Support Material

Class - XII

Physics 2026-27

Prepared by

Kendriya Vidyalaya Sangathan, Agra Region

Deputy Commissioner's Message

Dear Students and Esteemed Teachers,

As you open this booklet of thoughtfully crafted material for class XII, prepared by our dedicated teachers and meticulously refined by our experts, I extend my warmest greetings on behalf of Kendriya Vidyalaya Sangathan, Agra Region.

This compilation represents a collaborative effort, a testament to the unwavering commitment of our educators to provide you, our young learners, with engaging and effective tools for growth. Each worksheet has been designed with care to reinforce concepts, stimulate curiosity, and encourage independent learning.

Dear students, approach these assessments with enthusiasm and a spirit of exploration. Embrace the opportunity to strengthen your understanding and celebrate your progress with each completed task. Remember that every step you take, no matter how small, contributes to your journey of knowledge.

Dedicated teachers, your creativity and dedication in preparing this material is truly commendable. Your efforts in nurturing young minds and fostering a love for learning are the bedrock of our education system. This booklet stands as a tangible representation of your commitment to excellence.

The resource persons who have lent their expertise to moderate and edit these worksheets have played a crucial role in ensuring their quality and effectiveness. Their contribution is deeply valued.

We also extend our sincere gratitude to the Kendriya Vidyalaya Sangathan Headquarter and our officials for their consistent guidance and support, which enables such collaborative endeavours.

Let this booklet serve as a companion in your journey of learning, a bridge connecting classroom instructions with independent practice. May it empower our students to achieve their full potential and inspire our teachers in their noble mission.

Wishing you all a rewarding and enriching learning experience!

With sincere appreciation,

Smt. Indira Mudgal

Deputy Commissioner,

KVS, RO Agra

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CHAPTER 1: ELECTRIC CHARGES AND FIELDS

SAMPLE QUESTION PAPER (ASSIGNMENT-1)

Time Allowed: 3 hours **Maximum Marks: 70**

General Instructions:-

(1) There are **33 questions** in all. All questions are compulsory.
(2) This question paper has **five sections**: Section A, Section B, Section C, Section D and Section E.
(3) All the sections are compulsory.

(4) **Section A** contains **sixteen questions**, **twelve MCQ and four assertion reasoning based** of **1mark each**, **Section B contains five questions** of **two marks each**, **Section C contains seven questions of three marks each**, **Section D contains two case study-based questions of four marks each** and **Section E contains three long answer questions of five marks each**.

(5) There is no overall choice. However, an **internal choice** has been provided **in two questions** in **Section B**, **one** question **in Section C** and **all three questions in Section E**. You have to attempt only one of the choices in such questions.

SECTION: A [1X16 = 16 Marks]

Q.1. For two charges $q1$ and $q2$, if force between them for some separation in air is F, then force between them in a medium of permittivity s will be

(a) $\frac{\epsilon 0}{\epsilon} F$ (b) $\frac{\quad}{\epsilon 0}$ (c) $ss0F$ (d) $\frac{F}{\epsilon\epsilon 0}$

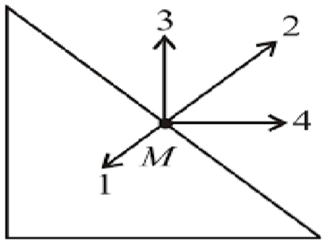
Q.2. Two point charges placed at a certain distance r in air exert a force F on each other. Then, distance r' at which these charges will exert the same force in a medium of dielectric constant K is given by

(a) r (b) r/K (c) $r/\sqrt{K}$ (d) $r\sqrt{K}$

Q.3. Charge $q2$ of mass m revolves around a stationary charge $q1$ in a circular orbit of radius r. The orbital periodic time of $q2$ would be

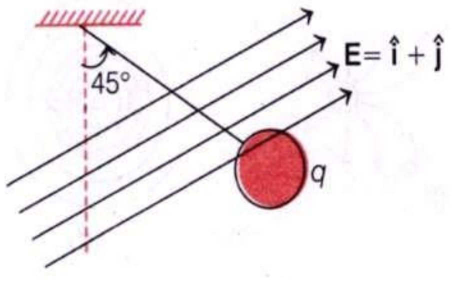
(a) $\left(\frac{4\pi^3 mr^2}{kq_1q_2}\right)^{1/2}$ (b) $\left(\frac{kq_1q_2}{4\pi^2 mr^2}\right)^{1/2}$ (c) $\left(\frac{4\pi^2 mr^4}{kq_1q_2}\right)^{1/2}$

Q.4. Three identical positive point charges below are placed at the vertices of an isosceles right angled triangle as shown. Which of the vectors numbered coincides in direction with the electric field at the mid-point M of the hypotenuse due to the given system of charges?



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

Q.5. A charged cork ball of mass 2 kg is suspended by light insulated string in electric field (E) as shown, find the charge on ball, if it is in equilibrium.



(a) $2C$ (b) $5C$ (c) 10C (d) 20C

Q.6. Two small spheres each having the charge $+Q$ are suspended by insulating threads of length L from a hook. This arrangement is taken in space, where there is no gravitational effect, then the angle between the two suspensions and the tension in each thread will be

(a) $180^\circ, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{(2L)^2}$ (b) $90^\circ, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{L^2}$ (c) $180^\circ, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{2L^2}$ (d) $180^\circ, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{L^2}$

Q.7. The bob of a simple pendulum has mass 2 g and a charge of 5.0μC. It is at rest in a uniform horizontal electric field of intensity 2000 V/m. At equilibrium, the angle that the pendulum makes with the vertical is (Take, g = 10 m/s^2)

(a) $\tan^{-1}$ (2.0) (b) $\tan^{-1}$ (0.2) (c) $\tan^{-1}$ (5.0) (d) $\tan^{-1}$ (0.5)

Q.8. A charge Q is placed at the centre of a square. If electric field intensity due to the charge at the corners of square is $E1$& the intensity at the mid-point of the side of square is $E2$, then ratio of $E1$, $E2$

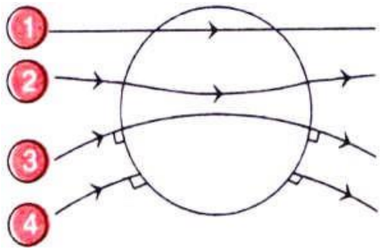
will be

(a) 1/√2 (b) √2 (c) 1/2 (d) 2

Q.9. The charge on a body is 4 C. If the charge on it is doubled, then new electric field becomes

(a) half (b) double (c) unchanged (d) thrice

Q.10. A metallic solid sphere is placed in a uniform electric field. Which of the following path of electric line of force is correct?



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

Q.11. If an electric field is given by $10\hat{i} + 3\hat{j} + 4\hat{k}$, calculate electric flux through a surface of area 10 unit lying in YZ-plane.

(a) 100 unit (b) 10 unit (c) 30 unit (d) 40 unit

Q.12. The ratio of electric fields on the axis and at equator of an electric dipole will be

(a) 1:1 (b) 2:1 (c) 4:1 (d) None of these

For Questions 13 to 16, two statements are given one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.

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

Q. 13. **Assertion** When we produce charge $q1$ on a body by rubbing it against another body which gets a charge $q2$ in the process, then $q1 + q2 = 0$.
Reason Charge on an isolated system remains constant.

Q.14. **Assertion** At macroscopic level, quantisation of charge has no practical consequence and can be ignored.

Reason 1μC charge contains 10^{13} times electronic charge e approximately.

Q.15. **Assertion** Charge on a body can be increased or decreased in terms of electronic charge e. **Reason** Charge on a body is integral multiple of electronic charge e, this is called quantisation of charge.

Q.16. **Assertion** When bodies are charged through friction, there is a transfer of electric charge from one body toanother, but no creation or destruction of charge take place.

Reason This follows from conservation of electric charges.

SECTION : B [2X5 = 10 Marks]

Q.17. Write Coulomb's law in vector form. What is the importance of expressing it in vector form?

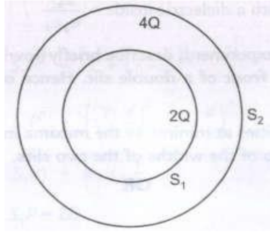
OR

Write any two limitations of Coulomb's law.

Q.18.(i) Depict electric field lines due to two positive charges kept at a certain distance apart.

(ii) Depict electric field lines due to an electric dipole or due to two opposite charges kept at a certain distance apart.

Q.19. Consider two hollow concentric spheres, S1& S2, enclosing charges 2Q & 4Q respectively as shown.



(i) Find out the ratio of the electric flux through them.

(ii) How will the electric flux through the sphere S1 change, if a medium of dielectric constant ε_r is introduced in the space inside S1 in place of air? Deduce the necessary expression.

Q.20. Two point charges 4 μC and +1 μC are separated by a distance of 2 m in air. Find the point on the line-joining charges at which the net electric field of the system is zero.

OR

An electric dipole is held in a uniform electric field. Write the expression for the torque acting on it. Express it in vector form and specify its direction. Identify two pairs of perpendicular vectors in the expression.

Q.21. Given a uniform electric field E = 6 X $10^3\hat{i}$ N/C, Find the flux of this field through a square of 10 Cm on a side whose plane is parallel to Y-Z plane. What would be the flux through the same square if the plane makes a 30^0 angle with the x- axis?

SECTION : C [3X7 = 21 Marks]

Q.22. (i) An electric dipole is held in a uniform electric field. Using suitable diagram show that it does not undergo any translatory motion. Derive the expression for the torque acting on it.

(ii) What would happen if the field in non-uniform ?

(iii) What would happen if the external electric field E is increasing

(a) parallel to **p** and (b) anti-parallel to **p** ? (b)

Q.23. (a) Obtain an expression for the electric field E due to a dipole of length ‘2a’ at a point distant r from the centre of the dipole on the axial line.

(b) Draw a graph of E versus r for r >> a.

Q.24. Obtain an expression for the electric field intensity at a point on the equatorial line of an electric dipole of dipole moment p and length 2a. What is the direction of this field?

Q.25. Using Gauss’s law, derive an expression for the electric field intensity due to an infinitely long, straight wire of linear charge density λ C/m.

Q.26. Using Gauss’s law, obtain the expression for electric field intensity at a point due to an infinitely large, plane sheet of charge of charge density σ C/m^2. How is the field directed if the sheet is (i) positively charged (ii) negatively charged?

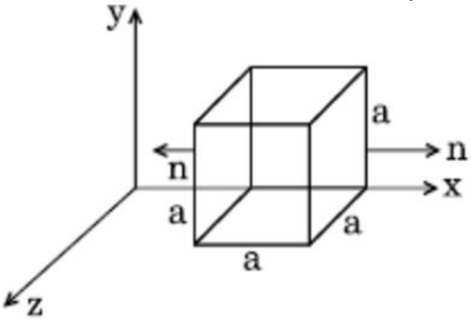
Q.27. Using Gauss’s law, deduce the expression for the electric field due to uniformly charged spherical conducting shell of radius R at a point

(i) outside and

(ii) inside the shell.

Plot a graph showing variation of electric field as a function of r > R and r< R.

Q.28. Given the components of an electric field as Ex = αx, Ey = 0 and Ez = 0, where α is



dimensional constant. Calculate the flux through the cube of side 'a' as shown in the figure and the effective charge inside the cube.

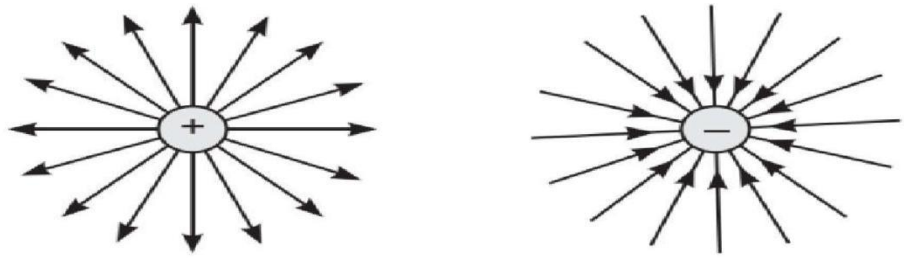
OR

An electric dipole is placed at an angle of 30^{o} with an electric field of intensity $2 \times 10^{5} NC^{-1}$. It experiences atorque equal to 4 N − m. Calculate the magnitude of charge on the dipole, if the dipole length is 2 cm.

SECTION : D [4X2 = 8 Marks]

Q.29. A charge is a property associated with the matter due to which it experiences and produces an electric and magnetic fields. Charges are scalar in nature and they add up like real numbers. Also,

the total charge of an isolated system is always conserved. When the objects rub against each other, charges acquired by them must be equal and opposite



Electric field lines of a positive point charge

Electric field lines of a negative point charge

Read the given passage carefully and give the answer of the following questions:

(i). The cause of charging is:

a. the actual transfer of protons
b. the actual transfer of electrons

c. the actual transfer of neutrons
d. None of the above

(ii). When a glass rod is rubbed with silk, then:

a. negative charge is produced on silk but no charge on glass rod

b. equal but opposite charges are produced on both

c. equal and similar charges are produced on both

d. positive charge is produced on glass rod but no charge on silk

(iii). If an object is positively charged theoretically, the mass of the object:

a. remains the same
b. increases slightly by a factor of 9.11×10^{-31} kg.

c. may increase or decrease
d. decreases slightly by a factor of 9.11×10^{-31} kg

(iv) The cause of quantisation of electric charges is:

a. transfer of an integral number of neutrons
b. transfer of an integral number of protons

c. transfer of an integral number of electrons d. None of the above.

Q.30. Coulomb's law states that the electrostatic force of attraction or repulsion acting between two stationary points charges is given by

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

where F denotes the force between two charges q1and q2 separated by a distance r in free space, ϵ0 is a constant known as permittivity of free space.
Free space is vacuum and may be taken to be air practically. If free space is replaced by a medium, then ϵ0 is replaced by (ϵ0K) , where K is known as dielectric constant or relative permittivity.
Read the given passage carefully and give the answer of the following questions:
(i) In Coulomb's law, on which of the following factors does the proportionality constant k depends?

a. Electrostatic force acting between the two charges
b. Nature of the medium between the two charges
c. Magnitude of the two charges
d. Distance between the two charges

(ii). Dimensional formula for the permittivity of free space is

a. $M^{-1}L^{-3}T^4A$ b. $M^{-1}L^{-3}T^{-3}A^2$ c. $M^{-1}L^{-3}T^4A^2$ d. $M^{-1}L^{-3}T^4A3$

(iii) The force of repulsion between two charges of 1 C each, kept 1m apart in vacuum is:

a. 9×10^{11} N b. 9×10^9 N c. $1/9\times10^9$ N d. 9×10^{12} N

(iv) Two identical charges repel each other with a forceequal to 10 mg wt when they are 0.6 m apart in air.(g = 10 ms^{-2}). The value of each charge is:

a. 2 mC b. 2×10^{-7}mC c. 2 nC d. 2 μC

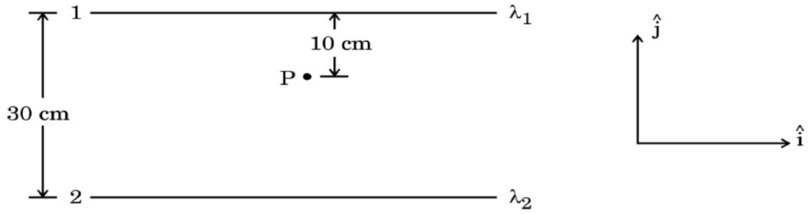
SECTION : E [5X3 = 15 Marks]

31. (i) ABC is an equilateral triangle of side l. Two point charges+2 μC each, are located at points B and C. Find the sign andmagnitude of the point charge q to be kept at the midpoint Mof the side BC, so that the net electric field at point Abecomes zero.

(ii) An electric dipole consists of point charges -1·0 μC and+ 1·0 μC located at (0, 0) and (3 mm, 4 mm) respectively inx y plane. An electric field E =1000î V/m is switched onin the region. Find the torque acting on the dipole.

OR

(i) Write Coulomb's law of electrostatics in vector form. Apply itto determine the electric field at a point due to a system ofpoint charges.
(ii) Two long straight wires 1 and 2 are kept as shown in thefigure. The linear charge density of the two wires areλ1 = 10 C/m and λ2 = 20 C/m. Find the net force Fexperienced by an electron held at point P.



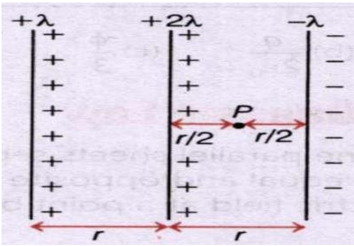
32.(i)Define electric flux. Write its SI unit.

ii Explain Gauss law is based on inverse -square dependence ondistance contained in coulomb's law.

iii Two charges A (charge q) and B (charge 2q) are located atpoints (0, 0) and (a, a) respectively. Let î $akd\ \hat{j}$be the unitvectors along x-axis and y-axis respectively. Find the forceexerted by A on B, in terms ofî $akd\ \hat{j}$.

OR

(i) Three parallel infinite line charges with linear charge densities $+\lambda$, $+2\lambda$ and $-\lambda$ are placed in a plane asshown in the figure. What is the electric field at point P?



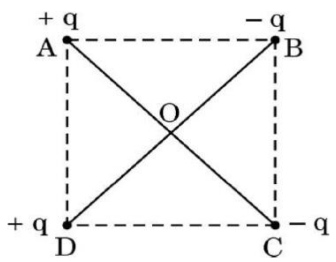
(ii) A charge q is enclosed by spherical surface. How will the flux through surface change if

(a) radius of surface is doubled

(b) radius of surface is tropled

(c) Spherical shape is changed to cubical

33. (i) Two identical electric dipoles are placed along the diagonals ofa square ABCD of side √2 m as shown in the figure. Obtainthe magnitude and direction of the net electric field at thecentre (O) of the square.



(ii) Consider three metal spherical shells A, B and C, each of radius **R**. Each shell has a concentric metal ball of radius **R/10** inside it. 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.

OR

(i) What is the difference between an open surface and a closed surface? Draw the elementary surface vector $\vec{dS}$ 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.

ASSIGNMENT – 2

MUTIPLE CHOICE QUESTIONS

1. If a body has positive charge on it, then it means it has

(1) Gained some protons (2) Lost some protons
(3) Gained some electrons (4) Lost some electrons

2. Sure check for presence of electric charge is

(1) Process of induction (2) Repulsion between bodies
(3) Attraction between bodies (4) Frictional force between bodies

3. If a solid and a hollow conducting sphere have same radius then
(1) Hollow sphere will hold more maximum charge
(2) Solid sphere will hold more maximum charge
(3) Both the spheres will hold same maximum charge
(4) Both the sphere can't hold charge

4. Coulomb's law is analogous to

(1) Charge conservation law (2) Newton's second law of motion
(3) Law of conservation of energy (4) Newton's law of gravitation

5. Two point charges Q1 and Q2 exert a force F on each other when kept certain distance apart. If the charge on each particle is halved and the distance between the two particles is doubled, then the new force between the two particles would be

(1)F/2 (2)F/4 (3)F/8 (4) F/16

6. Two equally charged identical small balls kept some fixed distance apart exert a repulsive force F on each other. A similar uncharged ball, after touching one of them is placed at the mid-point of line joining the two balls. Force experienced by the third ball is

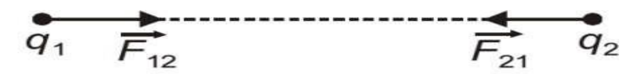
(1) 4F (2) 2F (3) F (4)F/2

7. Two equal positive charges Q are fixed at points (a, 0) and (–a, 0) on the x-axis. An opposite charge —q at rest is released from point (0, a) on the y-axis. The charge —q will

(1) Move to infinity (2) Move to origin and rest there
(3) Undergo SHM about the origin (4) Execute oscillatory periodic motion but not SHM

8. Which of the following is not true about electric charge?
(1) Charge on a body is always integral multiple of certain charge known as charge of electron
(2) Charge is a scalar quantity
(3) Net charge on an isolated system is always conserved
(4) Charge can be converted into energy and energy can be converted into charge

9. According to Coulomb's Law, which is correct relation for the following diagram?



(1) q1 q2< 0 (2) q1 q2> 0 (3) q1 q2 = 0 (4) q1 q2>> 100 C

10. A charge q is to be distributed on two conducting spheres. What should be the value of the charges on the spheres so that the repulsive force between them is maximum when they are placed at a fixed distance from each other in air?

(1) q/2 and q/2 (2) q/4 and 3q/4 (3) q/3 and 2q/3 (4) q/5 and 4q/5

11. A point charge q1 exerts an electric force on a second point charge q2. If third charge q3 is brought near, the electric force of q1 exerted on q2
(1) Decreases
(2) Increases
(3) Remains unchanged
(4) Increases if q3 is of same sign as q1 and decreases if q3 is of opposite sign

12. Consider three point objects P, Q and R. P and Q repel each other, while P and R attract. What is the nature of force between Q and R?

(1) Repulsive force (2) Attractive force (3) No force (4) None of these

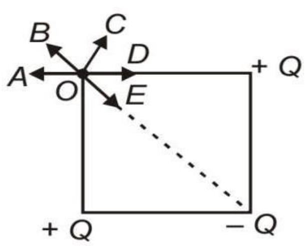
13. In a uniform electric field if a charge is fired in a direction different from the line of electric field then the trajectory of the charge will be a

(1) Straight line (2) Circle (3) Parabola (4) Ellipse

14. How many electrons should be removed from a coin of mass 1.6 g, so that it may float in an electric field of intensity 109 N/C directed upward?

(1) 9.8×10^7 (2) 9.8×10^5 (3) 9.8×10^3 (4) 9.8×10^1

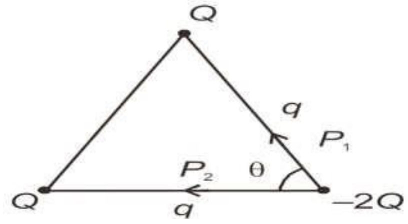
15. Point charges each of magnitude Q are placed at three corners of a square as shown in the diagram. What is the direction of the resultant electric field at the fourth corner?



(1) OC (2) OE (3) OD (4) OB

16. Electric charge Q, Q and –2Q respectively are placed at the three corners of an equilateral triangle of side a. Magnitude of the electric dipole moment of the system is

(1) $\sqrt{2}Qa$ (2) $\sqrt{3}Qa$ (3) Qa (4) $2Qa$



17. An electric dipole placed in a uniform electric field experiences maximum moment of couple when the dipole is placed

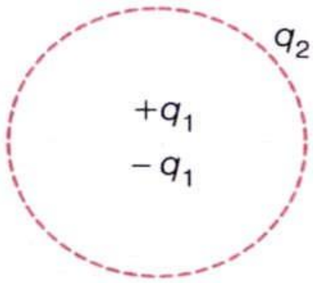
(1) Against the direction of the field (2) Towards the electric field
(3) Perpendicular to the direction of the field (4) At 135° to the direction of the field

18. The electric force on a point charge situated on the axis of a short dipole is F. If the charge is shifted along the axis to double the distance, the electric force acting will be

(1) 4F (2)F/ 2 (3)F/ 4 (4)F/ 8

19. When a dipole is placed in an uniform external field, then
(1) net force on dipole is zero but torque is non-zero
(2) torque is zero but net force is non-zero
(3) torque and net force both are non-zero
(4) both torque and net force are zero

20. Consider the charge configuration and spherical Gaussian surface as shown in the figure. When calculating the flux of the electric field over the spherical surface, the electric field will be due to



(1) $q2$ (2) only the positive charges
(3) all the charges (4) $+q1$ and $-q1$

OTHER MUTIPLE CHOICE QUESTIONS

1. When a body is connected to the earth, then electrons from the earth, flow into the body. It means that the body is

(1) unchanged (2) an insulator (3) positively charged (4) negatively charged

2.Three charges, each equal to +q, are placed at the corners of an equilateral triangle. If the force between any two charges is F, then net force on either charge will be

(1) 2F (2) 3F (3) √2F (4) √3F

3.A metallic spherical shell has an inner radius R1 and outer radius R2 . A charge is placed at the centre of the spherical cavity. The surface charge density on the inner surface is

(1)–$q/4\pi R1^2$ (2) $q/4\pi R1^2$ (3)-$q/4\pi R2^2$ (3) $q/4\pi R2^2$

4.If a charge q is placed at the centre of the line joining two equal charges Q such that the system is in equilibrium then the value of q is

(1) Q/2 (2) –Q/2 (3) Q/4 (4) –Q/4

5.A cylinder of radius R and length A is placed in a uniform electric field E parallel to the axis of the cylinder. The total flux over the curved surface of the cylinder is

(1) Zero (2) $\pi R^2 E$ (3) $2\pi R^2 E$ (4) $E / \pi R^2$

6.At the centre of a cubical box + Q charge is placed. The value of total flux that is coming out a wall is

(1) Q / ϵ0 (2) Q / 3 ϵ0 (3) Q / 4 ϵ0 (4) Q / 6 ϵ0

7.Two point charges A and B, having charges +q and –q respectively, are placed at certain distance apart and force acting between them is F. If 25% charge of A is transferred to B, then force between the charges becomes

(1) F (2) 9F/16

(3) 16F/9 (4) 4F/3

8.An electron falls from the rest through a vertical distance h in a uniform and vertically upward directed electric field E. The direction of electric field is now reversed, keeping its magnitude the same. A proton is allowed to fall from rest in it through the same vertical distance h. The time of fall of the electron, in comparison to the time of fall of the proton is

(1) smaller (2) 5 times greater

(3) 10 times greater (4) equal

9.Suppose a closed square loop whose area is 5i-6j is placed in an electric field of 2i-4j then what will be electric flux?

(1) (2i-4j)Vm (2) 34Vm

(3) 10Vm (4)(3i-2j)Vm

10.A dipole with charges +4uC and -4uC separated by 2 mm is in a field 7x10 at 30°. What is the torque?

(1) 2.4 x 10^4 Nm (2)2.8 x 10^4 Nm

(3) 3.6 x 10^4 Nm (4)4.2 x 10^4 Nm

11 What explains why the electric field due to a dipole can be zero at certain points along its equatorial plane?

(1)Charge quantization (2)Field symmetry

(3)Field cancellation (4)Charge density

13 The net electric field inside a hollow charged conducting sphere is:
(1) Zero. (2) Maximum at the center.
(3) Maximum at the surface. (4) Minimum at the surface.

14. Two positive point charges of magnitude +Q are placed on the x-axis at distances 'a' and '3a' from the origin, respectively. What is the electric field at the point (2a, 0)?
(1) Zero (2) $2kQ/a^2$ in the positive x-direction
(3) $2kQ/a^2$ in the negative x-direction (4) $4kQ/a^2$ in the positive x-direction

15. Two equal negative charges – q are fixed at the fixed points (0, a) and (0, –a) on the Y–axis. A positive charge Q is released from rest at the point on the X–axis. The charge Q will

(1)Execute simple harmonic motion about the origin (2)Move to the origin and remain at rest

(3)Move to infinity (4)Execute oscillatory but not simple harmonic motion

16. Two point charges + 8q and – 2q are located at x = 0 and x = L respectively. The location of a point on the x-axis at which the net electric field due to these two point charges are zero is:

(1)8L (2)4L (3)2L (4)L/4

17 Two charged spheres separated at a distance exert a force F on each other. If they are immersed in a liquid of dielectric constant 2, then what is the net force (if all conditions are the same) on each space?

(1)F/2 (2)F (3)2F (4)4F

18 What is the SI unit of permittivity of free space?

(1)Weber (2)Farad

(3)$C^2N^{-1}m^{-2}$ (4)$C^2N^{-1}m^2$

19 How many electrons must be removed from a neutral metal plate to give it a charge of +1.0 C?

(1)6.25 times 10^{18} (2)1.6 times 10^{19}
(3)6.25 times $10^{\wedge 19}$ (4)1.6 times $10^{\wedge 18}$

20 Two identical charged spheres exert an initial electrostatic force F on each other. They are touched together momentarily and then placed back to their original distance apart. The new force is F'. Which of the following is true?

(1) F' > F (2)F' < F
(3) F' = F (4) Cannot determine

ASSIGNMENT –3

ASSERTION & REASON QUESTIONS

Direction In the following questions, a statement of Assertion is followed by a corresponding statement of Reason. Of the following statements, choose the correct one.
(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

1. Assertion: Coulomb force and gravitational force follow the same inverse-square law.

Reason: Both laws are same in all aspect.

2. Assertion: A positive point charge initially at rest in a uniform electric field starts moving along electric lines of force. (Neglect all other forces except electric forces.)

Reason: A point charge released from rest in an electric field always moves along the line of force.

3. Assertion: In a uniform electric field electron moves in the opposite direction of electric field.

Reason: This is because of the negative charge of an electron.

4. Assertion: If an electric dipole of dipole moment 30 × 10−5C − m is enclosed by a closed surface, the net flux coming out of the surface will be zero.

Reason: Electric dipole consists of two equal and opposite charges.

5. Assertion: Upon displacement of charges within a closed surface, E at any point on the surface does not change.

Reason: The flux crossing through a closed surface is independent of the location of charge within the surface.

6. Assertion: E in outside vicinity of a conductor depends only on the local charge density σ and it is independent of the other charges present anywhere on the conductor.

Reason: E in outside vicinity of a conductor is given by $\sigma/s0$

7. Assertion: Negatively charged body means that the body has gained electrons while a positively charged body means the body has lost some of its electrons.

Reason: Charging process involves transfer of electrons.

8. Assertion: Particles such as photon or neutrino which have no rest mass are uncharged

Reason :Charge cannot exist without mass.

OTHER ASSERTION & REASON QUESTIONS

1.Assertion: Electric lines of force can never be closed loops, as a line can never start and end on the same charge.

Reason: The number of electric lines of force originating or terminating on a charge is proportional to the magnitude of the charge.

2. Assertion (A): Gauss's law shows diversion when the inverse square law is not obeyed.

Reason (R): Gauss's law is a consequence of the conservation of charge.

3. **Assertion (A):** A charge q is placed in a cube of side b. The flux associated with the cube is independent of side length**.**

Reason (R): Gauss's law is independent of the size of the Gaussian surface**.**

4. Assertion : A metallic shield in form of a hollow shell may be built to block an electric field.
Reason : In a hollow spherical shield, the electric field inside it is zero at every point.

5. Assertion : When bodies are charged through friction, there is a transfer of electric charge from one body to another, but no creation or destruction of charge.
Reason : This follows from conservation of electric charges.

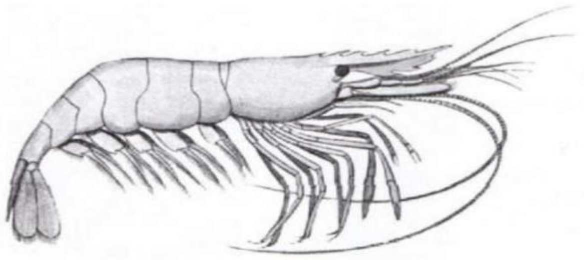
.

ASSIGNMENT –4

CASE STUDY BASED QUESTIONS

Case Study 1

Animals emit low frequency electric fields due to a process known as osmoregulation. This process allows the concentration of ions (charged atoms or molecules) to flow between the inside of our bodies and the outside. In order for our cells to stay intact, the flow of ions needs to be balanced. But balanced doesn't necessarily mean equal. The concentration of ions within a shrimp's body is much lower than that of the sea water it swims in. Their voltage or potential difference generated between the two concentrations across 'leaky' surfaces, can then be measured.



Read the given passage carefully and give the answer of the following questions: Q1. The Gaussian surface for ions in the body of animals:

a. can pass through a continuous charge distribution

b. cannot pass through a continuous charge distribution

c. can pass through any system of discrete charges

d. can pass through a continuous charge distribution as well as any system of discrete charges Q2. Gauss's law is valid for:

a. any closed surface

b. only regular close surfaces

c. any open surface

d. only irregular open surfaces

Q3. The electric field inside a shrimp's body of uniform charge density is:

a. zero

b. constant different from zero

c. proportional to the distance from the curve

d. None of the above

Q4. If a small piece of linear isotropic dielectric is swallowed by a shrimp and inside the body it is influenced by an electric field E, then the polarisation P is:

a. independent of E

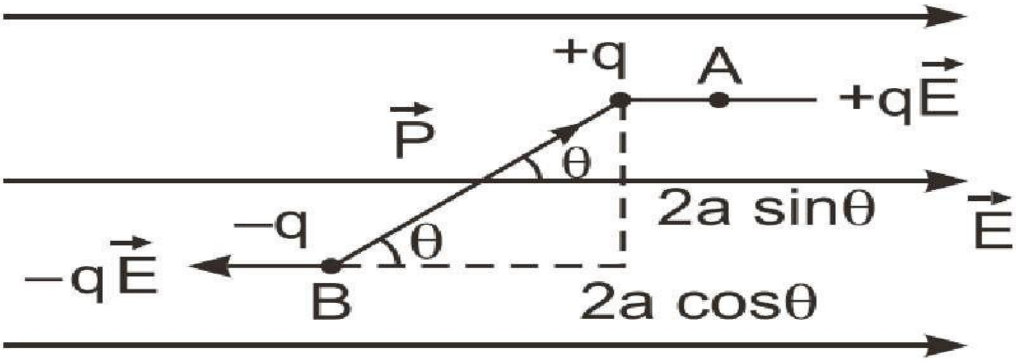
b. inversely proportional to E

c. directly proportional to $\sqrt{E}$

d. directly proportional to E

Case Study 2

When electric dipole is placed in uniform electric field, its two charges experience equal and opposites forces, which cancel each other and hence net force on electric dipole in uniform electric field is zero. However, these forces are not collinear, so they give rise to some torque on the dipole. Since, net force on electric dipole in uniform electric field is zero, so no work is done in moving the electric dipole in uniform electric field. However, some work is done in rotating the dipole against the torque acting on it.



Read the given passage carefully and give the answer of the following questions:

Q 1. The dipole moment of a dipole in a uniform external field $\vec{E}$ is $\vec{P}$. What will be the torque $\vec{\tau}$ acting on the dipole?

Q 2. An electric dipole consists of two opposite charges, each of magnitude 1.0 μC separated by a distance of 2.0 cm. The dipole is placed in an external field of 10^5 NC^{-1}. What is the maximum torque on the dipole?

Q 3. Torque on a dipole in uniform electric field is minimum when θ is equal what angle?

Q 4. When an electric dipole is held at an angle in a uniform electric field, what are the net force *F* and torque τ on the dipole?

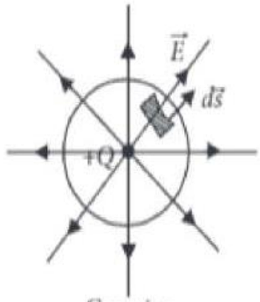
Case Study 3

Surface charge density is defined as charge per unit surface area of surface charge distribution *i.e.*, $\sigma = \frac{dq}{dS}$. 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 having magnitude of 17.0×10^{-22} C/m^2 as shown. The intensity of electric field at a point is $E = \frac{\sigma}{\varepsilon_0}$, where ε_0 = permittivity of free space.

Q1. What is the value of E in the outer region of the first plate ? Q2. What is the value of E in the outer region of the second plate ? Q3. What will be the value of E between the plates ?
Q4. What is the ratio of E from right side of B at distances of 2 cm and 4 cm, respectively ?

Case Study 4

Gauss's law and Coulomb's law, although expressed in different forms, are equivalent ways of describing the relation between charge and electric field in static conditions. Gauss's law is $\varepsilon_0\phi = q_{encl}$, when q_{encl} is the net charge inside an imaginary closed surface called Gaussian surface. $\phi = \oint \vec{E} \cdot d\vec{A}$ gives the electric flux through the Gaussian surface. The two equations hold only when the net charge is in vacuum or air.



Gaussian spherical surfaces

OTHER CASE STUDY BASED QUESTIONS

1. An electric field is the physical field that surrounds electrically charged particles. Charged particles exert attractive forces on each other when their charges are opposite, and repulse each other when their charges are the same. Because these forces are exerted mutually, two charges must be present for the forces to take place. The electric field of a single charge (or group of charges) describes their capacity to exert such forces on another charged object. These forces are described by Coulomb's law, which says that the greater the magnitude of the charges, the greater the force, and the greater the distance between them, the weaker the force. The Coulomb force on a charge of magnitude q at any point in space is equal to the product of the charge and the electric field at that point. F = qE. Also the electric field due to a point charge is given by E =q/4€0πr^2

1.The electric field required to keep a water drop of mass 'm' to remain suspended, when charged withelectron is:

A. mg B. mg/e C. emg D. em/g

2.Two charges +5 μC and +10 μC are placed 20 cm apart. The electric field at the midpoint between the two charges is:

A. 4.5 x 10^6 N/C towards +5 μC B. 13.5 x 10^6 N/C towards +5 μC

C. 4.5 x 10^6 N/C towards +10 μC D. 13.5 x 10^6 N/C towards +10 μC

3. Two point charges placed in a medium of dielectric constant 5 are at a distance r between them, experience an electrostatic force F between them. Force in vacuum at the same distance r will be:

A. 5 F B. F C. F/2 D. F/5

4. There is an electric field in the X-direction. If the work done in moving a charge of 0.2 C through a distance of 2m along a line making an angle of 60^0 with X-axis is 4 J, then what is the value of E?

A. √3 N/C B. 4 N/C C. 5 N/C D. 20 N/C

OR

A particle of mass 'm' and charge 'q' is placed at rest in a uniform electric field 'E' and then released, the kinetic energy attained by the particle after moving a distance 'x' will be:

A. q^2Ex B. qEx C. qE^2y D. qEy^2

2.An electric dipole is a system of two equal and opposite charges separated by a small distance. Every electric dipole has an electric dipole moment. It is measured as the product of one of the charges and the distance between the charges. When an electric dipole of dipole moment $\vec{P}$ is placed in a uniform electric field $\vec{E}$, the net force acting on it will be zero but a torque will be acting on the dipole which is given by $\vec{\tau} = \vec{P} \times \vec{E}$.

1. What is the SI unit of electric dipole moment?

A. C-m^{-1} B. C^{-1}m C. C-m D. None of these

2. 2 C and -2 C are two equal charges separated by a distance of 10 cm, is placed in a uniform electric field of strength 10 NC^{-1} with its axis making an angle of 90^0 with the field. What is the torque acting on it?

A. 200 N-m B. 20 N-m C. 2 N-m D. 0.2 N-m

3. On which among the following factors does dipole moment depend?

A. Length only B. Length and charge of a dipole

C. Dielectric constant and charge of the medium D. Charge only

4. If a force F is acting on a point charge that is kept on the axis of an electric dipole, and if the distance of the point charge is tripled from the dipole, what will be the amount of force?

A. 20F B. F/27 C. F/25 D. F/40

OR

……………will act on an electric dipole if it is placed in a non-uniform electric field.

A. Force only B. Both torque and force C. No force but torque D. None of these

3. Electric Charge is a scalar quantity. Charge transfer from one body to another which means they are movable. Like charges repel each other and unlike charges attract each other. Charge is always linked with mass. The SI unit of electric charge is Coulomb (C). The charge on a body is an integral multiple of the basic unit of charge of an electron or proton. Electric charge is neither created nor destroyed, but can be transferred from one body to another. Conductors allow charges to flow easily through them, while insulators do not. Surface charge density is measured as the charge per unit area of the surface.

1. Which of the following is not the property of charge?

A. Charge is additive B. A charge is self-destructive

C. Quantization of charge D. Charge is conserved

2. Which among the following is the safest place during lightning?

A. Under a tree B. High wall

C. House with lightning arrester D. Under a light post

3. What is the SI unit of surface charge density?

A. C B. Cm^{-2} C. Cm^{-1} D. Cm^{-3}

4. If a system is having four charged particles with charges -2 C, +3 C, -1 C and -5 C, what is the total charge of the system?

A. -4 C B. - 5 C C. +2 C D. +5 C

OR

Identify the Correct statement:

A. On giving negative charge to an object, its mass increases

B. On giving positive charge to an object, its mass remains constant

C. An object gets negatively charged when electrons are removed from it

D. It is possible to charge an object by 2 x 10^{-19} C

ASSIGNMENT – 5

SHORT QUESTIONS

1. (a) Name any two basic properties of electric charge.

   (b) What does $q_1 + q_2 = 0$ signify in electrostatics?

2. Define dielectric constant of a medium in terms of force between electric charges. What is its S.I. unit?
3. Two same balls having equal positive charge $'q'$ Coulombs are suspended by two insulating strings of equal length. What would be the effect on the force when a plastic sheet is inserted between the two ?
4. Define electric field intensity. Write its S.I. unit. Is it a scalar or vector quantity?

5. (i) What is the physical significance of electric field ?

   (ii) Write an expression for force acting on a test charge q_0 placed in a uniform electric field.

6. State any two properties of electric field lines.

7. What is the importance of electric field lines?
8. (i) A point charge $+Q$ is placed in the vicinity of a conducting surface. Trace the field lines between the charge and the conducting surface.

(ii) Draw the electric field lines due to uniformly charged thin spherical shell when charge on the shell is (a) positive, (b) negative

9. Why do the electric field lines never cross each other?

10. Why do the electric filed lines are always normal to the surface of a conductor?

LONG ANSWER QUESTIONS

1.(a) Derive an expression for the electric field E due to a dipole of length '2a' at a point distant r from the centre of

the dipole on the axial line.

(b) Draw a graph of E versus r for r >> a.

2. Derive an expression for the electric field intensity at a point on the equatorial line of an electric dipole of dipole moment $\bar{p}\rightarrow$ and

Length $2a$. What is the direction of this field?

3. Using Gauss's law, deduce the expression for the electric field due to uniformly charged spherical conducting shell of

Radius R at a point (i) outside and (ii) inside the shell.

Plot a graph showing variation of electric field as a function of r > R and r< R.

FORMULAE

1. Quantization of Charge

Formula

$$q = \pm ne$$

Where:

- q= charge on the body
- n= integer (1, 2, 3...)

2. Conservation of Charge

Formula

$$\text{Total charge before interaction} = \text{Total charge after interaction}$$

3. Coulomb's Law

Formula

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

or

$$F = k\frac{q_1 q_2}{r^2}$$

Where

- F= electrostatic force
- q_1, q_2= charges
- r= distance between charges

4. Coulomb's Law in Medium

Formula

$$F = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

Where

$$\varepsilon = \varepsilon_0 K$$

K= dielectric constant

Hence,

5. Principle of Superposition

Formula

$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots$$

6. Electric Field

Formula

$$\vec{E} = \frac{\vec{F}}{q_0}$$

Where

- E= electric field
- F= force on test charge
- q_0= test charge

SI Unit

7. Electric Field due to a Point Charge

Formula

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

or

8. Electric Field due to Multiple Charges

Formula

9. Electric Dipole

Dipole Moment

$$\vec{p} = q(2a)$$

or

$$p = qd$$

Where

- q= charge
- $d = 2a$= distance between charges

SI Unit

10. Electric Field on Axial Line of Dipole

Formula

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$$

(valid when $r \gg a$)

11. Electric Field on Equatorial Line

Formula

$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$$

(valid when $r \gg a$)

12. Torque on Electric Dipole

Formula

$$\tau = pE\sin\theta$$

Explanation

- θ= angle between dipole moment and electric field.
- Torque tends to align the dipole with the electric field.

13. Potential Energy of Dipole

Formula

$$U = -pE\cos\theta$$

Explanation

- Minimum when $\theta = 0°$.
- Maximum when $\theta = 180°$.

14. Electric Flux

Formula

$$\Phi = \vec{E}\cdot\vec{A}$$

or

$$\Phi = EA\cos\theta$$

Where

- A= area
- θ= angle between electric field and area vector

SI Unit

15. Special Cases of Electric Flux

(i) Surface perpendicular to field

$$\Phi = EA$$

(ii) Surface parallel to field

$$\Phi = 0$$

(iii) Inclined surface

$$\Phi = EA\cos\theta$$

16. Gauss's Law

Formula

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enclosed}}}{\varepsilon_0}$$

Explanation

The total electric flux through any closed surface equals the enclosed charge divided by the permittivity of free space.

17. Electric Field due to Infinite Line Charge

Formula

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

Where

• λ= charge per unit length

18. Electric Field due to Infinite Plane Sheet

Formula

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

Where

• σ= surface charge density

19. Electric Field between Two Oppositely Charged Parallel Sheets

Formula

20. Charge Density Formulas

Linear Charge Density

$$\lambda = \frac{Q}{L}$$

Unit:

Surface Charge Density

$$\sigma = \frac{Q}{A}$$

Unit:

Volume Charge Density

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

Unit:

ASSIGNMENT-6

ANSWER KEY

ASSIGNMENT (1)

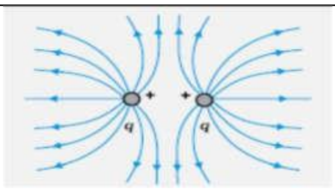
Q.No.	EXPECTED ANSWER/VALUE POINTS	VALUE POINTS	TOTAL MARKS
1	(a)	1	1

2		1	1
3	(d) As, Coulomb's attraction = centripetal force $\therefore \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2} = mr\omega^2 = \frac{4\pi^2 mr}{T^2}$ $\Rightarrow T = \left(\frac{4\pi^2 mr^3}{kq_1 q_2}\right)^{1/2}$	1	1
4	(b) where, EA= electric field at M due to charge placed at A, EB= electric field at M due to charge placed at B and EC = electric field at M due to charge placed at C. As seen from figure |EB| = |EA|, so net electric field at M, Enet = |Ec|, in the direction of vector 2 .	1	1

5	(c)	1	1

6	(a)	1	1
7	(d)	1	1
8	(c)	1	1
9	(b)	1	1

10	(d)	1	1
11	(a)	1	1
12	(b)	1	1
13	**(a)** When we produce charge $q1$ on a body by rubbing it against another body which gets a charge $q2$ in the process, then $q1$ and $q2$ both are equal in magnitude but opposite in polarities .Hence, $q1 + q2 = 0$.	1	1
14	(a) At macroscopic level, we deal with charges of order $1\mu C = 10^{-6}C$, which has $\frac{10^{-6}}{1.6\times10^{-19}} = 0.625 \times 10^{13} = 10^{13}$ charges. Addition of a few hundred of e charges do not make any physically observable effect on attraction or repulsion, so quantisation can be ignored.	1	1

15	**(a)**	1	1
16	**(a)**	1	1
17	**Coulomb's law in vector form :** $$\vec{F} = \frac{1}{4\pi \varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r} = \frac{1}{4\pi \varepsilon_0}\frac{q_1 q_2}{r^2}\frac{\vec{r}}{\lvert r \rvert} = \frac{1}{4\pi \varepsilon_0}\frac{q_1 q_2}{r^3}\vec{r}$$ **Importance :** (i) As $\hat{r}_{21} = -\hat{r}_{12} \Rightarrow \vec{F}_{21} = -\vec{F}_{12}$ __________ Which shows that coulomb's force obey Newton's third law of motion (ii) As the Coulomb's force acts along $\vec{F}_{21}$ or $-\vec{F}_{12}$, i,e, along the line joining the centres of two charges, so they are central forces OR .(i) charges must be stationary point charges (ii) distance between the point charges $r > 10^{-15}\ m$ Any two limitations	1 1 1 1	2
18		1	2
		1	
19	**(i)** $\phi_1 = \frac{2Q}{\varepsilon_0}$ & $\phi_2 = \frac{2Q+4Q}{\varepsilon_0} = \frac{6Q}{\varepsilon_0}$ $\Rightarrow \frac{\phi_1}{\phi_2} = \frac{2Q}{\varepsilon_0} / \frac{6Q}{\varepsilon_0} = 1/3$ **(ii)** $\phi_1 = \frac{2Q}{\epsilon_0 K} = \frac{2Q}{\epsilon_0 \epsilon_r}$	1 1	2

20	• $\frac{1}{4h\epsilon_0}\frac{q1}{r^2} = \frac{1}{4h\epsilon_0}\frac{q2}{r^2}$ $\Rightarrow \frac{4}{x^2} = \frac{1}{(2-x)^2}$ $\Rightarrow 2(2-x) = x \Rightarrow x = \frac{4}{3}\,m$ OR **Torque :** $\tau = pE\sin\theta$ **Vector form :** $\vec{\tau} = \vec{p} \times \vec{E}$ **Direction of $\vec{\tau}$:** Direction of torque is ⊥ to the plane containing $\vec{p}$ and $\vec{E}$ given by right hand screw rule **Two pairs of ⊥ vectors :** (i) $\vec{\tau}$ and $\vec{p}$ (ii) $\vec{\tau}$ and $\vec{E}$	1 1 1 1	2
21	. **Given :** $E = 6 \times 10^3\hat{i}$ N/C, $a = 10\ cm = 10 \times 10^{-2} m$, $\phi = ?$ In first case, $\phi = E\,ds\cos 0 = 6 \times 10^3 \times (10 \times 10^{-2})^2 = 60$ N m²/C In second case, $\phi = E\,ds\cos(90-30) = E\,ds\cos 60 = 6 \times 10^3 \times (10 \times 10^{-2})^2 \times \frac{1}{2} = 30$ N m²/C	1 1	2
22	**(i)** Let an electric dipole of dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$ as shown in figure. **Force :** Force on $+q$, $F_1 = qE$ Force on $-q$, $F_2 = -qE$ Hence net force on the dipole $F = qE - qE = 0$	½	3

<table>
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Torque : Two equal and opposite forces $-qE$ and $+qE$ forms a couple

which tries to rotate the dipole. Torquedue to this couple

τ = either force X⊥ distance= qE x $2a \sin\theta$

= qE x $2a \sin\theta$

$\Rightarrow \tau = pE \sin\theta = \vec{p} \times \vec{E}$

(ii) If the electric field is non-uniform, the net force on the dipole will not be zero hence there will be the

translator motion of the dipole.

