assertion is true, reason is false
(d) Assertion is false, reason is true.

1) **Assertion:** Density of all the nuclei is same.
Reason: Radius of nucleus is directly proportional to the cube root of mass number.
2) **Assertion**: The mass number of a nucleus is always less than its atomic number.
Reason: Mass number of a nucleus may be equal to its atomic number.
3) **Assertion**: Fusion of hydrogen nuclei into helium nuclei is the source of energy of all stars.
Reason: In fusion heavier nuclei split to form lighter nuclei.
4) **Assertion**: Neutrons penetrate matter more readily as compared to protons.
Reason: Neutrons are slightly more massive than protons
5) **Assertion(A) :** The fusion process occurs at extremely high temperatures**.**
Reason (R) : For fusion of two nuclei, enormously high kinetic energy is required.
6) **Assertion(A) :** The large angle scattering of a-particle is only due to nuclei.
Reason(R) : Nucleus is very heavy as compared to electrons.
7) **Assertion (A) :** The nucleus $_3X^7$ is more stable than the nucleus $_3Y^4$
Reason(R) : $_3X^7$ contains more number of protons**.**
8) **Assertion :** Fragments produced in the fission of U235 are radioactive**.**
Reason : The fragments have abnormally high proton to neutron ratio.
9) **Asertion:** The binding energy per nucleon, for nuclei with atomic mass number A > 100, decrease with A.
Reason: The forces are weak for heavier nuclei.
10) **Assertion:** It is not possible to use ^{35}Cl as the fuel for fusion energy.
Reason: The binding energy of ^{35}Cl is to small.

Answers

1) (a)	2) (a)	3) (c)	4) (b)	5) (a)
6) (b)	7) (c)	8) (c)	9) (c)	10) (c)

A. <u>SELECT RESPONSE TYPE QUESTIONS MCQ'S</u>

1) In the nuclear reaction $_7N^{14} + {}_2He^4 \rightarrow X + {}_1H^1$, X represents :
(a) $_7O^{16}$ (b) $_8N^{17}$ (c) $_8O^{17}$ (d) $_7N^{16}$

2) Which of the following quantities is not conserved in a nuclear reaction?
(a) Mass (b) Charge (c) Momentum (d) None of the above

3) Sun's radiant energy is due to
(a) Nuclear Fusion (b)Nuclear Fission (c)Photoelectric Effect (d)Radioactive Decay

4) The atomic number of an atom indicates
(a) Number of electrons (b) Number of protons
(c)Number neutrons (d) Both number of protons and neutrons

5) The volume of the nucleus is:
(a) directly proportional to the number of neutrons
(b) directly proportional to the atomic number
(c) directly proportional to the number of mesons
(d) directly proportional to the mass number

6) The curve of binding energy per nucleon as a function of atomic mass number has a sharp peak for helium nucleus. This implies that helium nucleus is
(a) radioactive
(b) unstable
(c) easily fissionable
(d) more stable nucleus than its neighbours

7) The mass density of a nucleus of mass number A is:
(a) proportional to $A^{1/3}$
(b) proportional to $A^{2/3}$
(c) independent of A
(d) proportional to A^3

8) The binding energy per nucleon is lower :
(a) for light nuclei only (b) for heavy nuclei only
(c) for nuclei of middle mass numbers only (d) both for the light nuclei and the heavy nuclei.

9) The wrong statement about binding energy is
(a) It is the sum of the rest mass energies of nucleons minus the rest mass energy of the nucleus.

(b) It is the energy released when the nucleons combine to form a nucleus.
(c) It is the energy required to break a given nucleus into its constituent nucleons.
(d) It is the sum of the kinetic energies of all the nucleons in the nucleus.

10) When two deuterium nuclei fuse together to form a tritium nucleus, we get
(a) neutron
(b) deuteron
(c) alpha particle
(d) proton

11) An Electric field can deflect
(a) α - particles (b) X - rays (c) Neutrons (d) γ - rays

12) In the following nuclear reaction
$_{13}Al^{27} + {_2}He^4 \rightarrow {_{15}}P^{30} + X$, X will be
a) Proton b) Electron c) Neutron d) α -particle

Answers:

1) (c)	2) (a)	3) (a)	4) (b)	5) (d)	6) (d)
7) (c)	8) (d)	9) (d)	10) (d)	11) (a)	12) (c)

****

B. CONSTRUCTED RESPONSE QUESTIONS

SHORT ANSWER QUESTIONS

1) (i)How is the size of a nucleus found experimentally? Write the relation between the radius and mass number of a nucleus.
(ii)Prove that the density of a nucleus is independent of its mass number.
2) (i) Distinguish between nuclear fission and fusion giving an example of each.
(ii) Explain the release of energy in nuclear fission and fusion on the basis of binding energy per nucleon curve.
3) Draw a curve between mass number and binding energy per nucleon. Give two salient features of the curve. Hence define binding energy. Why do lighter nuclei usually undergo nuclear fusion?
4) (a) In the following nuclear reaction
$$n + {_{92}}U^{235} \rightarrow ZBa^{144} + {_{36}}X^A + 3{_0}n^1,$$
assign the values of Z and A.

(b) If both the number of protons and the number of neutrons are conserved in each nuclear reaction, in what way is the mass converted into energy? Explain.

5) Draw a graph showing the variation of potential energy between a pair of nucleons as a function of their separation. Indicate the regions in which the nuclear force is (i) attractive, (ii) repulsive. Write two important conclusions which you can draw regarding the nature of the nuclear forces.

ANSWERS

1) (i)Size of nucleus of an atom is determined by scattering experiments in which fast electrons are

used to bombard targets.

Relation between radius and mass number of nucleus. $R = R_0 A^{1/3}$

(ii) Density of nucleus mass volume

$$nuclear\ density, \rho = \frac{mass}{volume} = \frac{mA}{(\frac{4}{3})\pi R^3} = \frac{mA}{(\frac{4}{3})\pi (R_0 A^{1/3})^3} = \frac{3m}{4\pi {R_0}^3}$$

Hence, density of nucleus is independent of mass number (A)

2) **Nuclear fission** – It is a process in which a heavy nucleus when excited (say on bombarding by a slow moving neutron) splits into two lighter nuclei of nearly comparable masses with a release of large amount of energy. Example of nuclear fission

Nuclear Fusion - It is a process in which two lighter nuclei fuse (at extremely high temperature) to form a heavy nucleus and large amount of energy is released.

Examples of nuclear fusion

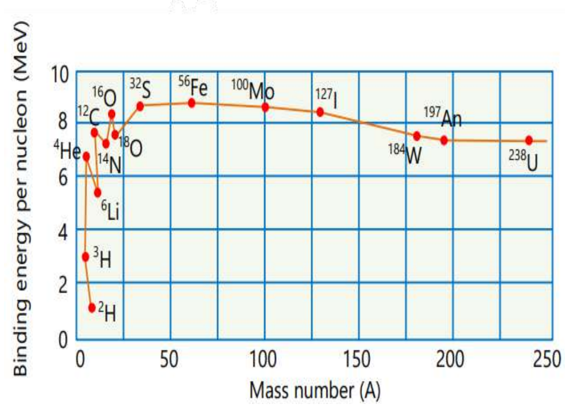
(i) $^1_1H + ^1_1H \rightarrow ^2_1H + e^+ + \nu + Q_1$

(ii) $^2_1H + ^2_1H \rightarrow ^3_2H + n + Q_2$

(iii) $^2_1H + ^2_1H \rightarrow ^3_1H + ^1_1H + Q_3$

(ii) The binding energy per nucleon of the products in the nuclear reactions (nuclear fission and nuclear fusion) is greater than that of the reactants .

3) The total energy required to disintegrate the nucleus into its constituent particles is called binding energy of the nucleus.



Salient features of the curve

(i) the binding energy per nucleon, E_{bn}, is practically constant, i.e. practically independent of the atomic number for nuclei of middle mass number (30 < A < 170).

(ii) E_{bn} is lower for both light nuclei (A < 30) and heavier nuclei (A > 170). So, they are unstable nuclei.

Two lighter nuclei fuse together to form heavier nuclei as the binding energy per nucleon of fused heavier nuclei is more than the binding energy per nucleon of the lighter nuclei. Thus the final system is more tightly bound than initial system.

4) (a) $n + {}_{92}U^{235} \rightarrow {}_ZBa^{144} + {}_{36}X^A + 3n$,

From law of conservation of atomic number

$0 + 92 = Z + 36$

$Z = 92 – 36 = 56$

From law of conservation of mass number,

$1 + 235 = (144 + A) + (3 \times 1) = 147 + A$

$A = 236 - 147 = 89$

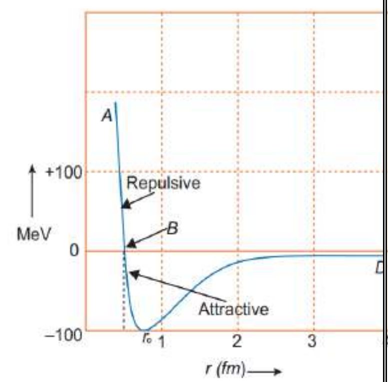
5) Conclusions:

(i) The potential energy is minimum at a distance r0 of about 0.8 fm.

(ii) Nuclear force is attractive for distance larger than r0.

(iii) Nuclear force is repulsive if two are separated by distance less than r_0.

(iv) Nuclear force decreases very rapidly at r0/equilibrium position.



SELF-ASSESSMENT

1) Two spherical nuclei have mass numbers 216 and 64 with their radii R_1 and R_2 respectively. The ratio R_1 / R_2 is equal to

(a) 3:2 (b) 1:3 (c)1:2 (d)2:3

2) The difference in mass 7X nucleus and total mass of its constituent nucleons is 21.00 u. The binding energy per nucleon for this nucleus is equal to the energy equivalent of

(a) 3u (b)3.5u (c)7u (d) 21u

3) The binding energy of deuteron is 2.2 MeV and that of ${}_2He^4$ is 28 MeV. If two deuterons are fused to form one ${}_2He^4$ then the energy released is :

(a) 25.8 MeV (b) 23.6 MeV (c) 19.2 MeV (d) 30.2 MeV

4) Two nuclei have mass numbers in the ratio 8 : 125. What is the ratio of their nuclear radii?

5) A nucleus with mass number A = 240 and BE/A = 7.6 MeV breaks into two fragments each of A = 120 with BE/A = 8.5 MeV. Calculate the released energy.

6) Two nuclei have mass numbers in the ratio 2 : 5. What is the ratio of their nuclear densities?

7) (A) State two distinguishing features of nuclear force.

(B) Draw a plot showing the variation of potential energy of a pair of nucleons as a function of their separation.

Mark the regions on the graph where the force is:

(i) attractive, and (ii) repulsive

8) The nuclear radius of ${}_{13}A^{l27}$ is 3.6 fermi. Find the nuclear radius of ${}_{29}Cu^{64.}$

9) An atomic power nuclear reactor can deliver 300 MW. The energy released due to fission of each nucleus of uranium atom ${}_{92}U^{238}$ is 170 MeV. Find the number of uranium atoms fissioned per hour.

10) A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy of nucleons in Y and Z is 8.5 MeV per nucleon. Calculate the energy Q released per fission in MeV.

****

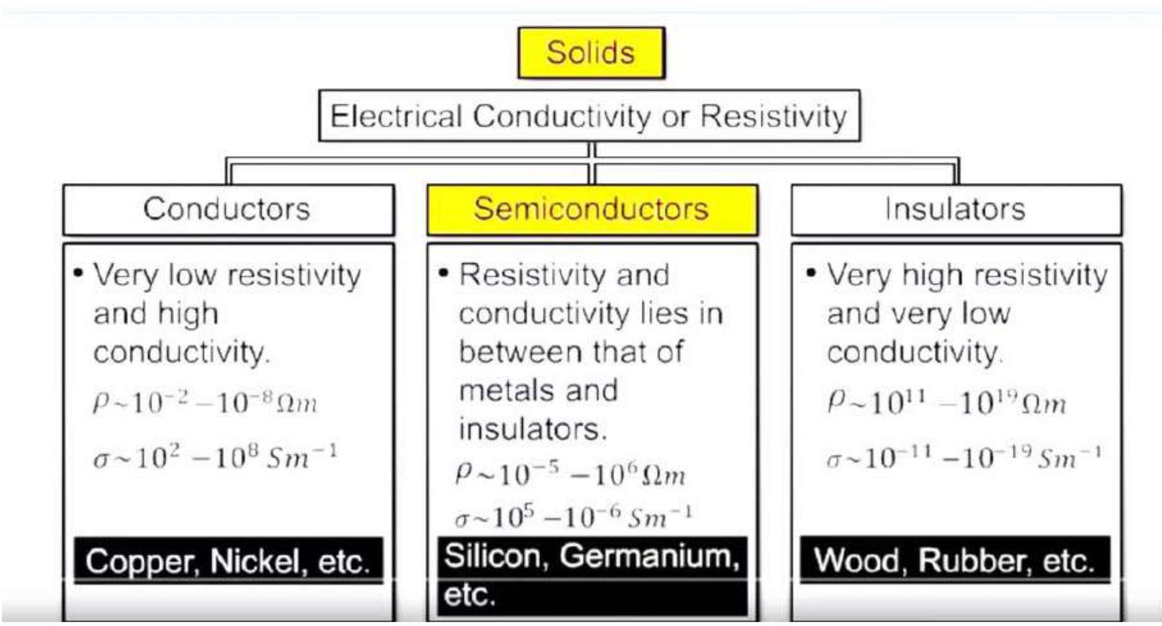
14. SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS

Energy bands in conductors, semiconductors and insulators (qualitative ideas only) Intrinsic and extrinsic semiconductors- p and n type, p-n junction Semiconductor diode - I-V characteristics in forward and reverse bias, application of junction diode -diode as a rectifier.

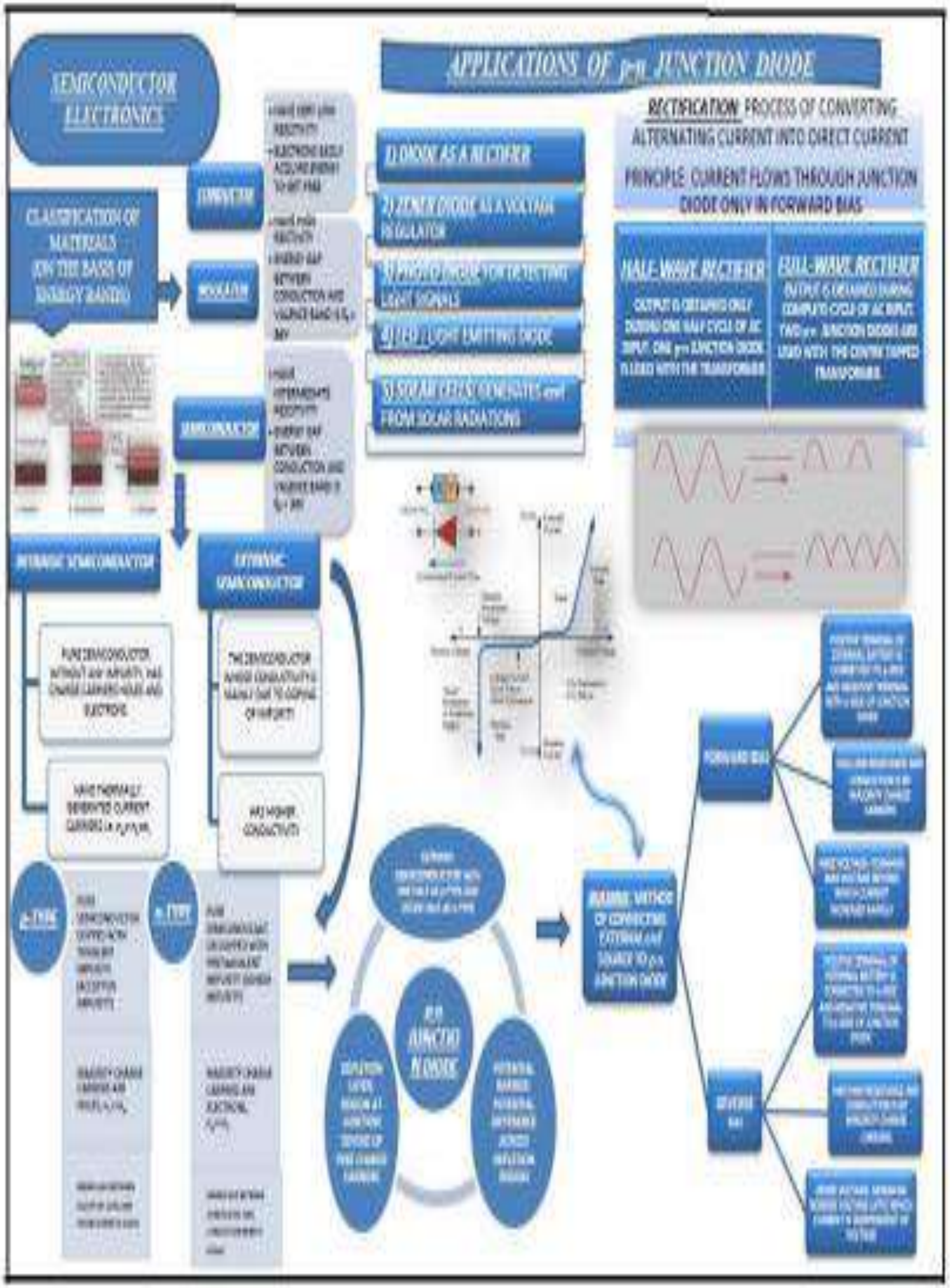
Before the discovery of transistor, devices such as vacuum diode were used to control the flow of electrons in a circuit. But these devices were bulky, consumed high power, operated at high voltages and had limited life and low reliability. In the 1930's it was realized that come solid state semiconductors and their junction offered the possibility of controlling the flow of charge carriers through them. This led to the development of the modern solid-state semiconductors. They consume low power, are small in size, operate at low voltages and have a long life and high reliability.

CLASSIFICATION OF CONDUCTORS, SEMICONDUCTORS AND INSULATORS

1)On the basis of conductivity



.


SEMICONDUCTOR ELECTRONICS
APPLICATIONS OF p-n JUNCTION DIODE
RECTIFICATION: PROCESS OF CONVERTING ALTERNATING CURRENT INTO DIRECT CURRENT
PRINCIPLE: CURRENT FLOWS THROUGH JUNCTION DIODE ONLY IN FORWARD BIAS
1) DIODE AS A RECTIFIER
2) ZENER DIODE AS A VOLTAGE REGULATOR
3) PHOTO DIODE FOR DETECTING LIGHT SIGNALS
4) LED : LIGHT EMITTING DIODE
5) SOLAR CELLS: GENERATES emf FROM SOLAR RADIATIONS
HALF-WAVE RECTIFIER
FULL-WAVE RECTIFIER
CLASSIFICATION OF MATERIALS ON THE BASIS OF ENERGY BANDS
CONDUCTOR
INSULATOR
SEMICONDUCTOR
INTRINSIC SEMICONDUCTOR
EXTRINSIC SEMICONDUCTOR
p-TYPE
n-TYPE
FORWARD BIAS
REVERSE BIAS

Semiconductors can be

(i) Elemental semiconductors: Si and Ge

(ii) Compound semiconductors: Examples are:

· Inorganic: CdS, GaAs, CdSe, InP, etc.

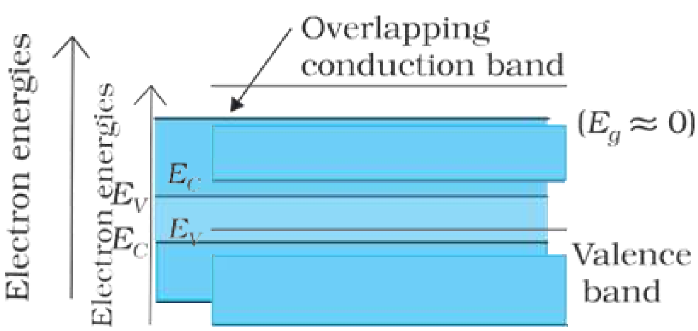
· Organic: anthracene, doped pthalocyanines, etc.

· Organic polymers: polypyrrole, polyaniline, polythiophene, etc.

