KENDRIYA VIDYALAYA SANGATHAN
RAIPUR REGION

तत् त्वं पूषन् अपावृणु
केन्द्रीय विद्यालय संगठन
KENDRIYA VIDYALAYA SANGATHAN

CLASS XII

SESSION 2025-26

STUDY MATERIAL
VOLUME II

PHYSICS (042)

OUR PATRONS

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UNIT	CHAPTER	SUB TR	KV
I	1: Electric Charges and Fields	Shri. Sushant Dey	Raipur No-1(S-I)
	2: Electrostatic Potential and Capacitance	Shri. Yogendra Kumar Tiwari	K V No.2 Raipur
II	3.Current Electricity	Shri. Shivendra Singh	Baikunthpur
III	4.Moving Charges and Magnetism	Shri. Suyash Rawat	Bacheli
	5.Magnetism and Matter	Shri. N D Sahu	Raipur No-1(S-2)
IV	6.Electromagnetic Induction	Shri. Vinod Kumar Verma	Korba No.4
	7.Alternating Current	Shri. Amitabh Adhikari	Dongargarh
V	8.Electromagnetic Waves	Ms. Renu	Maharajpur Kawardha
VI	9.Ray Optics and optical instruments	Smt. Runa Chaudhary Sh S.K. Chaturvedi	CISFBhilai Durg
	10.Wave Optics	Shri. Raju Prasad Gupta Shri. Mayadhar Panda	Ambikapur Raigarh
VII	11.Dual Nature of Radiation and Matter	Ms. Monika Yadav	Saraipali
VIII	12.Atoms	Shri. Krishna Kantiwal	Narayanpur
	13.Nuclei	Shri. H.S.Tripathi	Kurud
IX	14.Semiconductor Electronics: Materials, Devices and Simple Circuits	Shri. Ashish Verma	Bijapur
	Materials collection by	Smt. Archana Khare	Korba No-2(NTPC)

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CLASS XII

(2025-26) PHYSICS (THEORY)

Time: 3 hrs. **Max Marks: 70**

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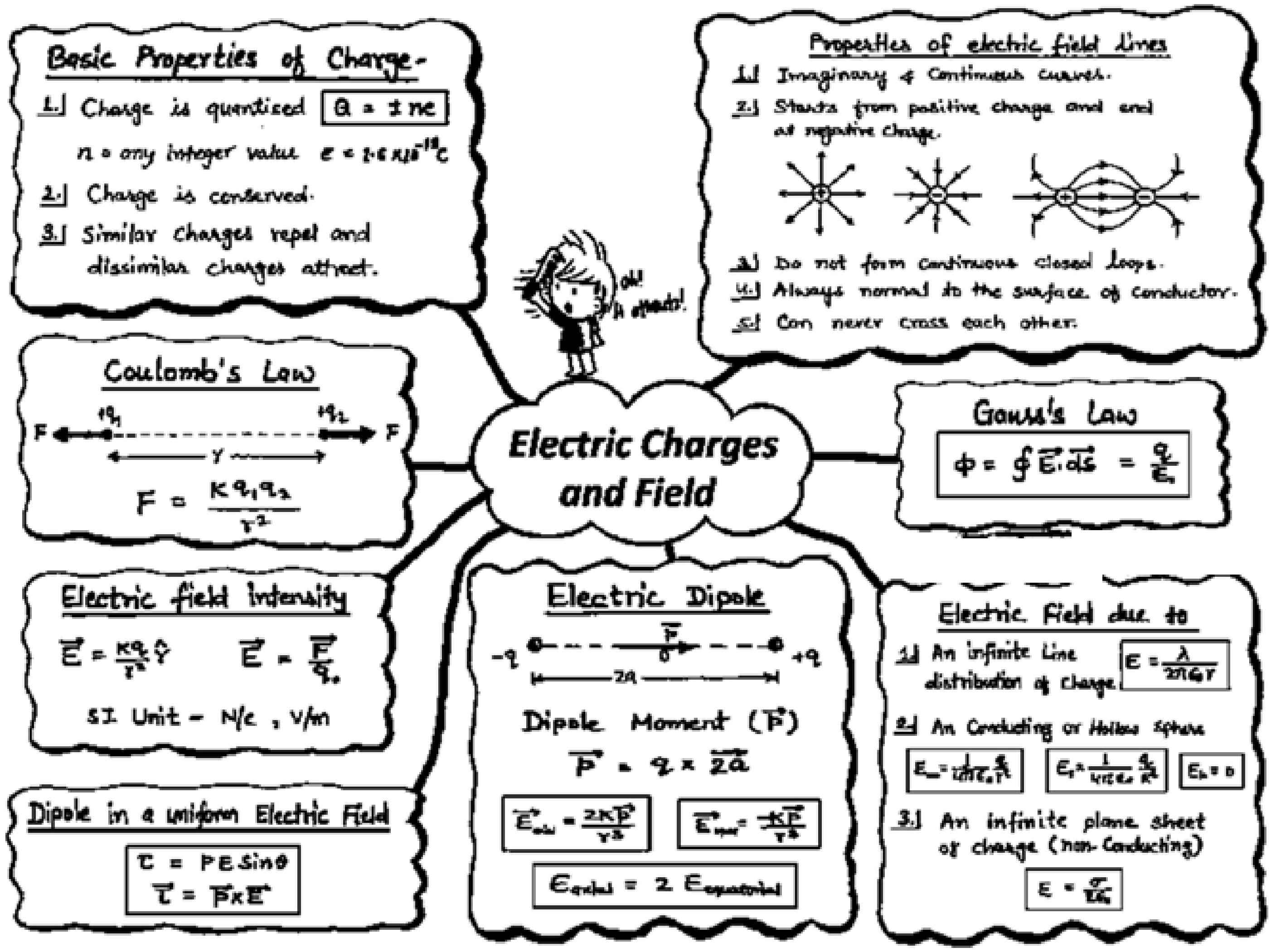
Total		**70**

CHAPTER 1

ELECTRIC CHARGES AND FIELDS



MULTIPLE CHOICE QUESTIONS

1.An electric dipole is placed inside an electric field which increases along the z axis . the dipole undergoes

(a) translational motion along z axis

b) rotational motion only

(c) rotational and translational motion along negative x axis

(d) rotational and translational motion along positive x axis

2. two point charges each of +2μc are placed at certain distance (in meters) if their locations are (1,1,1) and (3,2,3) in free space, then the electrostatic force between them will be:

(a) 1×10^3 n (b) 2×10^3 n (c) 3×10^3 n (d) 4×10^3 n

3. charge q is distributed to two different metallic spheres of radii r and 2r such that both spheres have equal surface charge density. then charge on large sphere is

(a) 4q/5 (b) q/4 (c) 3q/5 (d) 5q/4

4. what will be the total flux through the faces of the cube with side of length ‘a ‘if a charge of ‘q’ is placed at the corner inside the cube?

(a) q/ε_0 (b) $q/2\varepsilon_0$ (c) $q/4\varepsilon_0$ (d) $q/8\varepsilon_0$

5. two pitch balls each having equal mass 'm' and equal charge 'q'on them, are suspended by two insulating string of equal length. if a mica sheet is inserted between them, then the electrostatic force acting between them will:

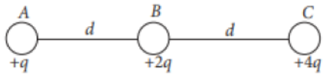
(a) increase (b) decrease (c) remain same

(d) change in force will be equal to the weight of the mica sheet.

6. a charge q is divided into two parts of q and q-q. if the coulomb repulsion between them when they are separated is to be maximum, the ratio of q/q should be

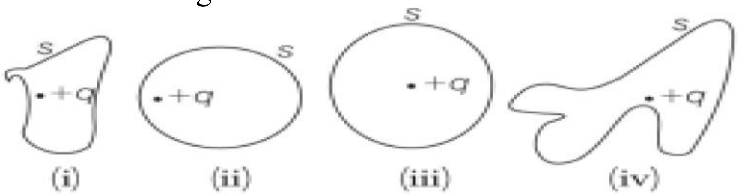
(a) 2:1 (b) ½ (c) 4:1 (d) ¼

7. three charges +q, +2q and +4q are connected by strings as shown in the figure, what is ratio of tensions in the strings ab and bc?



(A) 1:2 (B) 1:3 (C) 2:1 (D) 3:1

8. The electric flux through the surface



(A) In fig (iv) is the largest (B) In fig (iii) is the least

(C) In fig (ii) is same as fig (iii) but is smaller than fig (iv)

(D) Is same for all the figures

9. Which of the following charge is not possible

(A) 1.6×10^{-17} C (B) 1.6×10^{-18} C (C) 1.6×10^{-19} C (D) 1.6×10^{-20} C

10. Two-point charges of +2μC and +6μCrepel with a force of 12 N. If each is given an additional charge of - 4μC , the new force between them will be:

(A) + 4 N (B) – 4 N (C) 0 (D) 3 N

ASSERTION REASON QUESTIONS

OPTIONS:

(A) Both Assertion and reason are true and reason is correct explanation of assertion.

(B) Both Assertion and reason both are true but reason is not the correct explanation of assertion.

(C) Assertion is true, reason is false.

(D) Assertion is false, reason is true.

1. **Assertion:** If the bob of a simple pendulum is kept in horizontal electric field, then its period of oscillation will remain same.
Reason: If the bob is charged and kept in horizontal electric field, then the time period will be decreased.

2.**Assertion:** A point charge is brought in an electric field, the field at a nearby point will increase or decrease, depending on the nature of charge.

Reason: The electric field is independent of the nature of charge.

3.Assertion : The basic difference between magnetic lines of force and electric lines of force is electric lines of force are discontinuous and magnetic lines of force are continuous

Reason : Magnetic lines of force exist in a magnet but no electric lines of force exists in a charged body

4.Assertion : more electric field lines leave a Gaussian surface than those which enter into it, then the net charge enclosed by that surface will be positive

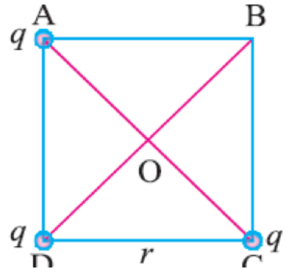
Reason : If the net flux passing through Gaussian surface is zero, then the net charge enclosed by that surface will be zero.

5.Assertion : In a non-uniform electric field, a dipole will have translatory as well as rotatory motion.

Reason : In non-uniform electric field a dipole experiences force as well as torque.

2 MARKS QUESTIONS

1. What is the electric field at O in the given Figure ABCD, which is a square of side *r*.



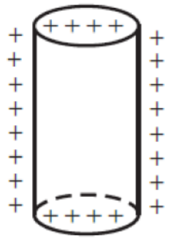
2. How many excess electrons must be added to an isolated spherical conductor 32.0 cm in diameter to produce an electric field of 1150 N/C just outside the surface?

3. A point charge of 2.0 μC is at the centre of a cubic Gaussian surface 9.0 cm on edge. What is the net electric flux through the surface?

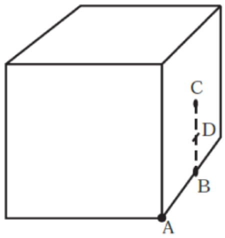
4. A solid metal sphere with radius 0.450 m carries a net charge of 0.250 nC. Find the magnitude of the electric field
   (a) at a point 0.100 m outside the surface of the sphere and
   (b) at a point inside the sphere, 0.100 m below the surface

5. 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, and (ii) the outer surface.

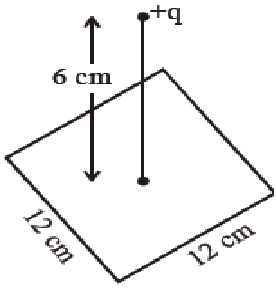
6. Sketch the electric field lines for a uniformly charged hollow cylinder shown in Figure



7. What will be the total flux through the faces of the cube with side of length $a$if a charge q is placed at
   (a) A: a corner of the cube. (b) B: mid-point of an edge of the cube.
   (c) C: centre of a face of the cube. (d) D: mid-point of B and C.

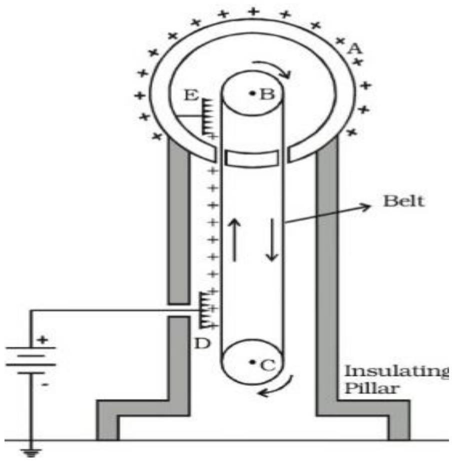


8. A charge of 5×10^{-8} C is placed at a distance of 0.2 m from another charge. If the electric field at that point is 2.25×10^{4} N/C, what is the magnitude of the second charge?
9. An attractive force of 5N is acting between two charges of +2.0 μC& -2.0 μC placed at some distance. If the charges are mutually touched and placed again at the same distance, what will be the new force between them?
10. Two dipoles, made from charges ±q and ±Q, respectively, have equal dipole moments. Give the (i) ratio between the 'separations' of these two pairs of charges
(ii) angle between the dipole axis of these two dipoles.
11. A point charge +12μC is at a distance 6cm directly above the centre of a square of side 10cm as shown in fig. What is the magnitude of flux through the square?



3 MARKS QUESTIONS

1. (a) You charge up the van de Graaff generator shown in Figure, and then bring an identical but uncharged hollow conducting sphere near iwithout letting the two spheres touch. Sketch the distribution of charges on the second sphere. What is the net flux through the second sphere? What is the electric field inside the second sphere?



(b) A hemispherical surface with radius in a region of uniform electric field has its axis aligned parallel to the direction of the field. Calculate the flux through the surface.

2. The electric field at a distance of 0.145 m from the surface of a solid insulating sphere with radius 0.355m is 1750 N/C

(a) Assuming the sphere's charge is uniformly distributed, what is the charge density inside it?

(b) Calculate the electric field inside the sphere at a distance of 0.200 m from the centre

3. A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge 'Q'. A charge 'q' is placed at the centre of the shell.

(a)What is the surface charge density on them (i) inner surface, (ii) outer surface of the shell?

(b) Write the expression for the electric field at a point $x > r_2$ from the centre of the shell.

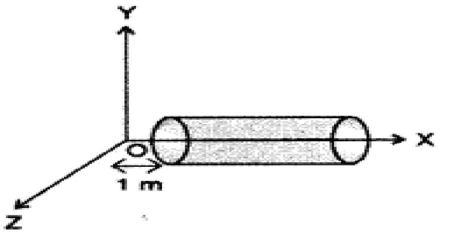
4. The electric field 0.400 m from a very long uniform line of charge is 840 N/C. How much charge is contained in a 2.00-cm section of the line?

5. A thin straight infinitely long conducting wire having charge density X is enclosed by a cylindrical surface of radius r and length l, its axis coinciding with the length of the wire.

(a) Find the expression for the electric flux through the surface of the cylinder.

(b) Thin long conductor has linear charge density of 20 micro coulomb/m. Calculate the electric field intensity at a point 5 cm from it. Draw a graph to show variation of electric field intensity with distance from the conductor.

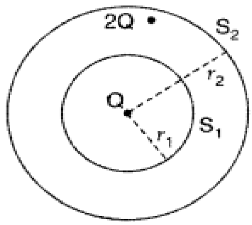
6. A hollow cylindrical box of length 1m and area of cross-section 25 cm^2 is placed in a three dimensional coordinate system as shown in the figure. The electric field in the region is given by $\vec{E} = 50\, x\hat{\imath}$ where E is in NC^{-1} and x is in metres. Find (i)Net flux through the cylinder.(ii) Charge enclosed by the cylinder.



7. Given a uniform electric field $\vec{E} = 5\times10^3\hat{i}$ N/C, find the flux of this field through a square of 10 cm on a side whose plane is parallel to the y-z plane. What would be the flux through the same square if the plane makes a 30° angle with the x-axis?

8. A hollow, conducting sphere with an outer radius of 0.250 m and an inner radius of 0.200 m has a uniform surface charge density of 6.37×10^{-6} C/m^2. A charge of -0.500 μC is now introduced into the cavity inside the sphere. (a) What is the new charge density on the outside of the sphere? (b) Calculate the strength of the electric field just outside the sphere. (c) What is the electric flux through a spherical surface just inside the inner surface of the sphere?

9. (a) A sphere S_1 of radius r_1 encloses a net charge Q. If there is another concentric sphere S_2 of radius r_2 ($r_2 > r$,) enclosing charge 2Q, find the ratio of the electric flux through S_1 and S_2.



(b)How will the electric flux through sphere S_1 change if a medium of dielectric constant K is introduced in the space inside S_2 in place of air?

(c)Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charges q_1 and q_2 respectively. Find the ratio of their surface charge densities in terms of their radii.

10. Figure shows the electric field lines around three point charges A, B and C.

(a) Which charges are positive?

(b) Which charge has the largest magnitude? Why?
(c) In which region or regions of the picture could the electric field be zero? Justify your answer.
(i) near A, (ii) near B, (iii) near C, (iv) nowhere
11. (a) A hemisphere is uniformely charged positively. The electric field at a point on a diameter away from the centre will be in which direction?
(b) The dimensions of an atom are of the order of an Angstrom. Thus there must be large electric fields between the protons and electrons.Why, then is the electrostatic field inside a conductor zero?

CASE BASED QUESTIONS

1. Satellites in space are exposed to solar radiation and cosmic particles that can cause them to accumulate electric charges. Th1is charging can interfere with sensitive instruments and communication systems onboard. To protect these systems, engineers often enclose them in conducting spherical shells, utilizing the principles of Gauss's Law to control electric fields and ensure operational safety. A communication satellite has sensitive instruments enclosed within a thin spherical conducting shell of radius 0.5 m. During operation, solar winds deposit a total net charge of 2.0×10^{-6} C uniformly on the shell.

(i). What does Gauss's Law state?
A) Electric field inside a conductor is always maximum.
B) The total electric flux through a closed surface is equal to the charge enclosed divided by ε_0.
C) Electric field lines always originate from negative charges.
D) Electric flux depends only on the surface area.

(ii). Why is a spherical shell effective in protecting sensitive satellite electronics?
A) It neutralizes the incoming charge
B) It ensures no electric field exists inside the shell, due to electrostatic shielding
C) It stores charge inside the cavity safely
D) It amplifies the internal field to stabilize the instruments

(iii). What is the electric field at a point 1 m outside the surface of the charged spherical shell?
A) 1.8×10^4 N/C B) 9.0×10^3 N/C C) 2.0×10^4 N/C D) 3.6×10^4 N/C

(iv). What is the electric field at a point 0.25 m from the center of the charged spherical shell?
A) 7.2×10^4 N/C B) Zero C) 4.5×10^3 N/C D) 1.8×10^4 N/C

2. Dipoles, whether electric or magnetic, are characterised by their dipole moments, which are vector quantities. Two equal and opposite charges separated by a small distance constitute an electric dipole, while a current carrying loop behaves as a magnetic dipole. Electric dipoles create electric fields around them. Electric dipoles experience a torque when placed in an external electric field

(i) Two identical electric dipoles, each consisting of charges – q and + q separated by distance d, are arranged in x-y plane such that their negative charges lie at the origin O and positive charges lie at points (d, 0) and (0, d) respectively. The net dipole moment of the system is
(a) $-qd\left(\hat{i}+\hat{j}\right)$ (b) $qd\left(\hat{i}+\hat{j}\right)$ (c) $qd\left(\hat{i}-\hat{j}\right)$ (d) $qd\left(\hat{j}-\hat{i}\right)$
(ii) E_1 and E_2 are magnitudes of electric field due to a dipole, consisting of charges –q and +q separated by distance 2a, at points r (>> a) (1) on its axis, and (2) on equatorial plane, respectively. Then the ratio of E_1 and E_2 is
(a) 0.25 (b) 0.5 (c) 2 (d) 4

(iii) An electric dipole of dipole moment 5.0×10^{-8} Cm is placed in a region where an electric field of magnitude 1.0×10^3 N/C acts at a given instant. At that instant the electric field E is inclined at an angle of 30° to dipole moment *p*. The magnitude of torque acting on the dipole, at that instant is :

(a) 2.5×10^{-5} Nm (b) 5.0×10^{-5} Nm (c) 1.0×10^{-4} Nm (d) 2.0×10^{-6} Nm

(iv) A plane surface has an area of 20 cm^2. It is placed in a region of uniform electric field of magnitude 1000 N/C. The angle between electric field and plane of the surface is 30º. The electric flux passing through the surface is

(a) 0 Wb (b) 1 Wb (c) 2 Wb (d) $\sqrt{3}$ Wb

LONG ANSWER QUESTIONS 5 MARKS EACH

1.(a) The earth (a conductor) has a net electric charge. The resulting electric field near the surface has an average value of about 150 N/C directed toward the center of the earth. (i) What is the corresponding surface charge density?

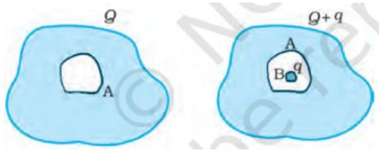
(ii) What is the total surface charge of the earth?

(b) An infinitely large thin plane sheet has a uniform surface charge density $+\sigma$. Obtain the expression for the amount of work done in bringing a point charge q from infinity to a point, distant r, in front of the charged plane sheet.

2. (a) (i) A conductor A with a cavity as shown in Figure is given a charge *Q*. Show that the entire charge must appear on the outer surface of the conductor.

(ii) Another conductor B with charge *q* is inserted into the cavity keeping B insulated from A. Show that the total charge on the outside surface of A is *Q* + *q*.

(iii) A sensitive instrument is to be shielded from the strong electrostatic fields in its environment. Suggest a possible way.



(b) A wire AB of length L has linear charge density λ = 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 this surface.

3. (a) Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and of magnitude 17.0×10^{-22} C/m^2. What is E:

(i) in the outer region of the first plate, (ii) in the outer region of the second plate, and

(iii) between the plates?

(b) The 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.

4. (a) A polythene piece rubbed with wool is found to have a negative charge of 3×10^{-7} C.

(i) Estimate the number of electrons transferred (from which to which?)

(ii) Is there a transfer of mass from wool to polythene?

(b) An electrostatic field line is a continuous curve. That is, a field line cannot have sudden breaks. Why not?

5. (a) A lightning rod is a rounded copper rod mounted on top of a building and welded to a heavy copper cable running down into the ground. Lightning rods are used to protect houses and barns from lightning; the lightning current runs through the copper rather than through the building. Why? Why should the end of the rod be rounded?

(b)An electric dipole with dipole moment 4×10^{-9} C m is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^4 NC^{-1}. Calculate the magnitude of the torque acting on the dipole.

ANSWER KEY

MULTIPLE CHOICE ANSWERS

1	2	3	4	5	6	7	8	9	10
D	B	A	D	B	A	B	D	D	B

ASSERTION REASON ANSWER

1	2	3	4	5
A	B	A	B	A

2 MARKS ANSWERS

Ans 1. By finding electric field due to individual charges present at three vertices, we can get the answer by vector addition as

$$\frac{2q}{4\pi\varepsilon_0 r^2}$$

Ans 2. The diameter is 32.0 cm, so the radius (r) is 16.0 cm or 0.16 meters.

The electric field (E) just outside a spherical conductor is given by $E = kQ/r^2$

Plugging in the values, $Q = (1150 \text{ N/C}) \times (0.16 \text{ m})^2 / (9 \times 10^9 \text{ N·m}^2/\text{C}^2 = 3.27 \times 10\text{-}^9$ Coulombs.

Find the number of electrons by $n = Q / e$.

Ans 3. $q = 2.0\mu C = (2.0 \times 10^{-6} \text{ C})$ and $\varepsilon_0 = 8.854 \times 10^{-12} \text{ N}^{-1}\text{C}^2\text{m}^{-2}$.

Putting in $\phi = \frac{q}{\varepsilon 0}$, $\phi = 2.3\text{x } 10^5 \text{ Nm}^2\text{C}^{-1}$

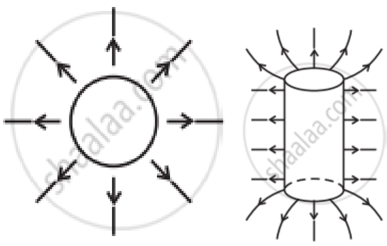
Ans 4. (a) The point is 0.100 m outside the surface, and the sphere's radius is 0.450 m, so the total distance from the center is 0.450 m + 0.100 m = 0.550 m.

The electric field due to a point charge is given by $E = k \times q / r^2$,

Plugging in the values, $E = (8.99 \times 10^9 \text{ N m}^2/\text{C}^2) \times (0.250 \times 10^{-9} \text{ C}) / (0.550 \text{ m})^2 = 7.43$ N/C.

b) For a solid metal sphere carrying a net charge, all the charge resides on the surface of the sphere. Therefore, the electric field inside the conductor is zero, Because all the charge is on the surface, there is no electric field inside the sphere.

Ans 5. Therefore, the surface charge density on the inner surface $(\sigma_1) = -q / (4\pi r_1^2)$
the surface charge density on the outer surface $(\sigma_2) = +q / (4\pi r_2^2)$.
Ans 6.



Top view Side view

Ans 7. (a) When a charge q is at a corner, it's shared by 8 such cubes. Therefore, $\phi = q/(8\varepsilon_0)$.

(b) When the charge q is at the midpoint of an edge, it's shared by 4 such cubes.

Therefore, $\phi = q/(4\varepsilon_0)$.

(c) When the charge q is at the center of a face, it's shared by 2 such cubes

Therefore, $\phi = q/(2\varepsilon_0)$.

(d) When the charge q is at the midpoint of B and C, it's also shared by 2 such cubes.

Therefore, $\phi = q/(2\varepsilon_0)$.

Ans 8.The electric field $E = k \times q / r^2$.

Therefore, $q_2 = 1 \times 10^{-7}$ C.

Ans 9. The new force between the charges after touching will be zero. When the two charges, initially having equal magnitude and opposite signs, are touched, they will neutralize each other. This is because touching allows charge to flow from the more charged object to the less charged object until both have the same charge, and in this case, they become neutral. Since both charges become neutral, there will be no force between them.

Ans 10. (i) Let d_1 be the separation of the first dipole and d_2 be the separation of the second dipole.

The dipole moments are given by: $p_1 = qd_1$ and $p_2 = Qd_2$

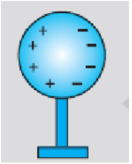
Since $p_1 = p_2$, $qd_1 = Qd_2$, $d_1/d_2 = Q/q$

(ii) For two dipoles with equal dipole moments, the most stable (equilibrium) configuration is when their dipole axes are aligned

i.e., the angle between them is 0^0

Ans 11. Flux through each face of cube will be $\emptyset = \frac{1}{6}\frac{q}{\epsilon_0} = 226 \times 10^{3}$ Nm^2/C

3 MARKS ANSWERS



1. (a) When an uncharged hollow conducting sphere is brought near a charged Van de Graaff generator, it will become polarized. The side of the sphere closest to the generator will develop a charge opposite to that of the generator, while the far side will develop an equal and opposite charge. This phenomenon is due to electrostatic induction. The net flux through the second sphere will be zero because the net enclosed charge is zero. The electric field inside the second sphere will be zero due to electrostatic equilibrium and the fact that it is a conductor.

(b) The flux through the hemispherical surface is equal to the flux through its circular base, which is given by $E\pi r^2$, where E is the electric field strength and r is the radius of the hemisphere. This is because the electric field lines are parallel to the axis of the hemisphere, and the curved surface does not intercept any field lines.

2. (a)Using formula $Q = E (R + r)^2 / k = 4.86 \times 10^{-8}$ C

The volume (V) of a sphere is given by: $V = (4/3)\pi R^3 = 0.188\ m^3$

The charge density, $\rho = Q / V$.

$\rho = 4.86 \times 10^{-8}\ C / 0.188\ m^3 \approx 2.59 \times 10^{-7}\ C/m^3$.

(b) Putting values in, Electric field $E_{in} = (kQr_{in}) / R^3$

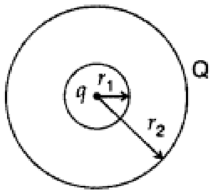
$E_{in} = 327$ N/C.

3. (a) Surface charge density on the :

(i) Inner surface of the shell, $\sigma_{in} = \frac{-q}{4\pi r_1^2}$

(ii) Outer surface of the shell,

$\sigma_{out} = \frac{Q+q}{4\pi r_2^2}$



(b) Electric field at a point x > r_2 from the centre of the shell will be E = $\frac{1}{4\pi\varepsilon 0}\frac{Q+q}{x^2}$

4. Find the linear charge density λ using the given electric field and distance.

Putting in $\lambda=2\pi r E\varepsilon_0$ = 7.44 X 10^{-9} C/m

Again putting in Q = λl = 1.49 X 10^{-10} C

5. (a) Since the field is everywhere radial, flux through the two ends of the cylindrical Gaussian surface is zero. At the cylindrical part of the surface, E is normal to the surface at every point, and its magnitude is constant, since it depends only on r. The surface area of the curved part is 2πrl, where l is the length of the cylinder.
Flux through the Gaussian surface = Flux through the curved cylindrical part of the surface is zero. At the cylindrical part of the surface, E is normal to the surface at every point, and its magnitude is constant, since at every point, and its magnitude is constant, since it depends only on r. The surface area of the cylinder.

$E \times 2\pi r l = \lambda l/\varepsilon_0$

i.e. $\boxed{E = \frac{\lambda}{2\pi\varepsilon_0 r}}$

(b) $\lambda = 20 \times 10^{-6}$ C/m, r = 5 cm = 0.05 m

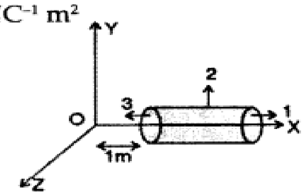
Putting in $E = \lambda / (2\pi\varepsilon_0 r)$

$E \approx 7.19 \times 10^6$ N/C

And the graph showing the relationship between them is a hyperbola.

5.

(i) The magnitude of the electric field at the left face is
$E = 50\ NC^{-1}$
Therefore flux through this face
$\phi_L = EA\cos\theta$
$= 50 \times 25 \times 10^{-4} \times \cos 180°$
$= -125 \times 10^{-3}\ NC^{-1}\ m^2$



The magnitude of the electric field at the right face is
$E = 100\ NC^{-1}$
Therefore flux through this face
$\phi_R = 100 \times 25 \times 10^{-4} \times \cos 0°$
$= 250 \times 10^{-3}\ NC^{-1}\ m^2$
Therefore net flux through cylinder is
$\boxed{\phi_R + \phi_L = 125 \times 10^{-3}\ NC^{-1}\ m^2}$

(ii) Charge enclosed by the cylinder $\phi = \frac{Q}{\varepsilon_0}$

$Q = \phi_{net} \times \varepsilon_0$
$= 125 \times 10^{-3} \times 8.856 \times 10^{-12}$ C
$= 1107 \times 10^{-15}$ C
$\boxed{Q = 1.107\ pC}$

6. Given : $\vec{E} = 5 \times 10^3\ \hat{i}$ N/C,
   $A = 10 \times 10 \times 10^{-4} m^2$,
   Flux (ϕ) = EA cos θ
   (i) For first case, $\theta = 0$, cos 0 = 1
   ∴ Flux = $(5 \times 10^3) \times (10 \times 10 \times 10^{-4})$
   (ii) Angle of square plane with x-axis = 30°
   Hence the 0 will be 90° – 30° = 60°
   EA cos $\theta = (5 \times 10^3) \times (10 \times 10 \times 10^{-4}) \times \cos 60 = 25\ Nm^2C^{-1}$
7. (a) charge initial outer = σ_initial x $4\pi r_{out}^2$

   charge initial outer ≈ 5.00×10^{-7} C
   Total charge (Q_t) = $Q_i + Q_{in}$ = 5.00 μC + 0.500 μC = 5.50 μC.
   $\sigma' = Q_t / A = 5.50 \times 10^{-6}$ C / 0.7854 m² = 7.00×10^{-6} C/m².
   (b) $E = kQ / r^2 = 7.91 \times 10^5$ N/C.
   Therefore, the electric field just outside the sphere is 7.91×10^5 N/C.
   (b) The electric flux (Φ) is given by: Φ = Qenc / ε_0, where Qenc is the enclosed charge and ε_0 is the permittivity of free space ($8.85 \times 10^{-12}\ C^2/(N\cdot m^2)$).

8. (a)

$$\text{Flux through } S_1(\phi_1) = \frac{Q}{\epsilon_0} \quad \ldots(i)$$

$$\text{Flux through } S_2(\phi_2) = \frac{Q+2Q}{\epsilon_0} = \frac{3Q}{\epsilon_0} \quad \ldots(ii)$$

$$\therefore \quad \text{Ratio of flux} = \frac{\phi_1}{\phi_2} = \frac{Q/\epsilon_0}{3Q/\epsilon_0} = \frac{1}{3}$$

Therefore, there will be no change in the flux through S_1 on introducing dielectric medium inside the sphere S_2.

(b)

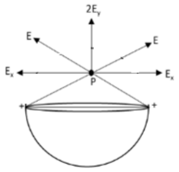
$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{R_1}$	$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{R_2}$
$\because \frac{q_1}{R_1} = \frac{q_2}{R_2}$	$\frac{q_1}{q_2} = \frac{R_1}{R_2}$
$\sigma_1 = \frac{q_1}{4\pi R_1^2}$	$\sigma_2 = \frac{q_2}{4\pi R_2^2}$

$$\therefore \frac{\sigma_1}{\sigma_2} = \frac{\frac{q_1}{4\pi R_1^2}}{\frac{q_2}{4\pi R_2^2}} = \frac{q_1}{q_2} \times \frac{R_2^2}{R_1^2} = \frac{R_1}{R_2} \times \frac{R_2^2}{R_1^2}$$

$$\therefore \boxed{\frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}}$$

9. (a) Charges A and C are positive, as electric field lines emanate from them.
   (b) Charge C has the largest magnitude because it has the most electric field lines emerging from it.
   (c) The electric field could be zero in the region near charge A, because the field lines from A and C are in opposite directions, and the weaker field from A may be canceled by a portion of the field from C.
10. (a) The electric field at a point on the diameter of a uniformly positively charged hemisphere, away from the center, is directed perpendicular to the diameter. This is because the components of the

electric field parallel to the diameter will cancel each other out due to symmetry, leaving only a perpendicular component.



(b) While it's true that atoms have a structure where protons and electrons are separated by distances of the order of an angstrom, leading to strong electric fields within the atom itself, the electrostatic field inside a conductor is generally zero because any excess charge present in a conductor distributes itself on the outer surface, effectively cancelling out the internal field.

CASE BASED QUESTIONS

	1	2	3	4
CBQ 1	**b**	**B**	**a**	**b**
CBQ 2	**b**	**C**	**a**	**b**

5 MARKS ANSWERS

1. (a) (i) The direction of the field means that σ is negative (corresponding to **E** being directed into the surface, so is negative).
Putting in $\sigma = \varepsilon_0 E_\perp$
$\sigma = -1.33$ Nc/m^2
(ii) Where R = 6.38 X 10^6m is the radius of the earth.
The total charge = $4\pi R^2 x\sigma$ Q = = -680 kC

$$(b)\ W = q\int_{\infty}^{r} \vec{E}\cdot d\vec{r}$$

$$= q\int_{\infty}^{r}(-E\,dr) = q\int_{\infty}^{r}\left(\frac{\sigma}{2\varepsilon_0}\right)dr = \frac{q\sigma}{2\varepsilon}[\infty - r]$$

$$\Rightarrow (\infty)$$

2. (a) (i) When charge Q is given to conductor A with a cavity, the free charges within the conductor redistribute themselves. The charges will move to the outer surface of the conductor, creating an electric field that cancels out the internal field, resulting in a zero field within the conductor and the cavity.
(ii) The charge +q on conductor B will induce a charge of -q on the inner surface of the cavity in conductor A. To maintain charge neutrality in conductor A, a charge of +q will be induced on its outer surface. Since the outer surface initially had a charge Q, the total charge on the outer surface becomes Q + q.
(iii) To shield a sensitive instrument from strong electrostatic fields, one can enclose it within
(b) a grounded conducting enclosure. Because the grounded enclosure acts as a Faraday
(c) cage. Any external electric field lines will terminate on the outer surface of the enclosure, and the electric field within the enclosure will be zero

(b) Given : Length of wire = L, Charge density (λ) = kx, ϕ = ?
We know

$$dq = \lambda dx = kx\, dx$$

$$Q = \int_0^q dq = \int_0^L kx\, dx = \frac{1}{2}kL^2$$

$$\therefore \quad \phi = \frac{Q}{\epsilon_0} = \frac{kL^2}{2\epsilon_0}$$

3. a) (i) In the outer region of the first plate, $E = \sigma / (2\varepsilon_0) - \sigma / (2\varepsilon_0) = 0$

(ii) In the outer region of the second plate, $E = \sigma / (2\varepsilon_0) - \sigma / (2\varepsilon_0) = 0$

(iii) $E = (17.0 \times 10^{-22}\ C/m^2) / (8.854 \times 10^{-12}\ C^2/N{\cdot}m^2) \approx 1.92 \times 10^{-10}$ N/C.

(b) Let the two charges of + q each placed at point A and B at a distance 2 m apart in air.

Hence, Q will be negative in nature. For charge (-Q) to be in equilibrium Force on charge (-q) due to charge (+q) at point A should be equal and opposite to charge (+Q) at B

$$\frac{1}{4\pi\varepsilon_0}\frac{Qq}{x^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qq}{(2-x)^2}$$

or $\quad (2-x)^2 = x^2$

$\Rightarrow \quad x = (2-x) \Rightarrow x = 1$ m

Therefore, for the system to be in equilibrium a charge – Q is placed at a mid point between the two charges of + q each.

4. (a) (i) No. Of electrons =3 x 10^{-7} C) / (1.602 x 10^{-19} C/electron) = 1.87 x 10^{12} electrons.

(ii) Yes, there is a transfer of mass from wool to polythene. This mass is negligible, though, due to the very small mass of an electron.

(b) Electrostatic field lines are continuous because the electric field is continuous. The field lines represent the direction of the force that a positive test charge would experience, and since the force is continuous, the field lines must also be continuous.

5. (a) Lightning rods are used to protect buildings from lightning damage by providing a path of least resistance for the electrical current to travel to the ground, bypassing the building. The rounded end of the rod helps to distribute the electrical charge and reduce the chance of a direct strike, as sharp points can create a stronger electric field, potentially attracting lightning.

(b) Dipole moment (p) = 4×10^{-9} C m

Electric field strength (E) = 5×10^4 NC^{-1}

Angle (θ) = 30°

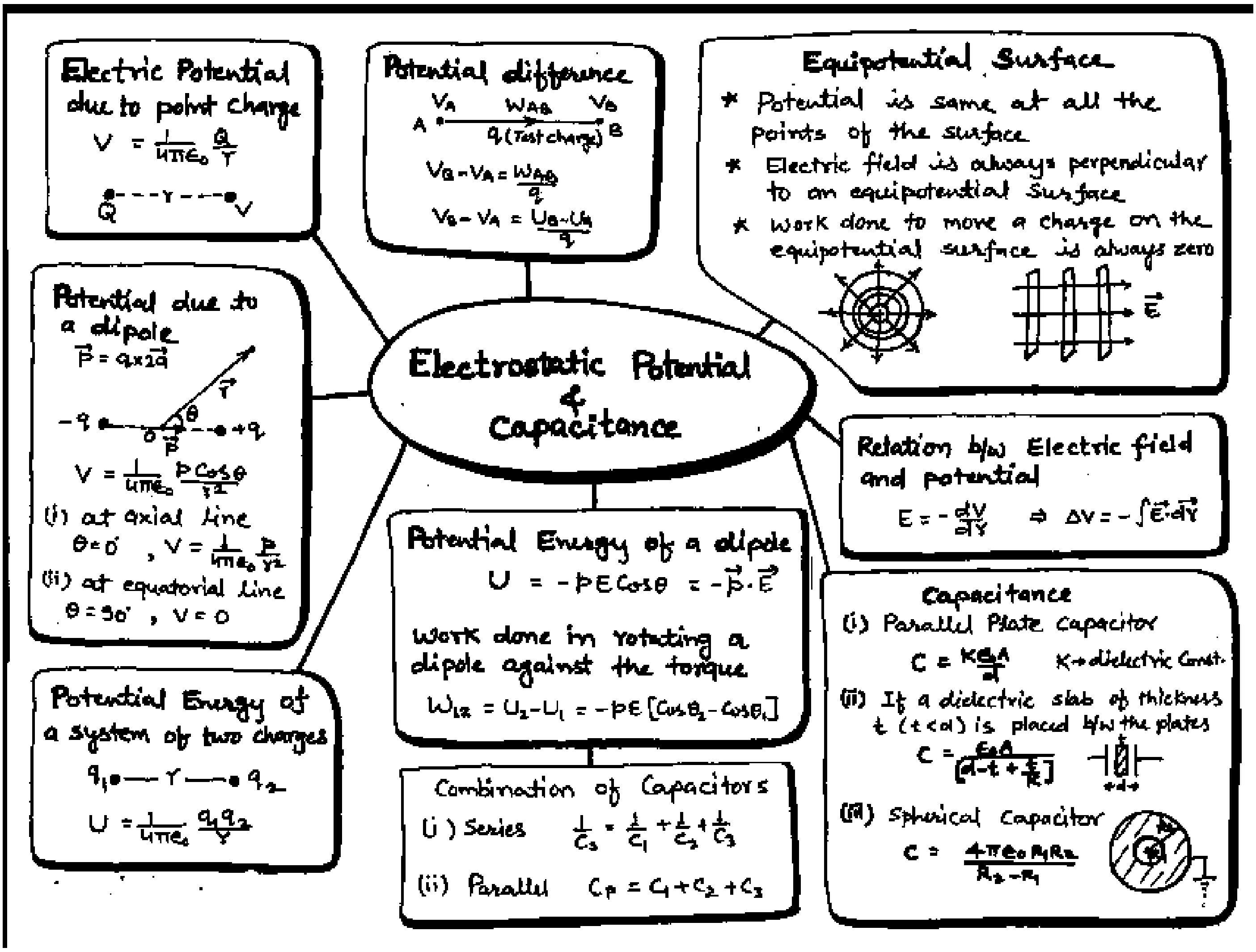
Putting in Torque (τ) = pEsinθ

$\tau = (4 \times 10^{-9}$ C m) x (5×104 NC^{-1}) .sin(30°)

$\tau = 20 \times 10^{-5}$ x (1/2) = 10^{-4} N m

CHAPTER-2

ELECTROSTATIC POTENTIAL AND CAPACITANCE



MULTIPLE CHOICE QUESTIONS-1

1.Two horizontal plates, separated by 1 cm, are arranged one above the other. A particle of mass 5 mg and charge 2 nC is released in air between the plates. The potential difference that should be applied to the plates so that the particle remains suspended between them, is :

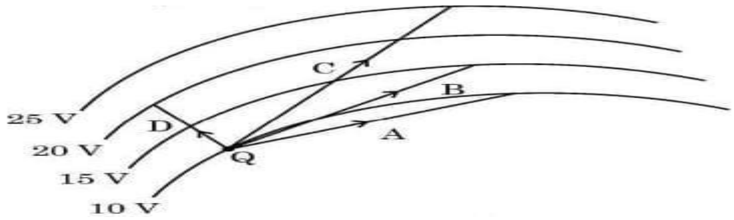
(a)250 V (b) 200 V (c)100 V (d) 50 V

2. A metal sheet is inserted between the plates of a parallel plate capacitor of capacitance C. If the sheet partly occupies the space between the plates, the capacitance :

(a)remains C (b)becomes greater than C

(c)becomes less than C (d) becomes zero

3.In the figure curved lines represent equipotential surfaces. A charge Qis moved along different paths A, B, C and D. The work done on the charge will be maximum along the path



(a) A (b) B (c) C (d) D

4. Two particles A and B of the same mass but having charges q and 4q respectively, are accelerated from rest through different potential differences V_A and V_B such that they attain same kinetic energies. The value of V_A/V_B

(a) 1/ 4 (b) 1/ 2 (c) 2 (d) 4

5.A parallel plate capacitor is charged by a battery. The battery is then disconnected and the plates of the charged capacitor are then moved farther apart. In the process :

(a) the charge on the capacitor increases. (b)the potential difference across the plates decreases.

(c)the capacitance of the capacitor increases. (d)the electrostatic energy stored in the capacitor increases.

6.A conducting sphere of radius R is given a charge Q. Consider three points A, B and C -A at the centre, B at a distance R/2 from the centre and C on the surface of the sphere. The electric potentials at these points are such that : (a) $V_A = V_B = V_C$ (b) $V_A = V_B \neq V_C$ (c) $V_A \neq V_B \neq V_C$ (d) $V_A \neq V_B = V_C$

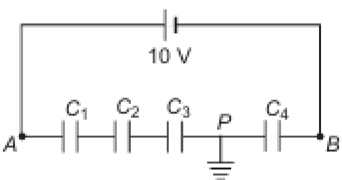
7.The capacitance of a parallel plate capacitor is 10 mF when the distance between its plates is 8 cm. If the distance between the plates is halved, the capacitance will become

(a) 10 mF (b) 15 mF (c) 20 mF (d) 40 mF

8.Ten capacitors, each of capacitance 1 μF, are connected in parallel to a source of 100 V. The total energy stored in the system is equal to :

(a) 10^2 J (b) 10^{-3} J (c) $0{\cdot}5 \times 10^{-3}$ J (d) $5{\cdot}0 \times 10^{-2}$ J

9. Four capacitors are connected in series with a battery of emf of 10v as shown in the figure. The point P is earthed. Then find the potential of point A



(a) 2.5V (b) 0V (c) 10V (d) 7.5V

10. A proton is taken from point P1 to point P2, both located in an electric field. The potentials at points P_1 and P_2 are- 5 V and + 5 V respectively. Assuming that kinetic energies of the proton at points P_1 and P_2 are zero, the work done on the proton is :

(a) $1{\cdot}6 \times 10^{18}$ J (b) $1{\cdot}6 \times 10^{-18}$ J (c) Zero (d) $0{\cdot}8 \times 10^{18}$ J

ASSERTION – 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) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) Assertion is correct, Reason is incorrect

(d) Both Assertion and Reason are correct.

1. ASSERTION: The surface of a charged conductor is always equipotential.

REASON:Electric field lines are always perpendicular to the equipotential surface.

2. ASSERTION: A capacitor is a device which stores electric energy in the form of electric field.

REASON: Net charge on the capacitor is always zero.

3. ASSERTION: Absolute value of potential is not defined.

REASON: Two equipotential lines cannot intersect each other.

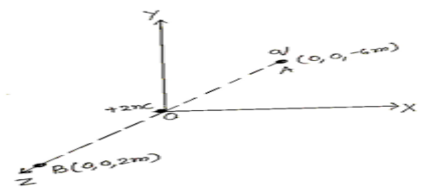
4. Assertion : If the distance between parallel plates of a capacitor is halved and dielectric constant is three times, then the capacitance becomes 6 times.

Reason : Capacity of the capacitor does not depend upon the nature of the material

5, Assertion: Electron move away from a region of lower potential to a region of higher potential.
Reason: An electron has a negative charge.

VERY SHORT ANSWER QUESTION 2

(1)A point charge of + 2 nC is kept at the origin of a three-dimensional coordinate system. Find the type and magnitude of the charge which should be kept at (0, 0, – 6m) so that the potential due to the system becomes zero at(0, 0, 2m).



2.Obtain an expression for electrostatic potential energy of a system of three charges q, 2q and 3q placed at the vertices of an equilateral triangle of side a

3)Two small conducting balls A and B of radius r_1 and r_2 charges q_1 and q_2 respectively. They are connected by a wire. Obtain the expression for charges on A and B, in equilibrium.

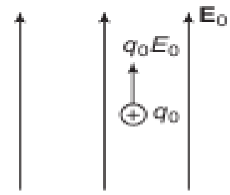
4.Depict the orientation of an electric dipole in (a) stable and (b) unstable equilibrium in an external uniform electric field. Write the potential energy of the dipole in each case.

5.A point charge Q is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero, if Q is

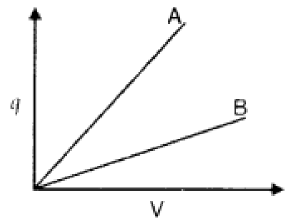
(i)positive (ii)negative?

6.Why is electrostatic potential constant throughout the volume of the conductor and has the same value (as inside) on its surface?

7.A uniform electric field E_0 is directed along positive y-direction. Find the change in electric potential energy of positive charge q when it is displaced in this field from $y_i = a$ to $y_f = 2a$ along the y-axis. (as hown in the figure).



8.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 separation but plate area of C_2 is greater than that of C_1. Which line (A or B) corresponds to C_1 and why?



9.Two point charges 20×10^{-6} C and -4×10^{-6} C are separated by a distance of 50 cm in air. Find the point on the line joining the charges, where the electric potential is zero

10.Draw E-r-graph corresponding toV- rgraph shown in Fig.

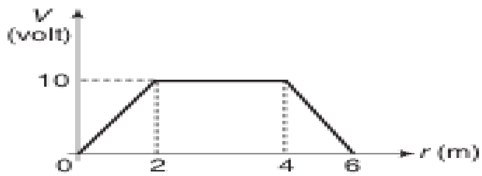


Fig. 24.35

SHORT ANSWER QUESTION-3 MARKS

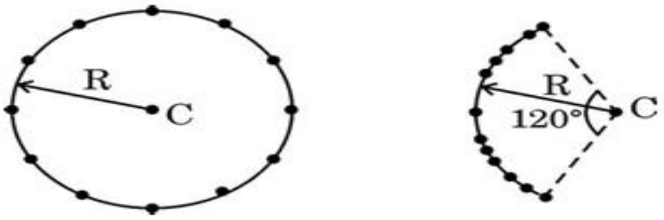
1.A parallel plate capacitor has plate area A and plate separation d. Half of the space between the plates is filled with a material of dielectric constant K in two ways as shown in the figure.

Fnd the values of the capacitance of the capacitors in the two cases.

2.Three point charges of − 2 nC, − 1 nC, and + 5 nC are kept at the vertices A, B and C of an equilateral triangle of side 0·2 m. Find the total amount of work done in shifting the charges from A to A_1, B to B_1 and C to C_1. Here A_1, B_1 and C_1 are the midpoints of sides AB, BC and CA, respectively

3.(a) Twelve negative charges of same magnitude are equally spaced and fixed on the circumference of a circle of radius R as shown in Fig. (i). Relative to potential being zero at infinity, find the electric potential and electric field at the centre C of the circle.

(b)If the charges are unequally spaced and fixed on an arc of 120^0 of radius R as shown in Fig. (ii), find electric potential at the centre C.

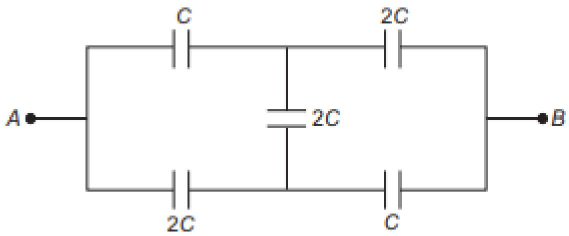


(i) (ii)

4.A 100 μF capacitor is charged by a 12 V battery. How much electrostatic energy is stored by the capacitor

(b) The capacitor is disconnected from the battery and connected in parallel to another uncharged 100 F capacitor. What is the electrostatic energy stored by the system ?

5. Find the equivalent capacitance between A and B.

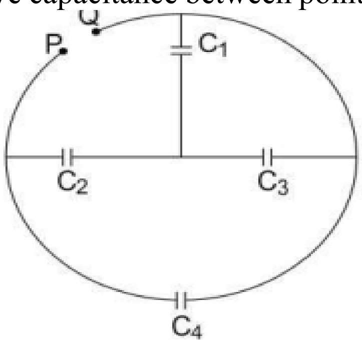


6.A parallel plate capacitor (A) of capacitance C is charged by a battery to voltage V. The battery is disconnected and an uncharged capacitor (B) of capacitance 2C is connected across A. Find the ratio of

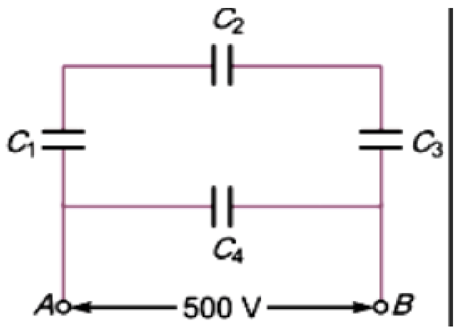
(i) final charges on A and B.

(ii) total electrostatic energy stored in A and B finally and that stored in A initially.

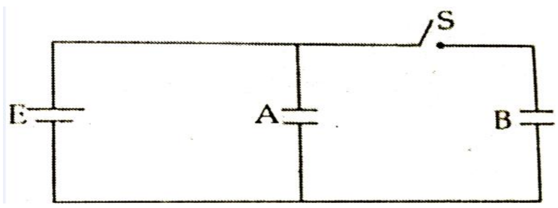
7) Find the effective capacitance between points P and Q, if each capacitor has a capacitance of 6μF.



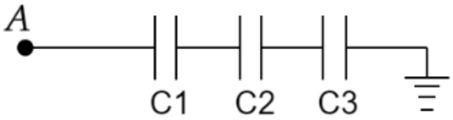
8. A network of four capacitors each of 12μF capacitance is connected to a 500 V supply as shown in the figure. Determine (a) equivalent capacitance of the network and (b) charge on each capacitor.



Q9. Two identical parallel plate capacitors A and B are connected to a battery of V volts with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric constant K. Find the ratio of the total electrostatic energy stored in both capacitors before and after the introduction of the dielectric.

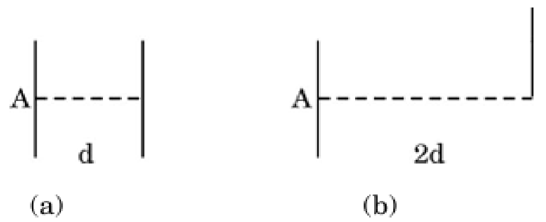


Q10. Calculate the potential difference and the energy stored in the capacitor C2 in the circuit shown in the figure. Given potential at A is 90 V, C1 = 20 μF, C2 = 30 μF and C3 = 15 μF.



CASE BASED QUESTION

1.A capacitor is a system of two conductors separated by an insulator. In practice, the two conductors have charges Q and Q with potential difference V =V_1-V_2 between them.The ratio $\frac{Q}{V}$ is a constant, denoted by C and is called the capacitance of the capacitor. It is independent of Q or V. It depends only on the geometrical configuration (shape, size, separation) of the two conductors and the medium separating the conductors. When a parallel plate capacitor is charged, the electric field E 0 is localised between the plates and is uniform throughout. When a slab of a dielectric is inserted between the charged plates (charge density), the dielectric is polarised by the field. Consequently opposite charges appear on the faces of the slab, near the plates, with surface charge density of magnitude p. For a linear dielectric p is proportional to E0. Introduction of a dielectric changes the electric field, and hence, the capacitance of a capacitor, and hence, the energy stored in the capacitor. Like resistors, capacitors can also be arranged in series or in parallel or in a combination of series and parallel. (i) Consider a capacitor of capacitance C, with plate area A and plate separation d, filled with air [Fig. (a)]. The distance between the plates is increased to 2d and one of the plates is shifted as shown in Fig. (b). The capacitance of the new system now is :



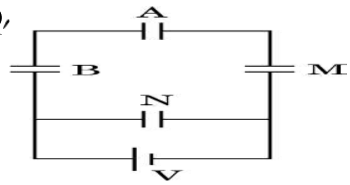
(a) $\frac{C}{4}$ (b)$\frac{C}{2}$ (c)2c (d) 4c

(ii)A slab (area A and thickness d1) of a linear dielectric of dielectric constant K is inserted between charged plates (charge density) of a parallel plate capacitor [plate area A and plate separation d (> d1)] and opposite charges with charge density of magnitude σp appear on the faces of the slab. The dielectric constant K is given by

(a) $\frac{\sigma + \sigma p}{\sigma}$ (b)$\frac{\sigma}{\sigma - \sigma p}$ (c)$\frac{\sigma + \sigma p}{\sigma p}$ (d) $\frac{\sigma}{\sigma p}$

(iii)An electric field E is established between the plates of an air filled parallel plate capacitor, with charges Q and_ Q. V is the volume of the space enclosed between the plates. The energy stored in the capacitor is

(a) $\frac{\varepsilon_0 E^2}{2}$ (b) $\varepsilon_{0Q}{}^2E$ (c) $\frac{\varepsilon_0 VE^2}{2}$ (d)ε_0QEV (iv)(a) Three capacitors A, B and M, each of capacitance C are connected to a capacitor N of capacitance 2C and a battery as shown in the figure. If the charges on A and N are Q and Q' respectively, then $\frac{Q'}{Q}$ is



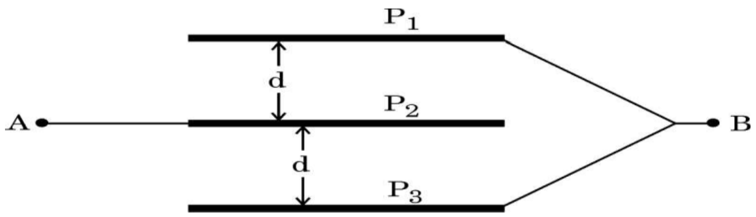
(a)$\frac{1}{6}$ (b)$\frac{1}{3}$ (c) 3 (d)6

OR

(b)A slab (area A and thickness-d/2) of dielectric constant K is inserted in a parallel plate capacitor of plate area A and plate separation d. If C and C_0 are the capacitances of the capacitors with and without the dielectric, then C/C_0

(a) $\frac{K+1}{2K}$ (b) $\frac{2K}{K+1}$ (c)$\frac{K}{K-1}$ (d) $\frac{K-1}{K}$

Case 2 A parallel plate capacitor consists of two conducting plates kept generally parallel to each other at a distance. When the capacitor is charged, the charge resides on the inner surfaces of the plates and an electric field is set up between them. Thus, electrostatic energy is stored in the t he figure shows three large square metallic plates each of side L held. parallel and equidistant from each other. The space between P1 and P2 and P2 and P3 is completely filled with mica sheets of dielectric constant K. The plate P2 is connected to point A and other plates P1 and P3 are connected to point B. Point A is maintained at a positive potential with respect to point B and the potential difference between A and B is V.



(i)The capacitance of the system between A and B will be :

(a) $\frac{\varepsilon_0 KL^2}{d}$ (b) $\frac{\varepsilon_0 KL^2}{2d}$ (c)$\frac{2\varepsilon_0 Kd}{L^2}$ (d) $\frac{2\varepsilon_0 KL^2}{d}$

(ii) The charge on the plate P_1 is:

(a) $\frac{\varepsilon_0 VKL^2}{2d}$ (b) $\frac{\varepsilon_0 VKL^2}{d}$ (c) $\frac{2\varepsilon_0 VKL^2}{d}$ (d) $\frac{\varepsilon_0 VKL^2}{4d}$

(iii)The electric field in the region between P1 and P2 is :

(a) $\frac{V}{d}$ (b) $\frac{2V}{d}$ (c) $\frac{V}{2d}$ (d) $\frac{d}{V}$

(iV) (a) The separation between the plates of same area (L^2) of a parallel plate air capacitor having capacitance equal to that of this system, will be :

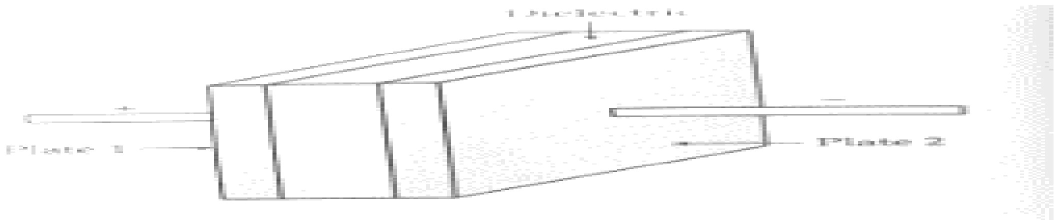
$(a)\frac{K}{d}$ (b) $\frac{2d}{K}$ (c) $\frac{d}{2K}$ (d) $\frac{d}{4K}$

OR

(b)If the source of potential difference applied between A and B is removed, and then A and B are connected by a conducting wire, the net charge on the system will be :

(a) $\frac{\varepsilon_0 VKL^2}{4d}$ (b) $\frac{\varepsilon_0 VKL^2}{4d}$ (c) $\frac{\varepsilon_0 VKL^2}{d}$ (d) zero

3.An arrangement of two conductors separated by an insulating medium can be used to store electric charge and electric energy. Such a system is called a capacitor. The more charge a capacitor can store, the greater is its capacitance. Usually, a capacitor consists of two conductors having equal and opposite charge +Q and -Q. Hence, there is a potential difference V between them. By the capacitance of a capacitor, we mean the ratio of the charge Q to the potential difference V. By the charge on a capacitor we mean only the charge Q on the positive plate. Total charge of the capacitor is zero. The capacitance of a capacitor is a constant and depends on geometric factors, such as the shapes, sizes and relative positions of the two conductors, and the nature of the medium between them. The unit of capacitance is farad (F), but the more convenient units are μF and pF. A commonly used capacitor consists of two long strips or metal foils, separated by two long strips of dielectrics, rolled up into a small cylinder. Common dielectric materials are plastics (such as polyestors and polycarbonates) and aluminium oxide. Capacitors are widely used in radio, television, computer, and other electric circuits.



1.A parallel plate capacitor C has a charge Q . The actual charge on its plates are

(a) Q,Q (b) Q/2, Q/2 (c) Q ,-Q (d) Q/2, -Q/2

2.A parallel plate capacitor is charged. If the plates are pulled apart .
(a) the capacitance increases (b) the potential difference increases
(c) the total charge increases same (d) the charge & potential difference remains

3.Three capacitors of 2 , 3 & 6 μF are connected in series to a 10 V source. The charge on the 3 μF capacitor is
(a) 5μC (b) 10μC (c) 12μC (d) 15μC

4.If n capacitors each of capacitance C are connected in series, then the equivalent capacitance of the combination is
(a) nC (b) n^2C (c) $\frac{C}{n}$ (d) $\frac{C}{n^2}$

LONG ANSWERS QUESTION

Q1. Two point charges 5 μC and -1 μC are placed at points (-3 cm, 0, 0) and (3 cm, 0, 0) respectively. An external electric field E= A/r ^{2}where A= 3 × 10^5 Vm is switched on in the region.

Calculate the change in electrostatic energy of the system due to the electric field.

(ii) A system of two conductors is placed in air and they have net charge of +80μC and -80μC which causes a potential difference of 16 V between them.

(1) Find the capacitance of the system.

(2) If the air between the capacitor is replaced by a dielectric medium of dielectric constant 3, what will be the potential difference between the two conductors?

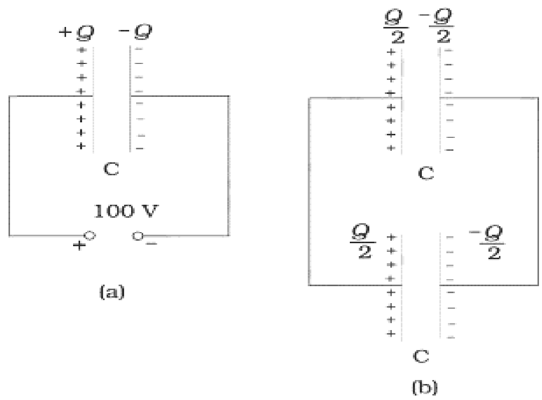
(3) If the charges on two conductors are changed to +160 μC and-160 μC, will the capacitance of the system change? Give reason for your answer.

Q2. (a)Compare the individual dipole moment and the specimen dipole moment for H2O molecule and O2 molecule when placed in (i) Absence of external electric field (ii) Presence of external electric field. Justify your answer.