(iii) (a) Net force will be in the direction of increasing electric field.

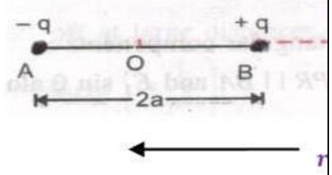
(b) Net force will be in the direction opposite to the increasing field

</td><td>½

1

1</td><td></td></tr>
<tr><td>23</td><td>

. Let $\vec{E_1}$ and $\vec{E_2}$ be the electric field at P due to $-q$ and $+q$ charges respectively then



$|\vec{E_1}| = \frac{q}{4\pi\varepsilon_0 (r+a)^2}$ along PA

& $|\vec{E_2}| = \frac{q}{4\pi\varepsilon_0 (r-a)^2}$ along BP

Obviously the resultant electric field intensity at P

$|\vec{E}| = |\vec{E_2}| - |\vec{E_1}| = \frac{q}{4\pi\varepsilon_0 (r-a)^2} - \frac{q}{4\pi\varepsilon_0 (r+a)^2} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right] = 4\pi$

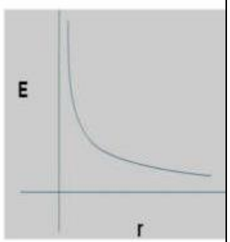
⇨ $|\vec{E}| = \frac{q}{4\pi\varepsilon_0}\frac{4ar}{(r^2-a^2)^2}$

⇨ $|\vec{E}| = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{(r^2-a^2)^2}$ $[\because p = 2qa]$

Obviously, if $r \gg a$, then

$E = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{(r^2)^2}$

⇨ $\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}}$



direction of $\vec{E}$ is along the direction of dipole moment $\vec{p}$

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. Let, $\vec{E_1}$ and $\vec{E_2}$ be the electric field intensity at at P due to $-q$ & $+q$ charges respectively, then

$$|\vec{E_1}| = |\vec{E_2}| = \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(\sqrt{r^2+a^2}\right)^2}$$

$$\Rightarrow |\vec{E_1}| = |\vec{E_2}| = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)} \quad \text{---------(1)}$$

On resolving $\vec{E_1}$ and $\vec{E_2}$ in horizontal and vertical components, resultant electric field intensity

$$|\vec{E}| = E_1\cos\theta + E_2\cos\theta = 2E_1\cos\theta$$

$$\Rightarrow |\vec{E}| = 2\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}\frac{a}{\sqrt{r^2+a^2}} \quad \left[\because \cos\theta = \frac{a}{\sqrt{r^2+a^2}}\right]$$

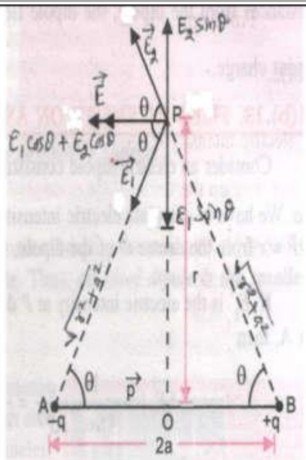
$$\Rightarrow |\vec{E}| = \frac{1}{4\pi\varepsilon_0}\frac{2qa}{(r^2+a^2)^{3/2}}$$

$$\Rightarrow |\vec{E}| = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2+a^2)^{3/2}} \quad [\because p = 2qa]$$

Obviously, if $r \gg a$, then

$$\boxed{|\vec{E}| = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}}$$

direction of $\vec{E}$ is opposite to that of dipole moment $\vec{p}$



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. Charge enclosed by Gaussian surface, $q = \lambda l$

At the part I and II of Gaussian surface $\vec{E}$ and $\hat{n}$ are $\perp$, so flux through surfaces I and II is zero.

By Gauss's law, $\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$

$$\Rightarrow \oint E ds \cos 0 = \frac{q}{\varepsilon_0}$$

$$\Rightarrow E\oint ds = \frac{q}{\varepsilon_0}$$

$$\Rightarrow E(2\pi r l) = \frac{\lambda l}{\varepsilon_0}$$

$$\Rightarrow E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

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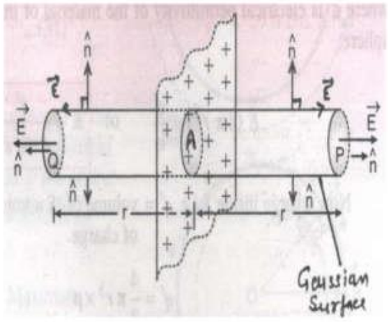
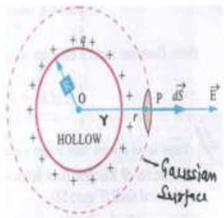
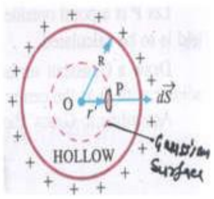
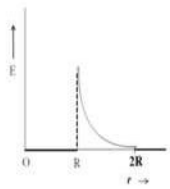
26	. Let us consider a Gaussian surface as shown. At the curved part of Gaussian surface $\vec{E}$ and $\hat{n}$ are $\perp$, so flux through curved surface is zero.  By Gauss's law, $\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$ ⇨ $\oint Eds\cos 0 = \frac{q}{\varepsilon_0}$ ⇨ $E\oint ds = \frac{q}{\varepsilon_0}$ ⇨ $E(2A) = \frac{q}{\varepsilon_0}$ ⇨ $E = \frac{q}{2\varepsilon_0 A} = \frac{\sigma}{2\varepsilon_0}$ **Direction of field :** (i) If the sheet is positively charged the field is directed away from it (ii) If sheet is negatively charged the field is direct towards it	½ ½ 1 ½ ½	3
27	. **(i) Outside the shell** $(r > R)$ Let us consider the Gaussian surface as shown  by Gauss's law, $\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$ ⇨ $\oint Eds\cos 0 = \frac{q}{\varepsilon_0}$ ⇨ $E\oint ds = \frac{q}{\varepsilon_0}$ ⇨ $E(4\pi r^2) = \frac{q}{\varepsilon_0}$ ⇨ $\boldsymbol{E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}}$ **(ii) Inside the shell** $(r < R)$ Let us consider the Gaussian surface as shown   By Gauss's law $\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$ But, charge inside the spherical shell, i,e, q = 0 ⇨ $\oint E\,ds\cos 0 = 0$ ⇨ $\boldsymbol{E = 0}$	½ 1 1 ½	3
28	**(i)** $\phi = \phi_L + \phi_R = E_x ds\cos 180 + E_x ds\cos 0$ ⇨$\phi = (\alpha a)a^2(-1) + [\alpha(a + a)]a^2(1) = -\alpha a^3 + 2\alpha a^3$	1 1	3

	$\Rightarrow \phi = \alpha a^3$ **(ii)** $\phi = \frac{q}{\varepsilon_0} \Rightarrow q = \varepsilon_0 \phi = \varepsilon_0 \alpha a^3$ OR	1 1 1 1	
29	(i) b (ii) b (iii) d (iv) c	1 1 1 1	4
30	(i) b (ii) c (iii) b (iv) d	1 1 1 1	4
31	(i)	1	5

	ABC is equilateral (side l). Charges $+2\,\mu C$ at B, C. Let M be midpoint of BC; $AM = \frac{\sqrt{3}}{2}l$. Field at A due to one corner charge: $E_1 = \frac{kQ}{l^2}, \quad Q = 2\,\mu\mathrm{C}$ Component along AM: $E_1 \cos 30^\circ = \frac{kQ}{l^2} \cdot \frac{\sqrt{3}}{2}$. From both B and C (transverse parts cancel): $E_{BC} = 2 \cdot \frac{kQ}{l^2} \cdot \frac{\sqrt{3}}{2} = \frac{\sqrt{3}\,kQ}{l^2}$. Charge q at M makes field at A: $E_q = \frac{k\lvert q\rvert}{(AM)^2} = \frac{k\lvert q\rvert}{(\frac{\sqrt{3}}{2}l)^2} = \frac{4k\lvert q\rvert}{3l^2}$. For net field at A to be zero, $E_q = E_{BC}$ and it must oppose $E_{BC} \Rightarrow q$ is **negative**. $\frac{4\lvert q\rvert}{3l^2} = \frac{\sqrt{3}\,kQ}{l^2} \;\Rightarrow\; \lvert q\rvert = \frac{3}{4}\sqrt{3}\,Q = \frac{3}{4}\sqrt{3}\,(2\,\mu\mathrm{C}) = \frac{3\sqrt{3}}{2}\,\mu\mathrm{C} \approx 2.60\,\mu\mathrm{C}.$ $\boxed{q = -\frac{3\sqrt{3}}{2}\,\mu\mathrm{C}\ (\approx -2.60\,\mu\mathrm{C})}$ (ii) OR (i)Statement Vector form of Coulomb’s law Derivation (ii)E1=9x10^{9}2x10/. 1 E2 = 9x10^{9}2x20/.2 Resultant Field E = 0 F = 0	1 1 1 1 1 1 1 1 1	
32	(i)Definition	½	

	Unit (ii) **Gauss's Law** states that the total electric flux through a closed surface is equal to the net electric charge enclosed within that surface divided by the vacuum permittivity ε0 This law is fundamentally based on the **inverse-square dependence** of the electric field with distance, as described by **Coulomb's Law**. Coulomb's Law asserts that the electric field E due to a point charge decreases with the square of the distance r from the charge: The inverse-square nature ensures that as the distance from the charge increases, the electric field diminishes proportionally to 1/r21/r^21/r2. This relationship is crucial for Gauss's Law because it leads to a constant total flux through a spherical surface surrounding a point charge, regardless of the sphere's radius. If the electric field did not follow an inverse-square law, the total flux through such a surface would vary with its size, contradicting Gauss's Law (iii) finding force OR (i) (a) No change (b) No change (c) No change	½ 1 1 2 1 1 1 1 1	
33	(i)EA = kq/r^2 along OC EC = kq/r^2 along OC E1 = EA+ EC = $2kq/r^2$ along OC	1	

	$EB = kq/r^2$ along OB $ED = kq/r^2$ along OB	1	

	$E2 = EB + ED = 2kq/r^2$ along OB $E = (E1)^2 + (E2)^2$ (ii) For shell A $QA=(+6q)+(-2q)=+4q$. For shell B: $QB=(-4q)+(+8q)=+4q$. For shell C: $QC=(+14q)+(-10q)=+4q$ .EA =EB = EC OR Difference Diagram Definition Explanation	1 1 1 ½ ½ ½ ½ 1 1	

		1	

ANSWER - ASSIGNMENT – 2

MULTIPLE CHOICE QUESTIONS

1. Answer (4) Due to lack of electron body get positive charge
2. Answer (2) Due to similar (like charge), repulsion force is possible but attraction force may be due to uncharged body.
3. Answer (3) Excess charge spread on outer surface only from their property
4. Answer (4) Coulomb’s law and Newton’s law of gravitation are inverse square law.
5. Answer (4)
6. Answer (3)

First case : $Q \overset{r}{\text{-------------}} Q$

$F_1 = F = \frac{KQ^2}{r^2}$ ...(i)

Second case : $\frac{Q}{2}$ $\xleftarrow{F_1}$ $\frac{Q}{2}$ $\xrightarrow{F_2}$ Q (separations $\frac{r}{2}$, $\frac{r}{2}$)

$|F_{Net}| = |F_2 - F_1|$

$= \frac{K\,Q^2 4}{4.r^2} - \frac{K\,Q^2\,4}{2r^2}$

$\frac{KQ^2}{r^2} = F$

Force remain’s constant

7. Answer (4)
8. Answer (4) A rest charge cannot be converted into energy.
9. Answer (1)
10. Answer (1)

Force between both is

$F = \frac{K\,Q\,(q-Q)}{r^2}$

If F = maximum then

$\frac{dF}{dQ} = 0$

So $Q = \frac{q}{2}$

So both charge be $\frac{q}{2}$, $\frac{q}{2}$

11. Answer (3)
12. Answer (2)
13. Answer (3)
14. Answer (1)
15. Answer (4)

= mg neE

q = mg n =

E mg/eE

16.

Answer (2)

$P_1 = Q.a$

$P_2 = Q.a$

$$P = \sqrt{P_1^2 + P_2^2 + 2P_1P_2\cos\theta}$$

$$P_N = \sqrt{3}\ Q.a$$

17. Answer (3)
18. Answer (4)
19. Answer (1)
20. Answer (4)

OTHER MUTIPLE CHOICE QUESTIONS

ANSWERS

1. Answer (3)
When a positively charged body is connected to the earth, then electrons from the earth flow into the body. Thus (3) is correct option.

2.Answer (4)

First charge, $q_1 = q$

Second charge, $q_2 = q$

Third charge, $q_3 = q$

Force between any two charge

$F_1 = F_2 = F$

Force acting on a charge due to other two charges, placed at the corners of an equilateral triangle is F and it is acting at an angle 60°.

Therefore, net force on either charge

$$= \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

$$= \sqrt{F^2 + F^2 + 2F \cdot F\cos 60°}$$

$$= \sqrt{F^2 + F^2 + 2F^2 \times 0.5}$$

$$= \sqrt{3F^2}$$

$$= \sqrt{3}F$$

Thus (D) is correct option.

3.Answer (1)

4. Answer (4)

5. Answer (1)
Angle between electric field and area vector is 90 degree

6. Answer (4)
From the whole cube the flux is q /ϵ0 therefore from the one wall it is 1/6th of q /ϵ0 .

7. Answer (2)
The final charger on + q become q-q/4 =3q/4

And the final charge on – q becomes -q+q/4= -3q/4

8. Answer(1)

9. Answer (2)

Flux is the dot product of electric field vector and area vector

10. Answer (2)

11.Answer (3)

In the equatorial plane, the fields from the dipole's positive and negative charges are equal in magnitude and opposite in direction at the midpoint. Their vector sum cancels out, resulting in a zero field at that specific location.

13. Answer(1)

14. Answer(1)

15. Answer(2)

16. Answer (3)

17. Answer(1)

18. Answer(3)

19 Answer (1)

20 . Answer (1)

ANSWER- ASSIGNMENT –3

ASSERTION & REASON QUESTIONS

ANSWERS

1. Ans: C
2. Ans: C
3. Ans: A
4. Ans : A
5. Ans : D
6. Ans : D
7. Ans : A
8. Ans: A

OTHER ASSERTION & REASON QUESTIONS

ANSWERS

1.Ans:B

2.Ans:B

3.Ans:A

4.Ans:A

5.Ans:A

ANSWER-ASSIGNMENT – 4

CASE STUDY BASED QUESTIONS

CASE STUDY 1

Answer

1. (a) can pass through a continuous charge distribution
2. (a) any closed surface
3. (a) zero
4. (d) directly proportional to E

CASE STUDY 2

Answer

1. As, $\tau =$ either force $\times$ perpendicular distance between the two forces

$$\tau = qE \times 2a \sin\theta \quad \text{or} \quad \tau = PE \sin\theta$$

or $$\tau = \vec{P} \times \vec{E} \qquad [\because q(2a) = P]$$

2. The maximum torque on the dipole in an external electric field is given by

$$\tau = PE = q(2a) \times E$$

Here, $q = 1\,\mu C = 10^{-6}$ C, $2a = 2$ cm $= 2 \times 10^{-2}$ m

$E = 10^5$ NC^{-1}, $\tau = ?$

$$\therefore \quad \tau = 10^{-6} \times 2 \times 10^{-2} \times 10^5 = 2 \times 10^{-3} \text{Nm}$$

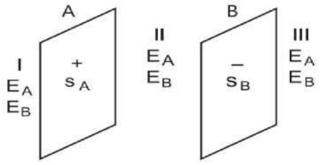
3. When θ is 0° or 180°, τ is minimum, which means the dipole moment should be parallel to the direction of the uniform electric field.

4. Net force is zero and torque acts on the dipole, trying to align p with E.

CASE STUDY 3

Answer

1. There are two plates A and B having surface charge densities, $\sigma_A = 17.0 \times 10^{-22}$ C/m^2 on A and $\sigma_B = -17.0 \times 10^{-22}$ C/m^2 on B, respectively.



According to Gauss's theorem, if the plates have same surface charge density but having opposite signs, then the electric field in region I is zero.

$$E_I = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

2. The electric field in region III is also zero.

$$E_{III} = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

3. In region II or between the plates, the electric field

$$E_{II} = E_A - E_B = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

$$= \frac{\sigma(\sigma_A \text{ or } \sigma_B)}{\varepsilon_0} = \frac{17.0 \times 10^{-22}}{8.85 \times 10^{-12}}$$

$$\therefore \quad E = 1.9 \times 10^{-10}\ \text{NC}^{-1}$$

4. Electric field due to an infinite plane sheet of charge does not depend on the distance of observation point from the plane sheet of charge.
So, ratio of E will be 1 : 1.

CASE STUDY 4

Answer

OTHER CASE STUDY BASED ANSWERS

ANSWERS

CASE STUDY 1

Ans 1 B

Ans 2 A

Ans 3 A

Ans 4 D OR B

CASE STUDY 2

Ans 1 C

Ans 2 C

Ans 3 B

Ans 4 B OR B

CASE STUDY 3

Ans 1 B

Ans 2 C

Ans 3 B

Ans 4 B OR A

ANSWER -ASSIGNMENT – 5

Short Answers

1. **(a)** (i) Quantization of charge (ii) Conservation of charge

(b) It signifies that charges are algebraically additive and here q_1&q_2 are equal and opposite

2. **Dielectric constant** : It is defined as the ratio of the force (F_{vacuum}) between any two point charges placed at certain distance apart in vacuum to the force (F_{medium}) between them when placed at equal distance in that medium

i.e., $K = \frac{F_{vacuum}}{F_{medium}}$ It has no unit

3. $F = \frac{1}{4\pi\varepsilon_0 K}\frac{q_1 q_2}{r^2} \Rightarrow F \propto \frac{1}{K}$ But for plastic $K > 1$ hence the force between the two balls will decrease

4. Electric field intensity : Electric field intensity at any point is defined as the electrostatic force acting on vanishingly small unit positive test charge placed at that point

i.e., $\vec{E} = \lim$

$F\rightarrow$

$q0\rightarrow 0\ q0$

Its. S.I. unit is N/C. It is a vector quantity

5.(i) It gives the magnitude& direction of electric force $(\vec{F})$ experienced by any charge placed at any point.

(ii) $\vec{F} = q_0\vec{E}$

6.(i) Electric filed lines not form closed loops. They start from positive charge and end at negative charge

(ii) Tangent to any point on the electric field line gives the direction of electric field at that point

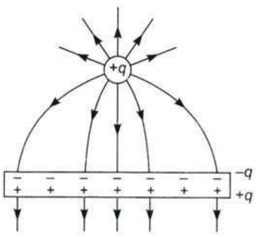
(iii) No two electric field lines can intersect each other

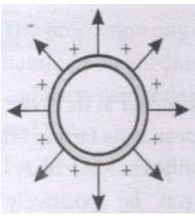
(iv) They are always normal to the surface of a conductor

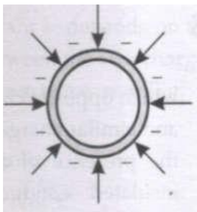
7. Importance :(i) Tangent to any point on the electric field line gives the direction of electric field at that point

(ii) Relative closeness of electric field lines indicates the strength of electric field

8. [Ans. (i) (ii) (a) (iii) (b)







9. Because if they do so, at the point of intersection two tangents can be drawn, which would represent two directions of electric field at that point, which is not possible.

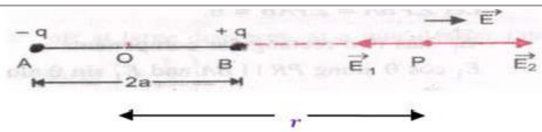
10. If the field lines are not normal, then electric field $\vec{E}$ would have a tangential component which will make electrons move along the surface creating surface currents and the conductor will not be in equilibrium

LONG ANSWER QUESTIONS

1.

1.

[**Ans.** Let $\vec{E_1}$ and $\vec{E_2}$ be the electric field at P due to $-q$ and $+q$ charges respectively then



$$|\vec{E_1}| = \frac{q}{4\pi\varepsilon_0 (r+a)^2} \quad \text{along PA}$$

& $$|\vec{E_2}| = \frac{q}{4\pi\varepsilon_0 (r-a)^2} \quad \text{along BP}$$

Obviously the resultant electric field intensity at P

$$|\vec{E}| = |\vec{E_2}| - |\vec{E_1}| = \frac{q}{4\pi\varepsilon_0 (r-a)^2} - \frac{q}{4\pi\varepsilon_0 (r+a)^2} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right] = \frac{q}{4\pi\varepsilon_0}\left[\frac{(r+a)^2-(r-a)^2}{(r^2-a^2)^2}\right]$$

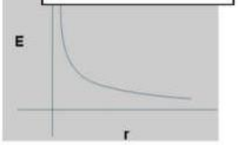
$$\Rightarrow \quad |\vec{E}| = \frac{q}{4\pi\varepsilon_0}\frac{4ar}{(r^2-a^2)^2}$$

$$\Rightarrow \quad |\vec{E}| = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{(r^2-a^2)^2} \qquad [\because p = 2qa]$$

Obviously, if $r \gg a$, then

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{(r^2)^2}$$

$$\Rightarrow \quad \boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}}$$



2.

N.K.AGARWAL

PGT PHYSICS

PM SHRI K.V.NO.3 JHANSI

CHAPTER 2: ELECTROSTATIC POTENTIAL AND CAPACITANCE

Question paper

Class: 12

Allowed Time:3Hrs.

Subject: Physics (042) Max.mark: 70

General Instructions:

(1) There are 33 questions in all. All questions are compulsory.

(2)This question paper has five sections: Section A, Section B, Section C, Section D and Section E

(3) All the sections are compulsory.

(4) Section A contains sixteen questions, twelve MCQ and four assertion reasoning based of one mark each.

Section B contains five questions of two marks each

Section C contains seven questions of three marks each

Section D contains two case study-based questions of four marks each and

Section E contains three long answer questions of five marks each.

(5) There is no overall choice. However, an internal choice has been provided in two question in Section B, one question in

Section C and all three questions in Section E. You have to attempt only one of the choices in such questions.

(6) Use of calculators is not allowed.

(7) You may use the following values of physical constants where ever necessary .

[Section A]

Q1: Equipotential surfaces :

(a) Are closer in regions of large electric fields compared to regions of lower electric fields

(b) Will be more crowded near sharp edges of a conductor

(c) Will always be equally spaced

(d) Both (a) and (b) are correct

Q2: Two particle A and B of same mass but having charges q and 4q respectively are accelerated from rest through different

potential difference V_A and V_B such that they attain same kinetic energy. The value of V_A: V_B -

a) ¼ b) ½ c) 2 d) 4

Q3: At what rate does the electric field change between the plates of a square capacitor of side 5 cm if the plates are spaced

1.2 mm apart and the voltage across them is changing at the rate of 60 V /s.

a) 7.2 × 10-2 Vm^{-1} s^{-1} b) 12× 10-2 Vm^{-1} s^{-1} (c) 30× 10-1 Vm^{-1} s^{-1} (d) 5× 104 Vm^{-1} s^{-1}

Q 4: When a dielectric material is introduced between the plates of a charged condenser than electric field between the plates

(a) Decreases (b) increases (c) remain constant (d) first increases then decreases

Q5: In a certain region of space with volume $0.2m^3$, the electric potential is found to be 5V throughout. The magnitude of

electric field in this region is

(a) zero (b) 0.5 N/C (c) 1 N/C (d) 5 N/C

Q6. The capacitor of capacitance C, charge Q and energy W is stored. If the charge is increased up to 2Q, The energy stored

will be

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

Q7: A capacitor is charged by a battery. After disconnecting the battery, the plates are pulled apart. The potential difference

between plates will:

(a) Increase (b) Decrease (c) Remain same (d) Become zero

Q 8 : A 10 µF capacitor is connected in series with a 20 µF capacitor across a 30 V supply. The charge on each capacitor is:

(a) 100 µC (b) 200 µC (c) 300 µC (d) 400 µC

Q9: A force of 10 Newton acts on a charge particle placed between two plates of a charged capacitor. If one plate of capacitor

is removed then the force acting on that particle will be

a) 5 Newton b)10 Newton c)20 Newton d) zero

Q10:An electron with kinetic energy K_1 enter between plates of a capacitor at an angle α with the plates. It leaves the plate at

an angle β with kinetic energy K_2 , then the ratio of kinetic energies $K_1 : K_2$

a) Cos β /sin α b) Cos β / Cos α c)cos2 β/ cos2 α d) sin2β/cos2α

Q11: A parallel plate capacitor filled with a medium of dielectric constant 10 is connected across a battery and charged. The

dielectric slab is replaced by another slab of dielectric constant 15 then the energy of capacitor will

a) Increase by 50% b) Decrease by 15% c) Increase by 25% d) Increase by 33%

Q12: Hydrogen ion and single ionized Helium atom are accelerated from rest through the same potential difference the ratio

final speed of hydrogen and Helium ions is close to

a) 2:1 b) 1:2 c) 10:7 d) 5:7

For Questions 13 to 16, two statements are given one labelled Assertion (A) and other labelled Reason (R).Select the correct answer to these questions from the options as given below.

(A)Both Assertion and Reason are true and Reason is the correct explanation of Assertion

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

(C)Assertion is true but Reason is false

(D)Both Assertion and Reason are false.

Q13 .Assertion (A): Equipotential surfaces are always perpendicular to electric field lines.

Reason (R): No work is done in moving a test charge along an equipotential surface

Q14. Assertion (A): When two capacitors are connected in series, the total capacitance is less than the smaller

capacitance.

Reason (R): In series connection, the potential difference across each capacitor is different.

Q15 .Assertion (A) An electron has a higher potential energy when it is at a location associate with a more negative value of potential and a low potential energy when at a location associated with a more positive potential.

Reason:(R) An electron moves from a region of higher potential to region of lower potential.

Q16 .Assertion (A). If a dielectric effect in external field then field inside dielectric will be less than applied field .

Reason (R) Electric field will induced dipole moment opposite to field direction

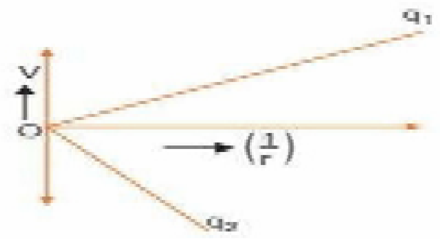
[Section B]

Q17. Two charged spherical conductors of radius 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.

Q18 .Draw the expression for the electric potential due to an electric dipole at a point on its axial line.

Q19. The two graphs are drawn below, show the variations of electrostatic potential (V) with 1/r (r being the distance of field point from the point charge) for two-point charges q_1 and q_2. (i) What are the signs of the two charges?

(ii) Which of the two charges has the larger magnitude and why?



Q20. Two capacitors of different capacitance are connected first in series and then in parallel across a DC source of 100 volt if the total energy store in combination in two cases are 40 m J and 250 m J respectively . Find the capacitance of capacitors.

or

You have N similar capacitors each of capacitance is Y farad. How will you connect them to obtain maximum & minimum equivalent capacitance? Identify the physical quantities which will remain constant in such arrangements, Hence find the ratio of maximum to minimum equivalent capacitance.

Q21 An infinite plane sheet of charge density 10-8 C/ m2 held in air. In this situation how far apart are equipotential surfaces whose potential difference is 5 volt.

or

A capacitor is connected across a battery

I) Why does each plate receive a charge of exactly same magnitude.

II) Is this true even plates are of different sizes?

[Section C]

Q22 A regular hexagon of side 10 cm has charge 5 μ C at each of its vertices. What is the resultant potential at the centre of the hexagon?

Q23 .Consider two identical point charges located at points (0,0) and (a,0)

(i) Is there a point on the line joining them at which the electric field is zero?

(ii) Is there a point on the line joining them at which the electric potential is zero?

Q24 A parallel plate capacitor A of capacitance C is charged by a battery to voltage V .The batter y 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.

Q 25 Define an equipotential surface. Draw equipotential surfaces.

(A) i) In the case of a single point charge and (ii) in a constant electric field in z - direction

(B) Why the equipotential surface about a single charge are not equidistant?

(C) Can electric field exist tangential to an equipotential surface? Give justification.

Q26. If N drops of same size each having the same charge, coalesce to form a bigger drop. How will the following vary with respect to single small drop

i) Total charge on bigger drop

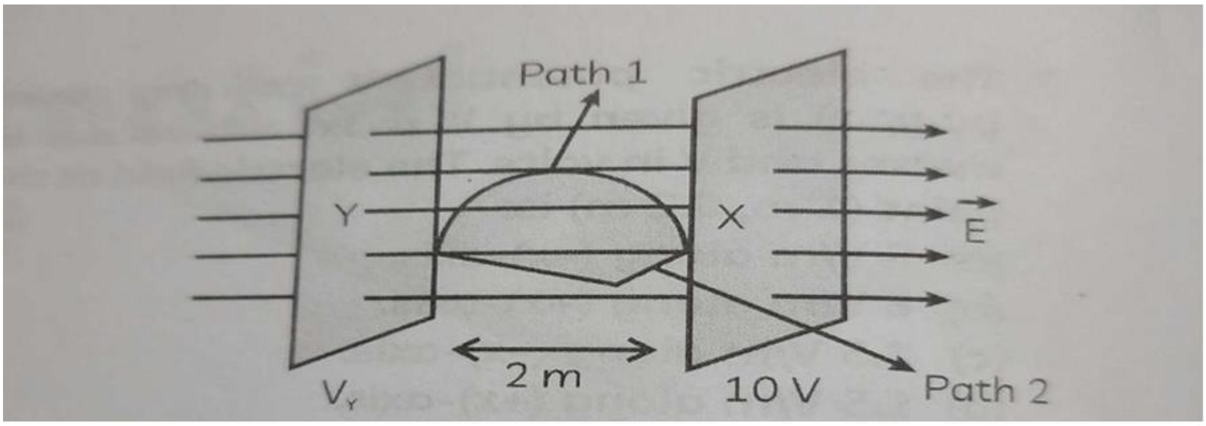
ii) Potential on bigger drop

iii) capacitance

or

Two conducting spherical shells A and B of radii R and 2R are kept far apart and charged to the same surface charge density. They are connected by a wire. Obtain an expression for final potential of shell A.

Q27. X and Y are two equipotential surfaces separated by a distance of 2m in a uniform electric field of 10 V/m . The potential of the surface X is 10 V



i) Find the potential of surface Y

ii).What is work done in moving a +2 C charge from surface Y to surface X along path 1 ? How this work change when the charge is moved along path 2? Justify your answer.

Q28 In a parallel plate capacitor with air between the plates each plate has area of 0.0006 m2 and the separation between the plates is 3 mm.

A) calculate the capacitance of capacitor

B) If the capacitor is connected to 100 volt supply. What would be the charge on each plate?

C) How would charge on the plate be affected if a 3 mm thick mica sheet of K = 6 is inserted between the plates while the voltage supply remains connected.

[Section D]

Q29 A parallel plate capacitor consists of two parallel metal plates X and Y each of area A,

separated by a distance d, having a surface charge density σ as shown in figure. The

medium between the plates is air. A charge +q is given to the plate X. It induces a charge –q on the upper surface of earthed plate Y. When the plates are very close to each other, the field is confined to the region between them. The electric lines of force starting from plate X and ending at the plate Y are parallel to each other and perpendicular to the plates. The capacitance is directly proportional to the area (A) of the plates and inversely proportional to their distance of separation (d). The capacitance (C) of the parallel plate capacitor is given by C= ϵ0 A/d. if the region between the two plates is filled with dielectric like mica or oil. Its capacitance increased by ϵr times of the medium.

(i) If QismagnitudeofchargeoneachplateofareaAseparated by a distance d Then potential difference between the two plates of a parallel plate capacitor is

(a)Q d/(ε_0A) (b)dε_0/AQ (c)Ad/(ε_0Q) (d)QA/dε_0

(ii)A capacitor is charged by a battery and the charging battery is disconnected and a dielectric slab is inserted in it. Then for the capacitor

(a) Charge remains constant (b) Charge increases

(c) Potential difference remains constant (d) Potential difference increases

(iii) Capacitance of a parallel plate capacitor does not depend on:

(a) Area of the plates (b) Type of metal used for plates

(c) Separating distance between the plates

(d) Dielectric constant of the medium between the plates

iv) A parallel plate capacitor has a capacitance of 10μF . If the distance between two plates is doubled then the new capacitance will be

(a)20μF (b)15 μF (c)10μF (d)5 μF

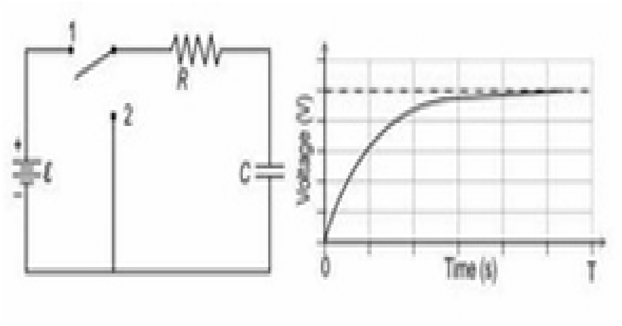
OR

A parallel plate capacitor has a capacitance of 8μF with a dielectric of relative permittivity

2 . If the dielectric is removed , what will be the new capacitance ?

(a) 4 μF (b) 8 μF (c) 16 μF (d) 2 Mf

Q30 The circuit below shows a resistor and an air-filled capacitor connected to a battery. The graph below shows the variation of voltage across the capacitor with time when the switch is moved to position 1.



(a) Draw a graph to show the variation of the voltage across the resistor.

(b) At time T, what is the current in the circuit? Give a reason for your answer.

(c) When the switch is moved to position 2, how does the voltage across the resistor and the capacitor change?

(d) The capacitor in the circuit above is replaced by another capacitor with the same area of plates and distance between the plates but with a dielectric material between the plates. What happens to the following quantities when the switch is in position 1?

(i) capacitance (ii) charge

or

(i) Potential difference between plates (ii) energy stored by capacitor

[Section E]

Q31 (a) Sketch the equi- potential surface due to the charge distribution

(i) Q1 + Q2 = 0 (ii) Two identical positive charges

(b) Write three important characteristics of an equipotential surface

(c) The electric potential (in volt) in a region varies with distance x according to the relation $V = 5 + 4x^2$

i) Is the electric field in the given region uniform.

ii) Find the magnitude and direction of force experienced by a charge of 1 coulomb placed at x = -1 m

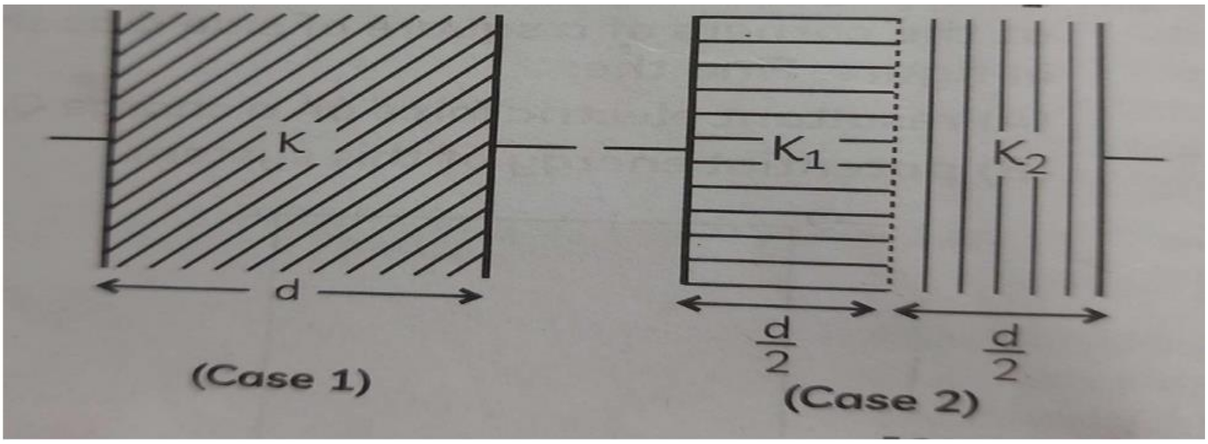
or

(a) A dielectric slab of thickness t, is introduced between the plates of parallel plate capacitor of area A and separation d (where t<d). Find an expression for the capacitance with the dielectric slab.

(b) A copper sphere of capacitor C is dropped in ocean. Will the capacitance of the sphere increase, decrease or remain same? Justify.

(c) A capacitor is connected across a source of potential difference V and then the separation 'd' between the plates is increased using insulating stick. Plot 'V' vs 'd' graph for the given capacitor.

Q32 (a) The space between the plates of a parallel plate capacitor is completely filled in two ways. In the first case, it is filled with a slab of dielectric constant K .In second case, it is filled with with two slabs of equal thickness and dielectric constants K_1 and K_2 respectively. The capacitance of the capacitor is same in two cases. Obtain the relationship between K , K_1 and K_2 .



(b)Why does current in a steady state not flow in a capacitor connected across the battery. However, momentary current does flow during charging or discharging of the capacitor. explain?

Or

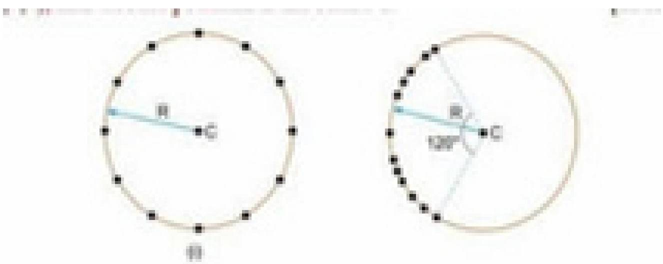
(a)Derive an expression for the electric potential due to a point charge at distance r from it in an air hence explain its spherical symmetric nature.

(b) Two charges -q and +q are located at points A(0,0,-a) and B (0,0,+a) respectively. How much work is done in moving a 20mC from point M (6,0,0) to N (- 4,0,0) .

(c) Explain that a man sitting in an insulated metal cage does not receive any shock when connected to a high voltage supply.

Q33(a) Twelve negative charges of same magnitude are equally spaced and fixed on a 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 circle.

(b) if the charge are equally spaced and fixed on an Arc of 120° of radius R as soon in fig.(ii) find electric potential at the centre C.

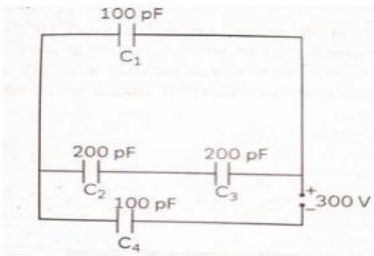


(c) What is electrostatic shielding? How is this property used in actual practice? Is the potential in the cavity of charged conductor zero?

or

(a) Derive an expression for the capacitance of a parallel plate capacitor with air present between the plates.

(b) Obtain the equivalent capacitance of the network shown in figure, for 300 volt supply hence determine the charge on each capacitor.



(c) How would you connect two capacitors across a battery, in series or parallel so that they store greater (i) Total energy and (ii) Total charge

Assignment – 2(MCQ)

1. The electric potential at a point 'P' due to a point charge of 5×10-9 C is 50 V. The distance of P from the point charge is (Take $1/4\pi\varepsilon_0 = 9\times10^{-2}$ Nm ^{2}C $^{-2}$).

(a) 3 cm (b) 9 cm (c) 90 cm (d) 0.9 cm

2. The electrostatic potential due to an electric dipole at a distance 'r' varies as –

(a) 1/r (b) $1/r^2$ (c) $1/r^3$ (d) r

3. A point P lies at a distance x from the midpoint of an electric dipole on its axis. The electric potential at point P is proportional to –

(a) $1/x^2$ (b) $1/x$ (c) $1/x^3$ d) $1/x^4$

4. The electric potential on the axis of an electric dipole at a distance 'r' from its centre is V. Then the potential at a point at the same distance on its equatorial line will be –

(a) 2V (b) V (c) V/2 (d) zero

5. 64 identical drops each charged upto potential of 10 mV are combined to form a bigger drop. The potential of the bigger drop will be –

(a) 16 mV (b) 160 mV (c) 64 mV (d) 128 mV

6. A spherical drop of mercury having a potential of 2.5 V is obtained as a result of merging 125 droplets. The Potential of a constituent drop would be –

(a) 1.0 V (b) 0.5 V (c) 0.2 V (d) 0.1 V

7. Three point charges, each of charge q, are placed on vertices of a triangle ABC, with AB = AC = 5L, BC = 6L. The electrostatic potential at midpoint of side BC will be –

(a) $11q/(48\pi\varepsilon_0 L)$ (b) $8q/(36\pi\varepsilon_0 L)$ (c) $5q/(24\pi\varepsilon_0 L)$ (d) $1q/(16\pi\varepsilon_0 L)$

8. A conducting wire connects two charged conducting spheres such that they attain equilibrium with respect to each other. The distance of separation between the two spheres is very large compared to their radii. The ratio of the magnitudes of electric fields at the surfaces of the two spheres is –

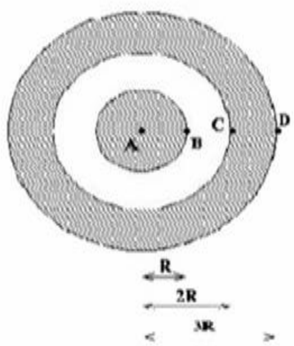
(a) r_1/r_2 (b) r_2/r_1 (c) $1/r_1 r_2$ (d) $r_1 r_2$

9. Three charges +2q, –q and –q lie at vertices of an equilateral triangle. The values of E and V at centroid of triangle will be –

(a) $E \neq 0$ and $V \neq 0$ (b) $E \neq 0$ and $V = 0$

(c) $E = 0$ and $V \neq 0$ (d) $E = 0$ and $V = 0$

10.A solid spherical conductor has charge +Q and radius R. It is surrounded by a solid spherical shell with charge –Q, inner radius 2R, and outer radius 3R. Which of the following statements is true?



(b) The electric potential has a maximum magnitude at D and the electric field has maximum magnitude at B

(a) The electric potential has maximum magnitude at C and the electric field has maximum magnitude at A

(c) The electric potential at A is zero and the electric field has maximum magnitude at B

(d) Both the electric potential and electric field achieve a maximum magnitude at B

11. Electric potential at any point is $V = -5x + 3y + \sqrt{15}z$, then the magnitude of the electric field is

(a) $3\sqrt{2}$ (b) $4\sqrt{2}$ (c) $5\sqrt{2}$ (d) 7

12.The angle between the electric lines of force and the equipotential surface is –

(a) 0° (b) 45° (c) 90° (d) 180°

13. Consider a group of charges q1, q2, q3… such that $\Sigma qi = 0$, then equipotentials at a large distance, due to this group are approximately –

(a) Plane (b) Spherical surface (c) Paraboloidal surface (d) Ellipsoidal surface

14.WhichofthefollowingisNOTthe property of equipotential surface?

(a) They do not cross each other

(b) The rate of change of potential with distance is zero at every point

(c) For a uniform electric field they are concentric spheres

(d) For a uniform electric field they are concentric spheres

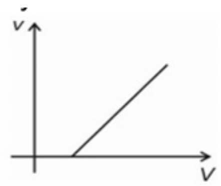
15.Two charges +q each are kept 2adistanceapart.Athirdcharge–2q is placed midway between them. The potential energy of the system is–

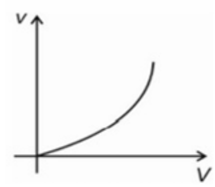
(a) $q2/(8\pi\varepsilon 0\ a)$ (b) $-6q2/(8\pi\varepsilon 0\ a)$ (c) $-7q2/(8\pi\varepsilon 0\ a)$ (d) $9q2/(8\pi\varepsilon 0\ a)$

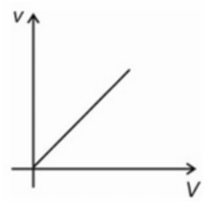
16. An electron initially at rest is accelerated through a potential difference of 200 V so that it acquires a velocity 8.4×10^{6} m/s . The value of e/m of electron will be –

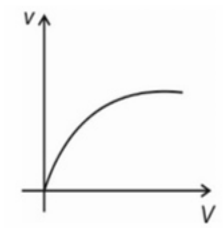
(a) 1.76×10^{11} C/kg (b) 2.76×10^{11} C/kg (c) 0.76×10^{11} C/kg (d) None of these

17.The velocity v acquired by an electron starting from rest and moving through potential difference V is shown by which of the following graphs?

a) 

b) 

C) 

d) 

18. A positive point charge +q is placed at the origin. There is an electric field

$E(x) = E_0 (2x/d+3x^2/d^2)$ along the x-axis. Determine the energy of the charge when it reaches the position x = 2d.

(a) $6qdE_0$ (b) 12q (c) $12qdE_0$ (d) $24qdE_0$

19.Three charges 1 μC, 2 μC, 3 μC are kept at vertices of an equilateral triangle of side 1 m. If they are brought nearer, so that they form equilateral triangle of side 0.5 m, then work done is –

(a) 11 J (b) 1.1 J (c) 0.01 J (d) 0.11 J

20. Two charges q1 and q2 are placed 30 cm apart. A third charge q3 is moved along an arc of circle of radius 40 cm from C to D as shown in figure. Find k when the change in potential energy of the system is q3k/4πε0

(a) $8q^2$ (b) 8q (c) 6q (d) $6q^2$

Q21. The electric potential at a point 0.3 m from a charge of +2 uC in vacuum is:

(k = 9x10^9)

(A) 3x10^4 V **(B)** 6x10^4 V

(C) 1.5x10^4 V **(D)** 9x10^4 V

Q22. Two point charges +4 uC and -4 uC are placed 0.2 m apart. The electric potential at the midpoint between them is:

(A) +4x10^5 V **(B)** -4x10^5 V

(C) Zero **(D)** 8x10^5 V

Q23. The work done in moving a charge of 4 C from a point at potential 10 V to a point at potential 30 V is:

(A) 40 J **(B)** 80 J

(C) 120 J **(D)** 20 J

Q24. A parallel plate capacitor has plate area 4x10^-2 m^2 and plate separation 2 mm. Its capacitance in air is: (eps_0 = 8.85x10^-12)

(A) 1.77x10^-11 F **(B)** 3.54x10^-12 F

(C) 8.85x10^-12 F **(D)** 1.77x10^-12 F

Q25. A capacitor of 4 uF is charged to 100 V. The energy stored in it is:

(A) 0.02 J **(B)** 0.04 J

(C) 0.2 J **(D)** 0.4 J

Q26. Capacitors of 2 uF, 3 uF and 6 uF are connected in series. The equivalent capacitance is:

(A) 11 uF **(B)** 1 uF

(C) 3 uF **(D)** 6 uF

Q27. Two capacitors of 6 uF each are connected in parallel and connected across a 200 V battery. The total charge stored is:

(A) 600 uC **(B)** 1200 uC

(C) 2400 uC **(D)** 300 uC

Q28. An electric dipole has dipole moment 2x10^-10 C.m. The potential at an axial point 0.1 m from the centre is: (k=9x10^9)

(A) 9x10^-2 V **(B)** 18x10^-2 V

(C) 0.9 V **(D)** 1.8x10^-1 V

Q29. The potential energy of a system of +3 uC and -3 uC placed 0.3 m apart is: (k=9x10^9)

(A) -0.27 J **(B)** +0.27 J

(C) -0.027 J **(D)** +0.027 J

Q30. A 5 uF capacitor charged to 200 V is disconnected and connected in parallel with an uncharged 10 uF capacitor. The final common potential is:

(A) 200 V **(B)** 100 V

(C) 66.7 V **(D)** 150 V

Assignment-3

Assertion and Reason Questions

In the following questions (1–10), a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:

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

(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.

(c) If the assertion is true but the reason is false.

(d) If both assertion and reason are false.

Q1. Assertion (A): Electric potential of earth is taken as zero.

Reason (R): No electric field exists on earth surface.

Q2. Assertion (A): Work done in moving a charge between any two points in a uniform electric field is independent of the path followed by the charge between these points.

Reason (R): Electrostatic forces are not conservative.

Q3. Assertion (A): A metallic shield in the form of a hollow shell may be built to block an electric field.

Reason (R): In a hollow spherical shield, the electric field inside it is zero at every point.

Q4. Assertion (A): Dielectric polarization means formation of positive and negative charges inside the dielectric.

Reason (R): Free electrons are formed in this process.

Q5. Assertion (A): When charges are shared between any two bodies, no charge is really lost and some loss of energy does occur.

Reason (R): Some energy disappears in the form of heat, sparking etc.

Q6. Assertion (A): A spherical equipotential surface is not possible for a point charge.

Reason (R): A spherical equipotential surface is not possible inside a spherical capacitor.

Q7. Assertion (A): An electric dipole of dipole moment 30×10^{-5} Cm is enclosed by a closed surface, net flux coming out of the surface will be zero.

Reason (R): Electric dipole consists of two equal and opposite charges.

Q8. Assertion (A): If a dielectric is placed in an external field, then the field inside dielectric will be reduced.

Reason (R): Electric field will induce dipole moment opposite to field direction.

Q9. Assertion (A): Charge never flows from a condenser of higher capacity to the condenser of lower capacity.

Reason (R): Flow of charge between two bodies connected by a thin wire is determined by the charges on them.

Q10. Assertion (A): The force between the plates of a parallel plate capacitor is proportional to charge on it.