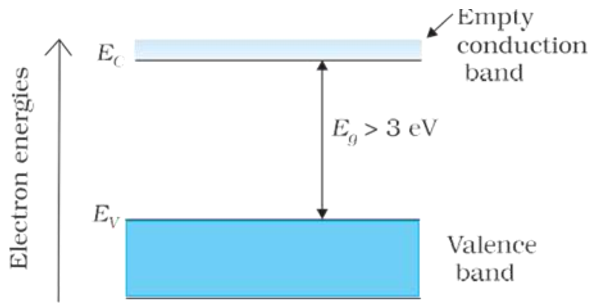
2) On the basis of energy bands

- According to Bohr model, every electron of an isolated atom has well defined energy levels.But when the atoms come together to form a solid they are close to each other. So the energy levels of electrons from neighbouring atoms would come very close or could even overlap
- These different energy levels with continuous variation forms what are called energy bands.
- The energy band which contains the energy levels of valence electrons is known as valence band. This is the lower energy band. This band is never empty.
- The energy band above the valence band is called the conduction band.Normally the conduction band is empty. But when it overlaps on the valence band electrons can move freely into it. This is the case with metallic conductors.
- The separation between the highest energy level of valence band and the lowest energy level of conduction band is known as Energy band gap. (E_g).). It may be large, small, or zero, depending upon the material.

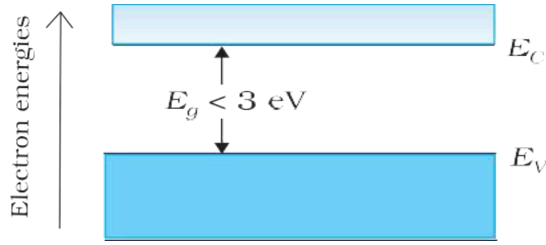
Metals:One can have a metal either when the conduction band is partially filled and the balanced band is partially empty or when the conduction and valance bands overlap. When there is overlap electrons from valence band can easily move into the conduction band. This situation makes a large number of electrons available for electrical conduction. When the valence band is partially empty, electrons from its lower level can move to higher level making conduction possible. Therefore, the resistance of such materials is low or the conductivity is high.



Insulator: In this case, as shown in Fig, a large band gap E_g exists (E_g > 3 eV). There are no electrons in the conduction band, and therefore no electrical conduction is possible. Note that the energy gap is so large that electrons cannot be excited from the valence band to the conduction band by thermal excitation.



Semiconductors: This situation is shown in Fig. Here a finite but small band gap (E_g < 3

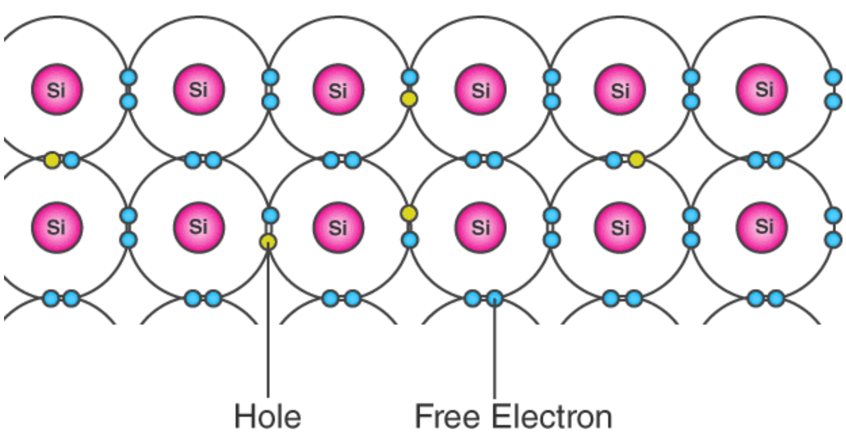


eV) exists. Because of the small band gap, at room temperature some electrons from valence band can acquire enough energy to cross the energy gap and enter the *conduction band*. These electrons (though small in numbers) can move in the conduction band. Hence, the resistance of *semiconductors* is not as high as that of the insulators.

Holes and Electrons in Semiconductors

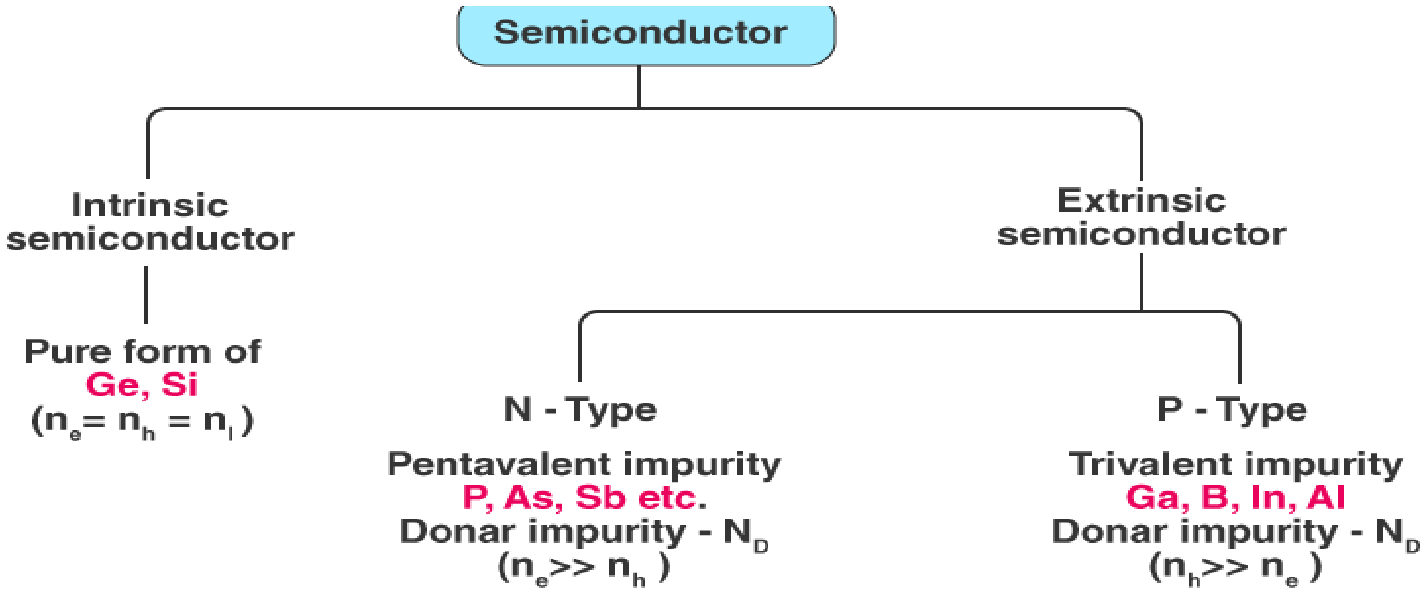
Holes and electrons are the types of charge carriers accountable for the flow of current in semiconductors. **Holes** (valence electrons) are the positively charged electric charge carrier whereas **electrons** are the negatively charged Both electrons and holes are equal in magnitude but opposite in polarity.

The bond model of electrons in silicon of valency 4 is shown below. Here, when one of the free electrons (blue dots) leaves the lattice position, it creates a hole (grey dots). This hole thus created takes the opposite charge of the electron and can be imagined as positive charge carriers moving in he lattice



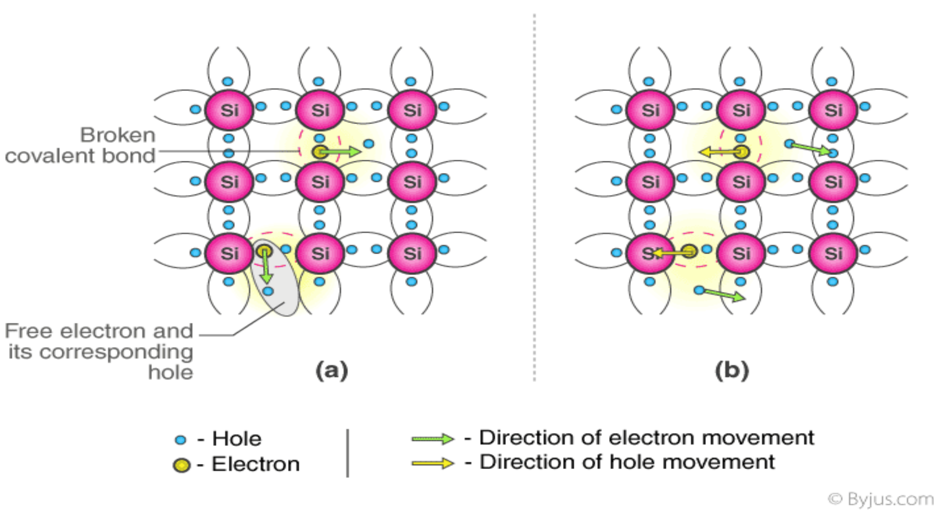
Types of Semiconductors Semiconductors can be classified as:

- **Intrinsic Semiconductor**
- **Extrinsic Semiconductors**



Classification of Semiconductors

Intrinsic Semiconductor



An **intrinsic type of semiconductor material** is made to be very pure chemically. It is made up of only a single type of element.

Conduction Mechanism in Case of Intrinsic Semiconductors (a) In absence of electric field (b) In presence of electric Field

Germanium (Ge) and Silicon (Si) are the most common type of intrinsic semiconductor elements. They have four valence electrons (tetravalent). They are bound to the atom by covalent bond at absolute zero temperature.

When the temperature rises, due to collisions, few electrons are unbounded and become free to move through the lattice, thus creating an absence in its original position (hole). These free electrons and holes contribute to the conduction of electricity in the semiconductor. The negative and positive charge carriers are equal in number.

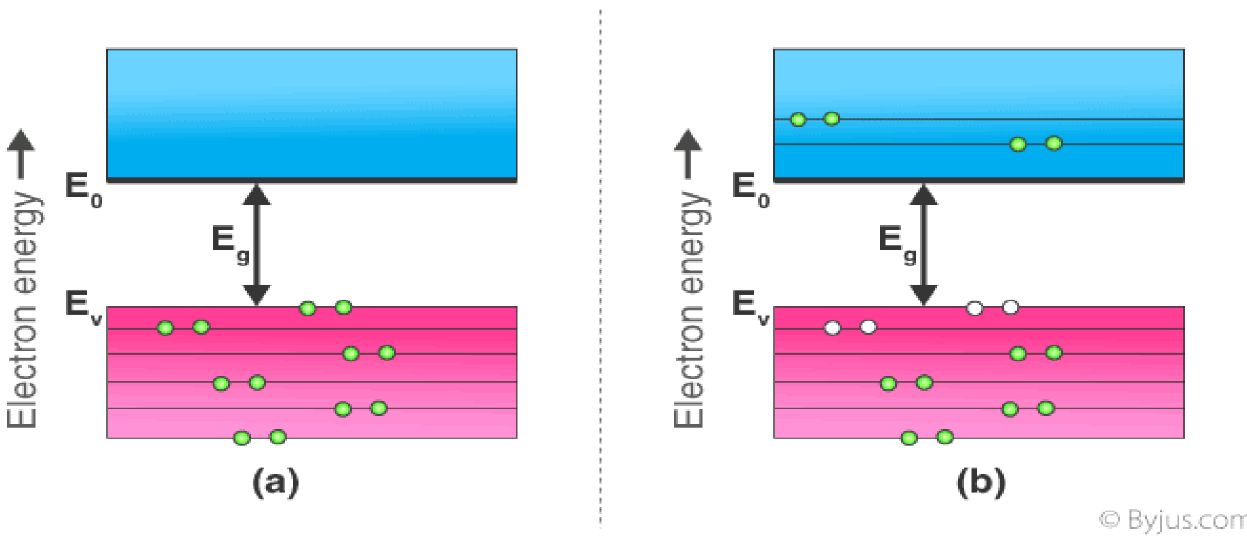
The thermal energy is capable of ionizing a few atoms in the lattice, and hence their conductivity is less.

Lattice of Pure Silicon Semiconductor at Different Temperatures

- **At absolute zero kelvin temperature:** At this temperature, the covalent bonds are very strong and there are no free electrons and the semiconductor behaves as a perfect insulator.
- **Above absolute temperature:** With the increase in temperature few valence electrons jump into the conduction band and hence it behaves like a poor conductor.

Energy Band Diagram of Intrinsic Semiconductor

The energy band diagram of an intrinsic semiconductor is shown below:



T = 0 Kelvin, behaves like an insulator At T>0 K

In intrinsic semiconductors, current flows due to the motion of free electrons as well as holes. The total current is the sum of the electron current I_e due to thermally generated electrons and the hole current I_h

Total Current (I) = $I_e + I_h$

For an intrinsic semiconductor, at finite temperature, the probability of electrons to exist in conduction band decreases exponentially with increasing bandgap (E_g)

$n = n_0 e^{-Eg/2.Kb.T}$ Where,

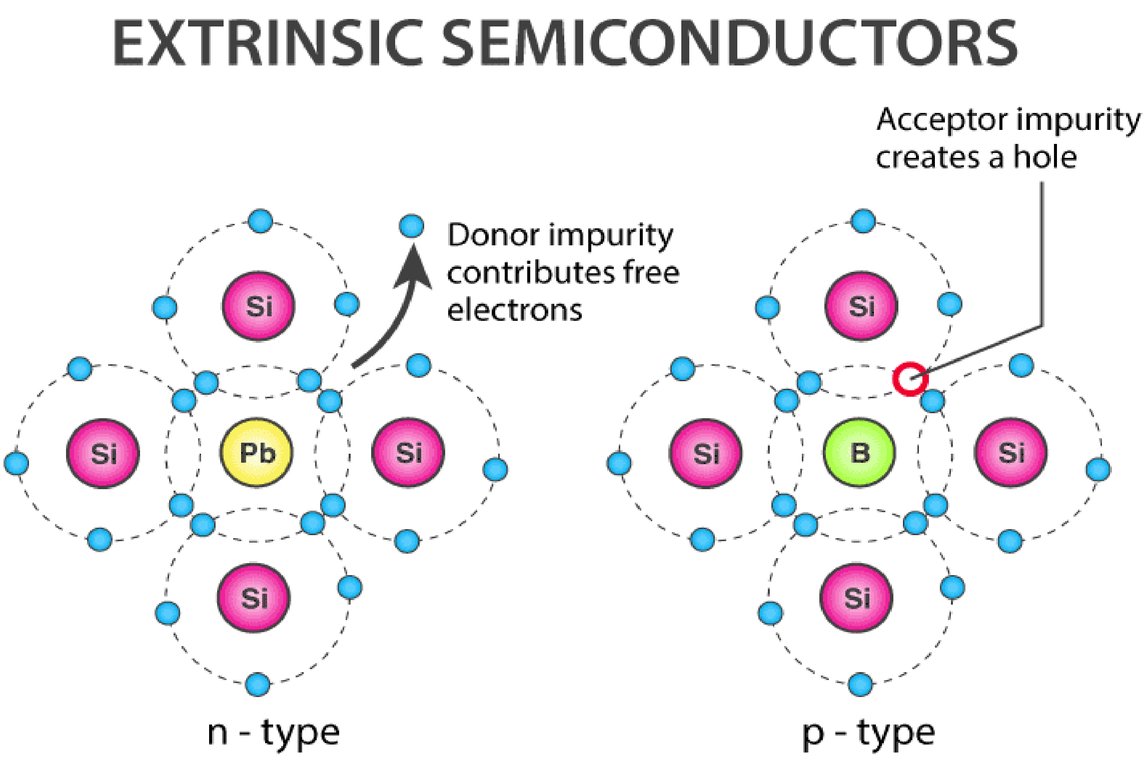
Eg = Energy bandgap

K_b = Boltzmann's constants

Extrinsic Semiconductor

The conductivity of semiconductors can be greatly improved by introducing a small number of suitable replacement atoms called IMPURITIES. The process of adding impurity atoms to the pure semiconductor is called DOPING. Usually, only 1 atom in 10^7 is replaced by a dopant atom in the doped semiconductor. An extrinsic semiconductor can be further classified into:

- **N-type Semiconductor**
- **P-type Semiconductor**



Classification of Extrinsic Semiconductor

N-Type Semiconductor

- Mainly due to electrons
- Entirely neutral
- $I = I_h$ and $n_h >> n_e$
- Majority – Electrons and Minority – Holes

When a pure semiconductor (Silicon or Germanium) is doped by pentavalent impurity (P, As, Sb, Bi) then, four electrons out of five valence electrons bonds with the four electrons of Ge or Si.

The fifth electron of the dopant is set free. Thus the impurity atom donates a free electron for conduction in the lattice and is called "**Donor**".

Since the number of free electron increases by the addition of an impurity, the negative charge carriers increase. Hence it is called n-type semiconductor.

Crystal as a whole is neutral, but the donor atom becomes an immobile positive ion. As conduction is due to a large number of free electrons, the electrons in the n-type semiconductor are the MAJORITY CARRIERS and holes are the MINORITY CARRIERS.

When a pure semiconductor (Silicon or Germanium) is doped by pentavalent impurity (P, As, Sb, Bi) then, four electrons out of five valence electrons bonds with the four electrons of Ge or Si.

The fifth electron of the dopant is set free. Thus the impurity atom donates a free electron for conduction in the lattice and is called "**Donor**".

Since the number of free electron increases by the addition of an impurity, the negative charge carriers increase. Hence it is called n-type semiconductor.

Crystal as a whole is neutral, but the donor atom becomes an immobile positive ion. As conduction is due to a large number of free electrons, the electrons in the n-type semiconductor are the MAJORITY CARRIERS and holes are the MINORITY CARRIERS.

P-Type Semiconductor

- Mainly due to holes
- Entirely neutral
- $I = I_h$ and $n_h >> n_e$
- Majority – Holes and Minority – Electrons

When a pure semiconductor is doped with a trivalent impurity (B, Al, In, Ga) then, the three valence electrons of the impurity bonds with three of the four valence electrons of the semiconductor.

This leaves an absence of electron (hole) in the impurity. These impurity atoms which are ready to accept bonded electrons are called "**Acceptors**".

With the increase in the number of impurities, holes (the positive charge carriers) are increased. Hence, it is called p-type semiconductor.

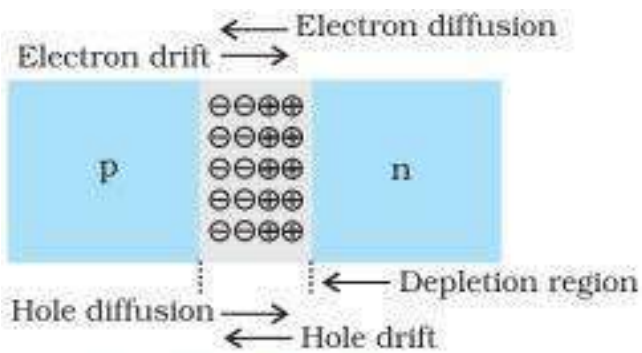
Crystal as a whole is neutral, but the acceptors become an immobile negative ion. As conduction is due to a large number of holes, the holes in the p-type semiconductor are MAJORITY CARRIERS and electrons are MINORITY CARRIERS.

What is P-N Junction?

Definition: *A p-n junction is an interface or a boundary between two semiconductor material types, namely the p-type and the n-type, inside a semiconductor.*

The p-side or the positive side of the semiconductor has an excess of holes and the n-side or the negative side has an excess of electrons. In a semiconductor, the p-n junction is created by the method of doping. The process of doping is explained in further details in the next section.

Formation of P-N Junction



p-n junction formation process.

As we know, if we use different semiconductor materials to make a p-n junction, there will be a grain boundary that would inhibit the movement of electrons from one side to the other by scattering the electrons and holes and thus we use the process of doping. We will understand the process of doping with the help of this example. Let us consider a thin p-type silicon semiconductor sheet. If we add a small amount of pentavalent impurity to this, a part of the p-type Si will get converted to n-type silicon. This sheet will now contain both p-type region and n-type region and a junction between these two regions. The processes that follow after the formation of a p-n junction are of two types – diffusion and drift. As we know, there is a difference in the concentration of holes and electrons at the two sides of a junction, the holes from the p-side diffuse to the n-side and the electrons from the n-side diffuse to the p-side. This gives rise to a diffusion current across the junction.