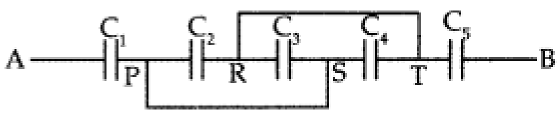
(b) Given two parallel conducting plates of area A and charge densities + σ & -σ. A dielectric slab of constant K and a conducting slab of thickness d each are inserted in between them as shown. (i) Find the potential difference between the plates. (ii) Plot E versus x graph, taking x=0 at positive plate and x=5d at negative plate

Q3 (a).Derive an expression for capacitance of parallel plate capacitor

(a) A 900 pF capacitor is charged by 100 V battery [Fig. (a)]. How much electrostatic energy is stored by the capacitor? (b) The capacitor is disconnected from the battery and connected to another 900 pF capacitor [Fig. (b)]. What is the electrostatic energy stored by the system?



Q4 Find equivalent capacitance between A and B in the combination given below. Each capacitor is of 2 μF capacitance



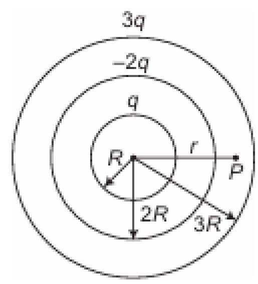
(ii) If a dc source of 7 V is connected across AB, how much charge is drawn from the source ?

Q5 (a) A camera usually operates at 1.5 V and this potential difference is not sufficient to emit light energy using flash. For this purpose, the flash circuit of the camera has a capacitor that is charged to 300 V-330 V using various electrical components. If the voltage generated across the plates of the capacitor is 300 V and the capacitance of the parallel plate capacitor used is 100 μF, then find the energy released when the trigger button on the camera is pressed.

(a) How much charge does the 100 μF capacitor charged to 300 V hold?

(b) If the distance between the parallel plate capacitor of capacitance 100 μF is increased two times, then calculate the capacitance of the capacitor.

(c) Three conducting spherical shells have charges q -2q and 3q as shown in the figure. Find electrostatic potential at point P as shown in the figure



ANSWERS MCQ 1(MARK)

Ans 1-a 2-c 3-c 4-d 5-d, 6-a 7-c 8-d ,9-d 10-b

ANSWER ASSERTION AND REASONING 1

Ans 1-a 2-B 3-B 4-C 5-A,

VSA ANSWERS (2 MARKS)

Ans-1 total potential at point B $V = V_1 + V_2 = k[\frac{2X10-9}{2} + \frac{q}{8}]$

Net potential is 0 hence $0 = k[\frac{2X10-9}{2} + \frac{q}{8}]$ by solving $q = -8X10^{-9}C$

Ans2 Net potential energy$=U_{12}+U_{13}+U_{23} = k(\frac{q.2q}{a}+\frac{q.3q}{a}+\frac{2q.3q}{a}) = 11kq^2/a$

Ans 3 concept when two conductor are connected than total charge remains constant flow of charges till potential remains constant $q_1+q_2=q_A+q_B=Q$

After connection potential remains constant $V_1=V_2$ which implies $\frac{q_A}{r_1} = \frac{q_B}{r_2}$

From conservation of charge $q_1+q_2=q_A+q_B$

$q_1+q_2=q_A+\frac{qr2}{q1}$ by solving $q_A = \frac{(q_1+q_2)r_1}{r_1+r_2}$ similarly $q_B = \frac{(q_1+q_2)r_2}{r_1+r_2}$

ANS-4(a) $\Theta=0$ U=-PE (b) $\Theta=180$ U=PE

Ans 5

$V_A-V_B=kQ(\frac{1}{OA} - \frac{1}{OB})$ As OA<OB, so the quantity within bracket is negative.
(i) If Q positive charge than V_A-V_B is negative

(ii) If q is negative charge, $V_A - V_B$ = positive

Ans 6 E=-dv/dr 0=-dv/dr v= constant

Ans 7 $\Delta U = -W_{i-f} = -qE_0\ (2a\_a) = -qE_0a$ work done Here,

work done by electrostatic force is positive. Hence, the potential energy is decreasing

Ans 8: line B corresponds to C1

Reason: Since slope (q-v) of 'B' is less than that of 'A'

Ans 9 no work is done

[$W = q\ V_{AB} = q \times 0 = 0$, since potential remains constant]

Potential at P due to charge q_1 is $V_1=\frac{kq_1}{AP}$ Potential at P due to charge q_1 is $V_2=\frac{kq_2}{BP}$

Potential at P = 0 $\frac{kq_1}{AP} + \frac{kq_2}{BP} = 0$

by soving x=(5/12)m

Ans 10.slope E=-10/2 =5from 0 to 2m E=10/2 =5from 4 to 6 between 2 to 4 is zero.

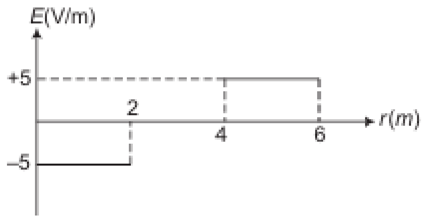


Fig. 24.36

SHORT ANSWER QUESTION (3MARKS)

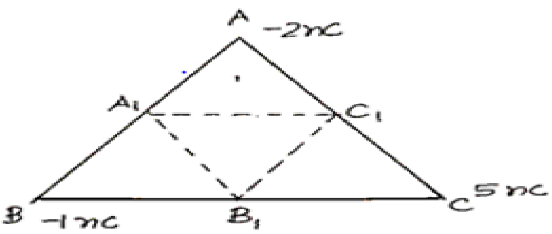
ANS 1 (a)

In diagram it represent capacitor is partially filled with dielectric by formula $C=\varepsilon_o A/(d-t+t/K)$ putting t=d/2 we get $C=2K\,\varepsilon_o A/[d(2K+1)]$

(b)it represent two capacitor connected in parallel with area of cross section is A/2

$C= K\varepsilon_o A/(2d) + \varepsilon_o A/(2d)= \varepsilon_o A(K+1)/(2d)$

Ans 2



Ui=k[qA.qB/AB + qc.qB/BC+ qA.qC/CA]=

By solving Ui=-5.85×10^{-7}J similarly Uf=-11.7×10^{-7}J

Change in potential energy=Uf-Ui=5.85×10^{-7}J

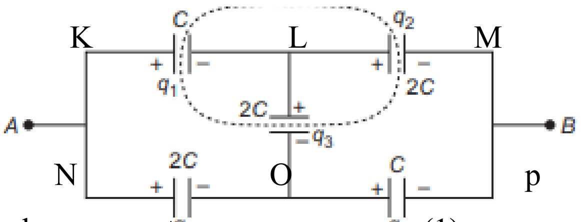
ANS 3 For 12 chages potential is V=-12kq/r

ANSWER 4

$U=1/2CV^2$=7.2Mj After connection Net $C=C_1+C_2=200\mu F$ common potential is V'=V/2

So new potential energy is Uf=1C'(V')/2 =3.6mJ.

Ans 5 by applying kirchhoff's rule



Net charge $q=q_1+q_2$ ………………..(1)

In loop KLONK $\frac{-q_1}{C} + \frac{-q_3}{2C} + \frac{-q_2}{2C}$ =0 or $-2q_1-q_3-q_2=0$

In loop lmop $\frac{q_1 - q_3}{2c} + \frac{q_2 + q_3}{c} + \frac{q_3}{2c} = 0$

Solving these three equations, we have $q_1=\frac{2q}{5}$ $q_2=\frac{3q}{5}$ $q_3 = \frac{q}{5}$

Now, let Ceq be the equivalent capacitance between A and B. Then,

$V_A-V_B=\frac{q}{C_{eq}} = \frac{-q_1}{C} + \frac{q_1 - q_3}{2c} = \frac{7q}{10}$ $C_{eq}=\frac{10C}{7}$

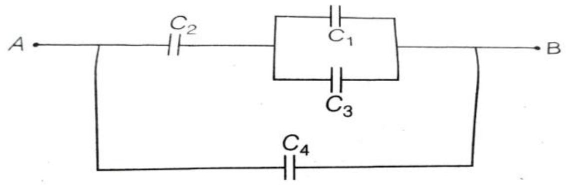
ANS 6

Common potential is $V=\frac{C_1V_1+C_2V_2}{C_1+C_2}$

$C_2=2C1$ $V=V_1/3$ Ceq=3C

$U_f/U_i= (0.5)C_{eq}V^2 /(0.5)CV_1^2=1/3$

ANS 7 Simplified circuit is



By solving net capacitance is 10 µF

Ans 8

C_{123} = 4µF (being in series)

Ceq = C_{123} + C_4 =16µF

(i) $Q_1 = C_4V= 12X\ 10^{-6}\ X(500/3\ ) =6\ X\ 10^{-3}$

(ii) $Q_2 = C_{123}\ V= 4X\ 10^{-6}\ X500= 2\ X\ 10^{-3}$ C

(iii) Charge on each of the capacitors C_1 ,C_2 ,C_3 = $2\ X\ 10^{-3}$ C

Ans:9 Given : CA= CB = C , Dielectric costant = K

Energy stored = 1/ 2 Cv^2

Net capacitance with switch S closed = C+C= 2C E1= Energy stored = CV^2

After switch S is opened, capacitance of each capacitor = KC

'Energy stored in capacitor A = 1/ 2 kCV^2 (iii)

For capacitor B, Energy stored = $CV^2/\ 2k$ (iv)

From equations (iii) & (iv) E2 = Total energy stored = 1 (k^2+1) /2k CV^2

Required Ratio = $E1/\ E2 = 2k/\ k^2+1$

ANS 10.Given VA= 90V, C1 = 20µF, C2 = 30µF and C3= 15µF

Since these capacitors are connected in series, net capacitance will be 1 c= 1/ 20+1/ 30+1/ 15= 20 /3 µF

Charge on each capacitor q = CV =600µC

Potential difference across the capacitor C2 V2 =q C2 =600 30 =20V

Energy stored in capacitor across C2 E2= 6000J

CASE BASED QUESTION

Ans ANS i(a) Ansii(b) Ans iii(c) Ans iv (d) or (b)

ANS 2

ANS i(C) Ansii (c) Ans iii(a) Ans iv (c) or (b)

ANS 3 4

ANS i(C) AnSii(B) Ans iii(B) Ans iv (c)

LONG ANSWER QUESTION

Ans (1)(a)dV=-Edr $V=3X10^5/r$

potential energy formula in absence of electric field$U_i=kq_1q_2/r$

Electrostatic potential energy in presence of the field $U_f = kq_1q_2/r+q_1V(r1)+ q_2V(r2)$

Change in potential energy= $q_1V(r_1)+ q_2V(r_2)$

By putting value $\Delta U=40J$

(b)C=Q/V=80/16=5μF

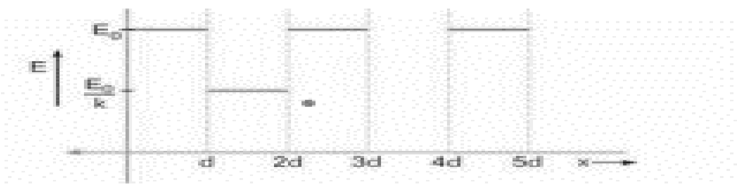
(c)C'=KC C'=3X5 =15 μF

V'=Q/C'=80 μC/15 μF=5.33V

(d)No the capacitance depends on geometry

ANS 2 A

Absence of electric field (1)	Non-Polar (O_2)	Polar molecule (H_2O)
Individual Specimen	No dipole moment exists No dipole moment exists	Dipole dipole moment exists Dipoles are randomly oriented. Net P=0
Dipoles are randomly oriented. Net P=0		
Individual	Dipole moment exists (molecules become polarised)	Torque acts on the molecules to align them parallel to E
Specimen	Dipole moment exists	Net dipole moment exists parallel to Dipole moment exists E.



ANS 3The charge on the capacitor is $Q = CV = 900 \times 10^{-12}$ F × 100 V = 9×10^{-8} C

The energy stored by the capacitor is = $\frac{CV^2}{2}$ = 4.5 × 10^{-6} J

(b)In the steady situation, the two capacitors have their positive plates at the same potential, and their negative plates at the same potential. Let the common potential difference be V'. The charge on each capacitor is then Q = CV'. By charge conservation, Q' = $\frac{Q}{2}$

This implies V = V/2.

The total energy of the system is = 2X $\frac{Q'V'}{2}$= 2.25 X10^{-6} J

Thus in going from (a) to (b), though no charge is lost; the final energy is only half the initial energy

ANS 4

C2,C3 and C4 are in parallel C_{234}=2+2+2=6μF

C_1,C_{234} and C_5 are connected in parallel=$\frac{1}{2}+\frac{1}{6}+\frac{1}{2}=\frac{6}{7}$ μF

Charge drawn from the source=$\frac{6X7}{72}$=6 μC

Ans5 (i) Q=CV=300X100X10^{-6}=3X10^{-2}C

(ii)C,= $\frac{C}{2}$ =50 μF

(iii) $V_P=V_q+V_{-2q}+V_{3q}=k(\frac{q}{r}+\frac{-2q}{r}+\frac{-3q}{3R})$

CHAPTER 3

CURRENT ELECTRICITY

Current Electricity

Electric Current
- $I = \frac{q}{t} = \frac{ne}{t}$
- In case of an electron revolving in a circle of radius r with speed v, period of revolution is $T = \frac{2\pi r}{v}$
- Frequency of revolution $\nu = \frac{v}{2\pi r}$
- Current at any point of the orbit is $I = \frac{e}{T} = \frac{ev}{2\pi r}$

Electric Power
$P = VI = I^2 R = \frac{V^2}{R}$

Variation of Resistance with Temperature
- Temperature coefficient of resistance, $\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$

If $T_1 = 0°C$ and $T_2 = T\,°C$ then $\alpha = \frac{R_T - R_0}{R_0 \times T}$ or $R_T = R_0(1 + \alpha T)$

Ohm's Law, Resistance and Resistivity
- $V = IR$
- Resistance of uniform conductor of length l and cross sectional area A, $R = \frac{\rho l}{A}$
- Resistivity or specific resistance, $\rho = \frac{RA}{l}$
- Effective specific resistance in series combination is $\frac{\rho_1 l_1 + \rho_2 l_2}{l_1 + l_2}$ (A is same).
- Effective specific resistance in parallel combination is $\frac{(A_1 + A_2)\rho_1\rho_2}{A_1\rho_2 + A_2\rho_1}$ (l is same).

Kirchhoff's Laws
- Law of conservation of charge applied at a junction, *i.e.*, $\Sigma I = 0$
- Law of conservation of energy applied in closed loop, *i.e.*, $\Sigma \varepsilon = \Sigma IR$

Combination of Resistances
- In series, equivalent resistance, $R_s = R_1 + R_2 + R_3 + ...$
- In parallel, equivalent resistance, $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$
- For two resistances in parallel current through the two resistances will be, $I_1 = \frac{R_2 I}{R_1 + R_2}$, $I_2 = \frac{R_1 I}{R_1 + R_2}$
- When resistances are connected in series, the current through each resistance is same. In parallel combination voltage is same.

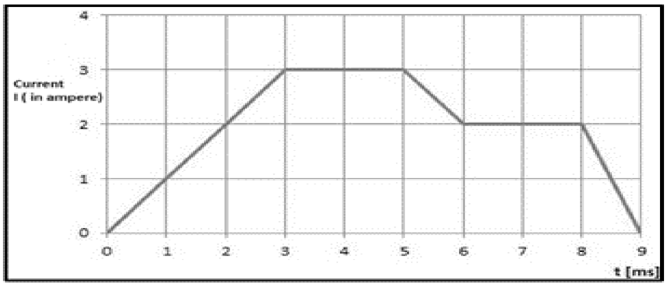
Current Density, Conductance and Conductivity
- Conductance, $G = \frac{1}{R}$
- Conductivity, $\sigma = \frac{1}{\rho} = \frac{l}{RA}$
- Current density, $j = \frac{I}{A} = \sigma E = nev_d$

Drift Velocity and Mobility of Charge
- Drift speed, $v_d = \frac{eE}{m}\tau$
- Mobility, $\mu_e = \frac{v_d}{E}$
- Current in terms of drift velocity, $I = neAv_d = \frac{ne^2 A\tau E}{m} = neA\mu_e E = neA\mu_e \frac{V}{l}$
- In terms of relaxation time τ, $R = \frac{ml}{ne^2\tau A}$ and $\rho = \frac{m}{ne^2\tau}$

Emf, Internal Resistance, Current in case of Grouping of Cells
- Emf of a cell, $\varepsilon = \frac{W}{q}$
- Terminal potential difference where current is being drawn from the cell, $V = \varepsilon - Ir$
- Terminal potential difference when the cell is being charged $V = \varepsilon + Ir$
- Internal resistance of a cell, $r = R\left[\frac{\varepsilon - V}{V}\right]$
- Grouping of identical cells:
  - Cells in series, $I = \frac{n\varepsilon}{R + nr}$ (n cells)
  - Cells in parallel, $I = \frac{m\varepsilon}{mR + r}$ (m cells)
  - Cells in mixed grouping, $I = \frac{mn\varepsilon}{mR + nr}$

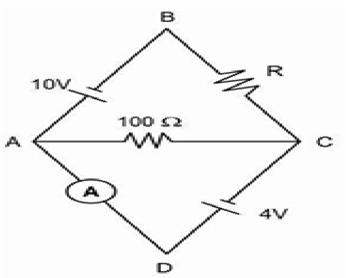
MCQ EACH 1 MARKS

1. The current passing through a wire varies with time as provided below.



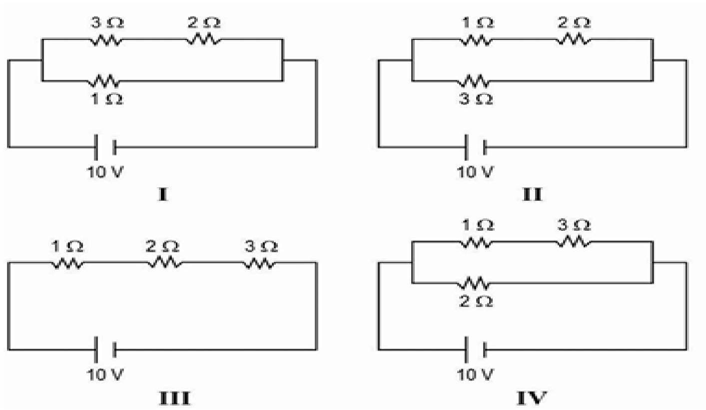
The charge passing through the wire from 0s to 5s is:
(a) 12.5 mC (b) 9 mC (c) 4.5 mC (d) 10.5 mC

2. If the ammeter reading in the given circuit is zero, find the value of the resistance R.



(a). 50 ohm (b). 100 ohm (c). 150 ohm (d).200 ohm

3.Which combination of the three resistors will dissipate maximum power from a 10V battery?



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

4. A cell of emf 2V, when short circuited gives a current of 4A. What is the internal resistance of the cell in ohm

(a) 0.5 (b) 1.0 (c) 2.0 (d) 4.0

5. When a current of 0.2 A is drawn from a battery then the potential difference between its terminals is 20V and when a current of 2A is drawn, then the potential difference drops to 16V. The emf of the battery is

(a) 15.1V (b) 20.4V (c) 18.9V (d) 23.3V

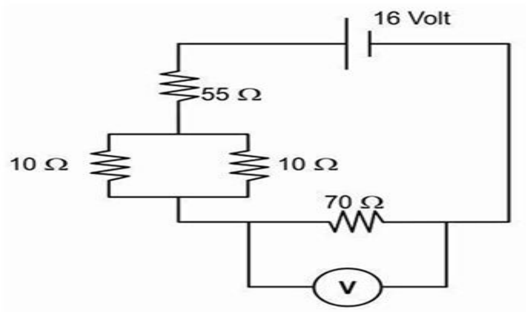
6. If two identical cells when connected in series or in parallel, supply the same amount of current through an external resistance of 2Ω, the internal resistance of the cell is

(a) 8 Ω (b) 2 Ω (c) 4 Ω (d) 1 Ω

7. If percentage change in current through a resistor is 1%, then the change in power through it would be

(a) 1% (b) 2% (c) 1.7% (d) 0.5%

8. If the voltmeter in the given circuit reads 8 V, what is the resistance of the voltmeter?



(a). 70/4119 Ω (b). 70 Ω (c). 420 Ω (d). 4200 Ω

9. A metal rod of length 10 cm and a rectangular cross-section of 1cm x 0.5 cm is connected to a battery across opposite faces. The resistance will be

(a) Maximum when the battery is connected across 1cm x 0.5 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 0.5 cm faces.

(d) Same irrespective of the three faces.

10. According to Kirchhoff's Loop Rule

(a) The absolute sum of changes in potential around any closed loop must be zero.

(b) The algebraic sum of changes in potential around any closed loop must be zero.

(c) The algebraic sum of changes in potential around any closed loop must be positive.
(d) The algebraic sum of changes in potential around any closed loop must be negative.

ANSWER OF MCQs

1	**d**	**2**	**C**	**3**	**a**	**4**	**a**	**5**	**b**
6	**b**	**7**	**B**	**8**	**c**	**9**	**a**	**10**	**b**

A&R EACH 1 MARKS

1. ASSERTION: Voltmeter always gives emf of a cell if it is connected across the terminals of a cell.
REASON: Terminal potential of a cell is given by V = E + ir.

2.ASSERTION: A domestic electrical appliance, working on a three-pin will continue working even if the top pin is removed.
REASON: The third pin is used only as a safety device.

3.ASSERTION: Insulators do not allow flow of current through them.
REASON : Insulators have no free charge carrier.

4. ASSERTION: When the length of a conductor is doubled; its resistance will also get doubled.
REASON: Resistance is directly proportional to the length of a conductor.

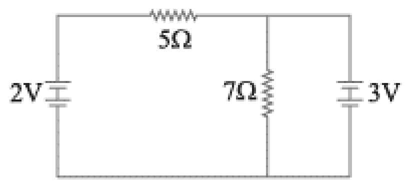
5. ASSERTION: The internal resistance of cell is constant.
REASON: Ionic concentration of the electrolyte remains same during use of cell

ANSWER OF A&R

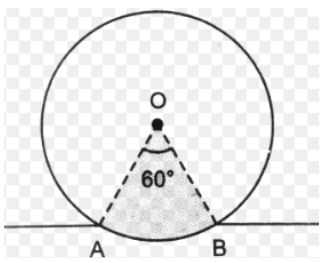
1	**d**	**2**	**a**	**3**	**a**	**4**	**a**	**5**	**d**

SAQ-I EACH 2 MARKS

1. Two resistance 5Ω and 7Ω are joined as shown to two batteries of emf 2V and 3V. If the 3V battery is short circuited. What will be the current through 5Ω.



2. A uniform wire of resistance R ohm is bent into a circular loop as shown in the figure. Compute effective resistance between points A and B.



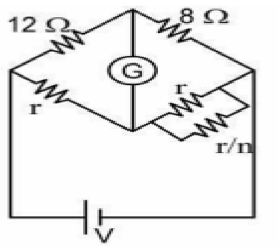
3. The charge is flowing in a conductor varies with time as, $\mathbf{q = at + bt^2/2 + ct^3/6}$

Where a, b, c are positive constants. Find current at t=0.

4.A battery of 6 V drives a current of 60 mA through an electric lamp. Another battery of 10 V drives a current of 70 mA through the same lamp. Is the lamp an ohmic device? Explain.

5. Under what condition will the current in the wire be same when connected in series and in parallel of an identical cell having internal resistance r and external resistance R?

6.A Wheatstone's bridge employs 5 resistors as shown. Find the value of n that will ensure that the bridge is always in a balanced condition, irrespective of the value of r.

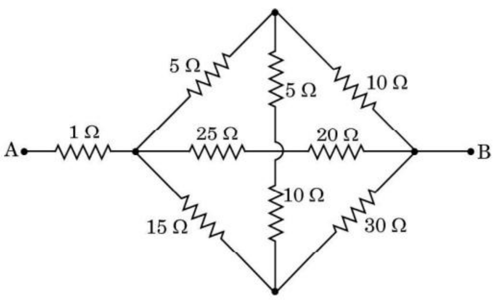


7.Accelerated alpha particles, constituting a beam current of 0.64 mA, are released by a cyclotron onto a target. Find the number of alpha particles that strike the target in one second.

8. 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.

9. 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?*

10. Find the equivalent resistance between points A and B for the network shown in the figure.



Answers:

1. I = 2/5 A **2.** 25R/18 **3**. a

4. Resistance of the circuit in the first case = V/I = 6/60 x 10^{-3} = 100 ohm

Resistance of the circuit in the second case= V/I = 10/70 x 10^{-3} = 142.8 ohm

The resistance represents the slope of V-I graph for the circuit and form the above calculation, it doesn't remain constant. It implies that VI graph is not a straight line. Hence the lamp used in the circuit is a non-ohmic device.

5. r=R **6.** n = ½

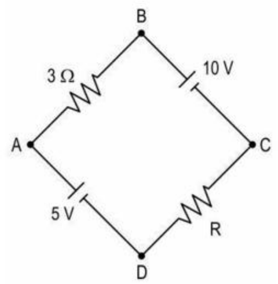
7. Current I = nQ/t = n x 2e/1

2 x 10^{15} alpha particles

8. Ans. 1.7 V, 0.12 Ohm **9.** 2R **10.** R_{eq} = 10 ∧

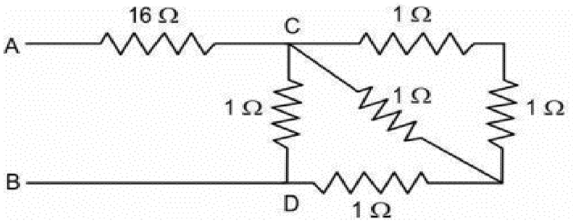
SAQ-II EACH 3 MARKS

1.Determine the value of R in the given network for each of the conditions separately.



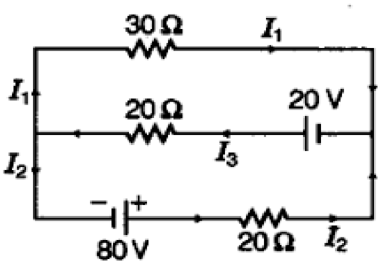
(a) If VB – VD = 8 V
(b) If VA - VC = 8 V

2. In the given network of resistors, the 16-ohm resistor burns out as soon as it begins to dissipate 100 W of power.

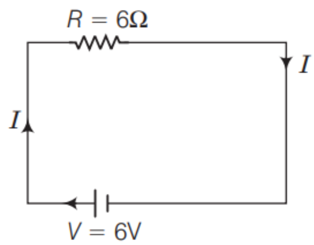


What MAXIMUM voltage can be applied across terminals A and B, in order to void the burn out of the 16-ohm resistor?

3. Use Kirchhoff's rule to determine the value of the current I_1 flowing in the circuit shown in the figure.

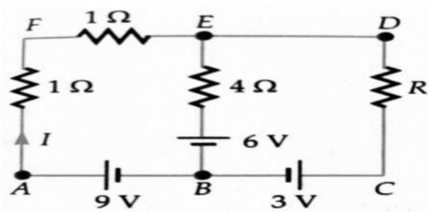


4. (a) Consider circuit in figure. How much energy is absorbed by electrons from the initial state of no current (Ignore thermal motion) to the state of drift velocity?



(b) Electrons give up energy at the rate of RI^2 per second to the thermal energy. What time scale would number associate with energy in problem (a)? n = number of electron/volume = 10^{29} / m^3. Length of circuit = 10 cm, cross-section= = A (1 mm)^2.

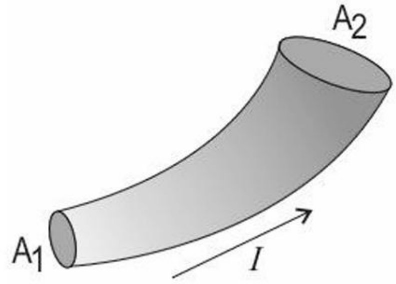
5. Using Kirchhoff's rules determine the value of unknown resistance R in the circuit shown, so that no current flows through 4Ω resistance. Also find the potential difference between A and D.



6. The resistance of a tungsten filament at 150 ^{0}C is 133 Ω. What will be its resistance at 500^{0}C? Given the temperature coefficient of tungsten is 0.0045/0C.

7. For a current-carrying conductor of changing diameter as shown below, how does each of the following quantities vary along the two ends of conductors with area of cross sections A_1 and A_2 ? Give an explanation for each.

(a) Current (b)Current density (c)Resistance



8.(a) Draw the graph showing variation of resistivity with temperature in case of a (i) metal (ii) semiconductor

(b) Consider the contribution of the following two factors I and II in resistivity of a metal: Relaxation time of electrons and Number of electrons per unit volume. Explain why resistivity of a metal increases with increase in temperature considering the effect of temperature on the two factors mentioned.

(c) When electrons drift in a conductor from lower to higher potential, does it mean that all the free electrons of the conductor are moving in the same direction?

9. What is the difference between emf and terminal voltage of a cell. Two cells of emfs E1 and E2 and internal resistances r1 and r2 are connected in parallel. Derive an expression for the emf and internal resistance of the equivalent cell.

10. A dimmer is a device that is connected to a light bulb and is used to lower the brightness of the light from the bulb. It introduces a resistance in series with the bulb for this purpose. A 44 W bulb in a household circuit is connected across a 220 V power supply.

(a) How much current does the bulb draw initially without the dimmer in action?

(b) What resistance in series would the dimmer introduce in order to drive a current of 0.1 A through this bulb?

Answers/Hints:

1. (a) 2 ohm (b) 9/2 ohm

2. 41.5 Volt

3. I_1 = -3/4 A, I_2 = 23/8 A, I_3 = 17/8 A

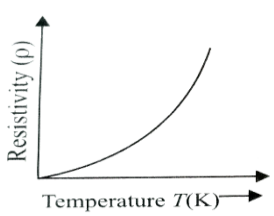
4. a) E=2 x 10^{-17} J (b) t= 10^{-17} s

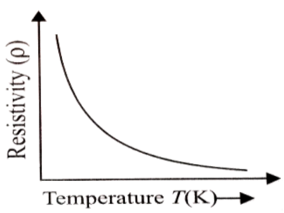
5. R=2 Ohm, V=3 Volt

6. 258 Ohm

7. Current : It remains the same along the length of the conductor. This is as per Kirchhoff's junction rule. Charge cannot collect at any point along the length of the conductor Current density J varies inversely with area cross section of the conductor. As $J = I/A$, more the area cross section, less is the current density, for a constant current through the conductor Resistance varies inversely with area cross section of the wire. R of the wire at broader parts will be lesser than along narrower part.

8. (a)





(b) With increase in temperature, relaxation time decreases and number of electrons per unit volume is almost constant.

(c) No, it doesn't mean all free electrons move in the same direction. While there is a net drift of electrons toward higher potential, individual electrons also move randomly due to thermal motion.

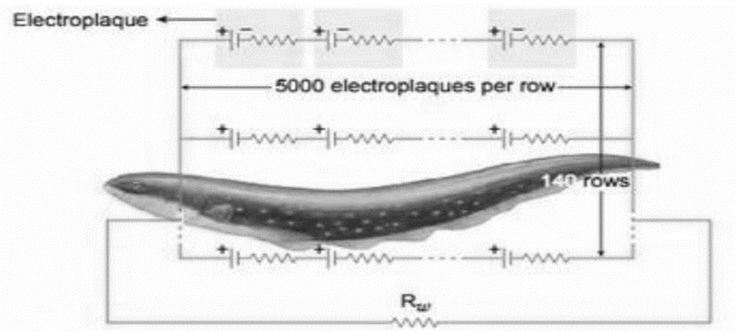
9. 1. Potential difference between the terminals of a cell in open circuit is emf and in closed circuit it is terminal voltage.
2. An emf does not depend on the external resistance, while terminal voltage depends on external resistance.
3 Derivation of $E = (E_1r_2 + E_2r_1)/(r_1+r_2)$
$r=(r_1\ r_2)/\ r_1 + r_2$
10. (a) Initially, without any dimmer in action, current through the bulb: $I = P/V = 44/220 = 1/5 = 0.2$ A

(b) Resistance of the bulb: $R = V^2/2 = 220^2/44 = 1100$ ohm
With the introduction of the resistance in series by the dimmer, $R = 220 /(0.1) = 2200$ ohm
But $R = R_1 + R_2$. From here, $R_2 = 1100$ ohm.

CASE BASED QUESTIONS EACH 4 MARKS

1. The materials can be classified as conductors, semi-conductors and insulators depending on their resistivities. Metals have low resistivities in the range of $10^{-8}\Omega$m. At the other end are insulators like ceramic, rubber and plastics having resistivities 10-18 times greater than metals or more. In between these two are semiconductors. These however have resistivities characteristically decreasing with a rise in temperature. The resistivities of semiconductors can be decreased by adding small amount of suitable impurities. This last feature is exploited in use of semiconductors for electronic devices.
(a) The resistivity of a semiconductor decreases from 2.5 Ω·m to 0.5 Ω·m when heated. Calculate the percentage decrease in resistivity.
(i) 20% (ii) 40% (iii) 60% (iv) 80%
(b) The temperature of coefficient of resistance is negative for
(i) Copper (ii) Gold (iii) Carbon (iv) Silver
(c) The resistance of a wire at 20^0C is 20Ω and at 500^0C it is 60Ω. At what temperature the resistance is the temperature is 25Ω
(i) 160^0C (ii) 250^0C (iii) 100^0C (iv) 80^0C
(d) The product of resistivity and conductivity of a conductor depends on
(i) Area of cross section (ii) Temperature (iii) Length (iv) None of these

2. Electric fish are able to generate current with biological cells called electroplaques, which are physiological emf devices. The electro-plaques in the South American ell shown in the photograph that opens this chapter are arranged in 140 rows, each row stretching horizontally along the body and each containing 5000 electro-plaques. The arrangement is suggested in figure each electro-plaque has an emf (E) of 0.15V and an internal resistance (r) of 0.258. The water surrounding the eel completes a circuit between the two ends of the electroplaque array, one end at the animal's head and the other near its tail.



(i) If the water surrounding the eel has resistance R, = 800 9 how much current can the eel produce in the water?

(a) 6.6 mA (b) 0.93 A (c) 6.6 A (d) 9.3 mA

(ii) If the cell has on emf of 4 V and the internal resistance of this cell is 0.2 2, it is connected to resistance of 3.8 2, terminal voltage through the cell will be

(a) 3.8 V (b) 4 V (c) 0.2 V (d) 1.8 V

(iii) 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 0, the
internal resistance of cell is

(a) 1ohm (b) 2 ohm (c) 4 ohm (d) 8 ohm

(iv) A group of girls connected 10 identical cell first in series and then in parallel across a bulb of resistance 50 R and they see that the reading of the ammeter 1 A in both cases. Then the internal resistance of any one cell will be

(a) 100 ohm (b) 50 ohm (c) 10ohm (d) 5 ohm

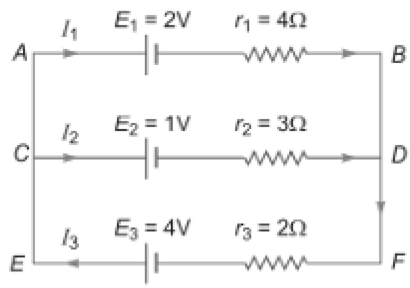
3. Tim is a music enthusiast who wishes to create good sound effects for his stereo system using his two sets of speakers at home. The first set consists of two speakers of resistance 10 Ω each.
The second set consists of two speakers with resistances 5 Ω and 10 Ω respectively. Initially, he connects the first set of two 10 Ω speakers in series to the 10 V stereo output. Later, he connects the second set of speakers such that each of them is parallel to the first set of speakers.

(a) What is the current through each of the 10 Ω speakers BEFORE the second set of speakers were connected?

(b) What is the new current through each of the 10 Ω speakers AFTER the second set of speakers are connected?

(c) If the loudness of the music is directly proportional to the amount of power used by the speaker, how has the loudness of the first set of speakers changed due to the introduction of the second set of speakers?

(d) What is the impact of connecting the second set of speakers in the circuit here?



Answers:

1: (a) (iv) (b) (iii) (c) (iv) (d) (iv)

2: (i) (b) (ii) (a) (iii) (a) (d) (b)

3: (a) 0.5 A (b) No changes

(c) Additional power is dissipated through the two speakers of the second set

LONG ANSWER QUESTION EACH 5 MARKS

1.(i) Two metal wires A and B of same material, same length and same diameter are kept at different temperatures. Wire A is at room temperature (25°C), and wire B is heated to 200°C. Which wire has a greater relaxation time? Justify your answer conceptually.

(ii) A copper wire of cross-sectional area 1 mm^2 carries a current of 3 A. The number density of free electrons in copper is approximately 8.5×10^{28} electrons/m^3. The mass of an electron is 9.1×10^{-31} kg, and the charge of an electron is 1.6×10^{-19} C.

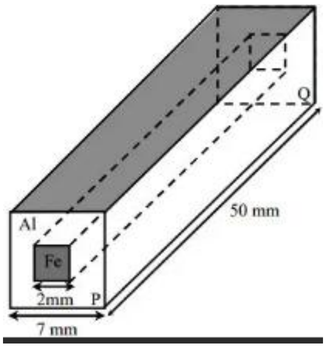
(a) Calculate the drift velocity of electrons in the wire.

(b) If the average relaxation time (τ) for electrons in copper is 2.5×10^{-14} s, calculate the resistivity of copper using this data.

2. 20 cells each of internal resistance 0.5 ohm and emf 1.5 V are used to send a current through an external resistance of (i) 500 ohm (ii) 0.005 ohm (iii) 2.5 ohm. How would you arrange them to get the maximum current in each case? Find the value of current in each case.

3. A cell of emf 2 V and internal resistance 0.1 ohm supplies a current through a coil of resistance 11.9 ohm. The current is being measured by an ammeter whose resistance is 6 ohm. What reading does it give ? What is the percentage difference from the actual current, when the meter is not used?

4.In an aluminium (Al) bar of square cross-section,a square hole is drilled and is filled with Iron (Fe)as shown in the figure, The electricalresistivities of Al and Fe are 2.7×10^{-8} ohm-m and1.0×10^{-7} ohm-m, respectively. Calculate electrical resistance between two faces P and Q of the composite bar.



5. State Kirchhoff's rules. Use these rules to write the expressions for the currents I1, I2 and I3 in the circuit diagram shown.

Answers:

1. (i) Wire A has a greater relaxation time.
(ii) (a) 2.21×10^{-4} m/s , (b) 1.67×10^{-8} ohm-m
2. (i) Cells are to be connected in series ; 0.059 A (ii) Cells are to be connected in parallel; 50.0 A (iii) Cells are to be connected in mixed grouping ; 2 rows in parallel and 10 cells in series in each row, 3.0 A]

3. 0-11 A ; 33-3%

4. $1875/64 \times 10^{-6}$ ohm

5. 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.,*
$\sum V=0$
$I_3 = I_1 + I_2$ ……(i)
$-2-4I_1 + 3I_2 + 1 = 0$
$4I_1 - 3I_2 = -1$ ……(ii)
$-2-4I_1-2I_3+4=0$
$4I_1+2I_3=2$ OR $2I_1 + I_3=1$
$3I_1+I_2=1$
$I_1= (2/13)$ A, $I_2= (7/13)$ A, $I_3= (9/13)$ A

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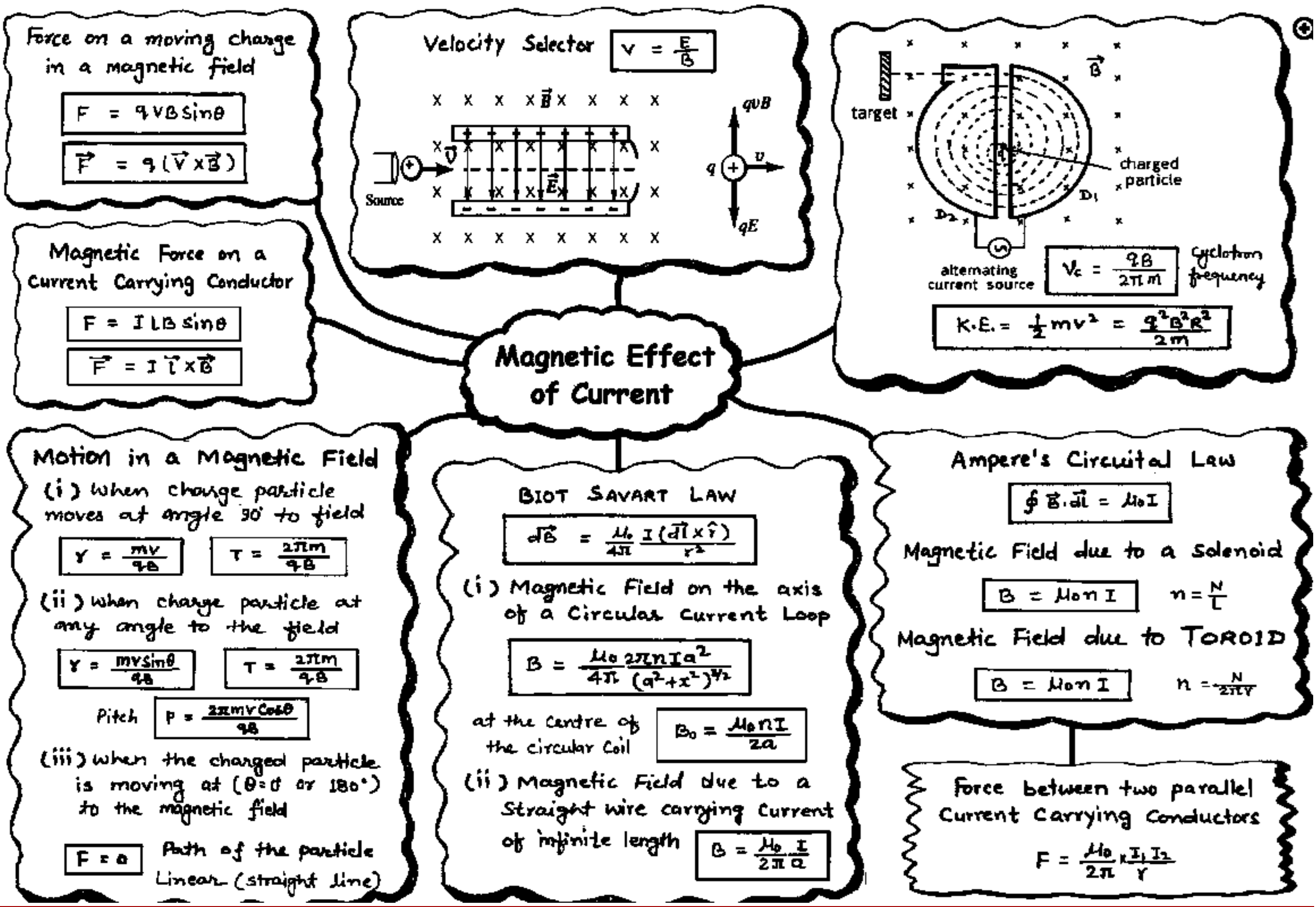
CHAPTER 4

MOVING CHARGES AND MAGNETISM



MULTIPLE CHOICE QUESTIONS:

1. If an electron is moving with velocity v produces a magnetic field *B* then-

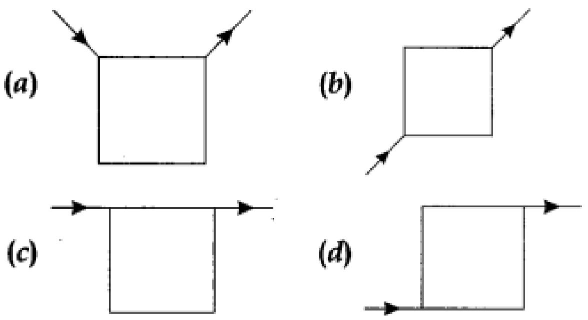
(a) the direction of field *B* will be same as the direction of velocity *v*.

(b) the direction of field *B* will be opposite to the direction of velocity *v*.

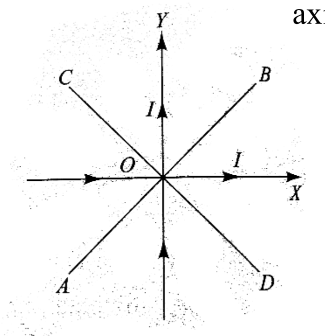
(c) the direction of field *B* will be perpendicular to the direction of velocity *v*.

(d) the direction of field *B* does not depend upon the direction of velocity *v*

2. Current flows through uniform, square frames as shown in the figure. In which case is the magnetic field at the centre of the frame not zero?



3. There are two straight long wires, insulated from each other, along X and Y axis carrying equal currents as shown in figure. AB and CD are lines in X-Y plane and at 45° with the axes. The magnetic field of the system is zero at points on the line



(a) AB (b) OB but not on OA

(c) CD (d) OC but not on OD

4. A proton moving with a constant velocity passes through a region of space without any change in its velocity. If E and B represent the electric and magnetic fields, respectively. Then, in this region of space which of these is not possible

(a) $E = 0, B = 0$ (b) $E = 0, B \neq 0$ (c) $E \neq 0, B = 0$ (d) $E \neq 0, B \neq 0$

5. Consider a wire carrying a steady current, I placed in a uniform magnetic field B perpendicular to its length. Consider the charges inside the wire. It is known that magnetic forces do no work. This implies that,

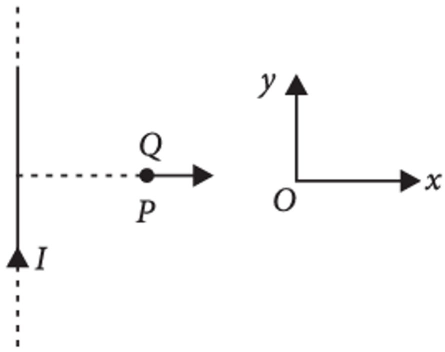
(a) motion of charges inside the conductor is unaffected by B since they do not absorb energy.

(b) some charges inside the wire move to the surface as a result of B.

(c) if the wire moves under the influence of B, no work is done by the force.

(d) if the wire moves under the influence of B, no work is done by the magnetic force on the ions, assumed fixed within the wire.

6. A very long straight wire carries a current I. At the instant when a charge $+Q$ has velocity v, as shown, the force on charge is



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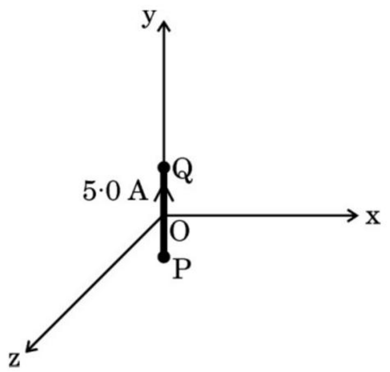
(a) Along Oy *(b)*Opposite to Oy *(c)*Along Ox *(d)*Opposite to Ox

7. An electron is projected with uniform velocity along the axis of a current carrying long solenoid. Which of the following is true?
(a) The electron will be accelerated along the axis.
(b) The electron path will be circular about the axis.
(c) The electron will experience a force at 45° to the axis and hence execute a helical path.
(d) The electron will continue to move with uniform velocity along the axis of the solenoid

8. A 2.0 cm segment of wire, carrying 5.0 A current in the positive y-direction lies along y-axis, as shown in the figure. The magnetic field at a point (3 m, 4 m, 0) due to this segment (part of a circuit) is:



(a) (0.12 nT) $\hat{j}$ (b) $-(0.10\ \text{nT})\hat{j}$ (c) $-(0.24\ \text{nT})\hat{k}$ (d) $(0.24\ \text{nT})\hat{k}$

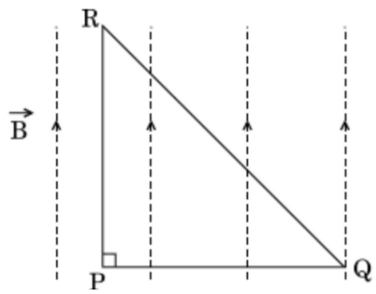
9. A circular loop of wire, carrying a current '*I'* is lying in *xy*-plane with its centre coinciding with the origin. It is subjected to a uniform magnetic field pointing along +*z*-axis. The loop will:

(A) move along *x*-axis (B) move along –*y*-axis
(C) move along *z*-axis (D) remain stationary

10. A long wire carrying a steady current is bent into a circular loop of one turn. The magnetic field at the centre of the loop is *B*. It is then bent into a circular coil of *n* turns. The magnetic field at the centre of this coil of *n* turns will be:

(a) nB (b) n^2B (c) $2nB$ (d) $2n^2B$

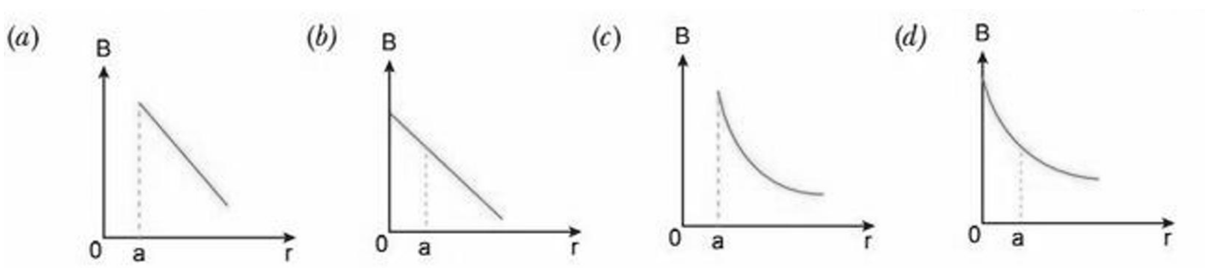
11. An isosceles right angled current carrying loop *PQR* is placed in a uniform magnetic field *B* pointing along *PR*. If the magnetic force acting on the arm *PQ* is *F*, then the magnetic force which acts on the arm *QR* will be



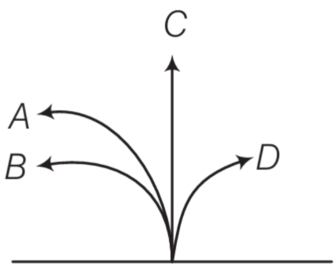
(a) F (b) $\sqrt{2}F$

(c) $\frac{F}{\sqrt{2}}$ (d) $-F$

12. Which of the following graphs correctly represents the variation of the magnitude of the magnetic field outside a straight infinite current carrying wire of radius '*a*', as a function of distance '*r*' from the centre of the wire?

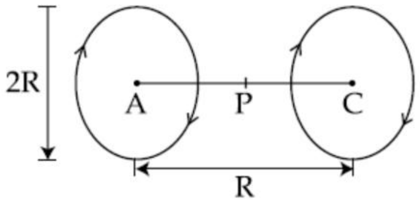


13. A neutron, a proton, an electron, and an α-particle enter a region of uniform magnetic field with the same velocities. The magnetic field is perpendicular and directed into the plane of the paper. The tracks of the particles are labelled in the figure. The electron follows the track



(a) *D* (b) *C* (c) *B* (d) *A*

14. A Helmholtz coil has pair of loops, each with *N* turns and radius *R*. They are placed coaxially at distance *R* and the same current *I* flows through the loops in the same direction. The magnitude of magnetic field at *P*, midway between the centres *A* and *C*, is given by



(a) $\frac{4N\mu_0 I}{5^{3/2}R}$ (b) $\frac{8N\mu_0 I}{5^{3/2}R}$ (a) $\frac{4N\mu_0 I}{5^{1/2}R}$ (a) $\frac{8N\mu_0 I}{5^{1/2}R}$

Answers:

1. (c)	2. (c)	3. (a)	4. (c)	5. (a)	6. (a)	7. (d)
8. (c)	9. (d)	10. (b)	11. (d)	12. (c)	13. (a)	14. (b)

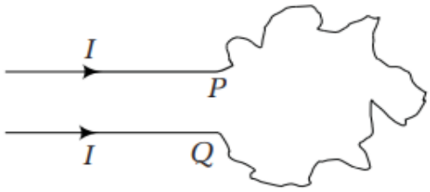
ASSERTION & REASON QUESTIONS:

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

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

1. Assertion (A) : Two long parallel wires, freely suspended and connected in series to a battery, move apart.
Reason (R) : Two wires carrying current in opposite directions repel each other
2. Assertion (A): The deflection of a magnetic needle in Oersted's experiment can be increased by placing it closer to the wire.
Reason (R): The magnetic field around a current-carrying straight conductor decreases inversely with the square of the distance.

3. Assertion (A): A wire bent into an irregular shape with the points P and Q fixed. If a current I is passed through the wire, then the area enclosed by the irregular potion of the wire increases.



Reason (R): Opposite current carrying wires repel each other.

4. Assertion (A): The resistance of an ideal voltmeter should be infinite.
Reason (R): The lower resistance of voltmeter gives a reading lower than the actual potential difference across the terminals

5. Assertion (A): The torque acting on square and circular current carrying coils having equal areas, placed in uniform magnetic field, will be same.

Reason (R): Torque acting on a current carrying coil placed in uniform magnetic field does not depend on the shape of the coil, if the areas of the coils are same

Answers:

1. (a) 2. (c) 3. (a) 4. (a) 5. (a)

VERY SHORT ANSWER QUESTIONS (2 Marks)

1. A current element $\Delta\vec{l} = \Delta x\hat{i}$ is placed at the origin and carries a current $I = 10$ A. Determine the magnetic field on the *y*-axis at a distance of 1 m. Given $\Delta x = 1$ cm.

2. Two identical coils, *P* and *Q* each of radius *R*, carrying currents 1 A and $\sqrt{3}$ A respectively, are placed concentrically and perpendicular to each other lying in the *XY* and *YZ* planes. Find the magnitude and direction of the net magnetic field at the center of the coils

3. A straight wire carrying a current of 10 A is bent into a semi-circular arc of radius 2.0 cm as shown in figure. Consider the magnetic field *B* at the centre of the arc.

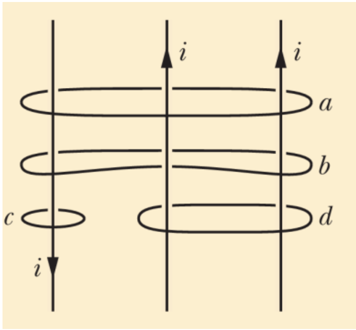
(a) What is the magnetic field due to the straight segments?

(b) In what way the contribution to *B* from the semicircle differs from that of a circular loop and in what way does it resemble?

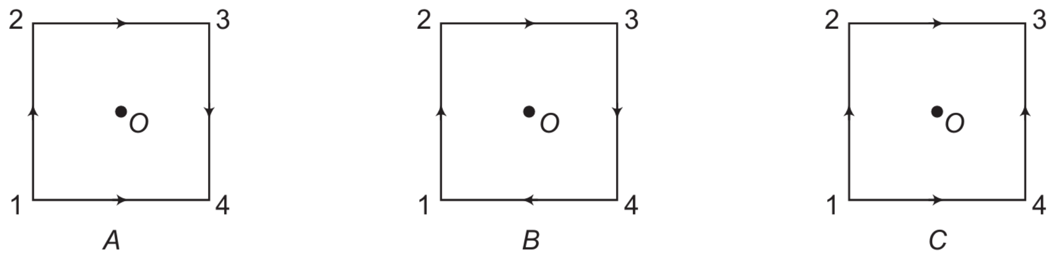
4. (a) In Ampere's circuital law, give the relation between the sign of current and the direction in which the boundary of the Amperian loop is traversed.

(b) Explain why a circular Amperian loop is used to determine the magnetic field due to an infinitely long current carrying wire.

5. The figure shows three equal currents *i* (two parallel and one antiparallel) and four Amperian loops. Rank the loops according to the magnitude of $\oint \vec{B}\cdot d\vec{l}$ in increasing order.



6. The figure shows three identical current-carrying square loops A, B, C. Current in each wire is I. Rank the loops in increasing order of magnitude of magnetic field at the center of each loop.



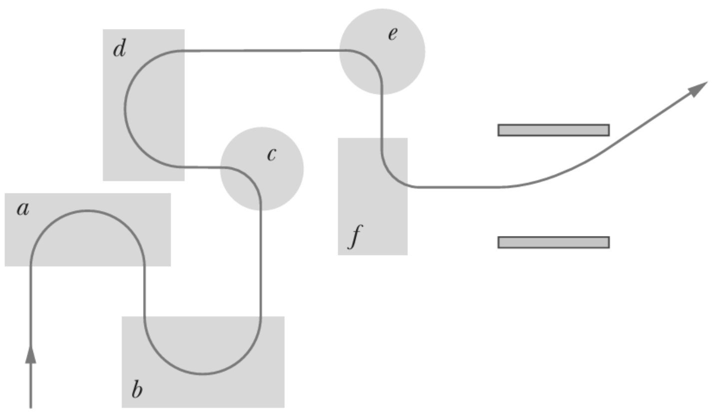
7. A straight horizontal wire of mass 100 g and length 2 m lies in the *XZ* plane and carries a current of 2 A. It is suspended in mid-air by a uniform magnetic field *B*. Find the magnitude and direction of the magnetic field.

8. (a) How is the direction of magnetic moment of a current carrying loop determined?

(b)An alpha particle revolves in a circular path of radius *R* with speed *v*. Determine the magnetic moment.

(c)A circular current loop of magnetic moment *M* is in an arbitrary orientation in an external magnetic field *B*. Determine the work done to rotate the loop by 30° about an axis perpendicular to its plane

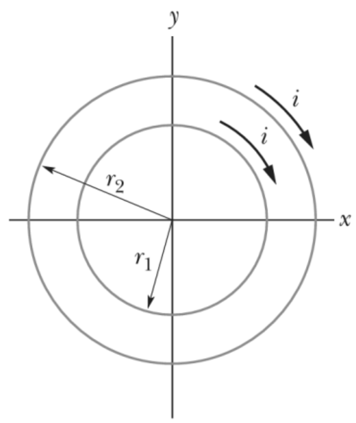
9. Figure shows the path of a particle through six regions of uniform magnetic field, where the path is either a half-circle or a quarter-circle. Upon leaving the last region, the particle travels between two charged, parallel plates and is deflected toward the plate of higher potential. What is the direction of the magnetic field in regions ***a***, ***c***, and ***d***.



10. Two concentric, circular wire loops, of radii $r_1 = 20$ cm and $r_2 = 30$ cm, are located in an x-y plane; each carries a clockwise current of 7 A.

(a) Find the magnitude of the net magnetic dipole moment of the system.

(b) If the current is reversed in the inner loop, what is the value of new dipole moment?

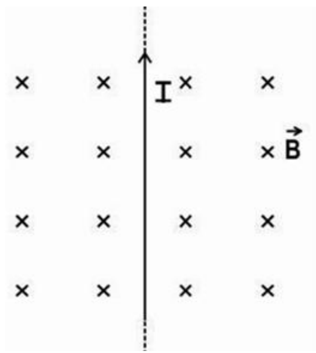


Answers/Hints:

1. Use Biot–Savart law. $dB = 2 \times 10^{-8}$ T
2. Use the formula for magnetic field at the centre of a current-carrying circular loop. $B = \dfrac{\mu_0 I}{R}$
3. Use Biot–Savart law.
4. Recall Ampere's circuital law, and the conditions in which its usage is applicable (symmetrical cases).
5. Use Ampere's circuital law.
6. Determine the direction of magnetic field at the centre due to each segment of the loop, and add vectorially.
7. Weight of the wire is balanced by the magnetic force acting on it.
8. Recall the concept of a current loop acting as a magnetic dipole. Use the formula for work done in rotating a dipole in an external magnetic field.
9. Particle gets deflected toward higher potential plate means it is negatively charged. Use $\vec{F} = q\left(\vec{v} \times \vec{B}\right)$ to determine direction of force [or note centripetal force's direction].
10. Use $M = IA$ and the rule for direction of magnetic moment.

SHORT ANSWER QUESTIONS (3 Marks)

1. A wire carrying a current $I = 200$ A in the upward direction is placed in a magnetic field $B = 2 \times 10^{-3}$ T as shown in the figure.

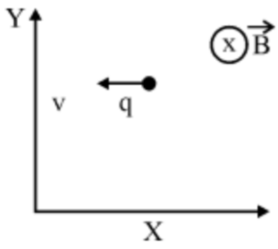


A null point represents the location of a point with zero net magnetic field.

(a) On which side of the wire will a null point be located?

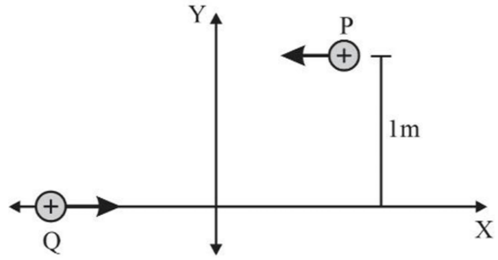
(b) On which side of the wire will a null point be located if the direction of applied magnetic field B is reversed? Calculate the perpendicular distance of the null point of the wire.

1. (a)A point charge q moving with speed v enters a uniform magnetic field B that is acting into the plane of the paper as shown. What is the path followed by the charge q and in which plane does it move?



(b)How does the path followed by the charge get affected if its velocity has a component parallel to B?
(c)If an electric field $\vec{E}$ is also applied such that the particle continues to move along the original straight- line path, what should be the magnitude and direction of the electric field $\vec{E}$?

3. P and Q are two identical charged particles each of mass 4×10^{-26} kg and charge 4.8×10^{-19} C, each moving with the same speed of 2.4 × 105 m/s as shown in the figure. The two particles are equidistant (0.5 m) from the vertical Y -axis. At some instant, a magnetic field B is switched on so that the two particles undergo head-on collision.



Find:

(a) the direction of the magnetic field and
(b) the magnitude of the magnetic field applied in the region.

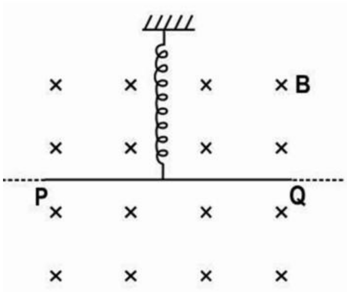
4. In a region of a uniform electric field $\vec{E}$, a negatively charged particle is moving with a constant velocity $\vec{v} = -2v_0\hat{i}$ near a long straight conductor coinciding with XX' axis and carrying current I towards $-x$ axis. The particle remains at a distance d from the conductor.
(i) Draw diagram showing direction of electric and magnetic fields.
(ii) What are the various forces acting on the charged particle?
(iii) Find the value of v_0 in terms of $\vec{E}$, d and I.

5. An electron of mass m and charge $-e$ is revolving anticlockwise around the nucleus of an atom.

(a) Obtain the expression for the magnetic dipole moment (M) of the atom.
(b) If $\vec{L}$ is the angular momentum of the electron, show that

$$\vec{M} = -\left(\frac{e}{2m}\right)\vec{L}$$

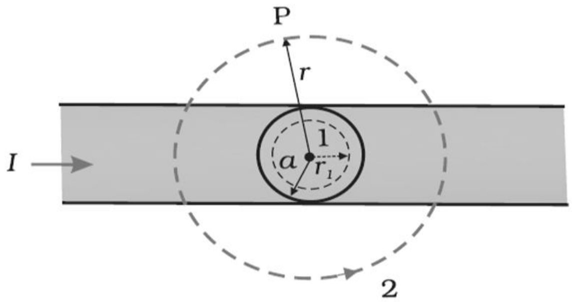
6. A uniform magnetic field B = 0.002 T acts on a 2 cm long section PQ of an insulated wire. The wire is attached to a spring of spring constant 0.8 N/m as shown in the figure.



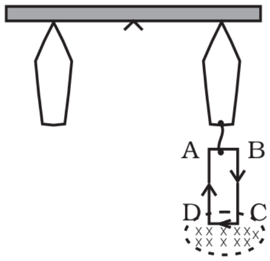
(a) What value of current should flow through *PQ* such that the spring is stretched by 2 x 10^{-4} m?

(b) Identify the possible direction of current through section *PQ*.