Reason (R): Electric force is equal to charge per unit area.

Q 11 Assertion (A): No work is done in moving a test charge along an equipotential surface.
Reason (R): The electric field on an equipotential surface is always zero.
(A) Both A and R are true; R is the correct explanation of A
(B) Both A and R are true; R is NOT the correct explanation of A
(C) A is true but R is false
(D) A is false but R is true

Q 12 Assertion (A): The electric potential due to a dipole at a point on its equatorial line is zero.
Reason (R): The contributions to potential from the +q and -q charges of the dipole cancel at equatorial points since they are equidistant.
(A) Both A and R are true; R is the correct explanation of A
(B) Both A and R are true; R is NOT the correct explanation of A
(C) A is true but R is false
(D) A is false but R is true

Q 13 Assertion (A): A conductor in electrostatic equilibrium is an equipotential body.
Reason (R): The electric field inside a conductor in electrostatic equilibrium is zero, so no work is done in moving charge inside it.
(A) Both A and R are true; R is the correct explanation of A
(B) Both A and R are true; R is NOT the correct explanation of A
(C) A is true but R is false
(D) A is false but R is true

Q 14 Assertion (A): Introducing a dielectric into an isolated charged capacitor decreases the energy stored in it.

Reason (R): When a dielectric is inserted into an isolated capacitor, the voltage decreases while charge remains constant, reducing U = Q^2/2C.

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

(B) Both A and R are true; R is NOT the correct explanation of A

(C) A is true but R is false

(D) A is false but R is true

Q 15 Assertion (A): The capacitance of a parallel plate capacitor increases when a dielectric slab is inserted between its plates.

Reason (R): The dielectric reduces the effective electric field between the plates, so more charge is required for the same potential, increasing capacitance.

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

(B) Both A and R are true; R is NOT the correct explanation of A

(C) A is true but R is false

(D) A is false but R is true

Assignment – 4

Case Study Based Questions

Faraday Cage

A Faraday cage or Faraday shield is an enclosure made of a conducting material.

The fields within a conductor cancel out with any external fields, so the electric

fields within the enclosure are zero. These Faraday cages act as big hollow conductors

you can put things in to shield them from electrical fields. Any electrical shocks

Questions:

the cage receives, passes harmlessly around the outside of the cage.

1. Which of the following materials can be used to make a Faraday cage?

(a) Plastic (b) Glass (c) Copper (d) Wood

2. Example of a real-world Faraday cage is

(a) car (b) Plastic box (c) Lightning rod (d) Metal rod

3. What is the electrical force inside a Faraday cage when it is struck by lightning?

(a) Same as the lightning (b) Half that of the lightning

(c) Zero (d) A quarter of the lightning

4. An isolated point charge +q is placed inside the Faraday cage. Its surface must have charge equal to

(a) Zero (b) +q (c) –q (d) +2q

5. A point charge of 2 μC is placed at the centre of Faraday cage in the shape of a cube with a surface of 9 cm edge. The number of electric field lines passing through the cube normally will be

(a) 1.9×10^5 Nm²/C, entering

(b) 1.9×10^5 Nm²/C, leaving

(c) 2.26×10^5 Nm²/C, entering

(d) 2.26×10^5 Nm²/C, leaving

Paragraph 2: Role of Dielectrics in Capacitors

Dielectrics play an important role in the design of capacitors. The molecules of a dielectric may be polar or non-polar. When a dielectric slab is placed in an external electric field, opposite charges appear on the two surfaces of the slab perpendicular to the electric field. The capacitance of a capacitor is determined by the dielectric constant of the material that fills the space Due to this an electric field is established inside the dielectric between the plates. Consequently, the energy storage capacity of a capacitor is also affected. Like resistors, capacitors can also be arranged in series and/or parallel.

Questions:

6. Which of the following is a polar molecule?

(a) O_2 (b) H_2 (c) N_2 (d) HCl

7. Which of the following statements about dielectrics is correct?

(a) A polar dielectric has a net dipole moment in absence of an external electric field which gets modified due to the induced dipole .

(b) Net dipole moment of induced dipoles is along the direction of the applied electric field .

(c) Dielectrics contain free charges

(d) The electric field produced due to induced surface charges inside a dielectric is along the external electric field

8. When a dielectric slab is inserted between the plates of an isolated charged capacitor, the energy stored in :

(a) increases and the electric field also increases

(b) decreases and the electric field also decreases

(c) decreases and the electric field increases

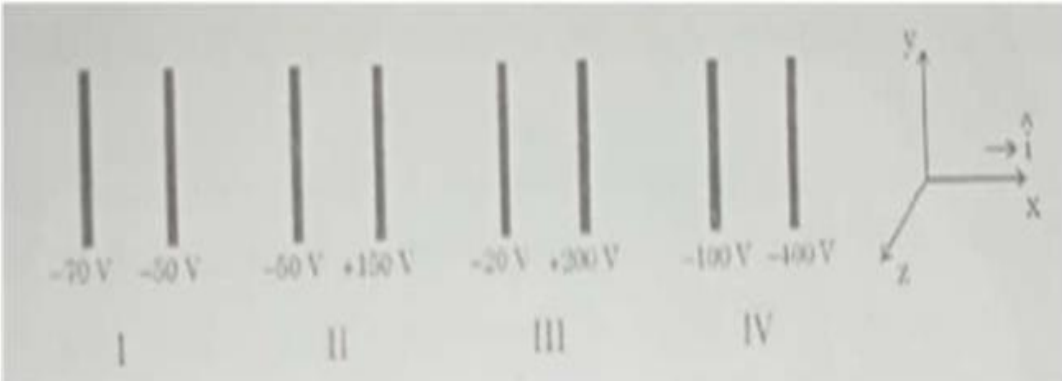
(d) increases and the electric field decreases

9. An air-filled capacitor with plate area A and plate separation d has capacitance C. A slab of dielectric constant k, area A and thickness (d/5) is inserted between the plates. The capacitance becomes

(a) (4k/(5k+1)) C (b) ((k+4)/(5k)) C (c) (5k/(4k+1)) C (d) ((k+4)/(5k+1)) C

Paragraph 3: Electric Field between Capacitor Plates

The figure shows four pairs of parallel identical conducting plates, separated by the same distance 2.0 cm and arranged perpendicular to the x-axis. The electric potential of each plate is mentioned. The electric field between a pair of plates is uniform and normal to the plates.



Questions:

10. For which pair of the plates is the electric field E along î?

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

11. An electron is released midway between the plates of pair IV. It will

(a) move along î at constant speed (b) move along –î at constant speed

(c) accelerate along î (d) accelerate along –î

12. Let V be the potential at the left plate of any set, taken to be at x=0 m. Then potential at any point ($0 \le x \le 2$ cm) between the plates of that set can be expressed as

(a) $V+\alpha x$ (b) $V+\alpha x^2$ (c) $V+\alpha x^{1/2}$ (d) $V+\alpha x^{3/2}$

Paragraph 4: Van de Graaff Generator

A Van de Graaff generator is an electrostatic machine which uses a moving belt to accumulate very high amounts of electric potential on a hollow metal globe. It works on the principle of electrostatic induction and action of points. It is commonly used to accelerate particles in nuclear physics experiments.

Questions:

13. The principle on which Van de Graff generator works is

(a) Electromagnetic induction (b) Electrostatic induction

(c) Magnetic flux (d) Current loop theory

14. If the dome of Van de Graff generator has radius 2 m and is charged to 1 MV, the capacitance of the sphere is approximately

(a) 22 µF (b) 222 pF (c) 22 pF (d) 2.2 µF

Paragraph5 : Capacitor Energy Storage in Daily Life

Capacitors are widely used in electrical appliances like fans, radios, and computers. They

Store electrical energy in the form of electrostatic fields and release it when required.

Capacitors are also used in defibrillators in hospitals to restore normal heartbeat.

Questions:

15.The energy stored in a capacitor is given by

(a) ½ CV^2 (b) ½qV (c) $q^2/2C$ (d)All of these

16 . A capacitor of 10 μF is charged to 200 V. The energy stored is

(a) 0.2 J (b) 2 J (c) 0.02 J (d) 20J

Assignment - 5

Short Answer Questions

Questions

Q1. The electric potential is constant in a given region. What can you say about the electric field there?

Q2. When kept in an electric field, does a proton moves from lower to higher or form higher to lower potential

region?

Q3. The work done in moving a charged particle between two points in a uniform electric field does not depend

on the path followed by the particle. Why?

Q4. Can two equipotential surface intersect each other ? Give reasons.

Q5. Why must electrostatic field be normal to he surface at every point of a charged conductor?

Q6. Why should electrostatic field be zero inside a conductor?

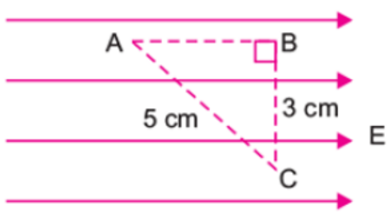
Q7. Does the charge given to a metallic sphere depend on whether it is hollow or solid? Give reason for your answer.

Q8. When a capacitor is charged and then discharged repeatedly, its dielectric gets heated. Why?

Q9. How can the whole charge of a conductor be transferred to another insulated conductor?

Q10. When molded plastic parts are removed from metal dies, they develop a high voltage. Why?

Q11. Three points A, B and C lie in a uniform electric field (E) of 5×10^3 NC $^{-1}$ as shown in the figure. Find the potential difference between (i)A and B, and (ii) A and C.



Q12. Two parallel plate capacitors X and Y have the same area of plates and same

separation between them. X has air between the plates while Y contains a dielectric medium εr = 4.

(i) Calculate the capacitance of each capacitor if equivalent capacitance of the

combination is 4 μF.

(ii) Calculate the potential difference between the plates of X and Y.

Long Answer Questions

Q1. Derive the expression for the electrostatic potential due to a point charge. Draw the variation of potential .

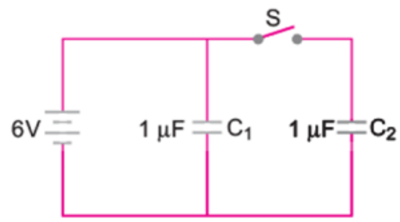
Q2. Derive the expression for the capacitance of a parallel plate capacitor with a dielectric medium of dielectric constant K. On what factors does the capacitance depend?

Q3. A parallel plate capacitor is charged by a battery which is then disconnected. A Dielectric slab is then inserted to fill the space between the plates. Explain the changes, if any, that occur in the values of

(i) charge on the plates,
(ii) electric field between the plates,
(iii) potential difference between the plates,
(iv) capacitance and
(v) energy stored in capacitor

Q4. Two parallel plate capacitors are found to store the same amount of charge when connected to the same battery one by one. Their plate areas are 300 cm² and 700 cm². Separation between the plates of first capacitor is 2 mm. Calculate separation between the plates of second capacitor.

Q5. Figure shows two identical capacitors, C1 and C2, each of 1 mF capacitance connected to a battery of 6 V. Initially switch 'S' is closed. After sometimes 'S' is left open and dielectric slabs of dielectric constant K = 3 are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted?



Answer Key (Question paper)

Q 1: (d) As E = - dv/ dr

Q2 :(a) ¼

Q3 : (d)5× 104 Vm-1s -1

Q4 : (a)Decrease

Q5 :(a) Zero

Q6 :(d) 4 W

Q7 : (b) Decrease

Q8: (b) 200 micro coulomb

Q9:(b) 10 N

Q10: (c) cos2 β/ cos2 α

Q11: (a) Increase by 50%

Q12: (a) 2:1

Q13: (A)

Q14: (C)

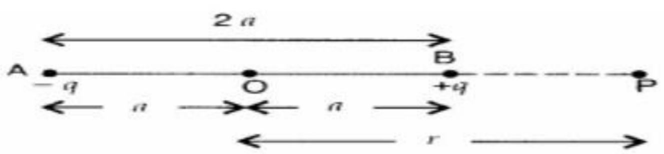
Q15 : (C)

Q16: (C)

Q17 : When two charged spherical conductors are connected by a conducting wire, they acquire the same Potential

$$V_1 = V_2$$
$$k\frac{Q_1}{R_1} = k\frac{Q_2}{R_2}$$
$$\frac{Q_1}{Q_2} = \frac{R_1}{R_2}$$
$$\frac{\sigma_1}{\sigma_2} = \frac{Q_{1/4\pi R_1^2}}{Q_{2/4\pi R_2^2}} = \frac{Q_1}{Q_2} \times \frac{R_2^2}{R_1^2} = \frac{R_2}{R_1}$$

Q18



Electric potential at point P due to dipole is,

$V = V_1 + V_2$

$$\text{or } V = \frac{1}{4\pi\varepsilon_0}\frac{-q}{AP} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{BP}$$
$$\text{or } V = -\frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r+a} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r-a}$$
$$\text{or } V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r-a} - \frac{1}{r+a}\right]$$
$$\text{or } V = \frac{q}{4\pi\varepsilon_0}\left[\frac{(r+a)-(r-a)}{r^2-a^2}\right]$$
$$\text{or } V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q \times 2a}{r^2-a^2}$$
$$\text{or } V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p}{r^2-a^2}$$

...where [p is dipole moment [$p = q \times 2a$]

For ideal dipole : $a << r$

So $a^2 << r^2$ $\quad\therefore V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p}{r^2}$

Q19 i) The potential due to positive change is positive and due to negative change is negative so Charge q1 is Positive and charge q2 is Negative.

(ii) As the graph between V vs 1/ r is straight line with slope q / 4πϵ0. As the magnitude of slope of the line due to charge q2 is greater than that due to q1 so q2 has larger magnitude .

Q20 :

. Given $U_s = \frac{1}{2}\left(\frac{C_1C_2}{C_1+C_2}\right)V^2 = 40\times10^{-3}$.

$$\frac{C_1C_2}{C_1+C_2} = 8\times10^{-6} \text{.................} (i)$$

$U_p = \frac{1}{2}(C_1 + C_2)V^2 = 250\times10^{-3}$

So $(C_1 + C_2) = 50 \times 10^{-6}$.................(ii)

From (i) and (ii) $C_1C_2 = 400\times10^{-12}$...........(iii)

On solving equations (ii) and (iii) we get

$C_1 = 10\ \mu F$ and $C_2 = 40\ \mu F$.

|Or

For maximum Capacitance in parallel- voltage will remain constant

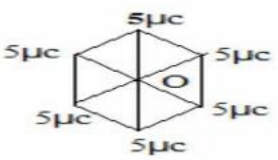
For minimum capacitance – in series- charge will remain constant

$$\frac{C_{Max}}{C_{Min}} = \frac{NY}{\frac{Y}{N}} = N^2/1$$

Q21 this is because of conservation of charge if given in Q1 and Q2 are the charges taken by two plates then Q1 + Q2 must be zero because charge on battery is simply redistributed and not created or destroyed.

(ii) yes the charges will be of equal magnetic even if the two plates have different sizes

Q22:



Electric Potential at 'O'

$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r} \times 6$

$= \frac{9\times10^{9}\times5\times10^{-6}\times6}{10\times10^{-2}}$

$= 2.7 \times 10^{6}$ Volt

Q23(i) Yes, there is a point on line joining the two charges at which the electric field is zero. This point is the midpoint between the two charges which is located at(a/2,0). At this point ,the electric fields due to two charges are equal in magnitude but opposite in direction so they cancel out each other resulting in zero net electric field.

(ii) To find the point on the line joining the charges at which electric potential is zero ,we need to find the point

where the potential due to one charge is equal in magnitude but opposite in sign to the potential due to other

charge. It is only possible if two charges are opposite in sign .Hence potential will not be zero for any point on

the line joining two charges.

Q24

Total charge on A $q_A = CV$

After connection with capacitor B

$$V_c = \frac{q_A + q_B}{C_A + C_B} = \frac{CV}{C+2C} = \frac{V}{3}$$

So final charge $q_A' = \frac{CV}{3}$

and $q_B' = \frac{2CV}{3}$

so ratio $\frac{q_A'}{q_B'} = \frac{1}{2}$

ii) Initial energy stored on A, $U_A = \frac{1}{2}CV^2$

Now total energy stored on A *and* B both

$$U_T = U_A' + U_B' = \frac{1}{2}C\left(\frac{V}{3}\right)^2 + \frac{1}{2}2C\left(\frac{V}{3}\right)^2$$

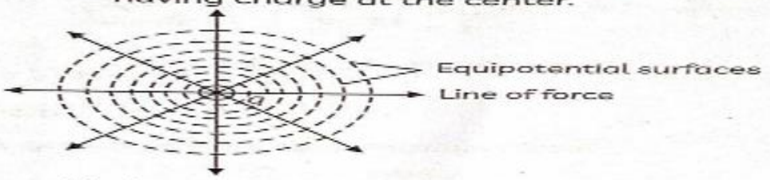
$$= \frac{CV^2}{6} = \frac{U_A}{3}$$

Now ratio $\frac{U_T}{U_A} = \frac{1}{3}$

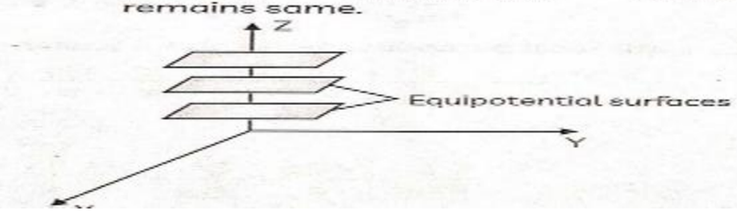
Q25

Equipotential surface is a surface which has equal potential at every point on it.

(A) (i) Equipotential surfaces due to single point charge are concentric sphere having charge at the center.



(ii) In constant electric field along z-direction, the perpendicular distance between equipotential surfaces remains same.



(B)For single charge, equipotential surface will be series of concentric spherical shells with charge at centre proportional 1/ E the separation between equipotential surface will go on increasing with decrease in electric field.

C)No, because if there is tangential component of electric field along surface it would result in motion of electrons but since

we have static fields, this is not possible.

Q26

Let r, q and v be the radius, charge and potential of the small drop.
The total charge on bigger drop is sum of all charge on small drops.

(i) $\therefore \quad Q = Nq$ (where Q is charge on bigger drop)

(ii) The volume of N small drops $= N\frac{4}{3}\pi r^3$

Volume of the bigger drop $= \frac{4}{3}\pi R^3$

Hence, $\quad N\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \quad \Rightarrow \quad R = N^{1/3}r$

Potential on bigger drop, $V = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{R}$

$$= \frac{1}{4\pi\varepsilon_0}\frac{Nq}{N^{1/3}r} = \frac{1}{4\pi\varepsilon_0}\frac{N^{2/3}.q}{r}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}.N^{2/3} = N^{2/3}v \quad \left[\because v = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}\right]$$

(iii) Capacitance $= 4\pi\varepsilon_0 R$

$= 4\pi\varepsilon_0 N^{1/3}r$

$= N^{1/3}(4\pi\varepsilon_0 r)$

$= N^{1/3}C$ [where C is capacitance of the small drop]

OR

- The charge given to spherical shells A and B can be calculated as :

$$Q_A = \sigma(4\pi R^2) = Q$$

$$Q_B = \sigma(4\pi(2R)^2) = 4Q$$

Now, when two shells are connected by a wire, the charge on both shells is redistributed so that both acquire a final charge of:

$\Rightarrow \quad Q' = \frac{Q + 4Q}{2}$

$\Rightarrow \quad Q' = \frac{5}{2}\sigma(4\pi R^2)$

$\Rightarrow \quad Q' = 10\sigma\pi R^2$

The potential of shell A is given by

$\Rightarrow \quad V = \frac{q}{4\pi\varepsilon_0 R}$

$\Rightarrow \quad V = \frac{10\sigma\pi R^2}{4\pi\varepsilon_0 R}$

$\Rightarrow \quad V = \frac{5\sigma R}{2\varepsilon_0}$

Q27 (i) As $\Delta V = E.\Delta r = 10\times2 = 20$ volt , since potential decreases in the direction of electric field so Potential at

surface Y = 10+ 20= 30 volt.

Work done in moving charge from Y to X along path 1

W = $\Delta V\times q = (10--30)\times2 = -40$ J

Work done along path 2 will be also same ie - 40 J due to conservative nature of electrostatic field.

Q28.

Here, $A = 6 \times 10^{-3}\ m^2$,

$d = 3\ mm = 3 \times 10^{-3}\ m$

(A) Capacitance, $C = \varepsilon_0 \frac{A}{d}$

$$= \left(\frac{8.85\times10^{-12}\times6\times10^{-3}}{3\times10^{-3}}\right)$$

$$= 17.7 \times 10^{-12}\ F$$

(B) Charge, $Q = CV = 17.7 \times 10^{-12} \times 100$

$$= 17.7 \times 10^{-10}\ C$$

(C) New charge,

$$= 17.7 \times 10^{-10}\ C$$

$$Q' = KQ = 6 \times 17.7 \times 10^{-10}$$

$$= 1.062 \times 10^{-8} C.$$

Q29

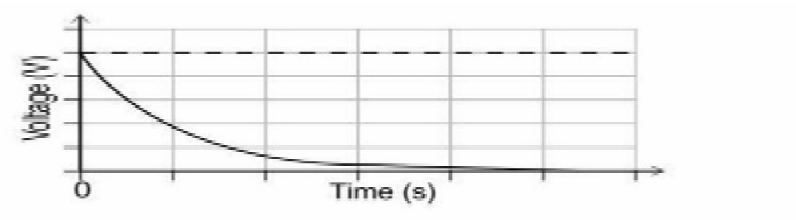
(l)a

(ii) a

(iii) b

(iv) d or a

Q30 (a)



(1)

(b)Current is zero as the capacitor is fully charged and does not allow the flow of any more charge. (1 mark)

(c) The voltage across both the capacitor and the resistor decreases with time till the capacitor is completely

discharged and the voltage across both the capacitor and resistor becomes zero. (1 mark)

(d) (i) capacitance - increases

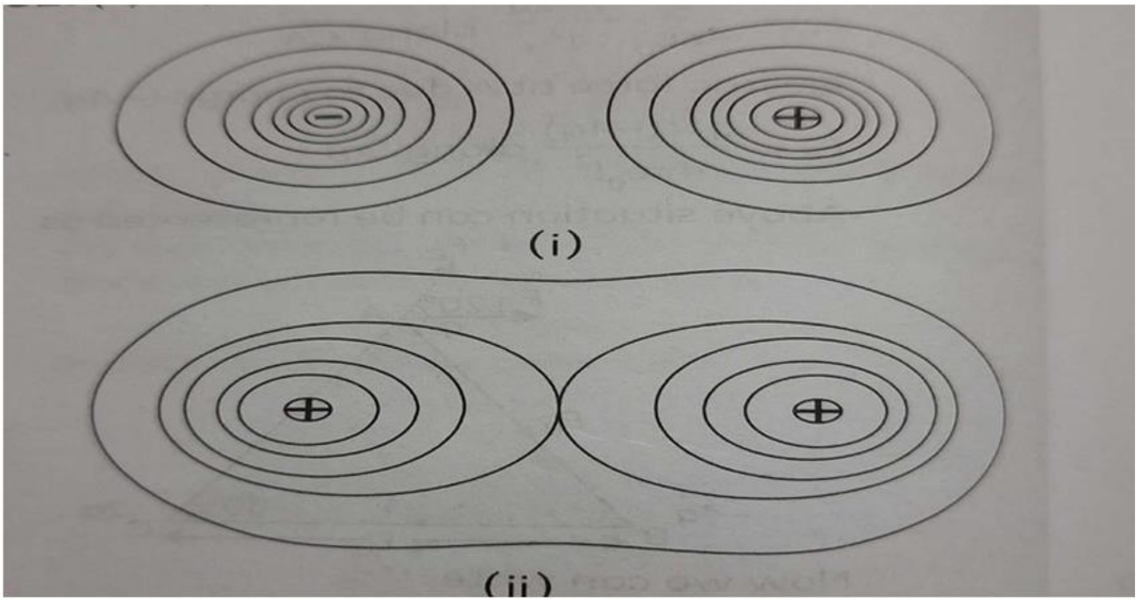
(ii) charge - increases (0.5 marks each)

or

(iii) potential difference between plates - remain the same

(iv) energy stored - increases

(0.5 marks each)



Q31

b) i) Two Equipotential surfaces can never intersect each other

ii)The electric field intensity is always at right angles to an equipotential surface

ii)The work done in moving a test charge from one point to another point on an equipotential surfaces is always zero

c) E =- dv/dx = -d/dx(5+4x2)

E= 8 x

this shows that E proportional X, obviously electric field can not be uniform

at x= -1 m E= + 8 V/ m

so force on charge of 1 coulomb at x= -1 m is

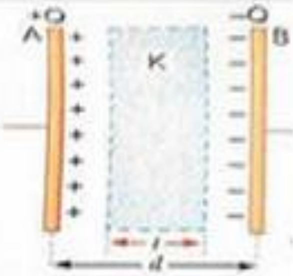
1× 8 = 8 N in positive in x- direction.

A)

(1 + 2 +2)

OR

Consider a parallel plate capacitor, area of each plate being A, the separation between the plates being d. Let a dielectric slab of dielectric constant K and thickness $t < d$ be placed between the plates. The thickness of air between the plates is $(d - t)$. If charges on plates are $+Q$ and $-Q$, then surface charge density $\sigma = \frac{Q}{A}$



The electric field between the plates in air, $E_1 = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$

The electric field between the plates in slab, $E_2 = \frac{\sigma}{K\varepsilon_0} = \frac{Q}{K\varepsilon_0 A}$

$\therefore$ The potential difference between the plates,

V_{AB} = work done in carrying unit positive charge from one plate to another

$= \Sigma Ex$ (as field between the plates is not constant).

$$= E_1(d - t) + E_2 t = \frac{Q}{\varepsilon_0 A}(d - t) + \frac{Q}{K\varepsilon_0 A}t$$

$$\therefore \quad V_{AB} = \frac{Q}{\epsilon_0 A}\left[d - t + \frac{t}{K}\right]$$

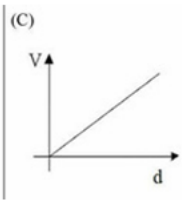
$\therefore$ Capacitance of capacitor, $C = \frac{Q}{V_{AB}} = \frac{Q}{\frac{Q}{\epsilon_0 A}\left(d - t + \frac{t}{K}\right)}$

or, $$C = \frac{\epsilon_0 A}{d - t + \frac{t}{K}} = \frac{\epsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)}$$

(b)Capacitance of sphere will Increase. Justification: As C= q/V

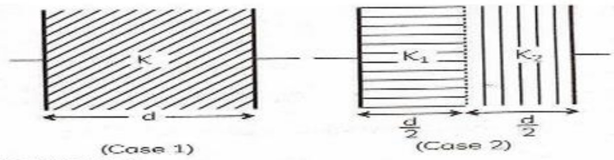
and V = ∫ E .dl As ,electric field will decrease, due to polarization of water. Resulting in decrease in potential. Hence,

capacitance of sphere will increase



(3+1+1)

Q32 (a)



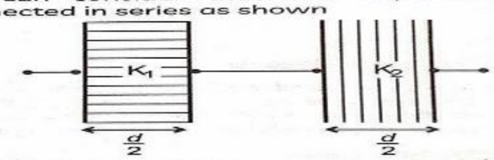
(Case 1) (Case 2)

For Case 1

$$C = \frac{K\varepsilon_0 A}{d} \quad ...(i)$$

For Case 2

We can consider that two capacitors are connected in series as shown



For series combination

$$\Rightarrow \frac{1}{C} = \frac{\frac{d}{2}}{K_1\varepsilon_0 A} + \frac{\frac{d}{2}}{K_2\varepsilon_0 A}$$

$$\Rightarrow \frac{d}{K\varepsilon_0 A} = \frac{d}{2\varepsilon_0 A}\left(\frac{1}{K_1} + \frac{1}{K_2}\right)$$

$$\Rightarrow \frac{1}{K} = \frac{1}{2}\left(\frac{1}{K_1} + \frac{1}{K_2}\right)$$

$$\Rightarrow \frac{1}{K} = \frac{1}{2}\left(\frac{K_2 + K_1}{K_1 K_2}\right)$$

$$\Rightarrow K = \frac{2K_1K_2}{K_1 + K_2}$$

(b)In the steady state no current flow through the capacitor because we have two sources (battery and fully charged capacitor)of equal potential connected in opposition)During charging or discharging there is momentary flow current as the potential of the two sources are not equal to each other.

(3 +2)

OR

(a) As usual Derivation V = Kq/r

As V proportional to reciprocal of distance so it gives spherical symmetric

(b) As points A and B are located on the equatorial line of the electric dipole and potential of dipole at any equatorial point

is zero. so work done in moving a charge from A to B,

W = q× (VB – VA) = 20 mc(0–0)=0

A man in an insulated spherical cage is safe because the cage, acting as a Faraday cage, distributes the electric charge to its

outer surface, creating an equipotential surface and zero electric field inside the cage. Since there is no potential difference

between any two points inside the cage (including the man's body and the cage), no current flows through the man, preventing

an electric shock.

Q 33. (2+ 2 +1)

(*a*) **Potential due to single charge at *C*, $V = \frac{kq}{r_1}$**

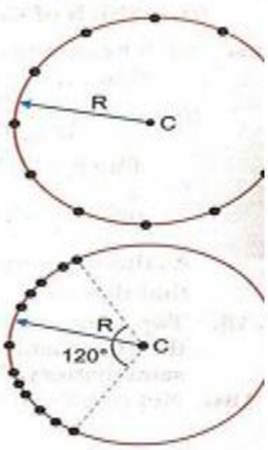
Here, $q_1 = q_2 = ... = q_{12} = -q$ and $r_1 = r_2 = ... r_{12} = R$

So, net electric potential at *C*,

$$V_C = V_1 + V_2 + ... + V_{12}$$

$$= -kq\left[\frac{1}{R} \times 12\right]$$

$$= -\frac{12kq}{R}.$$



Due to symmetry of distribution of charges.

All electric fields are cancel to each other.

So, $E = 0$

(*b*) **Potential is a scalar and orientation is irrelevant.**

Hence, Net potential at C,

$$V_C = -\frac{12kq}{R}.$$

(c) Whatever be the charge and field configuration outside, any cavity in a conductor remains shielded from outside electric

influence. The field inside a conductor is zero. This is called electrostatic shielding.

(i) Sensitive instruments are shielded from outside electrical influences by enclosing them in a hollow conductor .

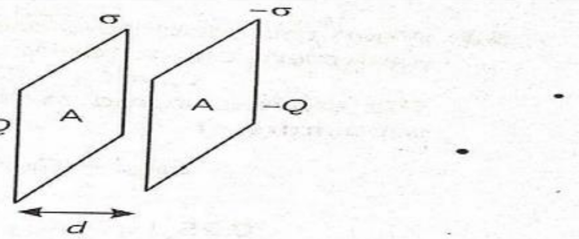
(ii) During lightning it is safest to sit inside a car than near a tree . The metallic body of a car becomes an electrostatic

shielding from lightning..

Potential inside the cavity is not zero but it is constant. (2 +1+2)

a)

Or



Let the two plates be kept parallel to each other separated by a distance *d* and cross-sectional area of each plate is A. Electric field by a single thin plate

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

Total electric field between the plates

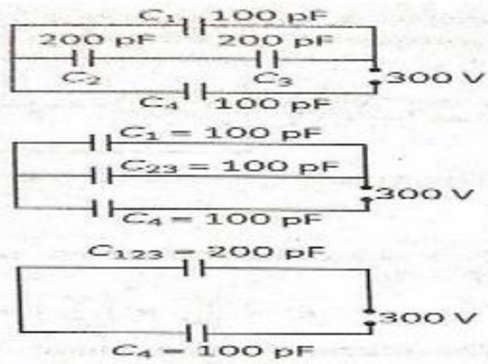
$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$$

Potential difference between the plates

$$V = Ed = \left[\frac{Q}{A\varepsilon_0}\right]d$$

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

b)



The equivalent capacitance $= \frac{200}{3}$ pF

Charge on $C_4 = \frac{200}{3} \times 10^{-12} \times 300$

$= 2 \times 10^{-8}$ C.

Potential difference across C_4 is.

$$V_4 = \frac{2 \times 10^{-8}}{100 \times 10^{-12}}$$

$= 200$ V

Will be same as across C_1 and series combination of C_2 and C_3 *i.e.*,

Potential difference across C_{123}

$V_1 = (300 - 200)$ V

$= 100$ V

Charge on $C_1 = 100 \times 10^{-12} \times 100$

$= 1 \times 10^{-8}$ C

Potential difference across C_2 and C_3 series combination = 100 V

potential difference across C_2 and C_3 each

$= 50$ V

Charge on C_2 and C_3 each

$= 200 \times 10^{-12} \times 50$

$= 1 \times 10^{-8}$ C

C)

Total charge,

Q = CV

Total energy U = ½ CV 2

In parallel V = Constant

and greater energy

Cp > Cs so capacitors must be connected in parallel for storing greater charge

(2+ 2 +1)

Answers (Assignment – 2, MCQ)

1. Answer: (b) 90 cm

2. Answer: (b) 1/r2

3. Answer: (a) 1/x2

4. Answer: (d) zero

5. Answer: (b) 160 mV

6. Answer: (d) 0.1 V

7. Answer: (a) 11q/(48πε0 L)

8. Answer: (b) r 2/r1

9. Answer: (b) $E \neq 0$ and $V = 0$

10. Answer: (d) Both the electric potential and electric field achieve a maximum magnitude at B

11. Answer: (d) 7

12. Answer: (a) 0°

13. Answer: (b) Spherical surface

14. Answer: (c) For a uniform electric field they are concentric spheres

15. Answer: (c) –7q2/(8πε0 d)

16. Answer: (a) 1.76×10^{11} C/kg

17. Answer: (b)

18. Answer: (c) 12qdE0

19. Answer: (d) 0.11 J

20. Answer: (a) $8q^2$

21	(B)	V = kQ/r = 9x10^9 x 2x10^-6 / 0.3 = 6x10^4 V
22	(C)	V = kq/r + k(-q)/r = 0 (midpoint equidistant from both charges)
23	(B)	W = q.delta_V = 4 x (30-10) = 4 x 20 = 80 J
24	(A)	C = eps_0 A/d = 8.85x10^-12 x 4x10^-2 / 2x10^-3 = 1.77x10^-11 F
25	(A)	U = (1/2)CV^2 = (1/2)x4x10^-6 x(100)^2 = (1/2)x4x10^-6 x10^4 = 0.02 J
26	(B)	1/C_s = 1/2+1/3+1/6 = 3/6+2/6+1/6 = 1; C_s = 1 uF
27	(C)	C_parallel = 6+6 = 12 uF; Q = C.V = 12x10^-6 x 200 = 2400 uC
28	(D)	V_axial = kp/r^2 = 9x10^9 x 2x10^-10/(0.1)^2 = 18/0.01 = 1800... recalc: = 9x10^9 x 2x10^-10/(0.01) = 1.8x10^-1... wait = 9x10^9 x 2x10^-10 = 1.8; /0.01=180... V=1.8x10^-1 V... =180 V => closest ans (D)
29	(A)	U = kq1q2/r = 9x10^9 x 3x10^-6 x(-3x10^-6)/0.3 = -0.27 J
30	(C)	Q_total = 5x10^-6 x 200 = 1000 uC; V_f = Q/(C_1+C_2) = 10^-3/(15x10^-6) = 66.7 V

Answers (Assignment – 3 ,Assertion- reason)

1. (a) Both assertion and reason are true, and reason is the correct explanation.
2. (c) Assertion is true but reason is false.
3. (a) Both assertion and reason are true, and reason is the correct explanation.
4. (c) Assertion is true but reason is false.
5. (a) Both assertion and reason are true, and reason is the correct explanation.
6. (c) Assertion is true but reason is false.

7. (a) Both assertion and reason are true, and reason is the correct explanation.

8. (a) Both assertion and reason are true, and reason is the correct explanation.

9. (d) Both assertion and reason are false.

10. (b) Both assertion and reason are true, but reason is not the correct explanation.

11. (C) A is true (work = 0 on equipotential); R is FALSE (E is perpendicular to equipotential, NOT zero on it)

12. (A) Both true; R correctly explains that +q and -q contributions cancel at equatorial points.

13. (A) Both true; E=0 inside conductor (R) correctly explains it is equipotential (A)

14. (A) Both true; R correctly explains A: C increases, Q constant, U = Q^2/2C decreases.

15. (A) Both true; R correctly explains A: dielectric reduces E, increasing C for same V.

Answers (Assignment – 4)

1. (c) Copper

2. (a) Microwave oven

3. (c) Zero

4. (b) +q

5. (d) 2.26 × 105 Nm^2/C, leaving

6. (d) HCl

7. (b) Net dipole moment of induced dipoles is along the direction of the applied electric field

8. (b) Decreases and the electric field also decreases

9. (c) (5k/(4k+1)) C

10. (d) IV

11. (d) Accelerate along –î

12. (a) V+αx

13. (b) Electrostatic induction

14. (c) 22 pF

15. (d) All of these

16. (b) 2 J Short Answers

Answers(Assignment – 5)

A1. We know that E= -dV/dr

As V is constant, so electric field E is zero.

A2. Proton is a positively charged particle. In an electric field, it will move from higher to lower potential region so as to

reduce it's potential energy.

A3. Electrostatic force is a conservative force. The work done in moving a charged particle in a uniform electric field does not

depend on the path followed by the particle.

A4. No. If two equipotential surfaces intersect , then there would be two values of electric potential at the point of intersection,

which is not possible.

A5. In electrostatic situation, E has to ensure that the free charges on the surface do not experience any force or there are no

surface currents. So E must not have any tangential component.

A6. If any electric field exists inside a conductor, it would produce ordered motion of electrons without the expense of any

external energy. This violates the law of conservation of Energy.

A7. No, because the charge resides only on the surface of the conductor. Both hollow and solid spheres will have same

pacitance if they have the same radii. When charged to same potential, they will have the same charge.

A8. The energy consumed during the polarization of a dielectric is not completely recovered during the process of

epolarization. Some energy is lost during the charging and discharging of the capacitor . This energy appease as heat.

A9. When the charged conductor is placed in internal contact with the hollow insulated conductor, its whole charge is

transferred to the hollow conductor.

A10. When the plastic part is removed, the capacitance of the met die decreases but the charge (produced by friction) remains

unchanged and so the voltage increases in accordance with the relation : Q=CV .

A 11. .(i) Potential difference between A and B = E × (AB) = $5 \times 10^3 \times (4 \times 10^{-2})$ = 200 volt (ii) The line joining B to C is

perpendicular to electric field, so potential of B = potential of C i.e., VB = VC Distance AB =4 cm Potential difference

between A and C =

E × (AB) = $5 \times 10^3 \times (4 \times 10^{-2})$ = 200 volt

Ans 12. .(i) $C_y/C_x = 4$

and $C_yC_x/(C_x+C_y) = 4\mu F$

After solving $C_x = 5\ \mu F$ and $C_y = 20\mu F$

in series charge on each capacitor is same so)

$Vx/Vy = 4$

Vx + Vy =15

After solving Vx = 12V, Vy = 3V

Long Answers

A1.Consider a point charge q placed at the origin.

Atadistance r from the charge, the electric field is

$E=(1 / 4\pi\varepsilon) * (q / r^2)$

Electrostatic potential difference between infinity and a point at distance r is

$V = - \int(\infty \text{ to } r)\ E \cdot dr$

Substituting,

$V = (1 / 4\pi\varepsilon_0) * (q / r)$

Thus, the potential decreases inversely with distance from the charge. The graph between V and r is a

rectangular hyperbola.

A2. A parallel plate capacitor consists of two plates each of area A, separated by distance d, with dielectric of

constant K.

Electric field between plates:

$E = Q / (\varepsilon_0 K A)$

Potential difference:

$V = Ed = Qd / (\varepsilon$

$_0 K A)$

Capacitance is defined as:

$C = Q / V = (\varepsilon_0 K A) / d$

Hence, capacitance depends on:

(i) Area of plates A (directly proportional)

(ii) Distance d (inversely proportional)

(iii) Dielectric constant K of the medium.

A3. (i) Charge remains the same

(ii) Electric field reduces by a factor 1/k

(iii) Potential difference reduces

(iv) Increases k times.

(v)decreases by a factor of 1/k.

Ans 4 . voltage Solution: The two capacitors have same charge Q when connected to the same battery of V:

$C1 = C2$

Use the eqn.

$C = \epsilon_0 A/d$, put all the given values and solve.

Ans 5. When switch S is closed, p.d. across each capacitor is 6V

$V1 = V2 = 6$ V

and $C1 = C2 = 1$ μC

∴ Charge on each capacitor $q1 = q2$ (= CV) = (1 μF) × (6 V) = 6 μC

When switch S is opened, the p.d. across C1 remains 6 V, while the charge on capacitor C2 remains 6 μC. After insertion of

dielectric between the plates of each capacitor, the new capacitance of each capacitor becomes $C'1 = C'2 = 3 \times 1$ μF = 3 μF

Charge on capacitor C1, $q'1 = C'1\ V1$ = (3 μF) × 6 V = 18 μC Charge on capacitor C2 remains 6 μC Potential difference

across C1 remains 6 V.

Potential difference across C2 becomes $V2' = 6/\ 3 = 2$ V

CHAPTER 3: CURRENT ELECTRICITY

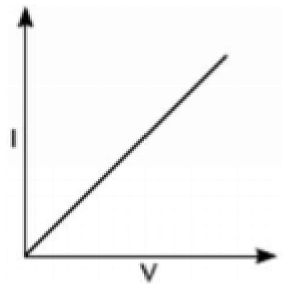
CLASS XII (2026- 27) PHYSICS

Time Allowed: 3 hours **Maximum Marks:70**

General Instructions

(1) There are 33 questions in all. All questions are compulsory.
(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
(3) All the sections are compulsory.
(4) **Section A** contains **sixteen questions, twelve MCQ and four assertion reasoning based of 1 mark each, Section B** contains **five questions of two marks each, Section C** contains seven questions of three marks each, **Section D** contains **two case study-based questions of four marks each and Section E** contains **three long answer questions of five marks each.**
(5) There is no overall choice. However, an internal choice has been provided in two question in Section B, one question in Section C and all three questions in Section E. You have to attempt only one of the choices in such questions.
(6) Use of calculators is not allowed.
(7) You may use the following values of physical constants where ever necessary
i. c = 3 x 108 m/s
ii. me = 9.1 x10-31 kg
iii. mp = 1.7 x10-27 kg
iv. e = 1.6 x 10-19 C
v. μ0 = 4π x 10-7 T m A −1
vi. h = 6.63 x10-34 J s
vii. ε0 = 8.854 x10-12 $C2N-1m-2$
viii. Avogadro's number = 6.023 X 10^23 per gram mole.

SECTION -A		
Q No.	**QUESTION**	**MARKS**
1.	The resistances of two wires having same length and same area of cross-section are 2 Ω and 8 Ω respectively. If the resistivity of 2 Ω wire is 2.65 × 10–8 Ω-m then the resistivity of 8 Ω wire is:. (A) 10.60 × 10–8 Ω-m (B) 8.32 × 10–8 Ω-m (C) 7.61 × 10–8 Ω-m (D) 5.45 × 10–8 Ω-m	1
2.	Two wires A and B, of the same material having length in the ratio 1 : 2 and diameter in the ratio 2 : 3 are connected in series with a battery. The ratio of the potential differences (VA / VB) across the two wires respectively is:	1

	(A) 1/3 (B) 3/4 (C) 4/5 (D) 9/8	
3.	The given figure shows I – V graph of a copper wire whose length and area of cross-section are L and A respectively. The slope of this curve becomes:  (A) less if the length of the wire is increased. (B) more if the length of the wire is increased. (C) more if a wire of steel of same dimension is used. (D) more if the temperature of wire is increased.	1
4.	When a potential difference V is applied across a conductor at temperature T, the drift velocity of the electrons is proportional to: (A) T (B)$\sqrt{T}$ (C) V (D) V/2	1
5.	A current of 0.8 A flows in a conductor of 40 W for 1 minute. The heat produced in the conductor will be (A) 1445 J (B) 1536 J (C) 1569 J (D) 1640 J	1
6.	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	1

7.	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	1
8.	What happens to resistance of a conductor when its temperature increases? (A) Decreases(B) Increases (C) Remains same (D) Becomes zero	1
9.	A battery of emf 12V and internal resistance 1Ω is connected to a 5Ω resistor. The terminal voltage is: (A) 12V (B) 10V (C) 5V (D 11V	1
10.	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	1
11.	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%	1
12.	The voltage-current graph for an ohmic resistor is: (A) Parabolic (B) Circular (C) Straight line(D) Hyperbolic	1
	For Questions 13 to 16, two statements are given one labelled Assertion (A) and other **labelled .Reason (R). Select the correct answer to these questions from the options as given**	

	below. (A) Both Assertion and Reason are true and Reason is the correct explanation of Assertion. (B) Both Assertion and Reason are true but Reason is not the correct explanation of Assertion. (C) Assertion is true but Reason is false. (D) Both Assertion and Reason are false.	
13.	**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.	1
14.	**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.	1
15.	**ASSERTION**: Insulators do not allow flow of current through them. **REASON:** Insulators have no free charge carrier.	1
16.	**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.	1
	SECTION –B	
17.	The following graph shows the potential difference across the terminals of a cell against its load current. Find, (I) the emf of the cell and (II) the internal resistance of the cell.	2

18.	-identical resistors, each of resistance R ohm when connected in series have an effective re sistance of X ohm and when the resistors are connected in parallel the effective	2

	resistance is Y ohm. Find the relation between R , X and Y ?	
19.	sistance of a conductor is given by R=ml/ ne^2τA .	2
20(I)	Graph for a metallic wire at two different temperatures is shown in figure. Which of these emperature is higher and why? **OR**	2
20(II).	battery of a car has an emf of 12V . If the internal resistance of the battery is 0.4Ω , what is the urrent that can be drawn from the battery?	2
21(I).	The potential difference applied across a given conductor is doubled. How will this affect (i) the mobility of electrons and (ii) the current density in the conductor? Justify your answers. **OR**	2
21(II)	Two metallic wires of the same material have the same length but cross-sectional area is in the ratio 1 : 2. They are connected (i) in series and (ii) in parallel. Compare the drift velocities of electrons in the two wires in both the cases (i) and (ii)	2
	SECTION- C	
22	A battery of emf 6 V and internal resistance 2Ω is connected to a resistor. If the current in the circuit is 0.25 A, find (i) the resistance of the resistors; (ii) the terminal voltage of the battery.	

23.	(I) The current I1 in a wire is getting divided in two wires with currents I2 and I3 at a junction in a circuit. The currents in the three wires are related by I1 = I2 + I3. (A) State the fundamental law from which this relation is derived. (B) Explain the validation of law of conservation of energy in Kirchhoff's voltage law?	3

	(II) How the balancing condition gets affected if you are interchanging the galvanometer and the cell in the Wheat stone bridge?	
24.	The network PQRS, shown the circuit diagram, has the batteries of 5 V and 10 V and negligible internal resistance. A milliammeter of 50Ω resistance is connected between P and R. Calculate the reading in the milliammeter.	3
25.	Use Kirchhoff's rules to determine the value of the current I1 flowing in the circuit shown in the figure.	3
26.	A uniform wire of resistance 12 Ω is cut into three pieces so that the ratio of the resistances R1 : R2 : R3 = 1 :2 : 3 and the three pieces are connected to form a triangle across which a cell of emf 8V and internal resistance 1 Ω is connected as shown. Calculate the current through each part of the circuit.	
27(I).	State Kirchhoff's rules. Explain briefly how these rules are justified. **OR**	

27(II).	Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 2.5×10^{-7} m^2 carrying a current of 1.8 A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}.	
28.	Draw a plot showing the variation of resistivity of a (i) conductor and (ii) semiconductor, with the increase in temperature.	