Also, when an electron diffuses from the n-side to the p-side, an ionized donor is left behind on the n-side, which is immobile. As the process goes on, a layer of positive charge is developed on the n-side of the junction. Similarly, when a hole goes from the p-side to the n-side, an ionized acceptor is left behind in the p-side, resulting in the formation of a layer of negative charges in the p-side of the junction. This region of positive charge and negative charge on either side of the junction is termed as the depletion region. Due to this positive space charge region on either side of the junction, an electric field direction from positive charge towards the negative charge is developed. Due to this electric field, an electron on the p-side of the junction moves to the n-side of the junction. This motion is termed as the drift. Here, we see that the direction of drift current is opposite to that of the diffusion current.

Biasing conditions for the p-n Junction Diode

There are two operating regions in p-n junction diode:

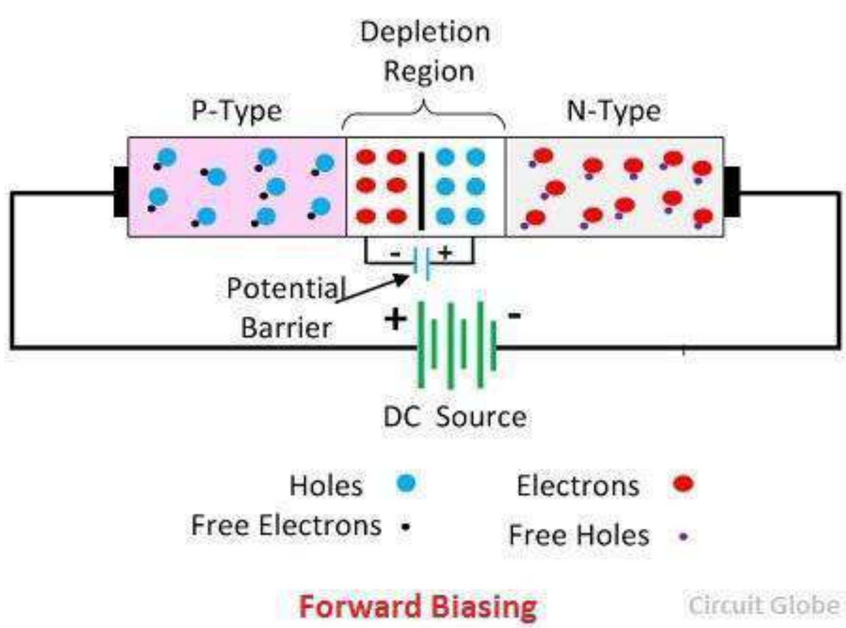
- P-type
- N-type

There are three biasing conditions for p-n junction diode and this is based on the voltage applied:

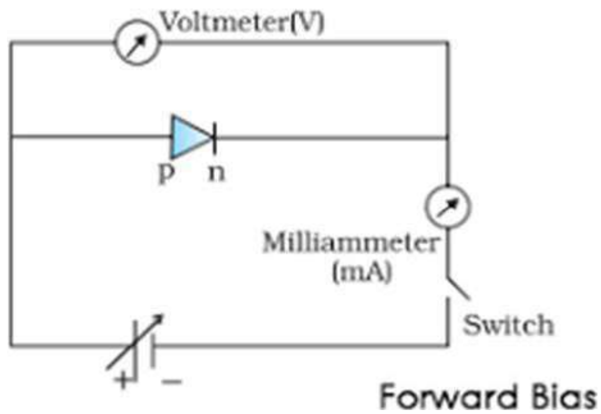
- Zero bias: There is no external voltage applied to the p-n junction diode.

- Forward bias: The positive terminal of the voltage potential is connected to the p-type while the negative terminal is connected to the n-type.
- Reverse bias: The negative terminal of the voltage potential is connected to the p-type and the positive is connected to the n-type.

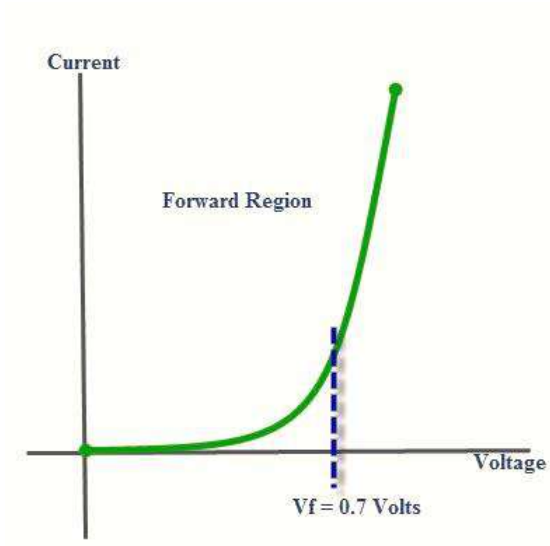
Forward Bias



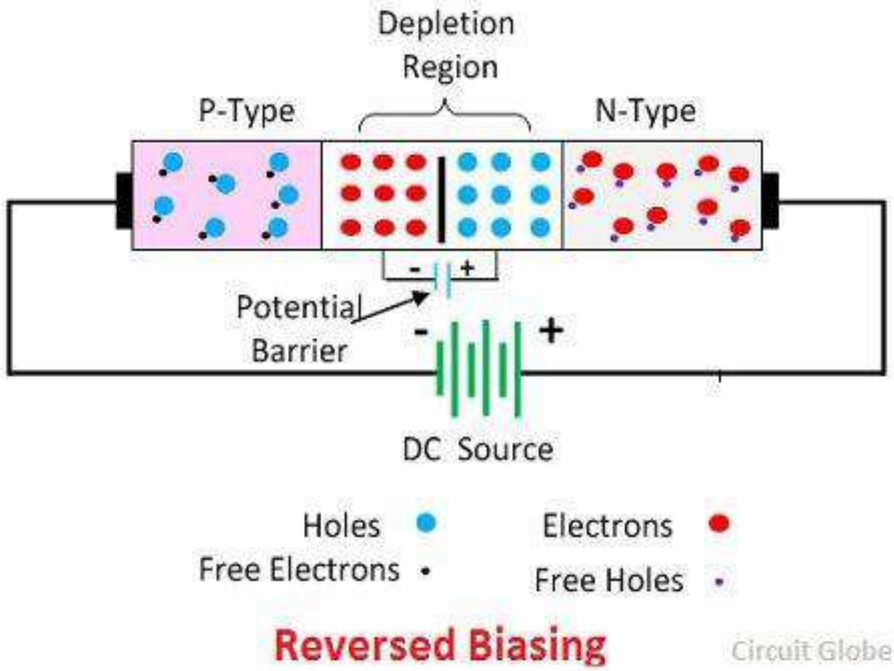
When the p-type is connected to the positive terminal of the battery and the n-type to the negative terminal then the p-n junction is said to be forward biased. When the p-n junction is forward biased, the built-in electric field at the p-n junction and the applied electric field are in opposite directions. When both the electric fields add up the resultant electric field has a magnitude lesser than the built-in electric field. This results in a less resistive and thinner depletion region. The depletion region's resistance becomes negligible when the applied voltage is large. In silicon, at the voltage of 0.6 V, the resistance of the depletion region becomes completely negligible and the current flows across it unimpeded



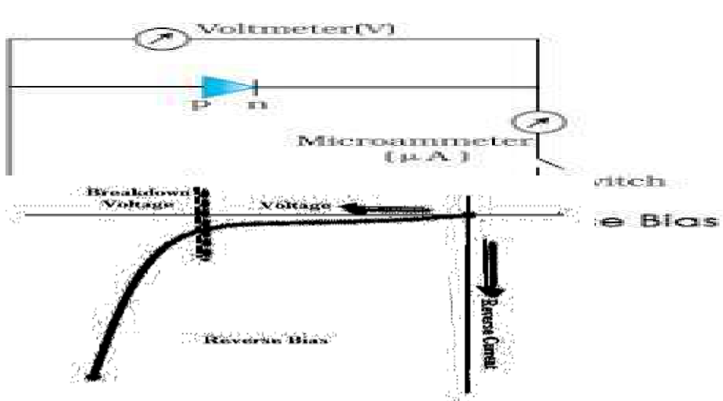
Forward characteristics of pn junction diode.



Reverse Bias

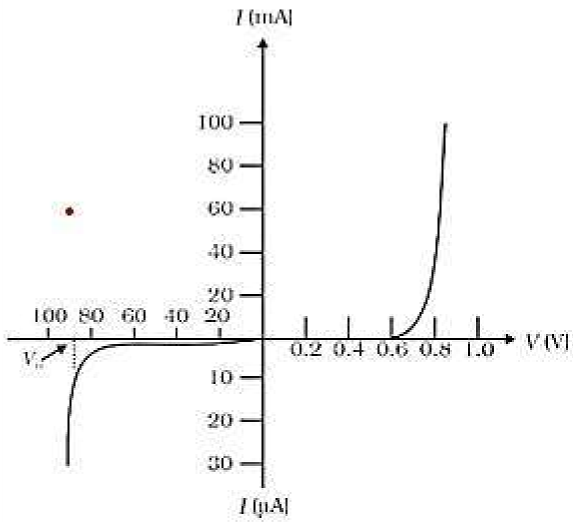


When the p-type is connected to the negative terminal of the battery and the n-type is connected to the positive side then the p-n junction is said to be reverse biased. In this case, the built-in electric field and the applied electric field are in the same direction. When the two fields are added, the resultant electric field is in the same direction as the built-in electric field creating a more resistive, thicker depletion region. The depletion region becomes more resistive and thicker if the applied voltage becomes larger.



The flow of electrons from n-side towards p-side of the junction takes place when there is increase in the voltage. Similarly, flow of holes from p-side towards n-side of the junction takes place along with the increase in the voltage. This results in the concentration gradient between on both the sides of the terminals. Because of formation of concentration gradient, there will be flow of charge carriers from higher concentration region to lower concentration region. The movement of charge carriers inside the pn junction is the reason behind current flow in the circuit.

V-I Characteristics of PN Junction Diode



Applications of PN Junction Diode

- p-n junction diode can be used as a photodiode as the diode is sensitive to the light when the configuration of the diode is reverse- biased.
- It can be used as a solar cell.
- When the diode is forward-biased, it can be used in LED lighting applications.
- It is used as rectifiers in many electric circuits and as voltage-controlled oscillator
  The main application of p-n junction diode is in rectification circuits. These circuits are used to describe the conversion of a.c signals to d.c in power supplies. Diode rectifier gives an alternating voltage which pulsates in accordance with time. The filter smoothes the pulsation in the voltage and to produce d.c voltage, a regulator is used which removes the ripples

There are two primary methods of diode rectification:

- Half Wave Rectifier
- Full Wave Rectifier

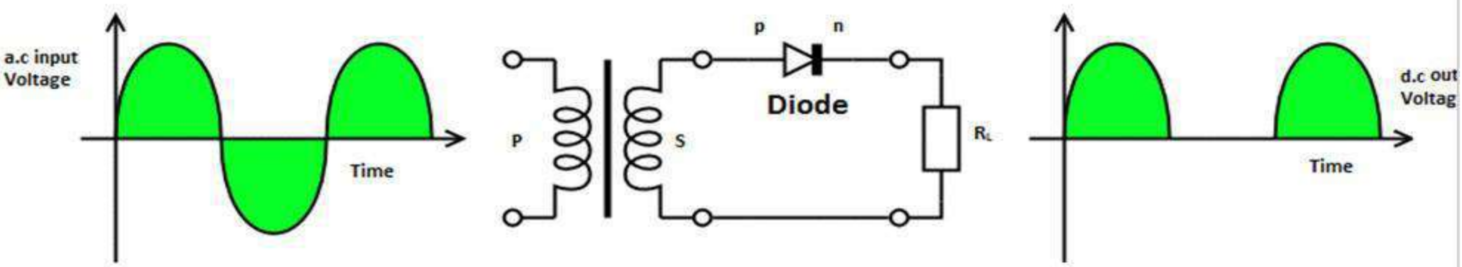
What is Half Wave Rectifier?

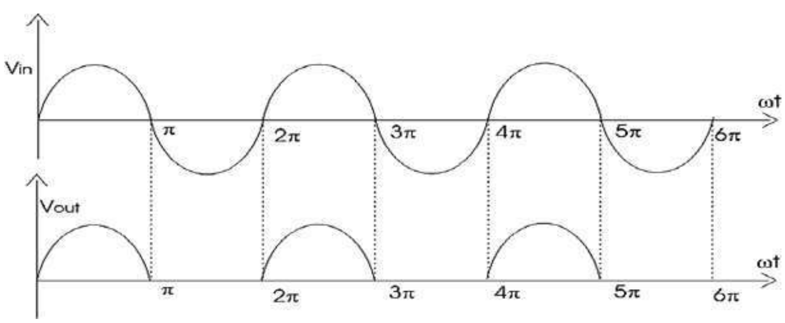
In a half-wave rectifier, one half of each a.c input cycle is rectified. When the p-n junction diode is forward biased, it gives little resistance and when it is reversing biased it provides high resistance. During one- half cycles, the diode is forward biased when the input voltage is applied and in the opposite half cycle, it is reverse biased. During alternate half cycles, the optimum result can be obtained.

Working of Half Wave Rectifier

- The half wave rectifier has both positive and negative cycles. During the positive half of the input, the current will flow from positive to negative which will generate only positive half cycle of the a.c supply. When a.c supply is applied to the transformer, the voltage will be decreasing at the secondary winding of the diode. All the variations in the a.c supply will reduce and we will get the pulsating d.c voltage to the load resistor.

In the second half cycle, current will flow from negative to positive and the diode will be reverse biased. Thus, at the output side, there will be no current generated and we cannot get power at the load resistance. A small amount of reverse current will flow during reverse bias due to minority carrier.





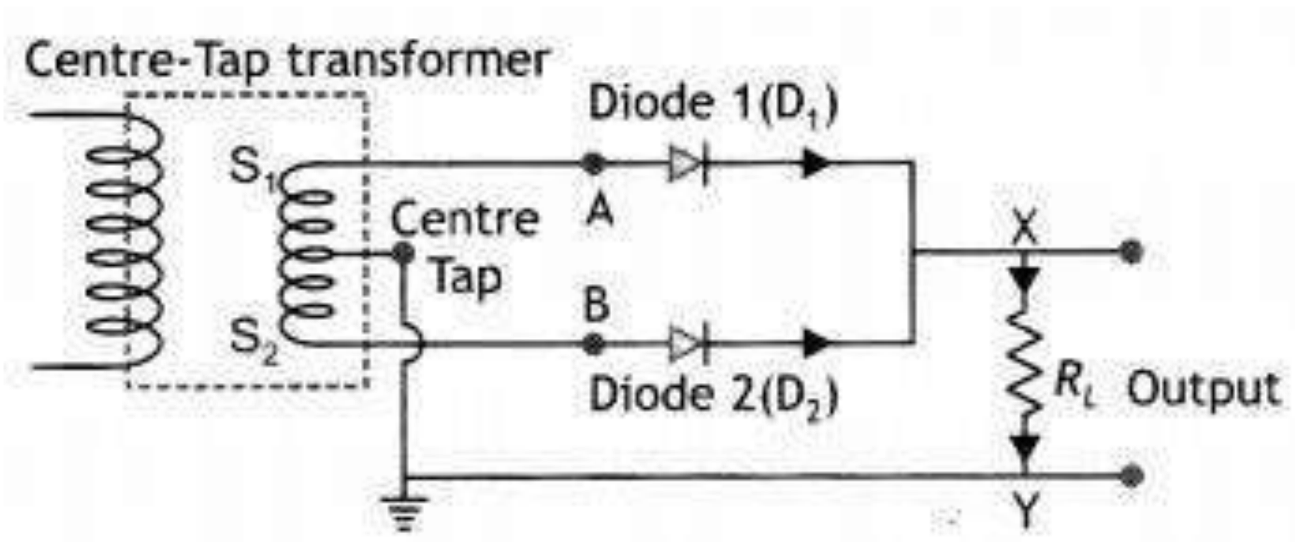
Applications of Half Wave Rectifier

Following are the uses of half wave rectification:

- **Power rectification:** Half wave rectifier is used along with transformer for power rectification as a powering equipment.
- **Signal demodulation:** Half wave rectifiers are used for demodulating the AM signals.
- **Signal peak detector:** Half wave rectifier is used for detecting the peak of the incoming waveform.

What is Full Wave Rectifier?

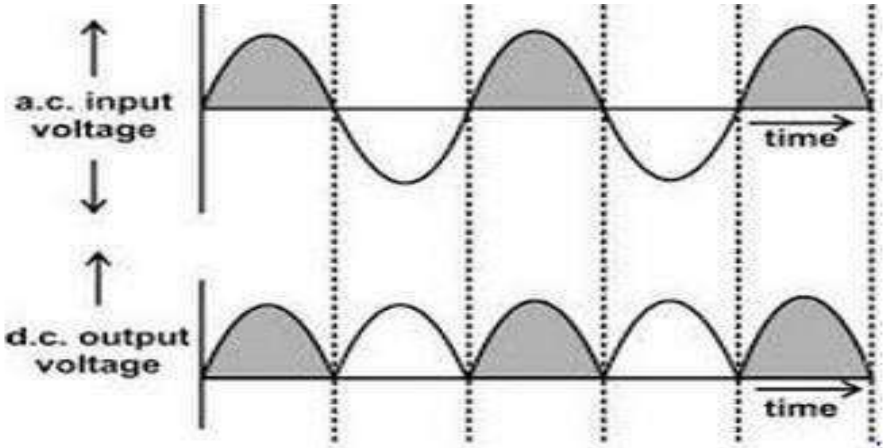
Full wave rectifier circuits are used for producing an output voltage or output current which is purely DC. The main advantage of full wave rectifier over half wave rectifier is that such as the average output voltage is higher in full wave rectifier, there is less ripple produced in full wave rectifier when compared to half wave rectifier.



Working of Full Wave Rectifier

Full wave rectifier utilizes both halves of each a.c input. When the p-n junction is forward biased, the diode offers low resistance and when it is reversing biased it gives high resistance. The circuit is designed in such a manner that in the first half cycle if the diode is forward biased then in the second half cycle it is reverse biased

and so on.



Rectifier Efficiency

Rectifier efficiency is used as a parameter to determine the efficiency of the rectifier to convert AC into DC. It is ratio of DC output power to the AC input power. ***Rectifier efficiency of a full wave rectifier is 81.2%.***

Types of Full Wave Rectifier

There are two main types of full wave rectifiers and they are:

- **Two diode full wave rectifier circuit** (requires center-tapped transformer and is used in vacuum tubes)
- **Bridge rectifier circuit** (doesn't require centre-tapped transformer and is used along with transformers for efficient usage)

Advantages of Full Wave Rectifier

- The rectifier efficiency of a full wave rectifier is high
- The power loss is very low
- Number of ripples generated are less

Disadvantages of Full Wave Rectifier

- Very expensive

Applications of Full Wave Rectifier Following are the

uses of full wave rectifier:

- Full wave rectifiers are used for supplying polarized voltage in welding and for this bridge rectifiers are used.

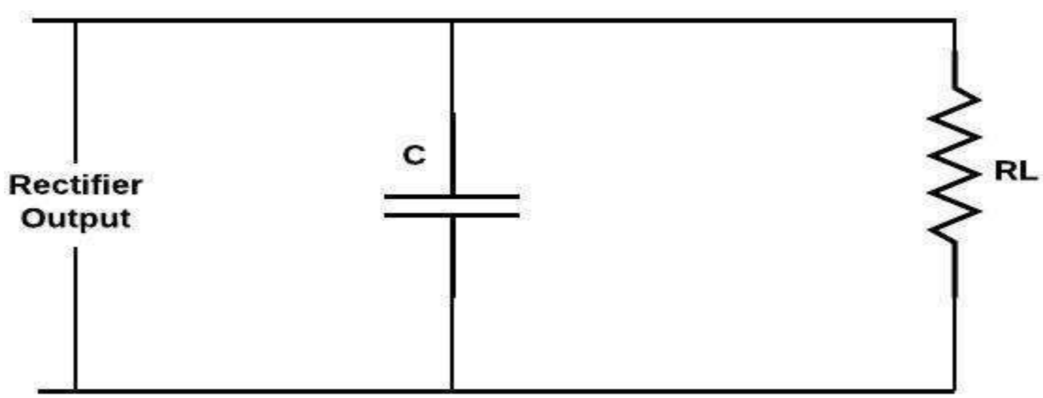
- Full wave rectifiers are used for detecting amplitude of modulated radio signals.