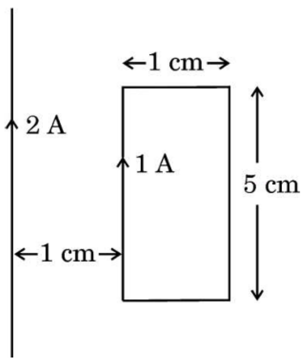
7. The given figure shows a long straight wire of a circular cross-section (radius *a*) carrying steady current *I*. The current *I* is uniformly distributed across this cross section. Calculate the magnetic field in the region $r < a$ and $r > a$.



8. A 100-turn rectangular coil *ABCD* (in *XY* plane) is hung from one arm of a balance. A mass 500 g is added to the other arm to balance the weight of the coil. A current 4.9 A passes through the coil and a constant magnetic field of 0.2 T acting inward (in *XZ* plane) is switched on such that only arm CD of length 1 cm lies in the field. How much additional mass 'm' must be added to regain the balance?



9. A rectangular loop carries a current of 1 A. A straight long wire carrying 2 A current is kept near the loop in the same plane as shown in the figure. Find



(a) the torque acting on the loop, and
(b) the magnitude and direction of the net force on the loop.

10. A moving coil galvanometer has 50 turns and each turn has an area 2×10^{-4} m^2. The magnetic field produced by the magnet inside the galvanometer is 0.02 T. The torsional constant of the suspension wire is 10^{-4} N m rad^{-1}. When a current flows through the galvanometer, a full-scale deflection occurs if the coil rotates by 0.2 rad. The resistance of the coil of the galvanometer is 50 Ω. This galvanometer is to be converted into an ammeter capable of measuring current in the range 0–10 A. For this purpose, a shunt resistance is to be added in parallel to the galvanometer. Find the value of this shunt resistance, in ohms.

Answers/Hints:

1.

(a) On the left side of the wire.

(b) On the right side of the wire. Null point is the point where the magnetic field due to the current-carrying wire is equal to the external magnetic field and is opposite in direction.

$$B = \frac{\mu_0}{2\pi}\frac{I}{r} \Rightarrow r = \frac{\mu_0}{2\pi}\frac{I}{B}$$

Put all values. $r = 0.02$ m.

2. (i) Path followed by the charge is anticlockwise in *XY* plane. The point charge moves in the plane perpendicular to both velocity and magnetic field.

(ii) It will move in helical path.

(iii) The direction of electric field should be opposite to the direction of magnetic force. The value of E can be calculated as

$qE = qvB$

$E = vB$

3.(a) The direction of the magnetic field is perpendicular and inward into the plane of the paper.

(b) For a head-on collision to take place, the radius of the path of each ion should be equal to 0.5 m.

$r = mv/qB = 0.5$ m

$B = mv/qr = 0.04$ T

4. (i) E is along positive y and B is negative z direction.

(ii) Electric and magnetic forces

(iii) $$ev_0B = eE \Rightarrow v_0\left(\frac{\mu_0 I}{2\pi d}\right) = E \Rightarrow v_0 = \frac{2\pi Ed}{\mu_0 I}$$

5.(a) $$M = IA = \frac{e}{T}\pi r^2 = \frac{e}{\left(\frac{2\pi r}{v}\right)}\pi r^2 = \frac{1}{2}evr$$

(b) $$M = \frac{evr}{2}\times\frac{m}{m} = \left(\frac{e}{2m}\right)mvr = \left(\frac{e}{2m}\right)L$$

6.a) When the spring is stretched, the restoring force on the spring upwards = the magnetic force acting on the wire *PQ* downwards

$kx = BIL$

$I = kx/BL =$ 4 A

(b) Direction of current is from Q to P

7. For $r>a$, consider Amperian loop of circle 2. From Ampere's law,

$B2\pi r = \mu_0 I$

$B = \mu_0 I/2\pi r$

For r<a, consider Amperian loop of circle 1. Current enclosed

$$I_e = I\left(\frac{\pi r^2}{\pi a^2}\right) = I\frac{r^2}{a^2}$$

From Ampere's law,

$$B2\pi r = \mu_0 I\frac{r^2}{a^2}$$

$$B = \frac{\mu_0 I}{2\pi a^2}r$$

8. Balance the torque, once when field is off and once when field is on. m = 1 g.

9. (i) Torque is zero since magnetic moment and magnetic field are parallel.

(ii)

$$F = \frac{\mu_0 I_1 I_2 l}{2\pi r}$$

$$F_{net} = \frac{\mu_0 I_1 I_2 l}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Put values:

$F_{net} = 1\times10^{-6}$ N. Force is towards the wire.

10. Use $NIAB = k\theta$ to find current corresponding maximum θ. This is the maximum deflection current for the galvanometer (I_g).

Use $S = \frac{I_g}{I - I_g}R_g$ to find S = 5.55 Ω.

CASE BASED QUESTIONS (4 Marks)

1. A moving coil galvanometer consists of a coil of wire wound on a light rectangular frame suspended in a radial magnetic field. The coil carries a current I and experiences a torque $\tau = nAIB$, where n is the number of turns, B is the magnetic field strength, and A is the area of the coil. The coil is attached to a spring of torsional constant k, which provides a restoring torque $\tau = k\theta$, where θ is the angular deflection.

When equilibrium is achieved, $nAIB = k\theta$, leading to the deflection $\theta = \frac{nIAB}{k}$. This implies the deflection is proportional to the current, and thus, the galvanometer can be calibrated to measure current.

To convert this galvanometer to a voltmeter or an ammeter, appropriate resistances are connected. For a voltmeter, a high resistance R is added in series; for an ammeter, a small shunt resistance S is connected in parallel.

(i) Which modification would **most effectively** increase the sensitivity (i.e., deflection per unit current) of a moving coil galvanometer?

(A) Reducing number of turns n and increasing magnetic field B

(B) Increasing spring constant k and area A

(C) Increasing n, A, and B, and reducing k

(D) Using a stronger spring and smaller magnetic field

(ii) If a radial magnetic field is not used in a moving coil galvanometer, which of the following best describes the consequence on its working?

(A) The torque becomes independent of current.

(B) The deflection is no longer linearly proportional to current due to variable torque.

(C) The magnetic field becomes zero at certain angles, so the galvanometer stops working.

(D) The coil experiences a constant torque irrespective of orientation.

(iii) The moving coil galvanometer is used in a circuit. If only 2% of the main current is to be passed through the galvanometer of resistance G, then the resistance of shunt will be

(A) $G/50$ (B) $G/49$ (C) $50G$ (D) $49G$

(iv) Suppose the coil of a galvanometer rotates slightly, producing an emf due to change in magnetic flux. Which of the following best describes this effect?

(A) It increases the current reading due to back emf

(B) It induces a voltage opposing the deflection, causing damping

(C) It causes infinite current and damages the coil

(D) It violates conservation of energy

OR

(v) The coil of a moving coil galvanometer has an area of 5×10^{-2} m^2. It is suspended in a magnetic field of 2×10^{-2} Wb m^{-2}. If the torsional constant of the suspension fiber is 2×10^{-9} N m deg^{-1}, find its current sensitivity in SI units.

(a) 2×10^5 (b) 5×10^5 (b) 1×10^5 (b) 2.5×10^5

2. In a vacuum chamber, a positively charged particle (mass *m*, charge *q*) is projected with velocity *v* perpendicular to a uniform magnetic field *B*. Due to the magnetic force, the particle undergoes uniform circular motion with radius: $r = \frac{mv}{qB}$ and time period: $T = \frac{2\pi m}{qB}$.

This motion is independent of the speed (in terms of period) and occurs because the magnetic force acts as a centripetal force, always perpendicular to velocity, thus doing no work.

In another scenario, a second identical particle is projected at an angle *θ* to the magnetic field. It then follows a helical path, with pitch: $p = v_{\parallel} T = v\cos\theta\left(\frac{2\pi m}{qB}\right)$

These principles are applied in cyclotrons, mass spectrometers, and charged particle traps.

(i) Two charged particles (mass *m*, charge +*q*) enter a uniform magnetic field *B* with velocities v_1 and v_2 perpendicular to *B*. The ratio of their radii is 2:1. What is the value of $2\left(\frac{v_1}{v_2}\right)^2 + \frac{T_1}{T_2}$?

(A) 9 (B) 10 (C) 3/2 (D) 3

(ii) In a mass spectrometer setup, ions with same kinetic energy but different masses and same charge enter a perpendicular magnetic field. What is the correct trend in their radius of curvature?

(A) Radius is inversely proportional to mass
(B) Radius is proportional to charge
(C) Radius is proportional to square root of mass
(D) Radius is proportional to square root of kinetic energy

(iii) If an electric field is switched on parallel to magnetic field, what happens to the pitch of the helical path?

(A) It increases linearly with time
(B) It remains constant, independent of *E*
(C) It becomes zero as particle slows down
(D) It becomes infinite because path straightens out

(iv) A proton is projected perpendicular to a magnetic field of 0.1 T with speed 2×10^6 m/s^2. Which of the following statements is **true** regarding its motion?

(A) The radius of path is independent of its charge
(B) The magnetic force increases its speed continuously
(C) The kinetic energy remains constant, but direction changes continuously
(D) The particle spirals inward due to energy loss in magnetic field

OR

(v) An alpha particle is projected with velocity $\vec{v} = \left(3\times10^5 \text{ m/s}\right)\hat{i}$ into a region in which magnetic field $\vec{B} = \left[\left(0.4 \text{ T}\right)\hat{i} + \left(0.3 \text{ T}\right)\hat{j}\right]$ exists. Calculate the acceleration $\vec{a}$ of the particle in the region.

Take the charge to mass ratio for alpha particle 5×10^{7} C/kg.

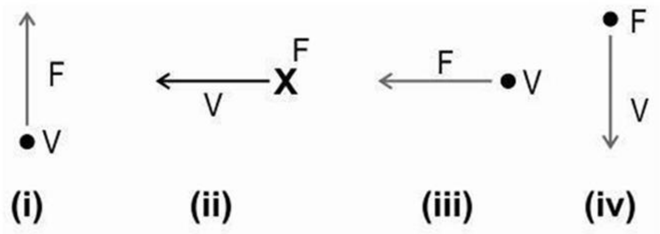
(a) 2.5×10^{12} m/s^2 (b) 4×10^{12} m/s^2 (c) 4.5×10^{12} m/s^2 (d) 6×10^{12} m/s^2

3. A particle of charge q is moving with velocity v in a region where a uniform magnetic field B is present. The magnetic force experienced by the particle is given by:

This force:

- Acts perpendicular to both v and B.
- Does no work on the particle.
- Changes the direction of velocity, not its magnitude.
- Produces circular or helical motion depending on the orientation of v and B.

(i) A negatively charged particle moves with velocity v through a magnetic field B and experiences a magnetic force F. In each of the diagrams below, the representation of magnetic field lines is missing.



Identify the probable direction of magnetic field lines in each case as Left, Right, Upwards or Downwards.

(A) i-Right, ii-Upwards, iii-Upwards, iv-Right (B) i-Left, ii-Downwards, iii-Downwards, iv-Left

(C) i-Downwards, ii-Right, iii-Upwards, iv-Upwards (D) i-Left, ii-Right, iii-Upwards, iv- Downwards

(ii) If the magnetic field in all diagrams of (i) suddenly becomes zero while the particle is still moving with the same initial velocity as shown, how will the particle's motion be affected immediately?

(A) The particle will spiral inward due to lack of centripetal force

(B) The particle will stop moving due to absence of magnetic force

(C) The particle will continue to move in a straight line with uniform velocity

(D) The particle will accelerate in the direction of original magnetic force

(iii) If a charged particle at rest experiences no electromagnetic force, the

(A) electric field must be zero (B) magnetic field must be zero

(C) electric field may or may not be zero (D) magnetic field may or may not be zero

(iv) If a charged particle is moving parallel to the axis of a solenoid. Current in the solenoid is switched on, then the particle

(A) continues to move along its original path (B) starts falling toward the solenoid

(C) starts moving away from the solenoid (D) comes to halt.

OR

(v) A tritium (isotope of hydrogen) and alpha particle having the same momentum are in turn allowed to pass through a magnetic field $\vec{B}$, acting normal to the direction of motion of the particles. The ratio of the radii of the circular paths described by them.

(A) 1 (B) 2 (C)1/2 (D)4

Answers/Hints:

1. (i) (C) (ii) (B) (iii) (B) (iv) (B) (v) (B)

2. (i) (A) (ii) (C) (iii) (A) (iv) (C) (v) (C)

3. (i) (B) (ii) (C) (iii) (A) (iv) (A) (v) (B)

LONG ANSWER QUESTIONS (5 Marks)

1. Three particles are projected into identical magnetic fields as per following data:

Particle	Proton	Deuteron	Alpha particle
Speed of projection	10^6 m/s	10^6 m/s	10^6 m/s
Angle between v and B	30^o	90^o	60^o
Charge q	e	e	2e
Mass M	m	2m	4m

Answer the following. Show the working in each case.

(a) Which of the particles will revolve along the circular paths with minimum frequency?
(b) Identify the particle/s that will follow spiral path.
(c) Which particle/s revolves around the curved path of minimum radius?

2. (a) 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 2 V. Also find the resistance G of the galvanometer in terms of R_1 and R_2

(b) 'The resistance of an ideal ammeter should be zero.' Explain.

3.(i) The magnitude F of the force between two straight parallel current carrying conductors kept at a distance d apart in air is given by $F = \frac{\mu_0 I_1 I_2}{2\pi d}$, where I_1 and I_2 are the currents flowing through the two wires.

Use this expression, and sign convention that the 'force of attraction is assigned a negative sign and force of repulsion is assigned a positive sign.'

Draw graphs showing dependence of F on

(a) $I_1 I_2$ when d is kept constant
(b) d when the product $I_1 I_2$ is maintained at a constant positive value.
(c) d when the product $I_1 I_2$ is maintained at a constant negative value.

(ii) A wire arranged in the form of a square is connected to a battery. When the battery is switched on, the area enclosed by the circuit increases or decreases or remains constant. Comment.

4.A loop of area A carrying a current I when placed in an external magnetic field B experiences torque.

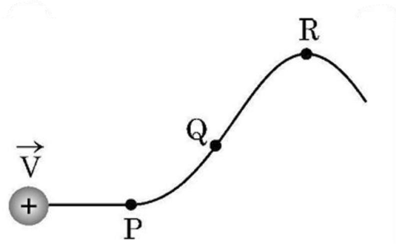
(a) What is the direction of the torque with respect to the plane of the loop?

(b) Can the loop rotate around itself like a spin wheel due to this torque? Give a reason for the answer.

(c) What is the shape of the graph between torque and angle θ, as it varies between 0 and 180°? Represent it pictorially.

(d) State the orientation of the current-carrying loop with respect to the external magnetic field in which the total magnetic flux through its area is minimum. Does this orientation constitute the stable or unstable equilibrium of the loop?

5.(a) A proton moving with velocity $\vec{v}$ in a non-uniform magnetic field traces a path as shown the figure.



The path followed by the proton is always in the plane of the paper. What is the direction of the magnetic field in the region near P, Q and R? Also, arrange the magnetic fields in increasing order of their magnitudes.

(b) A current carrying circular loop of perimeter p produces a magnetic field B at its center. Show that the magnetic moment of the loop is $\frac{Bp^3}{4\mu_0\pi^2}$.

Answers/Hints:

1.i. Frequency of revolution = $\frac{qB}{2\pi m}$

ii. The particle that has velocity component parallel to magnetic field direction will have a spiral path.

iii. Proton is projected at 30° to B: The velocity component parallel to B, that is, $v\cos 30 = \frac{\sqrt{3}v}{2}$. So, proton will follow a spiral path.

The deuteron is projected at 90° to B: The velocity component parallel to B, that is, $v\cos 90 = 0$. So, deuteron will follow a circular path.

2.For V: $V = I_g(G+R_1)$

For $V/2$: $\frac{V}{2} = I_g(G+R_2)$

For $2V$: $2V = I_g(G+R_3)$

From first two equations: $\frac{G+R_1}{G+R_2} = 2 \Rightarrow G = R_1 - 2R_2$

Put value of G in first equation and solve for Ig.

$$I_g = \frac{V}{2R_1 - 2R_2}$$

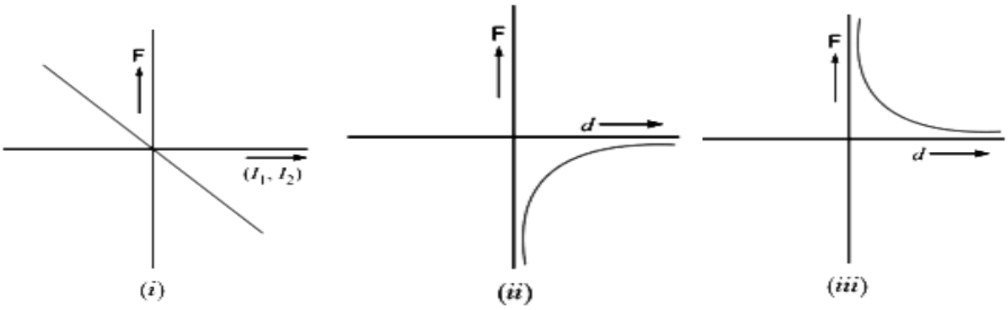
Substitute for Ig and G in third equation (For $2V$) to get

$$R_3 = 3R_1 - 2R_2$$

3. (i) Note that F is an attractive (–ve) force when the currents I_1 and I_2 are 'like' currents, *i.e.*, when the product I_1I_2 is positive.
Similarly F is a repulsive (+ve) force when the currents I_1 and I_2 are 'unlike' currents, *i.e.*, when the product I_1I_2 is negative.

Now $F \propto (I_1I_2)$ when d is kept constant and $F \propto 1/d$ when I_1I_2 is kept constant.

Plot graphs accordingly.



(ii) Increases. Because parallel segments of wires would have current flowing in opposite directions and hence they will repel each other.

4. (a) Torque on the current-carrying loop in the magnetic field always acts in the plane of the loop.

(b) No. For the loop to rotate around itself, it requires a torque that is along its vertical axis. But in this case, the torque is along the plane of the loop. So the loop cannot rotate like a spinwheel.

(c) It is sinusoidal.

(d) The magnetic flux is minimum when the area vector of the current-carrying loop is antiparallel to the magnetic field. This orientation constitutes unstable equilibrium.

5.(i) Near point P, magnetic field is acting into the plane of the paper as Force is acting upwards.

Near point Q, magnetic field is into the plane of paper as force is acting upwards.

Near point R, magnetic field is acting out of the plane of the paper as F is acting downwards.

Relative Magnitude of the Magnetic field: As $B \propto \frac{1}{r}$, therefore, near point P, magnitude of B is small. Near point Q, B is relatively smaller than point P. Near point R, B is relatively larger than point P. Thus, $B_Q < B_P < B_R$)

(ii) Let r be the radius of the circular coil and I is the current in the coil then

$$B = \frac{\mu_0 I}{2r} \Rightarrow I = \frac{2Br}{\mu_0}$$

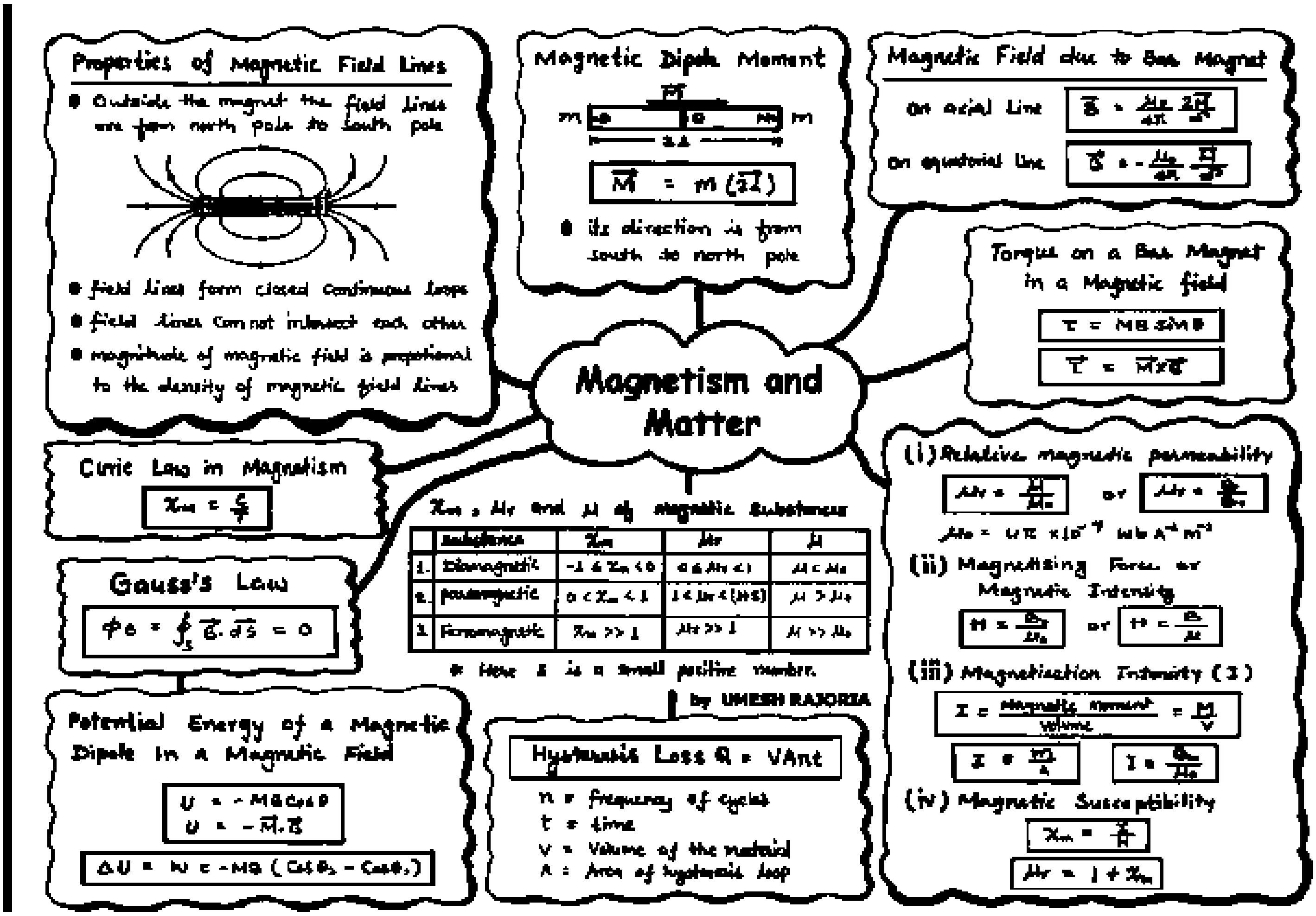
$$p = 2\pi r \Rightarrow r = \frac{p}{2\pi}$$

Magnetic moment:

$$M = IA = \frac{2Br}{\mu_0}\pi r^2 = \frac{2\pi B}{\mu_0}\left(\frac{p}{2\pi}\right)^3 = \frac{Bp^3}{4\pi^2\mu_0}$$

CHAPTER 5

MAGNETISM AND MATTER

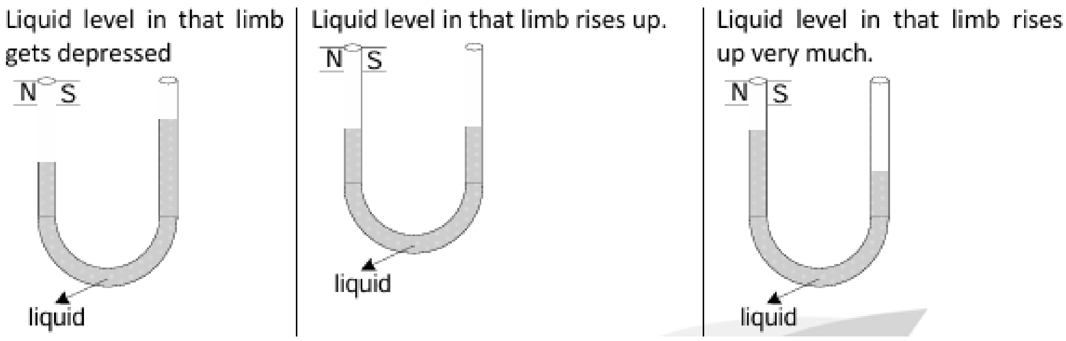


MULTIPLE CHOICE QUESTIONS:

1. A magnetic dipole of magnetic moment m is placed in a uniform magnetic field B. The maximum torque experienced is:

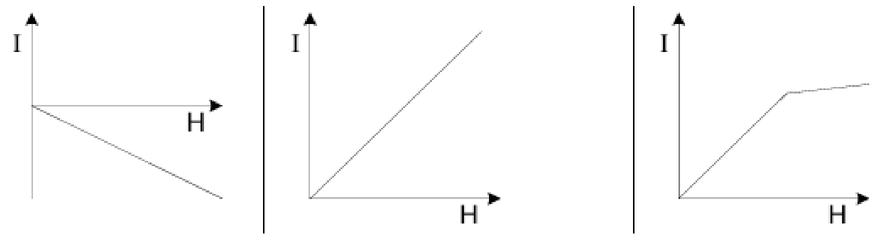
(a) mB (b) m/B (c) m^2B (d) Zero

2. Identify the substance in sequence:



(a) Paramagnet substance, diamagnetic substance, ferro magnetic substance
(b) diamagnetic substance, paramagnet substance, ferro magnetic substance
(c) Paramagnet substance, diamagnetic substance, ferro magnetic substance
(d) diamagnetic substance, ferro magnetic substance, Paramagnet substance

3. Identify the substance in sequence:



(a) Paramagnet substance, diamagnetic substance, ferro magnetic substance
(b) Diamagnetic substance, Paramagnet substance, ferro magnetic substance
(c) Paramagnet substance, diamagnetic substance, ferro magnetic substance
(d) diamagnetic substance, ferro magnetic substance, Paramagnet substance

4. 1000 turns per meter are wound over a Rowland ring of ferromagnetic material. On passing a current of 2 A in the coil, a magnetic field of 10 Wb/m^2 is produced in it. The magnetizing force generated in the material will be

(a) 1.2×10^{-3} A/m (b) 2.6×10^{-3} A/m (c) 2.6×10^{-4} A/m (d) 2×10^{3} A/m

5. A bar magnet AB with magnetic moment M is cut into two equal parts perpendicular to its axis. One part is kept over the other so that end B is exactly over A. What will be the magnetic moment of the combination so formed?

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

6. If a magnet of length l and magnetic moment M is bent in the form of a semicircular are then its new magnetic moment will be M' will be:

(a) $\frac{M}{\pi}$ (b) $\frac{2M}{\pi}$ (c) $\frac{4M}{\pi}$ (d) $\frac{M}{2\pi}$

7. The magnetic induction along the axis of an air solenoid is 0.03 T. On placing an iron core inside the solenoid, thsse magnetic induction becomes 15 T. The relative permeability of iron core will be

(a) 300 (b) 500 (c) 700 (d) 900

8. There are two points *A* and *B* on the extended axis of a 2 cm long bar magnet. Their distances from the centre of the magnet are *x* and 2*x* respectively. The ratio of magnetic fields at points *A* and *B* will be

(a) 8 : 1 approximately (b) 4:1 (approximately)

(c) 1:4 approximately (d) 1:8 approximately

9. The main difference between electric lines of force and magnetic lines of force is-

(a) Electric lines of force are closed curves whereas magnetic lines of force are open curves.

(b) Electric lines of force are open curves whereas magnetic lines of force are closed curves.

(c) Magnetic lines of force cut each other whereas electric lines of force do not cut.

(d) Electric lines of force cut each other whereas magnetic lines of force do not cut.

10. Among Iron Copper Silicon, Aluminium, Sodium, in which substance resultant magnetic moment in an atom is zero.

(a) Copper and Aluminium (b) Copper and sodium (c) Copper and Silicon (d) Aluminium and Sodium

Answers/Hints:

1. (a) 2. (b) 3. (b) 4. (d) 5. (b) 6. (b)

7. (b) 8. (d) 9. (b) 10. (c)

ASSERTION REASON

For each question, choose the correct option:

(a) Both Assertion (A) and Reason (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) and R both are false

1. **Assertion (A)**: A freely suspended bar magnet comes to rest in the north-south direction.
   Reason (R): Earth has a magnetic field that influences the orientation of the magnet.
2. **Assertion (A)**: The torque on a magnetic dipole is maximum when it is perpendicular to the magnetic field.
   Reason (R): Torque acting on a magnetic dipole is given by $\tau = MB\sin\theta$.
3. **Assertion (A)**: When radius of a circular loop carrying current is doubled, its magnetic moment become four times.
   Reason (R): Magnetic moment depends only on area of the loop.
4. **Assertion (A)**: Gauss's theorem is not applicable in magnetism as in Electrostatic
   Reason (R): Mono magnetic element does not exist.
5. **Assertion (A)**: When a magnetic dipole is placed in a non- uniform magnetic field, torque and force acts on it
   Reason (R): The magnetic field due to a magnet is generally uniform.

Answers:

1. (a) 2. (a) 3. (b) 4. (a) 5. (c)

VERY SHORT ANSWER QUESTIONS (2 Marks)

1. A short bar magnet placed with its axis at 30° with a uniform external magnetic field of 0.25 T experiences a torque of magnitude equal to 4.5×10^{-2} N m. What is the magnitude of magnetic moment of the magnet?
2. A magnet of magnetic moment 0.4 Am^2 is placed in a uniform field of 0.2 T. What is the potential energy when it is: (a) aligned parallel, (b) perpendicular to the field?
3. A bar magnet of length 20 cm has pole strength 3 A m. Find its magnetic dipole moment. If its shape is converted in L shape from its middle, then what will be its new magnetic dipole moment?
4. . A solenoid of 1000 turns per meter carries a current of 2 A. Find the magnetizing field H and the magnetic field B inside it (assume vacuum).
5. A bar magnet is placed along the axis of a circular current-carrying loop. The force on the magnet is zero, but torque may be non-zero. Explain with reasoning.
6. The magnetic susceptibility of a paramagnetic material is 3×10^{-3} at 300 K. What is its value at 400 K?
7. A magnetic material has $\chi = -0.002$. Identify the type of material. If $H = 500$ A/m, find M and B inside the material.
8. How does the (i) pole strength and (ii) magnetic moment of each part of a bar magnet change if it is cut into two equal pieces transverse to length?

Answers/Hints:

1. $B = 0.25$ T, $\tau = 4.5 \times 10^{-2}$ N m, $\theta = 30°$

$\tau = MB \sin\theta$® $4.5 \times 10^{-2} = M \times 0.25 \times 0.5$ ® $M = 0.36$ Am^2

2. $U = -MB\cos\theta$

(i) $\theta = 0$ ® $U = -0.4 \times 0.2 \times 1 = 0.08$ J

(ii) $\theta = 90°$® $U = -0.4 \times 0.2 \times 0 = 0$ J

3. (i) $M = m \times 2l = 0.3$ Am²

(ii) $M' = \sqrt{(0.3)^2 + (0.3)^2} = 0.42$ Am²

4. (i) $H = ni = 2000$ A/m

(ii) $B = \mu_0 ni = 2.51 \times 10^{-3}$ T

5. Force = 0, torque ≠ 0 due to magnetic interaction.

6. Since X is inversely proportional to temperature T,

$\frac{3 \times 10^{-3}}{X_2} = \frac{400}{300}$ ® $X_2 = 2.25 \times 10^{-3}$

7. (i) $M = \chi H = -0.002 \times 500 = -1.0$ A/m

(ii) $B = \mu_0 (H + M) = 4\pi\times10^{-7} \times (500 + (-1)) = 6.27\times10^{-4}$ T

8. When a bar magnet of magnetic moment ($M = m2l$) is cut into two equal pieces transverse to its length

(i) the pole strength remains unchanged (since pole strength depends on number of atoms in cross-sectional area).

(ii) the magnetic moment is reduced to half (since M µ length and here length is halved).

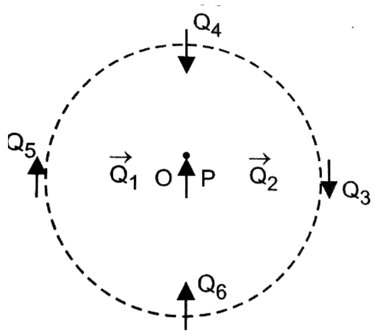
SHORT ANSWER QUESTIONS (3 Marks)

1. A magnetic needle of magnetic moment 0.06 Am² is free to rotate in a uniform magnetic field of 0.3 T. Calculate the work done in rotating the needle from its equilibrium position to a position 90° with the field.
2. A short bar magnet has a magnetic moment of 0.5 Am². (i) Calculate the magnetic field at a point on the equatorial line at a distance of 20 cm from its center. Also find the direction of the field. (ii) at what distance from the centre same magnetic field will be observed on axial line?
3. A magnetic dipole of moment 0.6 Am² is placed in a uniform magnetic field of 0.4 T. Find the potential energy of the dipole when the angle between the field and the dipole is (i) 0°, (ii) 90°, (iii) 180°.
4. A closely wound solenoid of 2000 turns and area of cross-section 1.6×10^{-4} m^2, carrying a current of 4.0 A is suspended through its centre allowing it to turn in a horizontal plane.

   (i) What is the magnetic moment associated with the solenoid?

(ii) What are the force and torque on the solenoid if a uniform magnetic field of 7.5 × 10-2 is set up at an angle of 30° with the axis of the solenoid?

5. Following figure shows a small magnetized needle *P* placed at a point *O*. The arrow shows the direction of its magnetic moment. The other arrows show different positions (and orientations of the magnetic moment) of another identical magnetized needle.



(a) In which configuration the system is not in equilibrium?

(b) In which configuration is the system in (i) stable, and (ii) unstable equilibrium?

(c) Which configuration corresponds to the lowest potential energy among all the configurations shown?

6. A coil of 'N' turns and radius 'R' carries a current 'I'. It is unwound and rewound to make a square coil of side 'a' having same number of turns (N). Keeping the current 'I' same, find the ratio of the magnetic moments of the square coil and the circular coil.

7. A solenoid has a core of a material with relative permeability 400. The windings of the solenoid are insulated from the core and carry a current of 2 A. If the number of turns is 1000 per meter, calculate (i) H, (ii) M and (iii) B

Answers/Hints:

1. Work done = $U = MB(1 - \cos\theta)$= 0.018 J

2. B_equatorial: $B = \frac{\mu_0}{4\pi}\frac{M}{r^3} =$ 6.25×10^{-5} T

   Direction: opposite to magnetic moment

   B_axial: $B' = \frac{\mu_0}{4\pi}\frac{2M}{r'^3}$

   For same field, $\frac{r'^3}{2} = r^3 \Rightarrow r' = 2^{1/3}(0.2)$

3. (i) U = $-$MB cos(0°) = $-$0.24 J

   (ii) U = $-$MB cos(90°) = 0

   (iii) U = $-$MB cos(180°) = +0.24 J

4. (i) Magnetic moment of solenoid, $m = NIA = 1.28$ A m^2

(ii) Net force on current carrying solenoid (or magnetic dipole) in uniform magnetic field is always zero.
Torque, $\tau = MB\sin\theta = 4.8 \times 10^{-2}$ N m

5. Equilibrium is stable when m_Q is parallel to B_P , and unstable when it is anti-parallel to B_P
   For instance, for the configuration Q_3 for which Q is along the perpendicular bisector of the dipole P, the magnetic moment of Q is parallel to the magnetic field at the position 3. Hence, Q3 is stable.

Thus,

(a) PQ_1 and PQ_2

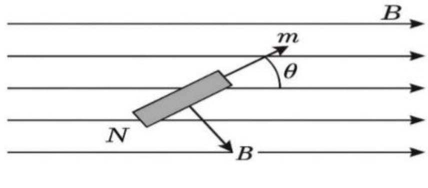
(b) (i) PQ_3 , PQ_6 (stable); (ii) PQ_5 , PQ_4 (unstable)

(c) PQ_6

6. Magnetic moment (M) of a coil is given by: M = NIA
   For the circular coil: Area $A_1 = \pi R^2$
   Magnetic moment: $M_1 = NI\pi R^2$
   For the square coil: Length of the wire = Circumference of the circular coil = $2\pi R$
   Each side of the square = a, so perimeter = 4a
   Equating the wire lengths: $2\pi R = 4a \Rightarrow a = \pi R / 2$
   Area $A_2 = a^2 = (\pi R / 2)^2 = \pi^2 R^2 / 4$
   Magnetic moment: $M_2 = NI(\pi^2 R^2/4)$
   Now, the ratio of magnetic moments: $M_2 / M_1 = \pi / 4$
7. (i) The field H is dependent of the material of the core, and is
   $H = nI = 1000 \times 2.0 = 2 \times 10^3$ A/m.
   (ii) The magnetic field B is given by
   $B = \mu_o \mu_r H =$ 1.0 T
   (iii) Magnetization is given by $M = (B - \mu_o H)/\mu_o = (\mu_r - 1)H = 399 \times H \cong 8 \times 10^5$ A/m

CASE BASED QUESTION (4 Marks)

Magnetic Dipole in a Magnetic Field: A bar magnet acts as a magnetic dipole with magnetic moment m. When it is placed in a uniform magnetic field B, it experiences a torque which tends to align the magnet along the field direction. Torque on the magnet is given by $\boldsymbol{\tau} = \boldsymbol{m} \times \boldsymbol{B}$. Potential energy of the magnetic dipole in a magnetic field is given by $U = -\boldsymbol{m} \cdot \boldsymbol{B} = -mB\cos\theta$, where θ is the angle between $\boldsymbol{m}$ and $\boldsymbol{B}$. The torque tends to rotate the dipole to minimize its potential energy.



(i) The torque on a magnetic dipole is maximum when angle between **m** and **B** is:

(a) 0° (b) 90° (c) 180° (d) 45°

(ii) In equilibrium, the potential energy of a magnetic dipole is:

(a) Maximum (b) Minimum (c) Zero (d) Infinite

(iii) A magnetic dipole will align itself along the magnetic field such that:

(a) *m* is perpendicular to *B* (b) *m* is parallel to *B*

(c) *m* is anti-parallel to *B* (d) It remains unaffected

(iv) If a bar magnet is rotated in a uniform magnetic field, its potential energy:

(a) Remains constant (b) Changes continuously

(c) Becomes zero always (d) Increases continuously

OR

(v) The unit of magnetic moment is:

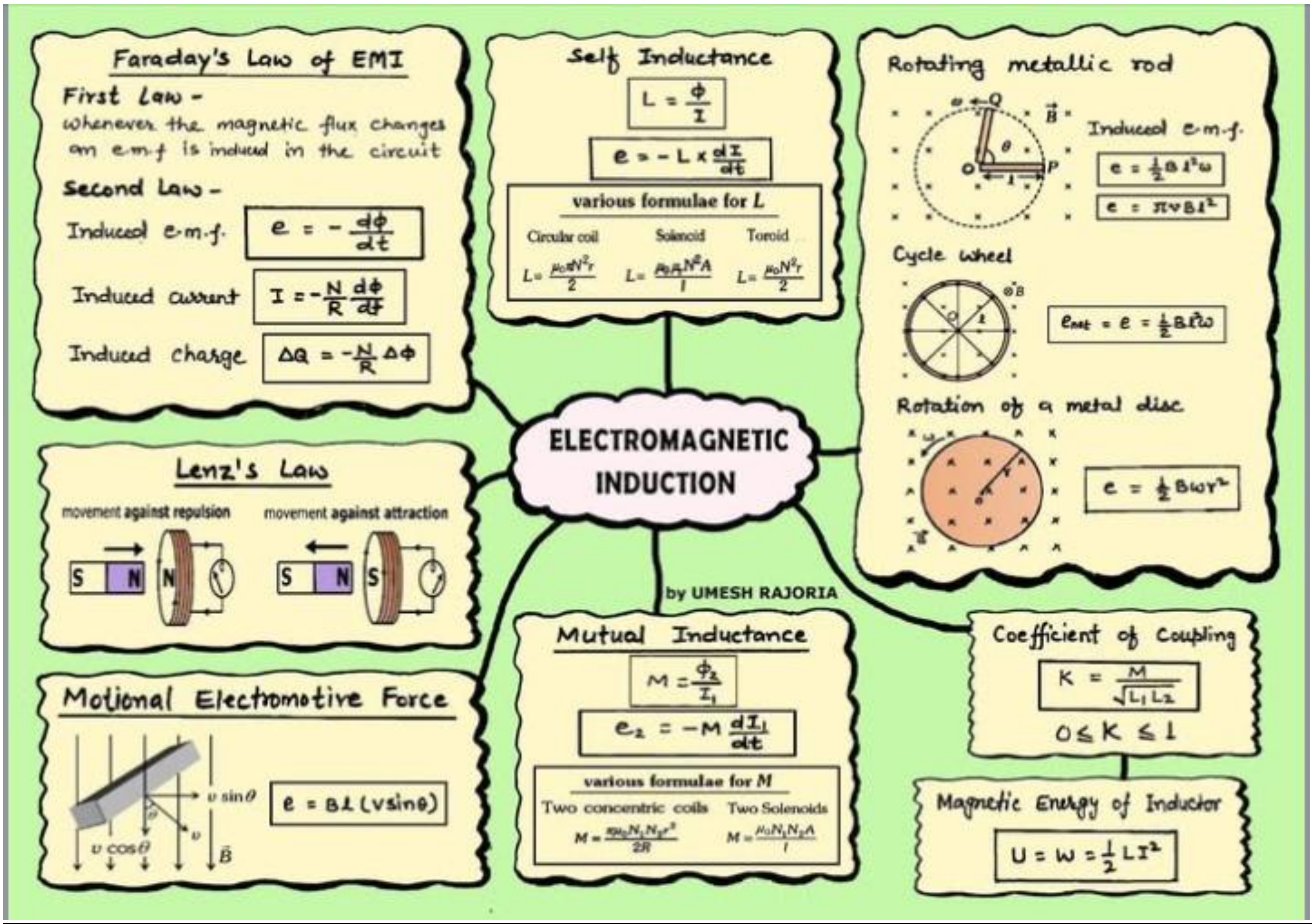
(a) A m² (b) N m (c) T m² (d) J s

Answers:

(i). (b) (ii). (b) (iii). (b) (iv). (b) (v). (a)

CHAPTER 6

ELECTROMAGNETIC INDUCTION



MULTIPLE CHOICE QUESTIONS:

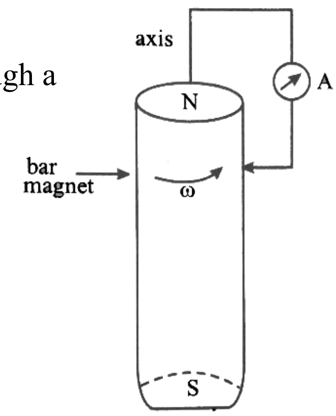
1. When the current in a coil changes from 5 A to 2 A in 0.1 s, an average voltage of 50 V is produced. The self-inductance of the coil is

   (a) 1.67 H (b) 6 H (c) 3 H (d) 0.67 H

2. A coil having 500 square loops of side 10 cm each is placed normal to magnetic field which increases at a rate of 1 T/s. The induced emf in the coil is

   (a) 0.1 V (b) 0.5 V (c)1 V (d) 5 V

3. A cylindrical bar magnet is rotated about its axis in the figure. A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then



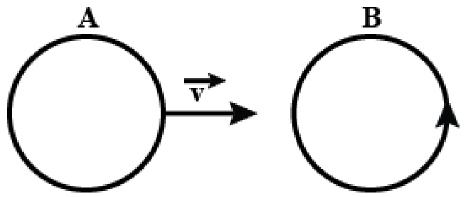
   (a) a direct current flows in the ammeter A.

   (b) no current flows through the ammeter A.

   (c) an alternating sinusoidal current flow through the ammeter A with a time period 2π/ω.

   (d) a time varying non-sinusoidal current flows through the ammeter A.

4. There are two coils *A* and *B* as shown in the figure. A current starts flowing in *B* as shown, *A* 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*.

5. In a coil of self-induction 5 H, the rate of change of current is 2 A/s. Then emf induced in the coil is

   (a) 10 V (b) −10 V (c) 5 V (d) −5 V

6. A solenoid is connected to a battery so that a steady current flows through it. If an iron core is inserted into the solenoid, the current will

   (a) increase (b) decrease (c) remain same (d) first increase then decrease

7. 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 the 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 charge.

8. There is a uniform magnetic field directed perpendicular and into the plane of the paper. An irregularly shaped conducting loop is slowly changing into a circular loop in the plane of the paper. Then
   (a) current is induced in the loop in the anti-clockwise direction.
   (b) current is induced in the loop in the clockwise direction.
   (c) ac is induced in the loop.
   (d) no current is induced in the loop.
9. A conducting circular loop is placed in a uniform magnetic field B = 50 mT with its plane perpendicular to the magnetic field. The radius of the loop is made to shrink at a constant rate of 1 mm s^{-1}. At the instant the radius of the loop is 4 cm, the induced emf in the loop is :

   (a) π μV (b) 2π μV (c) 4π μV (d) 8π μV
10. If the number of turns in primary and secondary coils is increased to two times each, then mutual inductance
   (a) becomes 4 times (b) becomes 2 times (c) becomes 3 times (d) remains unchanged

Answers/Hints:

1. a) 1.67 H
2. d) 5 V
3. b) No current flows through the ammeter A.

4 (d) There is a constant current in the counterclockwise direction in A.

5. (b) −10 V

6. (b) Decrease. This is because on inserting an iron core in the solenoid, the magnetic field increases**,** and hence magnetic flux linked with the solenoid increases. As per Lenz**'s** law, the emf induced in the solenoid will oppose this increase, which can be achieved by a decrease in Current.

7 (d) Lenz's law is a consequence of the law of conservation of Charge.

8. (a) Current is induced in the loop in the anti-clockwise direction. Due to change in the shape of the loop, the magnetic flux linked with the loop increases. Hence, current is induced in the loop in such a direction that it opposes the increases in flux. Therefore, induced current flows in the anticlockwise direction.

9. (c)

10. (a) Becomes 4 times

ASSERTION AND REASON:

Each question has 4 choices (A), (B), (C) and (D) out of which ONLY ONE is correct. Select the correct choice. Choices are:

(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, but REASON is False.

(d) ASSERTION and REASON are both False.

1. ASSERTION: The DC and AC both can be measured by a hot wire instrument

REASON: The hot wire instrument is based on the principle of magnetic effect of current.

2. ASSERTION: Induced emf will always occur whenever there is a change in magnetic flux.

REASON: Current always gets induced whenever there is a change in magnetic flux.

3. ASSERTION: Faraday's laws are a consequence of the conservation of energy.

REASON: The self-inductance of a coil depends on the current flowing through the coil.

4. ASSERTION: Only a change in magnetic flux will maintain an induced current in the coil.

REASON: The presence of large magnetic flux through a coil maintains a current in the coil if the circuit is continuous.

5. ASSERTION: Lenz's law violates the principle of conservation of energy.

REASON: Induced emf always opposes the change in magnetic flux responsible for its production.

Answers:

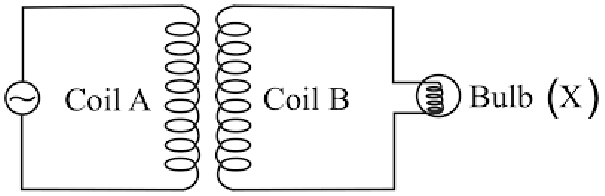
1. (c) 2. (c) 3. (c) 4. (c) 5. (a)

VERY SHORT ANSWER QUESTIONS (2 Marks):

1. A large circular coil of radius *R* and a small circular coil of radius *r* are kept in vicinity of each other. If the coefficient of mutual induction for this pair equals 1 mH, what would be the flux linked with the larger coil when a current of 0.5 A flows through the smaller coil? When the current in the smaller coil falls to zero what would be its effect in the larger coil?
2. A long solenoid with 15 turns/cm has a small loop of area 2 cm^2 placed inside normal to the axis of the solenoid. The current carried by the solenoid changes steadily from 2 A to 4 A in 0.1 sec. What is the induced emf in the loop while the current is changing?
3. The figure given below shows an arrangement by which current flows through the bulb *X* connected with coil *B* when AC is passed through coil *A*

   (i) Name the phenomenon involved.

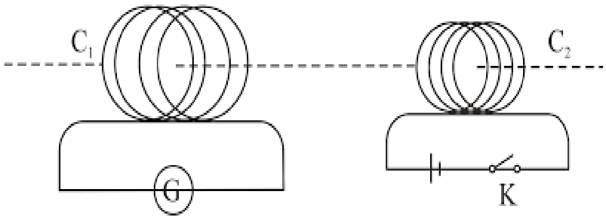
   (ii) If a copper sheet is inserted in the gap between the coils explain how the brightness of the bulb would change?



4. A current is induced in coil C_1 due to the motion of current carrying coil C_2.

   (i) Write any two ways by which a large deflection can be obtained in the galvanometer *G*.

   (ii) Suggest an alternative device to demonstrate the induced current in place of a galvanometer.

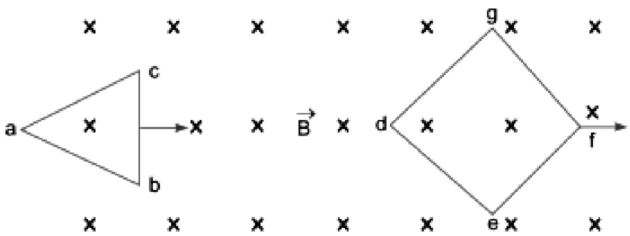


5. The flux linked with a large circular coil of radius *R* is 0.5×10^{-3} Wb. If a current of 0.5 A flows through a small neighboring coil of radius *r*, calculate the coefficient of mutual inductance for the given pair of coils. If the current through the small coil suddenly falls to zero, what would be its effect in the larger coil?
6. How is the mutual inductance of a pair of coils affected when

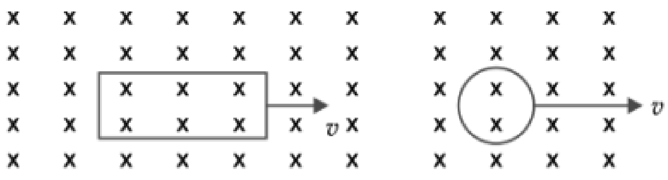
   (i) separation between the coils is increased?

   (ii) the number of turns in each coil is increased?

   (iii) a thin iron sheet is placed between the two coils, other factors remaining the same? Justify your answer in each case.
7. Two loops of different shapes are moved in the region of a uniform magnetic field pointing downward. The loops are moved in the directions shown by arrows. What is the direction of the induced current in each loop?

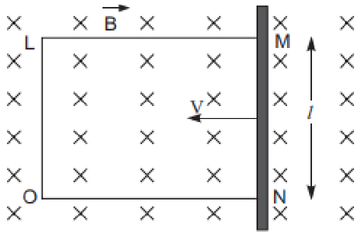


8. A rectangular loop and a circular loop are moving out of a uniform magnetic field region to a field-free region with a constant velocity. In which loop do you expect the induced emf to be a constant during the passage out of the field region? The field is normal to the loop.



(a) (b)

9. 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 the length of 20 cm is moved towards the left with a velocity of 10 ms^{-1}. 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.



10. (i) Define mutual inductance.
(ii) A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, what is the change of flux linkage with the other coil?

Answers/Hints:

1. ⎞ = *MI*, ⎞ = 5 ×10^{-4} Wb. Produces large induced emf in it.
2. $B = \mu_0 nI \Rightarrow \Delta B = \mu_0 n\Delta I$

$$\varepsilon = \frac{\Delta\phi}{\Delta t} = A\frac{\Delta B}{\Delta t} = A\mu_0 n\frac{\Delta I}{\Delta t} = 7.54\times10^{-6}\ \text{V}$$

3. (i) Mutual Induction (ii) Bulb X dimmer.
4. In the coil C_1 is anticlockwise and in C_2 is anticlockwise.
5. 1 mH
6. (i)When the relative distance between the coil is increased, the leakage of flux increases which reduces the magnetic coupling of the coils. So magnetic flux linked with all the turns decreases. Therefore, mutual inductance will be decreased.
ii) Mutual inductance for a pair of coil is given by

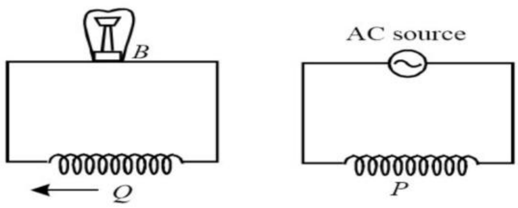
$$M = K(L_1 L_2)^{1/2}$$

where $L = \mu_0 N^2 A/l$ and *L* is called self- inductance. Therefore, when the number of turns in each coil increases, the mutual inductance also increases.
iii) When a thin iron sheet is placed between the two coils, the mutual inductance increases because of $M \propto$ permeability. The permeability of the medium between coils increases.
7. Loop *abc* is entering the magnetic field, so the magnetic flux linked with it begins to increase. According to Lenz's law, the current induced opposes the increases in magnetic flux, so the current induced will be anticlockwise which tends to decrease the magnetic field

8. In a rectangular coil the induced emf will remain constant because in this case rate of change of area in the magnetic field region remains constant, while in circular coil the rate of change of area in the magnetic field region is not constant.
9. Induced emf in a moving rod in a magnetic field is given by $\varepsilon = Blv$.
   Since the rod is moving to the left, so $\varepsilon = Blv = 0.5 \times 0.2 \times 10 = 1$ V.
   Current in the rod, $I = \varepsilon / R = 1/5 = 0.2$ A.
10. (i) Mutual inductance of two coils is the magnetic flux linked with the secondary coil when a unit current flows through the primary coil,
    $\phi_2 = MI_1$ or $M = \phi_2/I_1$
    ii) Change of flux for small change in current $d\phi = MdI = 1.5(20 - 0) = 30$ Weber

SHORT ANSWER QUESTIONS (3 Marks)

1. The current flowing through an inductor of self-inductance L is continuously increasing. Plot a graph showing the variation of
   (i) Magnetic flux versus the current
   (ii) Induced emf versus dI/dt
   (iii) Magnetic potential energy stored versus the current.
2. Derive an expression for self-inductance of a long air-cored solenoid of length l, cross-sectional area A and having number of turns N.
3. Obtain the expression for the mutual inductance of two long co-axial solenoids S_1 and S_2 wound one over the other, each of length L and radii r_1 and r_2 and n_1 and n_2 be number of turns per unit length when a current I is set up in the outer solenoid S_2.
4. Define self-inductance. A coil of a number of turns N, area A is rotated at a constant angular speed ω, in a uniform magnetic field B and connected to a resistor R. Deduce an expression for
   (i) maximum emf induced in the coil
   (ii) power dissipation in the coil
5. Define mutual inductance. How does the mutual inductance of a pair of coils change when
   (i) distance between the coils is increased and
   (ii) number of turns in the coils is increased
6. A coil Q is connected to low voltage bulb B and placed near another coil P as shown in the figure. Give reasons to explain the following observations:



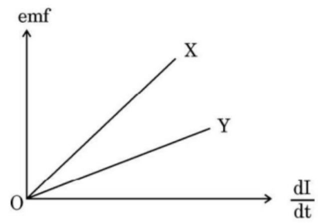
(i) The bulb '*B*' lights

(ii) Bulb gets dimmer if the coil *Q* is moved towards left.

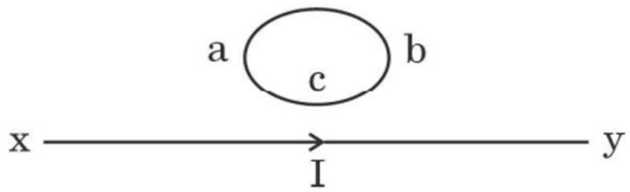
(iii) Find the direction of induced current in coil *Q*

7. A 100 turn coil of radius 1.6 cm and resistance 5 Ω is co-axial with a solenoid of 250 turns/cm and radius 1.8 cm. The solenoid current drops from 1.5 A to zero in 25 ms. Calculate the current induced in the coil in this duration. (Take $\pi^2 = 10$).

8. (i) The figure shows the variation of induced emf as a function of rate of change of current for two identical solenoids X and Y. One is air cored and the other is iron cored. Which of them is iron cored and why?



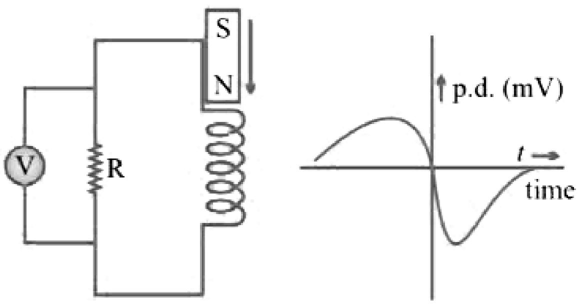
(ii) What is the direction of induced current in the loop *abc* if *I* decrease?



9. Two concentric circular coils one of small radius r_1 and the other of large radius r_2, such that $r_1 << r_2$, are placed co-axially with centers coinciding. Obtain the mutual inductance of the arrangement.

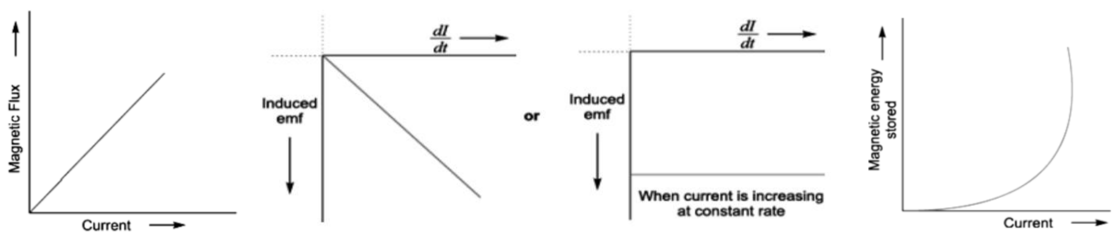
10. A bar magnet is dropped so that it falls vertically through coil *C*. The graph obtained for the voltage produced across the coil versus time is as shown in figure.

(i) Explain the shape of the graph and (ii) why is the negative peak longer than the positive peak?



Answers/Hints:

1.



2. **Derivation**

3. **Derivation**

4. Refer to text book and Correct derivation

5. Refer to text book (i) Mutual inductance decreases', because flux linked with the secondary coil decreases. (ii) M=μ0n 1n 2Al, so when n_1 and n_2 increase, mutual inductance (M) increases.

6. (i) The bulb *B* lights on account of emf induced in the coil *Q* due to mutual induction between *P* and *Q*.

(ii) When coil *Q* is moved towards left, magnetic flux linked with *Q* decreases and may even reduce to zero at some distance. The emf induced may decrease and the bulb *B* gets dimmer.

(iii) Clock wise

7. $B = \mu_0 nI \Rightarrow \Delta B = \mu_0 n \Delta I$

$$\varepsilon = \frac{\Delta\phi}{\Delta t} = A\frac{\Delta B}{\Delta t} = A\mu_0 n\frac{\Delta I}{\Delta t}$$

$$I_{\text{in}} = \frac{\varepsilon}{R}$$

8. (i) The solenoid with the higher induced emf for the same rate of change of current is iron cored. This is because the iron core increases the magnetic flux linkage due to its higher magnetic permeability. In the figure, solenoid X shows a higher emf, so X is iron cored.

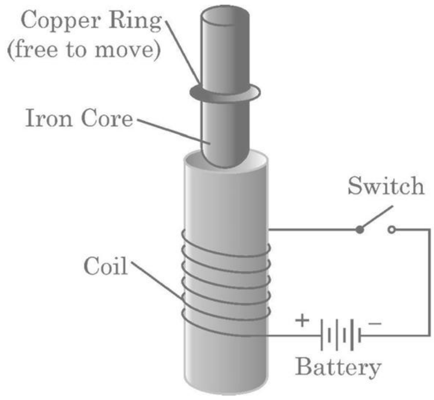
(ii) Along *abc*

9. **Derivation**

10. As the magnet approaches the coil, an emf is induced in it. As the magnet approaches the coil the magnetic flux linked with the coil increases. As a result, the induced emf increases. When the magnet enters the coil, the change in magnetic flux linked with the coil begins to decrease and becomes zero when the magnet is completely inside the coil. This starts decreasing the emf and makes it zero. When the magnet comes out of the coil the direction of induced emf changes direction and begins to increase in the opposite direction. When the magnet moves far away from the coil the induced emf becomes zero.

<u>CASE STUDY-BASED QUESTIONS (4 Marks)</u>

1. Consider the experimental set up shown in the figure. This jumping ring experiment is an outstanding demonstration of some simple laws of Physics. A conducting non-magnetic ring is placed over the vertical core of a solenoid. When current is passed through the solenoid, the ring is thrown off.



(i) The direction of induced current in the ring in jumping ring experiment is such that the polarity developed in the ring is same as that of the polarity on the face of the coil, then ring will jump up due to

(a) attractive force when the switch is closed in the circuit.

(b) repulsive force when the switch is closed in the circuit.

(c) attractive force when the switch is closed in the circuit.

(d) repulsive force when the switch is closed in the circuit.

(ii) What will happen if the terminals of the battery are reversed and the switch is closed?

(a) Ring will not be jump.

(b) Ring will jump again.

(c) Current will not induced in the ring.

(d) None of these

(iii) The jumping ring experiment based on which of the following law?

(a) Lenz's Law (b) Faraday's law (c) Snell's Law (d) Both (a) and (b)

(iv) Two identical circular loops *A* and *B* 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*.

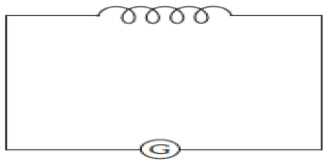
(c) is repelled by loop *A*. (d) rotates about its centre of mass with centre of mass fixed.

OR

An emf of 100 V is induced in a circuit when current in the circuit falls from 10 A to 0 A in 0.1 second. The self-inductance of the circuit is

(a) 0.5 H (b) 1.0 H (c) 2.0 H (d) 4.0 H

2. When a current *I* flows through a coil, flux linked with it is $\phi = LI$, 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) 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

(iii)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) $L \propto R^3$

(iv)The unit of self-inductance is

(a) Weber ampere (b) $Weber^{-1}$ ampere (c) Ohm second (d) Farad

OR

(v)The induced emf in a coil of 10 henry inductance in which current varies from 9 A to 4 A in 0.2sec is

(a) 200 V (b) 250 V (c) 300 V (d) 350 V

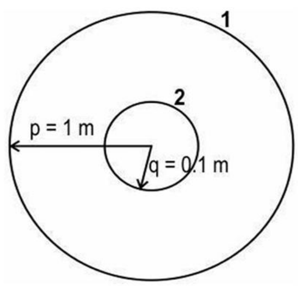
Answers:

1. (i) (b) (ii) (b) (iii) (d) (iv) (c) (v) (c)

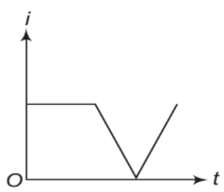
2. (i) (a) (ii) (b) (iii) (c) (iv) (c) (v) (b)

LONG ANSWER QUESTIONS (5 Marks):

1. (i) Given two coplanar and concentric loops 1 and 2 as shown. A time varying voltage $(4 + 2t)$ is applied to the larger loop 1. If the resistance of the loops is $R_1 = 10$ ohm and $R_2 = 1$ ohm, then determine the current induced in the smaller loop.



(ii) The current i in an induction coil varies with time t according to the graph shown. Sketch the variation of emf in the coil with time.



2. (i) Where is the energy stored in an inductor?

(ii) Show that magnetic energy required to build up the current I in a coil of self-inductance L is given by proportional to I^2.

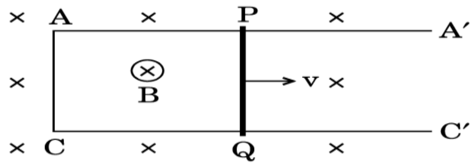
(iii) A 1.0 m metallic rod is rotated with an angular velocity of 400 rad/s about an axis normal to the rod passing through its one end. The other end of the rod is in contact with a circular metallic ring. A constant and uniform magnetic field of 0.5 T parallel to the axis exists everywhere. Calculate the emf developed between the centre and the ring.