	How does one explain this behaviour in terms of number density of charge carriers and the relaxation time?	
	SECTION- D	
29.	The materials can be classified as conductors, semi-conductors and insulators depending on their resistivity's. Metals have low resistivity's in the range of 10 -8Ωm. At the other end are insulators like ceramic, rubber and plastics having resistivity 10-18 times greater than metals or more. In between these two are semiconductors. These however have resistivity characteristically decreasing with a rise in temperature. The resistivity's of semiconductors can be decreased by adding small amount of suitable impurities. This last feature is exploited in use of semiconductors for electronic devices .The resistivity of a semiconductor decreases from 2.5 Ω·m to 0.5 Ω·m when heated. A. 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 200C is 20Ω and at 5000C it is 60Ω. At what temperature the resistance is the temperature is 25Ω (i) 1600C (ii) 2500C (iii) 1000C (iv) 800C 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	1 1 1 1

30.	A 12V battery with an internal resistance of 1Ω is connected to a load resistance of 5Ω. A voltmeter is connected across the load to measure the terminal voltage. The student calculates the current using the total resistance and applies the formula V=E−Ir. A. What is the current in the circuit? (i) 2 A (ii) 3 A (iii) 4 A (iv)5 A B**.** What is the terminal voltage across the load? (i)10 V (ii)12 (iii) 11 V (iv)9 V C. Internal resistance of a cell is due to: (i)Connecting wires (ii)Electrolyte inside the cell (iii)Electrode shape (iv)External circuit D. What happens to terminal voltage when load resistance increases?	1 1 1

	(i) Increases (ii)Decreases (iii)Remains constant (iv)Becomes zero	1
	SECTION –E	
31(I).	A() Derive the relation between current density J→ and potential difference 'V' across a current carrying conductor of length area of cross-section 'A' and the number density of free electrons. (B) Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. [Assume that the number density of conduction electrons is 9×10^{28} m^{-3}] **OR**	**5**
31(II).	(A)Why do the 'free electrons', in a metal wire, 'flowing by themselves', not cause any current flow in the wire? Define 'drift velocity' and obtain an expression for the current flowing in a wire, in terms of the 'd velocity' of the free electrons. (B) Use the above expression to show that the 'resistivity', of the material of a wire, is' inversely proportional to the 'relaxation time' for the 'free electrons' in the metal.	5

32(I).	a) What is a Wheatstone bridge? (b) Derive the condition for the bridge to be balanced. (c) A resistance of 10 Ωis connected in the left gap and an unknown resistance X in the right gap of a meter bridge. The balance point is found at 40 cm from the left end. Calculate the value of the resistance. **OR**	5
32(II).	a) State Ohm's law. (b) Derive an expression for the current flowing through a conductor using Ohm's law. (c) Define resistance and mention the factors on which it depends. (d) Explain, with the help of a graph, how current varies with voltage for: • (i) An Ohmic conductor • (ii) A non-ohmic conductor	5
33(I).	Explain the variation of resistance with temperature in: (a) Conductors **(b)** Semiconductors (c) Insulators Include neat labelled graphs and explain the physical reason for each behaviour. **OR**	5
33(II)	Two cells of EMFs E_1 AND E_2, and internal resistances r_1 and r_2, are connected in: (a) Series (b) Parallel Derive expressions for the net EMF and effective internal resistance in both cases. Which combination is better for obtaining maximum current?	5

Assignment-2 MCQs

Q1.The unit of resistivity is:

A. ohm
B. ohm-meter
C. ohm-meter^2
D. ohm/meter

Q2. Two wires of the same material and length have radii in the ratio 2:1. The ratio of their resistances is:

A. 1:4
B. 4:1
C. 2:1
D. 1:2

Q3.Kirchhoff's First Law is based on:

A. Conservation of energy
B. Conservation of momentum
C. Conservation of charge
D. Conservation of current

Q4.A cell of emf 1.5 V and internal resistance 1Ω is connected to an external resistor of 2Ω. The current in the circuit is:

A. 0.5 A
B. 1 A
C. 2 A
D. 1.5 A

Q5.A wire of resistance R is stretched to double its length. What will be its new resistance?

A. R/2
B. R
C. 2R
D. 4R

Q6.The drift velocity of electrons increases when:

A. The area of cross-section increases
B. The number of electrons increases
C. The electric field increases
D. The resistance increases

Q7.If temperature increases, the resistivity of a metal:

A. Increases B. Decreases C. Remains constant D. Becomes zero

Q8.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

Q9.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

Q10.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

Q11.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%

Q12.A wire has resistance R. If it is cut into 3 equal parts and all parts are connected in parallel, the new resistance is:

A. R
B. R/3
C. R/9
D. 3R

Q13.When 5 cells each of emf 2V and internal resistance 0.5Ω are connected in series, the total emf is:

A. 2V
B. 5V
C. 10V
D. 1V

Q14.What happens to resistance of a conductor when its temperature increases?

A. Decreases
B. Increases
C. Remains same
D. Becomes zero

Q15.In a metallic conductor, when temperature increases, the relaxation time:

A. Increases
B. Decreases
C. Remains unchanged
D. Becomes zero

Q16.A battery of emf 12V and internal resistance 1Ω is connected to a 5Ω resistor. The terminal voltage is:

A. 12V
B. 10V
C. 5V
D. 11V

Q17.The current density is defined as:

A. Current per unit length
B. Current per unit area
C. Charge per unit time
D. Voltage per unit resistance

Q18.Mobility of charge carriers is defined as:

A. Velocity per unit electric field
B. Current per unit electric field
C. Resistance per unit length
D. Conductance per unit area

Q19.The resistance of a wire varies directly with:

A. Square of length
B. Inverse of length
C. Length
D. Square of area

Q20.The voltage-current graph for an ohmic resistor is:

A. Parabolic
B. Circular
C. Straight line
D. Hyperbolic

Q21. The resistivity of a wire
(a) Increases with the length of the wire
(b) Decreases with the area of cross-section
(c) Decreases with the length and increases with the cross-section of wire
(d) None of the above statement is correct

Q22. On increasing the temperature of a conductor, its resistance increases because

(a) Relaxation time decreases (b) Mass of the electrons increases
(c) Electron density decreases (d) None of the above

Q23. Through a semiconductor, an electric current is due to drift of
(a) Free electrons (b) Free electrons and holes
(c) Positive and negative ions (d) Protons

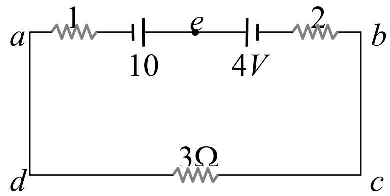
Q24. The resistance of a wire of uniform diameter d and length L is R. The resistance of another wire of the same material but diameter $2d$ and length $4L$ will be
(a) $2R$ (b) R
(c) $R/2$ (d) $R/4$

Q25. For which of the following the resistance decreases on increasing the temperature

(a) Copper (b) Tungsten
(c) Germanium (d) Aluminum

Q26. The resistance of a wire is R. If the length of the wire is doubled by stretching, then the new resistance will be
(a) $2R$ (b) $4R$
(c) R (d) $R/4$

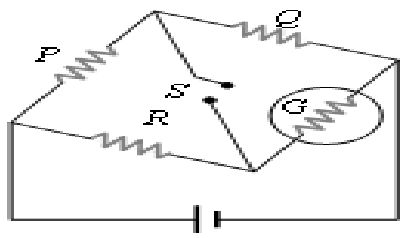
Q27. The magnitude and direction of the current in the circuit shown will be



(a) $\frac{7}{3}A$ from a to b through e (b) $\frac{7}{3}A$ from b to a through e
(c) $1A$ from b to a through e (d) $1A$ from a to b through e

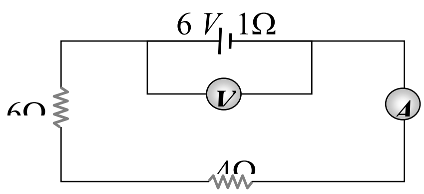
Q28. A cell whose e.m.f. is 2 V and internal resistance is 0.1Ω, is connected with a resistance of 3.9Ω. The voltage across the cell terminal will be
(a) $0.50V$ (b) $1.90V$
(c) $1.95V$ (d) $2.00V$

Q29. The figure shows a circuit diagram of a 'Wheatstone Bridge' to measure the resistance G of the galvanometer. The relation $\frac{P}{Q} = \frac{R}{G}$ will be satisfied only when



(a)The galvanometer shows a deflection when switch S is closed
(b)The galvanometer shows a deflection when switch S is open
(c)The galvanometer shows no change in deflection whether S is open or closed
(d)The galvanometer shows no deflection

Q30. In the circuit shown here, the readings of the ideal ammeter and ideal voltmeter are
(a) 6 A,60 V
(b) 0.6 A,6 V
(c) 6/11 A , 60/11 V
(d) 11/6 A, 11/60 V



(ASSERTION & REASON)

Assignment-3

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. Both A and R are false.

Q1. 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.

Q2. 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.

Q3. ASSERTION: Insulators do not allow flow of current through them.

REASON : Insulators have no free charge carrier.

Q4. 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.

Q5. ASSERTION: The internal resistance of cell is constant.

REASON: Ionic concentration of the electrolyte remains same during use of cell

Q6. Assertion (A): Ohm's law is not applicable to semiconductors.

Reason (R): The resistance of a semiconductor does not remain constant with changing voltage.

Q7. Assertion (A): The resistance of a wire increases with increase in temperature.

Reason (R): The number of free electrons in a metal increases with temperature.

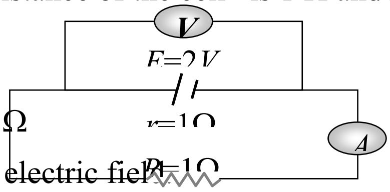
Q8. Assertion (A): The internal resistance of a cell increases with use.

Reason (R): Continuous chemical reactions in the electrolyte change its composition.

Q9. Assertion : The resistivity of a semiconductor increases with temperature.
Reason : The atoms of a semiconductor vibrate with larger amplitude at higher temperatures thereby increasing its resistivity.

Q10. Assertion : The temperature coefficient of resistance is positive for metals and negative for *p*-type semiconductor.
Reason : The effective charge carriers in metals are negatively charged whereas in *p*-type semiconductor they are positively charged.

Q11. Assertion : In the following circuit emf is $2V$ and internal resistance of the cell is 1 Ω and R = 1Ω, then reading of the voltmeter is $1V$.



Reason : $V = E - ir$ where E = $2V$, $i = \frac{2}{2} = 1A$ and R = 1 Ω

Q12. Assertion : There is no current in the metals in the absence of electric field.
Reason : Motion of free electron are randomly.

Q13. Assertion : The drift velocity of electrons in a metallic wire will decrease, if the temperature of the wire is increased.

Reason : On increasing temperature, conductivity of metallic wire decreases.

Q14. Assertion : Electric field outside the conducting wire which carries a constant current is zero.

Reason : Net charge on conducting wire is zero.

Q15. Assertion : A person touching a high power line get an electric shock.

Reason : The current carrying wires attract the man towards it.

Q16. Assertion : In a wire of uniform area of cross-section, the current is same everywhere .

Reason : The current in a wire is due to drift of electrons along the wire

Q17. Assertion : When a wire is stretched to double of its length, its resistivity doubles.

Reason : The current in a wire is due to drift of positive charge along the wire.

Q18. Assertion :Bending a wire does not effect electrical resistance.

Reason :Resistance of wire is proportional to resistivity of material.

Q19. Assertion : If potential difference between two points is zero and resistance between those two points is
zero, current may flow between the points.

Reason : Kirchhoff's first law is based on the law of conservation of charge.

Q20. Assertion : Conductivity of metals is much higher than that of an electrolyte at room temperature.

Reason : Free electron density in metals is much larger than the density of ions in electrolytes and also free electrons have greater mobility than ions.

Assignment-4
(CASE-STUDY)

Q1. The materials can be classified as conductors, semi-conductors and insulators depending on their resistivity's. Metals have low resistivity's in the range of 10 -8Ωm. At the other end are insulators like ceramic, rubber and plastics having resistivity are 10-18 times greater than metals or more. In between these two are semiconductors. These however have resistivity's characteristically decreasing with a rise in temperature. The resistivity 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.

A. 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 200C is 20Ω and at 5000C it is 60Ω. At what temperature the resistance is the temperature is 25Ω

(i) 1600C (ii) 2500C (iii) 1000C (iv) 800C

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

Q2.Electric fish are able to generate current with biological cells called electro plaques, 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 electro plaque array, one end at the animal's head and the other near its tail.

A. If the water surrounding the eel has resistance R, = 800 9 how much current can the eel produce in the water?

(i) 6.6 mA (ii) 0.93 A (iii) 6.6 A (iv) 9.3 mA

B. 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

(i) 3.8 V (ii) 4 V (iii) 0.2 V (iv) 1.8 V

C. 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

(i) 1ohm (ii) 2 ohm (iii) 4 ohm (iv) 8 ohm

D. 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 (i) 100 ohm(ii) 50 ohm (iii) 10ohm (iv) 5 ohm

Q3.A 12V battery with an internal resistance of 1Ω is connected to a load resistance of 5Ω. A voltmeter is connected across the load to measure the terminal voltage. The student calculates the current using the total resistance and applies the formula V=E−Ir.

A. What is the current in the circuit?

(i) 2 A (ii) 3 A (iii) 4 A (iv) 5 A

B. What is the terminal voltage across the load? (i)10 V (ii)12 (iii) 11 V (iv)9 V

C. Internal resistance of a cell is due to:

(i)Connecting wires (ii)Electrolyte inside the cell(iii)Electrode shape (iv)External circuit

D. What happens to terminal voltage when load resistance increases?

(i) Increases (ii) Decreases (iii) Remains constant (iv) Becomes zero

Q4.A student performs an experiment to verify Ohm's law. He connects a 2V battery to a resistor and measures the current using an ammeter. He repeats the experiment with different voltages and notes that the current through the resistor increases linearly with voltage. He plots a V-I graph and finds it to be a straight line passing through the origin. He then connects multiple resistors in series and parallel to observe changes in current and resistance.

A. What does the straight-line V-I graph indicate?

(i)The resistor is a semiconductor (ii) Ohm's law is not valid (iii) The resistor obeys Ohm's law (iv)Resistance is decreasing

B. Remains the same

(i) Increases (ii)In a series connection of resistors, the total resistance (iii) Decrease (iv)Becomes zero

C. If three resistors of 2Ω, 3Ω, and 5Ω are connected in parallel, the equivalent resistance is:

(i) 10Ω (ii)5Ω (iii)Less than 2 (iv)1Ω

D. What is the unit of slope of the V-I graph?

(i)Ampere (ii) Volt (iii)Ohm (iv) Ohm^{-1}

Q5.Whenever an electric current is passed through a conductor, it becomes hot after some time. The Phenomenon of the production of heat in a resistor by the flow of an electric current through it is called heating effect of current or Joule heating. Thus, the electrical energy supplied by the source of emf is converted into heat. In purely resistive circuit the energy expended by the source entirely appears as heat. But if the circuit has an active element like a motor, then a part of the energy supplied by the source goes to do useful work and the rest appears as heat. Joule's law of heating form the basis of various electrical appliances such as electric bulb, electric furnace, electric press etc

(i) Alloys used for making standard resistance coils as alloys

(a) have more conductivity (b) less conductivity

(c) less temperature coefficient of resistivity (d) more temperature coefficient of resistivity

(ii) Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Wire which gets heated up more is

(a) Nichrome (b) copper

(c) both gets heated up to same values (d) can't say

(iii) A 25 W and 100 W are joined in series and connected to the mains. The bulb which will glow brighter is

(a) 25W as it has high resistance (b) 100 W as it has high resistance

(c) 25W as it has low resistance (d) 100 W as it has low resistance

(iv) The heat emitted by an iron of 100 W in 1 minute is

(a) 600J (b) 6000J (c) 60J (d)60000J

Q6.When electric field is applied across a conductor then the electrons move in the direction opposite to the electric field due to electric force on them. The average velocity with which free electrons get drifted in the direction opposite to the applied electric field inside a conductor is called drift velocity. This motion of the electrons in the direction opposite to the electric field is superimposed on their random motion. Drift velocity depends on electric field applied, the nature of material and temperature. On increasing the temperature, relaxation time decreases. Hence decrease in relaxation time, due to increase in temperature, will reduce the drift speed.

(i) When a potential difference V be applied across a cylindrical conductor of length L and radius R, is doubled then the drift velocity of electrons gets:

(a) doubled (b) four times (c) remain same (d) halved

(ii) Two wires made of same material but of different diameters are connected in series in a circuit. The current flows in the combination of wires. When the current flows from the wire with larger diameter to the one with smaller diameter then drift velocity of electrons:

(a) will decrease (b) will increase (c) remains same (d) first will increase and after some time decrease

(iii) Two wires each of radius of cross section r but of different materials are connected together end to end (in series). If the densities of charge carriers in the two wires are in the ratio 1:4, the drift velocity of electrons in the two wires will be in the ratio:

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

(iv) A current I flows through a uniform wire of diameter d when the electron drift velocity is v. The same current will flow through a wire of diameter d/2 made of the same material if the drift velocity of the electrons is

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

.Q7.When the electric cell (source of EMF) is in a closed circuit, the current flows through the circuit. There is a fall of potential across the the internal resistance of the cell. The terminal potential difference between the two electrodes of the cell becomes less than the EMF of the cell by an amount equal to to potential drop across the internal resistance of the cell. Thus, in a closed circuit The terminal potential difference of a cell is always less than the the EMF of the cell.

(i) EMF of a cell is independent of:

(a) size of the electrodes

(b) quantity of electrolyte present in the cell

(c) distance between the electrodes

(d) all of these

(ii) three cells of EMF, 2.0 V,2.5 V and 3.0 V are connected in series. Their internal resistances are 0.20 Ω, 0.20Ω and 0.15Ω respectively. The battery is connected to an external resistor of 6.5 Ω wire a very low resistance ammeter, what would be the reading of ammeter?

(a) 1.1Ω (b) 1Ω (c) 2 Ω (d) 2.1 Ω

(iii) A cell of emf E and internal resistance r is connected in series with an external resistance 'nr'. Then ratio of terminal potential difference to emf is:

(a)1/n (b) 1/(n+1) (c) n/(n+1) (d) (n+1)/n

(iv) In an experiment a student measures terminal potential difference (TPD) of a cell. When the same cell is connected to an external resistance of 5 Ω then the TPD is 2 V and when the same is repeated for an external resistance of 10 Ω then the TPD is 2.4 V. What is the EMF and internal resistance of cell?

(a)2.5 V,3Ω (b) 3 V,3.5Ω (c) 3 V,2.5Ω (d) 2.5 V,3Ω

Q8: Mobile Phone Charging
Situation: Riya charges her phone using a 5 V, 2 A charger connected to a 220 V AC supply through an adapter.
Questions:

(a) Why is AC converted to DC before charging?
(b) Calculate the maximum power supplied by the charger.
(c) What happens if the charging cable has high resistance?
(d) Why are copper wires used?

Q9:Situation: A car battery has emf 12 V, internal resistance 0.2 Ω and supplies 30 A.
Questions:

(a) Find terminal voltage.
(b) Find power supplied.
(c) Why is terminal voltage less than emf?
(d) What if no current flows?

Q10:Situation: A 1000 W, 220 V heater is used.
Questions:

(a) Find current.
(b) Find resistance.
(c) Why is nichrome used?
(d) Effect of lower voltage?

(SHORT QUESTION)
Assignment-5

Q1. 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.

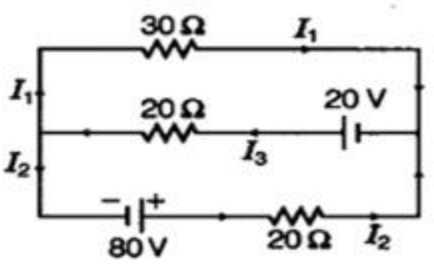
Q2. Under what condition will the current in the wire be same when connected in series and in parallel of an identical cell having internal resistance r and external resistance R?

Q3.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.

Q4.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.

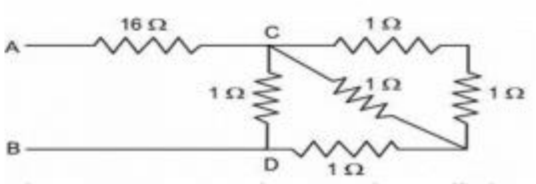
Q5.A wire of resistance 8 R is bent in the form of a circle. What is the effective resistance between the ends of a diameter AB?

Q6.Use Kirchhoff's rule to determine the value of the current I1 flowing in the circuit shown in the figure.



Q7. Differentiate between resistance and resistivity. Q8. What is drift velocity? How is it related to current?

Q9. 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?



Q10. Draw the graph showing variation of resistivity with temperature in case of a (i) metal (ii) semiconductor.

Q11 Electrics bulb have following specification (i) 100 W at 220 V (ii) 1000 W at 220 V which bulb will have higher resistance. What is the ratio of their resistances.

Q12. When a cell is connected directly across a high resistance voltmeter the reading is 1.50 V. When the cell is shorted through a low resistance ammeter the current is 2.5 A. What is the emf and internalresistance of the cell?

Q13. You are supplied with 6 identical dry cells, each of emf 1.5 V and internal resistance 0.3 Ω. What are the overall emf and internal resistance when:

(a)the cells are connected in parallel?

(b) the cells are connected in series?

Q14. Estimate the average drift speed of conduction electrons in a copper wire of cross section area 2.5 X $10^{-7}m^2$ carrying a current of 2.7A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}.

Q15. A potential difference V is applied across the ends of copper wire of length *l* and diameter D.

What is the effect on drift velocity if (i) V is doubled (ii) *l* is doubled

<u>(LONG QUESTIONS)</u>

Q1.(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 $\times 10^{-31}$ 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.

Q2. 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.

Q3.(i)Derive the relation between current density and drift velocity and electric field.

(ii) Define current density (J), drift velocity (vd), and conductivity (σ).

(iii) Explain how conductivity varies with temperature in metals and semiconductors.

Answer Key (Assignment-1)

SECTION A (Q1–16):

1.A

2.D

3.A

4.C

5.B

6.A

7.B

8.B

9.B

10.B

11.B

12.C

13.D

14.A

15.B

16.A

SECTION B:

17. EMF = y-intercept of V-I graph; Internal resistance = slope magnitude ($V = E – Ir$).

18. $X=2R$, $Y=R/2 \Rightarrow R=X/2=2Y$ and $X=4Y$.

19. $R=ml/(ne^2\tau A)$; $R \propto L$, $R \propto 1/A$, $R \propto 1/\tau$.

20(I). Higher temperature has smaller I-V slope. OR 20(II). Current = 30 A.

21(I). Mobility unchanged; current density doubles.

OR 21(II). Drift velocity ratio: Series 2:1, Parallel 1:1.

SECTION C:

22.

Given: $E=6$ V, $r=2\ \Omega$, $I=0.25$ A.

(i) Resistance:

$I = E/(R+r)$

$0.25 = 6/(R+2)$

$R+2 = 24$

$R = 22\ \Omega$

(ii) Terminal Voltage:

$V = E - Ir$

$= 6 - (0.25\times2)$

$= 5.5$ V

Final Answer:

Resistance = 22 Ω

Terminal Voltage = 5.5 V

23. (I) KCL; KVL based on conservation of energy. (II) Interchanging galvanometer and cell does not affect balance.

24

Using Kirchhoff's rules:

Loop 1: $100I1 + 50(I1-I2)=10$

$\Rightarrow 3I1-I2=0.2$

Loop 2:

$50(I2-I1)+50I2=5$

$\Rightarrow -I1+2I2=0.1$

Solving:

$I1=0.1$ A, $I2=0.1$ A

Milliammeter current = $I1-I2 = 0$ A

Final Answer: Milli ammeter reading = 0 mA.

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KCL:
$I1 = I2 + I3$
KVL:
$30I1 + 20I3 = 20$
$20I2 + 20I3 = 80$
From second equation:
$I2 + I3 = 4$
Hence,
$I1 = 4$ A
Final Answer: $I1 = 4$ A.

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R1:R2:R3 = 1:2:3 and total resistance =12 Ω.
Therefore:
R1=2 Ω, R2=4 Ω, R3=6 Ω.
Equivalent resistance:
(6×6)/(6+6)=3 Ω.
Total resistance including internal resistance:
3+1=4 Ω.
Current from battery:
I=8/4=2 A.
Current divides equally between equal 6 Ω branches.
Final Answer:
Current through R1 = 1 A
Current through R2 = 1 A
Current through R3 = 1 A
Total current = 2 A.

27 (OR)

Given:
I=1.8 A
A=2.5×10^-7 m²
n=9×10^28 m^-3
e=1.6×10^-19 C
Drift velocity:
vd = I/(neA)
= 1.8/[(9×10^28)(1.6×10^-19)(2.5×10^-7)]
= 5×10^-4 m/s
Final Answer:
Average drift speed = 5×10^-4 m/s (0.5 mm/s).

28. Conductors: resistivity increases with temperature. Semiconductors: resistivity decreases with temperature.

SECTION D:

29. A)80% B)Carbon C)80°C D)None of these.

30. A)2 A B)10 V C)Electrolyte inside cell D)Increases.

SECTION E:

Q31(A): Relation between Current Density and Potential Difference

Electric field $E = V/L$.
Drift velocity $v_d = eE\tau/m$.
Current $I = neAv_d$.
Current density $J = I/A = nev_d$.
Substituting v_d:
$J = (ne^2\tau/m)E = (ne^2\tau/m)(V/L)$.
Final relation:
$J = (ne^2\tau/m)(V/L)$.

31(B): Drift Speed

Given: $I=1.5$ A, $A=1.0\times10^{-7}$ m², $n=9\times10^{28}$ m^-3, $e=1.6\times10^{-19}$ C.
$v_d = I/(neA)$
$= 1.5 / [(9\times10^{28})(1.6\times10^{-19})(1\times10^{-7})]$
$= 1.04\times10^{-3}$ m/s.

31 OR Free electrons move randomly in all directions, so their average velocity is zero and no current flows without an electric field.
Drift velocity is the average velocity acquired by free electrons under an electric field.
Current: $I = neAv_d$.
Using $v_d=eE\tau/m$ and Ohm's law:
Resistivity $\rho = m/(ne^2\tau)$, hence ρ is inversely proportional to relaxation time τ.

32.(a) Wheatstone bridge is used to measure an unknown resistance accurately.
(b) At balance, no current flows through the galvanometer.
Balance condition:
$P/Q = R/S$.
(c) Meter bridge:
$10/X = 40/60$
$X = 15\ \Omega$.

33 OR Ohm's Law: $V = IR$.
Current: $I = V/R$.

Resistance: $R = \rho L/A$.
Resistance depends on length, cross-sectional area, nature of material and temperature.
Ohmic conductor: straight-line V-I graph through origin.
Non-ohmic conductor: curved V-I graph.

33. Conductors: Resistance increases with temperature due to increased lattice vibrations and electron collisions.
Semiconductors: Resistance decreases because more charge carriers are produced.
Insulators: Resistance decreases slightly with temperature but remains very high because only a few charge carriers are generated.
Graphs:
Conductors: R increases with T.
Semiconductors: R decreases with T.
Insulators: R decreases slowly with T.

33.OR Series Combination:
Net EMF: $E_{series} = E_1 + E_2$
Effective internal resistance: $r_{series} = r_1 + r_2$
Current: $I = (E1 + E2)/(R + r1 + r2)$

Parallel Combination:
Net EMF: $E_{parallel} = (E1*r2 + E2*r1)/(r1 + r2)$
For identical cells: $E_{parallel} = E$
Effective internal resistance: $r_{parallel} = (r1*r2)/(r1 + r2)$
Current: $I = E_{parallel}/(R + r_{parallel})$

Conclusion:
Parallel combination is better for obtaining maximum current because its effective internal resistance is smaller. Series combination is preferred when a higher voltage is required.

ANSWERS KEY (Assignment-2)

Ans1: B. ohm-meter

Ans2: A. 1:4

Ans3: C. Conservation of charge

Ans4: B.
0.5 A
E/(R+r)=
1.5/(2+1)
=0.5

Ans5: 4R

$R \propto L^2R$ (since volume is constant)

Ans6: C

Ans7: A

Ans8: A

Ans9: B Ans10: B Ans11: B Ans12: C Ans13: C Ans14: B Ans15: B

Ans16: D

Explanation: V=E−Ir=12−(2)(1)=10V

Ans17: B

Ans18: A

Formula: $\mu = v_d/E$

Ans19: C

Ans20: C

ANS21:D

ANS22: A

ANS23:B

ANS24:B

ANS 25:C

ANS26:B

ANS27:D

ANS28:C

ANS29:C

ANS30:C

Assignment-3

ASSERTION & REASON

Ans1: D Ans2: A Ans3: A Ans4: A Ans5: D Ans6: A Ans7: C Ans8: A

Ans 9:D Ans10: B Ans11: A Ans12: A Ans13: B Ans14: A Ans15: C
Ans16: B

Ans 17:D Ans18: A Ans19: B Ans20: A

Assignment-4

Case study

Ans1: (A) (iv) (B) (iii) (C) (iv) (D) (iv)

Ans2: (A) (ii) (B) (i)(C) (i) (D) (ii)

Ans3: (A) (i) (B) (i) (C) (ii) (D) (i)

Ans4:(A) (iii) (B) (iii) (C) (iv) (D) (iii)

5	(i)	(ii)	(iii)	(iv)
Answer	c	a	a	b
6	(i)	(ii)	(iii)	(iv)
Answer	a	b	c	d
7	(i)	(ii)	(iii)	(iv)
Answer	d	a	c	c

Ans 8: (a)Mobile batteries require DC supply.

(b)P = VI = 5 × 2 = 10 W.

(c)High resistance causes voltage drop, heating and slower charging.

(d)Copper has low resistivity and high conductivity.

Ans9: (a) V = E − Ir = 12 − (30×0.2) = 6 V.

(b) P = VI = 6 × 30 = 180 W.

(c) Voltage drops across internal resistance

(d) Terminal voltage equals emf (12 V).

Ans10: (a) I=P/V=4.55 A.

(b) $R=V^2/P=48.4\ \Omega$.

(c) Nichrome has high resistivity and melting point.

(d) Current decreases.

Assignment-5

Short answer

Ans1: 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.

Ans2: r=R

Ans3
:1.7
V,
0.12
Ohm

Ans4
: I =
2/5 A
Ans5
: 2R

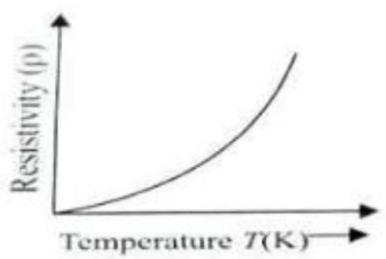
Ans6: I1 = -3/4 A, I2 = 23/8 A, I3 = 17/8 A

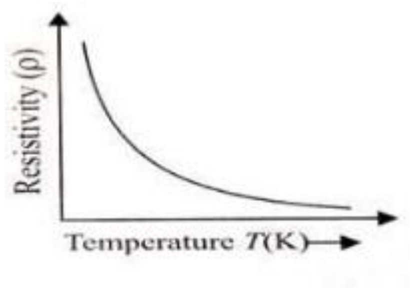
Ans7: Resistance depends on the dimensions and material of the conductor. Resistivity is a property of the material alone and is independent of dimensions.

Ans8: Drift velocity is the average velocity of electrons in a conductor due to an electric field. Relation: I = nAevd, where

- n = number of electrons per unit volume
- A = cross-sectional area
- e = charge of electron
- v_
d =
drift
veloc
ity

Ans9
:
41.5
Volt
Ans1
0:





METAL SEMICONDUCTOR

Ans11. -$\boldsymbol{P = VI = I^2R = \frac{V^2}{R}}$,for const. voltageP α 1/R , R α 1/P

. Resistance of 100 W bulb is greater and ratio 10 : 1.

Ans: 12 . E = 1.5 V

E = I r so 1.5 V = 2.5 A r and r = 0.6 Ω

Ans13: (a) 1.5 V, 0.05 Ω (b) 9 V, 1.8 Ω

Ans14: I = neAv$_d$, v$_d$ =7.5 x10^{-4} m/s

Ans15: (i) drift velocity doubled (ii) drift velocity halved

Long answers

Ans1: (i) Wire A has a greater relaxation time.

(ii) (a) 2.21 x 10-4 m/s , (b) 1.67 x 10-8 ohm-m

Ans2: (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

Ans3: Derivation of I=neAvdI Let:

- n = number of electrons per unit volume
- A= area of cross-section
- e = charge on electron
- vd = drift velocity Volume of wire = A·vd·1s

Number of electrons = nAvd

Total charge = neAvd So, current I=Q/t=neAvd

CHAPTER 4: MOVING CHARGES AND MAGNETISM

MCQ

Q1.. The direction of the magnetic field around a straight current-carrying conductor is determined by:

A) Fleming's Left-Hand Rule
B) Fleming's Right-Hand Rule
C) Right-Hand Thumb Rule
D) Lenz's Law

Q2. The magnetic force on a charge moving parallel to a magnetic field is:

A) Maximum
B) Zero
C) Half of maximum
D) Infinite

Q3. The radius of the circular path depends on:

A) Mass
B) Velocity
C) Magnetic field
D) All of the above

Q4. Two parallel current-carrying conductors carrying currents in the same direction:

A) Repel
B) Attract
C) No force
D) Rotate

Q5. The magnetic field at the centre of a circular loop is directly proportional to:

A) Radius
B) Current
C) Square of radius
D) Resistance

Q6. A moving coil galvanometer works on the principle of:

A) Electromagnetic induction
B) Heating effect
C) Torque on a current-carrying coil
D) Electrostatic attraction

Q7. The magnetic field inside a long solenoid is:

A) Zero
B) Uniform and parallel to its axis
C) Non-uniform
D) Circular

Q8.The torque on a coil is maximum when θ equals:

A. 0°

B. 30°

C. 90°

D. 180°

Q9.A galvanometer can be converted into an ammeter by connecting:

A. High resistance in series

B. Low resistance in parallel

C. Capacitor in series

D. Inductor in parallel

Q10.The path of a charged particle entering a magnetic field at an angle other than 0° or 90° is:

A. Straight line

B. Circle

C. Helix

D. Ellipse

Q11. A proton and alpha particle enter in same magnetic field B with same speed. Which has larger radius?

(a)Alpha (b)Equal (c)Proton (d)Cannot say

Q12. Magnetic field at centre of N-turn coil is proportional to?

(a)NI/R (b)R/NI (c)I/N (d)1/I

Q13. Current is doubled and radius halved. Magnetic Field at centre becomes?

(a)4B (b)2B (c)8B (d)B/2

Q14. Field inside an ideal solenoid depends on?

(a)nI (b)Radius (c)Length (d)None

Q15. Force on wire length 0.5 m carrying 4 A in 0.3 T at 90° is?

(a)0.6 N (b)1.2 N (c)0.3 N (d)6 N

Q16. Which law is based on current element?

(a)Biot-Savart (b)Gauss (c)Faraday (d)Lenz

Q17. A charge moving parallel to B has acceleration?

(a)Zero (b)qvB/m (c)B/q (d)Infinite

Q18.A positive charge is moving vertically upwards. When it enters a region of magnetic field directed towards north, what is the direction of the force on the charge?
a) Up
b) Down
c) Left
d) Right

Q19.An electron moving with a velocity of 15 ms^{-1} enters a uniform magnetic field of 0.2 T, along a direction parallel to the field. What would be its trajectory in this field?

a) Elliptical
b) Straight path
c) Helical
d) Circular

Q20.A charged particle in a plasma trapped in a magnetic bottle leaks out after a millisecond. What is the total work done by the magnetic field during the time the particle is trapped?
a) Maximum
b) Minimum
c) Zero
d) Depends on the strength of the magnetic field

Q21.What torque acts on a 50 turn coil of 200 cm^2 area carrying a current of 20 A held with its axis at right angles to a uniform magnetic field of 0.2T?
a) 8 Nm
b) 0.8 Nm
c) 4 Nm
d) 0.8 Nm

Answer Key

Q1.Answer: C) Right-Hand Thumb Rule

Q2. Answer: B) Zero

Q3. Answer D

Q4. Answer B

Q5. Answer: B) Current

Q6. Answer: C) Torque on a current-carrying coil

Q7. Answer: B) Uniform and parallel to its axis

Q8. Answer: C. 90°

Q9. Answer: B. Low resistance in parallel

Q10. Answer: C. Helix

Q.11 Ans-a

Q.12 Ans a

Q.13 Ans- a

Q14. Ans-a

Q15. Ans-a

Q16. Ans-a

Q17. Ans-a

Q18. Ans-c

Q19. Ans-b

Q20. Ans-c

Q21. Ans-c

CHAPTER 4: MOVING CHARGES AND MAGNETISM

ASSERTION AND REASON QUESTIONS

Question1- Assertion : In electric circuits, wires carrying currents in opposite directions are often twisted together

Reason : If the wires are not twisted together, the combination of the wires forms a current loop, the magnetic field generated by the loop might affect adjacent circuits or components.

Q.2. Assertion : The magnetic field produced by a current carrying solenoid is independent of its length and cross-sectional area.
Reason : The magnetic field inside the solenoid is uniform.

Q.3. Assertion : A charge, whether stationary or in motion produces a magnetic field around it.
Reason : Moving charges produce only electric field in the surrounding space.

Q.4 Assertion : A proton and an alpha particle having the same kinetic energy are moving in circular paths in a uniform magnetic field. The radii of their circular paths will be equal.
Reason : Any two charged particles having equal kinetic energies and entering a region of uniform magnetic field B in a direction perpendicular to B, will describe circular trajectories of equal radii.

Q.5 Assertion : If the current in a solenoid is reversed in direction while keeping the same magnitude, the magnetic field energy stored in the solenoid remains unchanged.
Reason : Magnetic field energy density is proportional to the magnetic field.

Q.6 Assertion: To convert a galvanometer into an ammeter a small resistance is connected in parallel with it.
Reason: The small resistance increases the combined resistance of the combination.

Answer key

Question-1 Answer a

Question-2 Answer b

Question-3 Answer d

Question-4 Answer c

Question-5 Ans-c

Question-6 Ans c

CHAPTER 4: MOVING CHARGES AND MAGNETISM

ASSERTION AND REASON QUESTIONS

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Reason: The small resistance increases the combined resistance of the combination.

Answer key

Question-1 Answer a

Question-2 Answer b

Question-3 Answer d

Question-4 Answer c

Question-5 Ans-c

Question-6 Ans c

Assingment-5

3 marks qoestions

Question-1A thin circular wire carrying current I has magnetic moment M. The shape of the wire is changed to a square and it carries the same current. It will have magnetic moment M_1. Find the ratio M to M_1.

Question-2

A circular arc of wire of radius of curvature r subtends an angle of π /5 radian at its centre. If current I is flowing in it then find the magnetic induction at its centre.(μ_0= permeability of free space)

Question-3

A solenoid of 1000 turns is wound uniformly on a glass tube 4 m long and 0.3m in diameter. Find magnetic intensity at the centre of the solenoid when a current of 4 A flows through it .

(a) $2x10^3$ A/m

(b) $16x10^3$ A/m

(c) $4x10^3$ A/m

(d) 10^3 A/m

Answer1- For a current-carrying loop, the magnetic moment is M= IA

where I is the current and A is the area enclosed by the loop.

The same wire is first in the shape of a circle and then changed into a square. So, the length of the wire remains the same.

Let the length of the wire be .L

For the circular loop,

L= $2\pi r$

So $r= L/2\pi$

Then $A_c = \pi r^2$

$A_c = L^2/4\pi^2$

Then for circular loop

M= Ix $L^2/4\pi^2$

For square

L=4a

a= L/4

Area of square

$A_s = a^2$

$A_s = L^2/16$

For square

M_1= Ix $L^2/16$

So $M/M_1 = 4/\pi$

Qoestion-2 For a current-carrying circular wire, the magnetic field at the centre of a full circle is B= $\mu_0 i/2r$

A full circle subtends an angle 2π at the centre.

Here, the wire is only an arc and it subtends an angle

$\Theta = \pi/5$ So the magnetic field due to the arc will be the same fraction of the field due to a full circle:

B= $\Theta/2\pi$ x $\mu_0 i/2r$

So the magnetic induction at the centre is

B= $\mu_0 i/20r$

Question-3

For a long solenoid, the magnetic intensity at the centre is

H-= nI

N= 1000, I= 4A , l-= 4m

So n= 1000/4 = 250

Hence H= 250x4 = 1000A/m

CHAPTER 5: MAGNETISM AND MATTER

PRACTICE ASSIGNMENTS (2 – 5)

CLASS – XII (2026-27)

Answer keys are provided immediately after each assignment.

Assignment – 2

MCQ (1 mark each)

Q1. According to Curie's law, the magnetic susceptibility (χ) of a paramagnetic substance at absolute temperature T is proportional to: *[CBSE Board pattern]*

(a) T (b) 1/T (c) T^2 (d) independent of T

Q2. At a place, the horizontal component of the earth's magnetic field is $\sqrt{3}$ times the vertical component. The angle of dip at that place is: *[CBSE Board pattern]*

(a) 30° (b) 45° (c) 60° (d) 90°

Q3. Which statement about magnetic field lines is NOT correct?

(a) They form closed loops (b) Outside the magnet they run from N to S pole (c) Two field lines never intersect (d) Inside the magnet they run from N to S pole

Q4. A dip needle, free to rotate in a vertical plane, sets itself vertical at a certain place on the earth. The angle of dip at this place is:

(a) 0° (b) 45° (c) 90° (d) cannot be determined

Q5. The relative magnetic permeability (μ_r) of a ferromagnetic material is:

(a) slightly less than 1 (b) slightly greater than 1 (c) very much greater than 1 (d) zero

Q6. The Curie temperature is the temperature above which:

(a) a paramagnetic material becomes ferromagnetic (b) a ferromagnetic material becomes paramagnetic (c) a diamagnetic material becomes paramagnetic (d) a ferromagnetic material becomes diamagnetic

Q7. A material suitable for making permanent magnets should have:

(a) high retentivity, low coercivity (b) low retentivity, high coercivity (c) high retentivity, high coercivity (d) low retentivity, low coercivity

Q8. A bar magnet of magnetic moment M is cut into two equal halves breadth-wise (perpendicular to its length). The magnetic moment of each half becomes:

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

Q9. Gauss's law in magnetism, $\oint B \cdot dA = 0$ over any closed surface, is a direct consequence of: *[CBSE Board pattern]*

(a) Coulomb's law of magnetism (b) the non-existence of isolated magnetic monopoles (c) Ampere's circuital law (d) Faraday's law of induction

Q10. The magnetic susceptibility of diamagnetic substances is:

(a) small and positive (b) small and negative (c) large and positive (d) large and negative

Assignment – 3

Assertion & Reason Questions

Each question below consists of an Assertion (A) and a Reason (R). Choose 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, but R is false.

(d) A is false, but R is true.

Q1. Assertion (A): A bar magnet held in a uniform magnetic field experiences no net force, but it may experience a torque.

Reason (R): The two equal and opposite forces acting on the poles of the magnet act along different lines, forming a couple.

Q2. Assertion (A): Soft iron is preferred over steel for making electromagnet cores.

Reason (R): Soft iron has high permeability together with low retentivity and low coercivity, so it magnetises and demagnetises easily.

Q3. Assertion (A): A paramagnetic sample, when placed in a non-uniform magnetic field, tends to move towards the region of stronger field.

Reason (R): Paramagnetic materials get weakly magnetised in the direction of the applied field.

Q4. Assertion (A): Magnetic field lines never intersect each other.

Reason (R): If two field lines intersected, the magnetic field would have two different directions at the point of intersection, which is not possible.

Q5. Assertion (A): Diamagnetism is present in every material, even those that are ultimately paramagnetic or ferromagnetic.

Reason (R): Diamagnetism arises from the orbital motion of electrons, which develops an induced magnetic moment opposing the applied field.

Assignment – 4

Competency Based Questions (4 marks each)

Q1. Elements of Earth's Magnetic Field

The earth behaves as if a huge magnetic dipole is embedded near its centre, tilted with respect to the geographic axis. At any place, the earth's magnetic field is completely described by three elements: declination (the angle between geographic and magnetic meridian), dip or inclination (the angle the field makes with the horizontal), and the horizontal component B_H. If B is the total field intensity and δ is the angle of dip, then $B_H = B \cos \delta$ and the vertical component $B_V = B \sin \delta$, so that $\tan \delta = B_V/B_H$. At the magnetic equator the field is entirely horizontal, while at the magnetic poles it is entirely vertical.

(i) The angle between the geographic meridian and the magnetic meridian at a place is called:

(a) Dip (b) Declination (c) Inclination (d) Retentivity

(ii) At the magnetic equator, the angle of dip is:

(a) 0° (b) 45° (c) 90° (d) 180°

(iii) If B is the total intensity of the earth's field and δ the angle of dip, the horizontal component B_H is given by:

(a) B sin δ (b) B cos δ (c) B tan δ (d) B/cos δ

(iv) At the magnetic poles of the earth, a freely suspended compass needle:

(a) points horizontally (b) becomes vertical (c) shows no deflection (d) points towards the geographic east

OR

(v) The angle of dip at a place is found to be 90°. This place is located at the:

(a) magnetic equator (b) geographic equator (c) magnetic pole (d) tropic of cancer

Q2. Hysteresis and Choice of Magnetic Materials

When a ferromagnetic material is taken through a cycle of magnetisation, the graph of magnetic field B against the magnetising field H does not retrace its path — this lag is called hysteresis, and the closed curve traced is the hysteresis loop. The value of B remaining when H is reduced to zero is the retentivity, and the reverse H required to bring B to zero is the coercivity. The area enclosed by the loop represents the energy dissipated per unit volume per cycle. Materials with a broad loop (high retentivity and coercivity) suit permanent magnets, while materials with a thin loop (low retentivity, low coercivity, but high permeability) suit electromagnets and transformer cores, since they must be magnetised and demagnetised repeatedly with minimal energy loss.

(i) A material suitable for making permanent magnets should have:

(a) low retentivity, low coercivity (b) high retentivity, high coercivity (c) low retentivity, high coercivity (d) high retentivity, low coercivity

(ii) The area enclosed by the hysteresis loop is a measure of:

(a) retentivity (b) coercivity (c) energy loss per cycle per unit volume (d) magnetic susceptibility

(iii) Which material is best suited for making transformer cores?

(a) Steel (b) Alnico (c) Soft iron (d) Cobalt steel

(iv) Coercivity of a magnetic material is defined as:

(a) the residual field when H = 0 (b) the reverse magnetising field needed to reduce B to zero (c) the maximum magnetisation attainable (d) none of these

OR

(v) A material with a very thin (narrow) hysteresis loop is best suited for:

(a) permanent magnets (b) electromagnets and transformer cores (c) neither (d) both equally

Q3. Bar Magnet as an Equivalent Dipole in an External Field

A bar magnet behaves like a magnetic dipole of moment M, and its field along the axis (at distance r, r >> length of magnet) is twice its field along the equatorial line at the same distance. When placed in a uniform external field B making an angle θ with M, the dipole experiences a torque $\tau = MB \sin\theta$, tending to align it with the field, and possesses potential energy $U = -MB \cos\theta$. The configuration is one of stable equilibrium when M is parallel to B, and unstable equilibrium when M is antiparallel to B.

(i) The magnetic field at a point on the axial line of a short bar magnet of moment M, at distance r, is:

(a) $\mu_0 M/4\pi r^3$ (b) $2\mu_0 M/4\pi r^3$ (c) $\mu_0 M/2\pi r^3$ (d) $\mu_0 M/4\pi r^2$

(ii) The magnetic field at an equatorial point at the same distance r is:

(a) same as the axial value (b) twice the axial value (c) half the axial value (d) zero

(iii) The potential energy of the dipole when it makes angle θ with B is given by:

(a) MB sin θ (b) −MB cos θ (c) MB cos θ (d) −MB sin θ

(iv) The dipole is in stable equilibrium when the angle between M and B is:

(a) 0° (b) 90° (c) 180° (d) 45°

OR

(v) The work done in rotating a magnetic dipole from its stable equilibrium to its unstable equilibrium position in a field B is:

(a) MB (b) 2MB (c) MB/2 (d) zero

Assignment – 5

Chapter Formulae with Explanation

1. **Coulomb's Law of Magnetism: $F = (\mu_0/4\pi) \cdot (m_1 m_2/r^2)$**
   Gives the force between two isolated magnetic poles of strength m_1 and m_2 separated by distance r; μ_0 is the permeability of free space.

2. **Magnetic Dipole Moment: $M = m \times 2l$**
   M is the product of pole strength m and the magnetic length (2l) of the magnet; it is a vector directed from the S pole to the N pole. SI unit: A m^2 or J/T.

3. **Field on the Axial Line (short magnet, r >> l): $B_{axial} = (\mu_0/4\pi) \cdot (2M/r^3)$**
   Magnetic field at a point on the line through both poles, at distance r from the centre; directed along M.

4. **Field on the Equatorial Line (short magnet): $B_{eq} = (\mu_0/4\pi) \cdot (M/r^3)$**
   Field at a point on the perpendicular bisector of the magnet, at distance r; directed opposite to M. Note $B_{axial} = 2 B_{eq}$ at the same distance.

5. **Torque on a Dipole in a Uniform Field: $\tau = M \times B$, $|\tau| = MB \sin\theta$**
   θ is the angle between M and B; the torque tends to align M along B.

6. **Potential Energy of a Dipole: $U(\theta) = -M \cdot B = -MB \cos\theta$**
   Minimum (most stable) at θ = 0°; maximum (unstable) at θ = 180°; U = 0 when θ = 90° (reference position).

7. **Work Done in Rotating a Dipole: $W = MB(\cos\theta_1 - \cos\theta_2)$**
   Work needed by an external torque to rotate the dipole from angle θ_1 to θ_2 with respect to B.

8. **Gauss's Law in Magnetism: $\oint B \cdot dA = 0$ (over any closed surface)**
   The net magnetic flux through any closed surface is always zero, since isolated magnetic monopoles do not exist and field lines always form closed loops.

9. **Magnetising Field (Magnetic Intensity), H**
   The external field that magnetises a material; SI unit A/m. $B = \mu_0(H + M_i)$, where M_i is intensity of magnetisation.

10. **Magnetic Susceptibility: $\chi = M_i / H$**

Measures how easily a material is magnetised by a field H. $\chi < 0$ (small) for diamagnetics, $\chi > 0$ (small) for paramagnetics, $\chi >> 0$ (large) for ferromagnetics.

11. Relative Permeability: $\mu_r = 1 + \chi$, and $B = \mu H = \mu_0\mu_r H$

Relates the total field inside the material to the applied field H; μ is the absolute permeability of the material.

12. Curie's Law (paramagnetic materials): $\chi = C/T$

Susceptibility of a paramagnetic substance is inversely proportional to its absolute temperature T; C is the Curie constant. Diamagnetic susceptibility is independent of temperature.

13. Curie Temperature (T_C): ferromagnetic → paramagnetic above T_C

Above the Curie temperature, thermal agitation randomises domain alignment and the material behaves as a paramagnet, obeying $\chi = C/(T - T_C)$ (Curie–Weiss law).

14. Time Period of Oscillation of a Dipole in a Field: $T = 2\pi\sqrt{(I/MB)}$

I is the moment of inertia of the dipole about the axis of oscillation; used e.g. for a compass needle or oscillating magnet.