Half Wave and Full Wave Rectifier with Capacitor Filter

The filter is one type of electronic device mainly used to perform signal processing. The main function of this filter is to allow the ac components and blocks the dc components of the load. The filter circuit output will be a stable dc voltage. The construction of a filter circuit can be done with the basic electronic components like resistors, inductors, and capacitors. There are different types of filters available namely LPF (**low pass filter**), BPF (bandpass filter), HPF (**high pass filter**), capacitor filter, etc. The main function of the capacitor, as well as an inductor in this circuit, is, a capacitor allows the ac and blocks the dc, whereas an inductor permits only DC components to supply and blocks ac.

What is a Capacitor Filter?

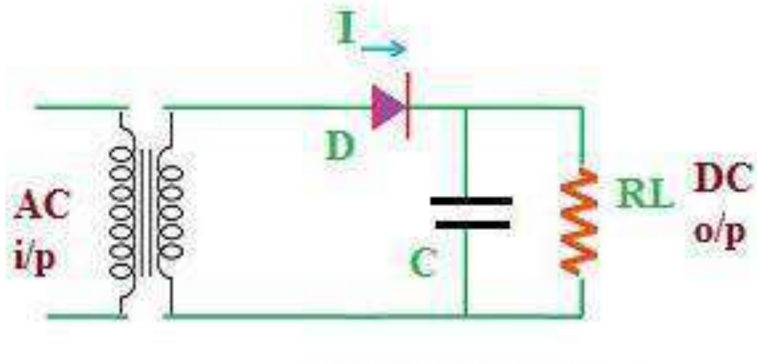
A typical **capacitor filter** circuit diagram is shown below. The designing of this circuit can be done with a capacitor (C) as well as load resistor (RL). The rectifier's exciting voltage is given across the terminals of a capacitor. Whenever the voltage of the rectifier enhances then the capacitor will be charged as well as supplies the current to the load.

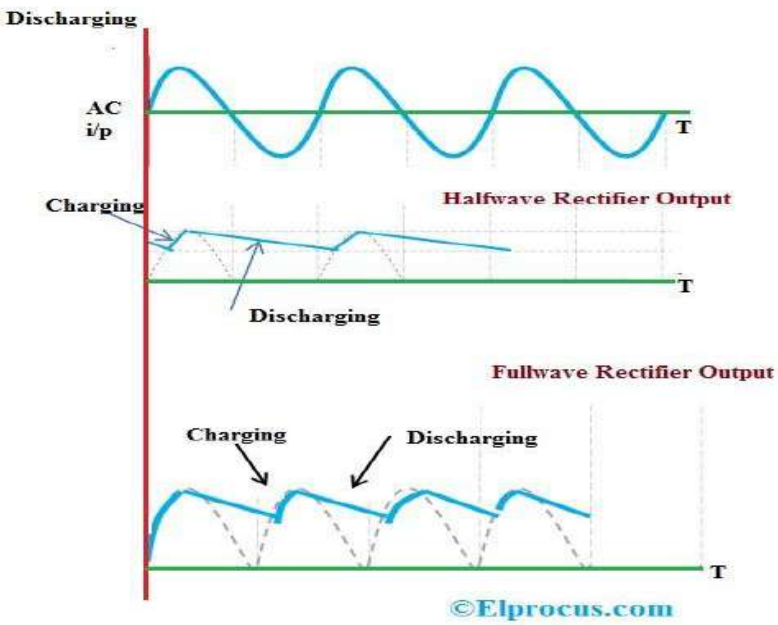


At the last part of the quarter phase, the capacitor will be charged to the highest rectifier voltage value that is denoted with Vm, and then the voltage of the rectifier starts to reduce. As this happens, the capacitor starts discharging through the voltage across it and load. The voltage across the load will reduce little only because the next peak voltage occurs instantaneously to charge the capacitor. This procedure will repeat many times and the output waveform will be seen that very slight ripple is missing in the output.

Furthermore, the output voltage is superior because it remains significantly close to the highest value of the output voltage of the rectifier.

\


I
D
AC
i/p
C
RL
DC
o/p


Discharging
AC
i/p
T
Charging
Halfwave Rectifier Output
T
Discharging
Fullwave Rectifier Output
Charging
Discharging
T
©Elprocus.com

FORMULAE

1) Electron and hole concentration in a semiconductor in thermal equilibrium

$n_e n_h = n_i^2$

2) Resistance of a Diode:

a) Static or DC Resistance $R_{dc} = V/I$

b) Dynamic or AC Resistance $= \Delta V/\Delta I$

MNEMONICS

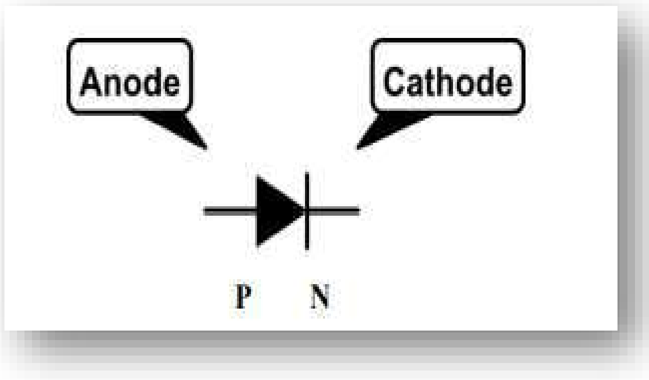
1) To remember names of impurities in semiconductors

BIG PAA

Boron, Indium, Gallium (all three are trivalent impurities)

Phosphorus, Antimony, Arsenic (all three are pentavalent impurities)

2) TO REMEMBER THE P AND N SECTIONS OF A DIODE.



The arrow in the schematic symbol for diodes points in the direction of Conventional (positive) current flow

MCQ

1) The energy gap is maximum in:

   a) metals
   b) superconductors
   c) insulators
   d) semiconductors

2) Choose the only false statement from the following

   a) In conductors the valence and conduction bands overlap.
   b) Substances with energy gap of the order of 10eV are insulators.
   c) The resistivity of a semiconductor increases with increase in temperature
   d) The conductivity of a semiconductor increases with increase in temperature.

3) The conductivity of a semiconductor increases with increase in temperature because:

   a. number density of free current carries increases
   b. relaxation time increases
   c. number density of carriers and relaxation time increases
   d. number density of current carries increase, relaxation time decreases but effect of decrease in relaxation time is much less than increase in number density

4) If a small amount of antimony is added to germanium crystal

   a) it becomes a p-type semiconductor.
   b) the antimony becomes an acceptor atom.
   c) there will be more free electrons than holes in the semiconductor.
   d) its resistance is increased

5) The impurity atoms with which pure silicon may be doped to make it a p-type semiconductor are those of

   a) phosphorus
   b) boron
   c) Antimony
   d) nitrogen

6) The forbidden gap for germanium is,

   a) 0.12 eV
   b) 0.72 eV
   c) 7.2 eV
   d) None of these

7) In Conductor, Semiconductor and Insulator, the forbidden energy gaps are E1, E2 and E3 respectively. Which one is correct?

(a) E1<E2<E3

(b) E1>E2=E3

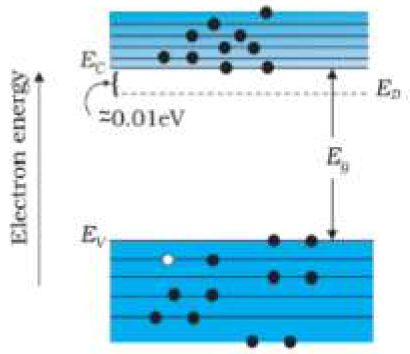
(c) E1=E2<E3

(d) E1>E2>E3

8) When p-n junction diode is forward biased then

(a) both the depletion region and barrier height are reduced
(b) the depletion region is widened and barrier height is reduced
(c) the depletion region is reduced and barrier height is increased
(d) Both the depletion region and barrier height are increased

9) In the energy band diagram of a material shown below, the open circles and filled circles denote holes and electrons respectively. The material is a/an



(A) p type semiconductor

(B) n type semiconductor

(C) insulator

(D) metal

10) In a full wave rectifier circuit operating from 50 Hz mains frequency, the frequency in the output waveform would be

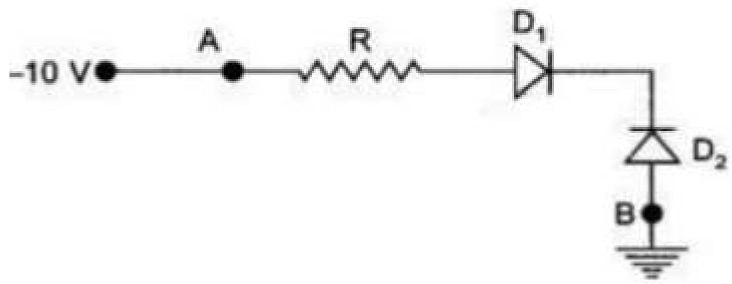
(a) 50 Hz
(b) 100 Hz
(c) 25 Hz
d) 150Hz

11) In a semiconductor diode, the barrier potential offers opposition to

(a) holes in P-region only
(b) free electrons in N-region only
(c) majority carriers in both regions
(d) majority as well as minority carriers in both regions

12) Depletion region in a p-n junction is
    (a) a region without free electrons and holes
    (b) a region with more free electrons and holes
    (c) a region without free electrons only
    (d) a region without holes only

13) In figure given, assuming the diodes to be ideal In figure given, assuming the diodes to be ideal



(a) D1 is forward biased and D2 is reverse biased and hence current flows from A to B.

(b) D2 is forward biased and D1 is reverse biased and hence no current flows from B to A and vice versa.

(c) D1 and D2 are both forward biased and hence current flows from A toB.

(d) D1 and D2 are both reverse biased and hence no current flows from A to B and vice versa.

14) Carbon, silicon and germanium have four valence electrons each. These are characterized by valence and conduction bands separated by energy band gap respectively equal to (Eg)C, (Eg)Si and (Eg)Ge. Which of the following statements is true?
    (a) (Eg)Si < (Eg)Ge < (Eg)c
    (b) (Eg)c < (Eg)Ge < (Eg)Si
    (c) (Eg)c > (Eg)Si > (Eg)Ge
    (d) (Eg)c = (Eg)Si = (Eg)Ge

15) If no external voltage is applied across p-n junction, then there would be
    (a) no electric field across the junction
    (b) an electric field pointing from n-type to p-type side across the junction
    (c) an electric field pointing from p-type to n-type side across the junction
    (d) a temporary electric field during formation of p-n junction that would subsequently disappear.

16) The dominant mechanism for the motion of charge carriers in forward and reverse biased silicon p-n junction are
    (a) drift in forward bias, diffuse in reversed bias
    (b) diffuse in forward bias, drift in reversed bias
    (c) diffusion in both forward and reverse bias

(d) drift in both forward and reverse bias

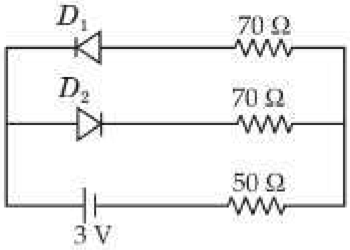
17) In intrinsic semiconductors at room temperature, the number of electrons and holes are

a. Unequal,
b. Equal,
c. Infinite,
d. Zero

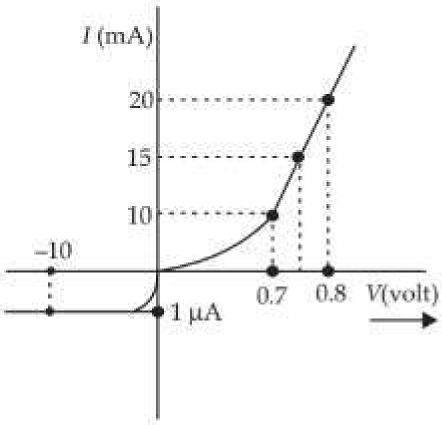
18) The breakdown in a reverse biased p-n junction diode is more likely to occur due to
(a) large velocity of the minority charge carriers if the doping concentration is small
(b) large velocity of the minority charge carriers if the doping concentration is large
(c) strong electric field in a depletion region if the doping concentration is small
(d) none of these

19) The circuit shown in the figure contains two diodes each with forward resistance of 30 Ω and with infinite backward resistance. If the battery is 3 V, the current through the 50 Ω resistance (in ampere) is

(a) zero
(b) 0.01
(c) 0.02
(d) 0.03



20) The V-I characteristic of a diode is shown in the figure. The ratio of forward to reverse bias resistance is



(a) 100

(b) 10^6

(c) 10

(d) 10^{-6}

Answers

1	2	3	4	5	6	7	8	9	10
c	c	d	c	d	b	a	a	b	b
11	12	13	14	15	16	17	18	19	20
c	a	b	c	b	b	b	b	c	d

ASSERTION – REASON QUESTIONS:

(A) Assertion and reason both are correct statements and Reason is correct explanation forAssertion

(B) Assertion and Reason both are correct statement but Reason is not correct explanationfor assertion.

(C) Assertion is correct statement but reason is wrong statement.

(D) Assertion is Wrong statement but Reason is correct statement.

1) **Assertion:** The electrical conductivity of a semiconductor increases with increase in temperature.
Reason: With increase in temperature, large number of electrons from the valence band can jump to the conduction band.

2) **Assertion:** When two semiconductors of p and n type are brought in contact, they form p-n junction which act like a rectifier.
Reason-A rectifier is used to convert alternating current into direct current

3) **Assertion-** The diffusion current in a p-n junction is from the p side to n side.
Reason- The diffusion current in a p-n junction is greater than the drift current when the junction is in forward biased.

4) **Assertion**- The drift current in a p-n junction is from the n side to the p side.
Reason- It is due to free electrons only.

5) **Assertion : A pure semiconductor has negative temperature coefficient of resistance.**
Reason : In a semiconductor on raising the temperature, more charge carriers are released, conductance increases and resistance decreases.

6) Assertion :Silicon is preferred over germanium for making semiconductor devices.
Reason :The energy gap in germanium is more than the energy gap in silicon.

7) Assertion: The p-n junction diode primarily allows the flow of) current only in one direction (forward bias)
Reason: The forward bias resistance is low as compared to the reverse bias resistance.

8) Assertion: The diffusion current in a p-n junction is from the p-side to the n-side.
Reason: The diffusion current in a p-n junction is greater than the drift current when the junction is in forward biased.

9) Assertion: The diffusion current in a p-n junction is from the p-side to the n-side.
Reason: The diffusion current in a p-n junction is greater than the drift current when the junction is in forward biased.

10) Assertion: An N-type semiconductor has a large number of electrons but still it is electrically

neutral.

Reason: An N-type semiconductor is obtained by doping an intrinsic semiconductor with a pentavalent impurity.

11) **Assertion: When diode is used as a rectifier, its specified reverse breakdown voltage should not be exceeded.**
Reason: When p-n junction diode crosses the reverse break down voltage, it gets destroyed.

12) **Assertion (A): An intrinsic semiconductor has equal number of electron and hole.**
Reason (R): Thermally generated electron- hole pairs are the charge carriers in intrinsic semiconductor.

13) **Assertion: For a half wave rectifier the output frequency is half of input**
Reason: Half wave rectifier got its name from such phenomena.

14) Assertion: At 0K germanium behaves as insulator.
Reason:- No free electrons present in conduction band at 0K.

15) **Assertion :** A p-type semiconductors is a positive type crystal.
Reason : A p- type semiconductor is an uncharged crystal.

Answers

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	B	B	A	A	C	A	B	A	B	A	A	D	A	D

1) Distinguish between Intrinsic and Extrinsic semiconductors.

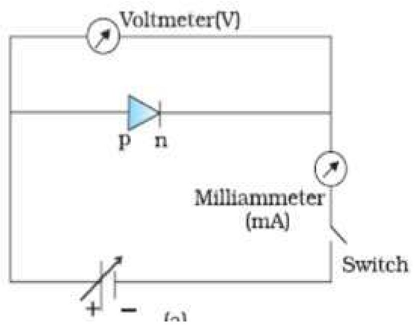
Intrinsic Semiconductor	**Extrinsic Semiconductor**
Semiconductor in pure form	Semiconductor obtained by adding impurities
Density of electrons is equal to the density of holes	Density of electrons is not equal to the density of holes
Electrical conductivity is low	Electrical conductivity is high
Conductivity depends on temperature only	Conductivity depends on amount of doping.

2) Explain briefly with the help of necessary diagrams, the forward and the reverse biasing of a p-n junction diode. Also draw their characteristic curves in the two cases.

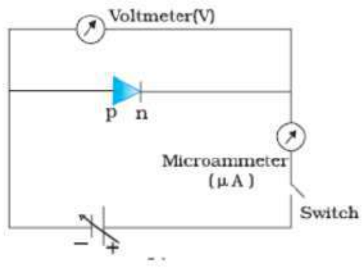
Answer:
The circuit arrangement for studying the V– I characteristics of a diode, are shown in figures The

battery is connected to the silicon diode through a potentiometer (or rheostat), so that the applied voltage can be changed for different values of voltages, the corresponding values of current are noted. A graph between V and I is obtained as shown in figure.

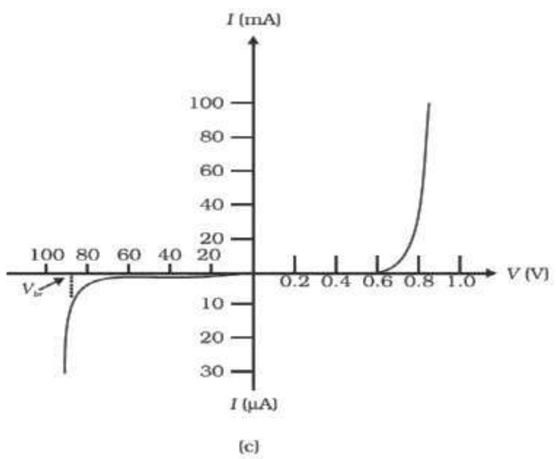
Forward biasing



Reverse biasing



Forward Bias & Reverse Bias Characteristics of a P-N Junction Diode



3) Why is the current under reverse bias almost independent of the applied potential up to a critical voltage?

Ans : Under the reverse bias condition, the holes of p-side are attracted towards the negative terminal of the battery and the electrons of the n-side are attracted towards the positive terminal of the battery. This increases the depletion layer and the potential barrier. However, the minoritycharge carriers are drifted across the junction producing a small current. At any temperature, thenumber of minority carriers is constant, so there is the small current at any applied potential.

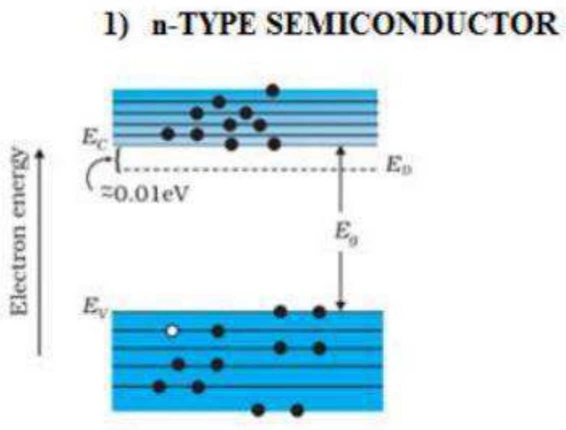
This is the reason for the current under reverse bias to be almost independent of appliedpotential.

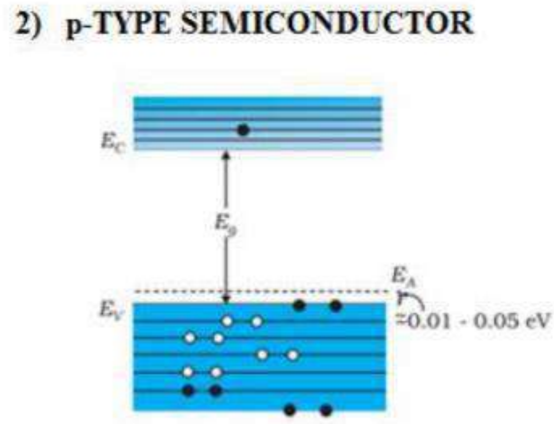
4) Under the reverse bias condition, the holes of p-side are attracted towards the negative terminal of the battery and the electrons of the n-side are attracted towards the positive terminal of the battery. This increases the depletion layer and the potential barrier. However, the minoritycharge carriers are drifted across the junction producing a small current. At any temperature, thenumber of minority carriers is constant, so there is the small current at any applied potential.
This is the reason for the current under reverse bias to be almost independent of appliedpotential.