3. A coil of number of turns *N*, area *A* is rotated at a constant angular speed ω in a uniform magnetic field *B* and connect to a resistor. Deduce an expression for

(i) maximum emf induced in the coil

(ii) power dissipated in the coil

4. (i) A conducting rod *PQ* of length 20 cm and resistance 0.1 ∧ rests on two smooth parallel rails of negligible resistance *AA*2 and *CC*2. It can slide on the rails and the arrangement is positioned between the poles of a permanent magnet producing uniform magnetic field $B = 0{\cdot}4$ T. The rails, the rod and the magnetic field are in three mutually perpendicular directions as shown in the figure.



If the ends *A* and *C* of the rails are short circuited, find the

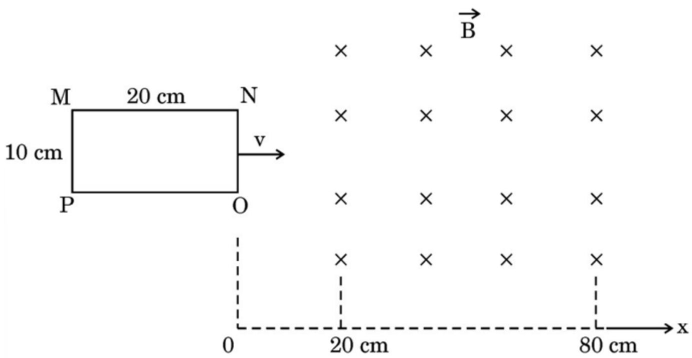
(a) Current in the loop

(b) external force required to move the rod with uniform velocity $v = 10$ cm/s, and

(c) power required to do so.

(ii) How does one understand the motional emf induced in a conductor by invoking the Lorentz force acting on the free charge carriers of the conductor? Explain.

5. (i) A rectangular loop of sides 10 cm × 20 cm is kept outside a region of uniform magnetic field $|\vec{B}| = 5\text{ mT}$ as shown in the figure. The loop is moved with the velocity of 5 cm/s till it goes completely out of the magnetic field.

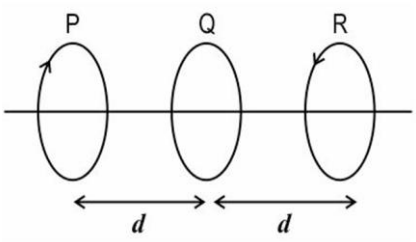


(a) Sketch the variation of the magnetic flux linked with the loop for $x(0 \le x \le 100\text{ cm})$.

(b) What is the maximum value of magnetic flux linked with the loop?

(c) Will an external work be required to be done to move the loop through the magnetic field?

(ii) Given three identical coils P, Q and R placed coaxially as shown. Equal and opposite currents flow through the coils P and R.



Coil P is moved to the right keeping the coils Q and R fixed. Will the flux linked with coil Q increase or decrease? Give reason. Using Lenz's law, identify the direction of induced current through coil. If the coil P is moved to the left, how the answers will change?

Answers/Hints:

1. (i) Current in loop 1

$$I_1 = \frac{V}{R_1} = \frac{4+2t}{10}$$

Magnetic field at center of loop 1

$$B_1 = \frac{\mu_0 I_1}{2p} = \frac{\mu_0 (4+2t)}{20}$$

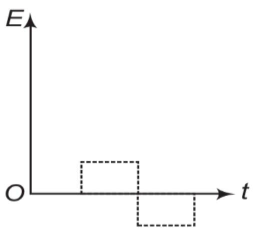
Flux linked with loop 2

$$\phi_2 = B_1 A_2 = \frac{\mu_0}{20}(4+2t)\pi(0.1)^2$$

Emf induced

$$\varepsilon_2 = \frac{d\phi_2}{dt} = \frac{\mu_0 \pi}{1000}$$ Induced current in loop 2 $$I_2 = \frac{\varepsilon_2}{R_2} = \frac{\mu_0 \pi}{1000}$$

(ii)



2. (i) **Derivation**

(ii) Emf developed between the centre of ring and the point on the ring

$$\varepsilon = \frac{1}{2} B\omega l^2$$ So. $\varepsilon = 100$ V .

3. (i) $\varepsilon_{\max} = NBA\omega$

(ii)

$$P = \frac{N^2B^2A^2\omega^2 \sin^2 \omega t}{R}$$

$$\langle P \rangle = \frac{N^2B^2A^2\omega^2}{2R}$$

4. (i) (a) $I = Bvl/R$

(b) $F = BlI = Bl\left(\frac{Bvl}{R}\right) = \frac{B^2l^2v}{R} = 6.4\times10^{-3}$ N

(c) $P = Fv = 0.64\times10^{-3}$ W

(ii) When conductor moves, charges inside conductor also move with same speed and experience Lorentz force, $F = qvB$. Its direction is along the length of conductor.

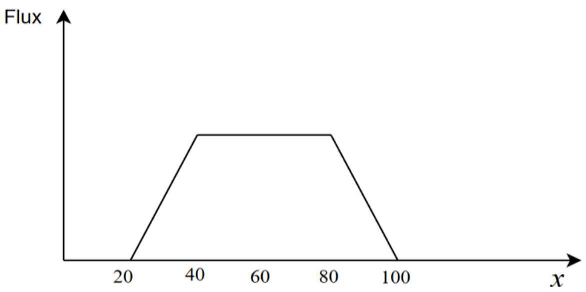
Work done in moving charge q along the conductor of length l

$W = Fl = qvBl$

Emf is work done per unit charge

$$\varepsilon = \frac{W}{q} = Bvl$$

5. (i) (a)



(b) $\phi = BA = 10^{-3}$ Wb

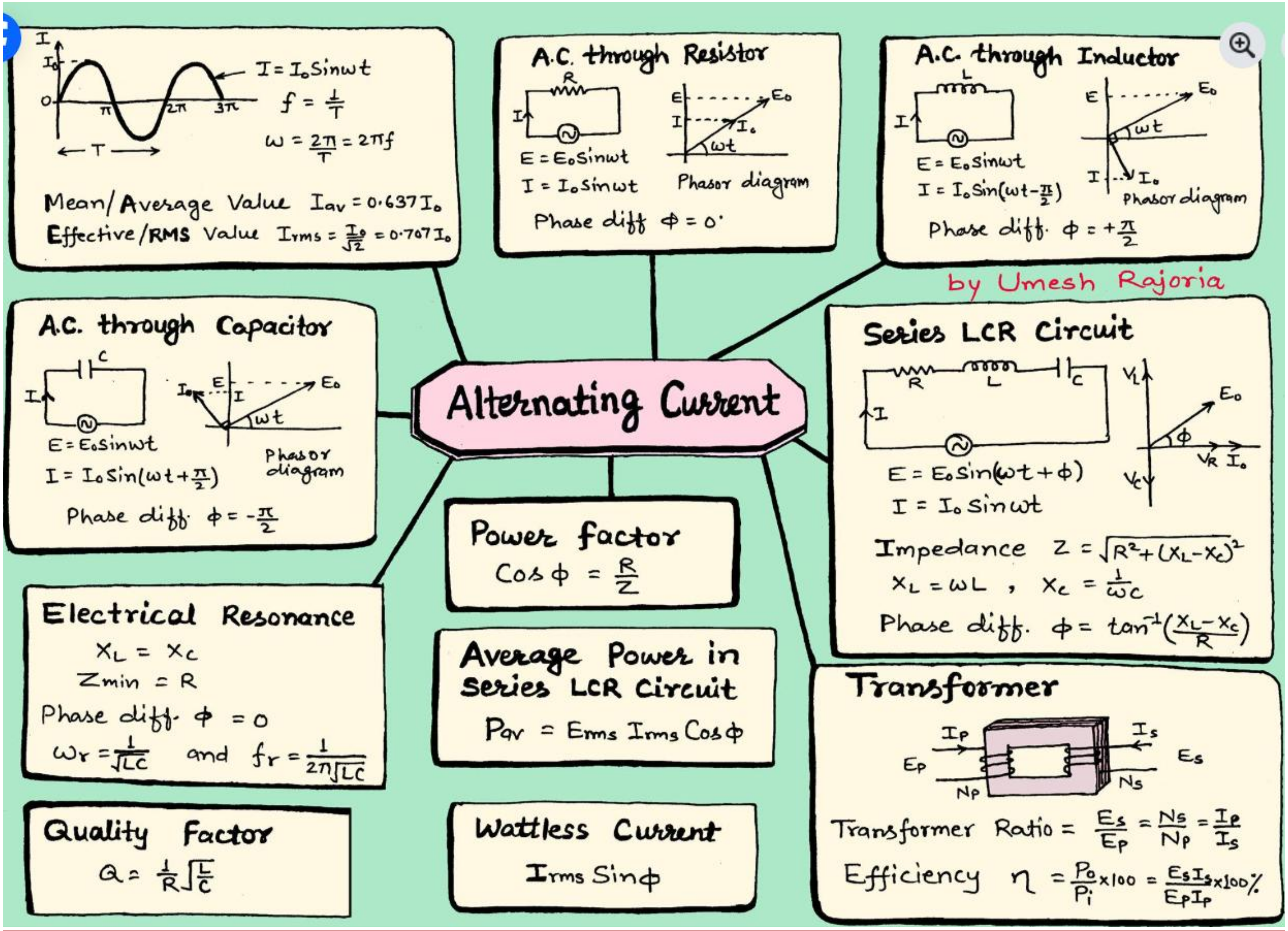
(c) Yes, external work is required.

(ii) Flux linked with coil Q due to coil P increases. Flux linked with coil Q due to coil R remains the same. So the overall flux linked with the coil Q increases. Induced current through Q flows in the direction opposite to that in P, that is anti-clockwise direction.

If the coil P is moved to left, flux linked with coil Q due to coil P decreases. Flux linked with coil Q due to coil R remains the same. Overall flux linked with the coil Q decreases. Induced current through Q flows in the direction same as that in P, that is clockwise direction.

CHAPTER 7

ALTERNATING CURRENT



MULTIPLE CHOICE QUESTIONS (1 Mark)

1. Adithya peddles a stationary bicycle the pedals of which are attached to a 500 turn coil of area 11 m^2. The coil rotates at half a revolution per second and it is placed in a uniform magnetic field of 20.5 T perpendicular to the axis of rotation of the coil. What is the maximum voltage generated in the coil?

(a) 354035 V (b) 85000V (c) 111647 V (d) 46464 V

2. Find out the net power consumed over a full cycle, if a 150 Ω resistor is connected to a 350 V, 100 Hz AC supply.

(a) 2.3 W (b) 350 W (c) 805 W (d) 500 W

3. An ac source is connected to a resistor and an inductor in series. The voltage across the resistor and inductor are 8 V and 6 V respectively. The voltage of the source is

(a) 10 V (b) 12 V (c) 14 V (d) 16 V

4. Find the true statement.

(a) Length of the phasor must be greater than the peak value of alternating voltage or alternating current

(b) When the current reaches its maximum value after emf becomes maximum, then the current is considered to be leading ahead of emf

(c) When the emf reaches its maximum value after current becomes maximum, then the emf is considered to be behind the current

(d) Phasors for voltage and current are in the same direction when the phase angle between voltage and current is zero

5. Why does an inductor offer an easy path to dc and a resistive path to ac?

(a) X_L is maximum for dc and infinite for ac (b) X_L is zero for dc and infinite for ac

(c) X_L is zero for dc and finite for ac (d) X_L is maximum for dc and finite for ac

6. A capacitor of capacitance 10 μF is connected to an oscillator giving an output voltage, $E = 10 \sin \omega t$ volt. If $\omega = 10$ rad s^{-1}, find the peak current in the circuit.

(a) 197 mA (b) 1 mA (c) 179 mA (d) 5 Ma

7. A 1.50 μF capacitor is connected to a 220 V, 50 Hz source. If the frequency is doubled, what happens to the capacitive reactance?

(a) Remains the same (b) Doubled (c) Halved (d) Becomes zero

8. Which among the following is the correct expression for finding capacitive reactance for an ac circuit containing capacitor only?

(a) Xc = 2πf (b) Xc = 1/2πfC (c) Xc = 2πfC (d) Xc = 2πf/C

9. If a 0.5 H inductor, 80 μF capacitor and a 40 Ω resistor are connected in series with a 150 V, 60 Hz supply. Calculate the impedance of the circuit.

(a) 100 Ω (b) 160.3 Ω (c) 50 Ω (d) 65 Ω

10. In a series LCR circuit, the voltage across the resistance, capacitance and inductance is 10 V each. If the capacitance is short circuited the voltage across the inductance will be

(a) 10 V (b) 10√2 V (c) 10/√2 V (d) 20 V

Answers:

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

ASSERTION & REASON BASED QUESTIONS (1 Mark)

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 one of 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 : In series LCR resonance circuit, the impedance is equal to the ohmic resistance.

Reason: At resonance, the inductive reactance exceeds the capacitive reactance.

2. Assertion : A capacitor is connected to a direct current source. Its reactance is infinite.

Reason : Reactance of a capacitor is given by $X_C = 1/\omega C$.

3. Assertion : The alternating current lags behind the emf by a phase angle of, $\pi/2$ when AC flows through an inductor.

Reason : The inductive reactance increases as the frequency of AC source increases.

4. Assertion : The power is produced when a transformer steps up the voltage.

Reason : In an ideal transformer VI = constant.

5. Assertion : The voltage and current in a series AC circuit are given by $V = V_0 \sin\omega t$ and $I = I_0\cos\omega t$. The power dissipated in the circuit is zero.

Reason : Power in AC circuit is given by $P = (V_0 I_0 \cos)/2$

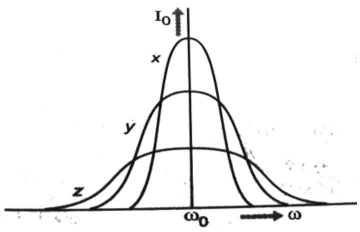
Answers:

1. (c) 2. (a) 3. (b) 4. (a) 5. (a)

VERY SHORT ANSWER QUESTIONS (2 Marks)

1. 11 kW of electric power can be transmitted to a distant station at (i) 220 V (ii) 22000 V. Which of the two transmission modes be preferred and why ? Support your answer with calculations.

2. Three students X,Y and Z performed an experiment for studying variation of ac with angular frequency in series LCR circuit, and obtained the graphs shown in figure. They all used ac source of same rms value and inductance of same value. What can we conclude about (i) Capacitance value (ii) Resistance value used by them? In which case will the quality factor be maximum? What we conclude about nature of impedance of set up at frequency ω_0?



3. A coil of 0.01 henry inductance and 1 ohm resistance is connected to 200 volt, 50 Hz ac supply. Find the impedance of the circuit and time lag between maximum alternating voltage and current.

4. A lamp is connected in series with a capacitor. Predict your observation when this combination is connected in turn across(i) ac source and (ii) a 'dc' battery. What change would you notice in each case if the capacitance of the capacitor is increased?

5. A series LCR circuit with L = 5.0 H, C = 80 μF, R = 40 Ω connected to a variable frequency 240 V source. Calculate

(i) The angular frequency of the source which drives the circuit at resonance.
(ii) The current at the resonating frequency.
(iii) The rms potential drop across the capacitor at resonance

6. In a series LCR circuit, $V_L = V_C \neq V_R$. What is the value of power factor for this circuit?

7. A resistor R and an inductor L are connected in series to a source $V = V_0 \sin \omega t$. (i) Find the peak value of the voltage drops across R and across L. (ii) phase difference between the applied voltage and current.
8. 11 kW of electric power can be transmitted to a distant station at (i) 220 V (ii) 22000 V. Which of the two transmission modes be preferred and why ? Support your answer with calculations.

9. A voltage $V = V_0 \sin\omega t$ is applied to a series LCR circuit. Under what condition is (i) no power dissipated even though the current flows through the circuit (ii) maximum power dissipated in the circuit?

10. An inductor 200 mH, capacitor 500 μF, resistor 10 Ω are connected in series with a 100 V, variable frequency ac source. Calculate the (i) frequency at which the power factor of the circuit is unity. (ii) current amplitude at this frequency.

<u>Answers/Hints:</u>

1. (i) When power is transmitted at $E_s = 220V$:
$I_s = E_p I_p / E_s = 50$ A
Energy lost a heat = $I^2_s R = (50)^2 R = 2500R$
(ii) When power is transmitted at $E_s = 22000V$:

$I_s = E_p I_p / E_s = 0.5$ A
Energy lost as heat = $I^2_s R = (0.5)^2 R = 0.25R$. Therefore, power transmission should be done at 22000 V.

2. For resonance, $X_L = X_C$. As L is same, therefore, capacitance used by all the three students must be the same for same value of ω_0.
Maximum value of current is inversely proportional to R. Therefore, resistance used by students X is lowest and resistance used by student Z is the highest.
At ω_0, impedance is equal to ohmic resistance only.

3. $Z = \sqrt{1^2 + (3.14)^2} = 3.3\ \Omega$

$$\tan\phi = \frac{3.14}{1} = 3.14;\ \omega = 2\pi(50) = 100\pi;\ \Delta t = \frac{\phi}{\omega} = \frac{1}{250}\ \text{s}$$

4. When dc source is connected, the condenser is charged but no current flows in the circuit, therefore, the lamp does not glow. No change occurs even when capacitance of capacitor is increased.

When ac source is connected, the capacitor offers capacitive reactance $X_C = 1/\omega C$. The current flows in the circuit and the lamp glows. On increasing capacitance, X_c decreases. Therefore, glow of the bulb increases.

5. $\omega = 1/(LC)^{1/2} = 50$ rad/s; $I_{rms} = V_{rms}/R = 6$ A

6. $V_L = V_C$ ® $X_L = X_C$ ® $Z = R$ ® $\cos\phi = R/Z = 1$. So, power factor is unity.

8. $\omega_0 = 1/(LC)^{1/2} = 50$ rad/s. At resonance $Z = R$, therefore $I_0 = 5.66$ A.

10. (i) Power factor, $\cos\phi = 1$(given) ® $R/Z = 1$ ® $Z = R$ ® $\sqrt{R^2 + (X_L - X_C)^2} = R$
® $X_L - X_C = 0$ ® $X_L = X_C$ ® $2\pi f L = 1/(2\pi f C)$. On Solving: $f \approx 16$ Hz.
(ii) Current amplitude at resonance: $I = 10$ A

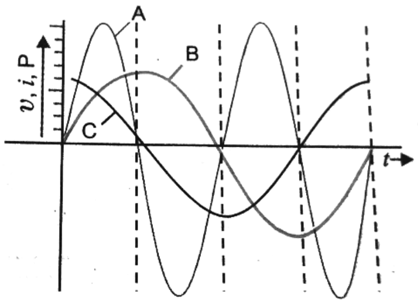
SHORT ANSWER QUESTIONS (3 Marks)

1. A device X is connected to an AC source. The variation of voltage, current and power in one complete cycle is shown in figure.

(a) Which curve shows power consumption over a full cycle?

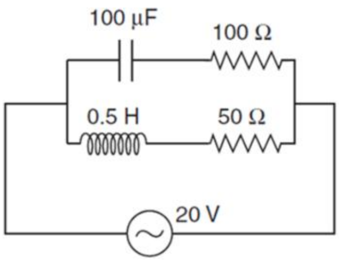
(b) What is the average power consumption over a cycle?

(c) Identify the device X.



2. In a series LR circuit (L = 35 mH and R = 11 Ω), a variable emf source ($V = V_0 \sin\omega t$) of $V_{rms} = 220$ V and frequency 50 Hz is applied. Find the current amplitude in the circuit and phase of current with respect to voltage. Draw current-time graph on given graph (π = 22/7).

3. In the given circuit, the AC source has ω = 100 rad s^{-1}. Considering the inductor and capacitor to be ideal, what will be the current I flowing through the circuit?



4. An ac generator is made up of two fixed pole pieces and a coil with 50 turns and a surface area of 2.5 m^2 that rotates in a uniform magnetic field *B* = 0.2 tesla at an angle of 60 $rads^{-1}$. The circuit's resistance, including the resistance of the coil, is 500 ohms**.**

(a) Determine the generator's maximum current draw.

(b) What is the flux at zero current?

(c) Would the generator still function if the coil were stationary, but the pole pieces spun at the same rate as before? Justify your response.

5. A little community 15 km from a 440 V electric producing station with a requirement for 800 kW of 220 V electricity. The two wirelines carrying power have a resistance of 0.5 per km. A substation in the town houses a 4000 – 220 V step-down transformer that provides the town with power from the line.

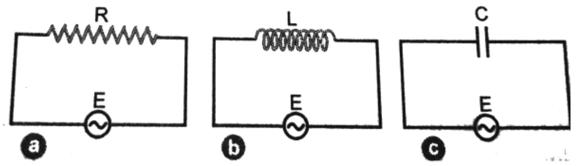
(a) Calculate the heat-related line power loss.

(b) Given a minimal power loss from leakage, how much electricity must the plant produce?

(c) Describe the plant's step-up transformer.

6. The secondary transformer, whose primary draw line voltage is wired to a 60 W load. What is the primary coil's current if the load has a 0.54 A current flow? Describe the kind of transformer that is being used.

7. Figure show three alternating circuits with equal currents. If frequency of alternating emf is increased, what will be the effect on currents in the three cases? Explain.



8. A series AC circuit containing an inductor (20 mH), a capacitor (120 μF) and a resistor (60 Ω) is driven by an AC source of 24 V/50 Hz. Calculate the energy dissipated in the circuit in 60 s .

9. A power transmission line feeds input power at 2300 V to a step-down transformer with its primary windings having 4000 turns. The output power is delivered at 230 V by the transformer. If the current in the primary of the transformer is 5 A and its efficiency is 90%, what would be the output current?

10. In an ac circuit, the instantaneous emf and current is given by $e = 100\sin 30t$, and $i = 20\sin(30t - \pi/4)$. Calculate the average power consumed by the circuit and the wattless current in one cycle of AC.

Answers/Hints:

1. (a) Power is the product of voltage and current (Power = P = VI). So, the curve of power will be having maximum amplitude, equals to the product of amplitudes of voltage (V) and current (I) curve. Frequencies , of B and C are-equal, therefore they represent V and I curves. So, the curve A represents power.

(b) Average power consumption over a cycle is zero.

(c) Here phase difference between V and I is π /2. Therefore, the device 'X' may be an inductor (L) or capacitor (C) or the series combination of L and C.

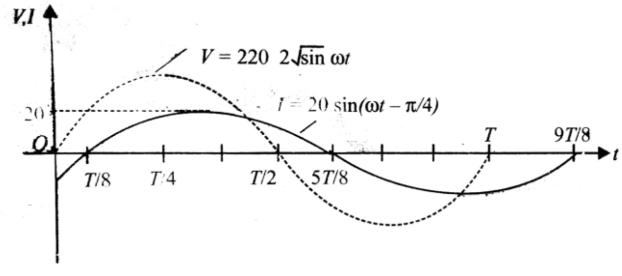
2. Impedance, $Z = \sqrt{R^2 + X_L^2} = 11\sqrt{2}\ \Omega$

Hence, amplitude of voltage: $V_0 = \sqrt{2} V_{rms} = 220\sqrt{2}$ V

Amplitude of current: $i_0 = V_0/Z = 20$ A

Phase difference: $\cos\phi = R/Z = \frac{1}{\sqrt{2}}$ ® $\phi = \pi/4$

In L-R circuit voltage leads the current. Hence, instantaneous current in the circuit is $I = 20\sin(\omega t - \pi/4)$ A.



3. Calculate the impedances of the capacitor and inductor branches separately. After impedance, calculate current in each branch using $I = V/Z$. Calculate phase difference for each using $\cos \phi = R/Z$. From this we will get to know the phase difference between currents in the two branches. It comes out to be $\pi/2$. So, $I = \sqrt{I_1^2 + I_2^2}$ = 0.3 A.

4. (a) The coil's maximum amount of induced emf is $\varepsilon_0 = nBA\omega$ = 1500 V. Maximum current is I_0 = 3 A.

(b) $\phi = nBA = 50 \times 0.2 \times 2.5 = 25$ Wb.

(c) Yes, the magnet and coil must move relative to one another for a generator to function.

5. (a) Total resistance of the wires, R = (15 + 15)×0.5 = 15 Ω

The rms current in the wires is given as $I_{rms} = P/V_1$ = 800000/4000 = 200 A

Line power loss = $I^2R = (200)^2 \times 15$ = 600 kW

(b) Assuming there will be little loss from leakage, total power supply equals town power demand plus line power loss = 800 kW + 600 kW = 1400 kW

(c) Voltage drop on the line is equals = IR = 200×15 = 3000 V.

Consequently, total voltage transmitted from plant V = 4000 + 3000 = 7000 V.

Power generated is 440 V. Hence, the rating of plant's step-up transformer is 440 V to 7000 V.

6. P_s = 60 W and I_s = 0.54 A.

$V_s = P_s/I_s$ = 60/0.54 = 111 V

The transformer is, therefore, a step-down transformer, and its transformation ratio is 1/2. As a result, I_p = 0.27 A

7. (i) In circuit (a), there will be no effect on the current flowing. This is because, R is not affected by frequency.
(ii) In circuit (b), current will decrease as inductive reactance $X_L = \omega L = 2\pi f L$ will increase with increasing frequency.
(iii) In circuit (c), current will increase as capacitive reactance $X_C = 1/\omega C = 1/2\pi f C$ will decrease on increasing the frequency.

8. Calculate $X_L = \omega L$ = 6.28 Ω and $X_C = (1/\omega C)$ = 26.54 Ω

Find Z: Z^2 = 4010

Average power dissipated, $P_{av} = V_{rms} I_{rms} \cos \phi$

$P_{av} = V_{rms} \times (V_{rms}/Z) \times (R/Z)$ ® $P_{av} = (V_{rms}{}^2/Z^2) \times R$ = 8.62 W

Energy dissipated in 60 s = 5.17×10^2 J

9. $\eta = P_o/P_i = (V_sI_s)/(V_pI_p)$ ® $I_s = (\eta V_pI_p)/V_s$ = 45 A

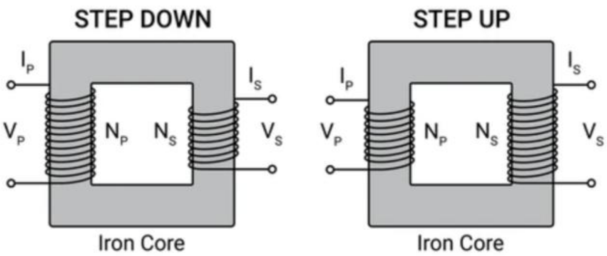
10. For average power use: $P_{avg} = V_{rms}I_{rms}\cos\theta = 1000/\sqrt{2}$ W

Wattless current = $I_{rms}\sin\theta$ = 10 amp

CASE BASED QUESTIONS (4 Marks)

1. A group of students is preparing for their physics exam, focusing on transformers and their applications in electrical systems. They explore how transformers operate based on electromagnetic induction principles, emphasizing their role in efficiently transferring electrical energy between circuits. They learn that transformers can step up or step-down voltages, which is crucial for long-distance power transmission, reducing energy losses.

During their study session, they discuss various types of transformers, such as step-up and step-down transformers, and how the turns ratio influences their functionality. They also consider real-world applications, like how high-voltage transmission lines minimize current and thus reduce resistive losses in the wires. As they prepare for practical questions, they recognize the importance of understanding the limitations of transformers, such as energy losses due to heat and the necessity for alternating current (AC) for operation.



(i). A power company uses transformers to step up the voltage to 500 kV for transmission over long distances. If a fault occurs, resulting in the voltage dropping to 100 kV at the substation, what could be the immediate consequences for the electrical grid?

(a) Increased power loss due to higher current flow. (b) Improved efficiency in power transmission.

(c) Immediate shutdown of all connected devices. (d) Decrease in voltage regulation across the grid.

(ii). An electric vehicle charging station utilizes a transformer to convert 480 V AC from the grid to 240 V AC for charging. If the transformer has an efficiency of 95% and the charging station requires 6 kW of power, what is the minimum input power required from the grid?

(a) 5.7 K W (b) 6.3 kW (c) 6.7 kW (d) 5.9 K W

(iii). In a renewable energy application, a solar power system uses a transformer to convert the generated voltage from the solar panels (typically low voltage) to a higher voltage suitable for feeding into the grid. If the transformer steps up the voltage from 48 V to 240 V, what is a key benefit of this voltage transformation in terms of energy transmission?

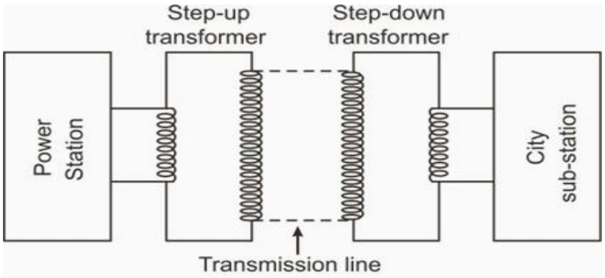
(a) It allows for lower current, reducing resistive losses over long distances.
(b) It increases the overall energy produced by the solar panels.
(c) It eliminates the need for batteries in the system.
(d) It increases the efficiency of solar panel operation.
(iv) A transformer operates at an efficiency of 90%. If the input power is 1000 W, what is the maximum output power it can deliver?
(a) 900 W (b) 1000 (c) 1100 W (d) 100 W

OR

(v) Which of the following factors primarily affects the voltage transformation ratio in a transformer?
(a) The frequency of the alternating current. (b)The material of the wire used for the coils.

(c) The number of turns in the primary and secondary coils. (d)The temperature of the transformer.

2. The large-scale transmission and distribution of electrical energy over long distances is done with the use of transformers. The voltage output of the generator is stepped-up.



Long distance power transmissions

It is then transmitted over long distances to an area sub-station near the consumers. Then the voltage is stepped-down. It is further stepped-down at distributing sub-stations and utility poles before a power supply of 240 V reaches our homes. Read the given passage carefully and give the answer of the following questions:

(i). Which of the following statement is true?

(a) Energy is created when a transformer steps-up the voltage

(b) A transformer is designed to convert an AC voltage to DC voltage

(c) Step-up transformer increases the power for transmission

(d) Step-down transformer decreases the AC voltage

(ii). If the secondary coil has a greater number of turns than the primary:

(a) the voltage is stepped-up ($V_s > V_p$) and arrangement is called a step-up transformer

(b) the voltage is stepped-down ($V_s < V_p$) and arrangement is called a step-down transformer

(c) the current is stepped-up ($I_s > I_p$) and arrangement is called a step-up transformer

(d) the current is stepped-down ($I_s < I_p$) and arrangement is called a step-down transformer.

(iii) We need to step-up the voltage for power transmission, so that:

(a) the current is reduced and consequently, the I^2R loss is cut down

(b) the voltage is increased the power losses are also increased

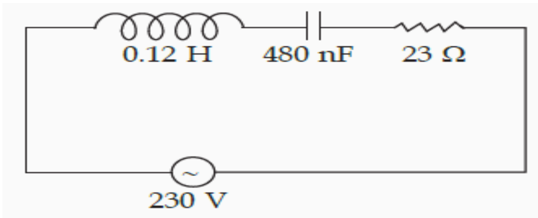
(c) the power is increased before transmission is done

(d) the voltage is decreased so V^2/R losses are reduced

(iv). A power transmission line feeds input power at 2300 V to a step-down transformer with its primary windings having 4000 turns. The number of turns in the secondary in order to get output power at 230 V are:

(a). 4 (b) 40 (c) 400 (d.)4000

3. 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.



(i) 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

(ii) The value of maximum current is

(a) 14.14 A (b) 22.52 A (c) 50.25 A (d) 47.41 A

(iii) The value of maximum power is

(a) 2200 W (b) 2299.3 W (c) 5500 W (d) 4700 W

(iv) What is the Q-factor of the given circuit?

(a) 25 (b) 42.21 (c) 35.42 (d) 21.74

(OR)

(v) At resonance which of the following physical quantity is maximum?

(a) Impedance (b) Current (c) Both (a) and (b) (d) Neither (a) nor (b).

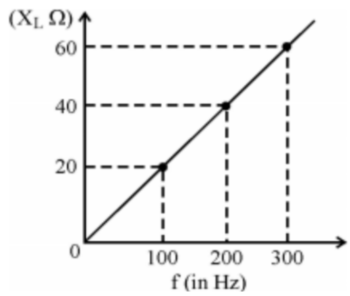
<u>Answers:</u>

1. (i) (a) (ii) (b) (iii) (a) (iv) (a) (v) (c)

2. (i) (d) (ii) (a) (iii) (a) (iv) (c)

3. (i) (c) (ii) (a) (iii) (b) (iv) (d) (v) (b)

<u>LONG ANSWER TYPE QUESTIONS (5 Marks)</u>



1. The variation of inductive resistance (X_L) of an inductor with the frequency (*f*) of the of 100 V and variable frequency is shown in the figure.

(i) Calculate the self-inductance of the inductor.

(ii) When this inductor is used in series with a capacitor of unknown value and a resistor of 10 Ω at 300 s^{-1}, maximum power dissipation occurs in the circuit.

Calculate the capacitance of the capacitor.

2. (i) With the help of a diagram, explain the principle of a device which changes a low ac voltage into a high voltage. Deduce the expression for the ratio of secondary voltage to the primary voltage in terms of the ratio of the number of turns of primary and secondary winding. For an ideal transformer, obtain the ratio of primary and secondary currents in terms of the ratio of the voltages in the secondary and primary coils.

(b) Write any two sources of the energy losses which occur in actual transformers.

(c) A step-up transformer converts a low input voltage into a high output voltage. Does it violate law of conservation of energy? Explain.

3. A series LCR 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 (i) maximum and (ii) minimum.

4. A circuit containing a 80 mH inductor and a 60 μF capacitor in series is connected to a 230 V, 50 Hz supply. The resistance of the circuit is negligible.

(a) Obtain the current amplitude and rms values.

(b) Obtain the rms values of potential drops across each element.

(c) What is the average power transferred to the inductor?

(d) What is the average power transferred to the capacitor.

(e) What is the total average power absorbed by the circuit?

5. (i) Write the principle of working of an ac generator. Draw its labelled diagram and explain its working.

(ii) A resistor of 400Ω , an inductor of (5/π) H and a capacitor of (50/π) μF are joined in series across an ac source $v = 140 \sin (100\pi)t$ V. Find the rms voltages across these three circuit elements. The algebraic sum of these voltages is more than the rms voltage of source. Explain.

6. (i) Differentiate between peak and rms values of alternating current. How are they related?

(ii) A current element X is connected across an ac source of emf $V = V_0 \sin 2\pi ft$. It is found that the voltage leads the current in phase by π/2 radian. If element X was replaced by element Y, the voltage lags behind the current in phase by π/2 radian.

(i) Identify elements X and Y by drawing phasor diagrams.

(ii) Obtain the condition of resonance when both elements X and Y are connected in series to the source and obtain expression for resonant frequency. What is the impedance value in this case ?

<u>Answers/Hints:</u>

1. (i) The slope gives ω. Using it, find $X_L = \omega L$= 32 mH

(ii) As at a frequency $f_0 = 300\ s^{-1}$, maximum power dissipation occurs. The frequency f_0 is the resonant frequency. Using its expression, find C = 8.85 F

2. (a) Correct explanation

(b) The two sources of energy losses are eddy current losses and flux leakage losses.

(c)There is no violation of the principle of the conservation of energy in a step-up transformer. Output voltage increases the output current decreases automatically keeping the power the same

4. (a) Find $Z = X_L – X_C$. Peak value of current = V_0/Z = 11.63 A. RMS value = 8.22 A

(b) $V_L = IX_L$, $V_C = IX_C$

(c) Average power consumed by the inductor is zero as the voltage leads current by $\pi/2$.

(d) Average power consumed by the capacitor is zero as the voltage lags current by $\pi/2$.

(e) The total power absorbed is zero.

5. $V_R = 80\text{V}, V_L = 40V, V_C = 100$

$V \neq V_R + V_C + V_L$

$V = \sqrt{(V_R^2 - (V_L - V_C)^2} = 100V = APPLIED\ VOLTAGE$

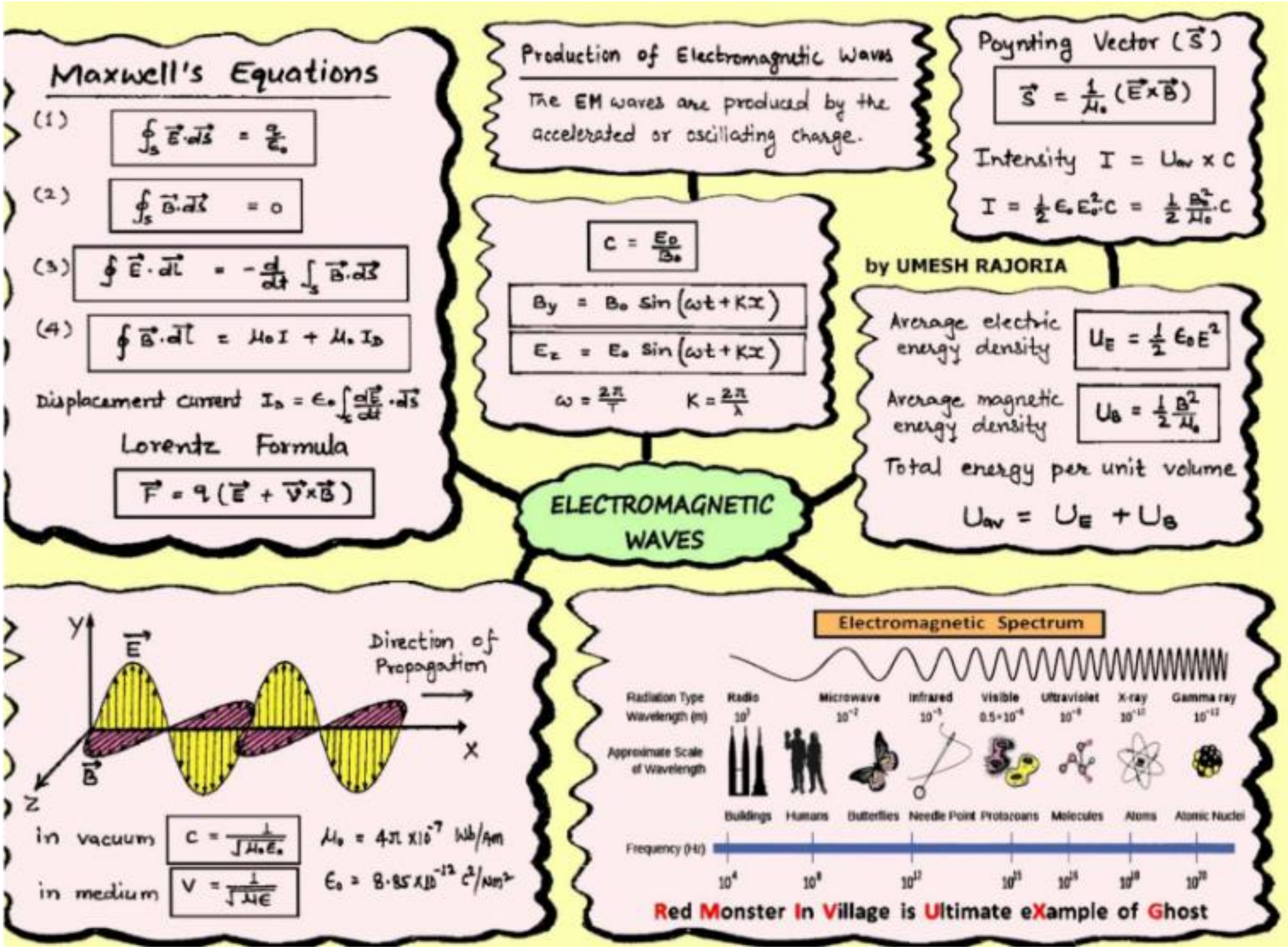
6. (i) X is inductor, Y is capacitor

(ii) Recall the formula for resonance frequency.

CHAPTER 8

ELECTROMAGNETIC WAVE

MIND MAP



MULTIPLE CHOICE QUESTIONS (1 MARK)

1.A radio wave has a frequency of 100 MHz and travels with the speed of light. Its wavelength is:

a) 3 m b) 1.5 m c)0.3 m d) 30 m

Correct Answer:

2.. The energy of a photon of light with wavelength 500 nm is approximately:

a) 2.48 eV b)3.1 eV c)4.14 eV d)1.24 eV

Correct Answer:

3.. The electric field of a plane EM wave is given by $E = E_0 \sin(kx - \omega t)$. What is the direction of propagation of the wave?

a). Along x-axis b.) Along y-axis c). Along z-axis d) Opposite to x-axis

Correct Answer4.. Calculate the frequency of an EM wave with a wavelength of 600 nm.

a) 5×10^{14} Hz b)3×10^{14} Hz c) 6×10^{14} Hz d)4×10^{14} Hz

Correct Answer: 5. If the electric field in a plane EM wave is E = 50 V/m, find the magnetic field B.

a.) 1.67×10^{-7} T   b) 5.67×10^{-7} T   c) 2.34×10^{-7} T   d) 3.5×10^{-7} T

Correct Answer:

6. The momentum of a photon with energy 3 eV is:

a.) 1.6×10^{-27} kg·m/s   b.) 1.6×10^{-22} kg·m/s   c.) 1.6×10^{-24} kg·m/s   d.) 1.6×10^{-30} kg·m/s

Correct Answer:

Solution: $p = E/c = (3 \times 1.6 \times 10-19\ J) / (3 \times 10^8\ m/s) = 1.6 \times 10^{-27}$ kg·m/s.

7. If the magnetic field of an EM wave is B = 1 μT, the energy density of the wave is:

a) 4×10^{-6} J/m³   b) 2×10^{-6} J/m³   c) 5×10^{-6} J/m³   d) 1×10^{-6} J/m³

Correct Answer:

Solution: $u = B^2/(2\mu_0) = (1\times10^{-6})^2 / (2\times4\pi\times10^{-7}) \approx 4 \times 10^{-6}$ J/m³.

8. A photon has energy 6.6×10^{-19} J. Its frequency is:

a) 1×10^{15} Hz   b) 3×10^{14} Hz   c) 2×10^{15} Hz   d) 5×10^{14} Hz

Correct Answer:

Solution: $f = E/h = (6.6\times10^{-19}) / (6.63\times10^{-34}) \approx 1 \times 10^{15}$ Hz.

9. An EM wave has electric field amplitude of 300 V/m. What is the magnetic field amplitude?

a) 1×10^{-8} T   b) 1×10^{-6} T   c). 1×10^{-7} T   d) 9×10^{-6} T

Answer:

10. The range of ultraviolet radiation is approximately:

a). 400 nm – 700 nm b) 1 mm – 700 nm c). 400 nm – 1 nm d) 0.01 nm – 0.1 nm

Answer:

<u>Assertion and Reason Questions:-</u>

11.Assertion: Electric field in EM wave is always perpendicular to magnetic field.
Reason: Both fields are parallel to direction of wave propagation.

12.Assertion: The ratio $E_0/B_0=c$ for an EM wave.
Reason: Speed of EM wave is constant in vacuum.

13.Assertion: Microwaves are used in radar and ovens.
Reason: They have short wavelength and are absorbed by water molecules.

14.Assertion: Displacement current is maximum when charging current is constant.
Reason: Displacement current depends on rate of change of electric flux.

15.Assertion: EM waves can travel in vacuum but sound waves cannot.
Reason: EM waves are mechanical in nature.

ANSWER MCQ

1- a, 2- a, 3-a, 4-c, 5-a, 6 – a, 7-a, 8-a, 9-c, 10- c

ANSWER ASSERTION REASON BASED QUESTIONS

11.b 12. a 13. a 14. a 15. b

<u>SAQ (2 Marks Questions):-</u>

1.An EM wave has electric field amplitude of 60 V/m. Calculate magnetic field amplitude.

2.Calculate frequency of EM wave with wavelength λ=0.5 m.

3.Name the part of electromagnetic spectrum of wavelength 10^{-2} m and mention its one application.

4.Name the electromagnetic radiation having the wavelength range from 1 nm to 700 nm. Give its two important applications.

5.Explain transverse nature of EM wave with a neat diagram.

6.Identify the following electromagnetic radiation as per the wavelength given below. Write one application of each. a)1mm b)10^{-3}nm

7. $E = 3.0 \sin(1.5\times10^7 t - 5x)$.

Find: (a) Frequency (b) Wavelength (c) Amplitude of B-field.

8.. A microwave oven operates at 2.45 GHz. Why is this ideal for heating-water?

9..The charging current for capacitor is 0.5 A. What is the displacement current across its plate?

10. The following table gives the wavelength of some constituents of EM spectrum. Select the wavelength range and name the associated EM wave that are used in

a).Radar system for aircraft navigation
b).Diagnostic tools in medicine

Table –

S. NO	Wavelength Range
1	10^{-10} m
2	1 m to 1mm
3	400nm to 1nm
4	10^{-3} nm

SAQ (3 Marks Questions):-

1.A radio can tune in to any station in the 7.5 MHz to 12 MHz band. What is the corresponding wavelength band ?

Hint: $\lambda = c / f$; compute λ_{max} at 7.5 MHz (~40 m) and λ_{min} at 12 MHz (~25 m)

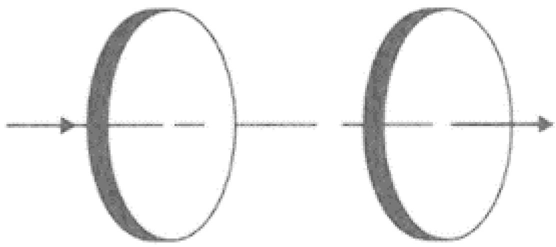
2..Suppose that the electric field part of an electromagnetic wave in vacuum is E = {(3.1 N/C) cos [(1.8 rad/m) y + (5.4 × 10^6 rad/s)t]}i. (a) What is the direction of propagation?

(b) What is the wavelength λ? (c) What is the frequency ν? (d) What is the amplitude of the magnetic field part of the wave? (e) Write an expression for the magnetic field part of the wave.

Hint: $\cos(ky + \omega t) \Rightarrow$ wave travels in $-\hat{y}$; $\lambda = 2\pi/k$; $\nu = \omega/2\pi$; $B_0 = E_0 / c$; B along $\pm\hat{j} \times \hat{i} = \pm\hat{k}$.

3. Two circular plates having radius of 12 cm each and separated by 5 cm are used to make a capacitor as shown in the Figure 8.6. An external source charges this capacitor. 0.15 A is the charging current which remains constant. (a) Determine the capacitance and the rate of charge of potential difference between the

two capacitiveplates. (b) Calculate the displacement current across the capacitive plates. (c) Kirchhoff's first rule (junction rule) is applicable to each plate of the capacitor. Yes or No. Give Reasons.



Hint $C = \varepsilon_0 A/d$; $I = C\, dV/dt \Rightarrow dV/dt$; $I_d = I$; Junction rule valid as displacement current completes the loop.

4.Suppose that the electric field amplitude of an electromagnetic wave is $E_0 = 120$ N/C and that its frequency is $\nu = 50.0$ MHz. (a) Determine, B_0, ω, k, and λ. (b) Find expressions for E and B.

What is electromagnetic spectrum? Name different regions.

Hint: $B_0 = E_0/c$; $\omega = 2\pi\nu$; $\lambda = c/\nu$; $k = 2\pi/\lambda$; choose mutually perpendicular directions.

5.Identify the following electromagnetic radiations as per the wavelengths given below. Write one application of each. (i) 1 nm (ii) 10^{-12} m (iii) 10^{-8} nm.

Hint: 1 nm: X-rays (imaging); 10^{-12} m: γ-rays (nuclear medicine); 10^{-8} nm ($\approx 10^{-17}$ m) likely misprint – treat as UV (sterilisation).

6.Identify the following electromagnetic radiations as per the frequencies given below. Write one application of each. (i) 10^{20} Hz (ii) 10^{12} Hz (iii) 10^{11} Hz.

7.In an electromagnetic wave the oscillating electric field having a frequency of 3×10^{10} Hz and an amplitude of 30 V/m propagates in the positive X-direction. (i) What is the wavelength of the electromagnetic wave? (ii) Write down the expression to represent the corresponding magnetic field.

Hint: $\lambda = c/f$; $B_0 = E_0/c$; B perpendicular to E & propagation – write sinusoidal function.

8.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 is $\vec{E} = 6.3$ V/m $\hat{j}$. Calculate $\vec{B}$ at this point.

Hint: $B = (E/c)\,\hat{k}$ (since $\hat{j} \times \hat{k} = \hat{i}$).

9.(i) Describe briefly how electromagnetic waves are produced by oscillating charges? (ii) Give one use of each of the following (a) microwave (b) Ultraviolet rays (c) Infrared rays (d) Gamma rays

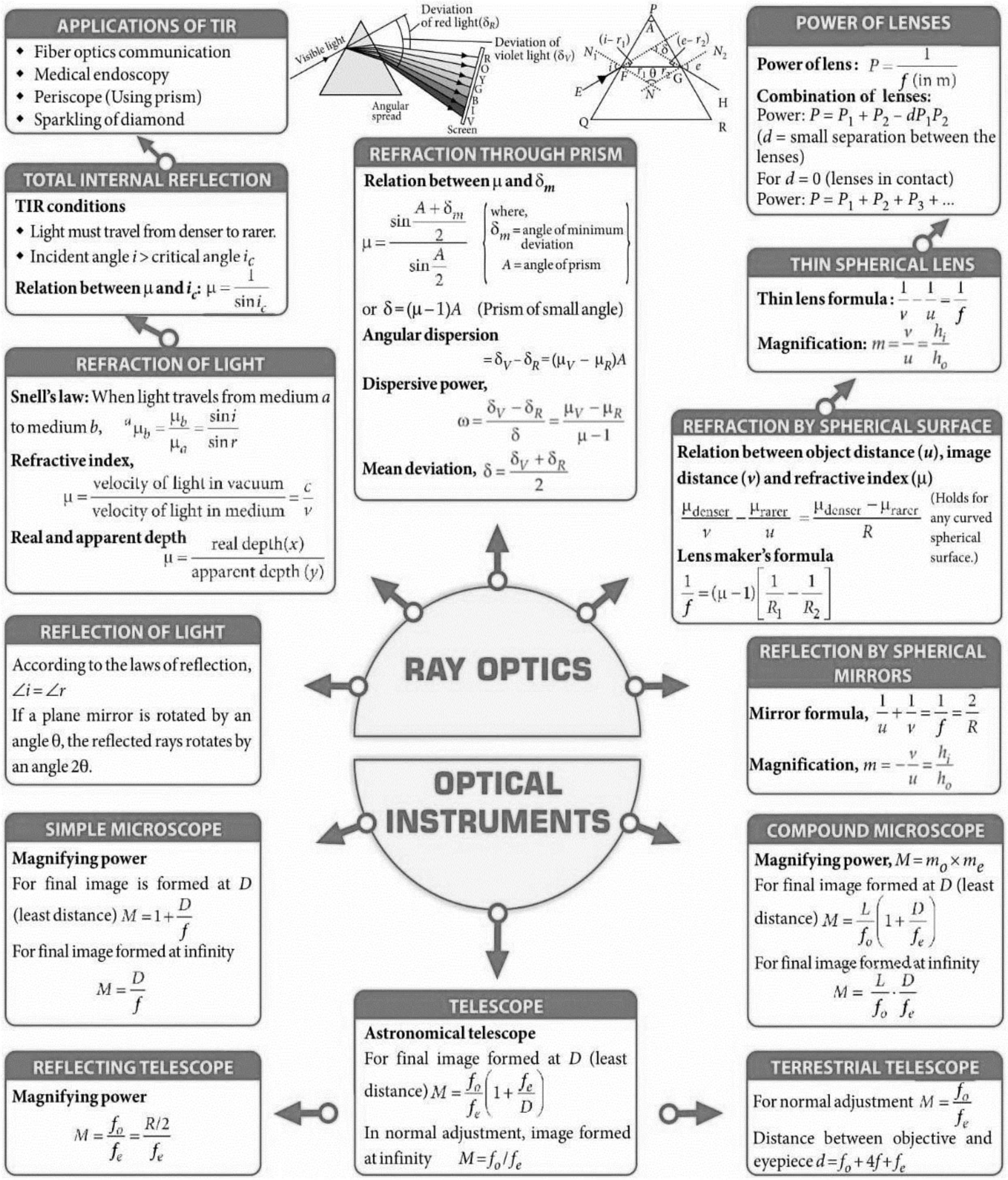
Hint: Accelerated charges radiate; state microwave oven, UV sterilisation, IR remote sensing, γ cancer therapy

10.In an electromagnetic wave propagating along the X-direction the magnetic field oscillates at a frequency of 3×10^{10} Hz and an amplitude of 10^{-7} T acting along the Y-direction. (i) What is the wavelength of the wave? (ii) Write the expression representing the corresponding oscillating electric field.

Hint: $\lambda = c/f$; $E_0 = c\,B_0$; E along ±Z direction from right-hand rule.

CHAPTER 9
RAY OPTICS AND OPTICAL INSTRUMENTS

BRAIN MAP AND FORMULA-



MULTIPLE CHOICE QUESTIONS (1 MARK)

1.An air bubble in a glass slab (u= 1.5) is 5 cm deep when viewed from one face and 2 cm deep when viewed from the opposite face. The thickness of the slab is

(a) 7 cm (b) 10 cm (c) 7.5 cm (d) 10.5 cm

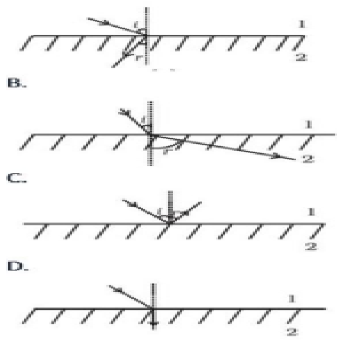
2. An object of height 1.5 cm is placed on the axis of a convex lens of focal length 25 cm. A real image is formed at a distance of 75 cm from the lens. The size of image will be

(a) 4.5 cm (b) 5 cm (c) 3.0 cm (d) 0.75 cm

3.Suppose while sitting in a parked car, you notice a jogger approaching towards you in the rear view mirror of R=2m. If the jogger is running at a speed of 5ms−1, how fast is the image of the jogger moving, when the jogger is 39 m.

(a) 1/150ms^{-1} (b) 1/60ms^{-1} (c) 1/280 ms^{-1} (d) 1/10 ms^{-1}

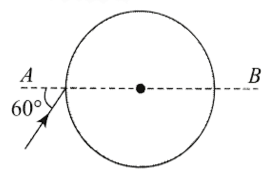
4. There are certain materials developed in laboratories which have a negative refractive index, Fig. A ray incident from air (medium 1) into such a medium (medium 2) shall follow a path given by



5. A Plano convex lens is made of refractive index 20 if the radius of curvature of the curved surface is 60 cm, then focal length of the lens is

(a) 50 cm (b) 100 cm (c) 200 cm (d) 400 cm

6 A ray of light falls on a transparent sphere with centre C as shown in the figure. The ray emerges from the sphere parallel to the line AB. Find the angle of refraction of A if the refractive index of material of sphere is √3.



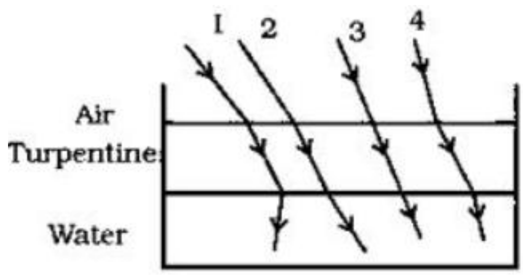
(a)√3 (b) 2 (c) √ 2 (d) 2.4

7. A biconvex lens has a radius of curvature of magnitude 20 cm. Which one of the following options describe best the image formed of an object of height 2 cm placed 30 cm from the lens?

(a) Virtual, upright, height = 1cm (b) Virtual, upright, height = 0.5cm

(c) Real, inverted, height = 4 cm (d) Real, inverted, height = 1 cm

8.The optical density of turpentine is higher than that of water, while its mass density is lower. Fig. shows a layer of turpentine floating over water in a container. For which one of the four rays incident on turpentine in Fig., the path shows is correct ?



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

9. 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

10. You are given two converging lenses of focal lengths 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, what will be the separation between the objective and the eyepiece.
A. 6.25cm B. 4.25cm C. 2.21cm D. 3.00cm

ANSWERS OF MCQ-

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

ASSERTION – REASONING BASED QUESTIONS (1 MARK)

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(b)Both Assertion (A) and Reason (R) are true and Reason (R) is NOT the correct explanation of Assertion (A).
(c) Assertion (A) is true and Reason (R) is false.
(d)Assertion (A) is false and Reason (R) is also false.

1.Assertion (A): Propagation of light through an optical fibre is due to total internal reflection taking place at the core-cladding interface.
Reason (R): Refractive index of the material of the cladding of the optical fibre is greater than that of the core.

2.. Assertion (A): A convex mirror cannot form real images.
Reason (R): Convex mirror converges the parallel rays that are incident on it.

3. Assertion : The resolving power of a telescope is more if the diameter of the objective lens is more.
Reason : Objective lens of large diameter collectd more light

4.. 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.

5. Assertion : The images formed by total internal reflections are much brighter than those formed by mirrors or lenses.
Reason : There is no loss of intensity in total internal reflection.

6. Assertion : Diamond are known for their spectacular brilliance, but diamonds found in nature rarely exhibit the brilliance.
Reason : By cutting the diamond suitably, multiple total internal reflections can be made to occur.

7.Assertion : The focal length of an equiconvex lens placed in air is equal to radius of curvature of either face.
Reason : For an equiconvex lens radius of curvature of both the faces is same.
9. Assertion : A beam of the white light shows no dispersion on emerging from a glass slab.
Reason : Dispersion in a glass slab is zero.
10. **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.

SOLUTION ASSERTION - REASON

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

SHORT ANSWER TYPE QUESTIONS (2 MARK)
1.When monochromatic light travels from a rarer to a denser medium, explain the following, giving reasons:
(i)Is the frequency of reflected and refracted light same as the frequency of incident light?
(ii) Does the decrease in speed imply a reduction in the energy carried by light wave?
2 A convex lens made of a material of refractive index n2 is kept in a medium of refractive index n1. A parallel beam of light is incident on the lens. Complete the path of rays of light emerging from the convex lens if
(i) $n1<n2$ (ii) $n1=n2$ (iii) $n1>n2$.
3. Explain giving reason, how the magnifying power of a compound microscope depends on the
(i) wavelength of incident light, and
(ii) focal length of the objective lens.
4.A tank is filled with water to a height of 12.5 cm The apparent depth of a needle lying at the bottom of the tank is measured by a microscope to be 9.4 cm. What is the refractive index of water ? If water is replaced by a liquid of refractive index 1.63 upto the same height, by what distance would the microscope have to be moved to focus on the needle again ?
5. You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope ? Give reason.

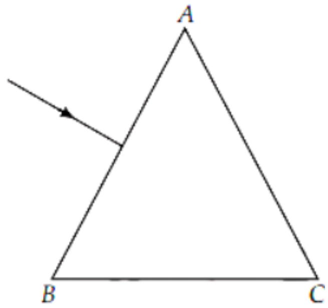
Lenses	Power (D)	Aperture (cm)
L_1	3	8
L_2	6	1
L_3	10	1

6..Use the mirror equation to deduct that :

(a) an object between f and 2f of a concave mirror produces a real image beyond 2f.

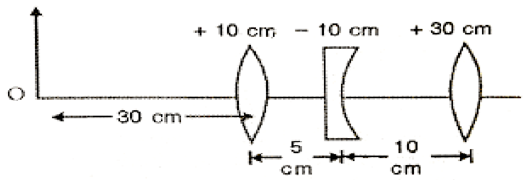
(b) a convex mirror always produces a virtual image independent of the location of the object.

7. The figure shows a ray of light falling normally on the face *A*B of an equilateral glass prism having refractive index 3/ 2 , placed in water of refractive index 4/ 3 . Will this ray suffer total internal reflection on striking the face AC? Justify your answer.

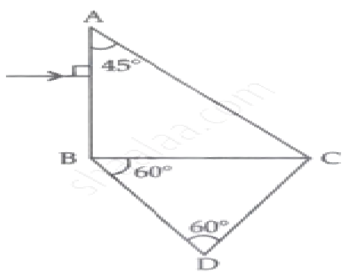


8. A point object in air is placed symmetrically at a distance of 60 cm in front of a concave spherical surface of refractive index 1.5. If the radius of curvature of the surface is 20 cm, find the position of the image formed.

9. Three lenses of focal length +10 cm, −10 cm and +30 cm are arranged coaxially as in the figure given below. Find the position of the final image formed by the combination.



10 A right-angled isosceles glass prism ABC is kept in contact with an equilateral triangular prism DBC as shown in the figure. Both prisms are made of the same glass of refractive index 1.6. Trace the path of the ray *MN* incident normally on face AB as it passes through the combination.

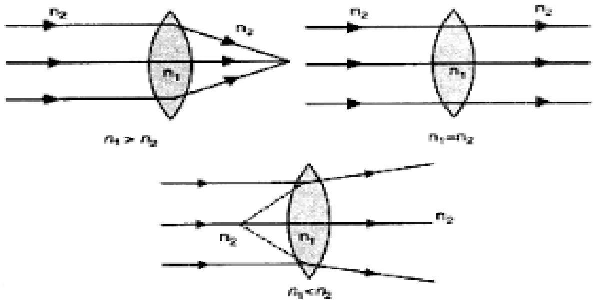


ANSWER/HINT OF SHORT ANSWER TYPE QUESTION(2 MARKS)

1..(i) Both the reflected and refracted lights have the same frequency as the frequency of incident light.

(ii) No, the reduction in the speed of light does not imply the reduction in the energy of the light wave because the energy carried by a wave depends on the amplitude of the wave, not on the speed of wave propagation.

2.



.

3(i) the magnifying power of a compound microscope varies inversely with the wavelength of the incident light.(ii) the magnifying power of a compound microscope is inversely proportional to the focal length of the objective len

4.. μ- real depth / apparent depth

The refractive index of water is approximately 1.33.

The microscope must be moved up by approximately 1.73 cm to focus on the needle again.

5. Objective lens : L_1 Eyepiece = L_3

As we know that m= - fo/fe , for higher magnification and brighter image , objective should have large aperture and large focal length and eyepiece shoula have small aperture and small focal length

6.. The mirror equation is 1/v+1/u=1/f or 1/v = 1/f – 1/u

For a concave mirror, f is positive i.e., f<0. As object is on the left, u is negative, i.e., u<0

As object lies between f and 2f of a concave mirror, ∴3f<u<f

1/2f>1/u>1/f or −1/2f<−1/u<−1/f or 1/f−1/2f<1/f−1/u<0 or 1/2f<1/v<0

∴1/v is negative or v negative. The image is real. Also v>2/f i.e., the image lies beyond2/f

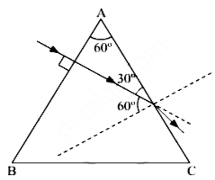
(b) For a convex mirror, f is positive i.e., f>0. As object is on the left, u is negative, i.e., u<0

As 1/v=1/f−1/u

∴1/v is positive or v is positive i.e., image is at the back of the mirror. Hence image is virtual, whatever be the value of u

7. For total internal reflection to happen at AC face,

sin θ ≥ μ water/ μ prism = (4 / 3)(3 / 2)= 0.89 where, θ is angle of incidence.



Now from the figure, we can see that angle of incidence will be 60O

So sin 60O = √ 3 /2 = 0.866 / which is less than 0.89

So total internal reflection will not take place at the face AC.

8. f=R/2 = -20/2 = -10 cm , 1/f=1v+1/u

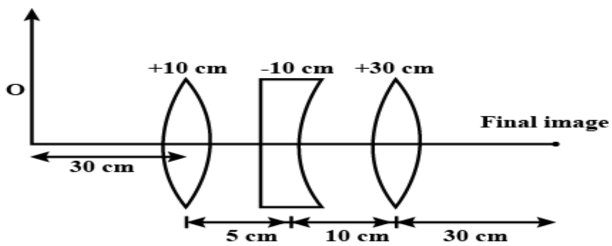
1/(-10) = 1/(-60)+1/v , v=-12 cm

9. 1/f = 1/v – 1/u

u=−30 cm , f=+10

1/ v_1=1/10 – 1/30 , v_1=15 cm

u=+10 cm , f=−10 cm , 1/v_2 = (1/10)-(1/10)= ∞



10. Since the ray MN is incident normally on face AB, it will pass through without bending.

The ray will then reach point B and enter the triangular prism DBC. . At point B, the angle of incidence is 0 º so the angle of refraction will also be 0 º .The ray will continue straight to point C

At point C, the ray will hit the face CD at an angle of 60 º(since the internal angle of triangle DBC is 60º).