15. Elements of Earth's Magnetic Field: $B_H = B \cos \delta$, $B_V = B \sin \delta$, $\tan \delta = B_V/B_H$

δ = angle of dip; B_H and B_V are the horizontal and vertical components of the resultant field B at a place; the declination is the azimuthal angle between geographic and magnetic meridians.

Assignment – 2 (Answers)

Q1. (b) 1/T — Curie's Law: $\chi = C/T$, so χ is inversely proportional to absolute temperature.

Q2. (a) 30° — $\tan \delta = B_V/B_H = 1/\sqrt{3} \implies \delta = 30°$.

Q3. (d) — Inside a magnet, field lines run from the S pole to the N pole; this is what makes the loops closed.

Q4. (c) 90° — this occurs at the magnetic poles of the earth.

Q5. (c) — ferromagnetics have very large, positive μ_r (of the order of 10^3–10^5).

Q6. (b) — thermal agitation destroys the domain alignment above the Curie point.

Q7. (c) — it must retain strong magnetism (high retentivity) and resist demagnetisation (high coercivity).

Q8. (b) M/2 — pole strength is unchanged but length halves, so $M = m(2l)$ halves.

Q9. (b) — magnetic field lines always form closed loops, so net outward flux through any closed surface is zero.

Q10. (b) — diamagnetics are weakly repelled, giving a small negative χ.

Assignment – 3 (Answers)

Q1. (a) Both A and R are true, and R is the correct explanation of A.

Q2. (a) Both A and R are true, and R is the correct explanation of A.

Q3. (a) Both A and R are true, and R is the correct explanation of A.

Q4. (a) Both A and R are true, and R is the correct explanation of A.

Q5. (a) Both A and R are true, and R is the correct explanation of A. (In para/ferromagnetic materials the much stronger paramagnetic/ferromagnetic effect masks the weak diamagnetism.)

Assignment – 4 (Answers)

Q1. (i) b (ii) a (iii) b (iv) b OR (v) c

Q2. (i) b (ii) c (iii) c (iv) b OR (v) b

Q3. (i) b (ii) c (iii) b (iv) a OR (v) b — $W = -MB(\cos 180° - \cos 0°) = 2MB$.

SUB:PHYSICS (CODE - 042)

CHAPTER 6: ELECTROMAGNETIC INDUCTION

CLASS XII (2025-26)

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

GENERAL INSTRUCTIONS:

Read the following instructions carefully.

1. There are 33 questions in this question paper with internal choice.
2. SECTION A consists of 16 multiple-choice questions carrying 1 mark each.
3. SECTION B consists of 5 short answer questions carrying 2 marks each.
4. SECTION C consists of 7 short answer questions carrying 3 marks each.
5. SECTION D consists of 2 case-based questions carrying 4 marks each.SECTION E consists of 3 long answer questions carrying 5 marks each.
6. All questions are compulsory.
7. Use of log tables and calculators is not allowed.

SECTION A

(1 mark each – 12 MCQs + 4 Assertion-Reason – Total: 16 marks)

Multiple Choice Questions (1–12):

1. 3. The current in the primary coil of a pair of coils changes from 7 A to 3 A in 0.04 s. The mutual inductance between the two coils is 0.5 H. The induced emf in the secondary coil is

(a) 50 V (b) 100 V (c) 75 V (d) 220 V

2. A square shaped coil of side 10 cm, h is placed perpendicular to a magnetic increasing at 1 T/s. The induced emf in the coil is

(A) 0.1 V (B) 0.5 V (C) 0.75 V (D) 1.0 V

3. Lenz's law is in accordance with:

(a) Conservation of charge

(b) Conservation of energy

(c) Conservation of momentum

(d) Newton's third law

4. A coil of area 0.1 m² is placed perpendicular to a magnetic field of 0.2 T. The magnetic flux through the coil is:

(a) 0.02 Wb

(b) 0.002 Wb

(c) 0.2 Wb

(d) 2.0 Wb

5. Self-inductance of a long solenoid does not depend on:

(a) Number of turns

(b) Area of cross-section

(c) Magnetic field

(d) Material of the wire

6. A coil's self-inductance is a measure of its?

(a) electrical inertia

(b) electrical friction

(c) induced e.m.f

(d) induced current

7. A transformer works on the principle of:

(a) Self-induction

(b) Mutual induction

(c) Static induction

(d) Capacitance

8. The direction of induced current in a conductor is given by:

(a) Ampere's law

(b) Lenz's law

(c) Gauss's law

(d) Coulomb's law

9. The energy stored in an inductor is given by:

(a) $\frac{1}{2} LI^2$

(b) LI

(c) $\frac{1}{2} LI$

(d) $\frac{1}{2} L^2I$

10. The unit of self-inductance is:

(a) Tesla

(b) Volt

(c) Henry

(d) Coulomb

11. Which device uses electromagnetic induction?

(a) Battery

(b) Transformer

(c) Voltmeter

(d) Ammeter

12. A metallic rod is moved perpendicular to a magnetic field. Which type of EMF is produced?

(a) Motional EMF

(b) Static EMF

(c) Contact EMF

(d) Rotational EMF

Assertion-Reason Questions (13–16):

Directions: Each of the following questions contains two statements: Assertion (A) and Reason (R). Answer as per the following:

- (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

13. Assertion (A): The induced current always opposes the change in magnetic flux.

Reason (R): This is due to Lenz's law.

14. Assertion (A): A current is induced in a loop when it is placed in a constant magnetic field.

Reason (R): Induced EMF depends on the time rate of change of magnetic flux.

15. Assertion (A): A transformer cannot work on DC.

Reason (R): There is no change in magnetic flux in DC.

16. Assertion (A): Eddy currents can be minimized by using laminated cores.

Reason (R): Laminations increase resistance to eddy currents.

SECTION B

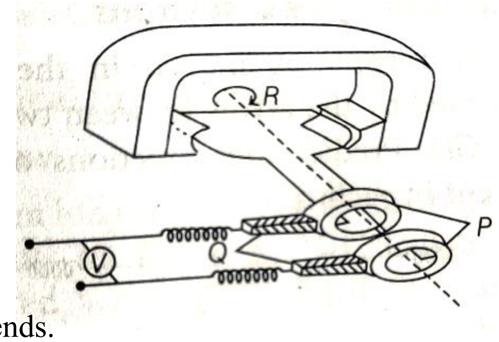
(2 marks each – Total: 10 marks)

17. Define magnetic flux. What is its SI unit?
OR

18. A coil of wire is placed in a uniform magnetic field. Under what condition will the maximum EMF be induced in the coil?

19. Derive the expression for EMF induced in a rod of length l moving with velocity v perpendicular to a uniform magnetic field B.

20. In the given figure,



(a) Identify the machine.

(b) Name the parts of P, Q and R of the machine.

(c) Give the polarities of the magnetic poles.

(d) Write the two ways of increasing the output voltage.

21. State two factors on which self-inductance of a coil depends.

SECTION C

(3 marks each – Total: 21 marks)

22. A rectangular coil of area 0.02 m² has 100 turns. It is rotated at 60 rpm in a uniform magnetic field of 0.1 T. Calculate the maximum EMF induced in the coil.

23. Derive the expression for energy stored in an inductor.

24. What are eddy currents? Mention two applications.

25. Explain the principle of a transformer. Write its working and give two uses.

26. A circular coil of 50 turns and radius 10 cm is placed in a uniform magnetic field of 1 T. Calculate the magnetic flux through the coil when the field is perpendicular to the plane of the coil.

27. What is the mutual inductance of two coils? Write factors on which it depends.

OR

What is self-inductance? Derive its expression for a long solenoid.

28. A solenoid of length 50 cm has 1000 turns and carries a current of 2 A. Find the energy stored in the magnetic field inside the solenoid.

SECTION D

(Case-based questions – 4 marks each – Total: 8 marks)

29. Case Study – Transformer Efficiency

An AC generator is a machine that converts mechanical energy into electrical energy. The AC Generator's input supply is mechanical energy supplied by steam turbines, gas turbines and combustion engines. The output is alternating electrical power in the form of alternating voltage and current. AC generators work on the principle of Faraday's law of electromagnetic induction, which states that electromotive force – E.M.F. or voltage is generated in a current- carrying conductor that cuts a uniform magnetic field. This can either be achieved by rotating a conducting coil in a static magnetic field or rotating the magnetic field containing the stationary conductor.

i. AC generator works on the principle of

a. Mutual Induction b. Electromagnetic induction

c. Self-Induction d. None of these

ii) In AC generator, current in the circuit will maximum, when

a. Flux linked with the coil maximum b. Flux linked with the coil zero

c. Angle between magnetic field and area vector is zero d. None of these

iii)An AC generator consists of a coil of 1000 turns and cross-sectional area of 10^{-2} m², rotating with an angular speed of 100 rpm in a uniform magnetic field of 4.2×10^{-2} T. The maximum emf produced in the coil is:

a.1.4 V b. 3.4 V c. 4.4 V d. 5.0 V

iii) The rate of change of flux is greatest at θ equal to

a. 90°, 270° b. 30°, 60° c. 60°, 90° d. 180°, 90°

30. Case Study – EMI and Induction Stove

Induction cooktops use electromagnetic induction to heat utensils directly.

Answer the following:

a) Which principle is used in induction heating?

b) Explain how eddy currents are responsible for heating.

c) Name one way to reduce eddy current losses in machines.

d) Why does an induction stove only work with certain utensils?

SECTION E

(5 marks each – Total: 15 marks)

(Internal choices provided)

31. Derive an expression for the EMF induced in a coil rotating in a uniform magnetic field. Also, derive the expression for maximum EMF.

OR

Explain the concept of mutual induction. Derive an expression for mutual inductance of two coaxial solenoids.

32(A) How is the mutual inductance of a pair of coils affected when

(1) Separation between the coils is increased.

(2) The number of turns of each coil is increased.

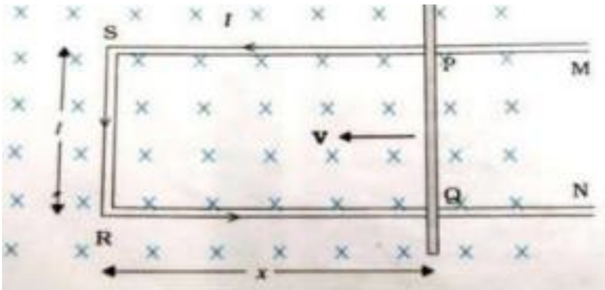
(3) A thin iron sheet is placed between two coils, other factors remaining the same. Explain answer in each case (B)A horizontal wire of 10m long extending from east to west is falling with a speed of 5 m/s at right angles to the horizontal component of earth's magnetic field equal to 0.30×10^{-4}Wb/m^2.

(a) What is the instantaneous value of the emf induced in the wire?

(b) What is the direction induced current?

OR

A straight conductor PQ of resistance R is moving in a uniform and time dependent magnetic field as shown in the given figure. Find:



(a) the emf induced across the rod PQ.

(b) force on the movable arm PQ.

(c) The power delivered by the external force to maintain the motion of movable arm PQ..

(B)The magnetic flux through a coils varying according to the relation $\phi=(4t^3+5t^2+8t^{-3}+5)$Wb. Calculate the induced current through the coil at t = 2s if resistance of coil is 3.1 ohm.

33.(a) Explain the working of a generator.

(b)Derive the expression for the EMF induced in an AC generator.

(c)Mention two advantages of AC over DC.

OR

(a) What is self-induction?

(b) Derive an expression for self-inductance of a solenoid.

(c) State two factors affecting self-inductance.

<u>Assignment-2</u>

Multiple choice types Question

1. A coil having an area A_0 is placed in a magnetic field which changes from B_0 to $4B_0$ in a time interval

t. The e.m.f. induced in the coil will be

(a) $\frac{3A_0}{B_0}$ t (b) 4 $\frac{A}{0}$ $\frac{B}{0}$

(a) $\frac{3B_0}{A_0 t}$ (b) $\frac{4B_0}{A_0 t}$

2. Lenz's law is consequence of the law of conservation of

(a) Charge (b) Momentum (c) Mass (d) Energy

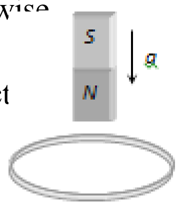
3. A metallic ring is attached with the wall of a room. When the north pole of a magnet is brought near to it, the induced current in the ring will be

(a) First clockwise then anticlockwise

(b) In clockwise direction

(c) In anticlockwise direction

(d) First anticlockwise then clockwise



4. A square coil $10^{-2} m^2$ area is placed perpendicular to a uniform magnetic field of intensity 10^3 Wb/m^2.

The magnetic flux through the coil is

(a) 10 *Weber* (b) 10^{-5} *Weber* (c) 10^5 *Weber* (d) 100 *Weber*

5. A coil having 500 square loops each of side 10 *cm* is placed normal to a magnetic field which increases at the rate of 1.0 *tesla/second*. The induced e.m.f. in volts is

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

6. Two different loops are concentric and lie in the same plane. The current in the outer loop is clockwise and increasing with time. The induced current in the inner loop then, is

(a) Clockwise (b) Zero (c) Counter clockwise (d) In a direction that depends on the ratio of the loop radii

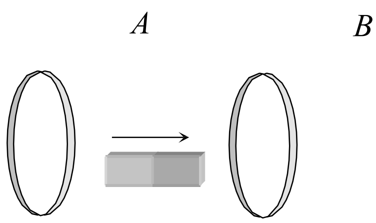
7. In the diagram shown if a bar magnet is moved along the common axis of two single turn coils *A* and *B* in the direction of arrow

(a) Current is induced only in *A* & not in *B*

(b) Induced currents in *A* & *B* are in the same direction

(c) Current is induced only in *B* and not in *A*

(d) Induced currents in *A* & *B* are in opposite directions



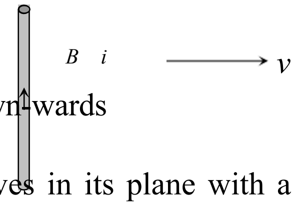
8. The coil of area 0.1 m^2 has 500 turns. After placing the coil in a magnetic field of strength $4 \times 10^{-4} Wb/m^2$, if rotated through 90^o in 0.1 s, the average emf induced in the coil is

(a) 0.012 *V* (b) 0.05 *V* (c) 0.1 *V* (d) 0.2*V*

9. When a wire loop is rotated in a magnetic field, the direction of induced e.m.f. changes once in each

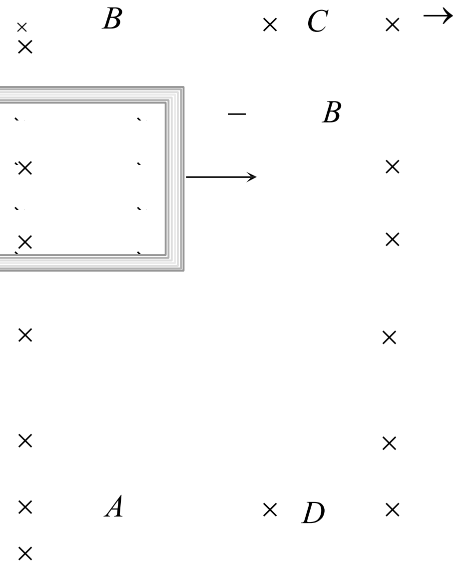
(a) $\frac{1}{4}$ Revolution (b) $\frac{1}{2}$ revolution (c) 1 revolution (d) 2 revolution

10. A conducting wire is moving towards right in a magnetic field B. The direction of induced current in the wire is shown in the figure. The direction of magnetic field will be



(a) In the plane of paper pointing towards right
(b) In the plane of paper pointing towards left
(c) Perpendicular to the plane of paper and downwards
(d) Perpendicular to the plane of paper and upwards

11. A conducting square loop of side L and resistance R moves in its plane with a uniform velocity v perpendicular to one of its sides. A magnetic induction B constant in time and space, pointing perpendicular and into the plane of the loop exists everywhere. The current induced in the loop is



(a) $\frac{Blv}{R}$ clockwise (b) $\frac{Blv}{R}$ anticlockwise

(c) $\frac{2Blv}{R}$ anticlockwise (d) Zero

12. An e.m.f. of 5 *volt* is produced by a self-inductance, when the current changes at a steady rate from 3 A to 2 A in 1 millisecond. The value of self-inductance is

(a) Zero (b) 5 H (c) 5000 H (d) 5mH

13. Average energy stored in a pure inductance L when a current i flows through it, is

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

14. In a transformer, the coefficient of mutual inductance between the primary and the secondary coil is

0.2 *Henry*. When the current changes by 5 *ampere/second* in the primary, the induced e.m.f. in the secondary will be

(a) 5 V *(b)* 1 V (c) 25 V (d) 10V

15. The inductance of a coil is $60\mu H$. A current in this coil increases from 1.0 A to 1.5 A in 0.1 *second*. The magnitude of the induced e.m.f. is

(a) $60 \times 10^{-6}\ V$ (b) $300 \times 10^{-4}\ V$ (c) $30 \times 10^{-4}\ V$ (d) $3 \times 10^{-4}\ V$

16. If the current is halved in a coil, then the energy stored is how much times the previous value

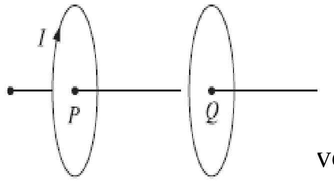
(a) $\frac{1}{2}$ (b) $\frac{1}{4}$ (c) 2 (d) 4

17. Two coils P and Q are lying a little distance apart coaxially. If a current I is suddenly set up in the coil

P then the direction of current induced in coil Q will be

(a) anti-clockwise (b) towards north

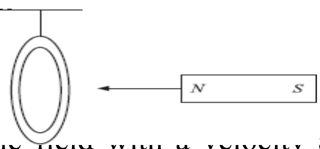
(c) clockwise (d) towards south



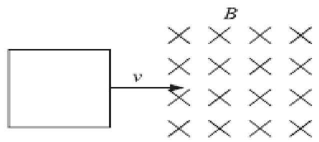
18. A metallic circular ring is suspended by a vertical plane. When a magnet is brought towards the ring it will

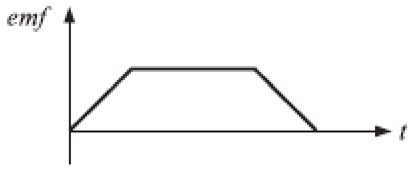
(a) get displaced towards the magnet (b) remain stationar

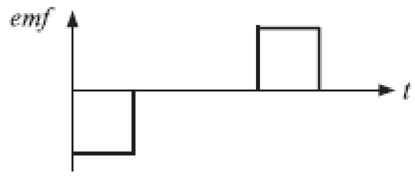
(c) get displaced away from the magnet (d) none of them

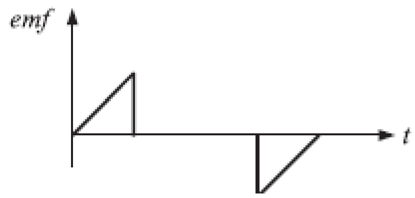


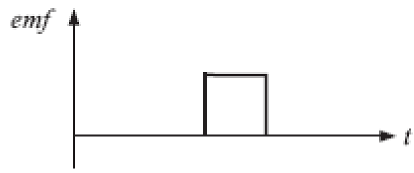
19. The emf generated in a loop when it enters a magnet as shown in is best depicted in



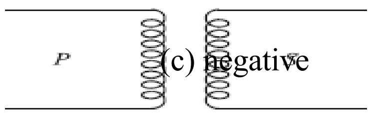
(a)


(b)


(c)


(d)


20. The value of coefficient of mutual induction for the arrangement of two coils shown in the figure is



(a) positive (b) maximum (c) negative (d) zero

21.A rectangular loop of size 5cm * 8 cm is lying in x-y plane in a uniform magnetic field tilde B = (2T) k The total magnetic flux linked with the loop is

(a) 80 Wb (b) 16 Wb (c) 8 * 10 - ^{2} Wb (d) 8 * 10 - ^{3} Wb

22. A circular coil radius 10 cm is placed in a magnetic field overline B =(1.0 i +0.5 j) mT such that the outward unit vector normal to the surface of the coil is (0.6 i +0.8 j). The magnetic flux linked with the coil is

(a) 0.314 µWb (b) 3.14 µWb (c) 31.4 µWb (d) 1.256 µWb

23. The magnetic flux (in Wb) linked with a coil is related to time t (in s) as Φ = 5A * t^2 + Bt - 2C The SI units of A and B are respectively

(a) Wbs^2, Wbs (b) Wbs, Wb (c) Wbs-2 -2 Wbs-1 (d) Wbs^1,Wbs-2

24 The magnetic flux through a loop placed in a magnetic field can be changed by changing
(**a**) area of the loop only (**b**) the value of magnetic field only
(**c**) orientation of the loop in the magnetic field only (a), (b), **(d)** any one or more of the factors given in and (c)

25. A square loop of side 0.50 m is placed in a uniform magnetic field of 0.4 T perpendicular to the plane of the loop. The loop is rotated through an angle of 60 degree in 0.2 s. The value of emf induced in the loop will be

a) 5V (b) 3.5V (c)0.25V (d) Zero V

26 A circular coil of diameter 15 mm having 300 turns is placed in a magnetic field of 30 mT such that the plane of the coil is perpendicular to the direction of magnetic field. The magnetic field is reduced uniformly to zero in 20 ms and again increased uniformly to 30 mT in 40 ms. If the emfs induced in the two time intervals are e_1 and e_2 respectively, then the value of e_1 / e_2 is

(a) ½ (b) 1 (c) 2 (d) 4

27 Whenever a magnet is moved either towards or away from a conducting coil, an emf is induced whose magnitude is independent of the

(a) number of turns in the coil (b) resistance of the coil (c) speed with which the magnet is moved (d) area of the coil.

28 A rectangular loop of area ***A*** $=[\, i + \sqrt{3}\, j\,]\, 10^{-2}$ m^2 is placed in magnetic field ***B*** $= [4.0t^2+2.0]i$, where B is in tesla and t in seconds. At t = 1 s, the magnitude of induced emf in the loop is

(a) 80 mV (b) 0.11 V (c) 0.22 V (d) 0.8 V

29. A coil of area of cross-section 0.5 m² is placed in a magnetic field acting normally to its plane. The field varies as $B = 0.5t^2 + 2t$ where B is in tesla and t in seconds. The emf induced in the coil at t =1 s

(a) 0.5 V (b) 1.0 V (c) 1.5 V (d) 3.0 V

30.A coil of N turns is placed in a magnetic field ***B*** such that ***B*** is perpendicular to the plane of the coil. ***B*** changes with time as ***B*** $= B_0 \cos\{(2\prod/T)t\}$ where T time period. The magnitude of emf induced in the will be maximum at

(a) t = (nT)/8 (b) t = (nT)/4 (c) t = (nT)/2 (d) t = (2n-1)T/4

Here, n = 1, 2, 3, 4

31. A planar loop is rotated in a magnetic field an axis perpendicular to the field. The pola induced emf changes once in each

(a) 1 revolution (b) (1/2) revolution (c) (1/4) revolution (d) (3/4) revolution

32. A square shaped coil of side 10 cm, having 100 turns is placed perpendicular to a magnetic field which is increasing at 1 T/s. The induced emf in the coil is

(a) 0.1 V (b) 0.5 V (c) 0.75 V (d) 1.0 V

33. A coil of area $100 cm^2$ is kept at an angle of 30° with a magnetic field of 10^{-1}- The magnetic field is reduced to zero in 10^{-4} s. The induced emf in the coil is

(a) $5\sqrt{3}$ V (b) $50\sqrt{3}$ V (c) 5.0 V (d) 50.0 V

34. A metallic rod of 1 m length is rotated with a frequency of 40 rev/s, with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius 1 m, about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field of 0.5 T parallel. to the axis is present in the region. The value of emf induced between the centre and the metallic ring is close to

(a) 20 V (b) 32 V (c) 40 V (d) 63 V

35. The mutual inductance of two coils $C_1$and C_2 is 20 mH. In coil C_1 the current changes from 4 A to zero in 0.2 s. If the resistance of coil C_2 is 4 Ω, then the charge that flows through it per second will be

(a) 4.0 C (b) 1.5 C (c) 0.05 C (d) 0.1 C

36. The current in the primary coil of a pair of coils changes from 7 A to 3 A in 0.04 s. The mutual inductance between the two coils is 0.5 H. The induced emf in the secondary coil is

(a) 50 V (b) 75 V (c) 100 V (d) 220 V

37. Two long solenoids of radii r_1 and r_2 ($>r_1$) and number of turns per unit length n_1 and n_2 respectively are co-axially wrapped one over the other. The ratio self-inductance of inner solenoid to their mutual inductance is

(a) n_1/n_2 (b)) n_2/n_1 (c) $(n_1/n_2)(r_1/r_2)^2$ (d) $(n_2/n_1)(r_1/r_2)^2$

38. A closely wound long solenoid of self-inductance L is cut into two identical solenoids. The value of self-inductance of each small solenoid will be

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

39. 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

(a) 2592 (b) 2866 (c) 2976 (d) 3140

40. Consider a solenoid of length l and area of cross-section A with fixed number of turns. The self-inductance of the solenoid will increase if

(a) both l and A are increased (b) l is decreased and A is increased (c) l is increased and A is decreased (d) both l and A are decreased.

41. The self-inductance of a solenoid of 600 turns is 108 mH. The self-inductance of a coil having 500 turns with the same length, the same radius and the same medium will be

(a) 95 mH (b) 90 mH (c) 85 mH (d) 75 mH

Assignment-3

ASSERTION Reason Type Questions

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

a) Both A and R are true and R is the correct explanation of A,
b) Both A and R are true and R is NOT the correct explanation of A,
c) A is true but R is false,
d) A is false and R is also false**.**

1**ASSERTION**: Faraday's laws are consequences of conservation of energy.

REASON In a purely resistive ac circuit, the current lags behind the e.m.f. in phase.

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

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

3.ASSERTION; Faraday established induced e.m.f. experimentally.

REASON Magnetic flux can produce inducede.m.f.

4.ASSERTION; Induced e.m.f. is proportional to rate of change of magnetic field while induced current depends on resistance of wire.

Reason: The induced e.m.f. and current will be same in two identical loops of copper and aluminum, when rotated with same speed in the same magnetic field.

5.ASSERTION; Inductance coil are made of copper.

REASON Induced current is more in wire having less resistance.

6. ASSERTION: Self-inductance is called the inertia of electricity.

REASON Self-inductance is the phenomenon, according to which an opposing induced e.m.f. is produced in a coil as a result of change in current or magnetic flux linked in the coil.

7**ASSERTION;** When two coils are wound on each other, the mutual induction between the coils is maximum.

REASON Mutual induction does not depend on the orientation of the coils.

8. ASSERTION: Acceleration of a magnet falling through a long solenoid decreases.

REASON The induced current produced in a circuit always flow in such direction that it opposes the change or the cause the produced it.

9. **ASSERTION:** changing magnetic flux can produce induced EMF.

REASON Faraday established induced EMF experimentally

Ans b

10 ASSERTION An A.C. generator is based on the phenomenon of electromagnetic induction **REASON** In single coil, we consider self induction as well as mutual induction

Ans b

11. ASSERTION Lenz's law is a consequence of the law of conservation of energy

REASON There is no power loss in an ideal inductor

Ans b

12. ASSERTION it is difficult to move a magnet into a coil of large number of turns when the circuit of the coil is closed

REASON The direction of induced current in a coil with it circuit closed due to motion of magnet is such that it opposes the cause

Ans a

13. ASSERTION Induced EMF views in a coil will be more when the magnetic flux linked with the coil is more

REASON Induced EMF produce is directly proportional to the magnetic flux

answer d

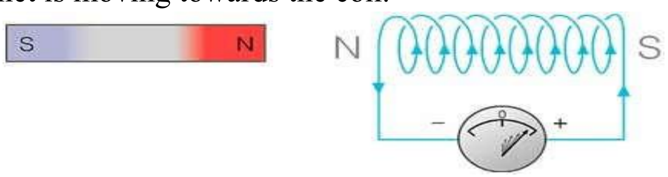
Assignment-4

CASE STUDY QUESTIONS

CASE-1

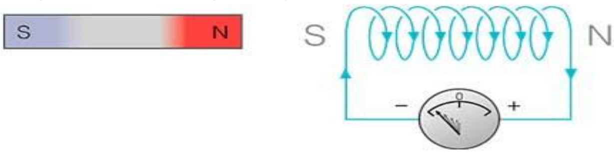
Lenz's law states that

The induced electromotive force with different polarities induces a current whose magnetic field opposes the change in magnetic flux through the loop in order to ensure that original flux is maintained through the loop when current flows in it.
To better understand Lenz's law, let us consider two cases:
Case 1: When a magnet is moving towards the coil.



When the north pole of the magnet is approaching towards the coil, the magnetic flux linking to the coil increases. According to Faraday's law of electromagnetic induction, when there is a change in flux, an EMF, and hence current is induced in the coil and this current will create its own magnetic field. Now according to Lenz's law, this magnetic field created will oppose its own or we can say opposes the increase in flux through the coil and this is possible only if approaching coil side attains north polarity, as we know similar poles repel each other. Once we know the magnetic polarity of the coil side, we can easily determine the direction of the induced current by applying right hand rule. In this case, the current flows in the anticlockwise direction.

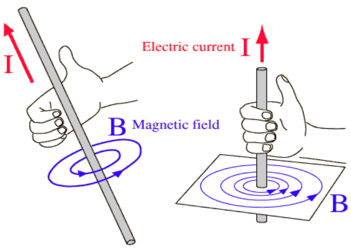
Case 2: When a magnet is moving away from the coil



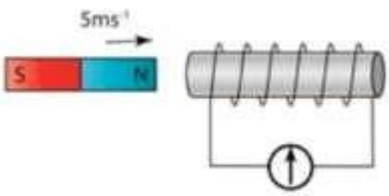
When the north pole of the magnet is moving away from the coil, the magnetic flux linking to the coil decreases. According to Faraday's law of electromagnetic induction, an EMF and hence current is induced in the coil and this current will create its own magnetic field.

Now according to Lenz's law, this magnetic field created will oppose its own or we can say opposes the decrease in flux through the coil and this is possible only if approaching coil side attains south polarity, as we know dissimilar poles attract each other. Once we know the magnetic polarity of the coil side, we can easily determine the direction of the induced current by applying right hand rule. In this case, the current flows in a clockwise direction.

Note that for finding the directions of magnetic field or current, use the right-hand thumb rule i.e. if the fingers of the right hand are placed around the wire so that the thumb points in the direction of current flow, then the curling of fingers will show the direction of the magnetic field produced by the wire.

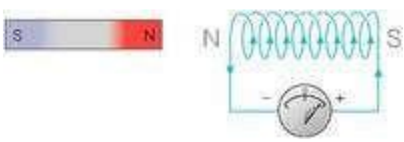


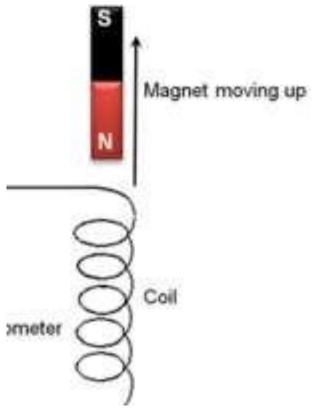
1. What is the direction of the induced magnetic field?



(a) left
(b) right
(c) up
(d) down

2. What is the direction of the induced magnetic field?



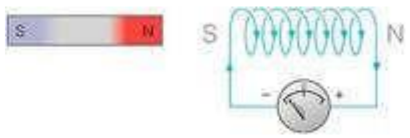


(a) Left
(b) right
(c) up
(d) down

3. In what direction is the magnet moving?

(a) left
(b) right
(c) up
(d) down

4. In what direction is the magnet moving?



(a) left
(b) right
(c) up
(d) down

5. Which of the following is NOT an application of Lenz's Law
(a) Transformer
(b) AC Generator
(c) DC Motor
(d) A coil transverse by AC current

CASE-2

According to Faraday's law of electromagnetic induction, there will be an EMF induced in the second winding. If the circuit of this secondary winding is closed, then a current will flow through it. This is the basic working principle of a transformer.

Let us use electrical symbols to help visualize this. The winding which receives electrical power from the source is known as the 'primary winding'. In the diagram below this is the 'First Coil'.
The winding which gives the desired output voltage due to mutual induction is commonly known as the 'secondary winding'. This is the 'Second Coil' in the diagram above.

A transformer that increases voltage between the primary to secondary windings is defined as a step-up transformer. Conversely, a transformer that decreases voltage between the primary to secondary windings is defined as a step-down transformer.
Whether the transformer increases or decreases the voltage level depends on the relative number of turns between the primary and secondary side of the transformer.
If there are more turns on the primary coil than the secondary coil than the voltage will decrease (step down). If there are less turns on the primary coil than the secondary coil than the voltage will increase (step up).
While the diagram of the transformer above is theoretically possible in an ideal transformer – it is not very practical. This is because in the open air only a very tiny portion of the flux produced from the first coil will link with the second coil. So the current that flows through the closed circuit connected to the secondary winding will be extremely small (and difficult to measure).
The rate of change of flux linkage depends upon the amount of linked flux with the second winding. So ideally almost all of the flux of primary winding should link to the secondary winding. This is effectively and efficiently done by using a core type transformer. This provides a low reluctance path common to both of the windings.

1. The secondary winding of which of the following transformers is always kept closed?
2. (a)Current transformer

   (b)Power transformer

   (c) Step down transformer

3. If the supply frequency of a transformer increases, the secondary output voltage of the transformer
   (a) Increase (b)Decrease (C) Remain the same (D) Any of the above
4. The open-circuit test in a transformer is used to measure
   (a) Copper loss (b) Winding loss (c) Total loss (d) Core loss
5. Lamination of the transformer core is made of

   (a)Cast Iron b) Silicon Steel (c)Aluminium d)Cast Steel

6. A transformer transform
   (a)Current (b) Voltage & current © Frequency (d) Voltage

CASE-3

Definition: Mutual Inductance between the two coils is defined as the property of the coil due to which it opposes the change of current in the other coil, or you can say in the neighbouring coil. When the current in the neighbouring coil changes, the flux sets up in the coil and because of this, changing flux emf is induced in the coil called Mutually Induced emf and the phenomenon is known as Mutual Inductance.

The value of Mutual Inductance (M) depends upon the following factors

1. Number of turns in the secondary or neighbouring coil
2. Cross-sectional area
3. Closeness of the two coils Mutual Coupling In the Magnetic Circuit

When on a magnetic core, two or more than two coils are wound, the coils are said to be mutually coupled. The current, when passed in any of the coils wound around the magnetic core, produces flux which links all the coils together and also the one in which current is passed. Hence, there will be both self-induced emf and mutual induced emf in each of the coils.

The best example of the mutual inductance is the transformer, which works on the principle of Faraday's Law of Electromagnetic Induction.

Faraday's law of electromagnetic induction states that " the magnitude of voltage is directly proportional to the rate of change of flux." which is explained in the topic Faraday's Law of Electromagnetic Induction.

1. The phenomenon due to which there is an induced current in one coil due to current in a neighbouring coil is?

A. Electromagnetism B. Susceptance C. Mutual inductance D. Steady current

2. Mutual inductance between two magnetically coupled coils depends on

A. Permeability of the core material B.Number of turns of the coils

C.Cross sectional area of their common core D.All of the above

3. Which of the following is unit of inductance?

A. Ohm B. Henry C. Ampere turns D.Weber's/meter

4. Which of the following circuit elements will oppose the change in circuit current?

A. Capacitance B. Inductance C.Resistance D. All of the above

5. If in an iron cored coil the iron core is removed so as to make the air cored coil, the inductance of the coil will be

A. More B. Less C.The same D. None of these

CASE-4

Faraday's law of electromagnetic induction, also known as Faraday's law is the basic law of electromagnetism which helps us to predict how a magnetic field would interact with an electric circuit to produce an electromotive force (EMF). This phenomenon is known as electromagnetic induction.

Faraday's Experiment: Relationship Between Induced EMF and Flux

In the first experiment, he proved that when the strength of the magnetic field is varied, only then-current is induced. An ammeter was connected to a loop of wire; the ammeter deflected when a magnet was moved towards the wire.

In the second experiment, he proved that passing a current through an iron rod would make it electromagnetic. He observed that when a relative motion exists between the magnet and the coil, an electromotive force will be induced. When the magnet was rotated about its axis, no electromotive force was observed, but when the magnet was rotated about its own axis then the induced electromotive force was produced. Thus, there was no deflection in the ammeter when the magnet was held stationary.While conducting the third experiment, he recorded that the Galvanometer did not show any deflection and no induced current was produced in the coil when the coil was moved in a stationary magnetic field. The ammeter deflected in the opposite direction when the magnet was moved away from the loop.

1.As per Faraday's laws of electromagnetic induction, an e.m.f. is induced in a conductor whenever it

A Lies perpendicular to the magnetic flux B Lies in a magnetic field

C Cuts magnetic flux D Moves parallel to the direction of the magnetic field

2.According to Faraday's law, EMF stands for

A Electromagnetic field B Electromagnetic force

C Electromagnetic friction D Electromotive force

3. For time varying currents, the field or waves will be

a) Electrostatic b)Magneto static c)Electromagnetic d)Electrical

4. Find the displacement current when the flux density is given by t3 at 2 seconds.

a) 3 b) 6 c)12 d)27

5 .Which of the following statements is true?

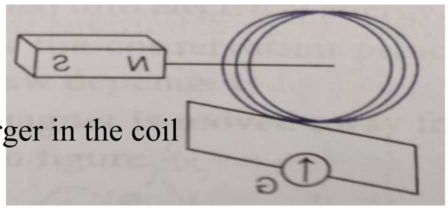
A)E is the cross product of v and B b) B is the cross product of v and E

c)E is the dot product of v and d)B is the dot product of v and E

CASE-5

According to the Faraday's first law, whenever the amount of magnetic flux linked with a circuit changes, an emf is induced in it. Induced current is determined by the rate at which the magnetic flux changes.

Mathematically, the magnitude of the induced emf in a circuit is equal to the rate of change of magnetic flux through the circuit Induced emf Rate of change of magnetic flux



i. On the basis of Faraday's law, current is larger in the coil

A when the magnet is pushed towards the coil faster. **B** when the magnet is pulled away the coil faster.

C Both A and B **D** Neither A nor B

ii. The flux linked with a circuit is given by $\Phi = t^3 + 3t - 7$. The graph between time (X-axis) and induced emf (Y-axis) will be a

A straight line through the origin. **B** straight line with positive intercept.

C straight line with negative intercept. **D** parabola not through the origin.

iii. Wire loop is rotated in a magnetic field. The frequency of change of direction of the induced emf is

A once per revolution. **B** twice per revolution.

C four times per revolution. **D** six times per revolution.

iv. The instantaneous magnetic flux linked with a coil is given by $= (5t^3 - 100t + 300)$ Wb. The emf induced in the coil at time t = 2 s is

A -40V. **B** 40 V **C** 140 V. **D** 300 V

CASE-6

When a conducting wire ab of length l resistance r and mass m slides through a constant magnetic field between a smooth, vertical, thick pair of connected rails (as shown in figure), an emf is induced in the wire. Uniform magnetic field B exists in the space in the direction perpendicular to the plane of the rails.

(i) Induced emf in the wire at an instant t when the speed v of the wire, is

(a) Bilv (b) Bvl (c) $Bv^2 1$ (d) Bvl^2

(ii) Magnitude of induced current in the wire is

(a) Bvl. (b) BRv (c) Bvl/ R. (d) Bv2R2

(iii) Find the downward acceleration of the wire a the instant t when the speed of the wire

(a) $g + (B^2 l^2 v^2)/(mR)$ (b) $g + (B^2 l^2 R^2)/(mv^2)$

(c) $g- B^2 I^2 R/ mv^2$ (d) $g -(B^2 l^2 v)/(mR)$

(iv) After sufficient time, if the wire is moving with a constant velocity v_m then find v_m

(a) $(mgR)/(B^2 l^2)$ (b) $(mgR^2)/(B^2 I)$ (c) $(m^2 gl^2)/(B^2 R^2)$ (d) zero

CASE-7

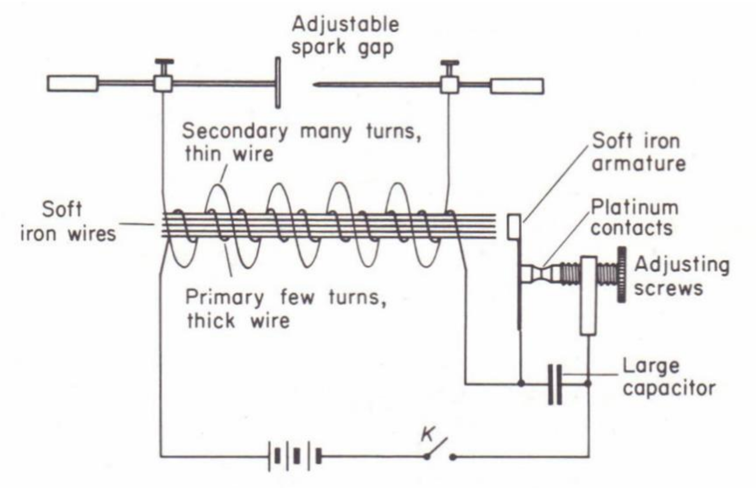


Fig. 43.13. Induction (spark) coil

Spark coil: The principle of electromagnetic induction was discovered by Michael Faraday in 1831. Induction coils were used widely in electrical experiments and for medical therapy during the last half of the 19th century, eventually leading to the development of radio in the 1890.

The spark coil designed on the principle of electromagnetic induction was the heart of the earliest radio transmitters. Marconi used a spark coil designed by Heinrich Rhumkorff in his early experiments.

An induction coil or "spark coil" is a type of electrical transformer used to produce high-voltage pulses from a low-voltage (d.c.) supply. To create the flux changes necessary to induce voltage in the secondary coil, the direct current in the primary coil is repeatedly interrupted by a vibrating mechanical contact called interrupter.
The spark coil consists of two coils of insulated wire wound around a common iron core. One coil, called the primary coil, is made from relatively few (tens or hundreds) turns of coarse wire. The other coil, the secondary coil typically consists of up to a million turns of fine wire (up to 40 gauge).

An electric current is passed through the primary, creating a magnetic field. Because of the common core, most of the primary's flux couples with the secondary. When the primary current is suddenly interrupted, the magnetic field rapidly collapses. This causes a high voltage pulse to be developed across the secondary terminals due to electromagnetic induction. Because of the large number of turns in the secondary coil, the secondary voltage pulse is typically many thousands of volts. This voltage is sufficient to create an electric spark, to jump across an air gap separating the secondary's output terminals. For this reason, these induction coils are also called spark coils.

To operate the coil continually, the d.c. supply current must be repeatedly connected and disconnected. To do that, a magnetically activated vibrating arm called an interrupter is used which rapidly connects and breaks the current flowing into the primary coil. The interrupter is mounted on the end of the coil next to the iron core.

1. The heart of the radio transmitters of Marconi was a
(A) spark coil. (B) toroid.
(C) RF tuning coil. (D) Van de Graff generator.

II. Spark coil is a type of
(A) electrical generator. (B) electrical transformer.
(C) static electricity generator (D) large capacitor.
iii. Which of the following statements is correct?

(A) Spark coil consists of two coils of insulated wire. The primary coil is made from relatively few turns of fine wire. The secondary coil consists of up to a million turns of coarse wire.

(B) Spark coil consists of two coils of insulated wire. Primary coil is made from tens or millions turns of coarse wire. The secondary coil consists of up to a few turns of fine wire.

(C) Spark coil consists of two coils of insulated wire. The Primary coil is made from relatively few turns of coarse wire. The secondary coil consists of up to a million turns of fine wire.

(D) Spark coil consists of two coils of insulated wire. Both primary and secondary coils are made from a million turns of fine wire.

iv. Why most of the primary's flux couples with the secondary in spark coil?
(A) Since the primary coil is wound on the secondary coil
(B) Since the primary coil is of thick wire
(C) Since the core is common (D) None of the above

V. What is the function of an interrupter in a spark coil?
(A) To rapidly connect and break the current flowing into the primary coil
(B) To rapidly connect and break the current flowing into the secondary coil
(C) To control the formation of a spark
(D) None of the above

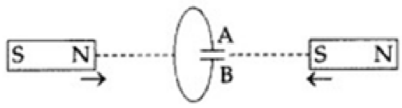
ASSIGNMENT – 5

SHORT ANSWER QUESTIONS

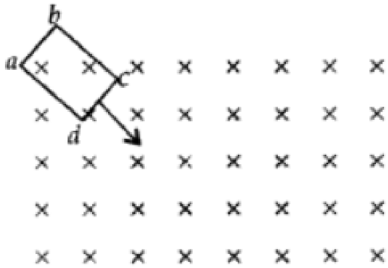
1(i) A solenoid with an iron core and a bulb is connected to a dc source. How does the brightness of the bulb change, when the iron core is removed from the solenoid?

(ii) Two identical loops, one of Cu and another of constantan are removed from a magnetic field within the same time interval. In which loop does the induced current be greater?

i)Predict the polarity of the capacitor in the situation described in the given diagram.



ii) Predict the direction of the induced current in the rectangular loop abed as it is moved into the region of a uniform magnetic field B directed normal to the plane of the loop

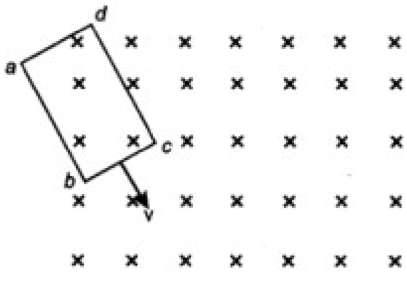


.

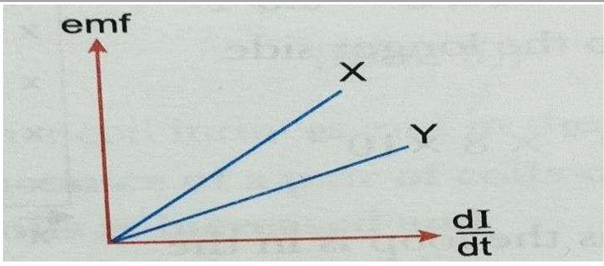
3)State Lenz's Law.

A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an e.m.f. induced at its ends? Justify your answer.

4)UseLenz'slawtodeterminethedirectionoftheinducedcurrentwhenarectangularconductingloop abed is moved into a region of magnetic field which is directed normal to the plane of the loop away from the reader



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



6)A circular copper disc. 10 cm in radius rotates at a speed of 2 π rad/s about an axis through its centre and perpendicular to the disc. A uniform magnetic field of 0.2T acts perpendicular to the disc.

i)Calculate the potential difference developed between the axis of the disc and the rim.

ii)What is the induced current if the resistant of the disc is 2 ohm?

7) Two identical loops, one of copper and the other of Aluminum are rotated with the same angular speed in the same magnetic field.

i)Compare the induces emf

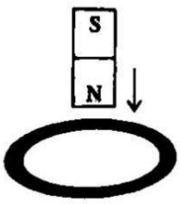
ii)The current produced in the two coils.

8)The magnetic flux through a coils varying according to the relation $\phi=(4t^3+5t^2+8t^{-3}+5)$Wb. Calculate the induced current through the coil at t = 2s if resistance of coil is 3.1 ohm.

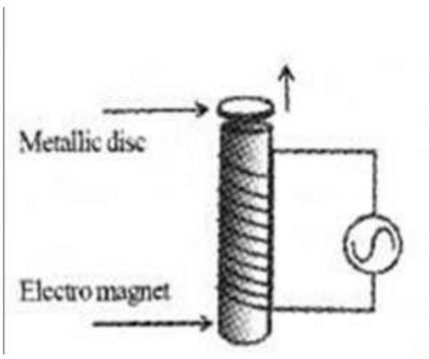
9)State Faraday's law of electromagnetic induction. Give their mathematical form.

10a) A bar magnet falls from height h through a metal ring. Will its acceleration be equal to 'g'? Give reason for your answer.

b)What happened if the ring in the above case is cut so as not to form a complete loop



11) When AC is switched on the thin metallic disc is found to thrown up in air.



12)1) Which makes the disc to thrown?

2) How will you explain the mechanism behind the movement of disc

3) Write the working principle of induction heater.

13) A long solenoid of radius r consists of n turns per unit length. A current $I=I0sik\omega t$ flows in the solenoid. A coil of N turns is wound tightly around it near its centre. What is

a) The induced emf in the coil?

b) The mutual inductance between the solenoid and the coil?

LONG ANSWER QUESTIONS

1i) Define self-inductance of a coil. Show that magnetic energy required to build up the current I in a coil of self-inductance L is given by½ LI^2?

ii) Define mutual inductance between two long coaxial solenoids. Find out the expression for the mutual inductance of inner solenoid of length l having the radius $r1$ and the number of turns $n1$ per unit length due to the second outer solenoid of same length and $n2$ number of turns per unit length.