5) What do you mean by depletion region and potential barrier in a junction diode?
Ans. Depletion region. A layer, created around the junction between p and n-sections of a

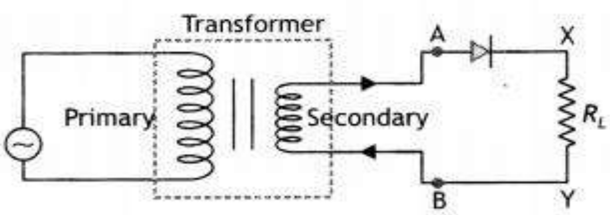
junction diode devoid of holes and electrons, is called depletion region. Potential barrier. The potential difference developed across the junction due to migration of majority carriers is called potential barrier.

6) Diffentiate between n-type and p-type semiconductors on the basis of energy band diagrams



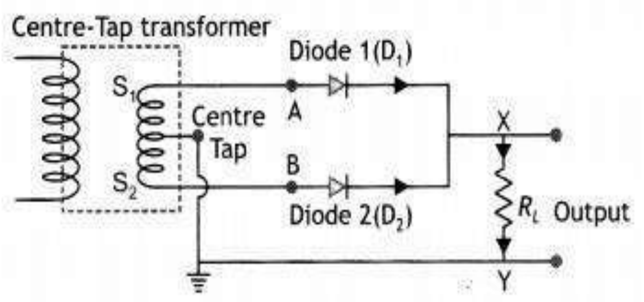


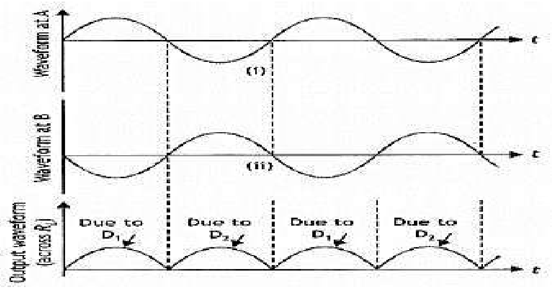
7) Draw the circuit diagram to show the use of a p-n junction diode as a half-waverectifier. Also show the input and the output voltages, graphically.



In the above diagram, during positive half cycle of the input AC, the p-n junction is forward biased. Thus the resistance in p-n junction becomes low and current flows. Hence we get output in the load.
During negative half cycle of the input AC, the p-n junction is reverse biased. Thus the resistance of the junction is high and current does not flow. Hence no output in the load. So, for complete cycle of AC current flows through the load resistance in the same direction. The output voltage is unidirectional but pulsating. This process is called half wave rectification and the arrangement is called half wave rectifier.

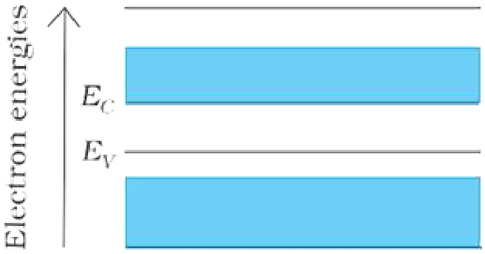
8) Draw the circuit diagram of a full-wave rectifier. Also, give the input and output waveform



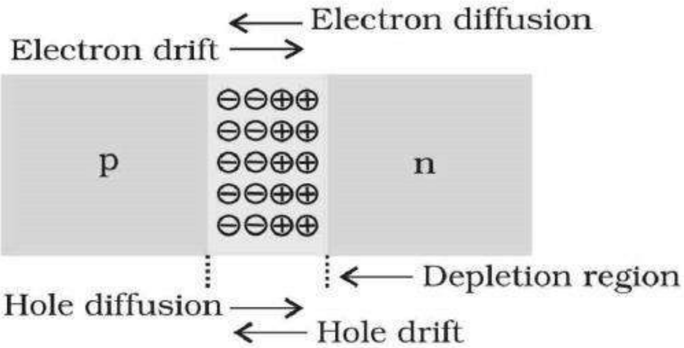


During the first half ofinput cycle, the upper end of the coil is at positive potential and lower end at negative potential. The function diode D_1 is forward biased and D_2 is reverse biased. Current flows in output load resistance in the direction shown in the figure. During the second half of input cycle, D_2 is forward biased. In this way, current flows in the load in in the single direction

9) **Explain with the help of a suitable diagram, the two processes which occur during theformations of a p-n junction diode.**



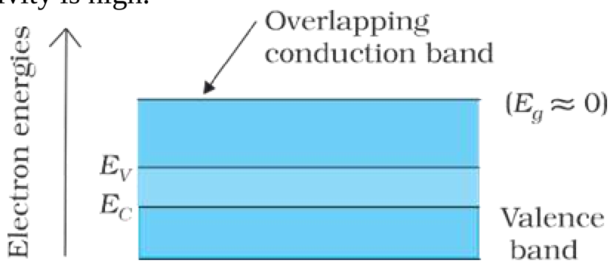
During the formation of p-n junction and due to difference in the concentration of charge carriers holes diffuse from p-side to n-side(p→n) and electrons diffuse from n-side to p-side9 (n→p). This motion of charge carriers gives rise to diffusion current across the junction. Drift is the process of movement of charge carriers due to the net electric field. Thus when a hole diffuses from p side to n side, it leaves behind an acceptor (negative charge) which is immobile. As the holes continue to diffuse, a layer of negatively charged immobile ions is developed on the p side of the junction. The diffused charge carriers combine with their counterparts in the immediate vicinity of the junction and neutralize each other. The region on either side of the junction which becomes depleted from the mobile charge carriers is called the depletion region or depletion layer whose width is of the order of 10-6m. This sets up a potential difference across the junction and an internal electric field E directed from n side to p side. This electric field set up stops further diffusion of majority charge carriers



10) Differentiate between conductors, insulators and semiconductors on the basis of energy band diagrams,

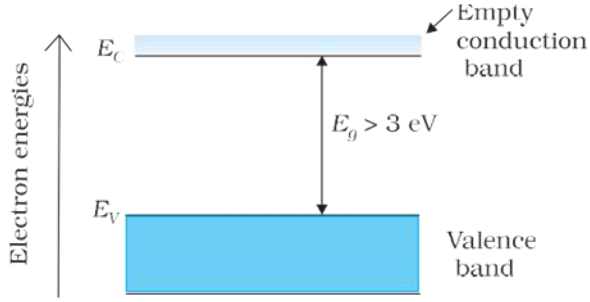
Ans:

In metals, either when the conduction band is partially filled and the balanced band is partially empty or when the conduction and valance bands overlap. When there is overlap electrons from valence band can easily move into the conduction band. This situation makes a large number of electrons available for electrical conduction. When the valence band is partially empty, electrons from its lower level can move to higher level making conduction possible. Therefore, the resistance of such materials is low or the conductivity is high.



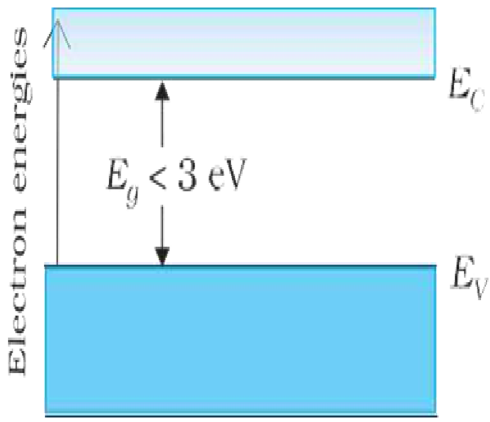
In insulators, the conduction band is empty and valence band is completely filled and forbiddengap is quite large ≈6 eV(>3eV).

Note that the energy gap is so large that electrons cannot be excited from the valence band to the conduction band by thermal excitation.



In semiconductors, the conduction band is empty and valence band is totally filled at T<0K. The forbidden gap between conduction band and valence band is quite small, which is about 1eV(<3eV).

Because of the small band gap, at room temperature some electrons from valence band can acquire enough energy to cross the energy gap and enter the conduction band. These electrons (though small in numbers) can move in the conduction band. Hence, the resistance of semiconductors is not as high as that of the insulators.



CASE BASED QUESTIONS

1)Read the passage given below and answer the following questions

The device used for convertion of AC to DC is called rectifier. Usually crystal diode are used in rectifier. The output of the rectifier is not 100% DC but consists of pulsating voltage. To reduce it again it will fed to filter circuit.

1) The property of crystal diode which makes it suitable for rectification is

(a) made of semiconductor

(b) Unidirectional flow of current

(c) Less current in reverse bias

(d) After knee voltage it expontially increase.

2) Capacitor is used in filter circuit because

(a) It allow DC

(b) It connect series with load resistor

(c) The pulsating AC can easily passed through capacitor

(d)None of above

3) The efficiency of rectifier is more when

(a) one diode is used

(b) two diode used in series

(c)two diode used in parallel

(d) one diode and a capacitor connected in parallel

2) Band theory of solid:

Consider that the Si or Ge crystal contains N atoms. Electrons of each atom will have discrete energies in different orbits. The electron energy will be same if all the atoms are isolated, i.e., separated from each other by a large distance. However, in a crystal, the atoms are close to each other (2 Å to 3 Å) and therefore the electrons interact with each other and also with the neighbouring atomic cores. The overlap (or interaction) will be more felt by the electrons in the outermost orbit while the inner orbit or core electron energies may remain unaffected. Therefore, for understanding electron energies in Si or Ge crystal, we need to consider the changes in the energies of the electrons in the outermost orbit only. For Si, the outermost orbit is the third orbit (n = 3), while for Ge it is the fourth orbit (n = 4). The number of electrons in the outermost orbit is 4 (2s and 2p electrons). Hence, the total number of outer electrons in the crystal is 4N. The maximum possible number of outer electrons in the orbit is 8 (2s + 6p electrons). So, out of the 4N electrons, 2N electrons are in the 2N s-states (orbital quantum number l = 0) and 2N electrons are in the available 6N p-states. Obviously, some p-electron states are empty. This is the case of well separated or isolated atoms.

1) The energy of electrons of atoms of a substance will be same if:
   (A) atoms are isolated.
   (B) atoms are closely spaced.
   (C) atoms are excited.
   (D) atoms are charged.

2) In a crystal, the distance between two atoms is:
   (A) 200 Å to 300 Å
   (B) 2 Å to 3 micron
   (C) 2 Å to 3 Å
   (D) 2 mm to 3 mm

3) The overlap (or interaction) will be more felt by the electrons when they are:

a) (A) in the outermost orbit

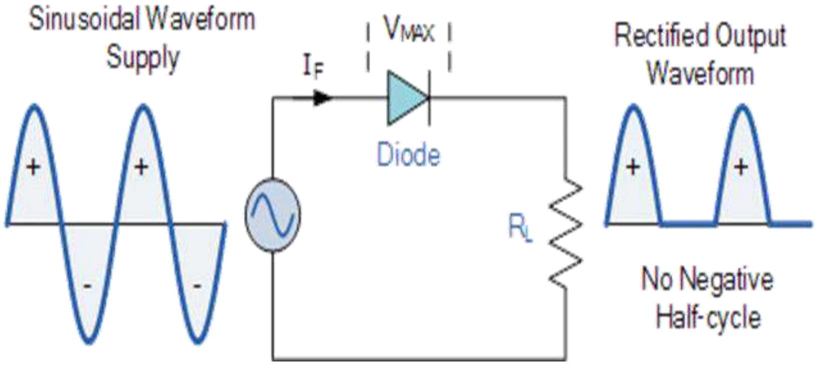
b) in the innermost orbit.

c) free.
d) in any orbit.

4) . For Silicon and Germanium the outermost orbits are respectively:
(A) n = 3 and n = 5
(B) n = 4 and n = 3
(C) n = 5 and n = 4
(D) n = 3 and n =

5) The maximum possible electrons in an orbit is:
(A)8 (2s + 6p electrons)
(B)8 (6s + 2p electrons)
(C)8 (4s + 4p electrons
(D)8 (1s + 7p electrons)

6) If an alternating voltage is applied across a diode in series with a load and a pulsating voltage will appear across the load only during the half cycles of the ac input during which the diode is forward biased. Such rectifier circuit is called a half-wave rectifier. The reverse saturation current of a diode is negligible and can be considered equal to zero for practical purposes.



(i)If input frequency of signal in half wave rectifier is 50 Hz then the output frequency will be
(A) 25 Hz
(B) 50 Hz
(C) 100 Hz
(D) Uncertain

(ii) If input frequency of signal in full wave rectifier is 50 Hz then the output frequency will be
(A) 25 Hz
(B) 50 Hz
(C) 100 Hz
(D) Uncertain

(iii) Rectifier converts- (A) AC to DC
(B) DC to AC
(C) AC to AC of different waveform
(D) All of these

(iv) Full wave rectifier can be used over half wave rectifier because Full wave rectifier is-
(A) More energy efficient
(B) More energy consuming
(C) More handy to use
(D)
(E) More cost effective to manufacture

7) Consider a thin p-type silicon (p-Si) semiconductor wafer. By adding precisely a small quantity of pentavalent impurity, part of the p-Si wafer can be converted into n-Si. There are several processes by which a semiconductor can be formed. The wafer now contains p-region and n-region and a metallurgical junction between p-, and n- region. Two important processes occur during the formation of a p-n junction: diffusion and drift. We know that in an n-type semiconductor, the concentration of electrons (number of electrons per unit volume) is more compared to the concentration of holes. Similarly, in a p-type semiconductor, the concentration of holes is more than the concentration of electrons. During the formation of p-n junction, and due to the concentration gradient across p-, and n- sides, holes diffuse from p- side to n-side (p → n) and electrons diffuse from n-side to p-side (n → p). This motion of chargecarries gives rise to diffusion current across the junction.

1) How can a p-type semiconductor be converted into n- type semiconductor?
a) adding pentavalent impurity
b) adding trivalent impurity
c) not possible
d) heavy doping

2) How can a p-type semiconductor be converted into n- type semiconductor?
a) adding pentavalent impurity
b) adding trivalent impurity
c) not possible
d) heavy doping

3. Which of the following is true about p type semiconductor?

a) concentration of electrons is less than that of holes.

b)concentration of electrons is more than that of holes.

c)concentration of electrons equal to that of holes.

d)None of these

4 . Which of the following is the reason about diffusion current?

a) diffusion of holes from p to n

b)diffusion of electronss from n to p

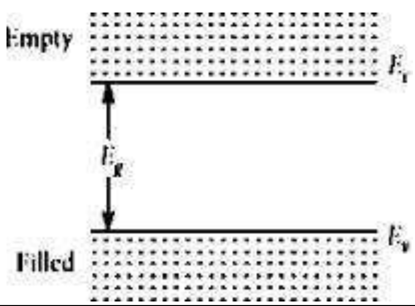
c) both (a) and (b)

d) None of these

SELF ASSESSMENT-SEMICONDUCTOR

Note: Q. No. 1-4 is of 01 mark each, Q. 5-6 is of 02 marks each, Q.No.7 is of 03 marks, Q. No. 8 is a case study based and is of 04 marks, Q. No. 11 is of 5 marks.

No	Question	Marks
1	The substance which is doped in an intrinsic semiconductor to make p-type semiconductor is (a) phosphorus (b) antimony (c) aluminium (d) arsenic	1
2	**Assertion (A):** The energy gap between the valence band and conduction band is greater insilicon than in germanium. **Reason (R):** Thermal energy produces fewer minority carriers in silicon than in germanium. i- Both assertion and reason are correct and the reason is the correct explanation of assertion.j- Both assertion and reason are correct and reason is not a correct explanation of assertion. k- Assertion is correct but the reason is incorrect l- Assertion is incorrect but the reason is correct.	1
3	The conductivity of a semiconductor increases with increase in temperature because (a) number density of free current carriers increases. (b) relaxation time increases. (c) both number density of carriers and relaxation time increase. (d) number density of current carriers increases; relaxation time decreases but effect of decrease inrelaxation time is much less than increase in number density.	1
4	Electrical conduction in a semiconductor occurs due to (a) electrons only (b) holes only (c) electrons and holes both (d) neither electrons nor holes	1
5	Write two characteristic features to distinguish between n-type and p-type semiconductors.	2
6	Draw the energy band diagram when intrinsic semiconductor (Ge) is doped with impurity atoms of	2

	Antimony (Sb). Name the extrinsic semiconductor so obtained and majority charge carriers in it.	
7	(i) Distinguish between n-type and p-type semiconductor on the basis of energy band diagram. (ii) Compare their conductivities at absolute zero temperature and at room temperature.	3
	Case study-based questions (questions no 8- 10) ENERGY BAND GAP From Bohr's atomic model, we know that the electrons have welldefined energy levels in an isolated atom. But due to interatomic interactions in a crystal, the electrons of the outer shells are forced to have energies different from those in isolated atoms. Each energy level splits into a number of energy levels forming acontinuous band. 'The gap between top of valence band and bottom of the conduction band in which no allowed energy levels for electronscan exist is called energy gap. 8. What is the energy gap in an insulator? 1 9. What is Fermi energy level? 1 10. Based on the band theory of conductors, insulators and semiconductors,which has thesmallest forbidden energy gap? 2 OR 10. Name the solids having highest energy level partially filled with electrons. 2 	4

11	Draw the circuit arrangement for studying the V–I characteristics of a p-n junction dioc (i) in forward bias and (ii) in reverse bias. Draw the typical V–I characteristics of a silicon diode. Describe briefly the following ter (i) “minority carrier injection” in forward bias (ii) “breakdown voltage” in reverse bias.

****

SAMPLE QUESTION PAPER
CLASS XII PHYSICS (042) 2024-25
BluePrint

1. Number of Sections 5, Section A, Section B, Section C, Section D and Section E.
2. **Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based question of 1 mark each.
3. **Section B** contains five questions of two marks each.
4. **Section C** contains seven questions of three marks each.
5. **Section D** contains two case study based questions of four marks each.
6. **Section E** contains three long answer questions of five marks each.
7. Internal choice is provided in one question in Section B, one question in Section

S. No.	UNIT	MCQ (1Mark)	Assertion reasoning (1 Mark)	SA 1 (2 Marks)	SA 2 (3 Marks)	Case Based Question (4 Marks)	Long Ans (5 Marks)	Total
1.	UNIT – I Electrostatics UNIT – II Current Electricity	2(2)	2(2)		1(3)	1(4)	1(5)	7(16)
2.	UNIT – III Magnetic effects of current and Magnetism UNIT – IV Electromagnetic Induction and Alternating currents	2(2)	1(1)	3(6)	1(3)		1(5)	8(17)
3.	UNIT – V Electromagneti c Waves UNIT – VI Optics	4(4)		1(2)	1(3)	1(4)	1(5)	8(18)
4.	UNIT – VII Dual Nature of Radiation and Matter UNIT – VII Atoms and Nuclei	3(3)	1(1)	1(2)	2(6)			7(12)
5.	UNIT – IX Electronic devices	1(1)			2(6)			3(7)
	TOTAL	12(12)	4(4)	5(10)	7(21)	2(8)	3(15)	33(70)

C, one question in each CBQ in Section D and all three questions in Section E.

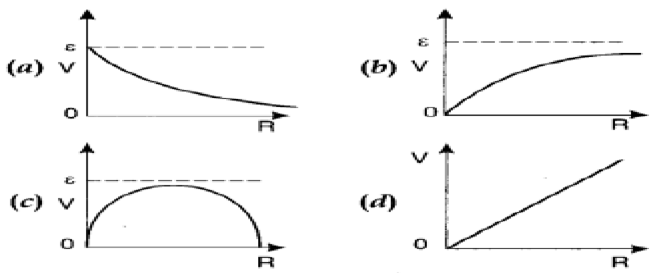
SAMPLE QUESTION PAPER 2024-25
PHYSICS (042)-XII

Maximum Marks: 70 **Time Allowed**: 3 hours.