We will apply Snell's law at point C to find the angle of refraction as it exits the prism.

The refractive index of glass is 1.6, and the refractive index of air is approximately 1.0. Using Snell's law:$n_1\sin(\theta_1)=n_2\sin(\theta_2)$, where n_1=1.6, θ_1=60∘, and n_2=1.0.

Solving for θ_2, we find:sin(θ_2)=1.01.6sin(60∘).

Calculate sin(60∘)=23, sosin(θ_2)=1.6·23.

Since sin(θ_2) cannot exceed 1, the ray will undergo total internal reflection at face CD.

The ray will reflect back towards point B and exit through face AB.

SHORT ANSWER TYPE QUESTIONS (03 MARKS)

1..A cardsheet divided into squares each of size 1mm^2 is being viewed at a distance of 9 cm through a magnifying glass (a converging lens of focal length 10 cm) held close to the eye.

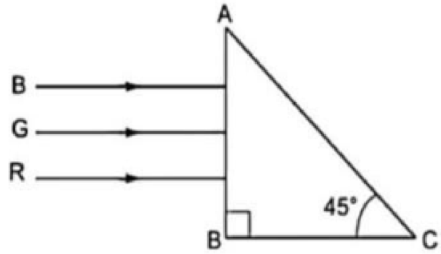
(a) What is the magnification produced by the lenas ? How much is the area of each square to the virtual image ?

(b) What is the angular magnification (magnifying power) of the lens ?

(c) Is the magnification in (a) equal to the magnifying power in (b) ? Explain

2. An object of size 3.0 cm is placed 14 cm in front of a concave lens of focal length 21 cm. Describe the image produced by the lens. What happens if the object is moved further away from the lens?

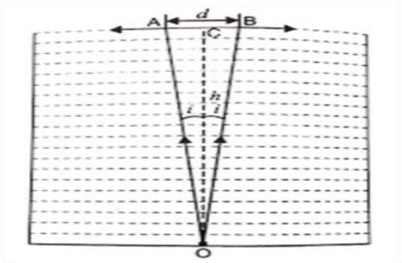
3 Three rays of light red (R), green (G) and blue (B) fall normally on one of the sides of an isosceles right angled prism as shown. The refractive index of prism for these rays is 1.39,1.44 and 1.47 respectively. Find which of these rays get internally reflected and



which get only refracted from AC. Trace the paths of rays. Justify your answer with the help of necessary calculations.

4.. A ray of monochromatic light passes through an equilateral glass prism in a way that angle of incidence is equal to the angle of emergence and each of these angles is3/4 times the angle of prism. Determine angle of deviation and refractive index of the glass prism.

5. A jar of height h is filled wih a transparent liquid of refractive index μ, Fig. At the centre of the jar on the botom surface is a dot. Find the minimum diameter of a disc, such that when placed on the top surface symmetrically about the centre, the dot is invisible.

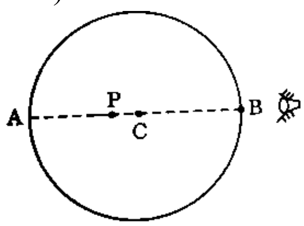


6. How is the working of a telescope different from that of a microscope?

The focal lengths of the objective and eyepiece of a microscope are 1.25 cm and 5 cm respectively. Find the position of the object relative to the objective to obtain an angular magnification of 30 in normal adjustment.

7.A combination of multiple convex lens kept in contact with each other has an equivalent focal length of 0.02 m. An object is placed at a distance of 0.03 m from the combination lens system. If one of the compo nent lens of focal length 0.1 m is removed from the combination, by what distance is the image of the object shifted from its initial position?

8. An air bubble is trapped at point P (CP = 1·75 cm) in a spherical glass ball (n = 1·5) of radius 7 cm as shown in the figure. Find the nature and position of the image when viewed from side B. Show the image formation by drawing a ray diagram.



9.You are given three lenses of power 0.5D , 4D , and 10D to design a telescope.

(i) Which lenses should be used as objective and eyepiece? Justify your answer.

(ii) Why is the aperture of the objective preferred to be large ?

10.A thin convex and a thin concave lens are placed along the same axis on an optical bench. A parallel beam of light falls on the convex lens. The distance d between the two lens is adjusted by moving the concave lens so that the light emerging out of the concave lens is parallel.

(a) Draw a suitable ray diagram to represent the flow of light through the lens system.

(b)State the condition that ensures that the emergent beam is parallel. If the focal length (convex) = 20cm and focal length (concave) = 8 cm, find d.

SHORT ANSWER TYPE QUESTIONS SOLUTION

1.Here, area of each (object) square =1mm2,u=−9cm,f=10cm.

As 1/v−1/u=1/f∴1/v=1/f+1/u=

1/10−1/9=

(9−10)/90=−1/90

v=−90cm.

Magnification, m=v/|u|=90/9=10

∴ Area of each square in virtual image =102×1=100sq.mm

(b) Magnifying power =d/u=25/9=2.8

(c) No, magnification in (a) which is (v/u) cannot be equal to magnifying power in) which is (d/u) unless v=d i.e. image is located at the least distance of distinct vision.

2. Size of the object, h_1 = 3 cm   Object distance, $u = -14$ cm

Focal length of the concave lens, $f = -21$ cm   Image distance = v

According to the lens formula, v =-8.4cm

Hence, the image is formed on the other side of the lens, 8.4 cm away from it. The negative sign shows that the image is erect and virtual.

$$m = \frac{\text{Image height}(h_2)}{\text{Object height}(h_1)} = \frac{v}{u}$$

$$\therefore h_2 = \frac{-8.4}{-14} \times 3 = 0.6 \times 3 = 1.8 \text{ cm}$$

Hence, the height of the image is 1.8 cm.

If the object is moved further away from the lens, then the virtual image will move toward the focus of the lens, but not beyond it. The size of the image will decrease with the increase in the object distance.

3.Critical angle for (i) Red light is sin c_1= 1/1 39 = = 0. 7194 or c1 = 46°

(ii) Green light is sin c2 =1/1 44 = = 0. 6944 or c2 = 44°

(iii) Blue light is sin c3 = 1/1 4. 7= 0.6802 or c3 = 43°

As angle of incidence i = 45° of red light ray on face AC is less that its critical angle of 46°, so red light ray will emerge out of face AC. .

4.Given,<A=60°, <e=<r,<e=<r=3460°=45°

We know that δ + A = I + e

δ = I + e – A

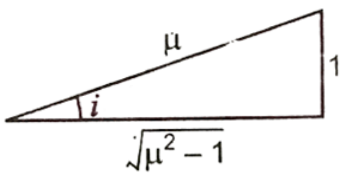
∴ δ = 45° + 45° – 60° = 30°

angle of deviation = 30°

ii) Using prism formula $\mu = 1.41$

Hence, Refractive index of prism =1.4

5. In Fig., O is a dot on the bottom surface of jar height h, filled with a transparent liquid of refractive index μ. AB=d is diameter of a disc such that when placed on the top surface, symmetrically about the centre, the dot is invisible. This would happen when rays OA and OB suffer total internal reflection.



If ∠AOC=i, then tani=AC/OC=d/2h ...(i)

For total internal reflection, i≥c,when sini=sinc=1μ and tani=1/$\sqrt{}\mu^2$−1,...(ii)

From (i) and (ii), d/2h=1/$\sqrt{}\mu^2$−1 d=2h/$\sqrt{}\mu^2$−1

6.

Telescope	Microscope
A) Resolving power should be higher for certain magnification. b) Focal length of objective should be kept larger while eyepiece focal length should be small for better magnification. c) Objective should be of large aperture. d) Distance between objective and eyepiece is adjusted to focus the object at infinity.	A) Resolving power is not so large but the magnification should be higher. b) Both objective and eyepiece should have less focal length for better magnification. c) Eyepiece should be of large aperture. d) Distance between objective and eyepiece is fixed, for focusing an object the distance of the objective is changed

Given : $f_0 = 1.25$ cm, $f_e = 5$ cm, $m = 30$

∴ Distance, $d = 30 - 5 = 25$ cm

Angular magnification = 30, $m = m_e \times m_0$

$$\Rightarrow m_e = \frac{d}{f_e} = \frac{25}{5} = 5 \quad \therefore m_0 = 30 \div 5 = 6$$

But $m_0 = \frac{v_0}{u_0}$ $\Rightarrow -6 = \frac{v_0}{u_0}$

∴ $v_0 = -6\, u_0$

Applying *lens equation* to the objective lens,

$$\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0} \qquad \Rightarrow \frac{1}{f_0} = \frac{1}{-6u_0} - \frac{1}{u_0}$$

7. Initially, $1/v_1 - 1/u = 1/F$

$1/v_1 - 1/(-3) = 1/2$

So initially the image is formed at v1 = +6 cm

For the combination lens system, $1/F = 1/f_1 + 1/f_2 + 1/f3 + \cdots = 1/f_1 + 1/F'$, here f1 is the focal length of th e lens that 3 is removed from the combination,

$1/F' = 1/F - 1/f_1 = 1/2 - 1/10$ $F' = 2.5$ cm. This is focal length of the remaining combination after the removal of one lens.

$1/v_2 - 1/u = 1/F'$ $1/v2 - 1/(-3) = 1/2.5$

$v_2 = +15$ cm So the final image of the object is shifted away from the lens system by a distance o f 9 cm.

8. Calculate the object distance (u): u = - (R - CP) = - (7 - 1.75) = -5.25 cm.

Use the lens formula: 1/f = 1/v - 1/u. Calculate the focal length: f = R/(n - 1) = 14 cm.

Substituting values into the lens formula: 1/14 = 1/v - 1/-5.25. Solve for v to find v = -8.4 cm.

Determine the nature of the image: Since v is negative, the image is virtual and located on the same side as the object.

The image is virtual and located approximately 8.4 cm from the center of the sphere on the same side as the bubble

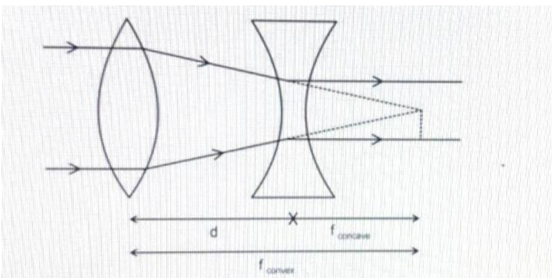
9. **.i)**The objective lens should have a smaller power, meaning a longer focal length, to gather light from distant objects. In the given options, the lens with power 0.5 D is best suited for the objective lens. Using the formula for power *P=1/f*, where *f* is the focal length in meters, the lens with power 0.5 D has a focal length of *f*=1/0.5=2 m.

The eyepiece lens should have a higher power, meaning a shorter focal length, to magnify the image formed by the objective lens. Therefore, the lens with power 10 D is suitable for the eyepiece. Its focal length is *f*=1/10=0.1 m.

(ii) A larger aperture allows the objective lens to collect more light, which is crucial for observing distant and faint objects like stars and galaxies. This feature improves the brightness and clarity of the image formed by the telescope.

Additionally, a larger aperture increases the telescope's resolving power, enabling it to distinguish finer details and separate objects that are close together in the sky.

10.(a)



(b) Parallel beam that enters the convex lens converges at its focus after refraction. If the emergent beam from the concave lens is to be parallel, then the rays coming from convex lens must virtually meet at the focus of concave lens. [1 mark for the correct reasoning] Distance d = fcx - fcv = 20

CASE BASED QUESTION (4 MARK)

1.COMPOUND MICROSCOPE

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) How far from the objective should an object be placed in order to obtain the condition described in above question?

(a)4.5 cm (b) 2.5 cm (c) 1.5 cm (d) 3.0 cm

(III) 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.

(IV) The magnifying power of a compound microscope increases when

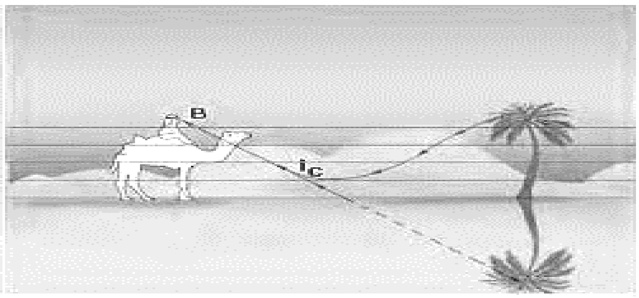
(a) the focal length of objective lens is increased and that of eye lens is decreased.

(b) the focal length of eye lens is increased and that of objective lens is decreased.

(c) focal lengths of both objective and eye-piece are increased.

(d) focal lengths of both objective and eye-piece are decreased.

2.Mirage in Deserts:



To a distant observer light appears to be coming from somewhere below the ground. The observer naturally assumes that light is being reflected from the ground, say, by a pool of water near the tall object.

Such inverted images of distant tall objects cause an optical illusion to the observer. This phenomenon is called Mirage. It is most common in deserts.

1).Study the data related to refractive index and critical angle as given here

Glass-air	Water- air	Glass-water	Diamond- air
Refractive index, n_{GA} = 1.5	Refractive index n_{WA} = 1.33	Refractive index, n_{GW} = 1.125	Refractive index, n_{DA} = 2.5
Critical angle, θc = sin- 1[1/1.5]= 42°	Critical angle, θc = sin 1[1/ 1.33]= 49°	Critical angle, θc = sin-1[1/1.125]= 63o	49o Critical angle, θc = sin- 1[1 /2.5]= 24o

Identify an INCORRECT conclusion.

(a) Lesser is the value of n, greater is the critical angle.

b).Greater is the wavelength of the incident light, greater is the corresponding critical angle in a given pair of media.

(c).For given beam of incident light containing all angles of incidences, maximum total internal refle ction is observed at glass-water interface.

(d).Incident light with angle of incidence equal to 50oin the denser medium will be total internally refl ected in all the above media except on glass- water interface.

2)A diver at a depth 12m inside water (μ_w / μ_a = 4/3) sees the sky in a cone of semi vertical angle

a) $\sin^{-1}$ 4/3 b) $\tan^{-1}$ 4/3 c) $\sin^{-1}$ ¾ d) cos 2/3

3) In an optical fiber, if $n_1$and $n_2$are the refractive indices of the core and cladding, then which among the following would be a correct equation?

a) $n_1 < n_2$ b) $n_1 > n_2$ c) $n_1 = n_2$ d) $n_1 << n_2$

4) A diamond is immersed in such a liquid which has its refractive index with respect to air as greater than the refractive index of water with respect to air. Then the critical angle of diamond-liquid interface as compared to critical angle of diamond- water interface will

a) depends on nature of the liquid b) remains same

c)decreases d)increases

3.

Refraction Through Spherical Surfaces

Refraction of light is the change in the path of light as it passes obliquely from one transparent medium to another medium. According to law of refraction $\frac{\sin i}{\sin r} = {}^1\mu_2$, where ${}^1\mu_2$ is called refractive index of second medium with respect to first medium. From refraction at a convex spherical surface, we have $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$. Similarly from refraction at a concave spherical surface when object lies in the rarer medium, we have $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$ and when object lies in the denser medium, we have $\frac{\mu_1}{v} - \frac{\mu_2}{u} = \frac{\mu_1 - \mu_2}{R}$.

(i) Refractive index of a medium depends upon

(a) nature of the medium (b) wavelength of the light used

(c) temperature (d) all of these

(ii) A ray of light of frequency 5×10^{14} Hz is passed through a liquid. The wavelength of light measured inside the liquid is found to be 450×10^{-9} m. The refractive index of the liquid is

(a) 1.33 (b) 2.52 (c) 2.22 (d) 0.75

(iii) A ray of light is incident at an angle of 60° on one face of a rectangular glass slab of refractive index 1.5. The angle of refraction is

(a) $\sin^{-1}(0.95)$ (b) $\sin^{-1}(0.58)$ (c) $\sin^{-1}(0.79)$ (d) $\sin^{-1}(0.86)$

(iv) A point object is placed at the centre of a glass sphere of radius 6 cm and refractive index 1.5. The distance of the virtual image from the surface of sphere is

(a) 2 cm (b) 4 cm (c) 6 cm (d) 12 cm

Q.1	a	b	b	b
Q.2	c	c	b	d
Q.3	d	a	b	c

LONG ANSWER TYPE QUESTIONS (05 MARKS)

1.(a) Draw a ray diagram to show the image formation of a distant object by a refracting telescope. Write the expression for its angular magnification in terms of the focal lengths of the lenses used

(b) An astronomical telescope has an objective lens of focal length 15 m and eyepiece of focal length 1cm.

(i) Find the angular magnification of the telescope.

(ii) If this telescope is used to view the moon. What is the diameter of the image of the moon formed by the objective lens ? The diameter of the moon is 3.48×10^{6} m and the radius of lunar orbit is 3.8×10^{8} cm

2.(i)Write any two advantage of a compound microscope over a simple microscope?

(ii)In a compound microscope, an object is placed at a distance of 1.5 cm from the objective of focal length 1.25cm. If the eyepiece has a focal length of 5cm and the final image is formed at the Infinity . Calculate the distance between the objective and the eye piece

3. (I)A ray of light passes through a triangular prism. Show graphically, how the angle of deviation varies with the angle of incidence ? Hence define the angle of minimum deviation.

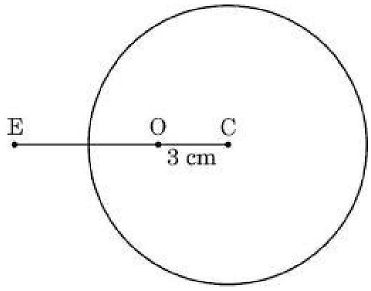
(ii) A ray of light is incident normally on a refracting face of a prism of prism angle A and suffers a deviation of angle . Prove that the refractive index n of the material of the prism is given by

$$\therefore\ \mu = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

(III)The refractive index of the material of a prism is√ 2. If the refracting angle of the prism is 60^{O} , find the (1) Angle of minimum deviation, and (2) Angle of incidence.

4.(i) A spherical surface of radius of curvature R separates two media of refractive indices n1 and n2 . A point object is placed in front of the surface at distance u in medium of refractive index n1 and its image is formed by the surface at distance v, in the medium of refractive index n2 . Derive a relation between u and v.

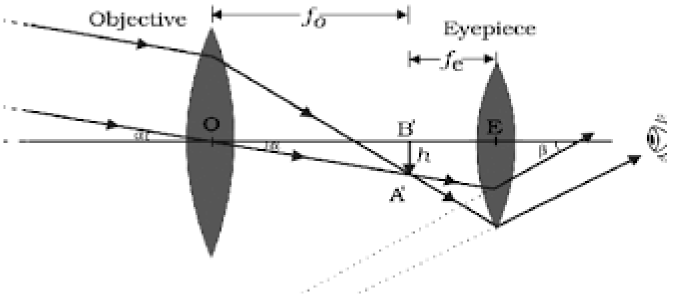
(ii) A solid glass sphere of radius 6 0 cm has a small air bubble trapped at a distance 3 0 cm from its centre C as shown in the figure. The refractive index of the material of the sphere is 1 5. Find the apparent position of this bubble when seen through the surface of the sphere from an outside point E in air.



5.A compound microscope 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. How far from the objective should an object be placed in order to obtain the final image at a) the least distance of distinct vision (25 cm) and b) infinity? What is the magnifying power of the microscope in each ca

SOLUTION

1(a)



The angular magnification (M) of a refracting telescope can be expressed as:

Where:m = fo/fe

fo= Focal length of the objective lens

fe= Focal length of the eyepiece lens

(b) (i)Angular magnification ImI = fo/fe = $15/1x10^{-2}$ = 1500

(ii) Angle substended by the moon =

Diameter of image of moon / radius of lunar orbit =

$3{\cdot}5\ X10^{6}$ m / $3{\cdot}8x10^{8}$ m = $0.92x10^{-2}$

Angle substended by the image = Diameter of image of moon/fo = D/fo = 13.73 cm

2.(i) 1.A simple microscope consists of a single lens, which magnifies the object directly. A compound microscope consists of two or more lenses (the objective and the eyepiece) that work together to magnify the object.

2. Because the compound microscope uses two lenses, it can achieve a much higher total magnification compared to a simple microscope. The total magnification is the product of the magnification of the objective lens and the eyepiece lens.

(ii) The object distance from the objective is uo =

The object distance from the objective is uo= -1.5

The focal length of the objective is fo=1.25 cm

The focal length of the eyepiece is fe=5 cm

The final image is formed at infinity.

For the final image to be at infinity, the image formed by the objective must be at the focal point of the eyepiece.

· Use the lens formula for the objective lens: $1/f_o = 1/v_o - 1/u_o$

$v_o = 7.5$ cm

The distance between the objective and the eyepiece is 7.5+ 5 = 12.5cm

3.(i)correct graph , correct defination

(ii) correct derivation

(iii)The angle of minimum deviation is $\delta m=30\circ$

The angle of incidence is $=45\circ$.

4. Identify the values: $n1=1$, $n2=1.5$, $u=-3$ cm, and $R=6$ cm.

Substitute the values into the refraction formula:

Now, solve for v:

$v=(1.5\times12) / 5=18/5=3.6$ cm.

The apparent position of the bubble as seen from point E is 3.6 cm from the center of the sphere.

5 (a)For eyepiece,ve=-25cm,fe=6.25cm, ue=? Using $1/f = 1/v - 1/u$

$1/u_e = 1/v_e - 1/f_e$

$= 1/-25 - 1/6.25 = -1/5$

u_e=-5cm

Therefore the image formed by the objective is formed at a distance of 10 cm towards the eyepiece.

Hence for the objective,

v_0=+10 cm,0=2cm, v_0=?

$1/u_0 = 1/v_0 - 1/f_0$

$= 1/10 - 1/2$

u_0=-2.5cm

Therefore the magnifying power

$M= (v_0/u_0)(1+D/f_e) =(10/2.5)(1+25/6.25)=20$

(b)When the final image is formed at infinity the object for the eyepiece must lie at its principal focus.

Therefore the distance of the image formed by the objective from its optical center, $v0$=15-6.25=8.75cm

$1/u_0 = 1/v_0 - 1/f_0$, $u0$= -2.6cm

$M= (v_0 |/u_0) .(D/f_e) = (8.75/2.6)\times(25/)6.25 =13.5$

CHAPTER 10

WAVE OPTICS

IMPORTANT FORMULA

- **Interference of light:-**

i) If two waves of same intensity I_o interfere, then the resultant intensity will be

$I = 4 I_o \cos^2 \frac{\phi}{2}$ where ϕ is the initial phase difference between the waves.

ii) Resultant intensity at a point in the region of superposition is

$I = a_1^2 + a_2^2 + 2a_1a_2\cos\phi = I_1 + I_2 + 2\sqrt{I_1 I_2}\ \cos\phi$ where

$I_1 = a_1^2$ *is the intensity of one wave* & $I_2 = a_2^2$ *is the intensity of other wave.*

iii) Condition for maxima: - Phase difference $\phi = 2n\pi$ & path difference $\Delta = n\lambda$ where n = 0,1,2,3,…..

iv) Condition for minima: - Phase difference $\phi = (2n-1)\pi$ &

Path difference $\Delta = (2n-1)\frac{\lambda}{2}$ where n = 0,1,2,3,…..

v) Fringe width $\beta = \frac{D\lambda}{d}$ where D = distance between the slits & the screen,

d= separation between the slits and λ is the wavelength of light used.

vi) Angular fringe width , $\beta_\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

vii) Minimum amplitude, $A_{min} = (a_1 - a_2)$

viii) Minimum intensity, $I_{min} = (a_1 - a_2)^2 = I_1 + I_2 - 2\sqrt{I_1 I_2}$

ix) Minimum amplitude, $A_{max} = (a_1 + a_2)$

x) Minimum intensity, $I_{min} = (a_1 + a_2)^2 = I_1 + I_2 + 2\sqrt{I_1 I_2}$

xi) Position of n^{th} maxima, $y_n = \frac{nD\lambda}{d}$

xii) Position of n^{th} minima, $y_n = (n - ½)\frac{D\lambda}{d}$

xiii) In interference, the ratio of maximum intensity to minimum intensity, $\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2}$

xiv) In interference, the relation between slit width (w) , intensity (I) and amplitude (a):

$\frac{w_1}{w_2} = \frac{I_1}{I_2} = \frac{(a_1)^2}{(a_2)^2}$

xv) The angular width of each fringe in interference pattern, $\Delta\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

xvi) In interference, Fringe width $\beta \propto \lambda$, $\beta \propto D$ and $\beta \propto$ 1/separation between the slits (d)

- **Diffraction of light: -**

i) The condition for the position of n^{th} minima : $d \sin\theta = n\lambda$

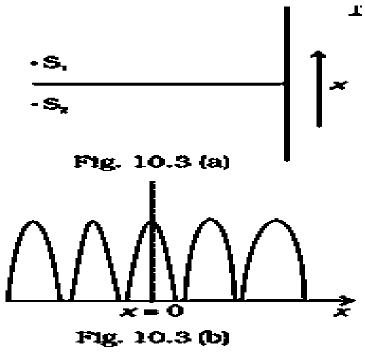
where d is the width of slit, θ is angle of diffraction and λ is the wavelength of light used.

ii) Linear half-width of central maximum : $y = \frac{D\lambda}{d}$

iii) Total linear width of central maximum : β_o or $2y = \frac{2D\lambda}{d}$

MULTIPLE CHOICE QUESTIONS

Q 1 Two source S_1 and S_2 of intensity I_1 and I_2 are placed in front of a screen The pattern of intensity distribution seen in the central portion is given by Fig. 10.3 (b). In this case which of the following statements are true?



(i) S_1 and S_2 have the same intensities.

(ii) S_1 and S_2 have a constant phase difference.

(iii) S_1 and S_2 have the same phase.

(iv) S_1 and S_2 have the same wavelength.

(a) (i), (ii), (iii), (b) (i), (ii), (iv) (c) (i), (iii), (iv) (d) (ii), (iii), (iv)

Q 2 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

Q.3 When interference of light takes place

(a) Energy is created in the region of maximum intensity

(b) Energy is destroyed in the region of maximum intensity

(c) Conservation of energy holds good and energy is redistributed

(d) Conservation of energy does not hold good

Q 4 Two coherent monochromatic light beams of intensities I and 4I superimpose. The maximum and minimum possible intensities in the resulting beam are:

(a) 5I and I (b) 5I and 3I (c) 3I and I (d) 9I and I

Q 5 A parallel beam of moving electrons is incident normally on a narrow slit. A fluorescent screen is placed at a large distance from the slit. If the size of the slit is further narrowed, then which of the following statements is correct?

(a) The diffraction pattern cannot be observed on the screen

(b) The angular width of the central maxima of the diffraction pattern will increase

(c) The angular width of the central maxima of the diffraction pattern will decrease

(d) The angular width of the central maxima of the diffraction pattern remains the same

Q6. One of the two slits in Young's double slit experiment is painted so that it transmits half the intensity then

(a) the fringe system would be disappeared

(b) the bright fringes would brighter & dark fringes would be darker

(c) the dark fringes would be brighter & bright fringes would be darker

(d) bright as well as dark fringes would be darker

Q 7. Figure 10.2 shows a standard two slit arrangement with slits S1, S_2. P_1, P_2 are the two minima points on either side of P (Fig.10.2). At P_2 on the screen, there is a hole and behind P2 is a second 2- slit arrangement with slits S_3, S_4 and a second screen behind them.

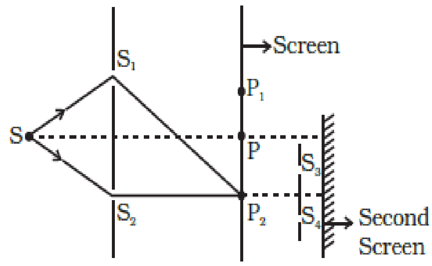


Fig. 10.2

(a) There would be no interference pattern on the second screen but it would be lighted.

(b) The second screen would be totally dark.

(c) There would be a single bright point on the second screen.

(d) There would be a regular two slit pattern on the second screen.

Q.8 How can the angular fringe width increases in Young's double slit experiment?

(i) By decreasing the width of the slit

(ii) By reducing the separation of slits

(iii) By increasing the wavelength of the slits

(iv) By increasing the distance between slits and the screen

(a) (i), (ii), (iii), **(b) (i), (ii), (iv)** **(c) (ii), (iii), (iv)** **(d) (ii), (iii),**

Q.9 What is the ratio of fringe width for bright and dark fringes in youngs double slit experiment

(A) 1 : 1 (B) 2: 1 (C) $\sqrt{2}$: 1 (D) 4 : 1

10. In a Young's double slit experiment, the separation between the slits is 0.1 mm, the wavelength of light used is 600nm and the interference pattern is observed on a screen 1m away. Find the separation between bright fringes.

(a) 6.6 mm (b) 6.0 mm

(c) 6 m (d) 60 cm

(ASSERTION & REASON QUESTION)

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.

Q.11 **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.

Q. 12 **Assertion (A):** When monochromatic light passes through a narrow opening, a pattern of alternate bright and dark fringes is produced.

Reason (R): The edges of the opening become sources of secondary waves, which superpose to produce the pattern .

Q.13 **Assertion:** It is necessary to have two waves of equal intensity to study interference pattern.

Reason: There will be an effect on clarity if the waves are of unequal intensity.

Q.14 **Assertion :** According to Huygen's principle, no backward wave-front is possible.

Reason : Amplitude of secondary wavelet is proportional to $(1 + \cos\theta)$ where θ is the angle between the ray at the point of consideration and the direction of secondary wavelet.

Q.15 **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 imensions of diffracting device.

(Ans.MCQs)

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
b	**c**	**c**	**D**	**c**	**c**	**b**	**d**	**a**	**a**
11	**12**	**13**	14	15					
a	**a**	**d**	B	b					

(SHORT ANS TYPE QUESTION)(2 MARKS)

Q 1 In a single-slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band ?

Q 2 In a single slit diffraction experiment, the first minima for red light (660nm) coincide with first maxima of some other wavelength λ_1 , find the value of λ_1 .

Q 3 (a) State the reason, why two independent sources of light cannot be considered as coherent sources.

(b) Monochromatic light of wavelength 589 nm is incident from air on a water surface. What are the wavelength, frequency and speed of refracted light? Refractive index of water is1.33.

Q.4 Sketch of a graph showing the variation of fringe width versus the distance of the screen from the plane of the slits (keeping other parameters same) of the Young's double slit experiment.

What information can one obtain from the slope of this graph?

Q.5 (a) How does the angular separation between fringes in single-slit diffraction experiment change, when the distance of separation between the slit and screen is doubled?

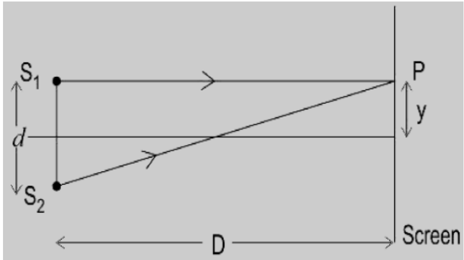
(b) Does the appearance of bright and dark fringes in the interference pattern violate, in any way, conservation of energy?

Q.6 A parallel beam of light of wavelength 600 nm is incident normally on a slit of width 'a'. If the distance between the slits and the screen is 0.8 m and the distance of 2nd order maximum from the centre of the screen is. 1.5 mm, calculate the width of the slit.

Q 7(a) Consider a plane wave front incident on a thin convex lens and Prism. Draw a proper diagram to show how the incident wave front traverses through the lens and after refraction focuses on the focal point of the lens, giving the shape of the emergent wave front for the lens and Prism.

Q 8 How many interference fringes will be seen in central maxima of detraction pattern if the size of each of the slit is $(1/5)^{th}$ the separation between the two slits?

Q.9 A white light is used to illuminate the two slits in a Young's double slit experiment. It results in the overlapping interference patterns on the screen as each wavelength corresponds to one interference pattern.



Refer to the diagram for the various parameters of the experimental, At a point P, that is directly opposite to the slit S1, find the series of wavelengths that will result in minima.

SOLUTION

Ans1 : In a single slit experiment, the width of the central maximum,

$Y_1=2\lambda D / d$...................(1)

when the when the width is doubled, while every other variable is kept constant

$Y_2=2\lambda D/ 2d$ ………………. (2)

$Y_1 = 2Y_2$ Hence width decreases

Intensity is directly proportional to the square of the fringe width $I \propto d^2$ $I_2=4I$

Ans 2 Position of first minima in single slit diffraction experiment, $x_1=\frac{\lambda D}{a}$

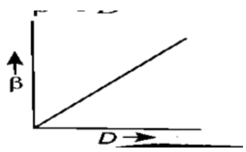
Position of first maxima in single slit diffraction experiment, $y_1=\frac{3\lambda 1D}{2a}$

λ_1 =440 nm

Ans3: (a) Coherent sources are defined as the sources in the initial phase difference remains constant. In the case of two independent sources, the initial phase difference cannot remain constant because light is emitted due to millions of atoms and their number goes on changing in a quite random.

(b) 444 nm

Ans 4



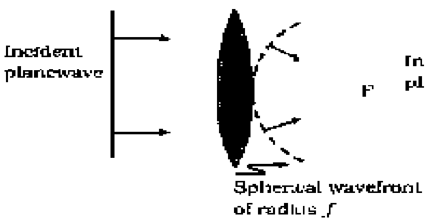
Slope= angular width

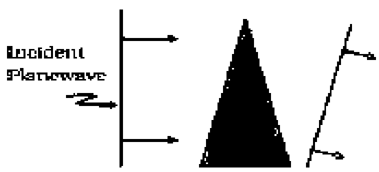
Ans 5 (a) independent of separation (D) of slit and screen

(b) No

Ans 6. By using formula $X_2=2\lambda D / d$, d= $(2 \times 600 \times 10^{-9} \times 0.8)/(1.5 \times 10^{-3}) = 6.4 \times 10^{-4}$ m =0.64 mm

Ans 7 (a) Spherical (b) plane





Ans 8 $2\lambda D/a = n\lambda D/d$, n=10

Ans 9 The distance y from center: y = (D/d) Δx ,where Δx is the path difference between two light waves reaching point P.

Δx = (n+1/2)λ with n = 0,1,2,3,…..

So y = D(2n+1)λ/2d

For the missing wavelengths (or minima points) at P,

As per the given diagram, y = d/2

$\lambda = d^2/D(2n+1)$, n= 0,1,2,3…

Here Δx is the path difference = nλ …. for the maxima at the position that is at a distance y from central maxima.

λ = yd/ nD where n = 1,2,3…

λ = 5000 Å, 2500 Å, 1666 Å,….

Out of these only the wavelength 5000 Å is in visible range.

(SHORT ANS TYPE QUESTION (3 MARKS)

Q 1 How will the interference pattern in Young's double slit experiment gets affected when

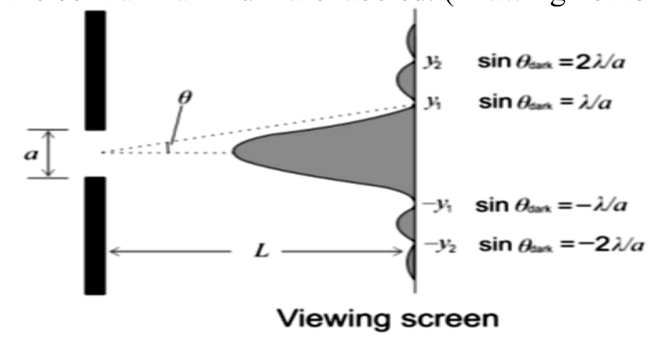
(i) distance between the slits S_1 and S_2 is reduced and

(ii) the entire set up is immersed in water. Justify your ans in each case.

Q.2 A lamp sends out a plane wave through a slit of width 2 μm. The light from the lamp is composed of two spectral lines of wavelengths D1 = 5896 Å and D2 = 5900 Å. Determine the distance between the first secondary maxima of each of the spectral lines in the diffraction pattern formed on the screen that is 2 m away from the slits.

Q 3 The ratio of the intensities at minima to the maxima in the Young's double slit experiment is 9 : 25. Find the ratio of the widths of the two slits.

Q 4 Study the intensity distribution diagram for a diffraction pattern from a single slit of width 'a'. The positions of two minima on each side of the central maximum are labeled. (Drawing not to scale.)



Answer the following questions:

(a)Determine the ratio of width of the central bright maximum to the width of the second secondary maxima above it.

(b) What is sine of an angle at which the second secondary maxima is produced above the central maxima?

(c) If the slit width in Figure is made half as wide, what will be effect on the width of its central bright fringe? Explain your answer.

Q.5 A beam of light consisting of two wavelengths 6500 A° and 5200 A° is used to obtain interference fringes. The distance between the slits is 2.0 mm and the distance between the plane of the slits and the screen is 120 cm.

a) Find position of third maxima for first wavelength.

b) Find the minimum distance at which maxima of the two wavelength coincide.

Q.6 Monochromatic light from a narrow slit illuminates two narrow slits 0.3 mm apart producing an interference pattern with bright fringes 1.5 mm apart on a screen 75 cm away. Find the wavelength of the light. How will the fringe width be altered If

i) the distance of the screen is doubled

ii) the separation between the slits is doubled ?

Q.7 Light of wavelength 550 nm is incident as parallel beam on a slit of width 0.1 mm. Find the angular width and the linear width of the principal maxima in the resulting diffraction pattern on a screen kept at a distance of 1.1 m from the slit, which of these width would not change if the screen were moved to a distance of 2.2 m from the slit?

Q.8 How is Huygen's principle used to obtain the diffraction pattern due to a single slit? Show the plot of variation of intensity with angle and state the reason for the reduction in intensity of secondary maxima compared to central maximum.

SOLUTION

Ans :i) fringe width increases

As $\beta = \lambda D/d$

ii) fringe width decreases $\beta \propto \lambda$

Ans2. Since $\sin\theta = (n + 1/2)\lambda/d = x/D$

so $x = (n + 1/2)\lambda D/d$

here d = slit width, x is the distance of the maxima from the central line and D is the perpendicular distance of the screen from the slit.

For the first secondary maxima

$x = (1 + 1/2)\lambda D/d = 3\lambda D/2d$

Distance between the two secondary maximas of the two spectral lines:

$\Delta x = 3D/2d\ (5900-5896) \times 10^{-6} = 6 \times 10^{-4}$ m

Ans 3: $I_1 / I_2 = 9/25 = (A_1 - A_2)^2 / (A_1 + A_2)^2$

$3/5 = (A_1 - A_2) / (A_1 + A_2)$

$A_1 : A_2 = 4:1$

Ans.4 a) Each of the secondary maxima are of same width, that is , λ/a

So the ratio = 2 : 1

b) Condition for the maxima :

$\sin\theta = (n + ½)\lambda/a$, where n = +/- 1, +/- 2,

For the second secondary maxima : n = +2

So $\sin\theta = (2 + ½)\lambda/a = 5\lambda/2a$

c) As the angles on the either side of the central maxima:

$\sin\theta = +/- \lambda/a$

With the decrease in slit width a, the angle θ on the either side of the central maxima will increase, the width of the central maxima will increase.

Ans: 5 (a) $y_3 = n. D\lambda/d$ = 3 x 1.2 m x 6500 x 10-10 m / 2 x 10-3 m = 0.12cm

(b) Let nth maxima of light with wavelength 6500 Å coincides with that of mth maxima of 5200Å.

m x 6500A° x D/d = n x 5200A° x D/d

m/n = 5200/6500 = 4/5

Least distance = y_4 = 4.D (6500Ao)/d = 0.16cm.

Ans.6 $ß = \lambda D/d$

substituting values and calculate

λ = 6 x10-7 m

D doubled then fringe width is doubled

(ii) d doubled then fringe width is halved.

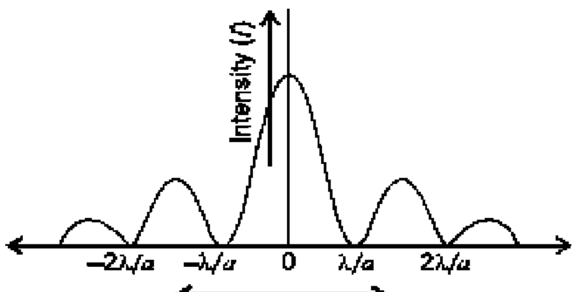
Ans 7 λ=550 nm, d= 0.1 mm,D = 1.1m, ω = ?, β = ? using $\omega = 2\theta = 2\lambda/d$, we get ω= .011 rad

using $\beta = 2\lambda D/d$,we get β = 12.1 mm

When the screen is moved to 2.2 m from the slit, the angular width will not change, linear width Increases

Ans.8

When a plane wavefront is incident on a single slit, all the point sources of light constituting the wavefronts are in same phase. The wavelets coming out from the wavefront might meet over the screen with some path difference, i.e., a phase difference is introduced between them. The brightness at a point on the screen depends on the phase difference between the wavelets meeting at the point. We imagine that the slit is divided into smaller parts and the wavelets coming out from these portions meet and superpose on the screen with proper phase difference. The wavelets from different parts of the wavefront, incident on the slit, meet with zero phase difference to constitute a central maximum. In case of secondary maxima, there are some wavelets meeting the screen out of phase, thus, reducing intensity of secondary maxima.



LONG ANSWER TYPE QUESTIONS (5 MARKS)

Q.1 (a) Write three characteristic features to distinguish between the interference fringes in Young's double slit experiment and the diffraction pattern obtained due to a narrow single slit.

(b) A parallel beam of light of wavelength 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 a distance of 2.5 mm away from the centre. Find the width of the slit.

Q.2 Red colour of light of wavelength λ is passed from two narrow slits which are distance d apart and interference pattern is obtained on the screen distance D apart from the plane of two slits. Then find the answer to following parts assuming that slit widths are equal to produce intensity I0 from each slit.

(a) Intensity at a point on the screen, situated at a distance 1/4 th of fringe separation from centre.

(b) Intensity in the screen, if the sources become incoherent by using two different lamps behind lamps S1 and S2.

(c) Angular position of 10th maxima, and the angular width of that fringe.

(d) Find the distance between 5th maxima and 3rd minima, at same side of central maxima

(e) If the phase difference between the two waves reaching two slits from the source slit is (i) 5π and (ii) 2π, then what will be the colour of central fringe?

Q 3 State Huygen's principle, On the basis of Huygen's Wave theory of light, show that angle of reflection is equal to angle of incidence. You must draw a labelled diagram for this derivation explain the following, giving reasons:

(i) Is the frequency of reflected and reflected light same as the frequency of incident light?

(ii)Does the decrease in speed imply a reduction in the energy carried by light wave?

Q 4 A slit of width 'a' is illuminated by white light.

(a) For what value of a will the first minimum for red light of $\lambda = 650$ nm be at $\theta = 15°$? (b) What is the wavelength λ' of the light whose first side diffraction maximum is at 15°, thus coinciding with the first minimum for the red light

Q.5 (a) (i) 'Two independent monochromatic sources of light cannot produce a sustained interference pattern'. Give reason.

(ii) Light waves each of amplitude a and frequency n, emanating from two coherent light sources superpose at a point. If the displacements due to these waves is given by y1 = a cos t and y2 = a cos (ωt + ϕ), what is the phase difference between the two, obtain the expression for the resultant intensity at the point.

(b) In Young's double slit experiment, using monochromatic light of wavelength, the intensity of light at a point on the screen where path difference is, is K units. Find out the intensity of light at a point where path difference is $2\lambda/3$

ANSWERS/HINTS

Ans.1 (a) (i) Interference is the superposition of light waves from two different wavefronts originating from the same source, while the diffraction is the interaction of light waves from different parts of the same wavefront.

(ii) In an interference pattern, fringes may or may not be of the same width, while in diffraction pattern, they are never of the same width.

(iii)In an interference pattern, bright fringes are of uniform intensity, while in diffractions pattern, they are of varying intensity.

(b) Here, λ=50nm=5×10^{-7}m, D=1m,

y=2.5mm=2.5×10^{-3}m,

d=?

$\sin\theta=\lambda/d=y/D$

$\therefore \lambda D/y=(5\times10^{-7}\times1)/12.5\times10^{-3}=2\times10^{-4}$m=0.2mm

Ans 2 (a) $2I_0$ (b) $I_{net} + I_1 + I_2$

(c) $10\lambda/d$ and λ/d (d) $2.5\ \lambda D/d$

(e) (i) dark fringe (ii) Bright Fringe

(a) According to the question,

$$X_n = \frac{1}{4}.\beta$$

$$X_n = \frac{1}{4}\frac{\lambda D}{d}$$

$\therefore$ Path difference $= \frac{\lambda}{4}$

Phase difference,

$$\phi = \frac{2\pi}{\lambda}\times\frac{\lambda}{4} = \frac{2\pi}{2}$$

$$\therefore \quad I = 4I_0\cos^2\frac{\phi}{2} = 4I_0\cos^2\frac{\pi}{4} = 2I_0$$

(b) If I_1 and I_2 be the intensities of waves from the sources, then the net intensity will be $I_{net} = I_1 + I_2$

(c) $\theta_{10} = 10\frac{\lambda}{d}$ $\left[\because \theta_n = \frac{n\lambda}{d}\right]$

θ = angular fringe width of 10^{th} maxima

$\theta = \frac{\lambda}{d}$ (independent of n)

$$x_5^{max} - x_3^{min} = \frac{5\lambda D}{d} - (2\times3-1)\frac{\lambda}{2}\frac{D}{d}$$

$$= [10-5]\frac{\lambda d}{2d}$$

$$= 2.5\frac{\lambda D}{d}$$

(e) (i) $\theta = 5\pi$

$$\therefore \quad I = 4I_0\cos^2\frac{5\pi}{2} = 0$$

Therefore, dark fringe will be formed.

(ii) $\theta = 2\pi$

$$\therefore \quad I = 4I_0\cos^2\frac{2\pi}{2} = 4I_0$$

Therefore, the colour of fringe will be bright red.

Ans.3 (i) Yes, frequency does not depends on medium

(ii) No, reduction in speed on passing from a rarer to a denser medium does not imply a reduction in energy of light because the frequency of light remains unchanged and the energy of a light photon depends only on its frequency

Ans.4 **(a)** At the first minimum, n = 1 in equation a sinθ = nλ, for n = 1,2,3,...

Solving for a, we then find

a = nλ / sinθ = (1) (650 nm) / (sin15°) = 2511 nm ≈ 2.5 μm

Therefore, the value of a the first minimum for red light of λ = 650 nm be at θ = 15° would be 2.5 μm. For the incident light to flare out that much (±15°) the slit has to be very fine indeed, amounting to about four times the wavelength. Note that a fine human hair may be about 100 μm in diameter.

(b) This maximum is about halfway between the first and second minima produced with wavelength λ'. we can find it without too much error by putting n = 1.5 in equation

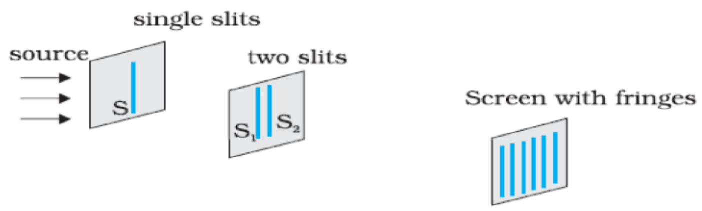
[a sinθ = nλ, for n = 1,2,3,...], obtaining a sinθ = 1.5 λ' Solving for λ' and substituting known data given

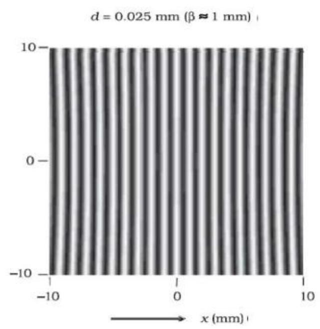
Ans.5 (a) (i) Light waves originating from two independent monochromatic sources, cannot have a constant phase difference. Therefore, sources will not be coherent, hence, they will not produce a sustained interference pattern.

(b)K/4

CASE BASED QUESTION

Q1. Interference (Young's Double slit experiment)





i) What is the path difference between the two light waves coming from coherent sources, which produces 3rd maxima.

a) π b) 2 π c) 3 π d 0

ii) What is the correct expression for fringe width(λ).

a) λ d/D (b) λ dD (c) d/ λ D (d) λ D/d

iii) what is the phase diff. between two interfering waves producing 1st dark fringe.

a) π b) 2π c) 3π d) 4π

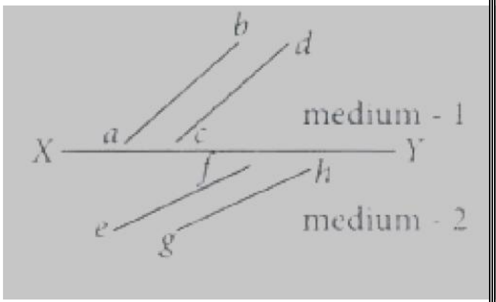
iv) The ratio of the widths of two slits in Young's double slit experiment is 4 : 1. Evaluate the ratio of intensities at maxima and minima in the interference pattern.

a) 1:1 b) 1:4 c) 3:1 d) 9:1

OR

v) In a Young's double slit experiment, the separation between the slits is 0.1 mm, the wavelength of light used is 600 nm and the interference pattern is observed on a screen 1m away. Find the separation between bright fringes.

(a) 6.6 mm (b) 6.0 mm (c) 6 m (d) 60cm



Q.2 Wavefront is a locus of points which vibrate in same phase. A ray of light is perpendicular to the wavefront. According to Huygens principle, each point of the wavefront is the source of a secondary disturbance and the wavelets connecting from these points spread out in all directions with the speed of wave. The figure shows a surface XY separating two transparent media, medium-1 and medium- 2. The lines ab and cd represent wavefronts of a light wave travelling in medium- 1 and incident on XY. The lines ef and gh represent wavefronts of the light wave in medium -2 after refraction.

(i) Light travels as a

a) parallel beam in each medium b) convergent beam in each medium

c) divergent beam in each medium

d) divergent beam in one medium and convergent beam in the other medium.

(ii) Wavefront is the locus of all points, where the particles of the medium vibrate with the same

a) phase b) amplitude c) frequency d) period

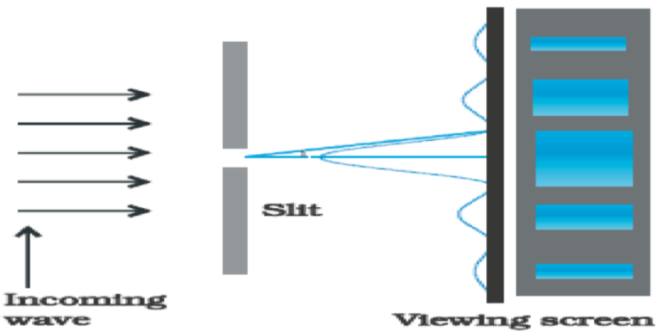
(iii) A point source that emits waves uniformly in all directions produces wavefronts that are

a) Spherical b) elliptical c) cylindrical d) planar

(iv) What are the types of wavefronts ?

a) Spherical b) Cylindrical c) Plane d) All of these

Q. 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(I) Central bright fringe is ·of maximum intensity and the intensity of any secondary bright fringe decreases with increase in its order.



(i) In the phenomena of Diffraction of light when the violet light is used in the experiment is used instead of red light then,

(a) Fringe width increases (b) No change in fridge width

(c) Fringe width decreases (d) Colour pattern is formed

(ii) Diffraction aspect is easier to notice in case of the sound waves then in case of the light waves because sound waves

(a) Have longer wavelength (b) Shorter wavelength

(c) Longitudinal wave (d) Transverse waves

(iii) Diffraction effects show that light does not travel in straight lines. Under what condition the concepts of ray optics are valid. (D = distance of screen from the slit).

(a) D < Zf (b) D = Zf (c) D > Zf (d) D << Zf

(iv) when 2nd secondary maxima is obtained in case of single slit diffraction pattern, the angular position is given by

(a) π (b) π /2 (c) 3 π /2 (d) 5 π /2

Answers 1

i) (c) ii) (d) iii) (a) iv) (d) v) (b)

Answers 3

(i) (c) (ii) (a) (iii) (d) (iv) (d)

CHAPTER 11
DUAL NATURE OF RADIATION AND MATTER

Important Formulas

1. Energy of a Photon (Einstein's Relation):

$$E=hv$$

   a. $h=6.63\times10^{-34}Jsh=6.63\times10^{-34}$Js (Planck's constant)
   b. vv = frequency of light
   c. $c=3\times108\ m/sc=3\times108$m/s (speed of light)
   d. λ = wavelength

2. Work Function ($\phi\phi$):

$$\phi=hv_0$$

   a. v_0 = threshold frequency
   b. λ_0 = threshold wavelength

3. Einstein's Photoelectric Equation:

$$K_{max}=hv-\phi$$

   a. K_{max} = max kinetic energy of photoelectrons

4. Stopping Potential (V_0):

$$eV_0=K_{max}=h\nu-\phi$$

a. $e=1.6\times10^{-19}C$=1.6×10^{-19}C (electron charge)

5. Relation between maximum kinetic energy and stopping potential
   $K_{max}= \frac{1}{2} mv_{max}^2 = eV_0$

6. de Broglie Wavelength (λ\):

$$\lambda=h/p=h/mv$$

   a. p = momentum

   b. m = mass, v = velocity

7. de Broglie Wavelength for Electron (accelerated by V):

$$\lambda=h/\sqrt{2meV}$$
$$\lambda(A^\circ)=12.27V$$

9. Photon Momentum:

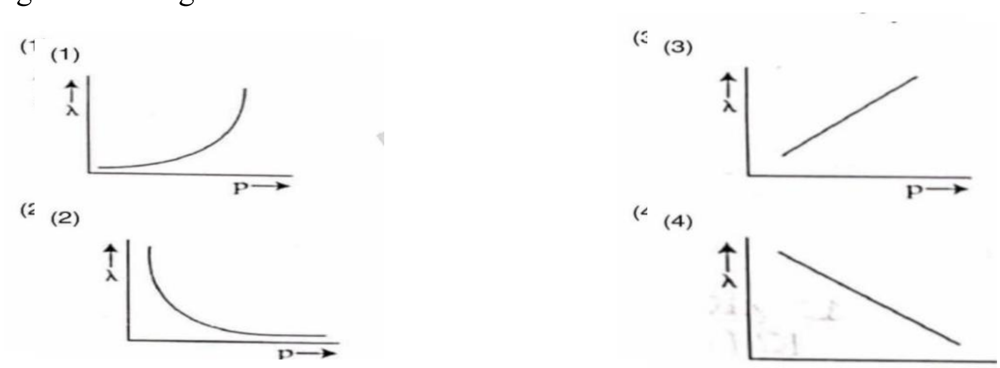
$$p=h/\lambda$$

Threshold Wavelength (λ_0):
$$\lambda_0=hc/\phi$$

MCQ QUESTION 1 MARKS

1. A graph is plotted between the stopping potential (on y-axis) and the frequency of incident radiation (on x-axis) for a metal. The product of the slope of the straight line obtained and the magnitude of charge on an electron is equal to
   (a) h (b)h/c (c) 2h/c (d)h/2c
2. Electrons used in an electron microscope are accelerated by a voltage of 25 KV. If the voltage is increased to 100 KV then the de Broglie wavelength associated with the electrons would
   (a) increase by 2 times (b)decrease by 2 times (c)decrease by 4 times (d)increase by 4 times

3. Which of the following figures represent the variation of particle momentum and the associated de Broglie wavelength?



4. If photon of frequency v are incident on the surface of two metal A, B of threshold frequency. v /2 and v /3 respectively, the ration of maximum kinetic energy of electrons emitted from A to that from B is
   (a) 2:3 (b)3:4 (c)1:3 (d)$\sqrt{3}:\sqrt{2}$

5. The wavelength of a photon needed to remove a proton from the nucleus which is bound to the nucleus with 1MeV energy is nearly
   (a) 1.2 nm (b)1.2×10^{-3} nm (c)1.2×10^{-6} nm (d)1.2×10^{-3} nm

Answers:
Q1. Answer: h
Q2. Answer: decrease by 2 times
Q3. Answer: Diagram-based question - Answer depends on figure
Q4. Answer: 1:3
Q5. Answer: 1.2×10^{-3} nm

ASSERTION REASONING QUESTION 1 MARKS

Instructions: Mark the correct option:
(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, R is false.
(d) A is false, R is true.

1. **Assertion(A):** On increasing the frequency of light, the photocurrent remains unchanged.
   Reason(R): Photocurrent is independent of frequency but depends only on intensity of incident light.
2. **Assertion(A):** An electron and a photon possessing same wavelength, will have the same momentum.
   Reason(R): Momentum of both particle is same by de-Broglie hypothesis.
3. **Assertion(A):** A graph of stopping potential versus frequency is a straight line.
   Reason(R): The slope of the graph gives the charge of the electron.
4. **Assertion**(A): If intensity of a incident light is doubled, the kinetic energy of photoelectrons is also doubled.
   Reason(R): The kinetic energy of photoelectron is directly proportional to intensity of incident light.
5. **Assertion(A):** An electron microscope is based on debroglie hypothesis
   Reason(R): A beam of electrons behaves as a wave which can be converged by electric and magnetic lenses.

Answers

Q1. ('1', '(b) Both A and R are true, but R is not the correct explanation of A')

Q2. ('2', '(a) Both A and R are true, and R is the correct explanation of A')

Q3. ('3', '(c) A is true, R is false')

Q4. ('4', '(d) A is false, R is true')

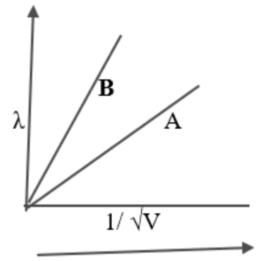
Q5. ('5', '(a) Both A and R are true, and R is the correct explanation of A')

SHORT ANSWER TYPE QUESTION 1 MARKS

1. A particle A with a mass mA is moving with a velocity v and hits a particle B (mass mB) at rest (one dimensional motion). Find the change in the de Broglie wavelength of the particle A. Treat the collision as elastic.
2. Sketch the graphs showing variation of stopping potential with frequency of incident radiation, for two photosensitive materials A and B having threshold frequencies $\nu_A > \nu_B$
   (i) In which case is the stopping potential more and why?
   (ii) Does the slope of the graph depend on the nature of the material used? Explain.
3. If light of wavelength 412.5 nm is incident on each of the metals given below, which ones will show photoelectric emission and why?

Metal	Work Function (eV)
Na	1.92
K	2.15
Ca	3.20
Mo	4.17

4. The two lines A and B shown in the graph plot the de-Broglie wavelength λ as function of 1/ √V (V is the accelerating potential) for two particles having the same charge. Which of the two represents the particle of heavier mass?



5. Light of frequency 7,21 $\times 10^{14}$ Hz is incident on a metal surface. Electrons with a maximum speed of 6.0 × 105 m/s are ejected from the surface. What is the threshold frequency for photoemission of electrons?
6. The work function of a metal is 2.5 eV. Calculate the threshold wavelength. Will light of wavelength 400 nm cause photoemission? (h = 6.63×10^-34 Js, c = 3×10^8 m/s, 1eV = 1.6×10^{-19} J)
7. (a) Draw a graph showing variation of photoelectric current (I) with anode potential (V) for different intensities of incident radiation. Name the characteristic of the incident radiation that is kept constant in this experiment.
   (b) If the potential difference used to accelerate electrons is doubled, by what factor does the de-Broglie wavelength associated with the electrons change?
8. A blue lamp mainly emits light of wavelength 4500 A^0. The lamp is rated at 150 W and 8% of the energy is emitted as visible light. How many photons are emitted by the lamp per second?

9. If the photoelectrons are to be emitted from a potassium surface with a speed of $6 \times 10^6\ ms^{-1}$. What frequency of radiation must be used? (Threshold frequency for potassium is 4.22×10^{14} Hz, h= 6.6×10^{-34}Js and $m_e = 9.1 \times 10^{-31}$kg)

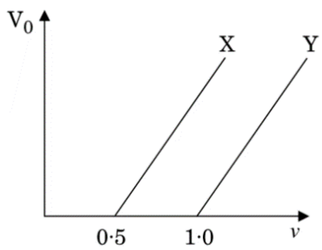
10. Ultraviolet light of wavelength 2271 $\dot{A}$ from a 100 W mercury source is incident on a photocell made of molybdenum metal. If the stopping potential is 1.3 V estimate the work function of the metal. (ii) How would the photocell respond to high intensity? ($10^5\ W/m^2$) red light of wavelength 6328 $\dot{A}$ produced by a He-Ne laser?

Answers

1. Using conservation of momentum and energy in elastic collision, calculate the change in de Broglie wavelength using: $\lambda = h / p$.
Q2. (i) Material A has more stopping potential as its threshold frequency is higher.
(ii) No, slope depends on Planck's constant h and e, not on material.
Q3. Use Einstein's photoelectric equation: $KE = hc/\lambda - \varphi$.
Check if $hc/\lambda > \varphi$ for each metal.
Q4. Line A has smaller slope; hence particle A has higher mass.
Q5. Use $KE = 0.5mv^2$ and Einstein's equation to find threshold frequency.
Q6. Threshold wavelength = hc/φ. Compare with 400 nm to see if photoemission occurs.
Q7a. Current vs Potential graph will show saturation. Frequency is kept constant.
Q7b. de Broglie wavelength $\propto 1/\sqrt{V}$, so it will reduce by $\sqrt{2}$.
Q 8. Use the formula
Energy of one photon=$hc\lambda$
Convert wavelength to meters before using the formula.
9. Calculate kinetic energy using $1/2mv^2$, then divide by h, and add to the threshold frequency f_0.
10. 1. Convert red light wavelength:$\lambda = 6328 A^\circ = 6.328 \times 10{-}7$m
2.Calculate energy of red light photon using $E = hc/\lambda$
3.Compare this photon energy to the work function from part
(i).If energy < work function → No photoemission, regardless of intensity.

SHORT ANSWER QUESTION 3 MARKS

1. (a)The following graph shows the variation of stopping potential V_o with the frequency ν of the incident radiation for two photosensitive metals X and Y

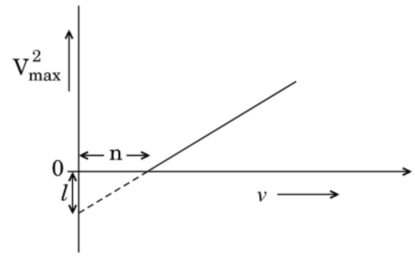


(i) Which of the metals has larger threshold wavelength? Give reason.
(ii) Explain giving reason which metal gives out electrons having larger kinetic energy.

For the same wavelength of the incident radiation. (iii) If the distance between the light source and metal X is halved how will the kinetic energy of electrons emitted from it change? Give reason.

2. Derive an expression for the de-Broglie wavelength associated with an electron accelerated through a potential V. Draw a schematic diagram of a localized wave describing the wave nature of the moving electron.

3. When a given photosensitive material is irradiated with light of frequency ν, the maximum speed of the emitted photoelectrons equals v_{max}. The graph shown in the figure gives a plot of v^2_{max} varying with frequency ν.



Obtain an expression for:

(a) Planck's constant, and

(b) The work function of the given photosensitive material in terms of the parameters l, n and mass m of the electron.

(c) How is threshold frequency determined from the plot?