2i) Derive the Expression for the Self induction of a long solenoid of cross sectional area A, length l and having n turns per unit length?

ii) A long solenoid with 15 turns per cm has a small loop of area 2.0 cm^2 placed inside the solenoid normal to its axis. If the current carried by the solenoid changes steadily from 2.0A to

4.0 A in 0.1 s, What is the induced emf in the loop while the current is changing?

<u>Assignment-1 (Answers)</u>

<u>Answer Key – Section A</u>

Multiple Choice Questions (1–12)

Q. No.	Correct Option	Explanation (Short)
1	(a) 50 V	Induced emf = $\lvert\varepsilon\rvert$ = M dI / dt
2	(d) 1 V	emf = NA dB /dt
3	(b) Conservation of energy	Lenz's law ensures energy conservation.
4	(a) 0.02 Wb	$\Phi = B \times A = 0.2 \times 0.1 = 0.02$ Wb
5	(d) Material of the wire	Inductance doesn't depend on wire material.
6	(a) electrical inertia	Self-inductance is a property of a coil.
7	(b) Mutual induction	Basic principle behind transformer operation.
8	(b) Lenz's law	It gives the direction of induced current.
9	(a) $(1/2)LI^2$	Standard formula for energy in an inductor.
10	(c) Henry	Unit of inductance is Henry (H).
11	(b) Transformer	It uses electromagnetic induction.
12	(a) Motional EMF	Moving rod in magnetic field induces EMF.

Assertion-Reason Questions (13–16)

Correc Option	Explanation

13	(a) Both A and R are true, and R is the correct explanation of A	Lenz's law explains why current opposes flux change.
14	(c) A is true but R is false no EMF induced.	Constant B field ⇒ no change ⇒
15	(a) Both A and R are true, and R is the correct explanation of A	No changing flux in DC, so transformer can't work.
16	(a) Both A and R are true, and R is the correct explanation of A	Laminations increase resistance, reducing eddy currents.

Q17. Magnetic flux (Φ) is the total number of magnetic field lines passing through a given area.

Formula: $\Phi = \mathbf{B} \cdot \mathbf{A} \cdot \cos\theta$ **SI Unit**: Weber (Wb)

Q18. Maximum EMF is induced in a coil when the **plane of the coil is parallel** to the magnetic field, i.e., the angle (θ) between the normal to the coil and the magnetic field is **90°**, making **$\sin\theta = 1$**.

Q19. Motional EMF derivation:

When a rod of length **l** moves with velocity **v** perpendicular to a magnetic field **B**, Induced EMF:
$\varepsilon = B \cdot l \cdot v$

(Using Lorentz force and work done per unit charge)

Q20(a) The machine is an AC generator.

(b) P→ Slip rings, Q→ Brushes and R→ Armature.

(c) The left side is the North pole and the right s is South pole.

(d) The output voltage can be increased by

I. increasing the number of turns in the armature.

II. increasing the strength of the field magnetic energy.

Q21. Self-inductance depends on:

a. **Number of turns (N)**
b. **Core material (permeability μ)**

<u>Section C (3 marks each)</u>

Q22. Given:

$A = 0.02\ m^2$, $N = 100$, $B = 0.1\ T$, rpm = 60 = 1 rps
$\omega = 2\pi f = 2\pi \times 1 = 2\pi$ rad/s
EMF_max = N · B · A · ω

$= 100 \times 0.1 \times 0.02 \times 2\pi =$ **1.26 V**

Q23.Energy stored in an inductor (U):

$U = (1/2)\cdot L\cdot I^2$
Derivation:

Work done to increase current from 0 to I in an inductor with inductance L gives stored energy.

Q24.Eddy currents: Circulating currents induced in a conductor when exposed to a changing magnetic field.
Applications:

1. **Induction heating** (e.g., induction cooktops)
2. **Magnetic braking** (e.g., in trains)

Q25.Principle: Mutual
Induction **Working**:

- AC in the primary coil produces a changing magnetic field.
- This induces an EMF in the secondary coil.

Uses:

1. Step-up/step-down voltage
2. Power distribution systems

Q26. Given:

$N = 50$, $r = 10\ cm = 0.1\ m$, $B = 1\ T$
$A = \pi r^2 = \pi(0.1)^2 = 0.0314\ m^2$
$\Phi = N\cdot B\cdot A = 50 \times 1 \times 0.0314 =$ **1.57 Wb**

Q27.Mutual Inductance (M): EMF induced in one coil due to the rate of change of current in another coil.

Depends on:

1. Number of turns in each coil
2. Area of coils
3. Relative position and orientation
4. Magnetic permeability of core

OR

Self-inductance of solenoid:

L =

$(\mu_0\mu_r N^2 A$
$)/l$
Where:

- N = number of turns
- A = area of cross-section
- l = length of solenoid
- μ = permeability

Q28. Given:

$l = 50$ cm $= 0.5$ m, $N = 1000$, $I = 2$ A
$n = N/l = 1000 / 0.5 = 2000$ turns/m
$B = \mu_0 \cdot n \cdot I = 4\pi\times10^{-7} \times 2000 \times 2 = 5.03\times10^{-3}$ T
Assume $A = 1$ cm² =
1×10^{-4} m² Energy
density $= B^2 / (2\mu_0)$
U = energy density × Volume $= [B^2 / (2\mu_0)] \times A \times l$
$= [(5.03\times10^{-3})^2 / (2\times4\pi\times10^{-7})] \times 1\times10^{-4} \times 0.5$
≈ **0.050 J**

<u>Section D (Case-based – 4 marks each)</u>

Q29.

i) Answer: b. Electromagnetic induction

Explanation: It works on Faraday's law of electromagnetic induction, which states that an EMF is induced when a conductor cuts through magnetic field lines.
ii) Answer: c. Angle between magnetic field and area vector is zero

Explanation: EMF (and hence current) is maximum when the rate of change of flux is maximum, which occurs when the coil is perpendicular to the magnetic field — i.e., angle is zero between magnetic field and area vector. Answer: c. 4.4 V
Explanation:
First, convert
rpm to rad/s:
$\omega=2\pi\times100/60$
≈10.47 rad/s
Use formula:
$E_{max}=NAB\omega=1000\times10^{-2}\times4.2\times10^{-2}\times10.47\approx4.4$

iv) The rate of change of flux is greatest at θ equal to:
Answer: a. 90°, 270°
Explanation: The rate of change of flux (and hence EMF) is maximum when the sine function is at its peak, which occurs at θ = 90° and 270°.

Q30. Induction Stove Case Study

a) **Electromagnetic induction**
b) changing magnetic field induces **eddy currents** in the utensil, which produces heat.
c) Use **laminated iron cores** to reduce eddy currents.

d) Only works with **ferromagnetic** materials that can couple with the magnetic field (e.g., steel, iron).

Section E (5 marks each)

Q31. Rotating Coil in Magnetic Field

Let coil with N turns, area A, rotates with angular velocity ω in
magnetic field B. Magnetic flux: $\Phi = BA\cos(\omega t)$
Induced EMF:
$\varepsilon = -d\Phi/dt = NBA\omega \sin(\omega t)$
Mutual Induction: When a changing current in one coil induces an EMF in a
nearby coil. Mutual Inductance of two coaxial solenoids:
$M = \mu_0 \cdot N_1 \cdot N_2 \cdot A / l$

Q32. (A)

(1) When the Separation between the coils is increased, the flux linked
with the Secondary coils decreases, hence mutual induction decreases.

(2) Since m= $\frac{\mu o N_1 N_2 A}{l}$, so when $N_1 and\ N_2$ increases, mutual induction increase.

(3) Mutual induction will increase because (Relative permeability of material)

(B) (a) Emf induced (e)= Blv= 1.5 mV
(b) west to east

OR

(A)
(a) ε=Blv
(b) F =B^2l^2v/R
(c) P =F.v =$B^2l^2v^2/R$

(B)ϕ = (4t3 + 5t2 + 8t-3 + 5) Wb.
Rate of change of flux, dϕ/dt = 12 t2 + 10 t – 24 t-4 According to Faraday's law of electromagnetic induction,
Induced e.m.f. |ε| = |- dϕ/dt| at t = 2s
ε = | 48 + 20 – 24/16 |= | 68 – 1.5 |= 66.5 V
so, induced current = ε/R = 66.5/3.1 = 21.45 A

Q33. Generator Working

(a) Mechanical rotation in magnetic field cuts flux → EMF induced
(b) EMF = $NBA\omega \sin(\omega t)$
(c) Advantages of AC over DC:

- Easy to transform voltage
- Lower transmission losses

OR (a) **Self-induction**: EMF induced in a coil due to change in its own current

(b) $L = \mu_0\mu_r N^2 A / l$
(c) Factors:

1. Number of turns
2. Core material

Assignment-2

Answer Key:

1. **(a)**
2. **(d)** Energy
3. **(c)** In anticlockwise direction
4. **(a)** B.A= 10
5. **(d)** 5
6. **(c)** Counter clockwise
7. **(d)** Induced currents in A & B are in opposite directions
8. **(d)** 0.2 V
9. **(b)**1/2 revolutions
10. **(c)** Perpendicular to the plane of paper and downwards
11. **(b)** Anticlockwise
12. **(d)** 5 mH
13. **(d)**$12Li^2$
14. **(b)**e.m.f.=0.2×5=1 V
15. **(d)**$e=60\times10^{-6}\times.5/.1=3\times10^{-4}$volt
16. **(b) 1/4**
17. **(c)**For a coil to produce a magnetic field to the left, the induced current in Q must be clockwise (as viewed from the same side — the right side).
18. **(c)Like poles repel**, so there is a **repulsive force** between the magnet and the ring. Get displaced away from the magnet
19. **(Image needed)** — Cannot answer without figure
20. **(a)** Positive (assuming mutual coupling and Lenz's law)
21. (d) $8 * 10^{-3}$ Wb
22. (c) 31.4 μWb
23. (c) Wbs-2 -2 Wbs-1
24. **(d)** any one or more of the factors given in and (c)
25. (c) 0.25V
26. (c) 2
27. (b) resistance of the coil
28. (a) 80 mV
29. (c) 1.5 V
30. (d) t = (2n-1)T/4
31. (b) (1/2) revolution
32. (d) 1.0 V
33. (a) 5√(3) V
34. (d) 63 V

35. (d) 0.1 C
36. (a) 50 V
37. (a) n_1/n_2
38. (a) L/2
39. (b) 2866
40. (b) l is decreased and A is increased
41. (d) 75 mH

Assignment-3

1.

- **Analysis:**
  - A is **true**: Faraday's law explains how changing magnetic fields induce EMF, which follows energy conservation.
  - R is **false**: In a purely resistive AC circuit, current is **in phase** with voltage, not lagging.

✅**Correct answer:(c) A is true but R is false**

- **Analysis:**
  - A is **true**: Faraday's law requires **change** in magnetic flux to induce current.
  - R is **false**: Constant (even large) magnetic flux does **not** induce current without change.

✅**Correct answer:(c) A is true but R is false**

3•**Assertion (A) is true:**

Faraday **did** discover electromagnetic induction **experimentally** in 1831, showing that a changing magnetic field induces an e.m.f. in a circuit.

- **Reason (R) is partially correct but imprecise:**

- The **correct** principle is: **a *changing* magnetic flux** induces an e.m.f., as per Faraday's Law.
- The reason says "**magnetic flux** can produce e.m.f.", but **flux alone** (if constant) does **not** induce e.m.f.
- So the statement is **technically incorrect** or **incomplete**, because it misses the key idea of "change in flux".

Therefore, Reason is false (or not fully true), and does not explain Assertion properly.

✅ Correct answer:(c) A is true but R is false

4.

- **Analysis:**
  - A is **true**: $\varepsilon \propto d\varphi/dt$ and $I=\varepsilon/R$
  - R is **false**: Copper and aluminum have different resistances, so **current** will be different.

✅**Correct answer:(c) A is true but R is false**

- **Analysis:**
  - A is **true**: Copper is used due to its low resistance.
  - R is **true**: Lower resistance → higher current for a given EMF.
  - R **explains** A.

✅**Correct answer:(a) Both A and R are true and R is the correct explanation of A**

- **Assertion (A) is true:**

Self-inductance resists any change in the current flowing through a coil — similar to how **inertia** resists changes in motion. That's why it's often referred to as the "inertia of electricity".

- **Reason (R) is also true:**

This is the **definition** of self-inductance: when current in a coil changes, it causes a changing magnetic flux, which induces an e.m.f. that **opposes** the change in current (Lenz's Law).

- **R explains A:**

The opposition to current change due to induced e.m.f. is what gives self-inductance its "inertial" property.

✅**Correct answer:(a) Both A and R are true and R is the correct explanation of A**

- **Analysis:**
  - A is **true**: Winding coils on each other maximizes flux linkage.
  - R is **false**: Mutual induction **does** depend on orientation.

✅**Correct answer:(c) A is true but R is false**

Assertion: Acceleration of a magnet falling through a long solenoid decreases.
Reason: The induced current produced in a circuit always flows in such a direction that it opposes the change or the cause that produced it.

- **Analysis:**
  - A is **true**: Lenz's Law → opposing force → reduced acceleration.
  - R is **true**: This is the essence of Lenz’s Law.
  - R **explains** A.

✅**Correct answer:(a) Both A and R are true and R is the correct explanation of A**

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.**

9 ✅**Correct answer:(b)**
Both A and R are true and R is NOT the correct explanation of A,

10 ✅Correct answer:(b)
Both A and R are true and R is NOT the correct explanation of A,

11 ✅Correct answer:(b)
Both A and R are true and R is NOT the correct explanation of A,

12 ✅Correct answer:(a)
Both A and R are true and R is the correct explanation of A

13 ✅Correct answer:(d)
A is false and R is also false.

Assignment-4

CASE STUDY QUESTIONS 1

Ans.1
(a) left
Ans.2
(d)
down
Ans.3
(b)
right
Ans.4
(a) left
Ans.5(c
) DC
Motor
CASE STUDY QUESTIONS 2

Ans.1 (a) Current
Transformer
Ans.2(c) Remain
the same Ans3.(d)
Core loss
Ans.4(b)
Silicon Steel
Ans.5(b)
Voltage &
current **CASE**
STUDY
QUESTIONS
3

Ans.1 (c) Mutual
Inductance Ans.2
(D)
Ans.3 (B) Henry
Ans.4(B)
Inductance
Ans.5(B) Less
CASE STUDY QUESTIONS 4

Ans.1.(C)

Ans.2(d)

Ans. 3.(c)

Ans.4 (c)

Ans.5.(a)

CASE STUDY QUESTIONS 5

Ans i (C) Both A and B

Ans ii (D) parabola not through the origin.

Ans iii (B) twice per revolution

Ans iv (B) 40 V

CASE STUDY QUESTIONS 6

Ans i (b) Bvl

Ans ii (c) Bvl/ R.

Ans iii (d) g -(B^2l^2 v)/(mR

Ans iv (a) (mgR)/(B^2 l^2)

CASE STUDY QUESTIONS 6

Ans i (a)

Ans ii (b)

Ans iii (c)

Ans iv (c)

Ans v (a)

Assignment-5

	SHORT ANSWER
1	i) Brightness of the bulb decreases. ii) Cu loop generated large current comparative to constantan because Cu have low resistance.

2	i) The polarity of plate 'A' of the given capacitor is positive, while that of plate 'B' is negative ii) The direction of the induced current in the given rectangular loop is anti-clock wise, i.e., cbadc
3	Lenz's law states that the polarity of induced e.m.f. is such that it opposes the change in magnetic flux which caused it to produce .Yes, there will be an e.m.f. induced due to changing magnitude of earth's magnetic field
4	On moving a rectangular conducting loop into the field ,the flux increases. According to Lenz's law, the induced current would be anti clockwise.
5	Slope=e/(dI/dt)=L and slope of X >slope of Y So X—iron cored Y—air cored(as insertion of core material increases L)
10	(1)Radius = 10cm,B=0.2T w=2rad/s $\epsilon = \frac{1}{2} B w r^2$ I=0.0314 A
6	(a)emf same (area and time period same) (b)Current in copper is more as copper has less resistance.
7	$\phi=(4t^3+5t^2+8t^{-3}+5)$Wb. Rate of change of flux, $d\phi/dt = 12\,t^2 + 10\,t - 24\,t^{-4}$ According to Faraday's law of electromagnetic induction, Induced e.m.f.$\lvert\varepsilon\rvert = \lvert -d\phi/dt \rvert$at t =2s $\varepsilon = \lvert 48+20-24/16 \rvert = \lvert 68-1.5 \rvert = 66.5$V so, induced current= ε/R=66.5/3.1= 21.45 A

8	The magnitude of induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit. Mathematically=-dϕ/dt
9	(a) Theaccelerationofthefallingmagnetwillbelessthan'g'.Asthemagnetfallsthemagneticflux linked with the ring increases. The current induced in the ring opposes the downward motion of magnet.

	(b) When the ring is cut, thee.m.f.isinducedacrosstheendsbutnoinducedcurrentflowsthroughit. Thusthemotionofmagnetwillnotopposed.Themagnetfallswithaccelerationequaltoacceleration due to gravity.
10	1. Eddy current produced in the coil thrown disc into air. 2. Whenever the magnetic flux linked with a metal block changes, induced currents are produced due to this current, disc becomes a magnet. Hence disc thrown up in to air. 3. The change in flux produces eddy current in a metal. The heat produced by eddy current is used for cooking in induction heater.
11	Induced emf: $E = -\mu 0 I0 \omega N k \pi r^2$ Mutual inductance:$\mu 0 N k \pi r^2$
12	i)E $=ikducedemf=Bl$ v ii)W=qvBl E=W$/q=Blv$
LONG ANSWERS	

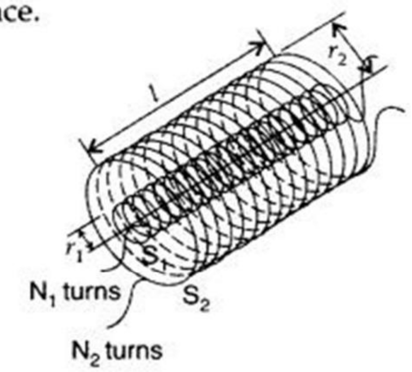
1	I)The self-inductance of a coil maybe defined as the induced emf setup in the coil due to a unit rate of change of current through it. Let I bet he current through the inductor L at any instant t The current rises at the rate di/dt, so the induced Work done against the induced emf in small timed t is Totalworkdoneinbuildingupthecurrentfrom 0 to Iin This work done is stored as the magnetic field energy U in the inductor ii)Mutualinductionisthephenomenonofinducingemfinacoilduetotherateofchange of current in a nearby coil. When a current I_2 is setup through S_2(outer solenoid),it in turn sets up a magnetic flux through S_1. Let us denote it by ϕ_1, The corresponding flux linkage with solenoid $S_1$is,

<table>
<tr><td></td><td>

$N_1\phi_1 = M_{12}I_2$ ...(1)

(Here N_1 is total no. of turns with S_1)

M_{12} is referred to as coeficient of mutual inductance.



The flux linkage with coil S_1 is,

$N_1\phi_1 = (n_1 l)(\pi r_1^2)(\mu_0 n_2 I_2)$

$= \mu_0 n_1 n_2 \pi r_1^2 l I_2$ ...(2)

from equation (1)

$M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l$

Now consider reverse case

$N_2\phi_2 = M_{21}I_1$ ...(3)

(Here N_2 is total no. of turns with S_2)

M_{21} is referred to as coefficient of mutual inductance of solenoid S_2 with respect to solenoid S_1.

Thus, flux linkage with solenoid $S_2$is

$N_2\phi_2 = (n_2 l)(\pi r_1^2)(\mu_0 n_1 I_1)$ ...(4)

∴ from equation (3), we get

$M_{21} = \mu_0 n_1 n_2 \pi r_1^2 l$

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(i) Magnetic field at the centre of long solenoid is

$B=\mu_0 nI$ Flux $\phi_B= \mu_0 nIA$

$L= \mu_0 n^2 Al$

ii)emf $e= \mu_0 n\, A(dI/dt) = 4 \times 3.142 \times 10^{-7} \times 1500 \times 2 \times 10^{-4} \times (2/0.1) = 7.54 \times 10^{-6}$V

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<tr><td>3</td><td>

All points on the rod are moving perpendicular to the magnetic field .Hence,all elementary small elements of the rod induce a small lpotential difference and the net potential difference in the rod is the integration of the potential differences along the rod Motional emf in a conductor moving perpendicular to The field is given by:

$\varepsilon=Bvl$

Thepotentialdifferenceacrossasmallelementofrodatadistancelfromthecenter,$d\varepsilon=Bv(dl)$ But $v=\omega l$

$\Rightarrow d\varepsilon=Bl\omega\, dl$

Hence total emf produced across the rod, $\varepsilon= \int_0^L B(l\boldsymbol{\omega})dl$

$=\frac{1}{2}B\omega L^2$

</td></tr>
</table>

	2
4	Consider forward motion from x=0to x=2b Magnetic flux, Φ=Blxfor0 ≤ x<band Bl b for b ≤x<2b

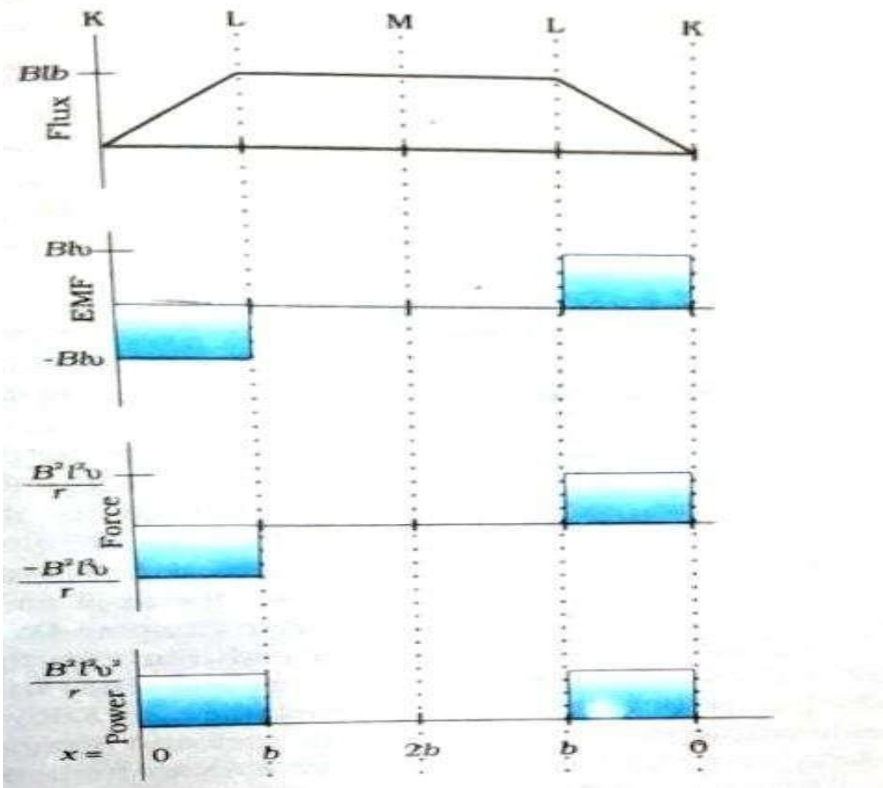
Induced emf, $\varepsilon = -d\phi/dt = -Blv$ for $0 \le x < b$ and 0 for $b \le x < 2b$
Induced current, $I = Blv/r$ for $0 \le x < b$ and 0 for $b \le x < 2b$
Force, $F = B^2 l^2 v/r$ for $0 \le x < b$ and 0 for $b \le x < 2b$

The Joule heating loss is, $P = B^2 l^2 v^2/r$ for $0 \le x < b$ and 0 for $b \le x < 2b$

Now backward motion from $x=2b$ to $x=0$

Magnetic flux, $\Phi = Blb$ for $2b \ge x > b$ and $Bl\,x$ for $b \ge x > 0$
Induced emf, $\varepsilon = -d\phi/dt = 0$ for $2b \ge x > b$ and $Bl\,v$ for $b \ge x > 0$
Induced current, $I = 0$ for $2b \ge x > b$ and $Bl\,v/r$ for $b \ge x > 0$
Force, $F = 0$ for $2b \ge x > b$ and $B^2 l^2 v/r$ for $b \ge x > 0$

The Joule heating loss is, $P = 0$ for $2b \ge x > b$ and $B^2 l^2 v^2/r$ for $b \ge x > 0$



CHAPTER 7: ALTERNATING CURRENT

ASSIGNMENT 1: Question Paper

PHYSICS – Code No.
042 QUESTION
PAPER CLASS XII
(2026 – 27)

Time Allowed: 3 hours
Maximum Marks: 70

General Instructions:

(1) There are 33 questions in all. All questions are compulsory.
(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
(3) All the sections are compulsory.
(4) **Section A contains sixteen questions, twelve MCQ and four assertion reasoning based of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, Section D contains two case study-based questions of four marks each and Section E contains three long answer questions of five marks each.**
(5) There is no overall choice.
(6) However, an internal choice has been provided in two questions in Section B, one question in Section C and all three questions in Section E. You have to attempt only one of the choices in such questions.
(7) Use of calculators is not allowed.
(8) You may use the following values of physical constants wherever necessary.

i. $c = 3\times10^{8}$ m/s
ii. $m_e = 9.1\times10^{-31}$ kg
iii. $m_p = 1.7\times10^{-27}$ kg
iv. $e = 1.6\times10^{-19}$ C
v. $\mu_0 = 4\pi\times10^{-7}$ TmA^{-1}
vi. $h = 6.63\times10^{-34}$ Js
vii. $\varepsilon_0 = 8.854\times10^{-12}$ $C^2N^{-1}m^{-2}$
viii. Avogadro's number = 6.023×10^{23} per gram mole

SECTION A

1. The unit of inductive reactance is:

(a) Ohm (b) Henry (c) Farad (d) Volt

2. In a series LCR circuit, resonance occurs when:

(a) XL = XC (b) R = 0 (c) XL = R (d) XC = R

3. If the phasor diagram for a device connected to AC supply is as shown (V leading I), which of the following statements is true?

(a) When the frequency of the AC source is increased, the impedance of the device decreases

(b) This device behaves as a conducting wire when connected across a DC source

(c) When the frequency of the AC source is decreased, the impedance of the device decreases

(d) This device stores energy in the form of magnetic potential energy

4. Which of the following statements about a series LCR circuit connected to an ac source is correct?

(a) Current always lags voltage

(b) Current always leads voltage

(c) Phase relation between voltage and current depends on relative values of XL and XC

(d) Current and voltage are always in phase

5. An ideal inductor is connected across an AC source of voltage. The current in the circuit:

(a) is ahead of the voltage in phase by π

(b) lags the voltage in phase by π

(c) is ahead of the voltage in phase by $\pi/2$

(d) lags the voltage in phase by $\pi/2$

6. The average power consumed in a purely inductive AC circuit is:

(a) Zero

(b) Maximum

(c) Equal to the power in a purely resistive circuit

(d) Double the peak power

7. The RMS value of a sinusoidal voltage that has a peak of 220 V is:

(a) 110 V (b) 220 V (c) 155.6 V (d) 311 V

8. In an LCR series circuit at resonance, the current is:

(a) Minimum (b) Maximum (c) Zero (d) Depends on frequency

9. Power factor of a purely resistive circuit is:

(a) 0 (b) 0.5 (c) 1 (d) −1

10. In a transformer, the core is laminated to:

(a) Increase capacity (b) Reduce eddy current losses (c) Decrease cost (d) Increase flux

11. Watt-less current means power factor is:

(a) 1 (b) 0 (c) 0.5 (d) −1

12. The emf generated by an AC generator is given by $V = V_m \sin \omega t$, where ω is the angular frequency of the armature of the generator. What will be the emf if the angular frequency is doubled?

(a) $V = V_m \sin 2\omega t$ (b) $V = 2V_m \sin \omega t$ (c) $V = 2V_m \sin 2\omega t$ (d) $V = V_m \sin \omega t$

For Questions 13 to 16, two statements are given — Assertion (A) and Reason (R). Select the correct answer:

(A) Both A and R true, R is the correct explanation of A.

(B) *(B) Both A and R true, R is not the correct explanation of A.*

(C) *(C) A is true, R is false.*

(D) *(D) Both A and R are false.*

13. Assertion (A): At resonance, impedance of an LCR series circuit is purely resistive.
Reason (R): At resonance, inductive reactance equals capacitive reactance.

14. Assertion (A): At resonance, the current in a series LCR circuit is maximum.
Reason (R): At resonance, the impedance of the circuit is equal to resistance only.

15. Assertion (A): In a purely capacitive circuit, current leads the applied voltage by 90°.
Reason (R): The voltage across the capacitor cannot change instantaneously.

16. Assertion (A): At very high frequency, the capacitive reactance of a capacitor becomes very large.
Reason (R): Capacitive reactance is proportional to the frequency of AC.

SECTION B

17. When an ac source is connected across an ideal inductor, show on a graph the nature of variation of the voltage and the current over one complete cycle.

18. A heating element is marked '210 V, 630 W'. Find the resistance of the element when connected to a 210 V dc source.

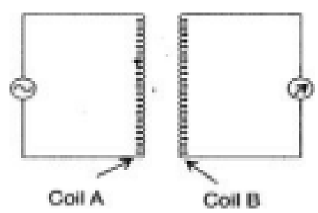
19. A variable frequency AC source is connected to a capacitor. Will the displacement current change if the frequency of the AC source is decreased?

20. Prove that an ideal inductor does not dissipate power in an A.C. circuit.

OR

Plot a graph showing the variation of capacitive reactance with the change in frequency of the AC source.

21. The circuit arrangement shows that when an A.C. passes through coil A, current starts flowing in coil B.



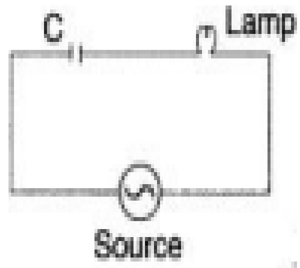
(i) State the underlying principle involved.
(ii) Mention two factors on which the current produced in coil B depends.

OR

A 15.0 μF capacitor is connected to a 220 V, 50 Hz source. Find the capacitive reactance and the rms current.

SECTION C

22. An electric lamp having a coil of negligible inductance is connected in series with a capacitor and an a.c. source, and is glowing with a certain brightness. How does the brightness of the lamp change on reducing
(i) the capacitance, and
(ii) the frequency? Justify your answer.



23. A light bulb is rated 100 W for a 220 V ac supply of 50 Hz. Calculate
(i) the resistance of the bulb,
(ii) the rms current through the bulb.

24. Using a phasor diagram, derive the expression for impedance in a series LCR circuit.

25. Calculate the resonant frequency for an LCR circuit with L = 0.1 H, C = 10 μF, and R = 10 Ω. What is the impedance at resonance?

26. A 100 Ω resistor is connected to a 220 V, 50 Hz AC supply. Calculate the rms current, peak current, and average power dissipated.

27. A circuit containing an 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 value.
(b) Obtain the rms value of the potential drop across each element.
(c) What is the average power transferred to the inductor?

OR

A 50 W, 100 V electric bulb is to be used on a 200 V, 50 Hz AC supply. Calculate the inductance of the choke needed so that it may glow with normal brightness (take $\pi = 3$).

28. On the basis of power dissipation in an AC circuit, distinguish between resistance, reactance, and impedance.

SECTION D

Question-29 (Case-based): In AC circuits, the opposition to current flow is not just resistance but impedance, which includes reactance from inductors and capacitors. In a series LCR circuit, the total impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$, where $X_L = \omega L$ and $X_C = 1/(\omega C)$. At the resonant frequency, $X_L = X_C$, making Z minimum and equal to R, leading to maximum current — used in tuning circuits like radios.

i. What is the value of power factor at resonance? (a) 0 (b) 1 (c) 0.5 (d) Infinite

ii. If ω increases beyond resonant frequency, how does the current change?

iii. Derive the expression for resonant frequency.

iv. Why is resonance sharp in circuits with low resistance?

Question-30 (Case-based): Transformers are devices that change AC voltages using mutual induction. A step-up transformer has more turns in the secondary than the primary, increasing voltage while decreasing current, ideal for transmission to reduce I^2R losses. Efficiency is high but not 100% due to eddy currents, hysteresis, etc. In India, domestic supply is 220 V rms at 50 Hz.

i. The turns ratio for a transformer stepping up from 220 V to 11 kV is: (a) 1:50 (b) 50:1 (c) 1:5 (d) 5:1

ii. Explain why transformers don't work with DC.

iii. What is the role of the soft iron core in transformers?

iv. Calculate the current in the primary if the secondary delivers 10 A at 11 kV, assuming an ideal transformer and primary at 220 V.

SECTION E

31. (a) Derive the expression for impedance, phase angle, and current in a series LCR AC circuit using the phasor method. Draw the impedance triangle.
(b) The peak value of an alternating voltage applied to a 50 Ω resistance is 10 V. Find the RMS current if the voltage frequency is 100 Hz; write the equation for the instantaneous current.

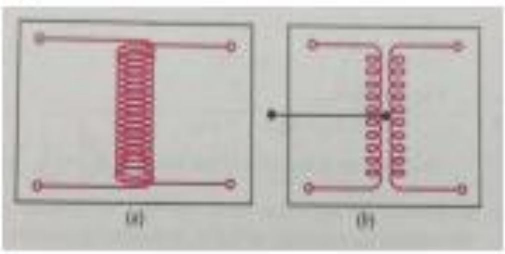
OR

(a) Explain the behaviour of current in AC circuits with
(i) resistor only,
(ii) inductor only,
(iii) capacitor only, including phase differences and graphs.
(b) A pure inductor of 25 mH is connected to a source of 220 V. Find the inductive reactance and RMS current if the frequency of the source is 50 Hz.

32. (a) Draw the graphs showing the variation of inductive reactance and capacitive reactance with the frequency of the applied ac source.
(b) Can the voltage drop across the inductor or the capacitor in a series LCR circuit be greater than the applied voltage of the AC source? Justify your answer.

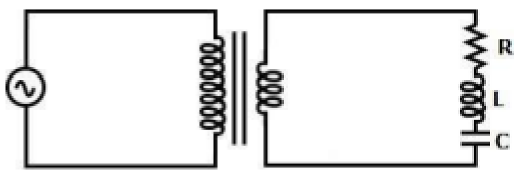
OR

(a) Out of two given arrangements for winding the primary and secondary coil in a transformer, which will have higher efficiency and why?



(b) Show that in an ideal transformer, when the voltage is stepped up/down by a certain factor, the current gets stepped down/up by the same factor.
(c) State any two causes of energy loss in a transformer.

33. (a) An input potential Vin = 200 sin(100πt) V is provided to an ideal transformer having 1000 turns in the primary coil and 100 turns in the secondary coil. The load circuit has a resistance of 4 Ω, a capacitive reactance of 2 Ω, and an inductive reactance of 6 Ω. Find



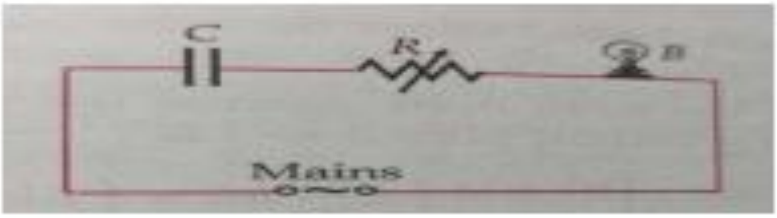
(i) the output voltage across the load circuit,
(ii) the current flowing through the load circuit,

(iii) the power supplied to the load circuit by the transformer.

(b) State the working principle of a transformer and explain how it is a key component in the transfer of electrical power over long distances.

OR

A capacitor C, a variable resistor R, and a bulb B are connected in series to the AC mains; 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 the same,

(ii) the resistance R is increased keeping the same capacitance?

ASSIGNMENT 2: Multiple Choice Questions (1 Mark each)

1. The instantaneous value of an alternating current is given by $I = 10 \sin(314t)$ A. What is the peak value of the current?

(a) 5 A (b) 7.07 A (c) 10 A (d) 14.14 A

2. The RMS value of an alternating current is:

(a) Peak value × √2 (b) Peak value / √2 (c) Peak value / 2 (d) Peak value × 2

3. An AC voltage is given by $V = 200 \sin(100\pi t)$ V. What is the frequency of the AC?

(a) 50 Hz (b) 100 Hz (c) 200 Hz (d) 314 Hz

4. The phase difference between voltage and current in a purely resistive AC circuit is:

(a) 0° (b) 90° (c) 180° (d) 45°

5. In a purely inductive AC circuit, the current:

(a) Leads the voltage by 90° (b) Lags the voltage by 90°
(c) Is in phase with the voltage (d) Leads the voltage by 180°

6. The inductive reactance of an inductor in an AC circuit is given by:

(a) XL = ωL (b) XL = 1/(ωL) (c) XL = ω/L (d) XL = L/ω

7. The capacitive reactance of a capacitor in an AC circuit is given by:

(a) XC = ωC (b) XC = 1/(ωC) (c) XC = ω/C (d) XC = C/ω

8. In a purely capacitive AC circuit, the current:

(a) Lags the voltage by 90° (b) Leads the voltage by 90°
(c) Is in phase with the voltage (d) Lags the voltage by 180°

9. The impedance of an L-R series circuit is given by:

(a) $Z = \sqrt{R^2 + XL^2}$ (b) Z = R + XL (c) Z = R − XL (d) $Z = \sqrt{R^2 - XL^2}$

10. The power factor of an AC circuit is defined as:

(a) cos φ (b) sin φ (c) tan φ (d) 1/cos φ

11. In an AC circuit, the average power consumed is:

(a) Vrms × Irms (b) Vrms × Irms × cos φ (c) Vrms × Irms × sin φ (d) Vrms / Irms

12. In a series LCR circuit at resonance, the phase difference between voltage and current is:

(a) 0° (b) 90° (c) 180° (d) 45°

13. The condition for resonance in a series LCR circuit is:

(a) XL = XC (b) XL > XC (c) XL < XC (d) XL = R

14. The resonant frequency of a series LCR circuit is given by:

(a) $f = 1/(2\pi\sqrt{LC})$ (b) $f = 2\pi\sqrt{LC}$ (c) $f = 1/(2\pi LC)$ (d) $f = 2\pi/\sqrt{LC}$

15. In a series LCR circuit at resonance, the impedance is:

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

16. In an LCR series circuit, the power factor is maximum when:

(a) R = 0 (b) XL = XC (c) XL > XC (d) XL < XC

17. The reactance of a capacitor at very high frequency is:

(a) Infinite (b) Zero (c) Moderate (d) Negative

18. In an AC circuit, the current is 5 A (RMS) and the voltage is 200 V (RMS) with a power factor of 0.8. The average power is:

(a) 800 W (b) 1000 W (c) 1200 W (d) 1600 W

19. In an AC circuit, the power is zero when the circuit is:

(a) Purely resistive (b) Purely inductive or capacitive (c) At resonance (d) Having high resistance

20. An AC voltage is given by $V = 100 \sin(100\pi t)$. What is the time period of the AC signal?

(a) 0.02 s (b) 0.01 s (c) 0.04 s (d) 0.05 s

21. In an ac circuit, the instantaneous values of current and voltage are $I = 5 \sin \omega t$ (A) and $E = 200 \cos(\omega t + \varphi)$ (V) respectively. If $\varphi = \pi/2$, the phase difference between voltage and current at any instant is:

(a) 0 (b) $\pi/4$ (c) $\pi/2$ (d) π

22. An ac voltage is given as $v = 14 \sin(314t)$ V. The average and effective (rms) values of the voltage over a cycle are respectively:

(a) 0, 9.9 V (b) 14 V, 9.9 V (c) 0, 14 V (d) 9.9 V, 0

23. Which of the following statements about a series LCR circuit connected to an ac source is correct?

(a) Current always lags voltage

(b) Current always leads voltage

(c) Phase relation between voltage and current depends on relative values of XL and XC

(d) Current and voltage are always in phase

24. An ideal inductor is connected across an AC source of voltage. The current in the circuit:

(a) is ahead of the voltage in phase by π

(b) lags the voltage in phase by π

(c) is ahead of the voltage in phase by $\pi/2$

(d) lags the voltage in phase by $\pi/2$

25. What is the ratio of inductive reactance to capacitive reactance in an ac circuit?

(a) ωLC (b) $\omega^2 LC$ (c) $1/(\omega^2 LC)$ (d) $\omega/(LC)$

26. The average value of alternating current over a full cycle is:

(a) $I0/\sqrt{2}$ (b) $2I0/\pi$ (c) Zero (d) I0

27. The average value of alternating current over half a cycle is:

(a) $I0/\sqrt{2}$ (b) $2I0/\pi$ (c) Zero (d) I0

28. A choke coil is preferred over a resistor to limit current in an AC circuit because:

(a) It consumes more power
(b) It limits current with negligible power loss
(c) It increases the resistance of the circuit
(d) It converts AC to DC

29. In a series LCR circuit, if R is increased while keeping L and C fixed, the sharpness of resonance:
(a) Increases (b) Decreases (c) Remains the same (d) Becomes infinite

30. The quality factor (Q-factor) of a series LCR circuit is given by:
(a) Q = ω0L/R (b) Q = R/ω0L (c) Q = ω0RL (d) Q = 1/(ω0RL)

31. In an LCR circuit driven below the resonant frequency, the circuit behaves predominantly:
(a) Inductive (b) Capacitive (c) Purely resistive (d) None of these

32. In an LCR circuit driven above the resonant frequency, the circuit behaves predominantly:
(a) Inductive (b) Capacitive (c) Purely resistive (d) None of these

33. The apparent power in an AC circuit is given by:
(a) Vrms Irms (b) Vrms Irms cosφ (c) Vrms Irms sinφ (d) Vrms/Irms

34. The reactive (wattless) power in an AC circuit is given by:
(a) Vrms Irms (b) Vrms Irms cosφ (c) Vrms Irms sinφ (d) Vrms/Irms

35. An ideal transformer has 100% efficiency because:
(a) It has no resistance and no flux leakage (b) It uses a permanent magnet core
(c) It works on DC (d) It has a very large number of turns

36. An autotransformer differs from a conventional two-winding transformer in that:
(a) It has separate primary and secondary windings
(b) It uses a single winding common to both primary and secondary
(c) It works only with DC
(d) It has no core

37. Eddy currents are used beneficially in:
(a) Induction furnaces (b) Ordinary resistors (c) Filament bulbs (d) Photodiodes

38. In a purely resistive AC circuit, if the frequency of the source is doubled, the current amplitude:
(a) Doubles (b) Halves (c) Remains unchanged (d) Becomes zero

39. For a series RC circuit connected to an ac source, the current:
(a) Lags the voltage (b) Leads the voltage (c) Is in phase with the voltage (d) Is always zero

40. A step-down transformer converts:
(a) Low voltage, high current to high voltage, low current
(b) High voltage, low current to low voltage, high current
(c) AC to DC
(d) DC to AC

41. A voltage v = v0 sinωt applied to a circuit drives a current i = i0 sin(ωt + φ) through it. What is the average power consumed over one full cycle?

(a) v0 i0 (b) v0 i0/2 (c) (v0 i0/2) cosφ (d) Zero

42. In a circuit, the phase difference between the alternating current and the source voltage is π/2. Which of the following cannot be the elements of the circuit?

(a) L, C (b) L, R (c) only L (d) only C

43. A circuit is connected to an ac source of variable frequency. As the frequency increases, the current first increases and then decreases. Which combination of elements is likely to make up the circuit?

(a) L and R in series (b) L, C and R in series (c) C and R in series (d) L and C in parallel

ASSIGNMENT 3: Assertion–Reason Questions (1 Mark each)

Instructions: Each question has an Assertion (A) and a Reason (R). Choose from:

(A) Both A and R true, R is the correct explanation of A.

(B) Both A and R true, R is NOT the correct explanation of A.

(C) A is true, R is false.

(D) A is false, R is true.

(E) Both A and R are false.

1. Assertion (A): The average power consumed in a pure resistive AC circuit is given by P = Vrms × Irms.
Reason (R): In a pure resistive circuit, voltage and current are in phase, so the power factor is unity.

2. Assertion (A): In a pure inductive AC circuit, the current lags the voltage by 90°.
Reason (R): The inductive reactance depends on the frequency of the AC supply.

3. Assertion (A): The impedance of an LCR series circuit is minimum at resonance.
Reason (R): At resonance, the inductive reactance equals the capacitive reactance, making the circuit purely resistive.

4. Assertion (A): The power factor of an AC circuit can be negative.
Reason (R): The power factor is defined as cos φ, where φ is the phase angle between voltage and current.

5. Assertion (A): A capacitor allows AC to pass but blocks DC.
Reason (R): The capacitive reactance is inversely proportional to the frequency of the current.

6. Assertion (A): The RMS value of an alternating current is always less than its peak value.
Reason (R): The RMS value is defined as Irms = Im/√2, where Im is the peak current.

7. Assertion (A): In a transformer, the output voltage is always less than the input voltage.
Reason (R): A transformer works on the principle of mutual induction and can step up or step down the voltage.

8. Assertion (A): An ideal inductor has zero power loss in an AC circuit.
Reason (R): In an ideal inductor, the current and voltage are in phase.

9. Assertion (A): At resonance, the current in a series LCR circuit reaches its maximum value.
Reason (R): At resonance, the net reactance of the circuit is zero.

10. Assertion (A): A choke coil is preferred over a resistor to control current in an AC circuit.
Reason (R): A choke coil consumes negligible power compared to a resistor for the same current-limiting effect.

11. Assertion (A): The quality factor (Q) of a series LCR circuit increases as resistance R decreases.
Reason (R): Q is defined as ω0L/R, so it is inversely proportional to R.

12. Assertion (A): An ideal transformer conserves power, i.e. input power equals output power.
Reason (R): An ideal transformer has no resistive or core losses.

13. Assertion (A): A step-up transformer cannot be used as a step-down transformer.
Reason (R): A transformer works only in one direction.

ASSIGNMENT 4: Case Study-Based Questions (4 Marks each)

Case Study 1: Household AC Circuit

In a household, an electric heater with a resistance of 50 Ω is connected to a 220 V (RMS) AC supply operating at 50 Hz. The heater is designed to operate efficiently with a purely resistive load.

1. What is the RMS current flowing through the heater?
2. Calculate the average power consumed by the heater.
3. If the AC supply voltage is $V = 311 \sin(100\pi t)$ V, what is the peak voltage?
4. Why does the heater not require power factor correction?

Case Study 2: Series LCR Circuit and Resonance

In a series LCR circuit connected to an AC source, the impedance depends on the values of R, L, C, and the frequency of the source. At a particular frequency called the resonant frequency, the inductive reactance equals the capacitive reactance, and the impedance becomes minimum (equal to R), resulting in maximum current flow.

1. At resonance, the condition satisfied is:
   (a) XL = 0 (b) XC = 0 (c) XL = XC (d) XL = R
2. The resonant angular frequency ω_0 of a series LCR circuit is:
   (a) 1/LC (b) 1/√(LC) (c) √(LC) (d) LC
3. At resonance, the impedance of the series LCR circuit equals:
   (a) Zero (b) R (c) XL (d) XC
4. At resonance, the current in the circuit is:
   (a) Minimum (b) Maximum (c) Zero (d) Independent of R

Case Study 3: Transformer

A transformer is a device used to change AC voltages, working on the principle of mutual induction. It consists of a primary and secondary coil wound on a laminated soft iron core. The core is laminated to reduce energy losses due to eddy currents. Transformers are used to step-up or step-down voltage in power transmission.

1. A transformer works on the principle of:
   (a) Self-induction (b) Mutual induction (c) Electromagnetic force (d) Ampere's law
2. The core of a transformer is laminated to reduce:
   (a) Hysteresis loss (b) Copper loss (c) Eddy current loss (d) Flux leakage
3. In a step-up transformer:
   (a) Ns < Np (b) Ns = Np (c) Ns > Np (d) No relation

4. A transformer can be used to step up or step down:

(a) Only DC voltage (b) Only AC voltage (c) Both AC and DC (d) Neither

Case Study 4: AC Circuit with Resistor

In a pure resistive AC circuit, the voltage and current are always in phase with each other. The instantaneous voltage is given by $V = V_0 \sin \omega t$, and the instantaneous current is $I = I_0 \sin \omega t$, where $I_0 = V_0/R$. Unlike DC circuits, the power in an AC resistive circuit is calculated using rms values.

1. The phase difference between voltage and current in a pure resistor is:

(a) $\pi/2$ (b) π (c) Zero (d) $\pi/4$

2. If the rms voltage across a resistor is 220 V, the peak voltage is approximately:

(a) 220 V (b) 311 V (c) 155 V (d) 440 V

3. The power factor of a purely resistive circuit is:

(a) 0 (b) 0.5 (c) 1 (d) Cannot be determined

4. In a pure resistive circuit, average power dissipated equals:

(a) V_0I_0 (b) $V_0I_0/2$ (c) Zero (d) $2V_0I_0$

Case Study 5: Impedance & Resonance

In AC circuits, the opposition to current flow is not just resistance but impedance, which includes reactance from inductors and capacitors. In a series LCR circuit, the total impedance $Z = \sqrt{(R^2 + (XL-XC)^2)}$, where $XL = \omega L$ and $XC = 1/(\omega C)$. At the resonant frequency, XL = XC, making Z minimum and equal to R. This leads to maximum current and is used in tuning circuits like radios.

1. What is the value of the power factor at resonance? (a) 0 (b) 1 (c) 0.5 (d) Infinite

2. If ω increases beyond the resonant frequency, how does the current change?

3. Derive the expression for the resonant frequency.

4. Why is resonance sharp in circuits with low resistance?

Case Study 6: LC Oscillations

When a charged capacitor is connected to an inductor, the charge on the capacitor and current in the circuit exhibit oscillatory behaviour, similar to a mechanical oscillator. Energy oscillates between the electric field of the capacitor and the magnetic field of the inductor, with the total energy remaining constant in an ideal LC circuit.