General Instructions:

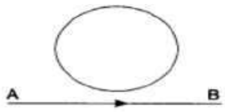
1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. All the sections are compulsory.
4. **Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based question of 1 mark each, **Section B** contains five questions of two marks each, **Section C c**ontains seven questions of three marks each, **Section D** contains two case study based questions of four marks each and **Section E** contains three long answer questions of five marks each.
5. There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.
6. Use of calculators is not allowed.
7. You may use the following values of physical constants where ever necessary

   i. $c = 3 \times 10^8$ m/s
   ii. $m_e = 9.1 \times 10^{-31}$ kg
   iii. $e = 1.6 \times 10^{-19}$ C
   iv. $\mu 0 = 4\pi \times 10^{-7}$ TmA^{-1}
   v. $h = 6.63 \times 10^{-34}$ Js
   vi. $\varepsilon 0 = 8.854 \times 10^{-12}$ $C^2N^{-1}m^{-2}$
   vii. Avogadro's number = 6.023 X 10^{23} per gram mole

SECTION- A		
1.	The angle between area of equipotential surface and electric field is- (a) 0^0 (b) 90^0 (c) Between 0^0 and 90^0 (d) Between 90^0 and 180^0	1M
2.	A cell having an emf E and internal resistance r is connected across a variable external resistance R. As the resistance R is increased, the plot of potential difference V across R is given by 	1M
3.	Which of the following does not resemble the Gauss' law in magnetism?	1M

(a) Magnetic poles exist in pair of unlike poles.
(b) Magnetic flux through a closed loop is zero.
(c) The number of magnetic field lines entering a closed surface is equals to that leaving the surface.
(d) Single pole exists in nature

4. In the given figure current from A to B in the straight wire is decreasing. The direction of induced current in the loop A is: — 1M



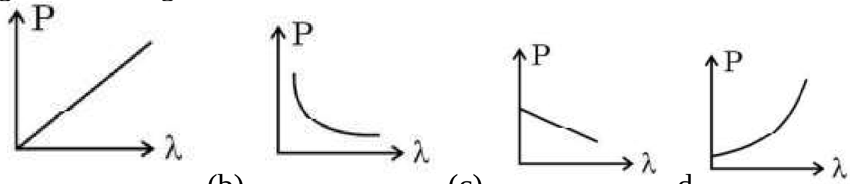
(a) Clockwise (b) anticlockwise (c) changing (d) nothing can be said

5. EM waves can be produced by a charge: — 1M
(a) An accelerated charged particles (b) A charged particles moving with constant speed
(c) at rest. (d) either at rest or moving with constant velocity.

6. Which of the following is transported by electromagnetic waves: — 1M
(a) charge and momentum (b) frequency and wavelength
(c) energy and momentum (d) wavelength and energy

7. A small object lies at the bottom of a vessel filled with water (refractive index 4/3) up to a height H. When viewed from a point above the surface of water, the object appears raised by n percent of H. The value of n is : — 1M
(a) 15 (b) 20 (c) 25 (d) 33

8. Which of the following figures represents the variation of a particle's momentum with the de Broglie wavelength associated with it ? — 1M



(a) (b) (c) d

9. Two nuclei have their mass numbers in the ratio of 1 : 27. What is the ratio of their nuclear densities? — 1M
(a) 1 : 27 (b) 1 : 1 (c) 1 : 9 (d) 1 : 3

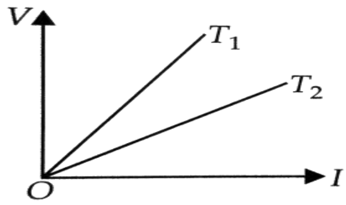
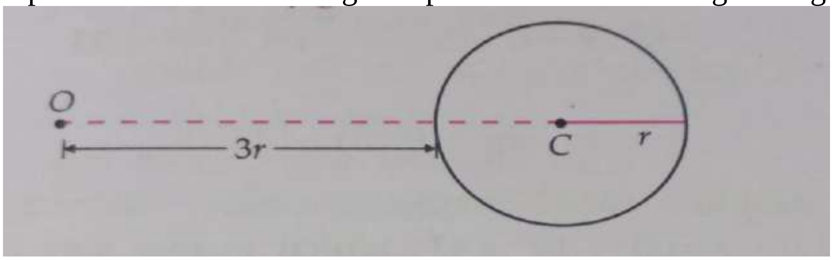
10. In the depletion region of unbiased p-n junction, — 1M
(a) it is vacant of charge carriers (b) has only electrons (c) has only holes (d) p-n junction has a weak electric field.

11. In a Young's double-slit experiment, the slit separation is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed to — 1M
(a) 2D (b) 4D (c) D/2 (d) D/4

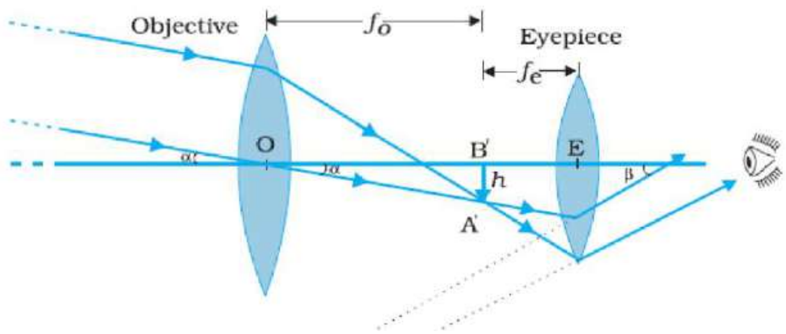
12. Which of the following transitions in hydrogen atom emits the photon of the highest frequency? — 1M
(a) n = 1 to n = 2 (b) n = 6 to n = 2 (c) n = 2 to n = 6 (d) n = 2 to n = 1

For Questions 13 to 16, two statements are given –one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.
(a)If both Assertion and Reason are true and Reason is correct explanation of Assertion.
(b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
(c) If Assertion is true but Reason is false.
(d) If both Assertion and Reason are false.

13. **Assertion** (A): For the radiation of a frequency greater than the threshold frequency, — 1M

	photoelectric current is proportional to the intensity of the radiation. **Reason (R)** : Greater the number of energy quanta available, greater is the number of electrons absorbing the energy quanta and greater is number of electrons coming out of the metal.	
14.	**Assertion (A)** : A planar loop of irregular shape carrying current is subjected to a magnetic field acting perpendicular to the plane of the loop. If the wire is flexible, the loop takes a circular shape. **Reason (R)** : The force acting on each point of a current carrying loop, in a magnetic field perpendicular to its plane, is radially outward.	1M
15.	**Assertion (A):** An electron has a higher potential energy when it is at a location associated with a negative value of potential and has a lower potential energy when at a location associated with a positive potential. **Reason (R):** Electrons move from a region of higher potential to a region of lower potential.	1M
16.	**Assertion (A):** In the graph shown below, temperature T1 > T2 **Reason (R):** The slope of V-I graph gives resistance of a conductor at a given temperature. 	1M
	SECTION- B	
17.	The wavelength of second line of the Balmer series in Hydrogen atom is 4861A^0. Calculate the wavelength of first line.	2M
18.	A point object is placed at O in front of a glass sphere as shown in the given figure:  Show the formation of image by the sphere.	2M
19.	When an alternating voltage of 220V is applied across an Inductor, a current of 0.25A flows which lags behind the applied voltage in phase by $\pi/2$ radian. If the same voltage is applied across resister, the same current flows but now it is in phase with the applied voltage Calculate the current flowing in the circuit when the same voltage is applied across the series combination of Inductor and Resistor	2M
20.	(a) Define current sensitivity of a galvanometer. Write its expression. (b) A galvanometer has resistance G and shows full scale deflection for current I_g. (i) How can it be converted into an ammeter to measure current up to I_0 ($I_0 > I_g$)? **OR** A long wire is bent into a circular coil of one turn and then into a circular coil of smaller radius having 'n' turns if the same current passes in both the coils find the ratio of magnetic fields produced at the centre in the two coils.	2M
21.	A long, rectangular, conducting loop of width l, mass m and resistance R placed partly in a	2M

	perpendicular magnetic field B. With what velocity should it be pushed downwards so that it may continue to fall without any acceleration?	
	SECTION- D	
22.	Two cells of emfs 1.5 V and 2.0 V having internal resistance 0.2 Ω and 0.3 Ω respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell.	3M
23.	Two long straight parallel conductors carry steady currents I_1 and I_2 separated by a distance d. If the currents are flowing in the same direction, which type of force does it produce Obtain the expression for this force. Hence define one ampere.	3M
24.	The total energy of electron in first excited state of hydrogen atom is about –3.4 eV. (a)What is the kinetic energy of the electron in this state? (b) What is the potential energy of the electron in this state? (c)Which of the answers above would change if the choice of the zero of potential energy is changed? **OR** The ground state energy of hydrogen atom is -13.6 eV. (i) What is the kinetic energy of an electron in the 2nd excited state? (ii) What is the potential energy of an electron in 3 rd excited state? (iii) If an electron jumps to the ground state from 3 rd excited state, calculate the wavelength of photon emitted.	3M
25.	A ray of light of frequency 5 x 10^{14} Hz is passed through a liquid. The wavelength of liquid is found to be 450 nm. Calculate (i) Wavelength of light in vacuum. (ii) Refractive index of liquid. (iii) Velocity of light in liquid. (C = 3 x 10^8)	3M
26.	Draw a graph showing the variation of stopping potential with frequency of the incident radiations. What does the slope of the line with the frequency axis indicate? Hence define threshold frequency?	3M
27.	Explain briefly, with the help of a circuit diagram, how a *p-n* junction diode works as a full wave rectifier. Explain the working. Draw the input and output waveforms.	3M
28.	Draw the energy band diagram (at T > 0 K) for n-type and p-type semiconductors. Using diagram, explain why in n-type semiconductor the conduction band has most electrons from the donor.	3M
	SECTION- D	
29.	Dielectric with polar molecules also develops a net dipole moment in an external field, but for a different reason. In the absence of any external field, the different permanent dipoles are oriented randomly due to thermal agitation; so, the total dipole moment is zero. When an external field is applied, the individual dipole moments tend to align with the field. When summed overall the molecules, there is then a net dipole moment in the direction of the external field, i.e., the dielectric is polarized. The extent of polarization depends on the relative strength of two factors: the dipole potential energy in the external field tending to align the dipoles mutually opposite with the field and thermal energy tending to disrupt the alignment. There may be, in addition, the 'induced dipole moment' effect as for non-polar molecules, but generally the alignment effect is more important for polar molecules. Thus, in either case,	4M

	whether polar or non-polar, a dielectric develops a net dipole moment in the presence of an external field. The dipole moment per unit volume is called polarization. (i) The best definition of polarization is (a) Orientation of dipoles in random direction (b) Electric dipole moment per unit volume (c) Orientation of dipole moments (d) Change in polarity of every dipole (ii) Calculate the polarization vector of the material which has 100 dipoles per unit volume in a volume of 2 units. (a) 200 (b) 50 (c) 0.02 (d) 100 (iii) The total polarization of a material is the (a) Product of all types of polarization (b) Sum of all types of polarization (c)Orientation directions of the dipoles (d)Total dipole moments in the (iv) Dipoles are created when dielectric is placed in ___________ (a) Magnetic Field (b) Electric field (c) Vacuum (d) Inert Environment **OR** Identify which type of polarization depends on temperature. (a)Electronic (b) Ionic (c) orientational (d) Interfacial	
30.	The telescope is used to provide angular magnification of distant objects. It also has an objective and an eyepiece. But here, the objective has a large focal length and a much larger aperture than the eyepiece. Light from a distant object enters the objective and a real image is formed in the tube at its second focal point. The eyepiece magnifies this image producing a final inverted image. The magnifying power *m* is the ratio of the angle β subtended at the eye by the final image to the angle α which the object subtends at the lens or the eye.  (i)An astronomical telescope uses two lenses of powers 10 D and 1 D. Its magnifying power in normal adjustment is (a) 20 (b)10 (c)0.05 (d)0.1 (ii)An astronomical telescope uses an objective lens of focal length of objective lens and eye piece are 150 m and 6 cm. In case when final image is formed at least distance of distinct vision, the magnifying power is (a)20 (b)30 (c)60 (d)15 (iii)You are given following three lenses. Two lenses which you will use as an eyepiece and as	4M

an objective to construct an astronomical telescope.

(a)L_1,L_3
(b) L_2,L_3
(c)L_3,L_2
(d)L_3,L_1

Lenses	Power (P)	Aperture (A)
L_1	3 D	8 cm
L_2	6 D	1 cm
L_3	10 D	1 cm

(iv) Limitations of a refracting telescope are (a) Chromatic aberration (b) spherical aberration

(c) Heavy (d) all of these

OR

In normal adjustment of an astronomical telescope, the final image is formed at

(a) near point (b) infinity (c) at 25cm (d) less than 25cm

SECTION-E

31. (a) Derive expression for refractive index of a Prism **5M**

(b) One face of prism of refractive angle 30^0 and refractive index 1.414 is silvered. At what angle must a ray of light fall on the un silvered face so that after refraction in to the prism and reflection at the silvered surface it retraces its path?

OR

(a) Derive expression for lens maker's formula.

(b) The focal length of plano - convex lens is 20 cm in air. Refractive index of glass is 1.5, calculate the radius of curvature of the lens and focal length of the lens when it is immersed in a medium of refractive index 1.6.

32. (a) Derive an expression for the impedance of an a.c. circuit consisting of an inductor and also draw its phasor diagram and graph of v and I versus wt. **5M**

(b) A resistor of 200 Ω and a capacitor of 15.0 µF are connected in series to a 220 V, 50 Hz ac source. (a) Calculate the current in the circuit; (b) Calculate the voltage (rms) across the resistor and the capacitor. Is the algebraic sum of these voltages more than the source voltage? If yes, resolve the paradox

OR

(a) Write any three differences between paramagnetic materials, diamagnetic materials and ferromagnetic materials, by giving one examples each.

(b) Find the relation between relative permeability and magnetic susceptibility.

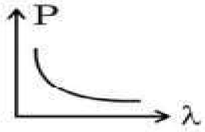
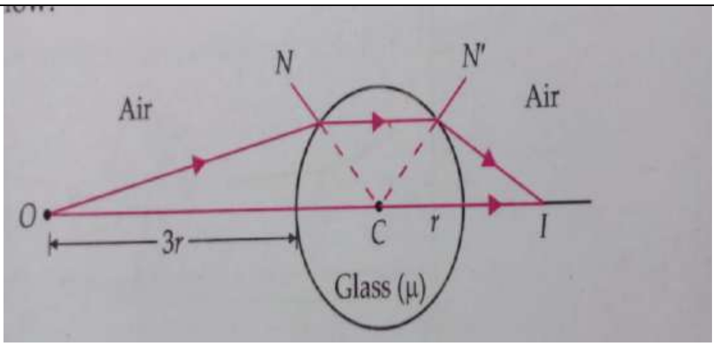
33. (a) Sate Gauss Theorem and Using Gauss's law derive an expression for the electric field intensity at any point near a uniformly charged thin wire of charge/length λ C/m. **5M**

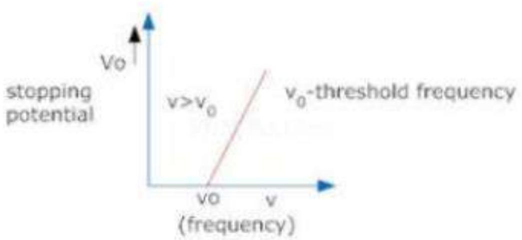
(b) A wire AB of length L has linear charge density λ= k x, where x is measured from the end A of the wire. This wire is enclosed by a Gaussian hollow surface. Find the expression for the electric flux through this surface.

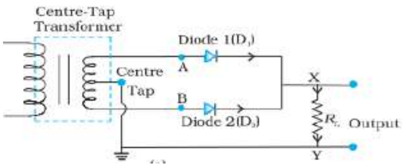
	OR (a) Find potential energy of an electric dipole place in uniform electric field. (b) Calculate the amount of work done in rotating a dipole, of dipole moment 3 X10^{-8} C-m, from its position of stable equilibrium to the position of unstable equilibrium, in a uniform electric field of intensity 10^4 N/C.	

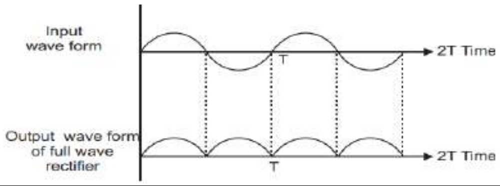
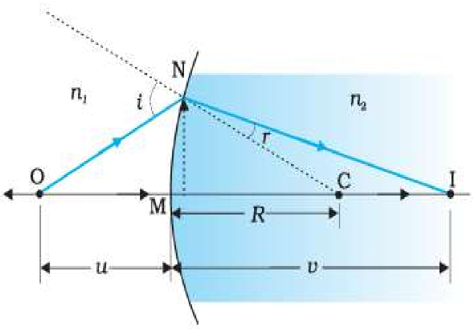
MARKING SCHEME 2024-25
PHYSICS (042)-XII

Answers

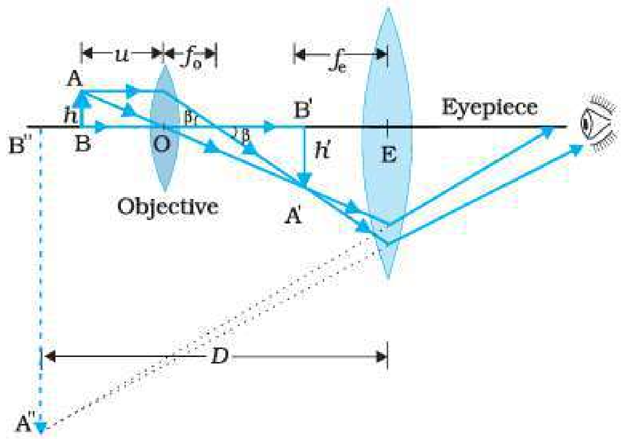
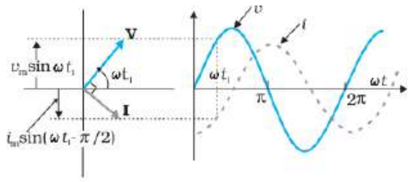
SECTION (A)		
1.	(b) 90^0	1
2.	(b)	1
3.	(d) Single pole exists in nature	1
4.	(b) Anticlockwise	1
5.	(a) An accelerated charged particles	1
6.	(b) $\lambda_m > \lambda v > \lambda x$	1
7.	(c) 25	1
8.	(b) 	1
9.	(b) 1 : 1	1
10.	(a) it is vacant of charge carriers	1
11.	(a) 2D	1
12.	(d) n = 2 to n = 1	1
13.	(a) both Assertion and Reason are true and Reason is correct explanation of Assertion	1
14.	(a) both Assertion and Reason are true and Reason is correct explanation of Assertion	1
15.	(c) Assertion is true but Reason is false	1
16.	(a) both Assertion and Reason are true and Reason is correct explanation of Assertion	1
SECTION (B)		
17.	Wavelength is 6562 A^0.	2
18.		2
19.	We are given that $0.25=220/X_L$, $X_L = 880\Omega$, Also $0.25=220/R$, $R = 880\Omega$ For the series combination of Inductor and Resistor, Equivalent impedance $Z = 880\sqrt{2}\ \Omega$, I= 0.177 A	1+1