4. Light consisting of wavelengths λ_1=400 nm (50% intensity) and λ2=600 nm (50% intensity) is incident on a metal with work function ϕ=1.9 eV. Calculate the stopping potential. (Hint: Weighted contribution of each wavelength to photocurrent.)
5. Using photon picture of light, show how Einstein's photoelectric equation can be established. Write two features of photoelectric effect which cannot be explained by wave theory.
6. The work function of a metal is 2.31eV. Photoelectric emission occurs when light of frequency 6.4 X 10^{14} Hz is incident on the metal surface. Calculate: (i) the energy of the incident radiation, (ii) the maximum kinetic energy of the emitted electron and (iii) the stopping potential of the surface.
7. A monochromatic light source of power 5mW emits 8 X 10^{15} photons per second. This light ejects photo electrons from a metal surface. the stopping potential for this set up is 2 V. Calculate the work function of the metal.
8. Plot suitable graphs to show the variation of photoelectric current with the collector plate potential for the incident radiation of
   (i) the same intensity but different frequencies v_1, v_2 and v_3($v_1 < v_2 < v_3$)
   (ii) the same frequency but different intensities I_1, I_2 and I_3($I_1 < I_2 < I_3$)

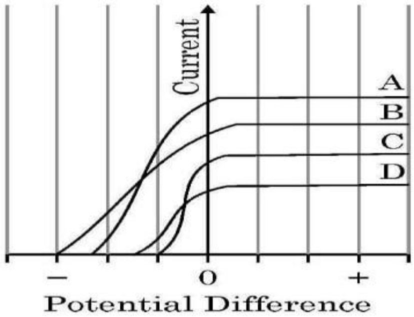
Answers

Q1. (i) Metal with longer threshold wavelength has lower threshold frequency.
(ii) Larger slope = higher kinetic energy for same frequency.
(iii) KE remains unchanged as it depends on frequency, not intensity.
Q2. $\lambda = h / \sqrt{(2meV)}$. Use de-Broglie relation and draw schematic of wave packet.
Q3. (a) h from slope = me × slope / 2.
(b) Work function = $h\nu_0$.
(c) Threshold frequency = x-intercept of ν vs v^2 graph.
Q4. Calculate energy from both λ1 and λ2, then apply Einstein's equation. Get average stopping potential.
Q5. Use photon energy = hf. Subtract work function to find KE. Wave theory can't explain instantaneous emission or threshold frequency.
Q6. (i) $E = hf = 6.4\times10^{14}\times6.63\times10^{-34} = 4.24$ eV
(ii) KE = E - φ = 4.24 - 2.31 = 1.93 eV
(iii) V_0 = 1.93 V
Q7. Power = Energy/sec. Find energy per photon, then divide total energy/sec by energy per photon.
Q8. $E = 0.5mv^2$; Use KE = hf - φ. Solve for f.
Q9. (i) E = hf – φ = eV. Solve for φ = hf – eV.
(ii) Red light has less energy → no photoemission even at high intensity.

CASE BASED QUESTION 3 MARKS

1. Read the paragraph given below and answer the questions that follow:

Figure shows the variation of photoelectric current measured in a photo cell circuit as a function of the potential difference between the plates of the photo cell when light beams **A, B, C, and D** of different wavelengths are incident on the photo cell. Examine the given figure and answer the following questions:



(i) Which light beam has the highest frequency?
(a) A (b) B (c) C (d) D

(ii) Which light beam ejects photoelectrons with maximum momentum?
(a) D (b) C (c) B (d) A

(iii) Consider a beam of electrons (each electron with energy E_0) incident on a metal surface kept in an evacuated chamber then
(a) electrons can be emitted with any energy, with a maximum of E_0
(b) electrons can be emitted with any energy, with a maximum of $E_0 - \varphi$ (φ is the work function)
(c) electrons can be emitted but all with an energy, E_0
(d) no electrons will be emitted as only photons can emit electrons

---

(iv) The stopping potential of a photocell, in which electrons with a maximum kinetic energy of 6 eV are emitted will be
(a) –6V (b) 6V (c) 3V (d) –3V

2. When a photon is incident on a metallic surface, it interacts with an atom in the metal and transfers all its energy to one of the atom's electrons. This electron may then escape through the electric field at the surface, which keeps less energetic electrons inside the metal. The emerging electron then has energy equal to the energy of the photon minus the energy W lost in escaping the metal. W, the work function of the surface, is a material-dependent constant. Since electrons also lose energy in collisions with other electrons before emerging, we may only specify the maximum possible energy for an electron liberated by light of frequency f from a metal. If the material work function is W, this maximum energy is Emax = hf -W

(1.) At stopping potential, the kinetic energy of emitted photo electron is
(a) Minimum (b) maximum (c) zero (d) cannot be predicted

(2.) Photo electric effect experiment
(a) Confirm Quantum nature of light (b) help to measure work function
(c) help to measure Planck's contant (d) All of the above

(3.) Kinetic energy of electrons emitted in photoelectric effect is
(a) directly proportional to the intensity of incident light.
(b) inversely proportional to the intensity of incident light.
(c) independent of the intensity of incident light.
(d) independent of the frequency of light.

(4.) What is true about emitted photo electron from the metal surface?
(a) $hf - W < 0$ (b) $hf - W \geq 0$ (c) f > threshold frequency (d) both b & c

3. The concept of 'wave nature of matter' was postulated by de Broglie in 1924. It was confirmed experimentally by Davisson and Germer a few years after its postulation. Therefore, the realization was

that 'wave nature' and 'particle nature' can be viewed as the 'two sides of a coin. Both matter and radiation can exhibit either of these 'natures', depending on the experimental situation. The phenomena of photoelectric effect and the concept of 'matter waves', have been put to very useful and interesting practical applications. We are aware of photocells, automatic doors at shops and malls, automatic light switches that turn on the lights as soon as the intensity drops.

1) Who confirmed experimentally the wave nature of electron?

i) De-Broglie ii) Davisson& Germer iii) Einstein iv) None of these

2) A proton and an electron have same kinetic energy. Which one has greater de-Broglie wavelength?

i) Electron ii) Proton iii) Same iv) Can't be calculated

3) An electron is accelerated through a potential difference of 100 volts. What is the de-Broglie? wavelength associated with it?

i) 1.227 A˚ (ii)12.27 A˚ (iii)122.7 A˚ (iv)1227 A˚

4) The de-Broglie wavelength, associated with a proton and neutron are found to be equal. Which of the two has a higher value of K.E?

i) Proton ii) Neutron iii) Same for both iv) Can't be calculated

5) An electron is accelerated through a potential difference of 300 volts. What is its energy in eV?

i) 30 eV ii) 300 eV iii) 10 eV iv) 0.3 eV

Answers

Q1. (i) (d) D (ii) (a) D (iii) (b) $E_0 - \varphi$ (iv) (b) 6 V

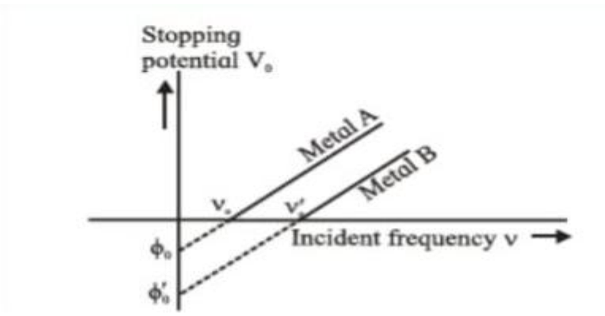
Q2. (1) (c) Zero (2) (d) All of the above (3) (c) Independent of intensity (4) (d) both b & c

Q3. (1) (ii) Davisson & Germer (2) (i) Electron

(3) (i) 1.227 Å (4) (i) Proton (5) (ii) 300 eV

LONG ANSWER TYPE QUESTION 5 MARKS

1. In the study of a photoelectric effect the graph between the stopping potential V and the frequency ν of the incident radiation on two different metals P and Q is shown below:
   Which one of the two metals has higher threshold frequency?



(i) Determine the work function of the metal which has greater value.

(ii) Find the maximum kinetic energy of electron emitted by the light of frequency 8 X 10^{14} Hz for this metal.

2. Answer the following:
   (a) Compare energy and momentum of photon and electron having same wavelength.
   (b) Which has higher energy and why?
3. Answer the following:
   (a) Calculate the wavelength of photon required to eject electrons from a metal with work function 2.2 eV.
   (b) If wavelength is 300 nm, find the kinetic energy of emitted electrons.
4. (a) Calculate the wavelength of de Broglie waves associated with a proton having energy (500/1.673) eV energy. How will the wavelength be affected for an alpha particle having the same energy?
   (b) Using photon picture of light, show how Einstein's photoelectric equation can be established. Write two features of photoelectric effect which cannot be explained by wave theory.

Answers

Q1. (i) Higher threshold frequency = metal with graph intercept farther right on ν-axis

(ii) $\varphi = h\nu_0$

(iii) KE = hf - φ

Q2. (a) p = h/λ same for both; E_photon = hc/λ; E_electron = $(h^2)/(2m\lambda^2)$

(b) Photon has more energy at same λ due to massless nature.

Q3. (i) λ = hc/φ

(ii) Use E = hc/λ - φ to find KE.

Q4. (a) Use λ = h / √(2meV)

Alpha particle → heavier mass → shorter wavelength.

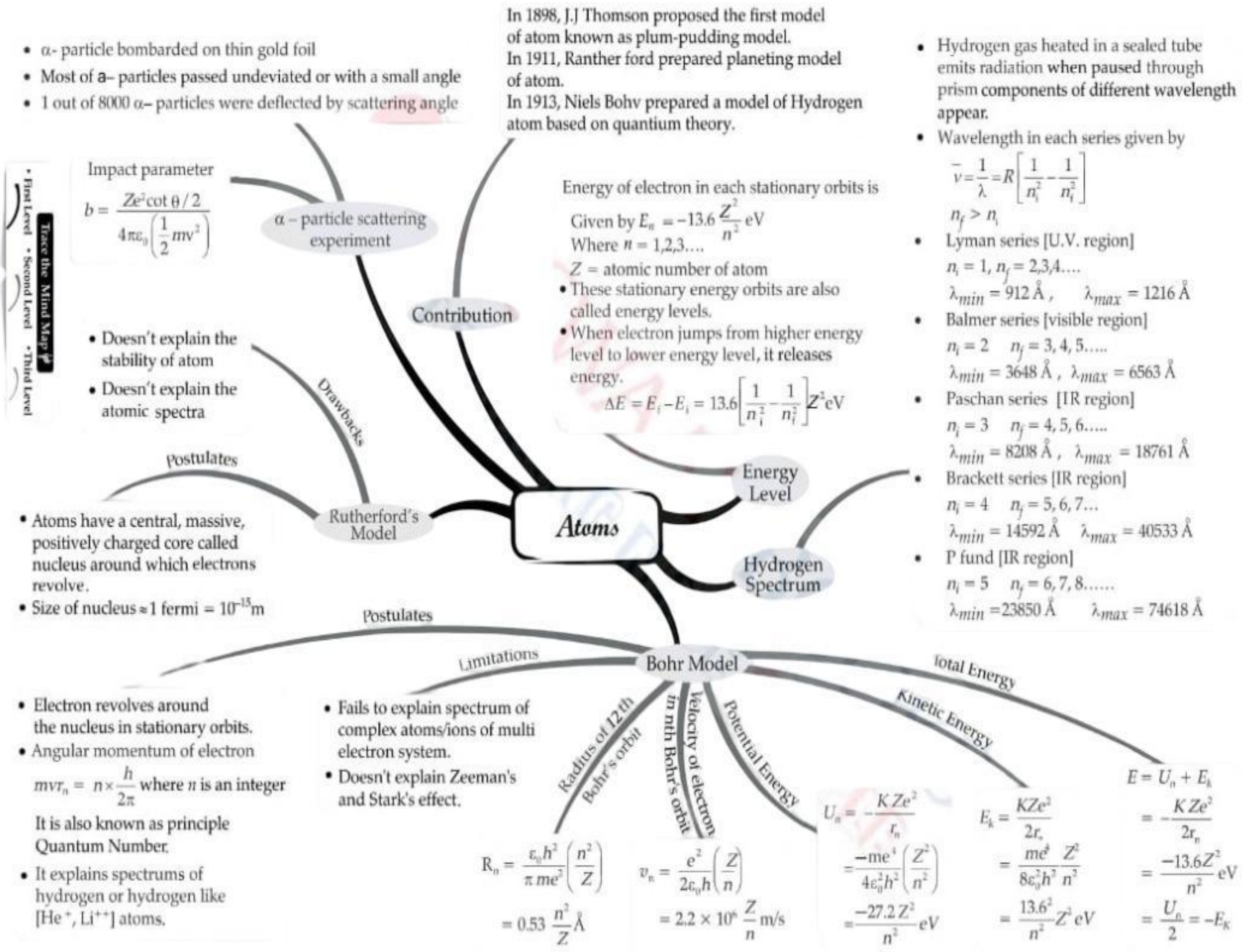
(b) Einstein's equation: KE = hf – φ.

Wave theory fails to explain threshold frequency and instant emission.

CHAPTER 12

ATOMS

MIND MAP



MULTIPLE CHOICE QUESTIONS

1. The ionization energy of the hydrogen atom is 13.6 eV. For a hydrogen-like atom, the transition from n = 2 to n = 1 has 81.6 eV more energy than that of hydrogen's same transition. What is the ionization energy of this hydrogen-like atom?

   (a) 13.6 eV (b) 40.8 eV (c) 105.4 eV (d) 122.4 eV

2. The hydrogen atom can give spectral lines in the Lyman, Balmer and Paschen series. Which of the following statements is correct?

   (a) Balmer series is in the visible region (b) Paschen series is in the visible region

   (c) Lyman series is in the infra-red region (d) Balmer series is in the ultraviolet region

3. In which of the following systems will the radius of first orbit be minimum?

   (a) hydrogen atom (b) deuterium atom (c) singly ionized helium (d) doubly ionized lithium

4. In a hydrogen atom, the electron makes a transition from n_1 to n_2 state. Considering classical electromagnetic theory, the initial frequency of light emitted by the electron in n_1 state is 8 times as that in state n_2. What are the possible values of n_1 and n_2?

   (a) $n_1 = 1, n_2 = 2$ (b) $n_1 = 2, n_2 = 1$ (c) $n_1 = 8, n_2 = 1$ (d) $n_1 = 1, n_2 = 8$

5. The ground state energy of hydrogen atom is -13.6 eV. What is the potential energy of the electron in this state?

   (a) 0 eV (b) 1 eV (c) 2 eV (d) -27.2 eV

6. As the electron in Bohr's orbit of hydrogen atom passes from state n = 2 to n = 1 , the kinetic energy K and the potential energy u change as

   (a) K four-fold and u two-fold (b) K two-fold and u four-fold

   (c) K two-fold and u also two-fold (d) K four-fold and u also four-fold

7. According to classical theory, the path of an electron in Rutherford's atom is

   (a) spiral (b) circular (c) parabolic (d) straight line

8. For an electron in the second orbit of Bohr's hydrogen atom, the moment of liner momentum is

   (a) πh (b) $2\pi h$ (c) h/π (d) $2h/\pi$

9. In the Bohr's atomic model, if the atomic radius of the first orbit is r_0, then radius of the fourth orbit is

   (a) r_0 (b) $4r_0$ (c) $8r_0$ (d) $16r_0$

10. In Bohr's atomic model of hydrogen atom, the product of binding energy of electron in nth orbit and its radius in nth orbit is

    (a) proportional to n^2 (b) proportional to n (c) independent of n (d) inversely proportional to n

Assertion Reason based questions

(a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) The Assertion is correct but Reason is incorrect.

(d) Both the Assertion and Reason are incorrect

11. **Assertion**: The specific charge of positive rays is not constant.
    Reason: The mass of ions varies with speed.
12. **Assertion**: Balmer series lies in the visible region of the electrons radiate.
    Reason: $1/\lambda = R(1/2^2 - 1/n^2)$, where n = 3,4,5
13. **Assertion** : Between any two given energy levels, the number of absorption transitions is always less than the number of emission transitions.
    Reason : Absorption transitions start from the lowest energy level only and may end at any higher energy level. But emission transitions may start from any higher energy level and end at any energy level below it.
14. **Assertion** : Bohr had to postulate that the electrons in stationary orbits around the nucleus do not radiate. **Reason** : According to classical physics all moving electrons radiate.
15. **Assertion (A):** The line spectrum of hydrogen suggests that the electron in a hydrogen atom can have only certain discrete energy values.
    Reason (R): According to Rutherford's model, the electrons revolve in circular orbits and continuously emit radiation, leading to a discrete spectrum.

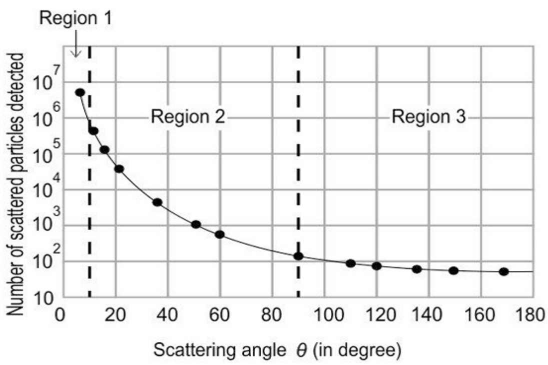
Short answer questions (2 M)

16. The angular momentum of a hydrogen atom in the excited state is $8.28/\pi \times 10^{15}$ eVs. What should be the minimum energy of light which can excite the electron from the ground state to this excited state? ($h = 4.14 \times 10^{-15}$ eVs).
17. The potential energy of an electron in an excited state of the hydrogen atom is about –3 eV. How many emission spectral lines are possible for this excited electron?
18. What is the impact parameter for scattering of -particles by 180°?
19. Angular momentum of an electron in a hydrogen atom is $3h/2\pi$, here h is the plank constant. Find the wavelength of the emitted photon in terms of R (Rydberg constant) when the atom de-excites to emit visible radiations.?
20. Let λ_e, λ_p, and λ_d be the wavelengths associated with an electron, a proton and a deuteron, all moving with the same speed. Then write the descending order of wavelengths of these.
21. What is the ratio of longest wavelength and the shortest wavelength observed in the Balmer series in the emission spectrum of hydrogen?
22. A hydrogen atom is in a state with energy -1.51 eV. In the Bohr model, what is the angular momentum of the electron in the atom, with respect to an axis at the nucleus?

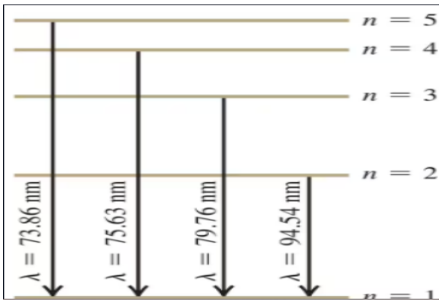
23. A proton has a de Broglie wavelength of 1.0×10^{-14} m. Calculate its kinetic energy in electron volts.
24. State de Broglie hypothesis. Write the expression for the de Broglie wavelength associated with a moving particle.
25. Show that the de Broglie wavelength of a particle is inversely proportional to the square root of the accelerating potential.

Short answer questions (3 M)

26. The below graph represents the variation in the number of alpha particles scattered and the scattering angle in Rutherford's alpha particle scattering experiment. The graph is divided into three regions (separated by two dashed lines). What can be concluded about the structure of atoms from the behavior of particles observed in Region 1 and Region 3?



27. In a set of experiments on a hypothetical one-electron atom, you measure the wavelengths of the photons emitted from transitions ending in the ground state (n =1) as shown in the energy-level diagram in figure. You also observe that it takes 17.50eV to ionize this atom. What is the energy of the atom in n = 3?

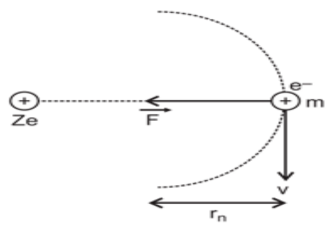


28. In the Hydrogen spectrum find the ratio between the wavelengths of the 'most energetic' spectral lines in the Balmer and Paschen series of the hydrogen spectrum.
29. Which state of the triply ionized Be^{+++} has the same orbital radius as that of the ground state of hydrogen? Compare the energies of two states.
30. The short wavelength limit for the Lyman series of the hydrogen spectrum is 913.4 A. Calculate the short wavelength limit for the Balmer series of the hydrogen spectrum.
31. Explain how de Broglie hypothesis proved Bohr’s second postulate of quantisation of angular momentum.
32. Why is the de Broglie wavelength not observable in everyday macroscopic objects like a cricket ball? Support your answer with a numerical example.

33. The ground state energy of a hydrogen atom is - 13.6 eV. If an electron makes a transition from an energy level - 0.85 eV to - 1.51 eV, calculate the wavelength of the spectral line emitted. To which series of hydrogen spectrum does this wavelength belong?
34. Calculate the de Broglie wavelength of an electron accelerated through a potential difference of 150 V.
35. In a Geiger-Marsden experiment, calculate the distance of the closest approach to the nucleus of Z = 80, when an -particle of 8 MeV energy impinges on it before it comes to momentarily rest and reverses its direction. How will the distance of the closest approach be affected when the kinetic energy of the -particle is doubled?

Case based Questions

36. Hydrogen is the simplest atom of nature. There is one proton in its nucleus and an electron moves around the nucleus in a circular orbit. According to Niels Bohr, the electron moves in a stationary orbit. When this electron is in the stationary orbit, it emits no electromagnetic radiation. The angular momentum of the electron is quantized, i.e., mvr = (nh/2π), where m = mass of the electron, v velocity of the electron in the orbit, r = radius of the orbit and n = 1, 2, 3, ... When transition takes place from kth orbit to jth orbit, energy photon is emitted. If the wavelength of the emitted photon is λ, we find that $\frac{1}{\lambda}$ = R ($\frac{1}{j2}$ - $\frac{1}{k2}$), Where R is Rydberg constant. On a different planet, the hydrogen atom's structure was somewhat different from ours. The angular momentum of electron was P = 2n(h/2π), i.e., an even multiple of (h/2π).



Read the given passage carefully and give the answer of the following questions:

(i) What is the minimum permissible radius of the orbit?

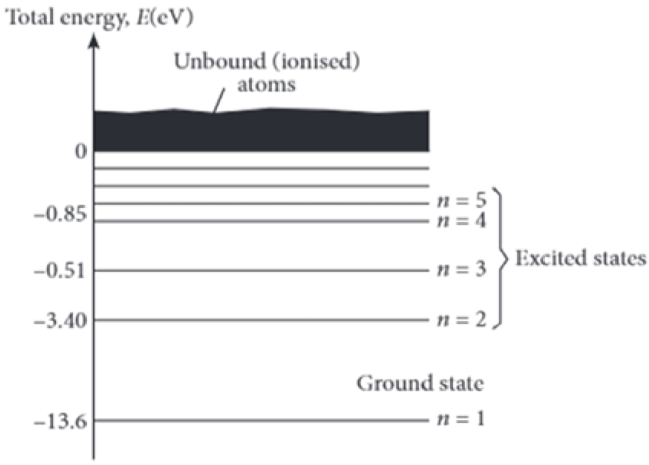
(ii) In our world, the velocity of electron is V_0, when the hydrogen atom is in the ground state. Find the velocity of the electron in this state on the other planet.

(iii) In our world the ionization potential energy of a hydrogen atom is 13.6 eV. What will be the ionization potential energy on the other planet.

(iv) What is the total energy of the electron in the stationary states in the nth orbit of the hydrogen atom?

37. Excited state of Atom

At room temperature, most of the H-atoms are in ground state. When an atom receives some energy (i.e., by electron collisions), the atom may acquire sufficient energy to raise electron to higher energy state. In this condition, the atom is said to be in excited state. From the excited state, the electron can fall back to a state of lower energy emitting a photon equal to the energy difference of the orbit.



In a mixture of H-He$^+$ gas (He$^+$ is single ionized He atom), H-atom and He$^+$ ions are excited to their respective first excited states. Subsequently, H-atoms transfer their total excitation energy to He$^+$ ions (by collisions).

(i) The quantum number n of the state finally populated in He$^+$ ions is

(a) 2 (b) 3 (c) 4 (d) 5

(ii) The wavelength of light emitted in the visible region by He$^+$ ions after collisions with H-atoms is

(a) 6.5×10^{-7} m (b) 5.6×10^{-7} m (c) 4.8×10^{-7} m (d) 4.0×10^{-7} m

(iii) The ration of kinetic energy of the electrons for the H-atoms to that of He$^+$ ions for n = 2 is

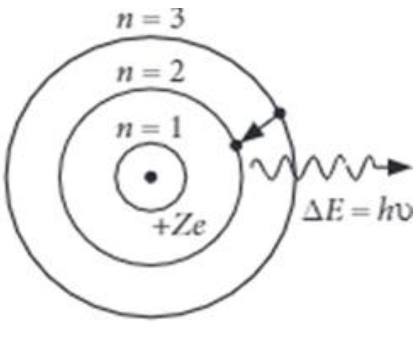
(a) $\frac{1}{4}$ (b) $\frac{1}{2}$ (c) 1 (d) 2

(iv) The radius of the ground state orbit of H-atoms is

(a) $\frac{\varepsilon_0}{h\pi me^2}$ (b) $\frac{h^2\varepsilon_0}{\pi me^2}$ (c) $\frac{\pi me^2}{h}$ (d) $\frac{2\pi h\varepsilon_0}{me^2}$

38. **Bohr's Model of Hydrogen Atom**

Niels Bohr introduced the atomic Hydrogen model in 1913. He described it as a positively charged nucleus, comprised of protons and neutrons, surrounded by a negatively charged electron cloud. In the model, electrons orbit the nucleus in atomic shells. The atom is held together by electrostatic forces between the positive nucleus and negative surroundings.



Bohr correctly proposed that the energy and radii of the orbits of electrons in atoms are quantized, with energy for transitions between orbits given by $\Delta E = h\nu = E_i, - E_f$, where ΔE is the change in energy between the initial and final orbits and $h\nu$ is the energy of an absorbed or emitted photon.

(i) In the Bohr model of the hydrogen atom, discrete radii and energy states result when an electron circles the atom in an integer number of

(a) De Broglie wavelengths (b) wave frequencies

(c) quantum numbers (d) diffraction patterns

(ii) The angular speed of the electron in the n^{th} orbit of Bohr's hydrogen atom is

(a) directly proportional to n (b) inversely proportional to $\sqrt{n}$

(c) inversely proportional to n^2 (d) inversely proportional to n^3

(iii) when electron jumps from n = 4 level to n = 1 level, the angular momentum of electron changes by

(a) $\frac{h}{2\pi}$ (b) $\frac{h}{\pi}$ (c) $\frac{3h}{2\pi}$ (d) $\frac{2h}{\pi}$

(iv) The lowest Bohr orbit in hydrogen atom has

(a) The maximum energy (b) the least energy

(C) infinite energy (d) zero energy

Long Answer Questions

39. (i) In a hydrogen atom, an electron undergoes transition from 2nd excited state to the first excited state and then to the ground state. Identify the spectral series to which these transitions belong. (ii) Find out the ratio of the wavelengths of the emitted radiations in the two cases.

40. Using Bohr's formula for energy quantization determine:

i. the longest wavelength in the Lyman series of hydrogen atom spectrum.

ii. the excitation energy of the n =3 level of He+ atom

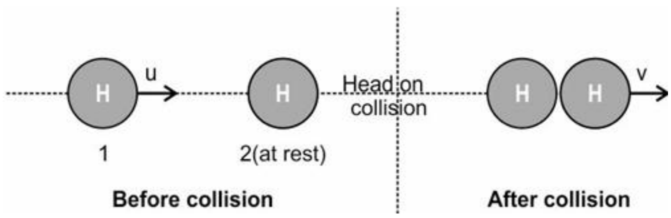
iii. the ionization potential of the ground state of Li++ atom.

41. The energy of the electron, the hydrogen atom, is known to be expressible in the form $E_n = -13.6/n^2$ eV (n = 1, 2, 3, . . .) Use this expression to show that the

i. Electron in the hydrogen atom can not have an energy of -2V.

ii. Spacing between the lines (consecutive energy levels) within the given set of the observed hydrogen atom spectrum decreases as n increases.

42. After a head-on inelastic collision between two hydrogen atoms that were initially in the ground states, the two atoms combine and move together into the excited state.



Initially second H atom was in rest and first H atom is moving with a velocity. Determine the minimum velocity of the first H atom that can result in the minimum possible excitation in the second H-atom in this collision. Assume that in perfectly inelastic collisions between the atoms, the excess KE is used for the excitation. Use: 1 eV = 1.6×10^{-19} J and Mass of H-atom = 1.6×10^{-27} kg.

43. Hydrogen atoms in their ground state are excited by means of monochromatic radiation of wavelength.

i. How many different lines are possible in the resulting spectrum?

ii. Calculate the longest wavelength amongst them. You may assume the ionization energy for hydrogen atoms as 13.6 eV.

ANSWERS

MCQs :

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

ASSERTION – REASON QUESTIONS

11. (c)	12. (a)	13. (d)	14. (a)	15. (c)

SHORT ANSWER QUESTIONS (2M)

16. From Bohr's quantization condition, $L = \frac{nh}{2\pi}$ so ⇒ $n = L\frac{2\pi}{h}$ ⇒ n = 4.

17. Given that P.E. = 3 eV so Total energy E = PE/2 = 1.5 eV

So $E_n = -\frac{13.6}{n^2}$ ⇒ $n^2 = \frac{13.6}{E_n}$ ⇒ n = 3

18. **Impact parameter for 180°:** b = 0 (head-on collision).

19. Comparing 3h/2π with nh/2π, the initial state of the hydrogen atom is $n_1 = 3$

As visible radiations are emitted the electron would de-excite to n2 = 2 (Balmer series)

Using $\frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{n^2})$, $\lambda = \frac{36}{5R}$

20. **λ order for same speed:** λ = h/mv so $m_e<m_p<m_d$; so $\lambda_e>\lambda_p>\lambda_d$

21. **Longest vs shortest Balmer:** $1/\lambda = R(1/2^2 - 1/n^2)$ For longest n=3, for shortest n=∞.

So ratio: $\lambda_{longest}/\lambda_{shortest} = (1/2^2 - 1/\infty)/(1/2^2 - 1/3^2) = (1/4)/(5/36) = 9/5 = 1.8$.

22. **Angular momentum for -1.51 eV:** $E_n = -13.6/n^2$, so $n^2 = 13.6/1.51 \approx 9$, n=3 $L = n\hbar = 3\hbar$.

23. KE = $p^2/2m$ and λ = h/p

24. **de Broglie hypothesis:** Matter has waves. λ = h/p = h/mv.

25. **$\lambda \propto 1/\sqrt{V}$:** K.E. = eV = $1/2mv^2$ So $v = \sqrt{2eV/m}$ So $\lambda = h/\sqrt{2eV/m}$.

SHORT **ANSWER QUESTIONS (3M)**

26. Observations of Rutherford experiment.

27. **Energy at n=3:** Given ionization = 17.5 eV = |E1|.

$E3 = -17.5/9 = -1.94$ eV.

28. **Balmer vs Paschen:** Most energetic line → shortest λ.

$\lambda_{Balmer}/\lambda_{Paschen} = (1/2^2 - 1/\infty)/(1/3^2 - 1/\infty) = (1/4)/(1/9) = 9/4 = 2.25$.

29. **Same radius Be^{3+} as H ground:** $r_n = n^2/Z \cdot a_0$, So for Be^{3+} (Z=4): $n^2/4 = 1$ → n = 2.

Energy comparison: $E_{Be} = -13.6 \times 4^2/2^2 = -54.4$ eV.

30. B**almer short λ:** $1/\lambda = R(1/2^2 - 1/\infty) = R/4$

So $\lambda = 1/(R/4) = 4/R$.

Use $\lambda_{Lyman} = 913.4A^\circ = 9.134\times10^{-8}$ m λ

So $R = 4/\lambda_{Lyman} \approx 4.38\times10^7\ m^{-1}$.

Then $\lambda_{Balmer} = 4/R \approx 9.13\times10^{-7}$ m = 9130A°.

31. Derivation $mvr = nh/2\pi$

32. For a cricket ball of mass 0.15 kg moving at 30 m/s,

$\lambda = h/mv = 6.63\times10^{-34} / 0.15\times30 \approx 1.5\times10^{-34}$m

This is extremely small (undetectable), so wave nature not observable.

33. Wavelength emitted by transition from -0.85 eV to -1.51 eV

Energy difference: $\Delta E = -0.85 - (-1.51) = 0.66$eV

Convert to joules: $= 0.66\times1.6\times10^{-19} = 1.056\times10^{-19}$J

Wavelength: $\lambda = hc/\Delta E = (6.63\times10^{-34}\times3\times10^8)/1.056\times10^{-19} \approx 1.88\times10^{-6}$m.

This is in **infrared**, belongs to **Paschen series**.

34. Use Momentum: $p = \sqrt{2mE}$ and then $\lambda = h/p$

35. Use: $(1/4\pi\epsilon0)2Ze^2/r = E$

So, $r = (1/4\pi\epsilon_0)2Ze^2/E$

36. (i) Given: $P = 2nh/2\pi$

So minimum when n = 1, $mvr = 2h/2\pi$

So $r_{min} = 2\times r_0 = 2\times0.53\times10^{-10} = 1.06\times10^{-10}$ m.

(ii) Angular momentum is twice. Thus velocity halves. So, $v' = V_0/2$.

(iii) Energy is proportional to $1/n^2$ and since angular momentum doubled, energy reduces by 1/4.

So ionization energy is = 13.6/4 = 3.4eV.

(iv) **Total energy in nth orbit** $E_n = -13.6\times(1)(2n)^2 = -13.6/4n^2$eV

37. (i) (c) (ii) (d) (iii) (a) (iv) (b)

38. (i) (a) (ii) (d) (iii) (c) (iv) (b)

39. (i) Spectral series

2nd excited → n=3 to n=2 : Balmer

then n=2 to n=1 : Lyman

(ii) Ratio of wavelengths $\lambda_1/\lambda_2 = \Delta E_2/\Delta E_1 = 10.2/1.89 \approx 5.4$

40. (i) Longest λ in Lyman n=∞ to n=1

$\lambda = 1/R(1-0) = 1/1.097\times10^7 = 91.2$nm

(ii) Excitation energy He^+ at n=3

$= 54.4(1-1/9) = 48.4$eV

(iii) Ionization energy of Li++ =13.6×9=122.4eV

41. (i) Electron cannot have -2 eV

As nearest energy is at n=2: E2=−3.4eV

and n=3: −1.51eV

so no n gives -2 eV

Spacing decreases as n increases $\Delta E = 13.6(\frac{1}{n^2} - \frac{1}{(n+1)^2})$ gets smaller for large n.

42. If absorption to n =3 → **Paschen**

to n=2 → **Balmer**

to n=1 → **Lyman**

43. (i) Number of lines: If excited to n=4, $= \frac{4(4-1)}{2} = 6$

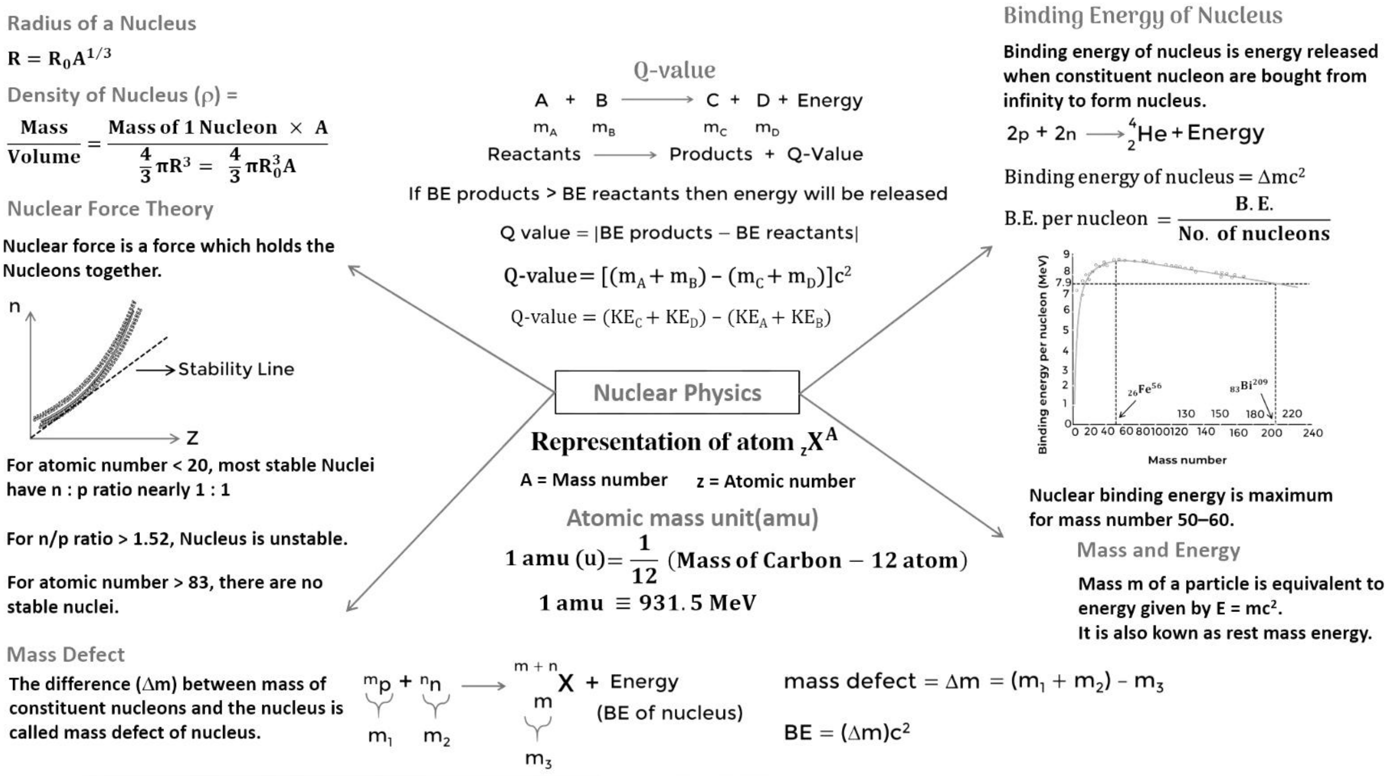
(ii) Longest wavelength: Smallest energy transition: 4→3

$\lambda = \frac{12400}{0.66} = 1.88\times10^{-6}\text{m}$

CHAPTER 13

NUCLEI

MIND MAP



MULTIPLE CHOICE QUESTIONS

Q1- The energy released in the following reaction will be

$^2H_1 + {^2H_1} \rightarrow {_2He^4} + Q$

$M(^2H_1) = 2.01471$ u $M(_2He^4) = 4.00388$ u

(A) 3.79 Mev   (B) 13.79 Mev   (C) 0.79 Mev   (D) 1.79MeV

Q2. Complete the series $6He \rightarrow e^- + 6Li^+$

(a) Neutrino   (b) antineutrino   (c) proton   (d) neutron

Q3- If the density of gold nucleus is X, density of Silver nucleus will be

(A) 4X   (B) X/2   (C) X   (D)2X

Q4- A stable nucleus has radius half of the radius of a nucleus of mass number A=64. The mass number of the nucleus will be

(A) 32 (B)16 (C) 8 (D) 1

Q5- If m_X, m_n and m_p represents masses of X nucleus, a neutron and a proton, respectively.

Then : (A) $m_X < (A - Z) m_n + Z m_p$ (B) $m_X = (A - Z) m_p + Z m_n$

(C) $m_X = (A - Z) m_n + Z m_p$ (D) $m_X > (A - Z) m_n + Z m_p$

ANS	1	2	3	4	5
	A	B	C	C	A

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

Q1- Assertion: Neutrons penetrate matter more readily as compared to protons.

Reason: Neutrons are slightly more massive than protons.

Q2- Assertion: The positively charged nucleus of an atom has a radius of almost 10^{-15} m.

Reason: In a-particle scattering experiment, the distance of closest approach for a particles is $\simeq 10^{-15}$ m.

Q3- Assertion: Density of all the nuclei is same.

Reason: Radius of nucleus is directly proportional to the cube root of mass number.

Q4- Assertion: The force of repulsion between atomic nucleus and α-particle varies with distance according to inverse square law.

Reason: Rutherford did α-particle scattering experiment.

Q5- Assertion (A) : Nuclear fission reactions are responsible for energy generation in the Sun.

Reason (R) : Light nuclei fuse together in the nuclear fusion reactions.

Answers:

1. Correct Answer: B

Solution: Neutron is about 0.1 more massive than proton. But the unique thing about the neutron is that while it is heavy, it has no charge (it is neutral). This lack of charge gives it the ability to penetrate matter without interacting as quickly as the beta particles or alpha particles.

2. Correct Answer: A

Solution: In a-particle scattering experiment, Rutherford found a small number of a particles which were scattered back through an angle approaching to 180∘. This is possible only if the positive charges are concentrated at the centre or nucleus of the atom.

3. Correct Answer: A

Solution: Experimentally it is found that the average radius of a nucleus is given by

$R = R_0 X A^{1/3}$, where $R_0 = 1.1 \times 10^{-15}$ m = 1.1 fm and A = mass number.

4. Correct Answer: B

5. Ans-D

SHORT ANSWER TYPE QUESTIONS(2 MARKS)

Q1- If 200 MeV energy is released in the fission of a single nucleus of $_{92}U^{238}$, how many fission must occur to produce a power of 1KW?

Q2- Draw a plot showing the variation of potential energy of a pair of nucleons as a function of their separation. Mark the regions where the nuclear force is (a) attractive and (b) repulsive.

Q3- Using the curve for the binding energy per nucleon as a function of mass number A, state clearly how the release of energy in the processes of nuclear fission and nuclear fusion can be explained.

Q4- 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 8.5MeV per nucleon. Calculate the energy Q released per fission in MeV.

Q5- Write characteristic properties of nuclear force.

Answers:

1. Solution-

Let the number of fissions per second be n.

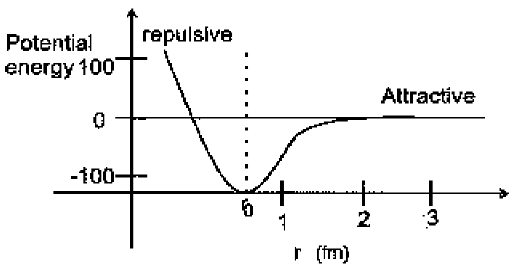
Energy released per second = nx200MeV = nx200X $1.6X10^{-19}$ J

Energy required per second = 1000J

nx200X $1.6X10^{-19}$ J = 1000

n = 3.125x10^{13}

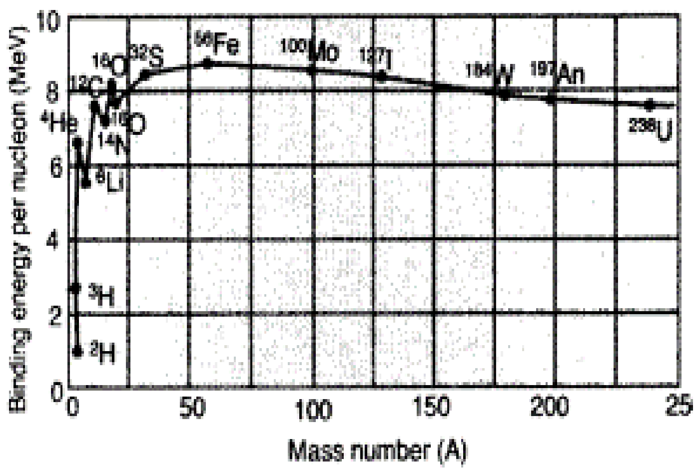
2. Solution-



3. Answer:

Nuclear fission: Binding energy per nucleon is smaller for heavier nuclei than the middle ones i.e. heavier nuclei are less stable. When a heavier nucleus splits into the lighter nuclei, the B.E./nucleon changes (increases) from about 7.6 MeV to 8.4 MeV. Greater binding energy of the product nuclei results in the liberation of energy. This is what happens in nuclear fission which is the basis of the atom bomb.

Nuclear fusion: The binding energy per nucleon is small for light nuclei, i.e., they are less stable. So when two light nuclei combine to form a heavier



nucleus, the higher binding energy per nucleon of the latter results in the release of energy.

4. Ans- 240 ×7.6=1824 MeV 240×8.5=2040 MeV 2040×1824=216 MeV

5. Refer NCERT text book

SHORT ANSWER TYPE QUESTIONS(3 MARKS)

Q1- (A)Imagine the fission of a $_{26}Fe^{56}$ into two equal fragments of $_{13}Al^{28}$ nucleus. Is the fission energetically possible? Justify your answer by working out Q value of the process.

(B) Why is the density of a nucleus much more than that of an atom ?

Q2- (A)Given the mass of iron nucleus as 55.85u and A=56, find the nuclear density?

(B) Calculate the energy equivalent of 1 g of substance.

Q3- Calculate the energy released in MeV in the following nuclear reaction

$^{238}U_{92} \rightarrow {}^{234}Th_{90} + {}^{4}He_{2} + Q$

Mass of $^{238}U_{92}$= 238.05079 u Mass of $^{234}Th_{90}$ = 234.043630 u

Mass of $^{4}He_{2}$= 4.002600 u 1u= 931.5 Mev/c^2

Answers:

1.Solution -(A)Given: m ($^{56}_{26}Fe$) = 55.93494u, m ($^{28}_{613}Al$) = 27.98191u.

Mass Difference = 55.93494 – 2 x 27.98191 = -0.02888u.

Fission not possible.

(B) Because the whole mass of the nucleus is concentrated at the centre of atom in a small space.

2. Solution- (A)mass of Fe = 55.85 u = 9.27×10^{-26} kg

Nuclear density = mass/ volume = 2.29×10^{17} kg m–3

(B) Solution Energy, E = $10^{-3} \times (3 \times 10^{8})^2$ J = 9×10^{13} J

3. Solution-

Nuclear reaction is $^{292}_{92}U$ ▼ → $^{234}_{90}Th_0 + ^{4}_{2}He$+Q

Energy released , Q= $\Delta m \times c^2$ = 4.25 MeV

CASE BASED QUESTIONS (4 MARKS)

Q1-**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. 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) All the nucleons in an atom are held by

(a) nuclear forces (b) vander waal's forces (c) tensor forces (d) coulomb forces

Q2-Einstein was the first to establish the equivalence between mass and energy. According to him, whenever a certain mass (Δm) disappears in some process the amount of energy released is E = Δm *c2, where c is the velocity of light in vacuum =3 x 10^8 m/s. The reverse is also true i.e. whenever energy E disappears an equivalent mass Δm = E/ c2 appears. Read the above passage and answer any 04 from the following –

i) What is the energy released when 1a.m.u mass disappears in a nuclear reaction?

a) 1.49 x10^{-10} J b) 1.49 x10^{-13} J c) 1.49 x10^{10} J d) 1.49 x10^{-10} MJ

ii)Which of the following process releases energy?

a)Nuclear Fission b)Nuclear Fusion c)Both (a) and (b) d)None

iii)Which process is used in today's nuclear power plant to harness nuclear energy?

a)Nuclear Fission b)Nuclear Fusion c)Both (a) and (b) d)None

iv)Which of the following is used as Moderator in a Nuclear Reactor?

a)Deuterium Water b)Normal Water c)Mineral Water

ANSWER CASE BASED QUESTIONS

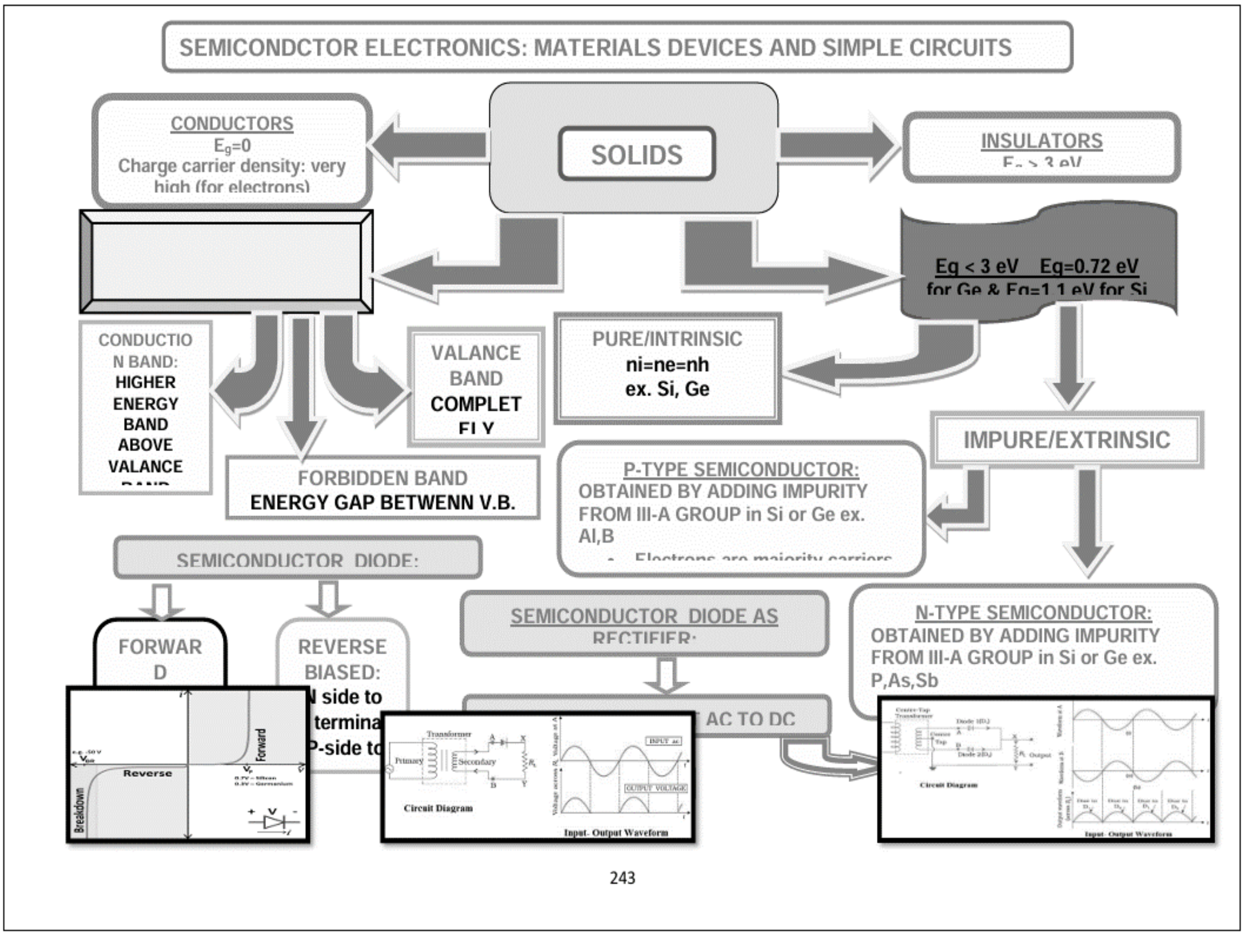
Ans1: (i) d (ii) d (iii) d (iv) a

Ans 2 (i) b (ii) c (iii) a (iv) a

CHAPTER 14

SEMICONDUCTORS

MIND MAP



MULTIPLE CHOICE QUESTIONS

1. n_e and v_d is the number of electron and drift velocity in a semiconductor respectively. How would they respond to increase in temperature of the semiconductor?

(a). n_e increases and v_d decreases (b). n_e decreases and v_d increases

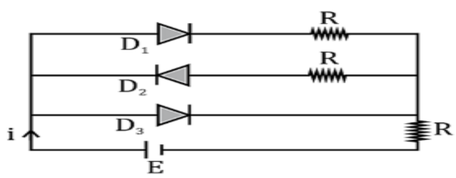
(c). Both n_e and v_d increases (d). Both n_e and v_d decreases

2. In a P-N junction diode if P region is more heavily doped than n region, then the depletion layer is

(a). Greater in P region (b). Greater in N region

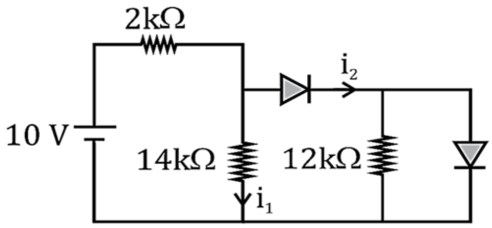
(c). Equal in both region (d). No depletion layer is formed in this case

3. In the following circuit of PN junction diodes D_1, D_2 and D_3 are ideal then I is



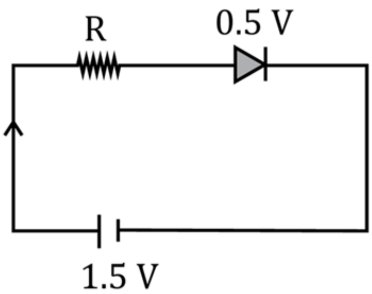
(a). E/R (b). E/2R (c). 2E/3R (d). Zero

4. In the following circuit I_1 and I_2 are respectively



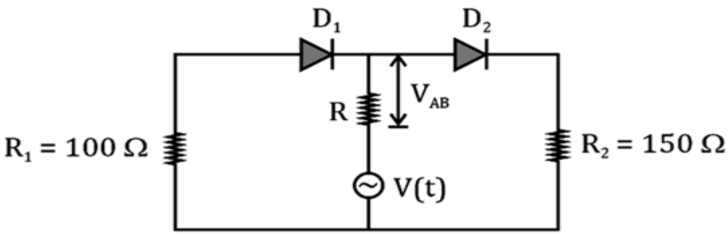
(a). 0, 0 (b). 5 mA, 5 Ma (c). 5 mA, 0 (d). 0, 5 mA

5. The diode used in the circuit shown in the figure has a constant voltage drop of 0.5 V at all currents and a maximum power rating of 100 milli watts. What should be the value of the resistor R connected in series with the diode for obtaining maximum current?



(a). 1.5 Ω (b). 5 Ω (c). 6.67 Ω (d). 200 Ω

6. In the circuit given below; V(t) is the sinusoidal voltage source, voltage drop $V_{AB}(t)$ across the resistance R



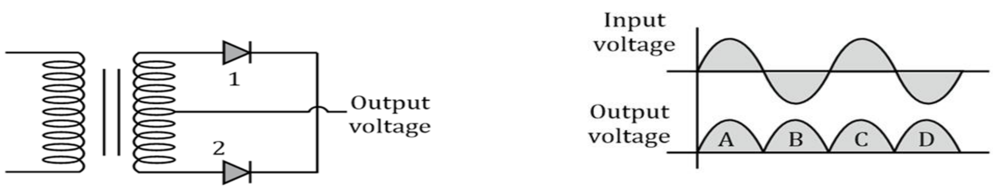
(a). Is half wave rectified

(b). Is full wave rectified

(c). Has the same peak value in the positive and negative half cycles

(d). Has different peak values during positive and negative half cycle

7. A full wave rectifier circuit along with the input and output voltage is shown in the figure. The contribution to output voltage from diode –2 is

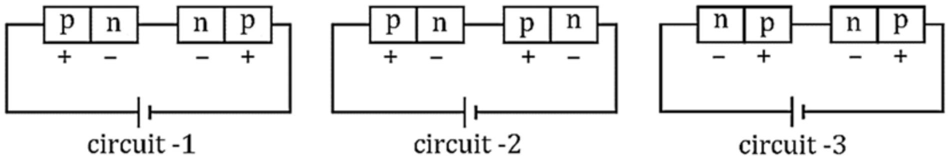


(a). A, C (b). B, D (c). B, C (d). A, D

8. The electrical conductivity of a semiconductor increases when electromagnetic radiation of wavelength shorter than 2480 nm is incident on it. The band gap (in eV) for the semiconductor is

(a). 0.9 (b). 0.7 (c). 0.5 (d). 1.1

9. Two identical p-n junctions may be connected in series with a battery in three ways. The potential drops across the two p-n junctions are equal in



(a). Circuit-1 and circuit-2 (b). Circuit-2 and circuit-3

(c). Circuit-3 and circuit-1 (d). Circuit-1 only

ASSERTION-REASON

Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct Ans 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 resistance of an intrinsic semiconductor decreases with increase in its temperature.

Reason (R) : The number of conduction electrons as well as hole increase in an intrinsic semiconductor with rise in its temperature.

2. 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.

3. Assertion (A): An n type semiconductor has a large number of electrons but still it is electrically neutral.

Reason(R): An n type semiconductor is obtained by doping of pentavalent impurity atoms and an atom on the whole is electrically neutral.

4. Assertion(A): The electrical conductivity of n-type semiconductor is higher than that of p-type semiconductor at a given temperature and voltage applied.

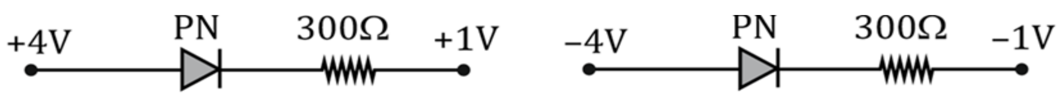
Reason(R): The mobility of electrons is higher than that of holes.

5. Assertion(A): The electrical conductivity of a semiconductor increases on doping.

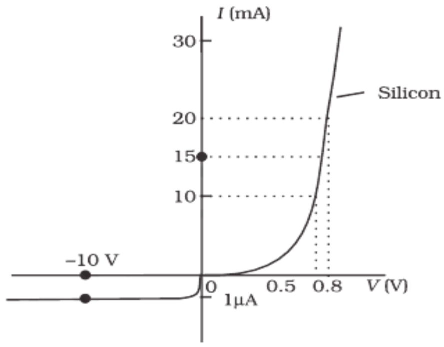
Reason(R): Doping always increases the number of electrons in the semiconductor.

SHORT ANSWER QUESTIONS (2 MARKS)

1. In the circuits given below, the value of the current is



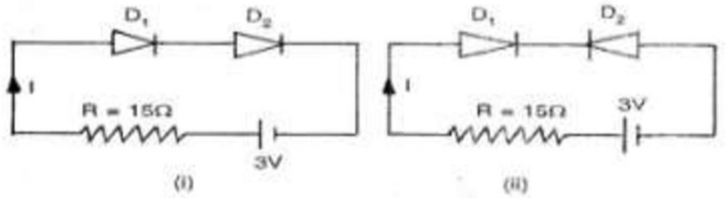
2. The V-I characteristic of a silicon diode is shown in the Figure. Calculate the resistance of the diode at (a) I_D = 15 mA and (b) V_D = –10 V.



3. i) In half-wave rectification, what is the output frequency if the input frequency is 50 Hz. What is the output frequency of a full-wave rectifier for the same input frequency?

ii) A silicon P–N junction is in forward biased condition with a resistance in series. It has knee voltage of 0.75 V and current flow in it is 10 mA. If the P–N junction is connected with 2.75 V battery then calculate the value of the resistance.

4. Determine the current through resistance "R" in each circuit. Diodes D_1 and D_2 are identical and ideal.



5. i) Describe the formation of the depletion area and potential barrier in a junction diode using a diagram.

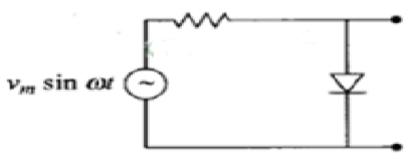
ii) How does a doping agent modify a semiconductor's conductivity?

SHORT ANSWER QUESTIONS (3 MARKS)

1. Draw V-I characteristics of a p-n junction diode. Ans the following questions, giving reasons: (i) Why is the current under reverse bias almost independent of the applied potential up to a critical voltage?

(ii) Why does the reverse current show a sudden increase at the critical voltage?

(iii) . What can you say about the output of the circuit given below?



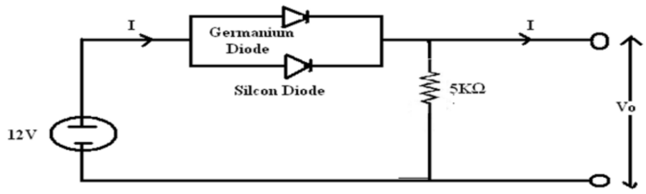
2. (i) Explain with a proper diagram how an ac signal can be converted into dc (pulsating) signal with output frequency as double than the input frequency using p-n junction diode. Give its input and output waveforms.

(ii) When an electric field is applied across a semiconductor
(a) electrons move from lower energy level to higher energy level in the conduction band
(b) electrons move from higher energy level to lower energy level in the conduction band

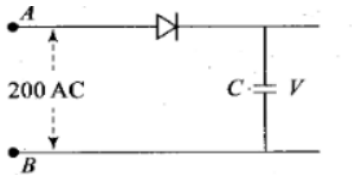
(c) holes in the valence band move from higher energy level to lower energy level
(d) holes in the valence band move from lower energy level to higher energy level

3. (i) Calculate the value of output voltage V_0 and Current I if Silicon diode and germanium diode conduct at 0.7 V and 0.3 V respectively.

(ii) If now Germanium diode is connected 12 V in reverse polarity, find new value of output voltage V_0 and Current I.

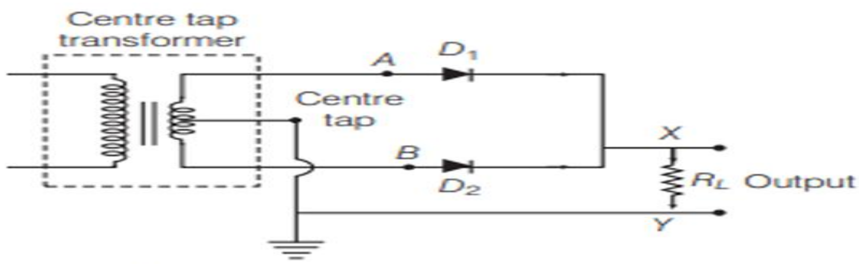


(iii) A 220 V AC supply is connected between points A and B (figure). What will be the potential difference V across the capacitor?



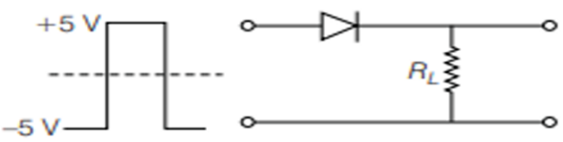
CASE BASED QUESTIONS

1. Full Wave Rectifier The process of converting alternating voltage/current into direct voltage/current is called rectification. Diode is used as a rectifier for converting alternating current/voltage current/voltage. into Diode direct allows current to pass only, when it is forward biased. So, if an alternating voltage is applied across a diode, the current flows only in that part of the cycle when the diode is forward biased. This property is used to rectify the current/voltage.



Circuit diagram of full wave rectifier

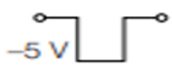
i) If in a p-n junction, a square input signal of 10V is applied as shown



Then, the output across R_L will be

(a) 

(b) 

(c) 

(d) 

ii) If in a p-n junction, a square input signal of 10V is applied as shown in figure, the input is across the terminals A and C and the output is across B and D.

Then, the output is

(a) Zero (b) same as the input

(c) half wave rectified (d) full wave rectified

iii) Which of the following is not true about a rectifier circuit?

(a) It can convert DC to AC. (b) It can convert AC to DC.

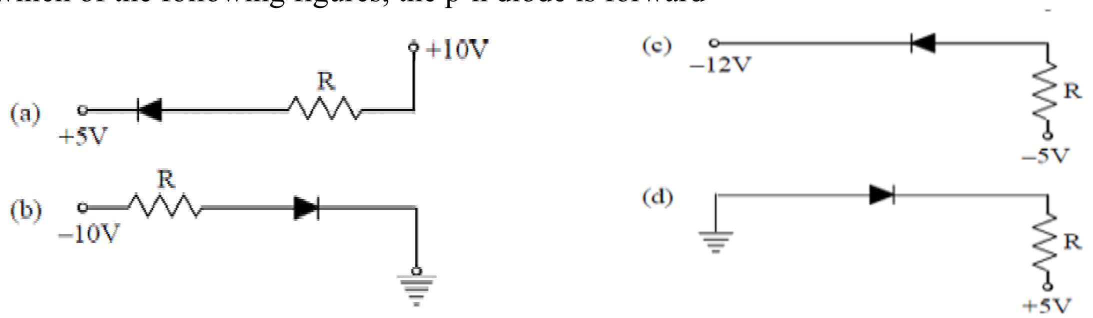
(c) It can shift voltage level (d)None of these

iv) The ratio of output frequencies of half-wave rectifier and a full wave rectifier, when an input of frequency 200 Hz is fed at input, is

(a) 1:2 (b) 2: 1 (c) 4 :1 (d) 1 : 4

2. When the diode is forward biased, it is found that beyond forward voltage $V = V_k$, called knee voltage, the conductivity is very high. At this value of battery biasing for p-n junction, the potential barrier is overcome and the current increases rapidly with an increase in forwarding voltage. When the diode is reverse biased, the reverse bias voltage produces a very small current about a few microamperes which almost remains constant with bias. This small current is reverse saturation current.

i) In which of the following figures, the p-n diode is forward



biased

(a) a, b and d (b) c only (c) c and a (d) b and d

ii) Based on the V-I characteristics of the diode, we can classify diode as

(a) bi-directional device (b) ohmic device (c) non-ohmic device (d) passive element

iii) In the case of forwarding biasing of a p-n junction diode, which one of the following statements is correct?