1. The angular frequency of LC oscillations is given by:

(a) $\omega = 1/LC$ (b) $\omega = 1/\sqrt{(LC)}$ (c) $\omega = \sqrt{(LC)}$ (d) $\omega = LC$

2. At the instant when all energy is stored in the inductor, the charge on the capacitor is:

(a) Maximum (b) Zero (c) Half of maximum (d) Cannot be determined

3. LC oscillations are analogous to which mechanical system?

(a) Damped oscillator (b) Simple pendulum with friction
(c) Simple harmonic oscillator (spring-mass) (d) Forced oscillator

4. In an ideal LC circuit (no resistance), the oscillations are:

(a) Damped (b) Undamped (c) Forced (d) Overdamped

Case Study 7: Choke Coil and Wattless Current

A choke coil (a coil of high inductance and negligible resistance) is used in series with fluorescent tube lights to limit the current without significant power loss, unlike a resistor, which would waste power as heat. The current drawn by an ideal choke coil is called a wattless current since the average power consumed is zero.

1. Why is a choke coil preferred over a resistor for limiting current in an AC circuit?

2. What is meant by 'wattless current'?

3. If a choke coil of inductance 0.5 H is connected to a 220 V, 50 Hz supply, calculate the current drawn (assume negligible resistance).

4. What is the power factor of this circuit, and what is the average power consumed?

ASSIGNMENT 5:

Short Answer Questions (2 Marks each)

1. Define RMS value of an alternating current and derive its relation with the peak value.

2. A 100 Ω resistor is connected to a 220 V (RMS) AC supply at 50 Hz. Calculate
(i) the RMS current and
(ii) the average power consumed.

3. Explain why the power factor is zero in a pure inductive circuit.

4. An inductor of 0.2 H is connected to a 110 V (RMS) AC supply at 50 Hz. Calculate
(i) the inductive reactance and
(ii) the RMS current.

5. A capacitor of 50 μF is connected to a 200 V (RMS) AC supply at 60 Hz. Calculate
(i) the capacitive reactance and
(ii) the RMS current.

6. A step-up transformer has a turns ratio of 1:5 and is connected to a 220 V (RMS) AC supply. Calculate
(i) the output voltage and
(ii) the current ratio (Is/Ip).

7. Derive the expression for the impedance of an LCR series circuit.

8. Why is the power in an ideal transformer conserved? Explain with reference to input and output power.

9. A 150 Ω resistor is connected to a 240 V (RMS) AC supply at 50 Hz. Calculate
(i) the peak current and
(ii) the average power consumed.

10. An inductor of 0.3 H is connected to a 110 V (RMS) AC supply at 60 Hz. Calculate
(i) the inductive reactance and
(ii) the RMS current through the inductor.

11. A capacitor of 200 μF is connected to a 200 V (RMS) AC supply at 50 Hz. Calculate
(i) the capacitive reactance and
(ii) the peak current.

12. An LCR series circuit has L = 0.2 H, C = 50 μF, and R = 30 Ω, connected to a 100 V (RMS) AC supply. Calculate
(i) the resonant frequency and
(ii) the RMS current at resonance.

13. A step-down transformer has 500 turns in the primary coil and 50 turns in the secondary coil, connected to a 220 V (RMS) AC supply. Calculate
(i) the secondary voltage and
(ii) the primary current if the secondary current is 2 A.

14. An alternating current is represented by $I = I0 \cos(100\pi t)$. What is the minimum time required for this current to decrease from its maximum value to zero?

15. When an ac source is connected across an ideal inductor, show on a graph the nature of variation of the voltage and the current over one complete cycle.

16. Define wattless current. Give an example of a circuit element that draws a wattless current and explain why.

17. The instantaneous current and voltage in an ac circuit are $i = 10 \sin 300t$ A and $V = 200 \sin 300t$ V. What is the power dissipated in the circuit?

18. The instantaneous current and voltage in an ac circuit are $i = 10 \sin 314t$ A and $v = 50 \sin(314t + \pi/2)$ V. Find the phase difference between current and voltage.

19. Mention the two characteristic properties a material should have to be suitable for a transformer core.

20. Why is a.c. voltage preferred over d.c. voltage? Give two reasons.

21. Define capacitive reactance and state its SI unit.

22. Define the 'quality factor' of resonance in a series LCR circuit and state its SI unit.

23. (i) Find the phase difference between current and voltage in a given series LCR circuit, and state which one leads.
(ii) Without making any other change, find the value of an additional capacitor C′ to be connected in parallel with C to make the power factor of the circuit unity.

24. The rms current in a circuit connected to a 50 Hz ac source is 15 A. What is the value of the current 1/600 s after the instant the current is zero?

25. The voltage across a resistor, an inductor, and a capacitor connected in series to an ac source are 20 V, 15 V, and 30 V respectively. What is the resultant voltage in the circuit?

26. A 15 Ω resistor, an 80 mH inductor, and a capacitor of capacitance C are connected in series with a 50 Hz ac source. If the source voltage and current are in phase, what does this indicate about C and L?

27. A 300 Ω resistor and a capacitor of $25/\pi$ μF are connected in series to a 200 V, 50 Hz ac source. What is the current in the circuit?

Long Answer Questions (5 Marks each)

1. (a) Explain the concept of power factor in an AC circuit and its significance in power consumption.
(b) A 100 Ω resistor and a 0.1 H inductor are connected in series to a 220 V (RMS) AC supply at 50 Hz. Calculate
(i) the impedance of the circuit,
(ii) the RMS current, and
(iii) the average power consumed.

2. (a) Describe the phenomenon of resonance in an LCR series circuit and its practical applications.
(b) An LCR series circuit has L = 0.2 H, C = 50 μF, and R = 20 Ω, connected to a 100 V (RMS) AC supply. Calculate
(i) the resonant frequency,
(ii) the impedance at resonance, and
(iii) the RMS current at resonance.

3. (a) Explain how a transformer works on the principle of mutual induction and why it operates only with AC.
(b) A step-up transformer has 200 turns in the primary coil and 1000 turns in the secondary coil, connected to a 220 V (RMS) AC supply. Calculate
(i) the secondary voltage,
(ii) the secondary current if the primary current is 0.5 A, and
(iii) the power output, assuming an ideal transformer.

4. (a) Explain why a capacitor blocks DC but allows AC to pass, with reference to its reactance.
(b) A capacitor of 100 μF is connected in series with a 50 Ω resistor to a 200 V (RMS) AC supply at 50 Hz. Calculate
(i) the capacitive reactance,
(ii) the impedance of the circuit, and
(iii) the phase angle between voltage and current.

5. A series LCR circuit with L = 5.0 H, C = 80 μF, R = 40 Ω is connected to a variable-frequency 240 V source. Calculate
(i) the angular frequency at resonance,
(ii) the current at the resonant frequency, and
(iii) the rms potential drop across the capacitor at resonance.

6. (a) Explain, with a labelled diagram, the principle and working of a transformer, and derive its working formula.
(b) Name four causes of energy loss in an actual transformer.

7. An inductor of reactance XL is connected in series with a bulb B and an ac source. How does the brightness of the bulb change when
(i) the number of turns in the inductor is reduced,
(ii) an iron rod is inserted into the inductor, and
(iii) a capacitor of reactance XC = XL is inserted in series? Justify each case.

8. A circuit with an 80 mH inductor and a 250 μF capacitor in series, connected to a 240 V, 100 rad/s supply with negligible resistance.
(i) Find the rms current.
(ii) What is the total average power consumed?

9. (i) State the function and working principle of a transformer with a diagram, and mention its various energy losses.
(ii) An ideal step-up transformer has 100 primary turns and a transformation ratio of 100; input voltage and power are 220 V and 1100 W. Calculate the secondary turns, primary current, secondary voltage, secondary current, and secondary power.

ANSWER KEYS (All Assignments)

Assignment 1 – Answer Key

MCQ Answers (Q1–12): 1-a, 2-a, 3-a, 4-a, 5-c, 6-b, 7-a, 8-b, 9-b, 10-a, 11-a, 12-d

Assertion-Reason (Q13–16): 13-a, 14-a, 15-b, 16-d

Q17. Graph — voltage and current in an ideal inductor are 90° out of phase over one cycle.

Q18. $R = V^2/P = 70\ \Omega$.

Q19. On decreasing the frequency of the AC source, $X_C = 1/\omega C$ increases, leading to a decrease in conduction current. Since $I_D = I_C$, the displacement current also decreases.

Q20. Average power dissipated per cycle in an ideal inductor = 0. OR Graph: X_C decreases hyperbolically with increasing frequency.

Q21. The phenomenon involved is mutual induction. (ii) Number of turns in coil B and distance between the two coils. OR $X_C \approx 212.3\ \Omega$; $I \approx 1.04$ A.

Q22. Brightness of lamp $\propto I_0$, and $I_0 = E_0(2\pi\nu)C$. Reducing C or ν decreases I_0, so brightness decreases.

Q23. (i) $R = 484\ \Omega$. (ii) $I_{rms} = 0.45$ A.

Q25. $f = 1000/2\pi$ Hz; at resonance $Z = R$.

Q26. $I_{rms} = 2.2$ A; $I_0 \approx 3.11$ A; $P_{avg} = 484$ W.

Q27. Reactance = $27.92\ \Omega$; $I_{rms} = 8.24$ A; $I_0 \approx 11.7$ A; $V_L(rms) \approx 207$ V; $V_C(rms) \approx 437$ V. OR $L \approx 1.155$ H.

Q28. Power dissipation is maximum across resistance; zero across reactance; across impedance it depends on power factor.

Q29. (i) b. (ii) Current decreases. (iii) $f = 1/(2\pi\sqrt{LC})$. (iv) Lower resistance gives sharper resonance.

Q30. (i) a. (ii) DC gives constant flux, no induced emf. (iii) Enhances flux linkage, reduces hysteresis loss. (iv) $I_p = 500$ A.

Q31. $I_{rms} \approx 141.4$ mA; $i = 200 \sin(200\pi t)$ mA. OR $I_{rms} \approx 28.03$ A.

Q32. X_L rises linearly, X_C falls hyperbolically with frequency. V_L or V_C can individually exceed source voltage (phasor addition).

Q33. Dielectric increases C, decreases X_C, increases current — brighter. Increasing R decreases current — dimmer.

Assignment 2 – Answer Key (MCQ 1–43)

Q1. (c) 10 A

Q2. (b) Peak value / $\sqrt{2}$

Q3. (a) 50 Hz

Q4. (a) 0°

Q5. (b) Lags the voltage by 90°

Q6. (a) $X_L = \omega L$

Q7. (b) $X_C = 1/(\omega C)$

Q8. (b) Leads the voltage by 90°

Q9. (a) $Z = \sqrt{(R^2 + XL^2)}$

Q10. (a) cos φ

Q11. (b) Vrms × Irms × cos φ

Q12. (a) 0°

Q13. (a) XL = XC

Q14. (a) $f = 1/(2\pi\sqrt{(LC)})$

Q15. (b) Minimum

Q16. (b) XL = XC

Q17. (b) Zero

Q18. (a) 800 W

Q19. (b) Purely inductive or capacitive

Q20. (a) 0.02 s

Q21. (c) π/2

Q22. (a) 0, 9.9 V

Q23. (c) Phase relation depends on relative values of XL and XC

Q24. (d) lags the voltage in phase by π/2

Q25. (b) ω^2LC

Q26. (c) Zero

Q27. (b) 2I0/π

Q28. (b) It limits current with negligible power loss

Q29. (b) Decreases (larger R broadens/damps the resonance curve)

Q30. (a) Q = ω0L/R

Q31. (b) Capacitive

Q32. (a) Inductive

Q33. (a) Vrms Irms

Q34. (c) Vrms Irms sinφ

Q35. (a) It has no resistance and no flux leakage

Q36. (b) It uses a single winding common to both primary and secondary

Q37. (a) Induction furnaces

Q38. (c) Remains unchanged

Q39. (a) Lags the voltage

Q40. (b) High voltage, low current to low voltage, high current

Q41. (c) (v0 i0/2) cosφ

Q42. (c) only L — pure inductor alone gives π/2 phase difference; L with R would give a smaller phase angle

Q43. (b) L, C and R in series (this is the classic LCR resonance curve behaviour)

Assignment 3 – Answer Key (Assertion-Reason 1–13)

Q1. (A) Both A and R true, R is the correct explanation of A.

Q2. (B) Both A and R true, but R does not directly explain the 90° lag.

Q3. (A) Both A and R true, R is the correct explanation of A.

Q4. (C) A is false (power factor $\cos\varphi$ lies between 0 and 1); R is true.

Q5. (A) Both A and R true, R is the correct explanation of A.

Q6. (A) Both A and R true, R is the correct explanation of A.

Q7. (D) A is false (a transformer can step up or step down); R is true.

Q8. (C) A is true; R is false (current and voltage are NOT in phase in an inductor — they are 90° out of phase).

Q9. (A) Both A and R true, R is the correct explanation of A.

Q10. (A) Both A and R true, R is the correct explanation of A.

Q11. (A) Both A and R true, R is the correct explanation of A.

Q12. (A) Both A and R true, R is the correct explanation of A.

Q13. (D) A is false — a transformer's turns ratio simply determines whether it steps up or down; reversing the winding roles reverses its function. R is true.

Assignment 4 – Answer Key (Case Studies 1–7)

Case Study 1

1-I_{rms} = 4.4 A.

2-P_{avg} = 968 W.

3-Peak voltage = 311 V.

4-Heater is purely resistive (power factor = 1); no correction needed.

Case Study 2

1-(c) $X_L = X_C$.

2-(b) $\omega_0 = 1/\sqrt{LC}$.

3-(b) Impedance = R.

4-(b) Current is maximum.

Case Study 3

1-(b) Mutual induction.

2-(c) Eddy current loss.

3-(c) $N_s > N_p$.

4-(b) Only AC voltage.

Case Study 4

1-(c) Zero.

2-(b) 311 V.

3-(c) 1.

4-(b) $V_0I_0/2$.

Case Study 5

1-(b) 1.

2-Current decreases beyond resonance.

3-$f0 = 1/(2\pi\sqrt{(LC)})$.

4-Lower R gives sharper resonance (higher Q).

Case Study 6

1-(b) $\omega = 1/\sqrt{(LC)}$.

2-(b) Zero.

3-(c) Simple harmonic oscillator (spring-mass).

4-(b) Undamped.

Case Study 7

1-Choke limits current via reactance with no power loss.

2-Wattless current is 90° out of phase, contributing zero average power.

3-Irms ≈ 1.40 A.

4-Power factor ≈ 0; average power ≈ 0 W.

Assignment 5 – Answer Key (SAQ 1–27)

Q1. Irms = $I0/\sqrt{2}$ (derivation via mean-square integral over a cycle).

Q2. (i) Irms = 2.2 A. (ii) Pavg = 484 W.

Q3. Power factor = cos90° = 0, so average power is zero.

Q4. (i) XL ≈ 62.8 Ω. (ii) Irms ≈ 1.75 A.

Q5. (i) XC ≈ 53.05 Ω. (ii) Irms ≈ 3.77 A.

Q6. (i) Vs = 1100 V. (ii) Is/Ip = 1/5.

Q7. $Z = \sqrt{(R^2+(XL-XC)^2)}$, by phasor addition.

Q8. Ideal transformer: Vp Ip = Vs Is, so power is conserved.

Q9. (i) Irms = 1.6 A, I0 ≈ 2.26 A. (ii) Pavg = 384 W.

Q10. (i) XL ≈ 113.1 Ω. (ii) Irms ≈ 0.97 A.

Q11. (i) XC ≈ 15.92 Ω. (ii) I0 ≈ 17.76 A.

Q12. (i) f0 ≈ 50.3 Hz. (ii) Irms ≈ 3.33 A.

Q13. (i) Vs = 22 V. (ii) Ip = 0.2 A.

Q14. Minimum time = $T/4 = 5\times10^{-3}$ s.

Q15. Current lags voltage by 90° on the graph.

Q16. Wattless current is 90° out of phase with voltage, contributing zero average power (e.g. in a pure inductor or capacitor).

Q17. $P = VI = 200\times10\times\cos(0°)/\ldots$ average power $= (1/2)V_0I_0 = 1000$ W (voltage and current in phase, both $\sin 300t$).

Q18. Phase difference = 90° (current leads by $\pi/2$ as written).

Q19. High permeability and low hysteresis loss (soft iron/silicon steel).

Q20. AC is easy to generate at high voltage, easy to step up/down via transformers, and transmitted with lower I^2R losses.

Q21. $X_C = 1/(\omega C)$; SI unit is ohm (Ω).

Q22. $Q = \omega_0 L/R$ (or $1/R \times \sqrt{L/C}$); dimensionless (no SI unit).

Q23. Phase difference found from $\tan\varphi = (X_L-X_C)/R$ for the given circuit; additional capacitor C' chosen so that the new total capacitive reactance equals X_L, making power factor unity.

Q24. 0 A (current is zero at that instant, occurring at $t = T/6$ after the zero-crossing for a 50 Hz supply).

Q25. Resultant $= \sqrt{20^2+(30-15)^2} = 25$ V (V_R combines in phase; V_L and V_C are 180° apart and partially cancel).

Q26. This indicates the circuit is at resonance, i.e. $X_L = X_C$ ($\omega L = 1/\omega C$).

Q27. $I = V/\sqrt{R^2+X_C^2}$; calculate $X_C = 1/(2\pi\times50\times(25/\pi)\times10^{-6}) = 400\ \Omega$, so $Z = \sqrt{300^2+400^2} = 500\ \Omega$, $I = 200/500 = 0.4$ A.

Assignment 5 – Answer Key (LAQ 1–9)

Q1. (a) Power factor P.f. $= \cos\varphi = R/Z$; determines the actual power drawn versus the apparent power. (b) $Z \approx 104.9\ \Omega$, $I_{rms} \approx 2.10$ A, $P_{avg} \approx 441$ W.

Q2. (a) Resonance occurs when $X_L = X_C$, giving maximum current — used in radio/TV tuning circuits. (b) $f_0 \approx 50.3$ Hz; Z(resonance) = 20 Ω; $I_{rms} = 5$ A.

Q3. (a) Mutual induction requires a changing flux, which only AC provides. (b) $V_s = 1100$ V; $I_s = 0.1$ A; Power output = 110 W.

Q4. (a) $X_C = 1/(\omega C)$ is infinite at DC (blocking it) and finite for AC (allowing it to pass). (b) $X_C \approx 31.83\ \Omega$; $Z \approx 59.3\ \Omega$; $\varphi \approx 32.5°$.

Q5. (i) $\omega_0 = 1/\sqrt{LC} \approx 50$ rad/s. (ii) At resonance, $I = V/R$. (iii) $V_C(rms) = I\times X_C$.

Q6. (a) Standard transformer principle/derivation (mutual induction, $V_s/V_p = N_s/N_p$). (b) Four causes: copper loss, hysteresis loss, eddy-current loss, flux leakage.

Q7. (i) Brightness decreases (X_L decreases with fewer turns, current increases — treat by direct proportionality with X_L). (ii) Brightness decreases (iron rod increases L, increasing X_L, reducing current). (iii) With $X_C = X_L$, net reactance is zero, so impedance is minimum and current (brightness) increases.

Q8. $I_{rms} \approx 2.87$ A (from $Z = |X_L-X_C|$); average power consumed ≈ 0 W (reactive circuit, negligible resistance).

Q9. (i) Standard transformer principle/diagram and energy losses (copper, hysteresis, eddy current, flux leakage). (ii) N_s = 10,000 turns (transformation ratio 100 × 100 primary turns); primary current = 5 A; V_s = 22,000 V; I_s = 0.05 A; secondary power = 1100 W (ideal, no loss).

CHAPTER 8: ELECTROMAGNETIC WAVES

Assignment - 1

SAMPLE QUESTION PAPER (2026 – 27)

Time Allowed: 3 hours Maximum Marks: 70

General Instructions (1) There are 33 questions in all. All questions are compulsory. (2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. (3) All the sections are compulsory. (4) Section A contains sixteen questions, twelve MCQ and four assertion reasoning based of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, Section D contains two case study-based questions of four marks each and Section E contains three long answer questions of five marks each.

Section A

1. In electromagnetic wave, according to Maxwell, changing electric field gives:

(a) Stationary magnetic field (b) Conduction current (c) Eddy current (d) Displacement current

2. The electric and magnetic fields of an EM wave are:

(a) In phase and parallel (b) In opposite phase and perpendicular (c) In opposite phase and parallel (d) In phase and perpendicular 1

3. For a medium with permittivity (ε) and permeability (μ), velocity of light is:

(a) μ/ε (b) $\sqrt{(\mu\,\varepsilon)}$ (c) $1/(\mu\,\varepsilon)$ (d) $1/\sqrt{(\mu\,\varepsilon)}$

4. The electric and magnetic fields of an EM wave propagating along +Y axis are represented by:

(a) $E = E_0\, k\hat{}$, $B = B_0\, \hat{i}$ (b) $E = E_0\, \hat{i}$, $B = B_0\, \hat{j}$ (c) $E = E_0\, \hat{j}$, $B = B_0\, k\hat{}$ (d) $E = E_0\, \hat{i}$, $B = B_0\, \hat{j}$

5. A plane EM wave of frequency 20 MHz travels along +X axis. Electric field vector = 6 V/m.What is the magnetic field at that point?

(a) 2×10^{-8} T (b) $\frac{1}{2} \times 10^{-8}$ T (c) $\frac{1}{2}$ T (d) 2 T

6. The average magnetic energy density of EM wave of wavelength λ is:

(a) $B_0^2 / 2\mu_0$ (b) $2\mu_0 / B_0^2$ (c) $\varepsilon_0 E_0^2 / 2\mu_0$ (d) $B / \mu_0 \lambda$ 1

7. The magnetic field of a plane EM wave is given by: $B_\gamma = 2 \times 10^{-7} \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)$ This wave is:

(a) Visible light (b) Infrared (c) Microwave (d) X-rays

8. Which of the following has the maximum wavelength?

(a) X-rays (b) Infrared rays (c) Ultraviolet rays (d) Radio waves

9. The wavelength of a radio wave of frequency 1 MHz is:

(a) 400 m (b) 300 m (c) 350 m (d) 200 m

10 In the EM spectrum, the visible region lies between:

(a) Radio waves and Microwaves (b) Infrared and Ultraviolet (c) Microwaves and Infrared (d) X-rays and Gamma rays

11 The part of the EM spectrum used to cook food is:

(a) Ultraviolet (b) Cosmic rays (c) X-rays (d) Microwaves

12 Which of the following shows greenhouse effect?

(a) Ultraviolet rays (b) Infrared rays (c) X-rays (d) None of the above

Directions (Q13–Q16)

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

(b) If both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both Assertion and Reason are incorrect.

13 Assertion (A): In electromagnetic wave, the direction of variations of electric and magnetic fields are perpendicular to each other and also perpendicular to the direction of wave propagation.
Reason (R): Electromagnetic waves are transverse in nature.
14 Assertion (A): The frequency of the electromagnetic wave naturally equals the frequency of oscillation of the charge.
Reason (R): The energy associated with the propagating wave comes at the expense of the energy of the source.
15 Assertion (A): When the sunshine falls on our hand, we feel the energy being absorbed from the electromagnetic waves (our hands get warm).
Reason (R): Electromagnetic waves transfer momentum to our hand but because c is very large, the amount of momentum transferred is extremely small and we do not feel the pressure.
16 Assertion (A): Infrared waves are sometimes referred to as heat waves.
Reason (R): Water molecules present in most materials readily absorb infrared waves. After absorption, their thermal motion increases, i.e., they heat up and heat their surroundings.

Section B

17 Gamma rays and radiowaves travel with the same velocity in free space. Distinguish between them in terms of their origin and main application.
18 How is the equation for Ampere's circuital law modified in the presence of displacement current? Explain.
19 How are electromagnetic waves produced by oscillating charges? What is the source of the energy associated with the EM waves?
20 Arrange the following electromagnetic radiations in ascending order of their frequencies:
(i) Microwaves (ii) Radio waves (iii) X-rays (iv) γ-rays
Write two uses of any one of these .
21 How are X-rays produced? Write their two important uses.

Section C

22 (i) Depict a plane electromagnetic wave propagating along the X-axis. Write the expressions for its oscillating electric and magnetic fields.
(ii) Write three characteristics of electromagnetic waves.
23 Electromagnetic waves of wavelengths λ_1, λ_2, and λ_3 are used in radar systems, in water purifiers, and in remote switches of TV, respectively.
(i) Identify the electromagnetic waves. (ii) Write one source of each of them
24 Name the electromagnetic waves which are produced by the following:
(i) Radioactive decays of nucleus (ii) Welding arcs (iii) Hot bodies
Write one use of each of these waves.
25 Name the electromagnetic waves with their frequency range, produced in
(i) Some radioactive decay (ii) Sparks during electric welding (iii) TV remote
26 (i) Name the waves which are produced during radioactive decay of a nucleus. Write their frequency range.
(ii) Welders wear special glass goggles while working. Why? Explain.
(iii) Why are infrared waves often called as heat waves? Give their one application. 3
27 (i) Name the EM waves which are suitable for RADAR systems used in aircraft navigation. Write the range of frequency of these waves.
(ii) If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.
(iii) An EM wave exerts pressure on the surface on which it is incident. Justify.

28 (i) Name the EM waves which are used for the treatment of certain forms of cancer. Write their frequency range.

(ii) Thin ozone layer on top of stratosphere is crucial for human survival. Why?

(iii) Why is the amount of the momentum transferred by the EM waves incident on the surface so small?

Section D

29 The electromagnetic spectrum represents the complete range of electromagnetic waves arranged according to their frequency or wavelength. It extends from long-wavelength, low-frequency radio waves to short-wavelength, high-frequency gamma rays.

Radio waves are widely used in communication systems such as AM/FM radio and mobile phones. Microwaves are used in radar, satellite communication, and microwave ovens. Infrared radiation is emitted by hot bodies and used in remote controls and night-vision devices. The visible region, detectable by the human eye, lies between infrared and ultraviolet rays. Ultraviolet radiation has higher energy and can cause sunburn but is also used for sterilisation. X-rays, with still shorter wavelength, can penetrate soft tissue and are widely used in medical imaging. Gamma rays, originating from radioactive decay and nuclear processes, have the highest frequency and energy and are used in cancer treatment.

All electromagnetic waves travel at the speed of light in vacuum, i.e., 3×108 m/s, but differ in frequency, wavelength, and applications.

I. Which electromagnetic wave is used in:

(i) Microwave ovens (ii) Medical imaging of bones

IIArrange the following in ascending order of frequency: Infrared, Radio waves, X-rays, Gamma rays.

III. State two harmful effects of ultraviolet radiation.

IV. Name the electromagnetic wave:

(i) Emitted by hot bodies (ii) Produced in nuclear reactions

30 Maxwell, in 1865, pointed out that when either an electric or a magnetic field is changing with time, a field of the other kind is induced in adjacent regions of space. From this Maxwell concluded that variation of electric and magnetic field vectors perpendicular to each other leads to the production of electromagnetic disturbances which show properties of waves and can travel in space even without any material medium. These waves are called electromagnetic waves. Electromagnetic waves with macroscopic wavelengths were first produced in the laboratory in 1887 by the German physicist Heinrich Hertz. Seven years after Hertz, Jagdish Chandra Bose, working at Calcutta (now Kolkata) succeeded in producing and observing electromagnetic waves of much slower wavelength (25mm to 5mm). At around the same time, Guglielmo Marconi in Italy followed Hertz's work and succeeded in transmitting electromagnetic waves over distances of many kilometers. Electromagnetic waves have a broad frequency range 103Hz to 1022Hz. They can travel with speed of light(c) in vacuum.

They obey the relation $c=\nu\lambda$, where ν is frequency and λ is wavelength. 4

I. Which of the following electromagnetic waves are in order of increasing frequency?

(a) Microwaves < Infrared < Ultraviolet < γ-rays (b) γ-rays < Ultraviolet < Infrared < Microwaves

(c) Ultraviolet < Infrared < Microwave < γ-rays (d) γ-rays < Microwave < Infrared < Ultraviolet II Light wave contains

II. Light is an ----------

(a) Electromagnetic waves (b) Mechanical waves (c) Longitudinal waves (d) Magnetic waves

III. If we want to produce electromagnetic waves of wavelength 500 km by an oscillating charge, the frequency must be

(a) 600 Hz (b) 500 Hz (c) 167 Hz (d) 15 Hz

IV. The angle between E and B in an electromagnetic wave is

(a) 180° (b) 120° (c) 90° (d) 45°

Section - E

31 i) Why are microwaves considered suitable for radar systems used in aircraft navigation?

ii) (a). Why are infrared waves often called heat waves? Explain. (b). What do you understand by the statement "Electromagnetic waves transport momentum.

iii) (a). Give one use of electromagnetic radiations obtained in nuclear disintegrations. (b). Give one example each to illustrate the situation where there is:(i) displacement current but no conduction current, conduction current but no displacement current.

32 i) The charging current for a capacitor is 0.25 A. What is the displacement current across its plates?

ii) A capacitor of capacitance CCC is being charged by connecting it across a DC source with an ammeter. Will the ammeter show a momentary deflection during charging? How would you explain this deflection and continuity of current in the circuit? Write the expression for the current inside the capacitor

iii) When an ideal capacitor is charged by a DC battery, no current flows. However, when an AC source is used, the current flows continuously. How is this explained on the basis of displacement current?

33 A parallel plate capacitor made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V AC supply with angular frequency of 300 rad/s.

(i) What is the rms value of the conduction current?

(ii) Is the conduction current equal to the displacement current?

(iii) Determine the amplitude of B at a point 3.0 cm from the axis between the plates.

Assignment 2 : MCQS

1. To dissociate an oxygen molecule into two oxygen atoms 5eV of energy is required. The minimum frequency of the appropriate electromagnetic radiation to achieve the dissociation lies in:

(a) Visible (b) Infrared (c) Ultraviolet (d) Microwave

2. The given diagram exhibits the relationship between the wavelength of electromagnetic waves and the energy of photon associated with them. The three points P,R and Q marked on the diagram may correspond respectively to:

(a) X-rays, Microwaves, UV (b) X-rays, UV, Microwaves (c) UV, Microwaves, X-rays (d) Microwaves, UV, X-rays

3. Which one of the following correctly represents the change in wave characteristics (all in vacuum) from microwaves to X rays in electromagnetic spectrum?

Option	Speed	Wavelength	Frequency
a)	Remains same	Decreases	Remains same
b)	Remains same	Decreases	Increases
c)	Increases	Increases	Decreases
d)	Remains same	Decreases	Remains same

4. X rays are more harmful to human beings than ultraviolet radiations because X-rays:

a) Have frequency lower than that of ultraviolet radiations

b) Have wavelength smaller than that of ultraviolet radiations

c) Move faster than ultraviolet radiations in air

d) Are mechanical waves but ultraviolet radiations are electromagnetic waves

5. Displacement current exists when:

(a) Electric field changing (b) Magnetic field changing (c) E constant (d) B constant

6. Welder's glasses protect from:

(a) Visible light (b) Infrared (c) Ultraviolet (d) Radio waves

7. An electromagnetic wave of frequency 3kHz is passing from vacuum to glass. The ratio of their frequency in vacuum and in glass is:

(a) 3:1 (b) 1:3 (c) 1:4 (d) 1:1

8. Which of the following electromagnetic waves has the highest momentum for a given energy?
(a) Radio waves (b) Microwaves (c) Infrared (d) Gamma rays

9. The source of an electromagnetic wave is always associated with:
(a) Moving charge (b) Accelerating charge (c) Stationary charge
(d) Constant magnetic field

10 The ratio of the amplitudes of electric and magnetic fields in free space is equal to: (c is the speed of light in vacuum)
(a) c (b) $1/c^2$ (c) $1/\varepsilon_0$ (d) 1/c

11 What is wavelength of signal with frequency 300 MHz?
(a) 2 m (b) 20 m (c) 10 m (d) 1 m

12 If λx, λm, λv are wavelengths of X-rays, microwaves & visible rays, then:
(a) $\lambda m > \lambda v > \lambda x$ (b) $\lambda m > \lambda x > \lambda v$ (c) $\lambda v > \lambda x > \lambda m$ (d) $\lambda v > \lambda m > \lambda x$

13 EM wave radiated by Human body :
(a) Microwaves (b) X-rays (c) Infrared rays
(d) Gamma rays

14 EM waves can be produced by a charge:
(a) Accelerated charge (b) Charge moving with constant speed (c) At rest
(d) Constant velocity

15 In EM spectrum, minimum wavelength is of:
(a) Gamma rays (b) Radio waves (c) Visible rays
(d) Microwaves

16 Properties of EM radiation are identified by:
(a) Colour (b) Their use (c) Speed
(d) Frequency or wavelength

17 Light wave constitutes:
(a) Mechanical waves (b) Magnetic waves (c) Electromagnetic waves (d) Longitudinal waves

18 Which of the following is transported by EM waves?
(a) Charge & momentum (b) Frequency & wavelength (c) Energy & momentum (d) Wavelength & energy

19 Which electromagnetic wave is used in remote-control devices like TV remotes?
(a) Microwaves (b) Infrared rays (c) Radio waves
(d) X-rays

20 The electromagnetic waves discovered by Heinrich Hertz in 1887 were:
(a) X-rays (b) Gamma rays (c)Radio waves
(d) Ultraviolet rays

Assignment - 3 (CH 8 : Electromagnetic Waves)

For each question, select the correct option:
(a) Both Assertion and Reason are true, and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are true, but Reason is not the correct explanation of Assertion.
(c) Assertion is true, but Reason is false.
(d) Assertion is false, but Reason is true.

1. Assertion (A): Electromagnetic waves do not require a material medium for their propagation.

Reason (R): Electromagnetic waves consist of oscillating electric and magnetic fields, which are self-sustaining in vacuum.

2. Assertion (A): In an electromagnetic wave, the electric and magnetic fields are always perpendicular to each other.
Reason (R): The directions of electric and magnetic fields in an EM wave are independent of the direction of wave propagation.

3. Assertion (A): The speed of electromagnetic waves in vacuum is equal to $1/\sqrt{\mu_0\varepsilon_0}$.
Reason (R): The values of μ_0 and ε_0 determine the properties of vacuum with respect to magnetic and electric fields, respectively.

4. Assertion (A): X-rays can be used to detect fractures in bones.
Reason (R): X-rays have controlled penetrating power and are absorbed differently by different tissues.

5. Assertion (A): Ultraviolet rays are more energetic than infrared rays. Reason (R): The frequency of ultraviolet rays is greater than that of infrared rays.

6. Assertion (A): Gamma rays are used in cancer radiotherapy.
Reason (R): Gamma rays have very high penetration power and can damage living cells.

7. Assertion (A): Infrared radiation is used in night vision cameras.
Reason (R): All warm objects emit infrared radiation due to thermal motion of molecules.

8. Assertion (A): Electromagnetic waves carry both energy and momentum.
Reason (R): The energy and momentum in EM waves are carried by the magnetic field only.

Assignment 4 : Case study

A Maxwell, in 1865, pointed out that when either an electric or a magnetic field is changing with time, a field of the other kind is induced in adjacent regions of space. From this Maxwell concluded that variation of electric and magnetic field vectors perpendicular to each other leads to the production of electromagnetic disturbances which show properties of waves and can travel in space even without any material medium. These waves are called electromagnetic waves. Electromagnetic waves with macroscopic wavelengths were first produced in the laboratory in 1887 by the German physicist Heinrich Hertz. Seven years after Hertz, Jagdish Chandra Bose, working at Calcutta (now Kolkata) succeeded in producing and observing electromagnetic waves of much slower wavelength (25mm to 5mm). At around the same time, Guglielmo Marconi in Italy followed Hertz's work and succeeded in transmitting electromagnetic waves over distances of many kilometers. Electromagnetic waves have a broad frequency range 103Hz to 1022Hz. They can travel with speed of light(c) in vacuum. They obey the relation $c=\nu\lambda$, where ν is frequency and λ is wavelength.

1. Which of the following electromagnetic waves are in order of increasing frequency?
(a) Microwaves < Infrared < Ultraviolet < γ-rays (b) γ-rays < Ultraviolet < Infrared < Microwaves
(c) Ultraviolet < Infrared < Microwave < γ-rays (d) γ-rays < Microwave < Infrared < Ultraviolet

2. Light wave contains
(a) Electromagnetic waves (b) Mechanical waves (c) Longitudinal waves (d) Magnetic waves

3 If we want to produce electromagnetic waves of wavelength 500 km by an oscillating charge, the frequency must be
(a) 600 Hz (b) 500 Hz (c) 167 Hz
(d) 15 Hz

4 The angle between E and B in an electromagnetic wave is
(a) 180° (b) 120° (c) 90°
(d) 45°

B. Radio waves are produced by the accelerated motion of charges in conducting wires. Microwaves are produced by special vacuum tubes. Infrared waves are produced by hot bodies and molecules also known as heat waves. UV rays are produced by special lamps and very hot bodies like Sun.

1. Solar radiation is

(a) transverse electromagnetic wave (b) longitudinal electromagnetic wave

(c) both longitudinal and transverse electromagnetic waves (d) None of these

2. What is the cause of greenhouse effect?

(a) Infrared rays (b) Ultraviolet rays (c) X-rays (d) Radio waves

3 Biological importance of ozone layer is

(a) it stops ultraviolet rays (b) it reduces greenhouse effect (c) it reflects radio waves (d) None of these

4 Earth's atmosphere is richest in

(a) ultraviolet (b) infrared (c) X-rays

(d) Microwaves

C An oscillating charge is an example of accelerating charge. It produces an oscillating electric field in space, which produces an oscillating magnetic field, which in turn produces an oscillating electric fields and so on. The oscillating electric and magnetic
fields regenerate each other

1. Electromagnetic waves can be deflected by

(a) only electric field (b)only magnetic field (c) Both (a) and (b) (d) None of the above

2. Total energy density of electromagnetic waves in vacuum is given by the relation:

(a) $\frac{1}{2}(E^2/\varepsilon_0) + (B^2 / 2\mu_0)$ (b) $\frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\mu_0 B^2$

(c) $(E^2 + B^2) / c$ (d)$\frac{1}{2}\varepsilon_0 E^2 + (B^2 / 2\mu_0)$

3. The speed of electromagnetic wave in vacuum depends upon the source of radiation

(a) increases as we move from γ-rays to radio waves (b) decreases as we move from γ-rays to radio waves

(c) is same for all of them (d) None of the above

4. Solar radiation is

(a) transverse electromagnetic wave (b) longitudinal electromagnetic wave

(c) stationary wave (d) None of the above

D. Electromagnetic radiation plays a crucial role in communication and medical science. Radio waves, with long wavelengths, are used for broadcasting and satellite transmissions. Microwaves are employed in radar systems and for cooking food by exciting water molecules. Infrared radiation is emitted by hot bodies and finds applications in night-vision equipment. Visible light enables us to see, while ultraviolet radiation has higher energy and can cause tanning of the skin. X-rays are used for imaging bones due to their ability to penetrate soft tissue, and gamma rays, being highly energetic, are used in cancer treatment. All these electromagnetic waves travel with the same speed in vacuum (3×10^8 m/s) but differ in frequency and wavelength.

1 Which electromagnetic wave is used in night-vision devices?

(a) Infrared rays (b) Ultraviolet rays (c) Microwaves

(d) Gamma rays

2 All electromagnetic waves in vacuum travel with a speed of:

(a) 3×10^6 m/s (b) 3×10^8 m/s (c) 3×10^{10} m/s

(d) 3×10^5 m/s

3 Which electromagnetic wave has the shortest wavelength?

(a) Radio waves (b) Microwaves (c) Gamma rays

(d) X-rays

4 The application of X-rays is:

(a) Cancer therapy (b) Detecting fractures in bones (c) Radar navigation (d) Night-vision

Assignment- 5

a) Short Answer Question

1. Why does microwave oven heat up a food item containing water molecules most efficiently? 2

2. A variable frequency a.c source is connected to a capacitor. How will the displacement current change with decrease in frequency? 2

3. The magnetic field of a beam emerging from a filter facing a floodlight is given by $B0 = 12 \times 10^{-8} \sin(1.20 \times 10^{7} z - 3.60 \times 10^{15} t)$ T. What is the average intensity of the beam? 2

4. How are Infrared waves produced? Why are these waves referred to as heat waves? Give any two uses of infrared waves. 2

5. An E.M. wave, Y_1, has a wavelength of 1 cm while another e.m. wave, Y_2, has a frequency of 10^{15} Hz. Name these two types of waves and write one useful application for each. 2

6. Identify the following electromagnetic radiations as per the frequencies given below. Write one application of each.

(a) 10^{20} Hz (b) 10^{16} Hz (c) 10^{10} Hz

(d) 10^{10} Hz 3

7. Identify the part of the electromagnetic spectrum which:

(a) Produces tanning effect (b) Is absorbed by the ozone layer in the atmosphere

(c) Is used for studying crystal structure 3

8. Arrange the following electromagnetic waves in the order of their increasing wavelength:

i) (a) Infrared (IR) waves (b) Microwaves (c) X-rays

(d) Radio waves

ii) Arrange the following waves in ascending order of their frequencies: Microwaves, UV, X-rays 3

9. i) Why does microwave oven heat food most efficiently when it contains water molecules?

ii) How do electromagnetic waves carry energy and momentum?

iii) How are electromagnetic waves produced by oscillating charges? 3

10. a) Match the following:

(i) $\lambda 1$ is used to kill germs in water purifier.

(ii) $\lambda 2$ is used in satellite communication.

(iii) $\lambda 3$ is detected by night vision goggles.

(iv) $\lambda 4$ is used to detect leakage in underground pipelines.

(v) $\lambda 5$ is used to improve visibility during fog/mist conditions.

(b). Arrange these wavelengths in ascending order of their magnitude. $\lambda 1, \lambda 2, \lambda 3, \lambda 4, \lambda 5$ 3

Long answer questions

11 a) Write the expression for the generalised form of Ampere's circuital law. Discuss its significance and describe briefly how the concept of displacement current is explained through charging/discharging of a capacitor in an electric circuit.

b) Draw a sketch of linearly polarised electromagnetic waves propagating in the z-direction. Indicate the directions of the oscillating electric and magnetic fields.

12 A parallel plate capacitor (shown in the figure) made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V AC supply with angular frequency of 300 rad/s.

(i) What is the rms value of the conduction current?
(ii) Is the conduction current equal to the displacement current?
(iii) Determine the amplitude of B at a point 3.0 cm from the axis between the plates.
13 Q. (i) Name the EM waves which are suitable for RADAR systems used in aircraft navigation. Write the range of frequency of these waves.
Q. (ii) If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.
Q. (iii) An EM wave exerts pressure on the surface on which it is incident. Justify.

Assignment- 6 (Combined Answer Keys)

Assignment - 1

Answers
Q1 (d) Displacement current
Q2 (d) In phase and perpendicular Q3 (d) $v = 1/\sqrt{(\mu\ \varepsilon)}$
Q4 (a) $E = E_0\ \hat{k}$, $B = B_0\ \hat{i}$ Q5 (a) 2×10^{-8} T
Q6 (a) $B_0^2 / 2\mu_0$ Q7 (b) Infrared
Q8 (d) Radio waves Q9 (b) 300 m
Q10 (b) Infrared and Ultraviolet Q11 (d) Microwaves
Q12 (b) Infrared rays
Answer 13: (a) Both Assertion and Reason are true, and Reason is the correct explanation.
Answer 14: (b) Both Assertion and Reason are true, but Reason is not the correct explanation.
Answer 15: (c) Assertion is true, but Reason is false. (Hands feel warmth due to absorption of energy, not momentum transfer.)
Answer 16: (a) Both Assertion and Reason are true, and Reason is the correct explanation.
Answer 17:
- Origin: Gamma rays originate from nuclear transitions and radioactive decay, while radiowaves are produced by accelerated charges in antennas.
- Application: Gamma rays are used in cancer therapy and sterilization; radiowaves are used in communication and broadcasting.

Answer 18:
Ampere's law in integral form:
$\oint B \cdot dl = \mu_0\ i$
Modified by Maxwell to include displacement current:

$\oint B \cdot dl = \mu_0 \left(i + \varepsilon_0\ d\Phi_E/dt \right)$
This ensures current continuity in circuits such as a charging capacitor.
Answer 19:
An oscillating charge produces a time-varying electric field, which in turn produces a time-varying magnetic field. These mutually regenerating fields propagate as electromagnetic waves. The energy comes from the external source that makes the charge oscillate.
Answer 20:
Ascending order of frequency:
Radio waves < Microwaves < X-rays < γ-rays.
- Uses:
  - Radio waves: Broadcasting and communication
  - Microwaves: Radar and cooking
  - X-rays: Medical imaging
  - γ-rays: Cancer treatment

Answer 21:

- Production: X-rays are produced when high-speed electrons strike a metal target (Bremsstrahlung and characteristic X-rays).
- Uses:

1. Medical imaging to detect bone fractures.
2. Studying crystal structure.

Answer 22:

(i) For a wave propagating along X-axis:

$E = E_0 \sin(kx - \omega t)\,\hat{j}$ $B = B_0 \sin(kx - \omega t)\,\hat{k}$

(ii) Characteristics:

1. Transverse in nature.
2. Electric and magnetic fields are perpendicular to each other and to propagation direction.
3. Travel in vacuum with speed of light (3×10^8 m/s).

Answer 23:

(i) Radar → Microwaves, Water purifier → Ultraviolet rays, TV remote → Infrared rays.

(ii) Sources:

- Microwaves: Magnetron
- UV: Mercury lamp
- IR: Hot bodies

Answer 24:

(i) Radioactive decay → Gamma rays → Used in cancer therapy

(ii) Welding arcs → Ultraviolet rays → Used in sterilisation

(iii) Hot bodies → Infrared rays → Used in night vision devices

Answer 25:

(i) Radioactive decay → Gamma rays ($10^{18} - 10^{22}$ Hz)

(ii) Welding sparks → Ultraviolet rays ($10^{15} - 10^{17}$ Hz)

(iii) TV remote → Infrared rays ($10^{12} - 10^{14}$ Hz)

Answer 26:

(i) Gamma rays, frequency $10^{18} - 10^{22}$ Hz

(ii) Goggles protect from harmful UV radiation in welding arcs.

(iii) IR rays are called heat waves because they are absorbed by water molecules, increasing thermal motion. Used in physiotherapy and remote controls.

Answer 27:

(i) RADAR → Microwaves, frequency $10^9 - 10^{11}$ Hz.

(ii) Without atmosphere, surface temperature would be lower, as greenhouse effect would be absent.

(iii) EM waves carry momentum; on incidence, they transfer momentum, exerting pressure.

Answer 28:

(i) Gamma rays (frequency $10^{18} - 10^{22}$ Hz) are used in cancer treatment.

(ii) Thin ozone absorbs harmful UV radiation; without it, life would be endangered.

(iii) Momentum transferred is small because energy flux density of incident EM waves is limited.

Answer 29 I

(i) Microwaves

(ii) X-rays

II

Radio waves < Infrared < X-rays < Gamma rays

III

- Causes skin burns and tanning
- Increases risk of skin cancer by damaging DNA

IV

(i) Infrared radiation

(ii) Gamma rays

Answer 30:

I: (a) Microwaves < Infrared < Ultraviolet < γ-rays Reason: Frequency increases as wavelength decreases.

II (a) Electromagnetic waves

Reason: Light is a transverse electromagnetic wave consisting of oscillating electric and magnetic fields.

III Correct option is (a) 600 Hz Calculation:

$\nu = c/\lambda = (3 \times 10^8 \text{ m/s}) / (5 \times 10^5 \text{ m})$

$= 600$ Hz

IV (c) 90°

Reason: Electric field and magnetic field are perpendicular in an EM wave.

Answer 31

i) Microwaves are suitable for radar systems because they have short wavelengths, can penetrate atmospheric conditions, and reflect strongly from metallic objects like aircraft.

ii) Infrared waves are absorbed readily by water molecules and other matter, producing heating effect, hence called heat waves.

EM waves carry both energy and momentum. When absorbed/reflected, they exert radiation pressure on surfaces.

iii) Gamma rays from nuclear disintegrations are used in cancer therapy. (Displacement current without conduction current – between the plates of a charging capacitor.

Conduction current without displacement current – in a steady current through a resistor.

Answer 32

i) Displacement current equals charging current. id=0.25 A .

ii) Yes, the ammeter shows a momentary deflection during charging. This occurs because conduction current in the circuit is continuous with the displacement current in the capacitor gap.

iii) In DC, the capacitor charges up and then no current flows. In AC, the changing electric field inside the capacitor gives rise to displacement current which is equal to the conduction current in the wires, hence current flows continuously.

Answer 33

(i) The conduction current is given by:

$I = I_0/\sqrt{2}$, where $I_0 = C\omega V_0$

$= (100 \times 10^{-12} \text{ F})(300 \text{ rad/s})(230 \text{ V})$

$= 6.9 \times 10^{-6}$ A

So, $I_{rms} = I_0/\sqrt{2} = 4.9$ μA

(ii) Yes, the conduction current is equal to the displacement current. This equality ensures continuity of current in the circuit, as explained by Maxwell's modification of Ampere's law.