20.	a) Deflection per unit current $I_s = \theta / I = BNA / K$ b) (i) By connecting a low resistance (Rs) in parallel to galvanometer such that $(I_0 - I_g)\, R_s = I_g G$ OR $B = \mu_o NI / 2r$, $l = 2\pi r_1$, $r_1 = l/2\pi$, $B_1 = \mu_o \pi I / l$ similarly $B_2 = \mu_o \pi I n^2 / l$, $B_1 : B_2 = 1:n^2$	½ ½ ½ ½ 1 1
21.	Let loop falls with uniform velocity v, then emf induced = Blv I = E/R = Blv/R Magnetic force in upper arm = BIl = vB^2l^2/R, acting upwards. As loop falls with uniform velocity F = mg or $vB^2l^2/R = mg$, or $v = mgR/B^2l^2$.	½ ½ ½ ½
SECTION (C)		
22.	$$E = \frac{E_1 r1 + E_2\ r2}{r1 + r2}$$ E=1.7v R =0.12 Ohm	1.5+1.5
23.	Diagram Derivation	1 2
24.	formula K=-E , U = -2K (a) K = 3.4 eV & (b) U= -6.8 eV (c) The kinetic energy of the electron will not change. The value of potential energy and consequently, the value of total energy of the electron will change. OR $E_3 = E_1/3^2$ =−13.6/9 =−1.51 eV $E_4 = E_1/4^2$ =−13.6/16 = −0.85 eV (i) KE of an electron in 2nd excited state = $-E_3$ = 1.51 eV (ii) PE of an electron in 3rd excited state = $2E_4$ = − 1.70 eV (iii) $E_4 - E_1 = hc/\lambda$ so $\lambda = hc/ E_4 - E_1$ =970 A	1 1 1 1 1 1
25.	(i) Velocity in liquid = 2.25 x 108 m/s. (ii) Refractive index = 1.33. (iii)Wavelength in vacuum = 600nm.	1 1 1
26.	Slope of graph=$\frac{\Delta\vartheta_0}{\Delta\vartheta}$ Einstein Photoelectric equation $eV_0 = h\,\nu - \varphi_0$ differentiate $\Delta V_0/\Delta\nu = h/e$ 	2,1

<table>
<tr><td></td><td>Threshold frequency: - The minimum value of frequency of the incidence radiation below which photoelectric emission is not possible is called threshold frequency</td><td></td></tr>
<tr><td>27.</td><td>Circuit Diagram


Working of rectifier

</td><td>1
1
1</td></tr>
<tr><td>28.</td><td>Each diagram.
When pure semiconductor is doped with donor impurities additional energy level called donor energy level is formed close to conduction band. Electrons from donor level easily jump to conduction band.</td><td>1+1
1</td></tr>
<tr><td colspan="3">SECTION (D)</td></tr>
<tr><td>29.</td><td>(i) (b) (ii) (a) (iii) (b) (iv) (b) OR (b)</td><td></td></tr>
<tr><td>30.</td><td>(i) (b)10 (ii) (b)30 (iii) (d)L_3,L_1 (iv) (d) all of these
OR (b) infinity</td><td></td></tr>
<tr><td colspan="3">SECTION (E)</td></tr>
<tr><td>31.</td><td>Relation between u, v, n1 and n2 for a spherical surface:


$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$
Lens Maker's Formula
$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$</td><td>3
2</td></tr>
</table>

	OR **Compound Microscope:**  **Magnifying power of a microscope** Magnification, M $$\text{Magnification, } M = -\frac{v_O}{u_O}\left(1+\frac{D}{f_e}\right)$$ For greater magnification of a compound microscope, *fe* should be small. As *f*0< *fe* , so *f*q is small. Hence, for greater magnification both *f*0 and *fe* should be small.	2 2 1
32.	(a) Derivation And Phasor diagram  (b) $Z = \sqrt{R^2 + X_C^2}$ $Z = \sqrt{R^2 + (2\pi\vartheta C)^{-2}}$ =291.5Ω Thus I=V/Z=220V/291.5Ω= 0.755A (b) Since the current is the same throughout the circuit, we have V_R=IR =0.755/200 =151 V V_C= IX_C= (0.755A)(212.3) =151 V The algebraic sum of the two voltages, V_R and V_C is 311.3 V which is more than the source voltage of 220 V. How to resolve this paradox? As you have learnt in the text, the two voltages are not in the same phase. Therefore, they cannot be added like ordinary numbers. The two voltages are out of phase by ninety degrees. Therefore, the total of these voltages must be obtained using the Pythagorean theorem: $V_{R+C}=\sqrt{V_R^2 + V_C^2}$ =220V	1 +2 2 3

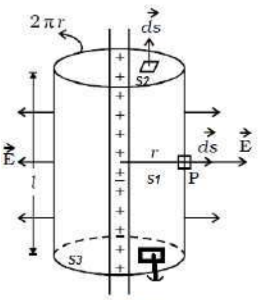
Thus, if the phase difference between two voltages is properly taken into account, the total voltage across the resistor and the capacitor is equal to the voltage of the source. — 2

OR(a) Any three differences

S. No.	Property	Paramagnetic materials	Diamagnetic materials	Ferromagnetic materials
1.	Effects of magnet	They are feebly attracted by magnets	They are feebly repelled by magnets	They are strongly attracted by magnets
2.	In external magnetic field	They acquire feeble magnetization in the direction of the magnetizing field.	They acquire feeble magnetization in the opposite direction of the magnetizing field.	They acquire strong magnetization in the direction of the magnetizing field.
3.	In uniform magnetic field	A freely suspended paramagnetic rod aligns itself parallel to the magnetic field.	A freely suspended diamagnetic rod aligns itself perpendicular to the magnetic field.	A freely suspended ferromagnetic rod aligns itself parallel to the magnetic field.
4.	In non - uniform magnetic field	They tend to move slowly from weaker parts to stronger parts of the field.	They tend to move slowly from stronger parts to weaker parts of the field	They tend to move quickly from weaker parts to stronger parts of the field
5.	Effect of temperature	Susceptibility varies inversely as temperature. $\chi_m \propto \frac{1}{T}$	Susceptibility is independent of temperature.	Susceptibility decreases with temperature in a complex manner. $\chi_m \propto \frac{1}{T-T_c}$, where $T > T_c$.

(b) Relation $\mu_r = 1 + \chi$

33. (a) The total electric flux through a closed surface is equal $1/\varepsilon_0$ the magnitude of charge enclosed $\varphi = \frac{q}{\varepsilon_o}$ — 1, 1



Infinitely long straight charged wire

By symmetry, the magnitude of the electric field will be the same at all points on the curved surface S1 of the cylinder and directed radially — 1, 2

outward. $\vec{E}$ and $\vec{ds}$ are along the same direction.

. $\vec{E}$ and $\vec{ds}$ are right angles to each other, through the plane caps S2 and S3 — 3

Total flux through the Gaussian surface,

$\varphi = \oint \vec{E} \cdot \vec{ds} = \oint_{S1} E ds \cos 0 + \oint_{S2} E ds \cos 90 + \oint_{S3} E ds \cos 90$ — 2

$= \oint_{S1} E ds + 0 + 0$

$= = E(2\pi r l)$ (∵The surface area of the curved part is $2\pi r l$)

The net charge enclosed by Gaussian surface is, $q = \lambda l$

∴By Gauss's law, $\varphi = \frac{q}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$

(b) $E\,(2\pi r l) = \frac{\lambda l}{\varepsilon_o}$ or $E = \frac{\lambda}{2\pi \varepsilon_o r}$

$dq = \lambda dx = kx dx$

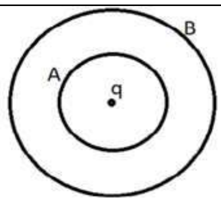
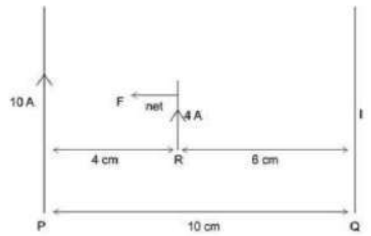
$$Q = \int_0^l kx dx = \frac{kl^2}{2}$$

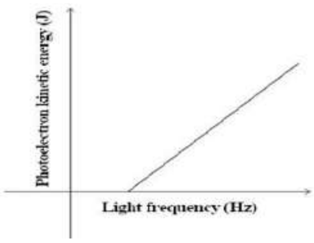
$$\phi = \frac{Q}{\xi_0} = \frac{kl^2}{2\xi_0}$$

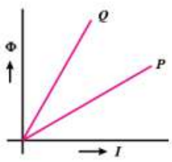
OR

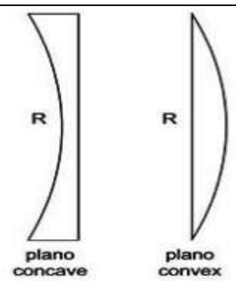
	(a)Diagram Derivation (b) P = 3 X10^{-8} C-m; E =10^4 N/C At stable equilibrium (θ_1)= 0° At unstable equilibrium (θ_2) =180° Work done in rotating dipole is given by: W = PE (cos θ_1 - cos θ_2) =6X10^{-8}J	

	KENDRIYA VIDYALAYA SANGTHAN ,BENGALURU REGION **PRACTICE QUESTION PAPER -01** **2024-2025**	
CLASS **SUBJECT**	**XII** **Maximum Marks** **PHYSICS** **Time**	**70** **3 hours**
	General instructions: 1. There are 33 questions in all. All questions are compulsory. 2. This question paper has five sections: Section A,Section B, Section C,Section D, and Section E. 3. All the sections are compulsory. 4. Section A contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, Section D contains two case study based questions of four marks each and Section E contains three long answer questions of five marks each. 5. There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C,one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions. 6. Use of calculators is not allowed. 7. You may use the following values of physical constants where ever necessary (i) c = 3 x 10^8 m/s (ii) m_e = 9.1 x10^{-31} kg (iii) e = 1.6 x 10^{-19} C (iv) μ_0 = 4π x 10^{-7} Tm$\boldsymbol{A}^{-1}$ (v) h = 6.63 x10^{-34}Js (vi) ε_0 = 8.85 x$10^{-12}$$\boldsymbol{C^2N^{-1}m^{-2}}$ (vii) Avogadro's number = 6.023 x $\mathbf{10^{23}}$ per gram mole	
Q No	Questions	Marks
	Section A	
1	An electric dipole having a dipole moment of 4 × 10^{-9} C m is placed in a uniform electric field such that the dipole is in stable equilibrium. If the magnitude of the electric field is 3 × 10^3 N/C, what is the work done in rotating the dipole to a position of unstable equilibrium? (A) zero (B) 1.2 × 10^{-5} J (C) 2.4 × 10^{-5} J (D) - 1.2 × 10^{-5} J	1
2	If A and B are two equipotential surfaces around a positive point charge q, what will happen if we place another point charge +Q between A and B?	1

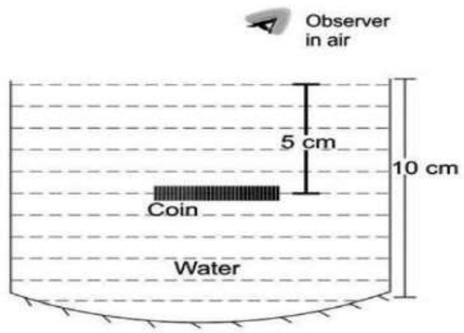
	 (A) It will remain stationary B) It will move from B to A C) It will move from A to B D)It will rotate in a circular path	
3	The electron drift speed is so small, and the electron's charge is also very small, but we still obtain large amounts of current in a conductor which is due to (A)Potential difference (B) length of conductor (C) electron number density (D)Area of cross section	1
4	Two long and straight current-carrying wires, P and Q are placed parallel to each other separated by a distance of 10 cm. A wire 'R' of length 8 cm and carrying a current of 4 A is placed between the two wires P and Q as shown below  If the wire R, experiences a net force towards wire P, then which of the following is definitely TRUE about the current 'I' in wire Q? A) Current I cannot be in the upward direction. B) Current I can have any magnitude greater than 0 A in the upward direction. C) Current I cannot have a magnitude of more than 15 A in the upward direction. D) Current I cannot have a magnitude of more than 10 A in the upward direction	1
5	Which of the following is the correct expression for Curie's law? A) $\chi = C\mu_0 T$ B) $\chi = C\mu_0/T$ C) $\mu 0 = C \chi T$ D) $\mu 0 = C \chi /T$	1
6	Which type of flux does transformer action need? A) Alternating electric flux B) Alternating magnetic flux C) Increasing magnetic flux D) Constant magnetic flux	1
7	Microwaves can't be used for long-distance transmission of signals. A) True B) False	1

	C) Can't say D) none	
8	A point object is placed at the centre of a glass sphere of radius 6cm and refractive index 1.5. The distance of virtual image from the surface of the sphere is (A) 2cm (B) 4 cm (C) 6 cm (D) 12 cm	1
9	Monochromatic yellow light is replaced with red light. The linear width of central bright fringe in diffraction at a single slit (A)Increases because $\lambda red<\lambda yellow$ (B)Decreases because $\lambda red>\lambda yellow$ (C)Increases because $\lambda red>\lambda yellow$ (D) Decreases because $\lambda red<\lambda yellow$	1
10	The graph below shows the variation of the maximum kinetic energy of the emitted photoelectron with the frequency of the incident radiation for a given metal.  Which of the following gives the work function of the metal? A) x-intercept B) y-intercept C) the slope of the graph D) the area under the graph	1
11	Binding energy per nucleon for a stable nucleus is (A) 8 eV (B)8 KeV (C)8 MeV (D)8 GeV	1
12	In an unbiased p-n junction, holes diffuse from the p-region to n-region because (A) free electrons in the n-region attract them. (B) they move across the junction by the potential difference. (C) hole concentration in p-region is more as compared to n-region. (D) All the above.	1
	For questions 13 to 16 , two statements are given- one labelled Assertion (A) and other labelled Reason (R). Select the correct answers to these questions from the options as given below- A) If both assertion and reason are true and reason is correct explanation of assertion.	

	B) If both assertion and reason are true and reason is not the correct explanation of assertion. C) If assertion is true but reason is false. D) If assertion is false but reason is true E) If both assertion and reason are false	
13	Assertion(A) : Electrons in the atom are held due to coulomb forces. Reason(R) : The atom is stable only because the centripetal force due to Coulomb's law is balanced by the centrifugal force.	1
14	Assertion(A): Two identical loops, one of copper and another of aluminium are rotated with the same speed in the same magnetic field. The emf induced in both the loop will be same. Reason(R): The magnitude of induced emf is directly proportional to the rate of change of magnetic flux linked with the circuit.	1
15	Assertion (A): If the focal length of two convex lenses is the same, the lens with the larger diameter will produce brighter images. Reason (R): Convex lenses with larger diameters are able to focus light better.	1
16	Assertion(A) : When two semiconductor of p and n type are brought in contact, they form p-n junction which act like a rectifier. Reason(R) : A rectifier is used to convent alternating current into direct current	1
	Section B	
17	Plot a graph showing the variation of coulomb force (F) versus 1/ r2 where r is the distance between the two charges of each pair of charge (i) (1 μC,2 μC) and (ii) (1 μC,−3 μC). Interpret the graphs obtained.	2
18	A long straight wire in the horizontal plane carries a current of 50 A in north to south direction. Give the magnitude of B at a point 2.5 m east of the wire.	2
19	(i)If the rate of change of current 2 A/s, induces an emf of 40 mV in the solenoid, what is the self-inductance of the solenoid? (ii) The given graph shows a plot of magnetic flux(φ) and the electric current(I) following through two inductors P and Q.  Which of the two inductors has smaller value of self-inductance.	2
20	Compare the focal lengths of the two lenses shown below if the radius of curvature of the curved surface is the same in both lenses	2

<table>
<tr><td></td><td>

OR



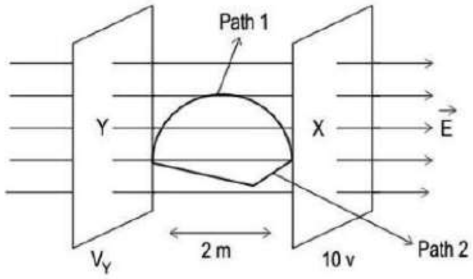
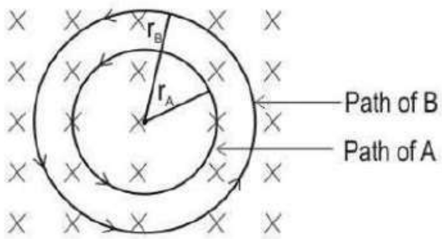
A plastic coin remains submerged in water at a depth of 5 cm from the top of the beaker. An observer sees the coin in the water and its image in the mirror. If the image formed by the curved mirror is seen by the observer at a distance of 15 cm from the surface of the water, what is the focal length of the curved surface? (Assume the silvered curved surface acts as a spherical mirror.)</td><td></td></tr>
<tr><td>21</td><td>Identify if the two nuclear reactions mentioned below are endothermic or exothermic. Show your calculations.

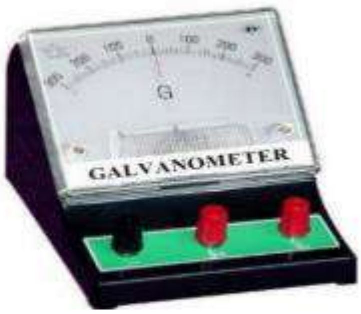
$^{1}_{1}p + ^{7}_{3}Li \rightarrow 2(^{4}_{2}He)$

$^{7}_{3}Li + ^{4}_{2}He \rightarrow ^{1}_{0}n + ^{10}_{5}B$

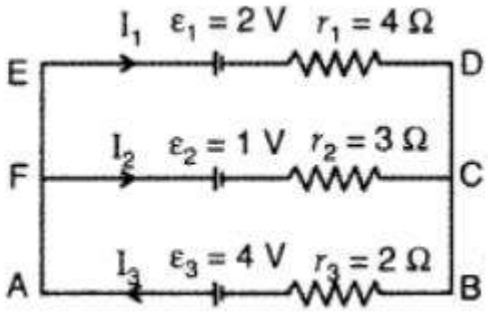
Use the information below to answer the question:

$^{1}_{1}p = 1.00728\ amu$
$^{7}_{3}Li = 7.0160\ amu$
$^{4}_{2}He = 4.0026\ amu$
$^{1}_{0}n = 1.0087\ amu$
$^{10}_{5}B = 10.01294\ amu$</td><td>2</td></tr>
<tr><td></td><td>Section C</td><td></td></tr>
<tr><td>22</td><td>X and Y are two equipotential surfaces separated by a distance of 2 m in a uniform electric field of 10 V/m. Surface X has a potential of 10 V</td><td>3</td></tr>
</table>

	(a) Calculate the potential of surface Y. (b) What is the work done in moving a +2 C charge from surface Y to surface X along path 1? How will this work change when the charge is moved along Path 2? Give a reason for your answer.  	
23	(i)Define magnetic susceptibility of a material. (ii) Name two elements, one having positive susceptibility and the other having negative susceptibility. (iii)What does negative susceptibility signify?	3
24	Two charges A and B, each having a velocity of v, traverse circular paths in a uniform magnetic field as shown below.  (a) Compare the charge-to-mass ratio of the two particles A and B. Show the necessary mathematical calculations. (b) Which of the two particles is likely to be a proton if the other is an alpha particle? Give reason. OR A circular ring of diameter 0.2 m is placed in a uniform magnetic field of 0.4 T. The ring is rotated about its diameter at a frequency of 60 Hz. (a)If the ring has 50 turns, then what is the maximum induced emf in the ring? (b) State one condition under which the induced emf in the circular ring will be zero?	3
25	(a) A radio wave and an infrasonic wave have the same wavelength when travelling through air. Are their frequencies the same or different? Give a reason for your answer.	3

	(b) An electromagnetic wave traveling east has a magnetic field that oscillates vertically and has a frequency of 60 kHz and an rms strength of 8×10^{-9} T. Determine the frequency and the rms strength of the electric field. What is the direction of the electric field?	
26	The distance between two point sources of light is 24 cm. Find out where would you place a converging lens of focal length 9 cm so that the images of both the sources are formed at the same point.	3
27	(i)Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom (ii)When an electron in an atom moves from the ground state to a higher energy level what happens to its kinetic and potential energies?	3
28	Draw the energy band diagram when intrinsic semiconductor (Ge^{32}) is doped with impurity atoms of Antimony (Sb^{51}). Name the extrinsic semiconductor so obtained and majority charge carriers in it. Also what will be the ratio n_e: n_h for the semiconductor so obtained where n_e is the number density of electrons and n_h is the number density of holes? OR Draw the energy band diagram when intrinsic semiconductor (Si^{14}) is doped with impurity atoms of Boron (B^5). Name the extrinsic semiconductor so obtained and majority charge carriers in it. Also what will be the ratio n_e:n_h for the semiconductor so obtained where n_e is the number density of electrons and n_h is the number density of holes?	3
	Section D (CASE STUDY)	
29	**Read the given paragraph and answer the following questions:** A galvanometer is used in an electric circuit to detect current and in some experiments to locate the null point. The galvanometer cannot be used as such to measure the value of current. A galvanometer is a very sensitive device. It gives full scale deflection even for a very small current of the order of few microamperes. On the passage of a large current the galvanometer may get damaged either due to the breaking of the pointer or the coil may burn due the production of the excessive heat. A galvanometer can be converted an ammeter by the use of a shunt resistance.  **(i)**How is a moving coil galvanometer converted into an ammeter of desired range? (a) Connecting a shunt resistance in series (b) Connecting a shunt resistance in parallel (c) Connecting large resistance in series	4