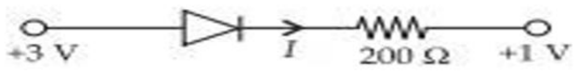
(a) effective barrier potential decreases

(b) majority charge carriers begin to flow away from junction

(c) width of depletion layer increases

(d) effective resistance across the junction increases

iv) If an ideal junction diode is connected as shown, then the value of the current I is

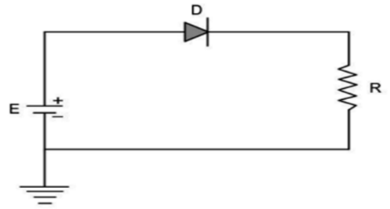


(a) 0.005 (b) 0.02 A (c) 0.01 A (d) 0.1A

LONG ANSWER QUESTIONS

1. In a forward biased, ideal p-n diode, the applied forward potential is opposite to the potential barrier of the depletion region. A small forward voltage is sufficient to overcome the potential barrier.

Once eliminated, the junction resistance is reduced to zero and an ideal p-n junction has zero ohmic potential drop across itself. The voltage at which the current starts to increase rapidly is called threshold voltage or cut in voltage or knee voltage of the p-n diode. If the diode voltage is more than knee voltage, it conducts easily otherwise it conducts poorly. For a silicon diode, V(threshold) = 0.7 V



a. In the circuit given here, determine the voltage across an ideal silicon diode D and resistor R and the current through the diode and resistor, if E = 3 V and R = 2 k-ohm.

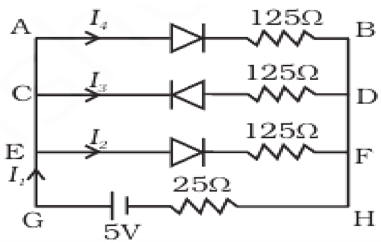
b. How will the value of current in part (a) change in case E is made 0.3 V?

c. What will be the current and potential difference across the diode if it has a forward resistance of 0.3 Ω?

2. (a) Can a slab of p-type semiconductor be physically joined to another n-type semiconductor slab to form p-n junction? Justify your answer.

(b) In a p-n junction diode, the forward bias resistance is low as compared to the reverse bias resistance. Give reason.

(c) If each diode in figure has a forward bias resistance of 25Ω and infinite resistance in reverse bias, what will be the values of the current I_1, I_2, I_3 and I_4?



3. Suppose a n-type wafer is created by doping Si crystal having 5×10^{28} atoms/m^3 with 1ppm concentration of As. On the surface 200 ppm Boron is added to create 'P' region in this wafer. Considering $n_i = 1.5 \times 10^{16}$ m^{-3},

(a) Calculate the densities of the charge carriers in the n & p regions.

(b) Comment which charge carriers would contribute largely for the reverse saturation current when diode is reverse biased.

(c) Assuming the ideal diode, draw the output waveform for the circuit given in figure. Explain the waveform.

ANSWERS

MULTIPLE CHOICE QUESTIONS

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

ASSERTION-REASON

1. (a)	2. (a)	3. (a)	4. (a)	5. (c)		

SHORT ANSWER QUESTIONS (2 MARK)

1. 10 mA, 0

2. (a) 30 Ω, (b) $10^7 \Omega$

3. (i) (a) 25 Hz, (b) 50 Hz, (ii) 200∧

4. In circuit (i) Both D_1 and D_2 are forward biased hence both will conduct current and resistance of each diode is "0". Therefore I = 3/15 = 0.2 A In circuit (ii) Diode D_1 is forward bias and D_2 is reverse bias, therefore resistance of diode D_1 is "0"and resistance of D_2 is infinite. Hence D_1 will conduct and D_2 do not conduct. No current flows in the circuit.

SHORT ANSWER QUESTIONS (3 MARK)

1. (i) In the reverse biasing, the current of order of μA is due to movement/drifting of minority charge carriers from one region to another through the junction. A small applied voltage is sufficient to sweep the minority charge carriers through the junction. So, reverse current is almost independent of critical voltage.

(ii) At critical voltage (or breakdown Reverse bias voltage), a large number of covalent bonds break, resulting in the increase of a large number of charge carriers. Hence, current increases at critical voltage.

(iii) Would be like a half wave rectifier with negative cycles in output.

2. (i) Working of full-wave rectifier.

(ii) (a, c)

3. (i) Germanium diode conducts at 0.3 V only, so current will prefer to pass through germanium diode so, $V_0 = 12 – 0.3 = 11.7$ V

And, I = 11.7/(5 x 10^3) = 2.34 mA

(ii) When germanium diode is reversed biased, the current will flow through the silicon diode. Then, V_0 = 12 – 0.7 = 11.3 V

And, I = 11.3/(5 x 10^3) = 2.26 mA

(iii) $220\sqrt{2}$ V

CASE BASED QUESTIONS

1. ANS: (i) (d)

(ii) (a)

Reason: two of the four diodes will always be in reverse bias.

(iii) (a)

(iv) (a)

2. ANS: (i) (c)

(ii) (c)

Reason: As voltage is not proportional to the current.

(iii) (a)

(iv) (c)

LONG ANSWER QUESTIONS

1. (a) 1.15 mA, (b) 0 mA as the diode is in reverse bias, (c) 1 mA, 0.3 mV

2. (c) I_1= 0.05 A, I_2= 0.025 A, I_3= 0 A, I_4= 0.025 A

3. (a) n-region:

Donor concentration (N_D) = $1 \times 10^{-6} \times 5 \times 10^{28} = 5 \times 10^{22}$ m^{-3}
Majority carriers (electrons): $n_n \approx N_D = 5 \times 10^{22}$ m^{-3}
Minority carriers (holes): $p_n = n_i^2 / n_n = (1.5 \times 10^{16})^2 / 5 \times 10^{22} = 4.5 \times 10^9$ m^{-3}

p-region:

Acceptor concentration (N_A) = $2 \times 10^{-4} \times 5 \times 10^{28} = 1 \times 10^{25}$ m^{-3}
Majority carriers (holes): $p_p \approx N_A = 1 \times 10^{25}$ m^{-3}
Minority carriers (electrons): $n_p = n_i^2 / p_p = (1.5 \times 10^{16})^2 / 1 \times 10^{25} = 2.25 \times 10^7$ m^{-3}

(b) Contribution to Reverse Saturation Current:

In reverse bias, minority carriers contribute to the reverse saturation current.
From n-side: minority holes = 4.5×10^9 m^{-3}
From p-side: minority electrons = 2.25×10^7 m^{-3}
Since minority hole concentration in the n-region is much higher than minority electron concentration in the p-region, the reverse saturation current is primarily due to minority holes from the n-region.

(c) The part of the waveform which is above 5V will be in the output as the diode will be forward biased only if the p-side of it is above 5V.

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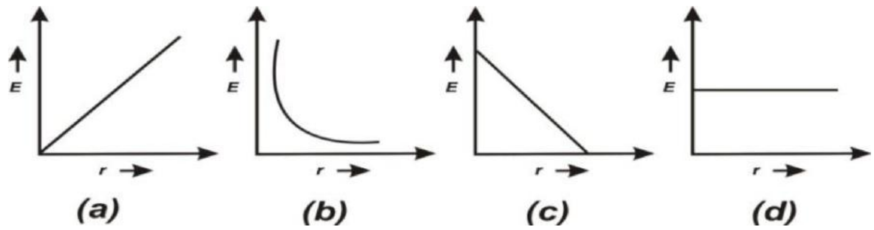
WORK SHEETS

WORK SHEET-1 ELECTRIC CHARGE AND FIELD

Q1. For a point charge, the graph between electric field versus distance is given by : -



Q2. In the process of charging, the mass of the negatively charged body-

(a) Increases (b) Decreases (c) Remains Constant (d) None of the above

Q3. Charge Q is kept in a sphere of 5 cm first than it is kept in a cube of side 5 cm. the outgoing flux will be-

(a) More in case of sphere (b) More in case of cube

(c) Same in both case (d) Information Incomplete

Q4. Four charges + 8Q, - 3Q +5Q and -10Q are kept inside a closed surface. What will be the outgoing flux through the surface.

(a) 26 V-m (b) 0 V-m (c) 10 V-m (d) 8 V-m

Q5. **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.**

Assertion(A): The total amount of charge on a body equal to $4X10^{-19}$ C is not possible.

Reason(R): Experimentally it is established that all free charges are integral multiples of a basic unit of charge denoted by *e*. Thus, charge *q* on a body is always given by $q = ne$

Q6. Define electric dipole moment. Is it scalar or a vector quantity? What is its SI unit?

Q7. Derive an expression for the torque experienced by an electric dipole kept in a uniformelectric field

Q8. Write the expression for the work done on an electric dipole of dipole moment p in turning it from its position of stable equilibrium to a position of unstable equilibrium in a uniform electric

Q9. (a) What is the electric flux through a cube of side 1 cm which encloses an electric dipole?

(b) How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased?

Q10. Show on a plot the nature of variation of the Electric field (E) and potential (V), of a (small) electric dipole with the distance (r) of the field point from the centre of the dipole.

Q11. Given a uniform electric field $\vec{E} = 2 \times 10^3 \hat{\imath}$N/ C, find the flux of this field through a square of side 20 cm, whose plane is parallel to the y-z plane. What would be the flux through the same square, if the plane makes an angle of 30° with the x-axis?

Q12. Derive an expression for the electric field at a point on the axis of an electric dipole of dipole moment $\vec{p}$

Q13. Derive the expression for the electric field at a point on the equatorial line of an electric dipole

Q14. An electric dipole is placed in a uniform electric field $\vec{E}$ with its dipole moment $\vec{p}$ parallel tfield. Find

(i) the work done in turning the dipole till its dipole moment points in the direction opposite to $\vec{E}$.

(ii) the orientation of the dipole for which the torque acting on it becomes maximum.

Q15. A thin straight infinitely long conducting wire having charge density λ is enclosed by a cylindrical surface of radius r and length l, its axis coinciding with the length of the wire. Find the expression for the electric field through the surface of the cylinder

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Q16. Using Gauss's law, prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of the distance from it. How is the field directed if (i) the sheet is positively charged, (ii) negatively charged?

WORKSHEET 2 ELECTROSTATIC POTENTIAL AND CAPACITANCE

1. The capacitors of capacitance 4 F, 6 F and 12 F are connected first in series and then in parallel. What is the ratio of equivalent capacitance in the two cases? 1

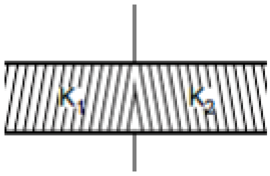
(a) 2 : 3 (b) 11 : 1 (c) 1 : 11 (d) 1 : 3 Ans: (c) 1 : 11

ANS ……………………………..

2. A charge Q is located at the centre of a circle of radius r. The work done in moving a test charge q0 from point A to point B (at opposite ends of diameter AB) so as to complete a semicircle is K=1 / $\pi\varepsilon_0$(a) Kq_0 Q / r (b) Kq_0 Q / 2R (c) kq0Q/3r (d) Zero 1

ANS…………………………………..

3. . A parallel plate capacitor with air as medium between the plates has a capacitance of 10 µF. The area of capacitor is divided into two equal halves and filled with two media having dielectric constant k1 = 2 and k2 = 4 as shown in the figure. The capacitance of the system will now be 1



(a) 10 µF (b) 20 µF (c) 30 µF (d) 40 µF

ANS ……………………………………………..

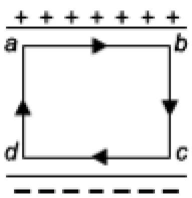
4. Assertion (A): Work done in moving a charge around a closed path, in an electric field is always zero. Reason (R): Electrostatic force is a conservative force 1

ANS……………………………………………………………….

5. . A charge Q is given to three capacitors C1, C2 and C3 connected in parallel. Determine the charge on each. 3

ANS………………………………………..

6. (a) The electric field inside a parallel plate capacitor is E. Find the amount of work done in moving a charge q over a closed rectangular loop a b c d a. 2



ANS
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7.(A)Derive an expression for capacitance pf parallel plate capacitor. 2

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(B) of 24μC is given to a hollow metallic sphere of radius 0.2 m. find the potential (3)

a. At the surface of the sphere

b. At a distance 0.1cm from the centre of the sphere

c. At the centre of the sphere.

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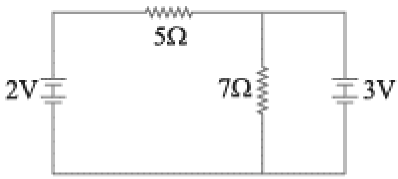
WORKSHEET-3 CURRENT ELECTRICITY

1. Two resistance 5Ω and 7Ω are joined as shown to two batteries of emf 2V and 3V. If the 3V battery is short circuited. What will be the current through 5Ω.



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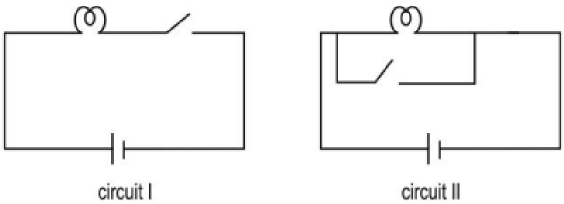
2. The image below shows two circuits (I and II) consisting of a battery, a bulb, and a switch.



(a) What is the difference in the working of the bulb in the two circuits when the switch is opened and closed? (b) Which circuit is preferred and why?

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3. What is the momentum acquired by the electrons in a wire of length l meter when a current i starts flowing in wire? Where m = mass of electron, e = charge of electron.

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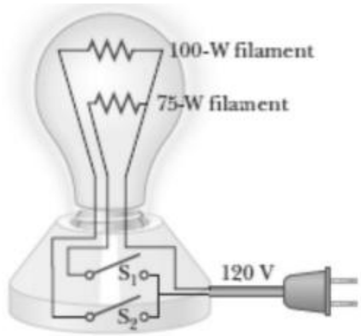
4. The image below shows a three-way bulb that can glow at three different brightness. The bulb is rated to operate at 120 V power supply.



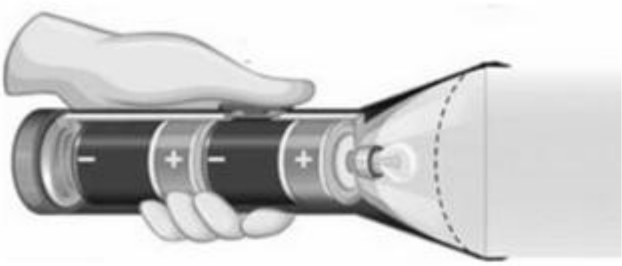
Determine how the bulb can have three different brightnesses. Determine the total current through the circuit which causes the bulb to glow in each of the three cases.

5. A current is maintained in a conductor of cross-section 10^{-4} m^2. If the number density of free electrons be 9 x 10^{28} $m^{-3}$and the drift velocity of free electrons be 6.94 x10^{-9} m/s, calculate the current in the conductor.

6.The resistance of a tungsten filament at 1500C is 133 Ω. What will be its resistance at 500^0C? Given the temperature coefficient of tungsten is 0.0045/0C.

WORKSHEET 4 CURRENT ELECTRICITY

1.A flashlight uses two batteries, each of emf 2 V and internal resistance 0.1 ohm, in series. The flashlight bulb has a resistance of 10 ohm.



(a) What is the current drawn by the flashlight bulb?

(b) How much power is dissipated through the flashlight bulb?

(c) If the two batteries have zero internal resistances, will the power dissipated through the flashlight bulb be more or less? Calculate the difference.

2.A battery of emf 2V and internal resistance 0.1Ω is being charged by a current of 5A. What will be the direction of current inside the battery? What is the potential difference between the terminals of the battery?

3.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 of electrons and (ii) resistance of the conductor be affected? Justify your answer.

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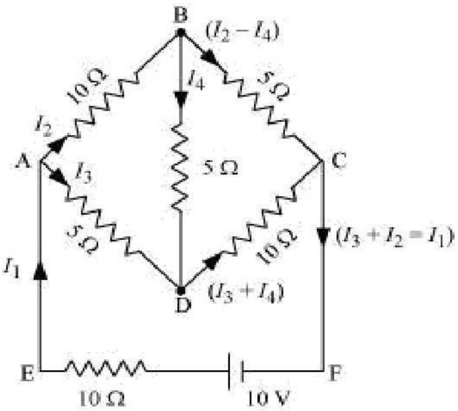
4. You are given several identical resistances each of value R = 10 ohm and each capable of carrying a maximum current of one ampere. It is required to make a suitable combination of these resistances so as to have a resistance of 5 ohm capable of carrying a current of 4 ampere. Find the minimum number of resistances of the type R that will be required for the job.

5.Determine the current in each branch of the network shown in fig



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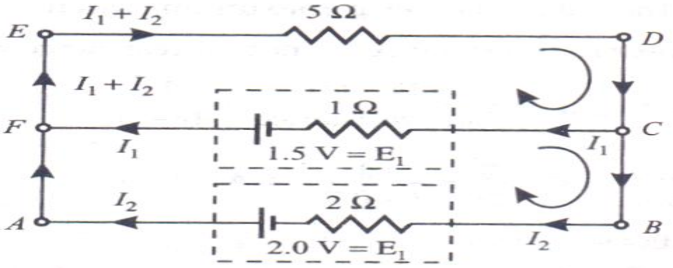
6. Two cells of emf 1.5 V and 2V and internal resistance 1 Ω and 2 Ω are connected in parallel to pass a current in the same direction through an external resistance of 5 Ω. (a) Draw Circuit Diagram. (b) Using Kirchhoff's laws, calculate the current through each branch of the circuit and p.d. across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



WORK SHEET -5 MOVING CHARGES AND MAGNETISM

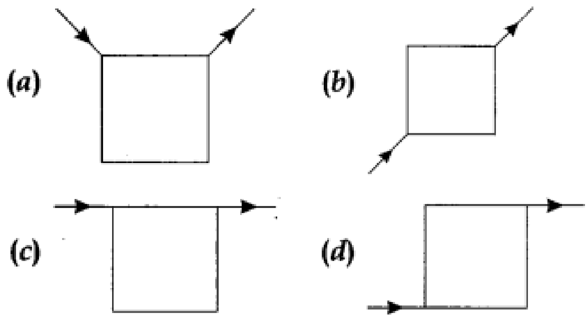
Note: Question number 1 to 4 carry 1 mark each, 5-6 carry 2 marks each, 7 carry 3 marks, 8 carry 4 marks and 9 carry 5 marks.

1. A long straight wire of circular cross section of radius *a* carries a steady current *I*. The current is uniformly distributed across its cross section. The ratio of magnitudes of the magnetic field at a point a/2 above the surface of wire to that of a point *a*/2 below its surface is

(A) 4:1 (B) 1:1 (C) 4:3 (D) 3:4

Ans:

2. Current flows through uniform, square frames as shown in the figure. In which case is the magnetic field at the centre of the frame not zero?



Ans:

3. If resistance of a galvanometer is 6 Ω and it can measure a maximum current of 2 A. Then required shunt resistance to convert it into an ammeter reading up to 6 A, will be

(a) 2 Ω (b) 3 Ω (c) 4 Ω (d)5 Ω

Ans:

4. Assertion (A): The deflection of a magnetic needle in Oersted's experiment can be increased by placing it closer to the wire.

Reason (R): The magnetic field around a current-carrying straight conductor decreases inversely with the distance.

(e) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(f) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

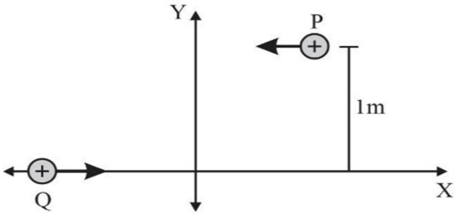
(g) Assertion (A) is true, but Reason (R) is false.

(h) Assertion (A) is false and Reason (R) is also false.

Ans:

5. P and Q are two identical charged particles each of mass 4 × 10–26 kg and charge 4.8 × 10–19 C, each moving with the same speed of 2.4 × 105 m/s as shown in the figure. The two particles are equidistant (0.5

m) from the vertical Y -axis. At some instant, a magnetic field B is switched on so that the two particles undergo head-on collision.



Find – (a) the direction of the magnetic field and (b) the magnitude of the magnetic field applied in the region.

Ans:

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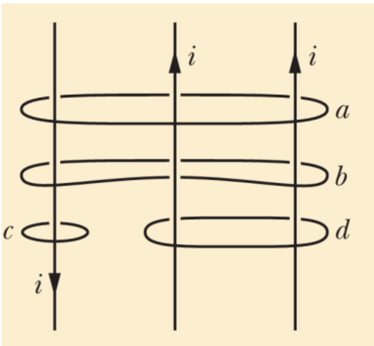
6. The figure shows three equal currents *i* (two parallel and one antiparallel) and four Amperian loops. Rank the loops according to the magnitude of $\oint \vec{B}\cdot d\vec{l}$ in decreasing order.



Ans:

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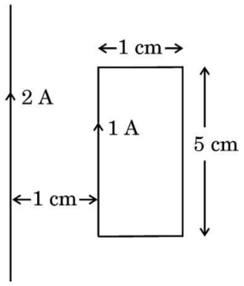
7. A rectangular loop carries a current of 1 A. A straight long wire carrying 2 A current is kept near the loop in the same plane as shown in the figure



Find

(c) the torque acting on the loop, and

(d) the magnitude and direction of the net force on the loop.

Ans:

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8. An electron with speed $v_o << c$ moves in a circle of radius r_o in a uniform magnetic field. This electron is able to traverse a circular path as the magnetic force acting on the electron is perpendicular to both v_o and B, as shown in the figure. This force continuously deflects the particle sideways without changing its speed and the particle will move along a circle perpendicular to the field. The time required for one revolution of the electron is T_o.

(i) If the speed of the electron is now doubled to $2v_o$. The radius of the circle will change to

(A) $4r_0$ (B) $2r_0$ (C) r_0 (D) $r_0/2$

(ii) If $v = 2v_o$, then the time required for one revolution of the electron (To) will change to

(A) $4T_0$ (B) $2T_0$ (C) T_0 (D) $T_0/2$

(iii) An alpha particle is projected with velocity $\vec{v} = \left(3\times10^5 \text{ m/s}\right)\hat{i}$ into a region in which magnetic field $\vec{B} = \left[\left(0.4 \text{ T}\right)\hat{i} + \left(0.3 \text{ T}\right)\hat{j}\right]$ exists. Calculate the acceleration $\vec{a}$ of the particle in the region.

Take the charge to mass ratio for alpha particle 5x107C/kg

(A) 2.5×10^{12} m/s^2 (B) 4×10^{12} m/s^2 (C) 4.5×10^{12} m/s^2 (D) 6×10^{12} m/s^2

(iv) If the given electron has a velocity not perpendicular to B, then trajectory of the electron is

(A) straight line (B) circular (C) helical (D) zig-zag

OR

(v) If an electric field is switched on parallel to magnetic field, what happens to the pitch of the helical path?

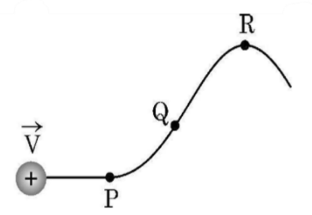
(A) It increases linearly with time

(B) It remains constant, independent of E

(C) It becomes zero as particle slows down

(D) It becomes infinite because path straightens out

9. (i) A proton moving with velocity $\vec{v}$ in a non-uniform magnetic field traces a path as shown the figure. The path followed by the proton is always in the plane of the paper. What is the direction of the magnetic field in the region near P, Q and R? Also, arrange the magnetic fields in decreasing order of their magnitudes.



(ii) A current carrying circular loop of area A produces a magnetic field B at its center. Show that the magnetic moment of the loop is $\frac{2BA}{\mu_0}\sqrt{\frac{A}{\pi}}$.

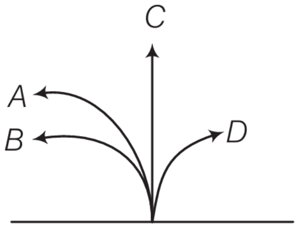
WORK SHEET -6 MOVING CHARGES AND MAGNETISM

Note: Question number 1 to 5 carry 1 mark each, 6-7 carry 2 marks each, 7-8 carry 3 marks, and 9 carry 5 marks.

1. A long wire carrying a steady current is bent into a circular loop of one turn. The magnetic field at the centre of the loop is B. It is then bent into a circular coil of n turns. The magnetic field at the centre of this coil of n turns will be:

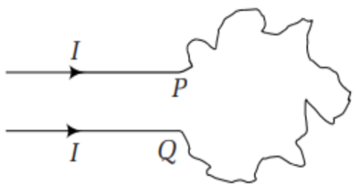
(a) nB (b) n^2B (c) $2nB$ (d) $2n^2B$

2. A neutron, a proton, an electron, and an α-particle enter a region of uniform magnetic field with the same velocities. The magnetic field is perpendicular and directed into the plane of the paper. The tracks of the particles are labelled in the figure. The proton follows the track



(a) D (b) C (c) B (d) A

3. Assertion (A): A wire bent into an irregular shape with the points P and Q fixed. If a current I is passed through the wire, then the area enclosed by the irregular potion of the wire increases.



Reason (R): Opposite current carrying wires attract each other.

4. A proton moving with a constant velocity passes through a region of space without any change in its velocity. If E and B represent the electric and magnetic fields, respectively. Then, in this region of space which of these is not possible

(a) $E = 0, B = 0$ (b) $E = 0, B \neq 0$ (c) $E \neq 0, B = 0$ (d) $E \neq 0, B \neq 0$

5. If an electron is moving with velocity v produces a magnetic field B then-

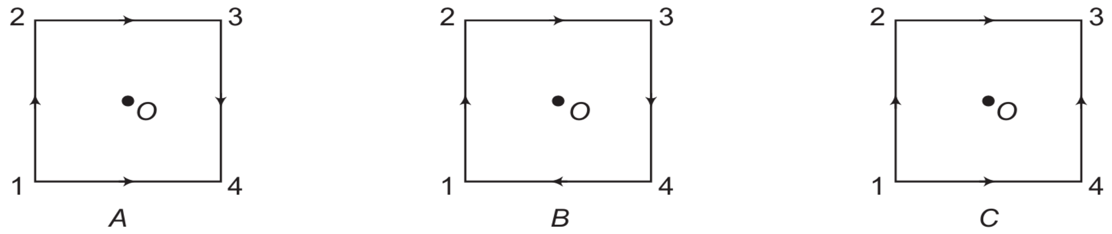
(a) the direction of field B will be same as the direction of velocity v.

(b) the direction of field B will be opposite to the direction of velocity v.

(c) the direction of field B will be perpendicular to the direction of velocity v.

(d) the direction of field B does not depend upon the direction of velocity v

6. The figure shows three identical current-carrying square loops A, B, C. Current in each wire is I. Rank the loops in decreasing order of magnitude of magnetic field at the center of each loop.



Ans:

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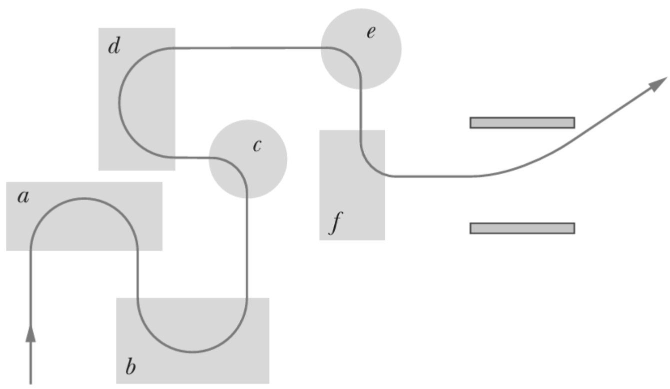
7. Figure shows the path of a particle through six regions of uniform magnetic field, where the path is either a half-circle or a quarter-circle. Upon leaving the last region, the particle travels between two charged, parallel plates and is deflected toward the plate of higher potential.

(i) What is the nature of charge of particle?

(ii) What is the direction of the magnetic field in regions ***b*** and ***f***.



Ans:

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8. (i) In a certain region of space, electric field $\vec{E}$ and magnetic field $\vec{B}$ are perpendicular to each other. An electron enters in the region perpendicular to the directions of both $\vec{B}$ and $\vec{E}$, and moves undeflected. Find the velocity of the electron.

(ii) If the electric field is switched off, what sort of motion would the electron undergo. What if the magnetic field is switched off?

Ans:

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9. A moving coil galvanometer has 50 turns and each turn has an area 2×10^{-4} m^2. The magnetic field produced by the magnet inside the galvanometer is 0.02 T. The torsional constant of the suspension wire is 10^{-4} N m rad^{-1}. When a current flows through the galvanometer, a full-scale deflection occurs if the coil rotates by 0.2 rad. The resistance of the coil of the galvanometer is 50 Ω. This galvanometer is to be converted into an ammeter capable of measuring current in the range 0–10 A. For this purpose, a shunt resistance is to be added in parallel to the galvanometer. Find the value of this shunt resistance, in ohms.

Ans:

10. Three particles are projected into identical magnetic fields as per following data:

Particle	Proton	Deuteron	Alpha particle
Speed of projection	10^6 m/s	10^6 m/s	10^6 m/s
Angle between v and B	30°	90°	60°
Charge q	e	e	2e
Mass M	m	2m	4m

Answer the following. Show the working in each case.

(d) Which of the particles will revolve along the circular paths with minimum angular frequency?

(e) Identify the particle/s that will follow circular path.

(f) Which particle/s revolves around the curved path of maximum radius?

Ans:

WORK SHEET -7 MAGNETISM AND MATTER

1 mark questions

1. A bar magnet having a magnetic moment of 2×10^4 J T^{-1} is free to rotate in a horizontal plane. A horizontal magnetic field $B = 6 \times 10^{-4}$ T exists in the space. The work done in taking the magnet slowly from a direction parallel to the field to a direction 60° from the field is

(*a*) 12 J (*b*) 6 J (*c*) 2 J (*d*) 0.6 J

2. A short bar magnet placed with its axis at 30° to a uniform magnetic field experiences a torque of 0.04 Nm. If its magnetic moment is 0.2 A·m^2, find the magnetic field.

(a) 1 T (b) 0.4 T (c) 1.15 T (d) 1.0 T

3. The work done in rotating a magnetic dipole of moment M through 180° in a uniform magnetic field B is:

(a) MB (b) 2MB (c) Zero (d) MB/2

4. The magnetic moment of a current-carrying loop is proportional to:

a) Current and area of the loop b) Only the current

c) Only the area of the loop d) Neither current nor area

5. A bar magnet of magnetic moment 6 J/T is aligned at 60° with a uniform external magnetic field of 0·44 T. Work done in turning the magnet to align its magnetic moment normal to the magnetic field is

(a) 1.32 J (b) 2.64 J (c) 0.65 J (d) none of these

2 marks questions

6. What happens if a bar magnet is cut into two pieces: (i) transverse to its length, (ii) along its length?

Ans:

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7. A short bar magnet of magnetic moment M , 0.32J / T is placed in a uniform magnetic field of 0.15T . If the bar is free to rotate in the plane of the field, which orientation and would correspond to its a) Stable equilibrium? What is the potential energy of the magnet in this case?

Ans:

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8. A closely wound solenoid of 2000 turns and area of cross-section 1.6×10^{-4} m^2, carrying a current of 4.0A , is suspended through its centre allowing it to turn in a horizontal plane.

a) What is the magnetic moment associated with the solenoid?

b) What is the force and torque on the solenoid if a uniform horizontal magnetic field of 7.5×10^{-2} T is set up at an angle of 30° with the axis of the solenoid?

Ans:

<u>3 marks questions:</u>

9. A short bar magnet of magnetic moment 5.25×10^{-2} J / T is placed with its axis perpendicular to the earth's field direction. Magnitude of the earth's field at the place is given to be 0.42G . Ignore the length of the magnet in comparison to the distances involved. At what distance from the centre of the magnet, the resultant field is inclined at 45° with earth's field on (a) its normal bisector and (b) its axis

Ans.:

10. What happens when a bar magnet is:

a) Heated beyond Curie temperature?

b) Broken into two halves?

c) Placed in a uniform magnetic field with its axis perpendicular to the field?

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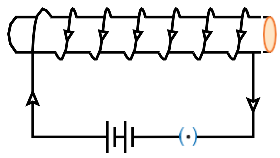
11. Draw the magnetic field lines for a current carrying solenoid when a rod made of (*a*) copper, (*b*) aluminium and (*c*) iron are inserted within the solenoid as shown



Ans:

WORK SHEET -8 ELECTRO MAGNETIC INDUCTION

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. 9 is of 05 marks.

1. A solenoid is connected to a battery so that a steady current flows through it. If an iron core is inserted into the solenoid, the current will

(a) increase (b) decrease

(c) remain same (d) first increase then decrease

Ans:

2. Energy in a current carrying coil is stored in the form of

(a) Electric field (b) magnetic field (c) dielectric strength (d) heat

Ans:

3. A 100 mH coil carries a current of 1 A energy stored in its magnetic field is

(a) 0.5 J (b) 1 J (c) 0.05 J (d) 0.1 J

Ans:

4. ASSERTION: Magnetic flux is given by) = L i = (product of the self-inductance and current).

REASON: When current is increased; self-inductance increases.

(a) Both assertion and reason are correct and the reason is the correct explanation of assertion.

(b) Both assertion and reason are correct and reason is not a correct explanation of assertion.

(c) Assertion is correct but the reason is incorrect

(d) Assertion is incorrect but the reason is correct.

Ans:

5. A wire in the form of a tightly wound solenoid is connected to a DC source, and carries a current. If the coil is stretched so that there are gaps between successive elements of the spiral coil, will the current increase or decrease? Explain.

Ans:

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6. Two identical loops, one of copper and the other of Aluminium, are rotated with the same angular speed in the same magnetic field. Compare

(i) the induced emf and (ii) the current produced in the two coils. Justify your answer.

Ans:

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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:

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8. Electromagnetic induction is defined as the production of an electromotive force across an electric conductor in the changing magnetic field. The discovery of induction was done by Michael Faraday in the year 1831. Electromagnetic induction finds many applications such as in electrical components which includes transformers, inductors, and other devices such as electric motors and generators. An inductor is a passive component that is used in most power electronic circuits to store energy in the form of magnetic energy when electricity is applied to it. When a current begins to flow through a coil of wire, it undergoes an opposition to its flow in addition to the resistance of the metal wire. On the other hand, when an electric circuit carrying a steady current and containing a coil is suddenly opened, the collapsing, and hence diminishing, magnetic field causes an induced electromotive force that tends to maintain the current and the magnetic field and may cause a spark between the contacts of the switch.

(i) How to increase the energy stored in an inductor by four times?

(a) By doubling the current (b) This is not possible

(c) By doubling the inductance (d) By making current $\sqrt{2}$ times

Ans:

(ii) Consider an inductor whose linear dimensions are tripled and the total number of turns per unit length is kept constant, what happens to the self-inductance?

(a) 9 times (b) 3 times (c) 27 times (d) 13 times

Ans:

(iii) What will be the acceleration of the falling bar magnet which passes through the ring such that the ring is held horizontally and the bar magnet is dropped along the axis of the ring?

(a) It depends on the diameter of the ring and the length of the magnet

(b) It is equal to acceleration due to gravity

(c) It is less than acceleration due to gravity

(d) It is more than acceleration due to gravity

Ans:

(iv) Which of the following statements is correct for a current carrying infinitely long wire kept along the diameter of a circular wire loop without touching it.

(a) The emf induced in the loop is zero if the current is constant

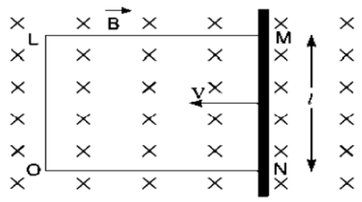
(b) The emf induced in the loop is finite if the current is constant

(c) The emf induced in the loop is finite if the current decreases at a steady rate

(d) The emf induced in the loop is finite if the current increases at a steady rate.

Ans:

9. (a) State Faraday's law of electromagnetic induction. (b) Figure shows 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.



Ans:

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WORK SHEET -9 ELECTRO MAGNETIC INDUCTION

Note: Question No. 1-4 is of 01 mark each, 5-6 is of 02 marks each, 7 is of 03 marks, 8 is a case study based and is of 04 marks, and 9 is of 05 marks.

1. A coil having 500 sq. loops of side 10 cm is placed normal to magnetic flux which increases at a rate of 1 T/s. The induced emf is

   (a) 0.1V (b) 0.5V (c) 1 V (d) 5 V

   Ans:

2. The current flows from A to B is as shown in the figure. The direction of the induced current in the loop is

   (a) clockwise. (b) anticlockwise. (c) straight line (d) no induced e.m.f. produce

   Ans:

3. A coil of wire of certain radius has 600 turns and a self inductance of 108 mH. The self inductance of a similar coil of 500 turns will be

   (a) 74 mH (b) 75 mH (c) 76 mH (d) 77 mH

   Ans:

4. ASSERTION: When the magnetic flux through a loop is maximum, induced emf is maximum.

   REASON: When the magnetic flux through a loop is minimum, induced emf is minimum.

   (a) Both assertion and reason are correct and the reason is the correct explanation of assertion.

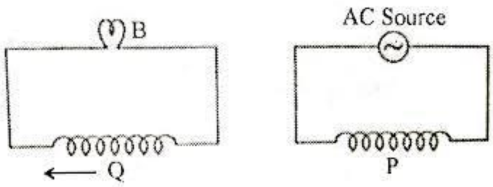
   (b) Both assertion and reason are correct and reason is not a correct explanation of assertion.

   (c) Assertion is correct but the reason is incorrect

   (d) Assertion is incorrect but the reason is correct.

   Ans:

5. A coil Q is connected to low voltage bulb B and placed near another coil P as shown in the figure. Give reasons to explain the following observations:



   (i) The bulb 'B' lights (ii) Bulb gets dimmer if the coil Q is moved towards left.

   Ans:

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6. The flux linked with a large circular coil of radius *R* is 0.5 x 10^{-3} Wb. When a current of 0.5 A flows through a small neighboring coil of radius *r* calculate the coefficient of mutual inductance for the given pair of coils. If the current through the small coil suddenly falls to zero what would be its effect in the larger coil?

Ans:

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7. (i) State faraday's law of electromagnetic induction. (ii) A jet plane is travelling towards west at a speed of 1800 km/h. what is the voltage difference developed between the ends of the wing having a span of 25m if the earth's magnetic field at the location has magnitude of 5x10^{-4} T and the dip angle is 30°?

Ans:

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8. Currents can be induced not only in conducting coils, but also in conducting sheets or blocks. Current is induced in solid metallic masses when the magnetic flux threading through them changes. Such currents flow in the form of irregularly shaped loops throughout the body of the metal. These currents look like eddies or whirlpools in water so they are known as eddy currents. Eddy currents have both undesirable effects and practically useful applications. For example, it causes unnecessary heating and wastage of power in electric motors, dynamos and in the cores of transformers.

(I) The working of speedometers of trains is based on

(a) wattless currents (b) eddy currents (c) alternating currents (d) pulsating currents

Ans:

(ii) Identify the wrong statement

(a) Eddy currents are produced in a steady magnetic field

(b) Induction furnace uses eddy currents to produce heat.

(c) Eddy currents can be used to produce braking force in moving trains

(d) Power meters work on the principle of eddy currents.

Ans:

(iii) Which of the following is the best method to reduce eddy currents?

(a) Laminating core (b) Using thick wires (c) By reducing hysteresis loss (d) None of these

Ans:

(iv) The direction of eddy currents is given by

(a) Fleming's left-hand rule (b) Biot-Savart law (c) Lenz's law (d) Ampere-circuital law

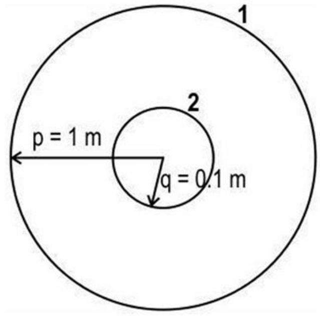
Ans:

(v) Eddy currents can be used to heat localized tissues of the human body. This branch of medical therapy is called

(a) Hyperthermia (b) Diathermy (c) Inductothermy (d) none of these

Ans:

9. Given two coplanar and concentric loops 1 and 2 as shown. A time-varying voltage $(6 + 2t)$ is applied to the larger loop 1. If the resistance of the loops is $R_1 = 10$ ohm and $R_2 = 1$ ohm , then determine the current induced in the smaller loop.



(ii) The current i in an induction coil varies with time t according to the graph shown. Sketch the variation of emf in the coil with time.

Ans:

WORK SHEET 10 - ALTERNATING CURRENT

Q.1 An alternating voltage V(t) = 220 sin100πt volts is applied to a purely resistive load of 50 Ω. The time taken for the current to rise from half of the peak value is

(a) 5 ms (b) 2.2 ms (c) 7.2 ms (d) 3.3 ms

ANS…………………………..

Q.2 An arc lamp requires a direct current of 10A at 80V to function. If it is connected to a 220V (RMS), 50 Hz AC supply, the series inductor needed for it to work is close to

(a) 0.065 H (b) 80 H (c) 0.08 H (d) 0.044 H

ANS………………………

Q.3 In a series, LCR circuit R = 200Ω and the voltage and the frequency of the main supply is 220 V and 50 Hz respectively. On taking out the capacitance from the circuit the current lags behind the voltage by 30^0. The power dissipated in the LCR circuit is

(a) 242 W (b) 305 W (c) 210 W (d) Zero

ANS…………………….

Q.4 A series AC circuit containing an inductor (20 mH), a capacitor (120 μF) and a resistor (60 Ω) is driven by an AC source of 24 V/50 Hz. The energy dissipated in the circuit in 60 s is

(a) 3.39×10^3 J (b) 5.65×10^2 J (c) 2.26×10^3 J (d) 5.17×10^2 J

ANS…………

Q.5 In an AC generator, a coil with N turns, all of the same area A and total resistance R, rotates with frequency ω in a magnetic field B. The maximum value of emf generated in the coil is

(a) NAB (b) NABR (c) NABω (d) NABRc

ANS……………..

Q.6 A light bulb is rated 150 W for 220 V ac supply of 60 Hz. Calculate

(i) the resistance of the bulb; ,

(ii) the rms current through the bulb.

ANS…………………………………………………………………………………………………
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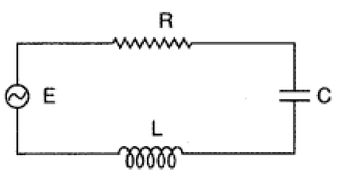
Q.7 The figure shows a series LCR circuit connected to a variable frequency 250 V source with L = 40 mH, C = 100 μF and R = 50 Ω. Determine the source frequency which derives the circuit in resonance.



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Q.10 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?

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Q.11 An ac generator is made up of two fixed pole pieces and a coil with 50 turns and a surface area of 2.5 m^2 that rotates in a uniform magnetic field B = 0.2 tesla at an angle of 60 $rads^{-1}$. The circuit's resistance, including the resistance of the coil, is 500 ohms. Determine the generator's maximum current draw.

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WORK SHEET 11 - ALTERNATING CURRENT

Q.1 A circuit connected to an ac source of emf $e = e_0 \sin(100\ t)$ with t in seconds, gives a phase difference of $\pi/4$ between the emf e and current I. Which of the following circuits will exhibit this?

(a) RC circuit with R = 1 kΩ and C = 10Mf (b) RL circuit with R = 1 kΩ and L = 10mH

(c) RC circuit with R = 1 kΩ and C = 1μF (d) RL circuit with R = 1 kΩ and L = 1mH

ANS………….

Q.2 Alternating current cannot be measured by D.C ammeter because

(a) A.C cannot pass through D.C ammeter (b) A.C changes direction

(c) The average value of current for the complete cycle is zero (d) D.C. ammeter will get damaged

ANS…………..

Q.3 An alternating voltage $V(t) = 220 \sin 100\pi t$ volts is applied to a purely resistive load of 50 Ω. The time taken for the current to rise from half of the peak value is

(a) 5 ms (b) 2.2 ms (c) 7.2 ms (d) 3.3 ms

ANS……….

Q.4 In a series, LCR circuit R = 200Ω and the voltage and the frequency of the main supply is 220 V and 50 Hz respectively. On taking out the capacitance from the circuit the current lags behind the voltage by 30^0. The power dissipated in the LCR circuit is

(a) 242 W (b) 305 W (c) 210 W (d) Zero

ANS……….

Q.5 The phase difference between the alternating current and emf is $\pi/2$. Which of the following cannot be the constituent of the circuit?

(a) LC (b) L alone (c) C alone (d) R, L

ANS…….

Q.6 An alternating voltage given by $V = 140 \sin 314\ t$ is connected across a pure resistor of 50 Ω. Find

(i) the frequency of the source.

(ii) the rms current through the resistor.

ANS……………………………………………………………………………………………………

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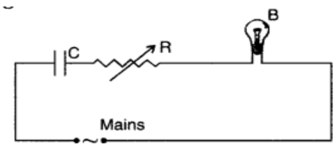
Q.7 A capacitor 'C', a variable resistor 'R' and a bulb 'B' are connected in series to the ac mains in a circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if

(i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same;

(ii) the resistance R is increased keeping the same capacitance?



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Q.8 A coil of inductance 0.50 H and resistance 100 Ω is connected to a 240 V, 50 Hz ac supply.

(a) What is the maximum current in the coil?

(b) What is the time lag between the voltage maximum and the current maximum?

ANS……

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Q.9 A power transmission line feeds input power at 2300 V to a step-down transformer, with its primary windings having 4000 turns. What should be the number of turns in the secondary in order to get output power at 230 V?

ANS……

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Q.10 The secondary transformer, whose primary draw line voltage is wired to a 60 W load. What is the primary coil's current if the load has a 0.54 A current flow? Describe the kind of transformer that is being used.

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WORKSHEET-12 E M WAVE

1. The wavelength of a microwave of frequency 3×10^9 Hz in vacuum is:

A) 0.1 m B) 0.3 m C) 3 m D) 30 m

2. The energy of a photon of frequency 6×10^{14} Hz is (Planck's constant $h = 6.63 \times 10^{-34}$ Js):

A) 3.98×10^{-19} J B) 4.23×10^{-19} J C) 3.5×10^{-19} J D) 5.2×10^{-19} J

3. Assertion (A): Gamma rays have the highest energy in the electromagnetic spectrum.

Reason (R): Gamma rays have the highest frequency among EM waves.

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, but R is true.

Assertion (A): Electromagnetic waves can propagate in vacuum.

Reason (R): EM waves are mechanical waves and need a medium to travel.

4.Calculate the speed of an electromagnetic wave in a medium with permittivity $\varepsilon = 4\varepsilon_0$ and permeability $\mu = \mu_0$.

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5.A radio station broadcasts waves of frequency 100 MHz. What is the wavelength of the wave in free space?

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6. Derive the expression for the speed of electromagnetic waves in vacuum using Maxwell's equations.

Also, calculate the speed using $\varepsilon_0 = 8.85 \times 10^{-12}$ C²/N•m² and $\mu_0 = 4\pi \times 10^{-7}$ T•m/A.

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8. An EM wave is propagating in a medium with electric field given by $E = 3 \sin(1.5 \times 10^7 t + 0.05x)$ V/m.

Find:

a) The frequency of the wave b) Wavelength c) Magnetic field amplitude (Assume $c = 3 \times 10^8$ m/s)

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WORKSHEET-13 RAY OPTICS AND OPTICAL INSTRUMENT

1.Which of the following actions will lead to an increase in the magnifying power of an astronomical telescope?

A. Increase in the length of the telescope tube.

B. Interchange the objective and the eyepiece of the telescope.

C. A small piece of paper on the objective of the telescope pointed towards the moon.

D. Increase in the focal length of the objective and decrease in the focal length of the eye piece.

Ans

2.A ray of light of wavelength 600 nm propagates from air into a medium. If its wavelength in the medium becomes 400 nm, the refractive index of the medium is

(a) 1.4 (b) 1.6 (c) 1.5 (d) 1.8

Ans

3.An object approaches a convergent lens from the left of the lens with a uniform speed 5 m/s and stop at the focus. The image

a. move away from the lens with a uniform speed 5 m/s

b. move away from the lens with a uniform acceleration

c. move away from the lens with a non uniform acceleration

d. move towards the lens with a non uniform acceleration (1)

Ans

4.(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

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

(c) Assertion (A) is true and Reason (R) is false.

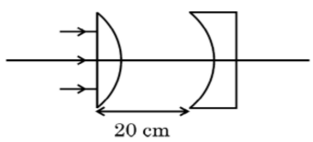
(d)Assertion (A) is false and Reason (R) is also false

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

Ans

5.In the given figure, the radius of curvature of curved face in the plano-convex and the plano-concave lens is 15 cm each. The refractive index of the material of the lenses is 1.5. Find the final position of the image formed. (2)



Ans

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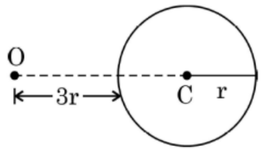
6(a)An object is placed in front of a converging lens. Obtain the conditions under which the magnification produced by the lens is (i) negative and (ii) positive.



(b)A point object is placed at 0 in front of a glass sphere as shown in figure. Show the formation of image by the sphere.

Ans-

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7.Case Study – Optical Instruments

Read the following paragraph and answer the questions.

A number of optical devices and instruments have been designed and developed such as periscope, binoculars, microscopes and telescopes utilising the reflecting and refracting properties of mirrors, lenses and prisms. Most of them are in common use. Our knowledge about the formation of images by the mirrors and lenses is the basic requirement for understanding the working of these devices.

i. Why the image formed at infinity is often considered most suitable for viewing. Explain

ii. In modern microscopes, multicomponent lenses are used for both the objective and the eyepiece. Why?

iii. Write two points of difference between a compound microscope and an astronomical telescope

iv.Write two distinct advantages of a reflecting type telescope over a refracting type telescope. (4)

Ans-

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8.(i) Explain with the help of a labelle d ray diagram the formation of final image by an astronomical telescope at infinity. Write the expression for its magnifying power.

(ii) The total magnification produced by a compound microscope is 20. The magnification produced by the eyepiece is 5. When the microscope is focussed on a certain object, the distance between the objective and eyepiece is observed to be 14 cm. Calculate the focal lengths of the objective and the eyepiece. (Given that the least distance of distinct vision = 25 cm) (5)

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WORKSHEET-14 RAY OPTICS AND OPTICAL INSTRUMENT

1.A glass slab having refractive index n and thickness d is placed on the paper on table. A dot (drop) of ink is made on paper below glass slab. At how much height will the dot be found if it is observed from the upper side of slab?

(a) (n−1)d/n (b) (n+1)d/n (c)nd/(n−1) (d)nd/(n+1) (1)

Ans

2.The focal length of a concave mirror in air is f. When the mirror is immersed in a liquid of refractive index 5/3, its focal length will become

(a) 5f/3 (b) 3f/5 (c 2f/3 d. f (1)

Ans

3 (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

(b)Both Assertion (A) and Reason (R) are true and Reason (R) is NOT the correct explanation of Assertion (A).

(c) Assertion (A) is true and Reason (R) is false.

(d)Assertion (A) is false and Reason (R) is also false

Assertion: A ray of light travelling from a rarer medium to a denser medium slows down and bends away from the normal. When it travels from a denser medium to a rarer medium, it speeds up and bends towards the normal.

Reason: The speed of light is higher in a rarer medium than in a denser medium (1)

Ans

4. Use mirror to deduce that a convex mirror always produces a virtual image of an object kept in front of it. (2)

Ans ..

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5.A convex lens of focal length 10 cm, a concave lens of focal length 15 cm and a third lens of unknown focal length are placed coaxially in contact. If the focal length of the combination is +12 cm, find the nature and focal length of the third lens, if all lenses are thin. Will the answer change if the lenses were thick ? (3)

Ans

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6. Two convex lenses A and B, each of focal length 10.0 cm , are mounted on an optical bench at 50.0 cm and 70.0 cm respectively. An object is mounted at 20.0 cm . Find the nature and position of the final image formed by the combination. (3)

Ans

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7. Read the following paragraphs and answer the questions that follow.

When light travels from an optically denser medium to an optically rarer medium, at the interface it is partly reflected back into the same medium and partly refracted to the second medium. The angle of incidence corresponding to an angle of refraction $90^0$is called the critical angle (i_c) for the given pair of media. This angle is related to the refractive index of medium 1 with respect to medium 2.

Refraction of light through a prism involves refraction at two plane interfaces. A relation for the refractive index of the material of the prism can be obtained in terms of the refracting angle of the prism and the angle of minimum deviation. For a thin prism, this relation reduces to a simple equation.

Laws of refraction are also valid for refraction of light at a spherical interface. When an object is placed in front of a spherical surface separating two media, its image is formed. A relation between object and image distance, in terms of refractive indices of two media and the radius of curvature of the spherical surface can be obtained. Using this relation for two surfaces of a lens, lens maker formula is obtained.

(1) A small bulb is placed at the bottom of a tank containing a transparent liquid (refractive index n) to a depth H. The radius of the circular area of the surface of liquid, through which light from the bulb can emerge out, is R. Then (R/H) is:

(4)

(a) $1/(\sqrt{(n^2 - 1)})$ (b) $\sqrt{(n^2 - 1)}$ (c)$(\sqrt{(n^2 + 1)})$ (d) $\sqrt{(n^2 + 1)}$

2 (a) A parallel beam of light is incident on a face of a prism with refracting angle 60°. The angle of minimum deviation is found to be 30°. The refractive index of the material of the prism is close to:

(A) 1-3 (B) 1-4 (C) 1-5 (D) 1-6

OR

(b) The angle of minimum deviation for a ray of light incident on a thin prism, made of crown glass (n = 1.52) is Dm. If the prism was made of dense flint glass (n = 1.62) instead of crown glass, the angle of minimum deviation will:

(A) decrease by 4% (B) increase by 4% (C) decrease by 19% (D) increase by 19%

3. An object is placed in front of a convex spherical glass surface (n = 1-5 and radius of curvature R) at a distance of 4R from it. As the object is moved slowly close to the surface, the image formed is:

(A) always real (B) always virtual (C) first real and then virtual (D) first virtual and then real

4. A double-convex lens, made of glass of refractive index 1-5, has focal length 10 cm. The radius of curvature of its each face, is:

(A) 10 cm (B) 15 cm (C) 20 cm (D) 40 cm

8. A) Draw a labelled ray diagram showing the formation of image by a compound microscope in normal adjustment. Derive the expression for its magnifying power.

B) A compound microscope 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. How far from the objective, should an object be placed in order to obtain the final image at the least distance of distinct vision (25 cm)? What is the magnifying power of the microscope in? (5)

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WORKSHEET 15 WAVE OPTICS

1. Two waves are said to be coherent if they have.

   (a) same phase and different amplitude (b) different frequency phase and amplitude

   (c) same frequency but different amplitude (d) same frequency, phase and amplitude

2. A linear aperture whose width is 0.02 cm is placed immediately in front of a lens of focal length 60 cm. The aperture is illuminated normally by a parallel beam of wavelength5 × 10–5 cm. The distance of the first dark band of the diffraction pattern from the centre of the screen is

   (a) 0.10 cm (b) 0.25 cm (c) 0.20 cm (d) 0.15 cm

3. To observe diffraction, the size of the obstacle

   (a) should beX/2, where X is the wavelength (b) should be of the order of wavelength.

   (c) has no relation to wavelength. (d) should be much larger than the wavelength

4. Two slits in Young's double slit experiment have widths in the ratio 81:1. The ratio of the amplitudes of light waves is

   (a) 3 :1 (b) 3 : 2 (c) 9 :1 (d) 6:1

Question no. 5 and 6 are assertion and reason type questions.

• **Directions:** These questions consist of two statements, each printed asAssertion 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.

5 . **Assertion :** In Young's double slit experiment if wavelength of incident monochromatic light is just doubled, number of bright fringe on the screen will increase.

Reason : Maximum number of bright fringe on the screen is inversely proportional to the wavelength of light used

6 . **Assertion :** Thin film such as soap bubble or a thin layer of oil on water show beautiful colours when illuminated by white light.

Reason : It happens due to the interference of light reflected from upper and lower face of the thin film

7. Name the phenomenon which is responsible for bending of light around sharp corners of an obstacle Under what conditions does this phenomenon take place? Give one application of this phenomenon in everyday life.

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8. A parallel beam of light of 600 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1.2 m away. It is observed that the first minimum is at a distance of 3 mm from the centre of the screen. Calculate the width of the slit. 2

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9. .(a) If one of two identical slits producing interference in Young's experiment is covered with glass, so that the light intensity passing through it is reduced to 50%, find the ratio of the maximum and minimum intensity of the fringe in the interference pattern. 2

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(b)What kind of fringes do you expect to observe if white light is used instead of monochromatic light? 1

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10. Two wavelengths of sodium light 590 nm and 596 nm are used, in turn, to study the diffraction taking place at a single slit of aperture 2×10^{-4} m. The distance between the slit and the screen is 1.5 m.Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases. 3

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CASE BASED QUESTION

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. When light is passed around the sharp edges of an obstacle it get bended and may enters into the geometrical shadow of that obstacle such a phenomenon of light is called as diffraction of light. In interference, there are equally spaced alternate bright and dark bands are possible. While in diffraction, the there is a only one bright central Maxima and around both sides of the central Maxima the intensity of the light decreases as we go away from that central Maxima.

Q I.) For coherent sources of light the phase difference must be___

a) one b) zero c) either zero or constant d) 90°

Q 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) diffraction of light

Q 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

Q IV.) The interference and diffraction of light explains which nature of light?

(a) Transverse Nature (b) Wave Nature (c) Particle Nature (d) None of these

1. Consider sunlight incident on a pinhole of width 10^{-3} A^0. The image of the pinhole seen on a screen shall be

(i) a sharp white ring.

(ii) different from geometrical image.

(iii) a diffused central spot, white in colour.

(iv) diffused coloured region around a sharp central white spot.

(a) (i), (ii), (iii), (b) (ii), (iii), (c) (ii), (iv), (d) (i), (ii),

2. Consider the diffraction patern for a small pinhole. As the size of the hole is increased

(i) the size decreases. (ii) the intensity increases.

(iii) the size increases. (iv) the intensity decreases.

(a) (i), (ii), (iii), (b) (ii), (iii), (c) (ii), (iv), (d) (i), (ii),

3. For light diverging from a point source

(a) the wavefront is spherical. (b) the intensity decreases in proportion to the distance squared.

(c) the wavefront is parabolic. (d) the intensity at the wavefront does not depend on the distance

(a) (i), (ii), (b) (ii), (iii), (c) (ii), (iv), (d) (i), (ii), (iii),

Question no. 4 and 5 are assertion and reason type questions.

• **Directions:** These questions consist of two statements, each printed asAssertion 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.

4. **Assertion** : When a light wave travels from a rarer to a denser medium, it loses speed. The reduction in speed imply a reduction in energy carried by the light wave.

Reason : The energy of a wave is proportional to velocity of wave.

5**. 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 slits.

6. A narrow monochromatic beam of light of intensity I is incident a glass plate. Another identical glass plate is kept close to the first one and parallel to it. Each plate reflects 25% of the incident light and transmits the reaming. Calculate the ratio of minimum and maximum intensity in the interference pattern formed by the two beams obtained after reflection from each plate.

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7. In Young's double slit experiment, light waves of wavelength 5.4 x 10^{-7} m and 6.85 x 10^{-8} m are used in turn keeping the same geometry. Find the ratio of fringe width from 1^{st} with second.

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8. A beam of light consisting of two wavelengths 6500 Ao and 5200 A^{o} is used to obtain interference fringes. The distance between the slits is 2.0 mm and the distance between the plane of the slits and the screen is 120 cm. a) Find position of third maxima for first wavelength.

b) Find the minimum distance at which maxima of the two wavelength coincide.

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9. Consider a two slit interference arrangements (Fig. 10.4) such that the distance of the screen from the slits is half the distance between the slits. Obtain the value of D in terms of λ such that the first minima on the screen falls at a distance D from the centre O.

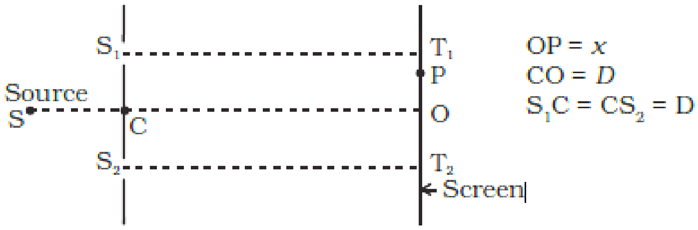

Fig. 10.4

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10. Four identical monochromatic sources A,B,C ,D as shown in the Fig. produce waves of the same wavelength λ and are coherent. Two receiver R_1 and R_2 are at great but equal distaces from B.

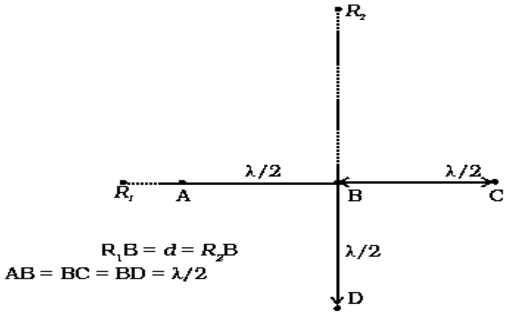

Fig. 10.7

(i) Which of the two receivers picks up the larger signal? (2)

(ii) Which of the two receivers picks up the larger signal when B is turned off? (1.5)

(iii) Which of the two receivers picks up the larger signal when D is turned off? (1.5)

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WORKSHEET 16 DUAL NATURE OF MATTER AND RADIATION

1. The work function of a metal is independent of (i) nature of the surface of the metal (ii) dimensions of the metal (iii) properties of the metal (iv) abundance of the metal (1)

(a) (i) only (b) (i) and (iii) c) (ii) and (iii) (d) (ii) and (iv)

2 The photoelectric current does not depend upon the (i) frequency of incident light (ii) work function of the metal (iii) stopping potential (iv) intensity of incident light (1)

(a) (i) and (iv) only (b) (i), (ii) and (iii) only

(c) (iii) only (d) (ii) only

3 The threshold frequency for a certain metal is v0. When light of frequency v= 2Vo is incident on it, the maximum velocity of photo electrons is 4×10^6 ms^{-1}. If the frequency of incident radiation is increased to 5 Vo, then the maximum velocity of photo electrons (m/s) is (1)

(a) 8×10^5 (b) 2×10^6 (c) 2×10^7 (d) 8×10^6

4. The stopping potential is directly related to (1)

(a) the work function of the metal

(b) intensity of incident radiation

(c) Saturation current for the given frequency

(d) K.E. gained by photoelectrons

5. Einstein's Law of photoelectric effect is based on the law of conservation of (1)

(a) momentum (b) energy (c) angular momentum (d) mass

Assertion Reason based questions

(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 Assertion

5. Assertion (A): Photoelectric saturation current increases with the increase in frequency of incident light

Reason (R): Energy of incident photons increases with increase in frequency and as a result photoelectric current increase. (1)

6. Assertion (A): The de Broglie equation has significance for any microscopic or sub microscopic particles.

Reason (R): The de Broglie wavelength is inversely proportional to the mass of the object if velocity is constant. (1)

7.Case Based Question: (1x4)

When a photon is incident on a metallic surface, it interacts with an atom in the metal and transfers all its energy to one of the atom's electrons. This electron may then escape through the electric field at the surface, which keeps less energetic electrons inside the metal. The emerging electron then has energy equal to the energy of the photon minus the energy W lost in escaping the metal. W, the work function of the surface, is a material-dependent constant. Since electrons also lose energy in collisions with other electrons before emerging, we may only specify the maximum possible energy for an electron liberated by light of frequency f from a metal. If the material work function is W, this maximum energy is Emax = hf -W

1. At stopping potential, the kinetic energy of emitted photo electron is

(a) Minimum (b) maximum (c) zero (d) cannot be predicted

2. Photo electric effect experiment

(a) Confirm Quantum nature of light (b) help to measure work function

(c) help to measure planck's contant (d) All of the above

3. Kinetic energy of electrons emitted in photoelectric effect is

(a) directly proportional to the intensity of incident light.

(b) inversely proportional to the intensity of incident light.

(c) independent of the intensity of incident light.

(d) independent of the frequency of light.

4. What is true about emitted photo electron from the metal surface?

(a) hf - W < 0 (b) hf - W ≥ 0 (c) f > threshold frequency (d) both b & c

OR

5. How does the maximum kinetic energy of electrons emitted vary with frequency of incident radiation.

7.A beam of electrons is moving with a velocity of 5×10^6 m/s. Calculate the de Broglie wavelength associated with the electrons. (Mass of electron = 9.1×10^-31 kg, h = 6.63×10^-34 Js) (2)

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8.Find the :-(a) maximum frequency and (b) minimum wavelength of X-rays produced by 30kV electrons.? (2)

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9. The work function of a metal is 2.5 eV. Calculate the threshold wavelength. Will light of wavelength 400 nm cause photoemission? (h = 6.63×10^-34 Js, c = 3×10^8 m/s, 1eV = 1.6×10^-19 J) (2)

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10. Plot a graph showing the variation of stopping potential with the frequency of incident radiation for two different photosensitive materials having work functions W1 and W2 (W1 > W2). On what factors does the slope and intercept of the lines depend?

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WORKSHEET 17 ATOMS

- Answer all questions.
- Each question carries 2 marks.

1. In a hydrogen like ion, the energy difference between the 2nd excitation energy state and ground is 108.8 eV. What is the atomic number of the ion?

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2. For a hydrogen atom, the ratio of the largest wavelength of Lyman series to that of the Balmer series is.

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3. For a nucleus of mass number A and radius R, Do mass density of nucleus depends on A? Justify

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4. Statement (I) : The dimensions of Planck's constant and angular momentum are same.
   Statement (II) : In Bohr's model electron revolve around the nucleus only in those orbits for which angular momentum is integral multiple of Planck's constant.)
   choose the most appropriate answer from the options given below:
   (a) Both statement are correct.
   (b) Statement I is correct but statement II is incorrect.
   (c) Both statements are incorrect.
   (d) Statement I is incorrect but statement II is correct.
5. Considering the Bohr model of hydrogen-like atoms, Calculate the ratio of the radius of 5th orbit of the electron in Li^{2+} and He^{+} ‘

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WORKSHEET -18 ATOMS

- Answer all questions.
- Each question carries 2 marks.

1. Assertion A : The Bohr model is applicable to hydrogen and hydrogen-like atoms only.

Reason : The formulation of Bohr model does not include repulsive force between electrons.?

a) Assertion and reason both are correct statements, and reason is the correct explanation for the assertion.

b) Assertion and reason both are correct statements, but reason is not the correct explanation for the assertion.

c) Assertion is a correct statement, but reason is a wrong statement.

d) Assertion is a wrong statement, but reason is a correct statement

2. Energy released when two deuterons fuse to form a helium nucleus is: (Given : Binding energy per nucleon of $_1H^2$ = 1.1MeV and binding energy per nucleon of $_2He^4$ = 7.0MeV).

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3. What are the number of spectral lines emitted by atomic hydrogen that is in the 4th energy level?

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4. How the frequency of revolution of the electron in Bohr's orbit varies with *n*, (the principal quantum number).

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5. What is the ratio of the shortest wavelength of Balmer series to the shortest wavelength of Lyman series for hydrogen atom?

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WORKSHEET 18 NUCLEI

MULTIPLE CHOICE QUESTIONS (1 MARK EACH)

Q1- The mass density of a nucleus of mass number A is :

(a) $A^{1/3}$ (b) $A^{2/3}$ (c) A^3 (d) A

Q2-m_X, m_n and m_p represents masses of X nucleus, a neutron and a proton, respectively.

Then : (A) $m_X < (A – Z) m_n + Z m_p$ (B) $m_X = (A – Z) m_p + Z m_n$

(C) $m_X = (A – Z) m_n + Z m_p$ (D) $m_X > (A – Z) m_n + Z m_p$

Q3- In the nuclear reaction $^{14}{}_7N + {}_2He^4$ ◄ $X + {}_1H^1$ represents :

(a) $^{16}O_7$ (b) $^{17}N_7$ (c) $^{17}O_8$ (d) $^{16}N_7$

Q4- Average binding energy is maximum for

(a) C^{12} (b) Fe^{56} (c) U^{235} (d) Po^{210}

ASSERTION AND REASON QUESTIONS (1 MARK EACH)

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.

Q5- Assertion : Density of all the nuclei is same.

Reason : Radius of nucleus is directly proportional to the cube root of mass number

Ans-

Q6- Assertion : Neutrons penetrate matter more readily as compared to protons.

Reason : Neutrons are slightly more massive than protons.

Ans-

SHORT ANSWER TYPE QUESTIONS(2 MARKS)

Q7- Using the curve for the binding energy per nucleon as a function of mass number A, identify the region of nuclear fission and nuclear fusion .

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Q8- 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 8.5MeV per nucleon. Calculate the energy Q released per fission in MeV.

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SHORT ANSWER TYPE QUESTIONS(3 MARKS)

Q9. (a) Briefly discuss three characteristics of the forces between nucleons.

(b) Which out of $_4X^8$ and $_3Y^5$ nuclei is more stable and why ?

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Q10- - Calculate the energy released in MeV in the following nuclear reaction

$^{238}U_{92} \rightarrow {}^{234}Th_{90} + {}^4He_2 + Q$

Mass of $^{238}U_{92}$= 238.05079 u

Mass of $^{234}Th_{90}$ = 234.043630 u

Mass of $^4He_2$= 4.002600 u

1u= 931.5 Mev/c^2

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CASE BASED QUESTIONS (4 MARKS)

Q11- Einstein was the first to establish the equivalence between mass and energy. According to him, whenever a certain mass (Δm) disappears in some process the amount of energy released is E = Δm *c2, where c is the velocity of light in vacuum =3 x 10^8 m/s. The reverse is also true i.e. whenever energy E disappears an equivalent mass Δm = E/ c2 appears. Read the above passage and answer any 04 from the following –

i) What is the energy released when 1a.m.u mass disappears in a nuclear reaction?

b) 1.49 x10^{-10} J b) 1.49 x10^{-13} J c) 1.49 x10^{10} J d) 1.49 x10^{-10} MJ

ii)Which of the following process releases energy?

a) Nuclear Fission b) Nuclear Fusion c)Both (a) and (b) d)None

iii)Which process is used in today's nuclear power plant to harness nuclear energy?

a) Nuclear Fission b)Nuclear Fusion c)Both (a) and (b) d)None

iv)Which of the following is used as Moderator in a Nuclear Reactor?

a) Deuterium Water b)Normal Water c) Mineral Water

WORKSHEET 19 NUCLEI

MULTIPLE CHOICE QUESTIONS (1 MARK EACH)

Q1- An electron emitted in beta radiation originates from

(a) free electrons existing in the nuclei

(b) inner orbits of an atom

(c) photon escaping from the nucleus

(d) decay of a neutron in a nuclei

Q2- Heavy stable nuclei have more neutrons than protons. This is because of the fact that

(a) neutrons are heavier than protons.

(b) electrostatic force between protons are repulsive

(c) neutrons decay into protons through beta decay

(d) nuclear forces between neutrons are weaker than that between protons.

Q3- In the nuclear reaction $^{14}{}_{7}N + {}_{2}He^{4} \rightarrow X + {}_{1}H^{1}$ represents :

(a) $^{16}O_7$ (b) $^{17}N_7$ (c) $^{17}O_8$ (d) $^{16}N_7$

Q4- Complete the series 6He→e−+6Li+

(a) Neutrino (b) antineutrino (c) proton (d) neutron

ASSERTION AND REASON QUESTIONS (1 MARK EACH)

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.

Q5- Assertion : The binding energy per nucleon, for nuclei with atomic mass number A > 100, decrease with A.

Reason : The forces are weak for heavier nuclei.

Ans-

Q6- Assertion: Naturally , thermonuclear fusion reaction is not possible on earth.

Reason : For thermonuclear fusion to take place, extreme condition of temperature and pressure are required

Ans-

SHORT ANSWER TYPE QUESTIONS(2 MARKS)

Q7-Draw a graph showing the variations 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. Writes two important conclusions which you can draw regarding the nature of the Nuclear Forces

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Q8- When four hydrogen nuclei combine to form a helium nucleus estimate the amount of energy in MeV released in this process of fusion. (Neglect the masses of electrons and neutrons). Given i) Mass of Hydrogen = 1.007825 u ii) Mass of helium nucleus = 4.002603 u, 1u = 931MeV / c2

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SHORT ANSWER TYPE QUESTIONS(3 MARKS)

Q9. (a) Briefly discuss three characteristics of the forces between nucleons.

(b) Which out of X $^{8}{}_{4}$ and Y $^{5}{}_{3}$ nuclei is more stable and why ?

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Q10- - Calculate the energy released in MeV in the following nuclear reaction

$^{238}U_{92}$ ▲ → $^{234}Th_{90}+{}^{4}He_{2}+Q$

Mass of $^{238}U_{92}$= 238.05079 u

Mass of $^{234}Th_{90}$ = 234.043630 u

Mass of $^{4}He_{2}$= 4.002600 u

1u= 931.5 Mev/c^2

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CASE BASED QUESTION (4 MARKS)

Q11- Nuclear fission reaction is the nuclear reaction which is induced by neutron. For example in the fission of uranium, the energy of the order of 200 MeV per fissioning nucleus is released. While the nuclear reaction in which two or more nuclei get fused together to form the larger nucleus is called as nuclear fusion reaction. The nuclear fusion which is initiated by increasing the temperature of the system is called as thermonuclear fusion.

The controlled fusion reaction are initiated to produce steady power. The heat energy created on the sun is due to the nuclear fusion reaction. While the huge amount of energy released after the explosion of atom bomb is only due to the nuclear fission reaction.

(i) For which value of multiplication factor the operation of the reactor is said to be critical___

a) $K > 1$ b) $K <1$ c) $K = 1$ d) $K = 0$

(ii) The source of energy output in the interior of the stars is due to ____

a) thermonuclear fission b) thermonuclear fusion

c) controlled thermonuclear fission d) none

(iii) The temperature of the interior of the sun is ___

a) 1.5×10^{7} K b) 1.5×10^{10} K c) 1.5×10^{19} K d) 1.5×10^{15} K

(iv) In Maharashtra where is nuclear reactor located?

WORKSHEET 20 SEMICONDUCTORS

MULTIPLE CHOICE QUESTIONS

1. n_e and v_d is the number of electron and drift velocity in a semiconductor respectively. How would they respond to increase in temperature of the semiconductor?

(a). n_e increases and v_d decreases   (b). n_e decreases and v_d increases

(c). Both n_e and v_d increases   (d). Both n_e and v_d decreases

ANS:

2. A Ge specimen is doped with Al. The concentration of acceptor atoms is ~10^{21} atoms/m^3. Given that the intrinsic concentration of electron hole pairs is ~10^{19}/m^3, the concentration of electrons in the specimen is

(a). 10^{17}/m^3 (b). 10^{15}/m^3

(c). 10^4/m^3 (d). 10^2/m^3

ANS:

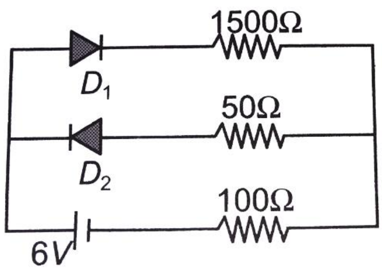
3. In a P-N junction diode if P region is more heavily doped than n region, then the depletion layer is

(a). Greater in P region   (b). Greater in N region

(c). Equal in both region   (d). No depletion layer is formed in this case

ANS:

4. In the following circuit of PN junction diodes D_1, D_2 and D_3 are ideal then I is

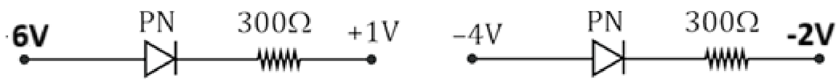


(a). 0   (b). 0.02   (c). 0.03   (d). 0.36

ANS:

SHORT ANSWER QUESTIONS (2 MARK)

5.



ANS:

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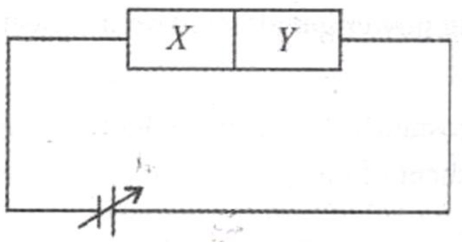
6. Two semiconductor materials X and Y shown in the figure are made by doping a Ge-crystal with indium and arsenic respectively. The two are joined end to end and connected to a battery as shown:



(i) Will the junction be forward biased or reverse biased.

(ii) Sketch a I-V graph for this arrangement

ANS

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7. (i) In half-wave rectification, what is the output frequency if the input frequency is 50 Hz. What is the output frequency of a full-wave rectifier for the same input frequency?

ii) A silicon P–N junction is in forward biased condition with a resistance in series. It has knee voltage of 0.6 V and current flow in it is 9 mA. If the P–N junction is connected with 3.0 V battery then calculate the value of the resistance.

ANS:

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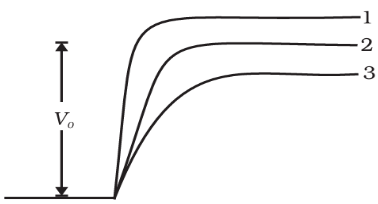
SHORT ANSWER QUESTIONS (3 MARK)

8. Draw V-I characteristics of a p-n junction diode

In the given figure, V_o is the potential barrier across a p-n junction, when no battery is connected across the junction , which of the following is correct justify



(a) 1 and 3 both correspond to forward bias of junction

(b) 3 corresponds to forward bias of junction and 1 corresponds to reverse bias of junction

(c) 1 corresponds to forward bias and 3 corresponds to reverse bias of junction.

ANS:

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9. (i) In forward bias condition the diode can be considered as a battery having voltage equal to its Knee voltage or Threshold voltage. Explain why?

(ii) In reverse bias there is always a "leakage current". What is the reason of this current?

(iii) Show the variation of resistivity of a semiconductor with temperature..

ANS:

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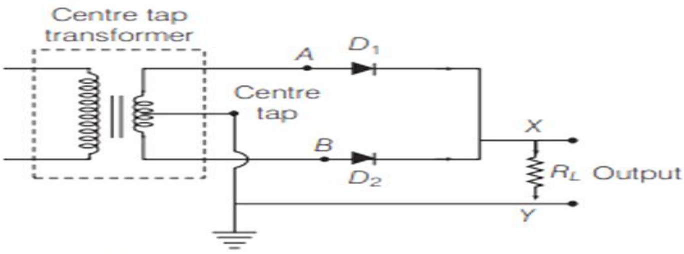
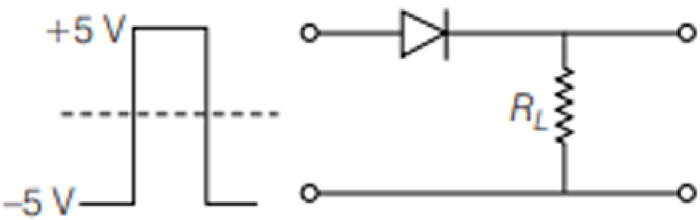
CASE BASED QUESTIONS

10. Full Wave Rectifier The process of converting alternating voltage/current into direct voltage/current is called rectification. Diode is used as a rectifier for converting alternating current/voltage current/voltage. into Diode direct allows current to pass only, when it is forward biased. So, if an alternating voltage is applied across a diode, the current flows only in that part of the cycle when the diode is forward biased. This property is used to rectify the current/voltage.



Circuit diagram of full wave rectifier

i) If in a p-n junction, a square input signal of 10V is applied as shown



Then, the output across R_L will be

ii) If in a p-n junction, a square input signal of 10V is applied as shown in figure, the input is across the terminals A and C and the output is across B and D.

Then, the output is

(a) Zero (b) same as the input

(c) half wave rectified (d) full wave rectified

iii) Which of the following is not true about a rectifier circuit?

(a) It can convert DC to AC. (b) It can convert AC to DC.

(c) It can shift voltage level (d)None of these

iv) The ratio of output frequencies of half-wave rectifier and a full wave rectifier, when an input of frequency 100 Hz is fed at input, is

(a) 1:2 (b) 2: 1 (c) 4 :1 (d) 1 : 4

****

Series : XYW1Z

SET ~ 1

रोल नं.
Roll No.

कोड नं.
Code No. **55/1/1**

परीक्षार्थी प्रश्न-पत्र कोड को उत्तर-पुस्तिका के मुख-पृष्ठ पर अवश्य लिखें ।
Candidates must write the Q.P. Code on the title page of the answer-book.

भौतिक विज्ञान (सैद्धान्तिक)
PHYSICS (Theory)

निर्धारित समय : 3 घण्टे | *अधिकतम अंक : 70*

Time allowed : 3 hours | *Maximum Marks : 70*

नोट / NOTE

(I) कृपया जाँच कर लें कि इस प्रश्न-पत्र में मुद्रित पृष्ठ **23** हैं ।
Please check that this question paper contains **23** printed pages.

(II) कृपया जाँच कर लें कि इस प्रश्न-पत्र में **33** प्रश्न हैं ।
Please check that this question paper contains **33** questions.

(III) प्रश्न-पत्र में दाहिने हाथ की ओर दिए गए प्रश्न-पत्र कोड को परीक्षार्थी उत्तर-पुस्तिका के मुख-पृष्ठ पर लिखें ।
Q.P. Code given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.

(IV) **कृपया प्रश्न का उत्तर लिखना शुरू करने से पहले, उत्तर-पुस्तिका में यथा स्थान पर प्रश्न का क्रमांक अवश्य लिखें ।**
Please write down the serial number of the question in the answer-book at the given place before attempting it.

(V) इस प्रश्न-पत्र को पढ़ने के लिए 15 मिनट का समय दिया गया है । प्रश्न-पत्र का वितरण पूर्वाह्न में 10.15 बजे किया जाएगा । 10.15 बजे से 10.30 बजे तक परीक्षार्थी केवल प्रश्न-पत्र को पढ़ेंगे और इस अवधि के दौरान वे उत्तर-पुस्तिका पर कोई उत्तर नहीं लिखेंगे ।
15 minute time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the candidates will read the question paper only and will not write any answer on the answer-book during this period.

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General Instructions :

Read the following instructions very carefully and follow them :

(i) *This question paper contains **33** questions. **All** questions are* **compulsory***.*

(ii) *Question paper is divided into **FIVE** sections – Sections **A, B, C, D** and **E**.*

(iii) *In* **Section A :** *Question numbers **1** to **16** are Multiple Choice (MCQ) type questions. Each question carries **1** mark.*

(iv) *In* **Section B :** *Question numbers **17** to **21** are Very Short Answer (VSA) type questions. Each question carries **2** marks.*

(v) *In* **Section C :** *Question numbers **22** to **28** are Short Answer (SA) type questions. Each question carries **3** marks.*

(vi) *In* **Section D :** *Question numbers **29** & **30** are Case Study-Based questions. Each question carries **4** marks.*

(vii) *In* **Section E :** *Question numbers **31** to **33** are Long Answer (LA) type questions. Each question carries **5** marks.*

(viii) *There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section A.*

(ix) *Kindly note that there is a separate question paper for Visually Impaired candidates.*

(x) *Use of calculators is NOT allowed.*

You may use the following values of physical constants wherever necessary :

$c = 3 \times 10^{8}$ m/s

$h = 6.63 \times 10^{-34}$ Js

$e = 1.6 \times 10^{-19}$ C

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}$ N m^2 C^{-2}

Mass of electron (m_e) = 9.1×10^{-31} kg.

Mass of neutron = 1.675×10^{-27} kg.

Mass of proton = 1.673×10^{-27} kg.

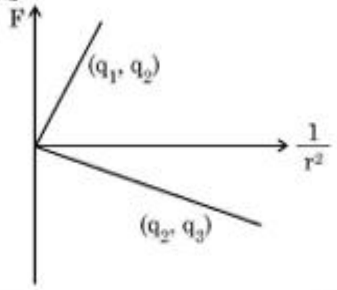
Avogadro's number = 6.023×10^{23} per gram mole

Boltzmann's constant = 1.38×10^{-23} JK^{-1}

~

SECTION – A

1. Figure shows variation of Coulomb force (F) acting between two point charges with $\frac{1}{r^2}$, r being the separation between the two charges (q_1, q_2) and (q_2, q_3). If q_2 is positive and least in magnitude, then the magnitudes of q_1, q_2 and q_3 are such that 1



(A) $q_2 < q_3 < q_1$ (B) $q_3 < q_1 < q_2$

(C) $q_1 < q_2 < q_3$ (D) $q_2 < q_1 < q_3$

2. Two wires P and Q are made of the same material. The wire Q has twice the diameter and half the length as that of wire P. If the resistance of wire P is R, the resistance of the wire Q will be 1

(A) R (B) $\frac{R}{2}$

(C) $\frac{R}{8}$ (D) 2R

3. A 1 cm segment of a wire lying along x-axis carries current of 0.5 A along +x direction. A magnetic field $\vec{B} = (0.4 \text{ mT})\,\hat{j} + (0.6 \text{ mT})\,\hat{k}$ is switched on, in the region. The force acting on the segment is 1

(A) $(2\hat{j} + 3\hat{k})$ mN (B) $(-3\hat{j} + 2\hat{k})$ μN

(C) $(6\hat{j} + 4\hat{k})$ mN (D) $(-4\hat{j} + 6\hat{k})$ μN

4. A coil has 100 turns, each of area 0.05 m^2 and total resistance 1.5 Ω. It is inserted at an instant in a magnetic field of 90 mT, with its axis parallel to the field. The charge induced in the coil at that instant is : 1

(A) 3.0 mC (B) 0.30 C

(C) 0.45 C (D) 1.5 C

5. You are required to design an air-filled solenoid of inductance 0.016 H having a length 0.81 m and radius 0.02 m. The number of turns in the solenoid should be 1

(A) 2592 (B) 2866

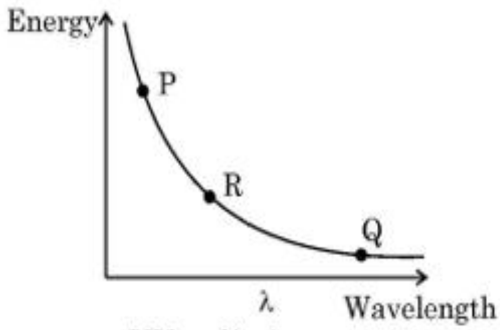
(C) 2976 (D) 3140

6. A voltage $v = v_0 \sin \omega t$ applied to a circuit drives a current $i = i_0 \sin(\omega t + \phi)$ in the circuit. The average power consumed in the circuit over a cycle is **1**

(A) Zero (B) $i_0 v_0 \cos \phi$

(C) $\frac{i_0 v_0}{2}$ (D) $\frac{i_0 v_0}{2} \cos \phi$

7. The given diagram exhibits the relationship between the wavelength of the electromagnetic waves and the energy of photon associated with them. The three points P, Q and R marked on the diagram may correspond respectively to : **1**



(A) X-rays, microwaves, UV radiation
(B) X-rays, UV radiation, microwaves
(C) UV radiation, microwaves, X-rays
(D) Microwaves, UV radiation, X-rays

8. A beaker is filled with water (refractive index $\frac{4}{3}$) upto a height H. A coin is placed at its bottom. The depth of the coin, when viewed along the near normal direction, will be **1**

(A) $\frac{H}{4}$ (B) $\frac{3H}{4}$

(C) H (D) $\frac{4H}{3}$

9. The stopping potential V_0 measured in a photoelectric experiment for a metal surface is plotted against frequency ν of the incident radiation. Let m be the slope of the straight line so obtained. Then the value of charge of an electron is given by (h is the Planck's constant.) **1**

(A) mh (B) $\frac{m}{h}$

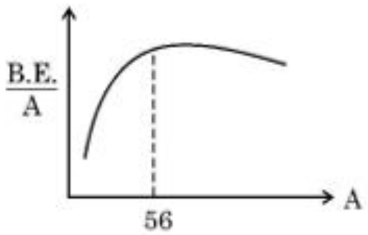
(C) $\frac{h}{m}$ (D) $\frac{1}{mh}$

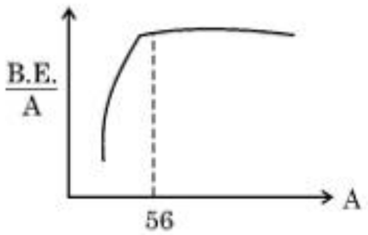
10. Let λ_e, λ_p and λ_d be the wavelengths associated with an electron, a proton and a deuteron, all moving with the same speed. Then the correct relation between them is **1**

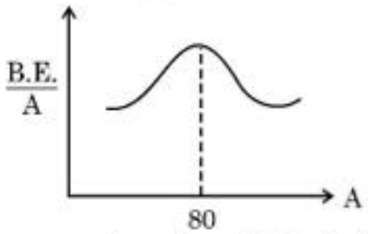
(A) $\lambda_d > \lambda_p > \lambda_e$ (B) $\lambda_e > \lambda_p > \lambda_d$

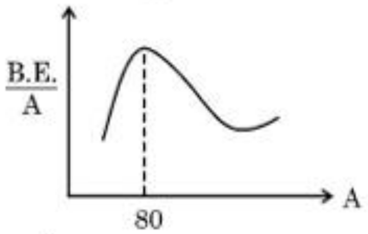
(C) $\lambda_p > \lambda_e > \lambda_d$ (D) $\lambda_e = \lambda_p = \lambda_d$

11. Which of the following figures correctly represent the shape of curve of binding energy per nucleon as a function of mass number ? **1**

(A) 

(B) 

(C) 

(D) 

12. When a p-n junction diode is forward biased **1**

(A) the barrier height and the depletion layer width both increase.
(B) the barrier height increases and the depletion layer width decreases.
(C) the barrier height and the depletion layer width both decrease.
(D) the barrier height decreases and the depletion layer width increases.

Note : Question numbers **13** to **16** are Assertion (A) and Reason (R) type questions. Two statements are given – one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (A), (B), (C) and (D) as given below :

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).
(C) Assertion (A) is true, but Reason (R) is false.
(D) Assertion (A) is false and Reason (R) is also false.

13. **Assertion (A)** : It is difficult to move a magnet into a coil of large number of turns when the circuit of the coil is closed. **1**

Reason (R) : The direction of induced current in a coil with its circuit closed, due to motion of a magnet, is such that it opposes the cause.

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14. **Assertion (A)** : The deflection in a galvanometer is directly proportional to the current passing through it. 1

Reason (R) : The coil of a galvanometer is suspended in a uniform radial magnetic field.

15. **Assertion (A)** : We cannot form a p-n junction diode by taking a slab of a p-type semiconductor and physically joining it to another slab of a n-type semiconductor. 1

Reason (R) : In a p-type semiconductor $\eta_e >> \eta_h$ while in a n-type semiconductor $\eta_h >> \eta_e$.

16. **Assertion (A)** : The potential energy of an electron revolving in any stationary orbit in a hydrogen atom is positive. 1

Reason (R) : The total energy of a charged particle is always positive.

SECTION – B

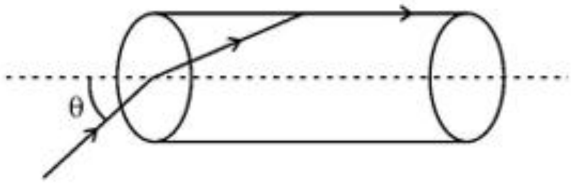
17. A battery of emf E and internal resistance r is connected to a rheostat. When a current of 2A is dawn from the battery, the potential difference across the rheostat is $5V$. The potential difference becomes $4V$ when a current of 4A is drawn from the battery. Calculate the value of E and r. 2

18. (a) In a diffraction experiment, the slit is illuminated by light of wavelength 600 nm. The first minimum of the pattern falls at $\theta = 30°$. Calculate the width of the slit. 2

OR

(b) In a Young's double-slit experiment, two light waves, each of intensity I_o, interfere at a point, having a path difference $\frac{\lambda}{8}$ on the screen. Find the intensity at this point.

19. A transparent solid cylindrical rod (refractive index $\frac{2}{\sqrt{3}}$) is kept in air. A ray of light incident on its face travels along the surface of the rod, as shown in figure. Calculate the angle θ. 2



20. Prove that, in Bohr model of hydrogen atom, the time period of revolution of an electron in n^{th} orbit is proportional to n^3. 2

~

21. A p-type Si semiconductor is made by doping an average of one dopant atom per 5×10^7 silicon atoms. If the number density of silicon atoms in the specimen is 5×10^{28} atoms m^{-3}, find the number of holes created per cubic centimetre in the specimen due to doping. Also give one example of such dopants. **2**

SECTION – C

22. (a) Two batteries of emf's 3V & 6V and internal resistances 0.2 Ω & 0.4 Ω are connected in parallel. This combination is connected to a 4 Ω resistor. Find : **3**
   (i) the equivalent emf of the combination
   (ii) the equivalent internal resistance of the combination
   (iii) the current drawn from the combination

OR

(b) (i) A conductor of length l is connected across an ideal cell of emf E. Keeping the cell connected, the length of the conductor is increased to $2l$ by gradually stretching it. If R and R′ are initial and final values of resistance and v_d and v_d' are initial and final values of drift velocity, find the relation between (i) R′ and R and (ii) v_d' and v_d.
   (ii) When electrons drift in a conductor from lower to higher potential, does it mean that all the 'free electrons' of the conductor are moving in the same direction ?

23. Using Biot-Savart law, derive expression for the magnetic field ($\vec{B}$) due to a circular current carrying loop at a point on its axis and hence at its centre. **3**

24. (a) Show that the energy required to build up the current I in a coil of inductance L is $\frac{1}{2}LI^2$. **3**
   (b) Considering the case of magnetic field produced by air-filled current carrying solenoid, show that the magnetic energy density of a magnetic field B is $\frac{B^2}{2\mu_0}$.

25. (a) A parallel plate capacitor is charged by an ac source. Show that the sum of conduction current (I_c) and the displacement current (I_d) has the same value at all points of the circuit. **3**
   (b) In case (a) above, is Kirchhoff's first rule (junction rule) valid at each plate of the capacitor ? Explain.

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26. Answer the following giving reason : **3**
   (a) All the photo electrons do not eject with the same kinetic energy when monochromatic light is incident on a metal surface.
   (b) The saturation current in case (a) is different for different intensity.
   (c) If one goes on increasing the wavelength of light incident on a metal surface, keeping its intensity constant, emission of photo electrons stop at a certain wavelength for this metal.

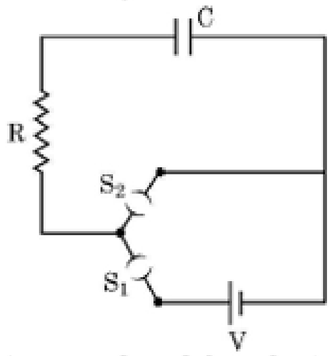
27. (a) Define 'Mass defect' and 'Binding energy' of a nucleus. Describe 'Fission process' on the basis of binding energy per nucleon. **3**
   (b) A deuteron contains a proton and a neutron and has a mass of 2.013553 u. Calculate the mass defect for it in u and its energy equivalence in MeV. (m_p = 1.007277 u, m_n = 1.008665 u, 1u = 931.5 MeV/c^2)

28. (a) Draw circuit arrangement for studying V-I characteristics of a p-n junction diode. **3**
   (b) Show the shape of the characteristics of a diode.
   (c) Mention two information that you can get from these characteristics.

SECTION – D

Question numbers **29** and **30** are case study based questions. Read the following paragraphs and answer the questions that follow.

29. A circuit consisting of a capacitor C, a resistor of resistance R and an ideal battery of emf V, as shown in figure is known as RC series circuit. **4 × 1 = 4**



As soon as the circuit is completed by closing key S_1 (keeping S_2 open) charges begin to flow between the capacitor plates and the battery terminals. The charge on the capacitor increases and consequently the potential difference V_c (= q/C) across the capacitor also increases with time. When this potential difference equals the potential difference across the battery, the capacitor is fully charged (Q = VC). During this process of charging, the charge q on the capacitor changes with time t as $q = Q[1 - e^{-t/RC}]$

The charging current can be obtained by differentiating it and using $\frac{d}{dx}(e^{mx}) = me^{mx}$.

Consider the case when R = 20 kΩ, C = 500 μF and V = 10 V.

~

(i) The final charge on the capacitor, when key S_1 is closed and S_2 is open, is

(A) 5 μC (B) 5 mC

(C) 25 mC (D) 0.1 C

(ii) For sufficient time the key S_1 is closed and S_2 is open. Now key S_2 is closed and S_1 is open. What is the final charge on the capacitor ?

(A) Zero (B) 5 mC

(C) 2.5 mC (D) 5 μC

(iii) The dimensional formula for RC is

(A) $[M L^2 T^{-3} A^{-2}]$ (B) $[M^0 L^0 T^{-1} A^0]$

(C) $[M^{-1} L^{-2} T^4 A^2]$ (D) $[M^0 L^0 T A^0]$

(iv) The key S_1 is closed and S_2 is open. The value of current in the resistor after 5 seconds, is

(A) $\frac{1}{2\sqrt{e}}$ mA (B) $\sqrt{e}$ mA

(C) $\frac{1}{\sqrt{e}}$ mA (D) $\frac{1}{2e}$ mA

OR

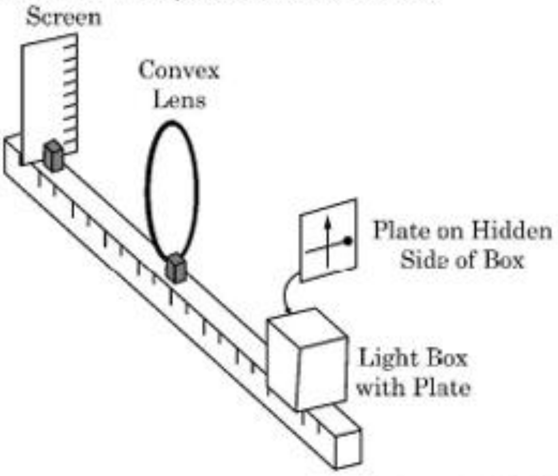
(iv) The key S_1 is closed and S_2 is open. The initial value of charging current in the resistor, is

(A) 5 mA (B) 0.5 mA

(C) 2 mA (D) 1 mA

30. A thin lens is a transparent optical medium bounded by two surfaces, at least one of which should be spherical. Applying the formula for image formation by a single spherical surface successively at the two surfaces of a lens, one can obtain the 'lens maker formula' and then the 'lens formula'. A lens has two foci – called 'first focal point' and 'second focal point' of the lens, one on each side. **4 × 1 = 4**

(i)



Consider the arrangement shown in figure. A black vertical arrow and a horizontal thick line with a ball are painted on a glass plate. It serves as the object. When the plate is illuminated, its real image is formed on the screen.

Which of the following correctly represents the image formed on the screen ?

(A) (B) (C) (D)

(ii) Which of the following statements is incorrect ?

(A) For a convex mirror magnification is always negative.

(B) For all virtual images formed by a mirror magnification is positive.

(C) For a concave lens magnification is always positive.

(D) For real and inverted images, magnification is always negative.

(iii) A convex lens of focal length 'f' is cut into two equal parts perpendicular to the principal axis. The focal length of each part will be :

(A) f (B) 2 f

(C) $\frac{f}{2}$ (D) $\frac{f}{4}$

OR

(iii) If an object in case (i) above is 20 cm from the lens and the screen is 50 cm away from the object, the focal length of the lens used is

(A) 10 cm (B) 12 cm

(C) 16 cm (D) 20 cm

(iv) The distance of an object from first focal point of a biconvex lens is X_1 and distance of the image from second focal point is X_2. The focal length of the lens is

(A) $X_1 X_2$ (B) $\sqrt{X_1 + X_2}$

(C) $\sqrt{X_1 X_2}$ (D) $\sqrt{\frac{X_2}{X_1}}$

SECTION – E

31\. (a) (i) Two point charges 5 μC and –1 μC are placed at points (–3 cm, 0, 0) and (3 cm, 0, 0) respectively. An external electric field $\vec{E} = \frac{A}{r^2}\hat{r}$ where $A = 3 \times 10^5$ Vm is switched on in the region. Calculate the change in electrostatic energy of the system due to the electric field. **5**

(ii) A system of two conductors is placed in air and they have net charge of +80μC and –80μC which causes a potential difference of 16 V between them.

(1) Find the capacitance of the system.

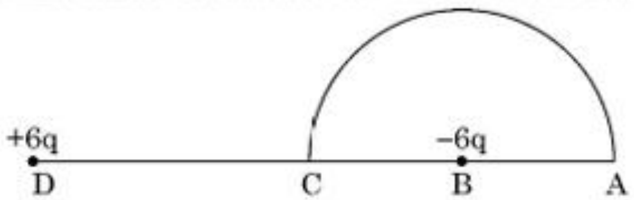
(2) If the air between the capacitor is replaced by a dielectric medium of dielectric constant 3, what will be the potential difference between the two conductors ?

(3) If the charges on two conductors are changed to +160 μC and –160 μC, will the capacitance of the system change ? Give reason for your answer.

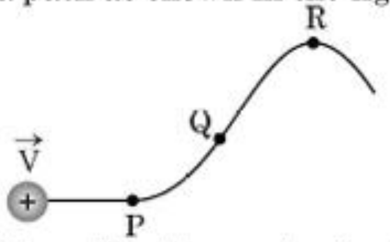
OR

(b) (i) Consider three metal spherical shells A, B and C, each of radius R. Each shell is having a concentric metal ball of radius R/10. The spherical shells A, B and C are given charges +6q, –4q, and 14q respectively. Their inner metal balls are also given charges –2q, +8q and –10q respectively. Compare the magnitude of the electric fields due to shells A, B and C at a distance 3R from their centres.

(ii) A charge –6 μC is placed at the centre B of a semicircle of radius 5 cm, as shown in the figure. An equal and opposite charge is placed at point D at a distance of 10 cm from B. A charge +5 μC is moved from point 'C' to point 'A' along the circumference. Calculate the work done on the charge.



32. (a) (i) A proton moving with velocity $\vec{V}$ in a non-uniform magnetic field traces a path as shown in the figure. **5**



The path followed by the proton is always in the plane of the paper. What is the direction of the magnetic field in the region near points P, Q and R ? What can you say about relative magnitude of magnetic fields at these points ?

(ii) A current carrying circular loop of area A produces a magnetic field B at its centre. Show that the magnetic moment of the loop is $\frac{2\,BA}{\mu_0}\sqrt{\frac{A}{\pi}}$.

OR

(b) (i) Derive an expression for the torque acting on a rectangular current loop suspended in a uniform magnetic field.

(ii) A charged particle is moving in a circular path with velocity $\vec{V}$ in a uniform magnetic field $\vec{B}$. It is made to pass through a sheet of lead and as a consequence, it looses one half of its kinetic energy without change in its direction. How will (1) the radius of its path (2) its time period of revolution change ?

33. (a) (i) (1) What are coherent sources ? Why are they necessary for observing a sustained interference pattern ? **5**

(2) Lights from two independent sources are not coherent. Explain.

(ii) Two slits 0.1 mm apart are arranged 1.20 m from a screen. Light of wavelength 600 nm from a distant source is incident on the slits.

(1) How far apart will adjacent bright interference fringes be on the screen ?

(2) Find the angular width (in degree) of the first bright fringe.

OR

(b) (i) Define a wavefront. An incident plane wave falls on a convex lens and gets refracted through it. Draw a diagram to show the incident and refracted wavefront.

(ii) A beam of light coming from a distant source is refracted by a spherical glass ball (refractive index 1.5) of radius 15 cm. Draw the ray diagram and obtain the position of the final image formed.

Series : YXZW2

SET ~ 3

रोल नं.
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कोड नं.
Code No. **55/2/3**

परीक्षार्थी प्रश्न-पत्र कोड को उत्तर-पुस्तिका के मुख-पृष्ठ पर अवश्य लिखें ।
Candidates must write the Q.P. Code on the title page of the answer-book.

भौतिक विज्ञान (सैद्धान्तिक)
PHYSICS (Theory)

निर्धारित समय : 3 घण्टे | *अधिकतम अंक : 70*

Time allowed : 3 hours | *Maximum Marks : 70*

नोट / NOTE

(I) कृपया जाँच कर लें कि इस प्रश्न-पत्र में मुद्रित पृष्ठ **23** हैं ।
Please check that this question paper contains **23** printed pages.

(II) कृपया जाँच कर लें कि इस प्रश्न-पत्र में **33** प्रश्न हैं ।
Please check that this question paper contains **33** questions.

(III) प्रश्न-पत्र में दाहिने हाथ की ओर दिए गए प्रश्न-पत्र कोड को परीक्षार्थी उत्तर-पुस्तिका के मुख-पृष्ठ पर लिखें ।
Q.P. Code given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.

(IV) **कृपया प्रश्न का उत्तर लिखना शुरू करने से पहले, उत्तर-पुस्तिका में यथा स्थान पर प्रश्न का क्रमांक अवश्य लिखें ।**
Please write down the serial number of the question in the answer-book at the given place before attempting it.

(V) इस प्रश्न-पत्र को पढ़ने के लिए 15 मिनट का समय दिया गया है । प्रश्न-पत्र का वितरण पूर्वाह्न में 10.15 बजे किया जाएगा । 10.15 बजे से 10.30 बजे तक परीक्षार्थी केवल प्रश्न-पत्र को पढ़ेंगे और इस अवधि के दौरान वे उत्तर-पुस्तिका पर कोई उत्तर नहीं लिखेंगे ।
15 minute time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the candidates will read the question paper only and will not write any answer on the answer-book during this period.

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General Instructions :

Read the following instructions very carefully and follow them :

(i) *This question paper contains **33** questions. **All** questions are **compulsory**.*

(ii) *This question paper is divided into **five** sections – Sections **A, B, C, D** and **E**.*

(iii) *In **Section A** : Question numbers **1** to **16** are Multiple Choice type questions. Each question carries **1** mark.*

(iv) *In **Section B** : Question numbers **17** to **21** are Very Short Answer type questions. Each question carries **2** marks.*

(v) *In **Section C** : Question numbers **22** to **28** are Short Answer type questions. Each question carries **3** marks.*

(vi) *In **Section D** : Question numbers **29** & **30** are case study-based questions. Each question carries **4** marks.*

(vii) *In **Section E** : Question numbers **31** to **33** are Long Answer type questions. Each question carries **5** marks.*

(viii) *There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section **A**.*

(ix) *Kindly note that there is a separate question paper for Visually Impaired candidates.*

(x) *Use of calculators is **not** allowed.*

You may use the following values of physical constants wherever necessary :

$c = 3 \times 10^8$ m/s

$h = 6.63 \times 10^{-34}$ Js

$e = 1.6 \times 10^{-19}$ C

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2}

Mass of electron (m_e) = 9.1×10^{-31} kg.

Mass of neutron = 1.675×10^{-27} kg.

Mass of proton = 1.673×10^{-27} kg.

Avogadro's number = 6.023×10^{23} per gram mole

Boltzman's constant = 1.38×10^{-23} JK^{-1}

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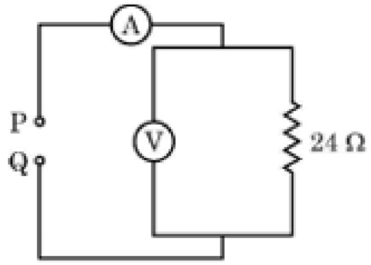
SECTION – A

1. Consider two identical dipoles D_1 and D_2. Charges –q and q of dipole D_1 are located at (0, 0) and (a, 0) and that of dipole D_2 at (0, a) and (0, 2a) in x-y plane, respectively. The net dipole moment of the system is **1**

(A) $qa(\hat{i} + \hat{j})$ (B) $-qa(\hat{i} + \hat{j})$

(C) $qa(\hat{i} - \hat{j})$ (D) $-qa(\hat{i} - \hat{j})$

2. Which pair of readings of ideal voltmeter and ideal ammeter in the given circuit is possible when a suitable power source of 3 Ω internal resistance is connected between P and Q ? **1**

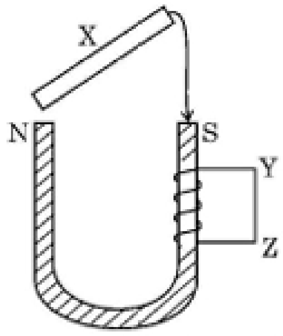


(A) 12.0 V, 2.0 A (B) 2.0 V, 0.5 A
(C) 6.0 V, 2.0 A (D) 12 V, 0.5 A

3. Which one of the following statements is correct ?
Electric field due to static charges is **1**
(A) conservative and field lines do not form closed loops.
(B) conservative and field lines form closed loops.
(C) non-conservative and field lines do not form closed loops.
(D) non-conservative and field lines form closed loops.

4. A material is pushed out when placed in a uniform magnetic field. The material is **1**
(A) non-magnetic (B) diamagnetic
(C) paramagnetic (D) ferromagnetic

5. A soft iron rod X is allowed to fall on the two poles of a U shaped permanent magnet as shown in figure. A coil is wrapped over one arm of the U shaped magnet. **1**

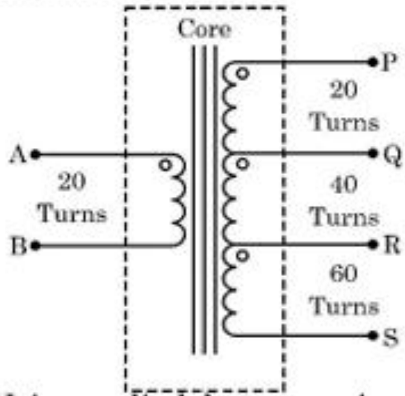


During fall of the rod, the current in the coil will be
(A) clockwise current (B) anticlockwise current
(C) alternating current (D) zero

6. A 1 cm straight segment of a conductor carrying 1 A current in x direction lies symmetrically at origin of Cartesian coordinate system. The magnetic field due to this segment at point (1m, 1m, 0) is **1**

(A) $1.0 \times 10^{-9}\,\hat{k}$ T
(B) $-1.0 \times 10^{-9}\,\hat{k}$ T
(C) $\frac{5.0}{\sqrt{2}} \times 10^{-10}\,\hat{k}$ T
(D) $-\frac{5.0}{\sqrt{2}} \times 10^{-10}\,\hat{k}$ T

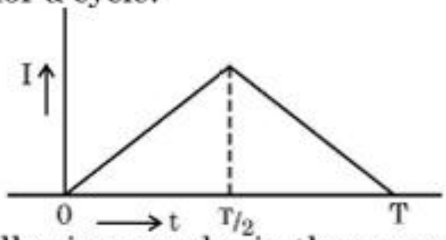
7. The number of turns between different pairs of output terminals are shown for a step-up transformer. **1**



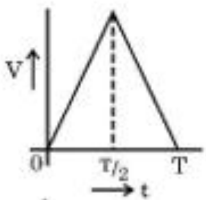
Input voltage of 20 V is applied between A and B. Between which two terminals will the output be 120 V ?

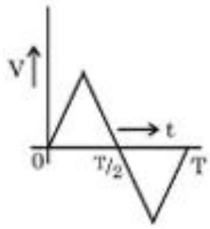
(A) P and Q
(B) Q and S
(C) P and R
(D) P and S

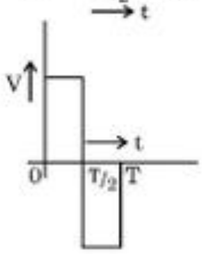
8. The alternating current I in an inductor is observed to vary with time t as shown in the graph for a cycle. **1**

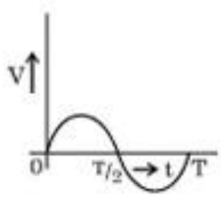


Which one of the following graphs is the correct representation of wave form of voltage V with time t ?

(A) 

(B) 

(C) 

(D) 

9. The plane face of a planoconvex lens is silvered. The refractive index of material and radius of curvature of the curved surface of the lens are n and R respectively. This lens will behave as a concave mirror of focal length 1

(A) $\frac{R}{n}$ (B) $\frac{R}{(n-1)}$

(C) nR (D) $\frac{R}{2(n-1)}$

10. When the resistance measured between p and n ends of a p-n junction diode is high, it can act as a/an – 1

(A) resistor (B) inductor

(C) capacitor (D) switch

11. Atomic spectral emission lines of hydrogen atom are incident on a zinc surface. The lines which can emit photoelectrons from the surface are members of 1

(A) Balmer series

(B) Paschen series

(C) Lyman series

(D) Neither Balmer, nor Paschen nor Lyman series

12. The energy of an electron in a hydrogen atom in ground state is –13.6 eV. Its energy in an orbit corresponding to quantum number n is –0.544 eV. The value of n is 1

(A) 2 (B) 3

(C) 4 (D) 5

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 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 but Reason (R) is not the correct explanation of Assertion (A).

(C) If Assertion (A) is true but Reason (R) is false.

(D) If both Assertion (A) and Reason (R) are false.

13. **Assertion (A)** : In an ideal step-down transformer, the electrical energy is not lost. 1

Reason (R) : In a step-down transformer, voltage decreases but the current increases.

14. **Assertion (A)** : Out of Infrared and radio waves, the radio waves show more diffraction effect. 1

Reason (R) : Radio waves have greater frequency than infrared waves.

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15. **Assertion (A)** : In a semiconductor diode the thickness of depletion layer is not fixed. **1**

Reason (R) : Thickness of depletion layer in a semiconductor device depends upon many factors such as biasing of the semiconductor.

16. **Assertion (A)** : In Bohr model of hydrogen atom, the angular momentum of an electron in n^{th} orbit is proportional to the square root of its orbit radius r_n. **1**

Reason (R) : According to Bohr model, electron can jump to its nearest orbits only.

SECTION – B

17. The threshold voltage of a silicon diode is 0.7 V. It is operated at this point by connecting the diode in series with a battery of V volt and a resistor of 1000 Ω. Find the value of V when the current drawn is 15 mA. **2**

18. In a double slit experiment, it is observed that the angular width of one fringe formed on the screen is 0.2°. The wavelength of light used in the experiment is 500 nm. Calculate the separation of the two slits. **2**

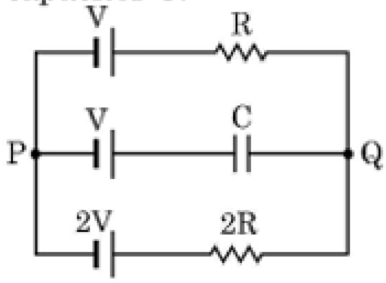
19. A light beam converges at a point O. In the path of this beam, a concave lens of focal length 15 cm is placed at a distance of 10 cm before point O. The beam now converges at a point O'. Find the magnitude and the direction of shift OO'. **2**

20. The threshold wavelength of a metal is 450 nm. Calculate (i) the work function of the metal in eV and (ii) the maximum energy of the ejected photoelectrons in eV by incident radiation of 250 nm. **2**

21. (a) Two wires of the same material and the same radius have their lengths in the ratio 2 : 3. They are connected in parallel to a battery which supplies a current of 15 A. Find the current through the wires. **2**

OR

(b) In the circuit three ideal cells of e.m.f. V, V and 2V are connected to a resistor of resistance R, a capacitor of capacitance C and another resistor of resistance 2R as shown in figure. In the steady state find (i) the potential difference between P and Q and (ii) potential difference across capacitor C.



SECTION – C

22. (a) Define Electrical conductivity. Obtain the expression of electrical conductivity of a conductor in terms of number density and relaxation time of free electrons. **3**

(b) Explain qualitative change in resistivity of a conductor with temperature using expression obtained in (a).

23. (a) Show the variation of binding energy per nucleon with mass number. Write the significance of the binding energy curve. **3**

(b) Two nuclei with lower binding energy per nucleon form a nuclei with more binding energy per nucleon.

(i) What type of nuclear reaction is it ?

(ii) Whether the total mass of nuclei increases, decreases or remains unchanged ?

(iii) Does the process require energy or produce energy ?

24. (a) ac voltage of frequency ω is applied across a series LCR circuit. Draw the phasor diagram and obtain the impedance of the circuit. **3**

(b) Discuss 'resonance' in a series LCR circuit and write the expression for resonant frequency.

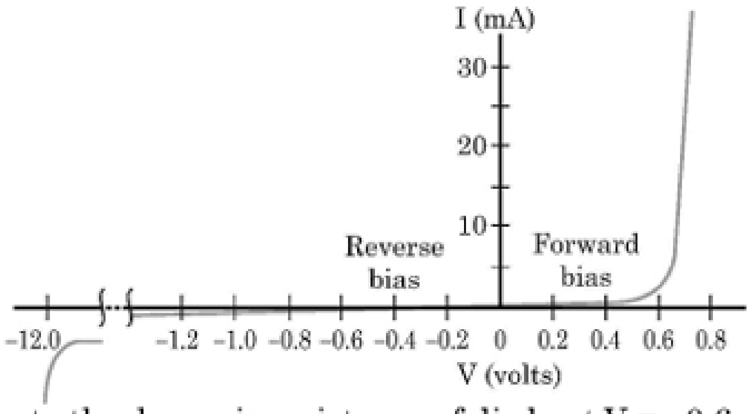
25. (a) The amplitude of a light wave becomes n times. This results in intensity of the wave becoming m times. What is the relation between n and m ? **3**

(b) White light is incident on three identical surfaces – a black surface, a yellow surface and a white surface, one by one. For which surface, the pressure exerted on the surface by the incident light will be (i) maximum (ii) minimum ? Justify your answer.

26. (a) What are majority and minority charge carriers in an extrinsic semiconductor ? **3**

(b) A p-n junction is forward biased. Describe the movement of the charge carriers which produce current in it.

(c) The graph shows the variation of current with voltage for a p-n junction diode.



Estimate the dynamic resistance of diode at V = –0.6 volt.

27. (a) In a region of a uniform electric field $\vec{E}$, a negatively charged particle is moving with a constant velocity $\vec{v} = -v_o\hat{i}$ near a long straight conductor coinciding with XX' axis and carrying current I towards –X axis. The particle remains at a distance d from the conductor. **3**

(i) Draw diagram showing direction of electric and magnetic fields.

(ii) What are the various forces acting on the charged particle ?

(iii) Find the value of v_o in terms of E, d and I.

OR

(b) Two infinitely long conductors kept along XX' and YY' axes are carrying current I_1 and I_2 along –X axis and –Y axis respectively. Find the magnitude and direction of the net magnetic field produced at point P(X, Y).

28. (a) When a parallel beam of light enters water surface obliquely at some angle, what is the effect on the width of the beam ? **3**

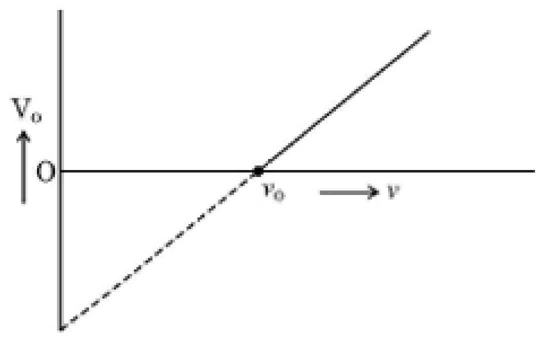
(b) With the help of a ray diagram, show that a straw appears bent when it is partly dipped in water and explain it.

(c) Explain the transmission of optical signal through an optical fibre by a diagram.

SECTION – D

Question numbers **29** and **30** are case study based questions. Read the following paragraphs and answer the questions that follow.

29. When a photon of suitable frequency is incident on a metal surface, photoelectron is emitted from it. If the frequency is below a threshold frequency (v_o) for the surface, no photoelectron is emitted. For a photon of frequency $v(v > v_o)$, the kinetic energy of the emitted photoelectrons is $h(v - v_o)$. The photocurrent can be stopped by applying a potential V_o called 'stopping potential' on the anode. Thus maximum kinetic energy of photoelectrons $K_m = eV_o = h(v - v_o)$. The experimental graph between V_o and v for a metal is shown in figure. This is a straight line of slope m. **4 × 1 = 4**



(i) The straight line graphs obtained for two metals
- (A) coincide each other.
- (B) are parallel to each other.
- (C) are not parallel to each other and cross at a point on v-axis.
- (D) are not parallel to each other and do not cross at a point on v-axis.

(ii) The value of Planck's constant for this metal is
- (A) $\frac{e}{m}$ (B) $\frac{1}{me}$
- (C) me (D) $\frac{m}{e}$

(iii) The intercepts on v-axis and V_o-axis of the graph are respectively :
- (A) $v_o, \frac{hv_o}{e}$ (B) v_o, hv_o
- (C) $\frac{hv_o}{e}, v_o$ (D) hv_o, v_o

OR

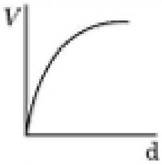
(iii) When the wavelength of a photon is doubled, how many times its wave number and frequency become, respectively ?
- (A) $2, \frac{1}{2}$ (B) $\frac{1}{2}, \frac{1}{2}$
- (C) $\frac{1}{2}, 2$ (D) 2, 2

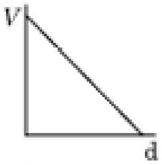
(iv) The momentum of a photon is 5.0×10^{-29} kg. m/s. Ignoring relativistic effects (if any), the wavelength of the photon is
- (A) 1.33 μm (B) 3.3 μm
- (C) 16.6 μm (D) 13.3 μm

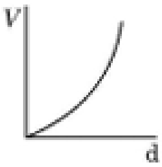
30. A parallel plate capacitor has two parallel plates which are separated by an insulating medium like air, mica, etc. When the plates are connected to the terminals of a battery, they get equal and opposite charges and an electric field is set up in between them. This electric field between the two plates depends upon the potential difference applied, the separation of the plates and nature of the medium between the plates. **4 × 1 = 4**

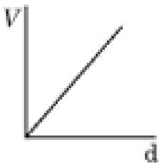
(i) The electric field between the plates of a parallel plate capacitor is E. Now the separation between the plates is doubled and simultaneously the applied potential difference between the plates is reduced to half of its initial value. The new value of the electric field between the plates will be :
- (A) E (B) 2E
- (C) $\frac{E}{4}$ (D) $\frac{E}{2}$

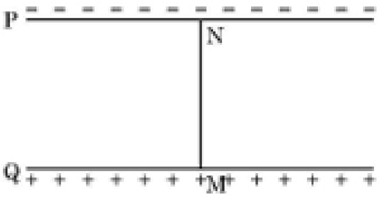
(ii) A constant electric field is to be maintained between the two plates of a capacitor whose separation d changes with time. Which of the graphs correctly depict the potential difference (*V*) to be applied between the plates as a function of separation between the plates (d) to maintain the constant electric field ?

(A) 

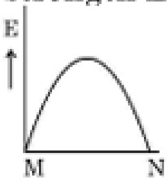
(B) 

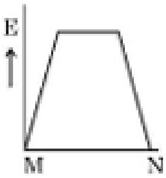
(C) 

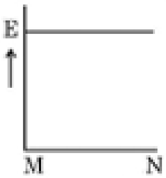
(D) 

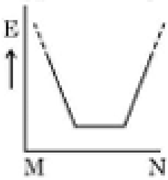
(iii) 

In the above figure P, Q are the two parallel plates of a capacitor. Plate Q is at positive potential with respect to plate P. MN is an imaginary line drawn perpendicular to the plates. Which of the graphs shows correctly the variations of the magnitude of electric field strength E along the line MN ?

(A) 

(B) 

(C) 

(D) 

(iv) Three parallel plates are placed above each other with equal displacement $\vec{d}$ between neighbouring plates. The electric field between the first pair of the plates is $\vec{E}_1$ and the electric field between the second pair of the plates is $\vec{E}_2$. The potential difference between the third and the first plate is –

(A) $(\vec{E}_1 + \vec{E}_2) \cdot \vec{d}$ (B) $(\vec{E}_1 - \vec{E}_2) \cdot \vec{d}$

(C) $(\vec{E}_2 - \vec{E}_1) \cdot \vec{d}$ (D) $\frac{d(E_1 + E_2)}{2}$

OR

(iv) A material of dielectric constant K is filled in a parallel plate capacitor of capacitance C. The new value of its capacitance becomes

(A) C (B) $\frac{C}{K}$

(C) CK (D) $C\left(1+\frac{1}{K}\right)$

SECTION – E

31. (a) (i) What is the source of force acting on a current-carrying conductor placed in a magnetic field ? Obtain the expression for force acting between two long straight parallel conductors carrying steady currents and hence define 'ampere'. **5**

(ii) A point charge q is moving with velocity $\vec{v}$ in a uniform magnetic field $\vec{B}$. Find the work done by the magnetic force on the charge.

(iii) Explain the necessary conditions in which the trajectory of a charged particle is helical in a uniform magnetic field.

OR

(b) (i) A current carrying loop can be considered as a magnetic dipole placed along its axis. Explain.

(ii) Obtain the relation for magnetic dipole moment $\vec{M}$ of current carrying coil. Give the direction of $\vec{M}$.

(iii) A current carrying coil is placed in an external uniform magnetic field. The coil is free to turn in the magnetic field. What is the net force acting on the coil ? Obtain the orientation of the coil in stable equilibrium. Show that in this orientation the flux of the total field (field produced by the loop + external field) through the coil is maximum.

32. (a) (i) A thin pencil of length (f/4) is placed coinciding with the principal axis of a mirror of focal length f. The image of the pencil is real and enlarged, just touches the pencil. Calculate the magnification produced by the mirror. **5**

(ii) A ray of light is incident on a refracting face AB of a prism ABC at an angle of 45°. The ray emerges from face AC and the angle of deviation is 15°. The angle of prism is 30°. Show that the emergent ray is normal to the face AC from which it emerges out. Find the refraction index of the material of the prism.

OR

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(b) (i) Light consisting of two wavelengths 600 nm and 480 nm is used to obtain interference fringes in a double slit experiment. The screen is placed 1.0 m away from slits which are 1.0 nm apart.

(1) Calculate the distance of the third bright fringe on the screen from the central maximum for wavelength 600 nm.

(2) Find the least distance from the central maximum where the bright fringes due to both the wavelengths coincide.

(ii) (1) Draw the variation of intensity with angle of diffraction in single slit diffraction pattern. Write the expression for value of angle corresponding to zero intensity locations.

(2) In what way diffraction of light waves differs from diffraction of sound waves ?

33. (a) (i) A small conducting sphere A of radius r charged to a potential V, is enclosed by a spherical conducting shell B of radius R. If A and B are connected by a thin wire, calculate the final potential on sphere A and shell B. 5

(ii) Write two characteristics of equipotential surfaces. A uniform electric field of 50 NC^{-1} is set up in a region along $+x$ axis. If the potential at the origin (0, 0) is 220 V, find the potential at a point (4m, 3m).

OR

(b) (i) What is difference between an open surface and a closed surface ? Draw elementary surface vector $d\vec{S}$ for a spherical surface S.

(ii) Define electric flux through a surface. Give the significance of a Gaussian surface. A charge outside a Gaussian surface does not contribute to total electric flux through the surface. Why ?

(iii) A small spherical shell S_1 has point charges $q_1 = -3\ \mu C$, $q_2 = -2\ \mu C$ and $q_3 = 9\ \mu C$ inside it. This shell is enclosed by another big spherical shell S_2. A point charge Q is placed in between the two surfaces S_1 and S_2. If the electric flux through the surface S_2 is four times the flux through surface S_1, find charge Q.