	(d) Connecting a large resistance in parallel **(ii)** A moving coil galvanometer of resistance G gives a full-scale deflection for a current Ig. It is converted into an ammeter of range 0-I ampere. What should be the value of shunt resistance to convert it into an ammeter of desired range? (a) $S = \frac{I_g}{I-I_g}G$ (b) $S = \frac{I-Ig}{I}G$ (c) $S = \frac{I}{Ig}G$ (d) $S = \frac{Ig}{I}G$ **(iii)** Which one will have the greatest resistance, a micro-ammeter, a milli-ammeter, or an ammeter? (a) Microammeter (b) Milliammeter (c) Ammeter (d) All will have the same resistance **(iv)** The sensitivity of a galvanometer is 60 div/ampere. When a shunt resistance is connected its current sensitivity decreases to 10 div/ampere. What will be the shunt resistance if the resistance of the galvanometer is 20 ohm? (a) 4 ohm (b) 5 ohm (c) 4.5 ohm (d) 5.5 ohm OR An ammeter reads up to 1 ampere. Its internal resistance is 0.81 ohm. To increase the range to 10A, the value of the required shunt is (a) 0.9 ohm (b) 0.09 ohm (c) 0.03 ohm (d) 0.3 ohm	
30	**Read the given paragraph and answer the following questions:** French physicist Louis Victor de Broglie in 1924 put forward the bold hypothesis that moving particles of matter should display wave-like properties under suitable conditions. He reasoned that nature was symmetrical and that the two basic physical entities – matter and energy, must have symmetrical character. If radiation shows dual aspects, so should matter. de Broglie proposed that the wave length λ associated with a particle of momentum p is given as λ=h/p=h/mv. From this equation λ is smaller for a heavier particle (large m) or more energetic particle (large v). de Broglie wavelength of an electron accelerated by a potential difference 'V' can be calculated by λ =12.27/√V Å. **(i)** Which of the following is not an electromagnetic wave? (a) Matter wave (b) X Rays (c) Radio wave	4

	(d) Ultraviolet **(ii)** The temperature at which average de-Broglie wavelength of helium atom becomes 0.5 nm is (a) 6.6 K (b) 7.1 K (c) 279.6 K (d) 280.1 K **(iii)** An electron, proton and alpha particle, all are accelerated with same potential difference V volt. The particle with minimum de Broglie wavelength will be (a) electron (b) proton (c) alpha particle (d) deuteron **(iv)**A photon of wavelength λ (less than threshold wavelength λ_0) is incident on a metal surface of work function W_0. The de-Broglie wavelength of the ejected electron of mass m is (a) $h\left[2m\left(\frac{hc}{\lambda}-W_0\right)\right]$ (b) $\frac{h}{2m\left(\frac{hc}{\lambda}-W_0\right)}$ (c) $\frac{h}{\sqrt{2m\left(\frac{hc}{\lambda}-W_0\right)}}$ (d) $\frac{1}{h\sqrt{2m\left(\frac{hc}{\lambda}-W_0\right)}}$ **OR** The velocity of a de-Broglie wave of wavelength λ = h/mv where m is the mass of the particle and v is the velocity of particle and c the speed of light in vacuum is … (a) (v+c) (b) (c-v) (c) v^2/c (d) c^2/v	
	Section E	
31	State Kirchhoff's rules. Use these rules to find the values of the current I_1, I_2 and I_3 in the circuit diagram shown. 	5
32	(a) A voltage $e = e_0 \sin \omega t$ applied to a series LCR circuit drives a current	5

	$i = i_0 \sin(\omega t + \phi)$ in the circuit. Deduce the expression for the average power dissipated in the circuit. (b) For circuits used for transporting electric power, a low power factor implies large power loss in transmission. Explain. (c) In a series LR circuit, $X_L = R$ and the power factor of the circuit is P_1. When a capacitor of capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2. Find P_1/P_2 **OR** (a) A series LCR circuit is connected to an ac source having voltage $e = e_0 \sin \omega t$. Derive the expression for the instantaneous current and its phase relationship to the applied voltage. Obtain the condition for resonance to occur. (b) In a series LCR circuit, impedance is the same at two frequencies f_1 and f_2. Show that the resonant frequency is $\sqrt{f_1 f_2}$	
33	**(a) State Huygens principle. Draw the geometrical construction of wavefront.** **(b) A slit of width 'a' is illuminated by light of wavelength $6000\ A^o$. For what value of 'a' will the :-** **(i) First maximum fall at an angle of diffraction of 30^o?** **(ii) First minimum fall at an angle of diffraction 30^o?**	5

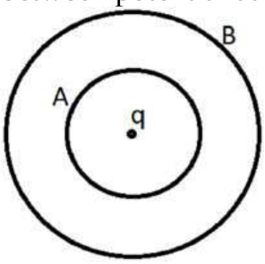
.....

KENDRIYA VIDYALAYA SANGTHAN **PRACTICE QUESTION PAPER -02** **[PHYSICS(042) THEORY]** **EXAMINATION – 2024-25**			
Subject:	**Physics**	**Class:**	**XII**
Time:	**3 Hours**	**Maximum Marks:**	**70 M**

General Instructions:

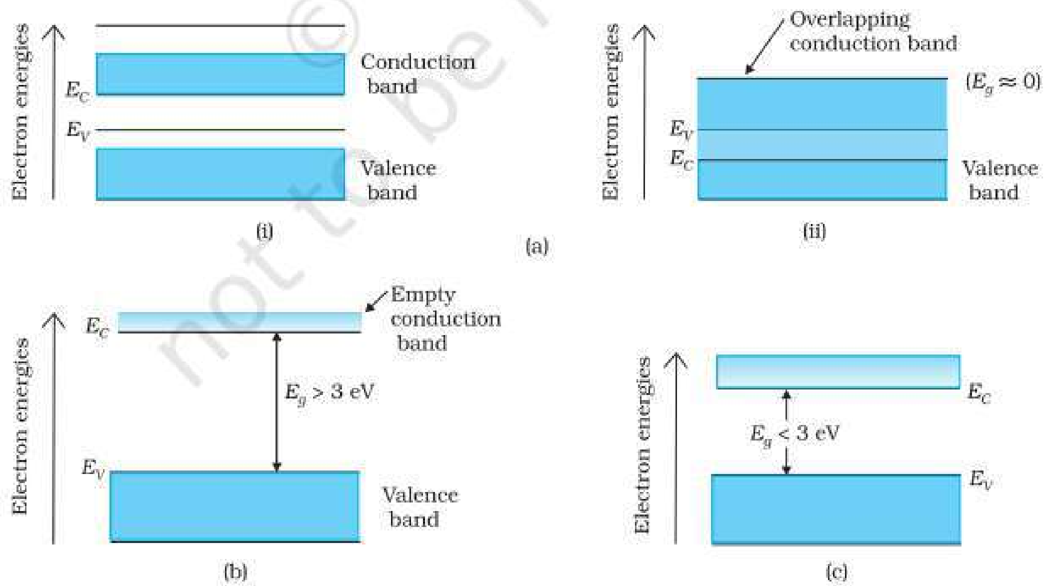
(1) There are 33 questions in all. All questions are compulsory
(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
(3) Section A contains sixteen questions, twelve MCQ and four Assertion and Reasoning based of one mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, section D contains two case study based questions of four marks each and Section E contains three long answer questions of five marks each.
(4) There is no overall choice. However, an internal choice has been provided in one question in section B, one question in section C, one question in each CBQ in section D and all three questions in section E. You have to attempt only one of the choices in such questions.
(5) Use of calculators is not allowed.
(6)You may use the following values of physical constants wherever necessary.
i. $c = 3 \times 10^8$ m/s
ii. $m_e = 9.1 \times 10^{-31}$ kg
iii. $e = 1.6 \times 10^{-19}$ C
iv. $\mu_0 = 4\pi \times 10^{-7}$ T m/A
v. $h = 6.63 \times 10^{-34}$ Js
vi. $\varepsilon_0 = 8.854 \times 10^{-12}\ C^2N^{-1}m^{-2}$
vii. Avogadro's number = 6.023×10^{23} per gram mole

SECTION- A

1.	If A and B are two equipotential surfaces around a positive point charge q, what is the relation between potential at A and B?  a) $V_A > V_B$ b) $V_A < V_B$ c) $V_A = V_B$ d) $V_A \neq V_B$	1
2.	Two conducting solid spheres of radii R and 2R are given equal charge Q. when they are connected by a thin conducting wire, the ratio of charges on then respectively a) $\frac{Q_1}{Q_2} = 1$ b) $\frac{Q_1}{Q_2} = 2$ c) $\frac{Q_1}{Q_2} = \frac{1}{2}$ d) $\frac{Q_1}{Q_2} = \frac{1}{4}$	1
3.	The stopping potential of wavelength of $4000A^0$ is 2V. If wavelength changed to $6000A^0$,The stopping potential will be a) 2V b) less than 2V c) 0 d) more than 2V	1
4.	The distance of closest approach can be decreases by . a) increasing Kinetic energy b) decreasing Kinetic energy c) distance of closest approach cannot be changed d) none	1
5.	At which angle the maximum force is experienced on electron moving in the uniform magnetic field a) 0^0 b) 90^0 c) 60^0 d) 30^0	1

6.	Which of the following is the correct expression for Curie's law? a) $\chi = C\mu_0 T$ b) $\chi = C\mu_0/T$ c) $\mu0 = C \chi T$ d) $\mu0 = C \chi /T$	1
7.	What are the resistances of ideal Ammeter and ideal Voltmeter. a) zero, infinity b) infinity , zero c) zero, zero d) infinity, infinity	1
8.	The Bohr Magneton is given by a) eh/2m b) eh/2πm c) eh/4m d) eh/4πm	1
9.	Which type of flux does transformer action need? a) Alternating electric flux b) Alternating magnetic flux c) Increasing magnetic flux d) Constant magnetic flux	1
10.	Microwaves can't be used for long-distance transmission of signals. a) True b) False c) Can't say d) none	1
11.	The formula for induced emf if magnetic field, length and velocity of conductor all are mutually perpendicular is a) $emf=B^2l$ b) emf=Bil c) emf=Blv d) $emf=B^2v$	1
12.	When a hydrogen atom is in its first excited level, what is the relation of radius and Bohr radius? a) Twice b) 4 times c) Same d) Half	1
	For questions 13 to 16 , two statements are given- one labelled Assesrtion (A) and other labelled Reason (R). Select the correct answers to these questions from the options as given below- a) If both assertion and reason are true and reason is correct explanation of assertion. b)) If both assertion and reason are true and reason is not the correct explanation of assertion. c) If assertion is true but reason is false. d) If both assertion and reason are false e) If assertion is false but reason is true .	
13.	**Assertion** : Two sources of equal intensity always emit equal number of photons in any time interval. **Reason** : Two sources of equal intensity may emit equal number of photons in any time interval.	1
14.	**Assertion** : When two semi conductor of p and n type are brought in contact, they form p-n junction which act like a rectifier. **Reason** : A rectifier is used to convent alternating current into direct current.	1
15.	**Assertion** : Electrons in the atom are held due to coulomb forces. **Reason** : The atom is stable only because the centripetal force due to Coulomb's law is balanced by the centrifugal force.	1
16.	**Assertion** : An empty test tube dipped into water in a beaker appears silver, when viewed from a suitable direction. **Reason** : Due to refraction of light, the substance in water appears silvery.	1
	SECTION B	
17.	Give two differences between a half-wave rectifier and a full-wave rectifier.	2
18.	Light of wavelength 3500 Å is incident on two metals A and B. Which metal will yield more photoelectrons if their work functions are 5 eV and 2 eV respectively?	2
19.	A ray of monochromatic light passes through an equilateral glass prism in such a way that the angle of incidence is equal to the angle of emergence and each of these angles is 3/4 times the angle of the prism. Determine the angle of deviation and the refractive index of the glass prism.?	2
20.	Establish the relation between conductivity of conductor and relaxation time.	2

21.	Using Huygens' principle, draw a diagram to show how a plane wave front incident at the interface of the two media gets refracted when it propagates from a rarer to a denser medium. Hence verify Snell's law of refraction. **OR** (a) State two conditions for sustained interference of light to take place. (b) How does the angular separation of interference fringes change, in Young's double slit experiment, if the distance between the slits is increased?Justify your answer.	2
	SECTION C	
22.	(a)Draw the plot of binding energy per nucleon as a function of mass number Write two important conclusions regarding the nature of nuclear force. (b)Use this graph to explain the release of energy in nuclear fission and nuclear fusion	3
23.	Derive an expression for the potential at a point along the axial line of a short electric dipole?	3
24.	Using Bohr's postulates of the atomic model, derive the expression for radius of nth electron orbit. Hence obtain the expression for Bohr's radius.	3
25.	**A battery of e.m.f 10 V and internal resistance 3 Ω is connected resistor. If the current in the circuit is 0.5 A, what is the resistance of the resistor? What is the terminal voltage of the battery when the circuit is closed?**	3
26.	A long straight wire in the horizontal plane carries a current of 50 A in north to south direction. Give the magnitude and direction of B at a point 2.5m east of the wire.	3
27	Identify the electromagnetic waves whose wavelengths lie in the range.(I). 10^{-11} m < < 10^{-14} m (ii). 10^{-4} m < < 10^{-6} m Write one use of each.	3
28	**How is the mutual inductance of a pair of coils affected when** **(1) Separation between the coils is increased.** **(2) The number of turns of each coil is increased.** **(3) A thin iron sheet is placed between two coils, other factors remaining the same.** **Explain answer in each case.**	3
	SECTION-D (CASE STUDY)	
29	**Read the following paragraph and answer the question follows:** Inside the crystal each electron has a unique position and no two electrons see exactly the same pattern of surrounding charges. Because of this, each electron will have a different energy level. These different energy levels with continuous energy variation form what are called energy bands. The energy band which includes the energy levels of the valence electrons is called the valence band. The energy band above the valence band is called the conduction band. On the basis of band gap materials are classified as insulator, conductors and semiconductors. The band diagram of different types of materials are given below :	4

	 i) In a semiconductor, the forbidden energy gap between the valence band and the conduction band is of the order is (a) 1 MeV (b) 0.1 Mev (c) 1 eV (d) 5 eV ii) The conduction band and valance band for a substance are overlapping each other, the substance is- (a) Insulator (b)Metal (c) Semiconductors (d)Non of these iii) In an insulator, the forbidden energy gap between the valence band and conduction band is approximately- (a) 1 MeV (b) 0.1 MeV (c) 1 eV (d) 5 eV iv) In semiconductors, at room temperature- (a) the conduction band is completely empty (b) the valence band is partially empty and the conduction band is partially filled (c) the valence band is completely filled and the conduction band is partially filled (d) the valence band is completely filled	
30	**Read the following paragraph and answer the questions that follow:** According to superposition principle, the resultant displacement produced due the number of waves at a particular point is the vector sum of displacement produced by the each vector at that point. The point at which two waves are in phase or if trough of one wave coincides with the trough of other or crest of one wave coincides with the crest of other then the resultant intensity produced at that point will be larger and amplitude also maximum. Such points are the points where constructive interference takes place. While there are some points where two light waves are not in phase with each other and crest of one wave coincides with the trough of other and vice versa due to which resultant intensity at that point is minimum and amplitude also get decreased. Such points are the points where destructive interference takes place. For sustained interference two sources must be coherent. For constructive interference, the path difference is equal to integral multiple of wavelengths and resultant intensity will be maximum at that points. While for destructive interference, the path difference is (n + 1/2) multiple of wavelengths and where resultant intensity is zero. i) For coherent sources of light the phase difference must be- a) 180^0 b) Zero c) Either zero or constant d) 90°	4

ii) If the phase difference is 0, +2π, -4π then the interference should be -
a) Constructive interference b) Destructive interference
c) Both a and b d) None of these

iii) For destructive interference -
a) Path difference is (n +1/2) times wavelength
b) Phase difference is π, -3π, +5π
c) Path difference is integral multiple of wavelengths
d) Both a and b

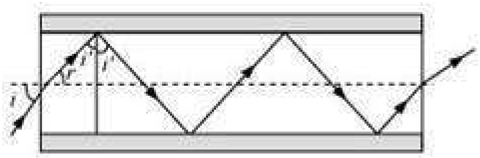
iv) When two waves of same amplitude add constructively, the intensity becomes –
a) Double b) Half c) Four Times d) One-Fourth

OR

If instead of monochromatic light white light is used for interference of light, what would be the change in the observation?
a) The pattern will not be visible
b) The Thickness of fringes dicreased
c) Coloured fringes will be observed with a white bright fringe at the centre
d) The bright and dark fringes will change positions

SECTION -E

31 (a) **Figure shows a cross-section of a 'light pipe' made of a glass fibre of refractive index 1.68.** — 5



The outer covering of the pipe is made of a material of refractive index 1.44. What is the range of the angles of the incident rays with the axis of the pipe for which total reflections inside the pipe take place, as shown in the figure.

(b) What is the answer if there is no outer covering of the pipe?

OR

(a) State Huygens principle. Draw wave fronts through (i) prism (ii) lens.

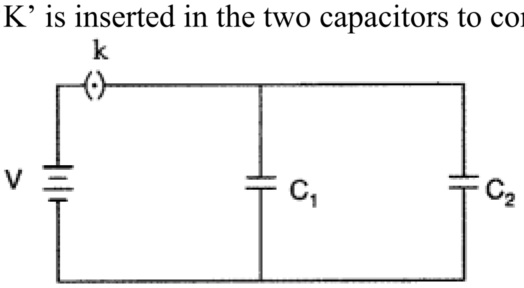
(b) A slit of width 'a' is illuminated by light of wavelength 6000 A^0**. For what value of 'a' will the**

(i) First maximum fall at an angle of diffraction of 30^0**?**

(ii) First minimum fall at an angle of diffraction 30^0**?**

32 (a) How does a dielectric affect the capacitance when a dielectric slab is inserted between the plates of a capacitor? — 5

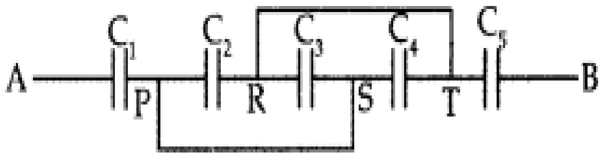
(b) Two parallel plate capacitors of capacitances C_1 and C_2 such that $C_1 = 3C_2$ are connected across a battery of V volts as shown in the figure. Initially the key (k) is kept dosed to fully charge the capacitors. The key is now thrown open and a dielectric slab of dielectric constant 'K' is inserted in the two capacitors to completely fill the gap between the plates,



Find the ratio of
(i) the net capacitance and
(ii) the energies stored in the combination, before and after the introduction of the dielectric slab.

OR

(a) (i) Find equivalent capacitance between A and B in the combination given below. Each capacitor is of 4 μF capacitance



(ii) If a dc source of 14 V is connected across AB, how much charge is drawn from the source and what is the energy stored in the network?

(b) Derive energy density between the plates of a charged capacitor? Write its physical significance.

33 (i)Draw a schematic arrangement for winding of primary and secondary coils in a transformer when the two coils are wound on top of each other.

(ii) State the underlying principle of a transformer and obtain the expression for the ratio of secondary to primary voltage in terms of the number of secondary and primary windings and primary and secondary currents.

(iii) Write the main assumption involved in deriving the above relations.

(iv) Write any two reasons due to which energy losses may occur in actual transformers

OR

In an LCR series combination, R = 400 Ω, L = 100 mH and C = μF. This combination is connected to a 25 sin 2000 t volt source. Find

i) the Impedance,
ii) peak value of current,
iii) phase difference of voltage and current
iv) power factor and
v) dissipated power In the circuit.