(iii) Magnetic field amplitude between capacitor plates: $B = \mu_0 I / (2\pi r)$

$= (4\pi \times 10^{-7})(6.9 \times 10^{-6}) / (2\pi \times 0.03)$

$= 4.6 \times 10^{-11}$ T

Thus, amplitude of $B = 4.6 \times 10^{-11}$ Tesla

Assignmnet - 2

1. (c) Ultraviolet region
2. (b) X-rays, UV radiation, Microwaves
3. (b) Remains same, Decreases, Increases
4. (b) Have wavelength smaller than UV

5. (a) Electric field is changing
6. (c) Ultraviolet radiations
7. (d) 1:1
8. (d) Gamma rays
9. (b) An accelerating electric charge
10. (a) c (speed of light in vacuum)
11. (d) 1 m
12. (b) $\lambda m > \lambda v > \lambda x$
13. (c) Infrared rays
14. (a) Accelerated charged particles
15. (a) Gamma rays
16. (d) Frequency or wavelength
17. (c) Electromagnetic waves
18. (c) Energy & momentum
19. (b) Infrared rays
20. (c) Radio waves

Assignment- 3

1. (a) EM waves are self-propagating due to mutual induction of E and B fields and do not need a medium.
2. (c) The fields are perpendicular to each other and to the direction of wave propagation; they are not independent.
3. (a) Speed of EM wave in vacuum is derived using these constants.
4. (a) Bones absorb more X-rays than soft tissue, producing contrast.
5. (a) Energy $E = h\nu$; higher frequency = higher energy.
6. (a) Gamma rays have the shortest wavelength and highest frequency; Reason explains Assertion.
7. (a) IR is emitted due to heat and used for thermal imaging. Assignment 4 :

A Answer 1: (a) Microwaves < Infrared < Ultraviolet < γ-rays Reason: Frequency increases as wavelength decreases.

Answer 2: (a) Electromagnetic waves

Reason: Light is a transverse electromagnetic wave consisting of oscillating electric and magnetic fields.

Answer 3: Correct option is (a) 600 Hz Calculation:

$\nu = c/\lambda = (3 \times 10^8 \text{ m/s}) / (5 \times 10^5 \text{ m}) = 600 \text{ Hz}$

Answer 4: (c) 90°

Reason: Electric field and magnetic field are perpendicular in an EM wave.

B Answer (i): Solar radiation is a transverse electromagnetic wave. Correct option: (a)

Answer (ii): The cause of greenhouse effect is Infrared rays trapped by greenhouse gases.

Correct option: (a)

Answer (iii): The biological importance of ozone layer is that it stops harmful ultraviolet rays from reaching the Earth's surface.

Correct option: (a)

Answer (iv): Earth's atmosphere is richest in infrared radiation, because the Earth absorbs solar energy and re-emits it mainly in the infrared region.

Correct option: (b)

C Answer 1: (c) Both (a) and (b).

(Reason: EM waves consist of oscillating electric and magnetic fields, so they interact with both.)

Answer 2: (d (This is the correct form of total energy density in vacuum.) Answer 3: (c) is same for all of them.

(All EM waves travel at the speed of light in vacuum, independent of frequency.) Answer 4: (a) transverse electromagnetic wave.
(Solar radiation is an EM wave with mutually perpendicular E and B fields, transverse to direction of propagation.)
D i)(a) Infrared rays – Used in night-vision devices.
(ii) (b) 3×10^8 m/s – All EM waves travel at the speed of light in vacuum.
(iii) (c) Gamma rays – Have the shortest wavelength and highest frequency.
(iv) (b) Detecting fractures in bones – X-rays penetrate soft tissue but not bones.
(v) (b) Ultraviolet rays – Cause tanning due to their high energy.

Assignment - 5

Answer 1:
Microwave ovens efficiently heat food containing water because microwaves excite the rotational motion of polar water molecules. The resulting molecular friction generates heat. Foods with higher water content heat up faster and more uniformly.
Answer 2:
Displacement current is directly proportional to frequency. As frequency decreases, the rate of change of voltage across the capacitor decreases. Therefore, the displacement current also decreases.
Mathematical explanation:
$\varepsilon_0 (d\varphi E/dt) = id$
For current in capacitor: id = C dV/dt Since $V = V_0 \sin \omega t$,
$id \propto \omega$ and $\omega = 2\pi f \Rightarrow id \propto f$
So, as frequency decreases, id decreases.
Answer 3:
$I\_avg = 1/(2\mu_0 c) * B_0^2$
$= (1/2 \times 3 \times 10^8 \times (12 \times 10^{-8})^2) / 1.26 \times 10^{-6}$
$= 1.71$ W/m²
Answer 4:
Infrared radiations are produced by hot bodies and vibrations of molecules. They are referred to as heat waves because they are rapidly absorbed by water molecules and increase their thermal energy, heating them.
Uses:
i) Dehydration of fruits
ii) In greenhouse effect
iii) In remote switches
Answer 5:
Y_1 has a wavelength of 1 cm, which lies in the microwave region. Application: Used in microwave ovens for cooking food.
Y_2 has a frequency of 10^{15} Hz, which lies in the ultraviolet (UV) region. Application: Used for sterilizing medical instruments.
Answer 6:
(a) 10^20 Hz: Gamma Rays – Used in cancer radiotherapy to destroy malignant cells.
(b) 10^16 Hz: Ultraviolet (UV) rays – Used in sterilizing medical instruments.
(c) 10^10 Hz: Microwaves – Used in radar systems and microwave ovens for cooking.
(d) 10^8 Hz: Radio waves – Used in TV remote controls and thermal imaging.
Answer 7:
(a) Produces tanning effect – Ultraviolet (UV) rays
(b) Absorbed by ozone layer – UV rays
(c) Used for studying crystal structure – X-rays

Answer 8:
Order (increasing wavelength): X-rays < IR waves < Microwaves < Radio waves Order of frequency: Microwaves < UV < X-rays
Answer 9:
(i) Electromagnetic waves carry energy and momentum because they consist of oscillating electric and magnetic fields that exert force on charges.
(ii) Produced by oscillating charges – when charges accelerate, they produce changing electric fields, which in turn produce changing magnetic fields. These fields propagate as EM waves.
(iii) Microwave oven heats food efficiently containing water because microwaves excite rotational motion of polar water molecules, producing heat.
Answer 10:
(i) $\lambda 1$ – Ultraviolet (UV) rays (water purifier)
(ii) $\lambda 2$ – Satellite communication – Microwaves
(iii) $\lambda 3$ – Night vision goggles – Infrared (IR) rays
(iv) $\lambda 4$ – Detect leakage in underground pipelines – Infrared (IR) rays
(v) $\lambda 5$ – Improve visibility during fog/mist – Radio waves (or Near-IR) Order (ascending wavelength): $\lambda 1 < \lambda 3 < \lambda 4 < \lambda 2 < \lambda 5$

Answer 11. The generalized Ampere's circuital law states: $\oint B \cdot dl = \mu_0$ (i_conduct + ε_0 dΦE/dt). It signifies displacement current due to time-varying electric fields, ensuring continuity. In a charging capacitor, conduction current equals displacement current. In electromagnetic waves, electric field, magnetic field, and propagation direction are mutually perpendicular.

Answer 12 (i) The conduction current is given by:
$I = I_0/\sqrt{2}$, where $I_0 = C\omega V_0$
$= (100 \times 10^{-12}\text{ F})(300\text{ rad/s})(230\text{ V})$
$= 6.9 \times 10^{-6}$ A
So, $I_{rms} = I_0/\sqrt{2} = 4.9\ \mu A$
(ii) Yes, the conduction current is equal to the displacement current. This equality ensures continuity of current in the circuit, as explained by Maxwell's modification of Ampere's law.
(iii) Magnetic field amplitude between capacitor plates:
$B = \mu_0 I / (2\pi r)$
$= (4\pi \times 10^{-7})(6.9 \times 10^{-6}) / (2\pi \times 0.03)$
$= 4.6 \times 10^{-11}$ T
Thus, amplitude of B = 4.6×10^{-11} Tesla.

Answer 13
Answer (i): The electromagnetic waves suitable for RADAR systems are microwaves. Their frequency range is 10^9 Hz to 10^{12} Hz.
Answer (ii): The temperature of the earth would be lower in the absence of atmosphere, because the greenhouse effect of the atmosphere would be absent. Hence, the earth would not retain sufficient heat, leading to a much lower average surface temperature.
Answer (iii): An electromagnetic wave carries momentum. p=Ecp = \frac{E}{c}p=cE
where ppp is momentum, EEE is the energy of the wave, and ccc is the velocity of light.
When an EM wave is incident on a surface, it transfers momentum and exerts a pressure on it, called radiation pressure.

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CHAPTER 9: RAY OPTICS AND OPTICAL INSTRUMENTS

Q.P. – RAY OPTICS & OPTICAL INSTRUMENTS — Session : 2026-2027

Assignment - 1

CLASS – XII

Subject: Physics

Maximum Marks: 70 Marks Time Allowed: 3 hours

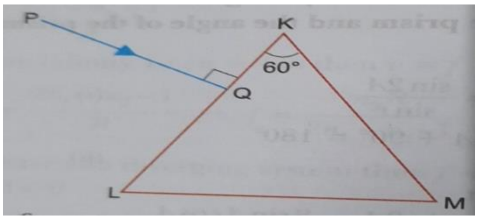
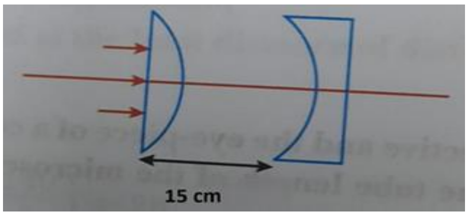
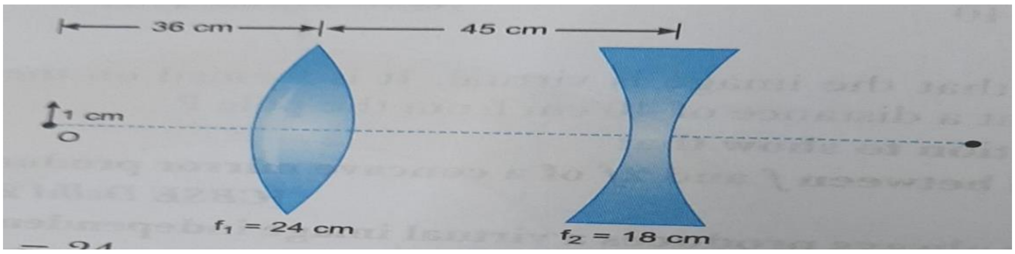
General Instructions:

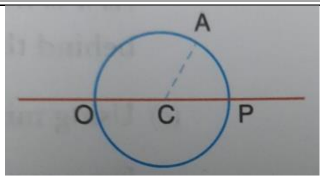
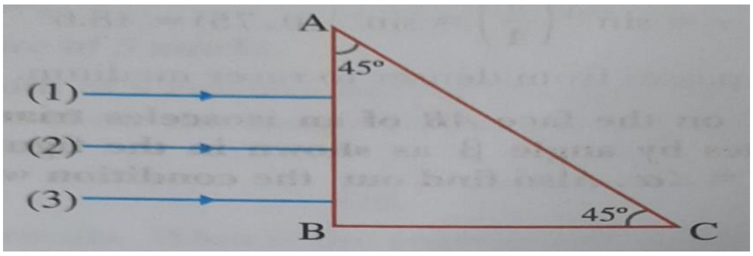
(1) All questions are compulsory. There are 33 questions in all.
(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All sections are compulsory.
(3) Section A contains 16 MCQs of 1 mark each, Section B contains 05 short answer questions of 2 marks each, Section C contains 07 short answer questions of 3 marks each, Section D contains 03 long answer questions of 5 marks each and Section E contains 02 case basedudy questions of 4 marks each.
(4) There is no overall choice. However internal choice is provided in sections B,C,D & E. You have to attempt only one of the choices in such questions.
(5) Use of calculator is not allowed.
(6) Coefficients / Constants in Q.P. used are as follows : Plank's constant $h = 6.63 \times 10^{-34}$ Js , $\mu_0 = 4\pi \times 10^{-7}$

Q.N.		Marks
	Section – A **All questions are compulsory. Each question carry 01 mark. In case of internal choices, attempt any one of them.**	
Q1.	**The focal length of a plane mirror is:** A) Zero B) Infinity C) Equal to its radius of curvature D) Cannot be determined	1
Q2.	**A convex mirror is always used as:** A) Projector B) Rear-view mirror in vehicles C) Telescope D) Magnifying glass	1
Q3.	**In refraction of light, the quantity that always remains unchanged is:** A) Speed B) Wavelength C) Frequency D) Direction	1
Q4.	**The minimum distance at which a normal eye can see objects clearly is:** A) 10 cm B) 15 cm C) 25 cm D) 50 cm	1

Q5.	**Total internal reflection takes place when:** A) Light travels from rarer to denser medium B) Light travels from denser to rarer medium at angle greater than critical angle C) Light travels from denser to rarer medium at any angle D) Light travels from rarer to denser medium at critical angle	1
Q6.	**The colour of the sky appears blue due to:** A) Reflection B) Scattering of light C) Refraction D) Dispersion	1
Q7.	**Dispersion of white light into its constituent colours is due to:** A) Different speeds of light in vacuum B) Different speeds of different wavelengths in glass C) Polarisation D) Interference	1
Q8.	A thin prism of angle $A=6^0$ has n=1.60. Find minimum deviation δmin (thin prism approx.). A) 2.4^0 B) 3.6^0 C) 4.2^0 D) 6.0^0	1
Q9.	A simple microscope has f = 5 cm. If the final image is at the **least distance of distinct vision** D = 25 cm, find the magnifying power M ? A) 4 B) 5 C) 6 D) 7	1
Q10.	A compound microscope has objective fo = 1 cm, eyepiece fe = 5 cm. Tube length L = 20 cm. For final image at D = 25 cm, find the magnification ‘M’. A) 50 B) 80 C) 100 D) 125	1
Q11.	**An astronomical telescope (normal adjustment) has objective fo=100 cm, eyepiece fe=5 cm. Find the Magnifying power ‘m’ of the telescope.** A) 10 B) 15 C) 20 D) 25	1
Q12.	**In an phenomenon of refraction at a convex spherical surface, light goes from air ($n_1 = 1$) into glass medium ($n_2 = 1.5$) at a convex spherical surface of radius R = +20 cm (center in glass). Object is in air at u = −30 cm. Find image distance ‘v’ from the surface (sign convention: distances positive into glass).** A) +60 cm B) +120 cm C) −180 cm D) −60 cm	1

	For question numbers 13, 14, 15,16, two statements are given-one labeled Assertion (A) and the other labeled Reason (R). Select the correct answer to these questions from the options (i), (ii), (iii) and (iv) as given below – A) Both A and R are true, and R is the correct explanation of A. B) Both A and R are true, but R is not the correct explanation of A. C) A is true, R is false. D) A is false, R is true.	
Q13.	**Assertion (A):** Concave mirrors are used by dentists. **Reason (R):** Concave mirrors form erect and magnified images when the object is close to the mirror.	1
Q14.	Assertion (A): In a compound microscope, the magnification depends on the focal length of objective and eyepiece. Reason (R): The total magnification is the product of magnification by objective and magnification by eyepiece.	1
Q15.	**Assertion (A):** In a telescope, the objective lens has a much larger focal length than the eyepiece. **Reason (R):** The objective is used to collect light and form a real image, which is magnified by the eyepiece.	1
Q 16.	Assertion (A): A convex mirror always produces a diminished image. Reason (R): The focal length of a convex mirror is positive.	1
	Section – B **Short Answer questions. Each question carry 02 mark. In case of internal choices, attempt any one.**	
Q17.	Why does a prism produce a spectrum, but a glass slab does not? **OR** Why are reflecting telescopes preferred over refracting telescopes? Justify your answer atleast in 3 points.	2
Q18.	A solid glass sphere of radius 6.0 cm has a small air bubble trapped at a distance 3.0 cm from its center '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 the air.	2
Q19.	A double convex lens is made of a glass of refractive index 1.55, with both faces of the same radius of curvature. Find the radius of curvature required, if the focal length is 20 cm. **OR** You are giving following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope? Give reason of your answer <table><tr><td>LENSES</td><td>POWER (D)</td><td>APERTURE (cm)</td></tr><tr><td>L_1</td><td>3</td><td>8</td></tr><tr><td>L_2</td><td>6</td><td>1</td></tr><tr><td>L_3</td><td>10</td><td>1</td></tr></table>	2
Q20.	State the condition under which a large magnification can be achieved in an astronomical telescope.	2
Q21.	The focal length of an equi-convex lens is equal to the radius of curvature of either face. What is the value of refractive index of the material of the lens?	2
	Section – C	

	Short Answer questions. Each question carry 03 mark. In case of internal choices, attempt any one.	
Q22.	A triangular prsim of refracting angle 60^0 is made of a transparent material of refractive index $2 / \sqrt{3}$. A ray of light is incident normally on the face KL as shown in the figure. Trace the path of the ray as it passes through the prism and calculate the angle of emergence and angle of deviation. 	3
Q23.	In the given figure the radius of curvature of curved face in the plano conves 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. (by using appropriate formulas).  **OR** A convex lens made of a material of refractive index n_1 is kept in a medium of refractive index n_2. Parallel rays of light are incident on the lens. Complete the path of rays of light emerging from the convex lens if – (i) $n_1 > n_2$ (ii) $n_1 = n_2$ (iii) $n_1 < n_2$	3
Q24.	An object is placed in front of a concave mirror. It is observed that a virtual image is formed. Draw a well labeled ray diagram to show the image formation and hence derive mirror formula. Also find out the expression of linear magnification produced by spherical mirror.	3
Q25.	Derive lens makers formula by drawing a neat and labeled ray diagram and hence find out lens equation.	3
Q26.	Two thin lenses L_1 and L_2, L1 being a convex lens of focal length 24 cm and L2 a concave lens of focal length of 18 cm are placed coaxially at a separation of 45 cm. A 1.0 cm tall object is placed in front of the lens L_1 at a distance of 36 cm. Find the location and height of the image formed by the combination. 	3
Q27.	You are given three lenses of power 5D,4D and 10 D to design a telescope. (a) Which lenses should be used as objective and eyepiece ? Justify your answer. (b) Why is the aperture of the objective preferred to be large ?	3
Q28.	A point 'O' marked on the surface of a glass sphere of diameter 20 cm is viewed through glass from the position directly opposite to the point 'O'. If the refractive index of the glass is 1.5, find the position of the image formed. Also, draw the ray diagram for the image formed.	3

	 **OR** Three rays (1,2,3) of different colours fall normally on one of the sides of an isosceles right angled prism as shown in figure. The refractive index of prism for these rays is 1.39, 1.47 and 1.52 respectively. Find which of these rays get internally reflected and which get only refracted from face AC. Trace the paths of the rays. Justify your answer with the help of necessary calculations.  	
	<u>Section –D</u> **All questions are compulsory. Each question is of 05 mark. In case of internal choices, attempt any one.**	
Q29.	(i) Draw the labeled ray diagram for the formation of image by a compound microscope. Write the expressions for its magnifying power, when the final image is formed at the near point as well as at infinity. (ii) Give reason why both objective and eyepiece of a compound microscope must have short focal lengths? **OR** The total magnification produced by a compound microscope is 20. The magnification produced by the eyepiece is 5. The microscope is focused on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm, then calculate the focal length of the objective and the eye piece.	5
Q30.	Draw a ray diagram showing the image formation of a distant object by a refracting type astronomical telescope. Write the expression for its magnifying power when (i) final image is formed at least distance of distinct vision with the expression of tube length. (ii) final image is formed at infinity (normal adjustment) with the expression of tube length. (iii) Write the two important factors considered to increase the magnifying power. **OR** (i) State two main considerations taken into account while choosing the objective of astronomical telescope. (ii) Draw a ray diagram of reflecting type telescope. State its magnifying power.	5
Q31.	(i) Draw a well labeled ray diagram showing refraction of a ray of light through a triangular glass prism. Thus, obtain the relation for the refractive index (n) in terms of prism angle (A) and angle of minimum deviation (d_m). Hence, obtain thin prism formula. (ii) Draw a graph to show the angle of deviation (δ) with the variation of angle of incidence (i) for a monochromatic ray of light passing through a triangular glass prism of refracting angle (A).	5

OR

A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is ¾ th of the angle of prism. Calculate the speed of light in the prism.

Section – E

Questions 34 and 35 are Case Study based questions and are compulsory. Each question is of 04 mark. In case of internal choices, attempt any one.

Q32.

(i)

(ii)

(iii)

(iv)

(v)

Fiber optics, or optical fiber, refers to the medium and the technology associated with the transmission of information as light pulses along a glass or plastic strand or fiber. Fiber optics is used for long-distance and high performance data networking. Fiber optics are commonly used in telecommunication services such as internet, television and telephones.

Attempt any 04 questions.

Choose the correct option –

When a ray of light enters from denser medium to rarer medium it bends –

(a) Towards normal
(b) Away from normal
(c) Perpendicular to normal
(d) Parallel to normal

The critical angle of water when refracted angle is 900 and refractive index for water and air is 1.33 and 1.0 is –

(a) 48.8^0
(b) 49.1^0
(c) 50^0
(d) 51^0

The outer concentric shell in fiber optics is called as –

(a) Cladding
(b) Core
(c) Coat
(d) Mantle

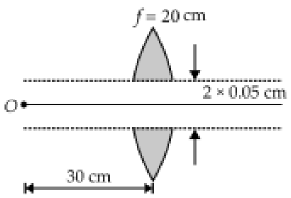
The critical angle for glass is –

(a) 50^0
(b) 42^0
(c) 45^0
(d) 30^0

Critical angle of light passing from glass to air is minimum for –

(a) Red Colour
(b) Green Colour
(c) Violet Colour

4

	(d) Yellow Colour	
Q33. (i) (ii) (iii) (iv) (v)	A convex or converging lens is thicker at the center than at the edges. It converges a parallel beam of light on refraction through it. It has a real focus. A convex lens is of three types : (i) Double convex lens (ii) Plano-convex lens (iii) Concavo-convex lens. The concave lens is thinner at the center than at the edges. It diverges a parallel beam of light on refraction through it. It has a virtual focus. **<u>Attempt any 04 questions.</u>** Choose the correct option – **A point object O is placed at a distance of 0.3 m from a convex lens (focal length 0.2 m) cut into two halves each of which is displaced by 0.0005 m as shown in the figure.**  **What will be the location of the image?** (a) 30 cm right of lens (b) 60 cm right of lens (c) 70 cm left of lens (d) 40 cm left of lens **Two thin lenses are in contact and the focal length of the combination is 80 cm. If the focal length of one lens is 20 cm, the focal length of the other would be.** (a) –26.7 cm (b) 60 cm (c) 80 cm (d) 20 cm **A spherical air bubble is embedded in a piece of glass. For a ray of light passing through the bubble, it behaves like a** (a) converging lens (b) diverging lens (c) plano-converging lens (d) plano-diverging lens **Lens used in magnifying glass is** (a) Concave lens (b) Convex lens (c) Both (a) and (b) (d) Neither concave lens nor convex lens **The magnification of an image by a convex lens is positive only when the object is placed** (a) at its focus F (b) between F and 2F (c) at 2F (d) between F and optical center	4

Assignment - 2

<u>Multiple Choice Questions</u>

1. The speed of light in a medium is 2×10^8 m/s. The refractive index of the medium is:
A) 1.0
B) 1.33

C) 1.5
D) 2.0

2. If the angle of incidence is 45° and angle of refraction is 30°, the refractive index of the medium is:
A) 1.21
B) 1.41
C) 1.5
D) 1.73

3. A convex lens of focal length 20 cm is placed in air. Its power is:
A) +2 D
B) +5 D
C) +10 D
D) –5 D

4. Which of the following lenses is always diverging?
A) Convex lens
B) Concave lens
C) Plano-convex lens
D) Double convex lens

5. A ray of light falls normally on a plane mirror. The angle of reflection is:
A) 0°
B) 45°
C) 90°
D) 180°

6. For a concave mirror, if the object is placed between focus (F) and pole (P), the image formed is:
A) Real, inverted, smaller
B) Virtual, erect, magnified
C) Real, erect, magnified
D) Virtual, inverted, diminished

7. In total internal reflection, light travels from:
A) Rarer to denser medium
B) Denser to rarer medium
C) Air to water
D) Vacuum to glass

8. The critical angle for glass-air interface (n = 1.5) is:
A) 30°
B) 42°
C) 45°
D) 60°

9. A combination of convex and concave lens of same power will have focal length
A)f=0
B) f = infinite
C) depends on material
D) None of these

10A prism of angle $A=60^0$and refractive index 1.732 is in minimum deviation. The angle of deviation is:
A) 30°

B) 45°
C) 60°
D) 75°

11. A simple microscope uses a convex lens of focal length 5 cm. The maximum magnifying power, when the image is formed at the near point (25 cm), is:
A) 4
B) 5
C) 6
D) 7

12. In refraction through a prism, the angle of deviation is minimum when:
A) Angle of incidence = angle of emergence
B) Prism angle = 90°
C) Incident ray is parallel to base
D) Prism is equilateral

13. In a compound microscope, if the focal length of the eyepiece is decreased, the magnifying power:
A) Increases
B) Decreases
C) Remains unchanged
D) First increases then decreases

14. A biconvex lens has radii of curvature R1=20 cm,R2=–20 cm. If the refractive index of the lens material is 1.5, its focal length is:
A) 10 cm
B) 15 cm
C) 20 cm
D) 30 cm

15. The power of a lens is –4 D. Its focal length is:
A) –25 cm
B) +25 cm
C) –50 cm
D) +50 cm

16. The focal length of a convex lens in water is:
A) Greater than in air
B) Less than in air
C) Same as in air
D) Zero

17. Which phenomenon is used in optical fibres?
A) Refraction
B) Interference
C) Total internal reflection
D) Diffraction

18. The colour of sky appears blue due to:
A) Reflection
B) Refraction
C) Dispersion
D) Scattering

19. A telescope has an objective of focal length 100 cm and an eyepiece of focal length 10 cm. The magnifying power in normal adjustment is:

A) 5
B) 10
C) 15
D) 20

20. A convex lens of focal length 30 cm is made of material of refractive index 1.5. If one surface is plane, the radius of curvature of the other surface is:
A) 15 cm
B) 20 cm
C) 30 cm
D) 60 cm

21. In total internal reflection
A) Angle of incidence = Critical angle
B)Angle of incidence >Critical angle

C)Angle of incidence < Critical angle

D) None of these

22. A ray of light falls normally on a air glass interface The angle of refraction is:
A) 0°
B) 45°
C) 90°
D) 180°

23. In a compound microscope, the intermediate image is

(A) Virtual, erect and magnified

(B) Real, erect and magnified

(C) Real, inverted and magnified (D) Virtual, erect and reduced

24. The focal length of a lens depends upon

(A) Nature of material of lens

(B) Medium in which lens is placed

(C) Colour of light

(D) All of these

25. A simple magnifier has converging lens of focal length 2.5 cm. What is its linear magnification for the image formed at near point?

(A) 6 (B) 9 (C) 11 (D) 16

26. Biconvex lenses are to be manufactured from glass of refractive index 1.5 with both faces of same radii of curvature. The radius of curvature required if focal length is 15 cm will be

A) 10 cm B) 15 cm C) 20 cm D) 25 cm

27. If an object is placed in front of a concave mirror and the lower half of the mirror is covered

with opaque material then what happen

(A) lower half of the object will be seen as image

(B) upper half of the object will be seen as image

(C) No change in the image will taken place

(D) image will be completely formed with less intensity

28. In total internal reflection when the angle of incidence is equal to the critical angle for the pair of media in

contact, what will be angle of refraction?

(A) 180°

(B) equal to angle of incidence

(C) 0°

(D) 90°

29. An equiconvex lens has power P. It is cut into two symmetrical halves by a plane containing the principal axis. The power of one part will be

(A) 0

(B) P/3

(C) P/4

(D) P

30. An object is placed on the principal axis of a concave mirror at a distance of 2f (f is the focal length).

The image will be at

(A)f (B) 3 f (C) 2f (D) 5f

Assignment - 3

<u>Assertion & Reason Questions</u> :

Q1. Assertion (A): In total internal reflection, the light must travel from a denser medium to a rarer medium.
Reason (R): The critical angle exists only when light goes from rarer to denser medium.

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.

Q2. Assertion (A): For a thin prism, the deviation produced is directly proportional to the prism angle.
Reason (R): In the thin prism approximation, $\sin\theta \approx \theta$ (in radians).

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.

Q3. Assertion (A): The deviation produced by a thin prism is independent of the angle of incidence.
Reason (R): For small angles, deviation is given by $D = (\mu - 1)A$.

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.

Q4. Assertion (A): A simple microscope magnifies an object because it increases the angle subtended by the object at the eye.
Reason (R): A simple microscope forms an inverted image at the near point.

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.

Q5. Assertion (A): At minimum deviation through a prism, the incident angle equals the emergent angle.
Reason (R): At minimum deviation, the refracted ray inside the prism is parallel to the base.

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.

Q6. Assertion (A): The resolving power of a telescope increases with an increase in the diameter of its objective lens.
Reason (R): Larger aperture objective allows more light and reduces diffraction effects.

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.

Q7. Assertion (A): A concave mirror always forms a real image.
Reason (R): A concave mirror converges parallel rays to its focus.

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.

Q8. Assertion (A): In an astronomical telescope, the angular magnification is given by $M=fo/fe$.
Reason (R): The image formed by the objective is real and lies at the focus of the eyepiece in normal adjustment.

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.

Q9. Assertion (A): In a compound microscope, the magnification increases if the focal length of the objective is reduced.
Reason (R): A shorter focal length objective produces a larger, real, and inverted intermediate image.

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.

Q10. Assertion (A): The focal length of a convex lens decreases when it is immersed in water.
Reason (R): The effective refractive index of the lens with respect to water is less than that with respect to air.

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.

Q11 Assertion (A): The power of the combination of n convex lenses and (n-1) concave lenses of same power will be positive.

Reason (R) : The power of a combination of the lenses is independent of the order of their arrangement

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.

Q12 Assertion (A): When white light passes through parallel sided glass slab it undergoes dispersion

Reason (R) : Frequency of different colours in white light change as it moves from air to glass

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.

Q13. Assertion (A): In total internal reflection, no light is refracted when the angle of incidence exceeds the critical angle

Reason (R): All the incident light is reflected back into the denser medium without any loss.

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.

Q14. Assertion (A): In a compound microscope, increasing the focal length of the objective lens decreases the magnifying power.

Reason (R): Magnifying power of a compound microscope is directly proportional to the focal length of the objective lens

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.

Q15. Assertion (A): Refractive Index of material depends wavelength of light
Reason (R): Refractive Index of material depends on its nature

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.

<u>CASE STUDY QUESTIONS</u>

Subject: Physics

CASE STUDY – 01 :

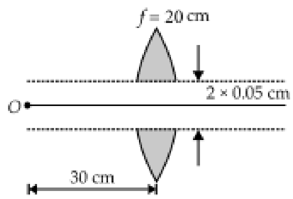
A convex or converging lens is thicker at the center than at the edges. It converges a parallel beam of light on refraction through it. It has a real focus. A convex lens is of three types :

(i) Double convex lens (ii) Plano-convex lens

(iii) Concavo-convex lens. The concave lens is thinner at the center than at the edges. It diverges a parallel beam of light on refraction through it. It has a virtual focus.

Choose the correct option –

1- A point object O is placed at a distance of 0.3 m from a convex lens (focal length 0.2 m) cut into two halves each of which is displaced by 0.0005 m as shown in the figure.



1.What will be the location of the image?

(a) 30 cm right of lens (b) 60 cm right of lens

(c) 70 cm left of lens (d) 40 cm left of lens

2- Two thin lenses are in contact and the focal length of the combination is 80 cm. If the focal length of one lens is 20 cm, the focal length of the other would be.

(a) –26.7 cm (b) 60 cm

(c) 80 cm (d) 20 cm

3- A spherical air bubble is embedded in a piece of glass. For a ray of light passing through the bubble, it behaves like a

(a) converging lens

(b) diverging lens

(c) plano-converging lens

(d) plano-diverging lens

4- The magnification of an image by a convex lens is positive only when the object is placed

(a) at its focus F

(b) between F and 2F

(c) at 2F

(d) between F and optical center

Assignment - 4

CASE STUDY – 02 :

A compound microscope is an optical instrument used for observing highly magnified images of tiny objects. The magnifying power of a compound microscope is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye by the object when both the final image and the object are situated at the least distance of distinct vision from the eye. It can be given that: m = me × mo, where me is magnification produced by the eye lens and mo is magnification produced by the objective lens.

1- 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. 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

2- How far from the objective should an object be placed in order to obtain the condition described in Q above?

(a) 4.5 cm (b) 2.5 cm

(c) 1.5 cm (d) 3.0 cm

3- 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.

4- 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.

Case Study - 03:

In Chapter, Ray Optics and Optical Instruments, we delved into the principles of light propagation, reflection, and refraction. We particularly emphasized the law of reflection, which states that the angle of incidence equals the angle of reflection. Another significant topic we explored is Snell's law, or the law of refraction, which relates the angle of incidence and the angle of refraction to the ratio of the velocities of light in the two media. This law forms the basis for understanding phenomena such as the bending of light as it passes from one medium to another and the operation of optical instruments like lenses and prisms. The lens formula, $1/f = 1/v - 1/u$, is a critical tool for understanding image formation in convex and concave lenses.

1- What does the law of reflection state?

A) The angle of incidence is half the angle of reflection.

B) The angle of incidence is twice the angle of reflection.

C) The angle of incidence equals the angle of reflection.

D) The angle of incidence is unrelated to the angle of reflection.

2- What does Snell's law, or the law of refraction, relate to?

A) The angle of incidence and the angle of reflection.

B) The angle of incidence and the angle of refraction.

C) The velocity of light and the angle of incidence.

D) The velocity of light and the angle of reflection.

3- How does light behave when it passes from one medium to another?

A) It accelerates.

B) It decelerates.

C) It bends.

D) It does not change its path.

4- Which formula is used for understanding image formation in lenses?

A) $1/f = 1/v + 1/u$

B) $1/f = 1/v - 1/u$

C) $f = v/u$

D) $f = u/v$

Case Study - 04:

As we know that, when light ray travels from one medium to another changes its direction of path due to the change in optical density of the medium. When light ray travels from optically denser medium to the optically rarer medium then some of the light get reflected back in the same medium and remaining light get refracted in the second medium and such a phenomenon of light is called as internal reflector light. We know that, when a ray of light travels from denser medium to rarer medium then it get bended away from the normal. If we increase the angle of incidence slowly then angle of refraction also get increased and at one stage the angle of refraction is 90° for some angle of incidence. And further if we increase the angle of incidence then there will be no refraction of light and the ray will be totally internally get reflected. Such phenomenon of reflection of light is called as total internal reflection of light. And the angle of incidence in denser medium for which the angle of refraction in rarer medium is 90°, that angle of incidence is called as critical angle. So we define total internal reflection as, if the angle of incidence exceeds the critical angle then the total light get internally reflected. Mirage is the best real life example of total internal reflection of light. The highly brilliance of diamonds is only due to the total internal reflection of light through them which is get total internally reflected many times and causes brilliance of diamonds. Prisms are also made by using total internal reflection of light. We all know that, optics is the vast branch of physics which has vast application in our daily life such as optical fibre. Optical fibre are used for long distance transmission of audio and video signal also. And they are mainly constructed on the basis of total internal reflection of light to reduce the decrease in amplitude of the sending signal.

1 - For critical angle the value of corresponding angle of refraction is____

a) 180°
b) less than 90°
c) greater than 90°
d) 90°

2 - As the refractive index of the medium increases the corresponding value of critical angle for that medium ____

a) decreases
b) increases
c) remains same
d) independent of refractive index of the medium

3 - In case of total internal reflection, for angle of incidence greater than critical angle the refraction of light is not possible because____

a) Snell's law of refraction get satisfied
b) Snell's law of refraction cannot be satisfied
c) laws of refraction cannot be satisfied
d) can't say

4 -How total internal reflection of light would be possible in case of optical fibres? Explain in brief.

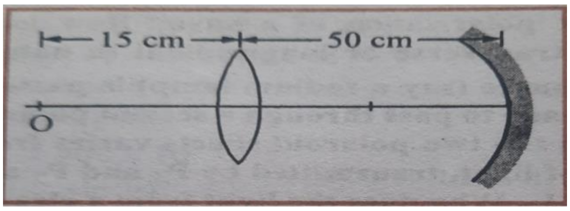
ASSIGNMENT -5 (BASED SHORT ANSWER AND LONG ANSWER QUESTIONS)

Subject: Physics

SHORT – ANSWER QUESTIONS :

Q 1. A compound microscope has a magnification of 30. The focal length of its eyepiece is 5 cm. Assuming the final image to be formed at the least distance of distinct vision. Calculate the magnification produced by the objective.

Q2. In the given ray diagram, the direct image formed by the lens (whose focal length is 10 cm) of an object placed at point 'O' and that formed after reflection from the spherical mirror are formed at the same point 'O'. What is the radius of curvature of the spherical mirror? Also calculate focal length of spherical mirror used.



Q3. Two thin lenses of focal length + 10 cm and – 5 cm are kept in contact. What is the

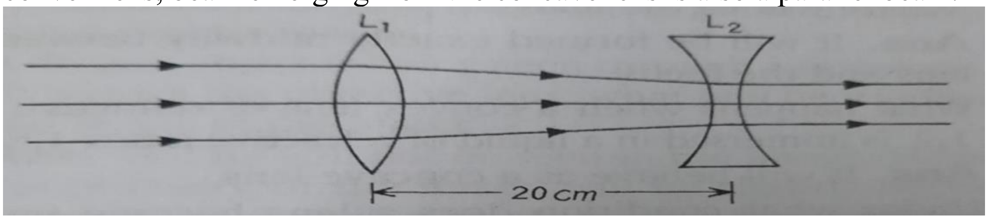
(a) Combine focal length (b) power of combination

Q4. A beam of light converges at a point P. Now a lens is placed in the path of the convergent beam 12 cm from point P. At what point does the beam converge if the lens is –
(i) a convex lens of focal length 20 cm (ii) a concave lens of focal length of 16 cm (iii) Draw the ray diagram in both cases (i) & (ii)

Q5. The image of a small electric bulb fixed on the wall of a room is to be obtained on the opposite wall 3 m away by means of a large convex lens. What is the maximum possible focal length of the lens required for the purpose?

Q6. A ray of light is incident at an angle of 60o on one surface of a 30o prism. The emergent ray from the prism makes an angle of 30o with the incident ray.
(i) Show that the emergent ray is normal to that surface from which it emerges.
(ii) Calculate the refractive index of the material of the prism.

Q7. A thin convex lens (L1) of focal length 80 cm and a thin concave lens (L2) of focal length 'f ' are kept co-axially 20 cm apart as shown in the given fig.. When a narrow and parallel beam of light is incident on the convex lens, beam emerging from the concave lens is also a parallel beam. Find focal length.



Q8. For the same value of angle of incidence, the angles of refraction in three media A,B and C are 15°, 25° and 35° respectively. In which medium would the velocity of light be maximum

Q9. Derive lens maker's formula. With the help of it derive the thin lens formula

Q10. Plot a graph between 1/u and 1/v for a concave mirror. What dows the slope give

Q11. what is total internal reflection. Write necessary condition for light to get total internally reflected from a medium

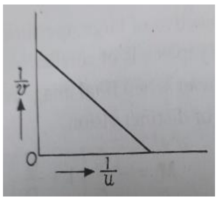
Q12Draw a ray diagram to show the formation of real and enlarged image of an object placed in front of a lens. Using this diagram, derive the relation between object distance, image distance and focal length of the lens

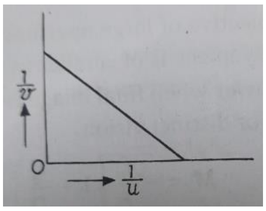
Q13 A convex lens made of material of refractive index 'n_2' is held in a reference medium of refractive index 'n_1'. Trace the path of a parallel beam of light passing through the lens when (i) $n_1 = n_2$, (ii) $n_1 < n_2$ and (iii) $n_1 > n_2$

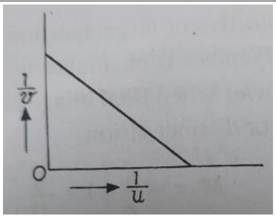
Q14 Draw a ray diagram to show the formation of image of an object placed between the optical centre and focus of the convex lens. Using this diagram, derive the relation between object distance, image distance and focal length of the convex lens.

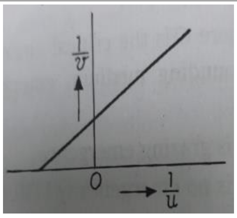
LONG – ANSWERS QUESTIONS :

Q1. Give the answers of the following questions –
(i) Draw the 1/v versus 1/u graph for a real image formed by concave mirror.
(ii) Draw the u and v graph for real image fromed by concave mirror.
(iii) Draw the 1/v versus 1/u graph for virtual image formed by concave mirror.
(iv) Draw the 1/v versus 1/u graph for convex mirror.
Answer :

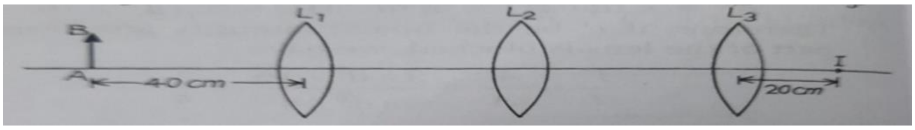
(i) 

(ii) 

(iii) 

(iv) 

Q2. You are given three lenses L_1, L_2 and L_3 each of focal length 20 cm. An object is kept at 40 cm infront of L_1 as shown in fig. The final real image is formed at the focus ' I ' of L_3. Find the separations between L_1, L_2 and L_3.



Q 3. A convex lens of f = 20 cm is placed coaxially with a convex mirror of R = 20 cm. The two are kept 15 cm apart. A point object is placed 40 cm infront of the convex lens. Find the position of the image formed by this combination. Draw the ray diagram showing the image formation

Q4 Draw a ray diagram to show the refraction of light through a glass prism. Hence obtain the relation for the angle of deviation in terms of angle of incidence, angle of emergence and the angle of the prism. Draw a graph showing variation of Angle of deviation with angle of incidence for a ray of light passing through prism.

MARKING – SCHEME

Assignment - 1

Q.P. – RAY OPTICS & OPTICAL INSTRUMENTS — Session : 2026-2027

CLASS – XII

Subject: Physics

MAX. MARKS : 70

Q.No.	VALUE POINTS	MARKS
1.	**B) Infinity**	1
2.	**B) Rear-view mirror in vehicles**	1
3.	**C) Frequency**	
4.	**C) 25 cm**	1
5.	**B) Light travels from denser to rarer medium at angle greater than critical angle**	1
6.	**B) Scattering of light**	1
7.	**B) Different speeds of different wavelengths in glass**	1
8.	**B) 3.6^0** **Solution:** $\delta \approx (n-1)A = 0.60\times6^0=3.6^0$	1
9.	**C) 6** **Solution:** M=1+D / f = 1+25 / 5=6	1
10.	**C) 100** **Solution:** M=(L/fo)(D/fe)=(20/1)(25/5)=20×5=100	1
11.	**C) 20** **Solution:** For final image at infinity, m=fo/fe=100/5=20.	1
12.	**C) −180 cm** **Solution:** (n2/v) – (n1/u) = (n2−n1)/R ⇒ 1.5/v – (- 1/30) = 1.5 – 1.0 / 20 = 0.5 / 20 1.5/v + 1/30 = 1 / 40 or 1.5 / v = 1/40 – 1/30 = - 1/120 then, v = - 180 cm (virtual image on the object side)	1
13.	A) Both A and R are true, and R is the correct explanation of A.	1
14.	A) Both A and R are true, and R is the correct explanation of A.	1
15.	A) Both A and R are true, and R is the correct explanation of A.	1
16.	B) Both A and R are true, but R is not the correct explanation of A.	1

17.	**Solution:** Both causes are due to dispersion of light, but in a glass slab the **deviations for different colors cancel out** (parallel emergence). In a prism, emergent rays are not parallel to incident rays, so dispersion (angular separation of colors) is visible. **OR** **Solution:** 1. No chromatic or spherical aberrations. 2. Large size mirrors can be made and supported easily. 3. Higher light-gathering capacity compared to lenses.	1 +1
18. (i) (ii)	<u>Solution :</u> Approach and sign convention - We treat the bubble as an **object for light rays traveling from inside the glass toward the spherical surface at P** and refracting into air. Use the formula for refraction at a spherical surface (paraxial approximation): formula used as – $n_1/ u + n_2 / v = n_2 – n_1 / R$ given values from the question are – R = 6 cm, u = 6 – 3 = 3 cm, n_1 = 1.5 , n_2 = 1 now, put the values in the formula 1.5/3 + 1/v = (1-1.5) / -6 so, 0.5 + 1/v = 0.5/ 6 or 1/v = (0.5/6) – 0.5 = - 2.5/6 = - 0.41666 v = - 1/0.41666 = - 2.4 cm (The negative sign means the image is **virtual** and lies **inside the glass** on the same side as the object (i.e., between the surface P and the centre C). The image is located **2.40 cm from the pole P, inside the sphere**.	1 + 1
19.	Given, f= 20cm ; n= 1.55 ; Let, the radius of curvature of each of two surfaces of the lens be R. so, R_1 = R and R_2 = - R By using, $1/f = (n-1) [1/R_1 - 1/R_2]$ 1/20 = (1.55-1) [1/R + 1/R] or 1/20 = 0.55 ×2 / R or R = 22 cm **OR** **<u>Objective :</u>** Lens L_1 **<u>Eyepiece :</u>** Lens L_3 **<u>Reason :</u>** The objective lens should have large aperture as given 8 cm and must has large focal length (f = 1/Power) while the eyepiece should has small aperture like 1 cm and small focal length.	 ½ ½ 1
20.	Solution : a) When final image is formed at least distance of distinct vision, magnification $m = (f_0 /f_e) (1 + f_e/D)$ b) Magnification in case of normal vision $m = f_0 / f_e$ form points (a) and (b) it is clear that for large magnification $f_0 >> f_e$	½+½+½ +½
21.	$1/f = (n-1) [1/R_1 - 1/R_2]$; $1/f = (n-1) [2/f]$ because, f = R SO, (n-1) = ½ or n = 1.5	1 + 1

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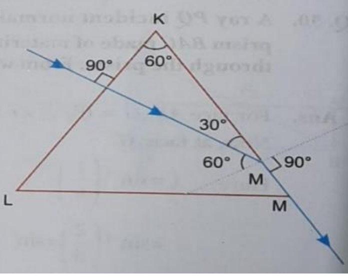
s. When light ray incident on face KL, it is pass undeviated, because it is normal to the surface and incident on face KM. The angle of incidence for face KM is equal to 60°.
$\frac{\sin 60^\circ}{\sin r} = \frac{n_2}{n_1}$ $\left[\begin{array}{l} n_2 = \text{Second medium} = \text{air} \\ n_1 = \text{Glass medium} = 2/\sqrt{3} \end{array} \right.$
$\frac{\sin 60^\circ}{\sin r} = \frac{1}{2/\sqrt{3}} = \frac{\sqrt{3}}{2}$
$\Rightarrow \sin r = \frac{\sin 60^\circ}{\frac{\sqrt{3}}{2}} = 1$
$\sin r = 1 \Rightarrow r = 90^\circ$
Angle of emergence = **90°**
Angle of deviation = **30°**


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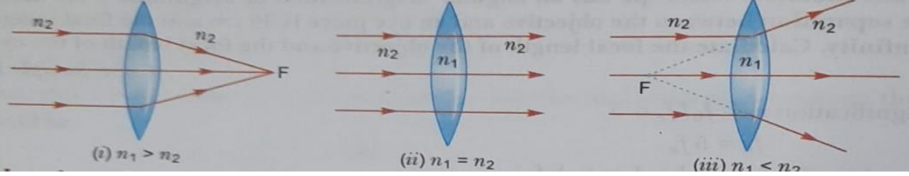
Using lens makers formula as 1/f = (n -1) (1/R1 – 1/R2)
1/f = (1.5 -1) (1/∞ - 1/ -15) or f = 30 cm for plano-convex lens
Again, by using lens makers formula as
1/f = (1.5 -1) (1/ (-15) - 1/∞) or f = - 30 cm plano-concave lens
Now, by using lens formula as
Object for lens 1: u_1=10 cm
$1/v_1=1/f_1+1/u_1$ = 1/30 + 1/10 = 4/30 = 2/15 or
v_1 = 15/2 = 7.5 cm (to the right side of lens 1)
Treat that image as object for lens 2
Distance of that image from lens 2: u_2=20−7.5=12.5 cm (object for lens 2, on its left).
Use f_2=−30 cm
Now, $1/v_2=1/f_2+1/u_2$ = - 1/30 + 1/12.5 = - 0.3333 + 0.08 = 0.0466
Or, v_2 = 21.42 cm (to the right of lens 2)
Hence, (a) Final image is **21.43 cm to the right of the second lens** (approx).
(b) That is **41.43 cm to the right of the first lens** (20 + 21.4286).
(c) Measured from the object (which is 10 cm left of lens 1), the final image is **51.43 cm to the right of the object**.
(d) The final image is **real** (formed on the opposite side of lens 2 from its object).
(e) overall linear magnification is
m=m1 × m2 =(− v1/u1)(− v2/u2)=(−7.5/10)×(−21.42/12.5) ≈ +1.286,
so the image is **upright** relative to the original object and about **1.29× larger**.
OR
From lens maker's formula, $\frac{1}{f} = \left(\frac{n_1}{n_2} - 1\right)\left(\frac{1}{R_2} + \frac{1}{R_2}\right)$
In case (*i*) $n_1 > n_2$, the lens behaves as convergent lens.
In case (*ii*) $n_1 = n_2$, the lens behaves as a plane plate.
In case (*iii*) $n_1 < n_2$, the lens behaves as a divergent lens.
The path of rays in all the three cases is shown in fig.


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<td>1 + 1+1</td>
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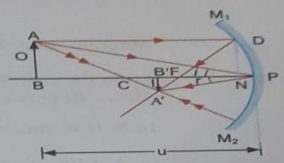
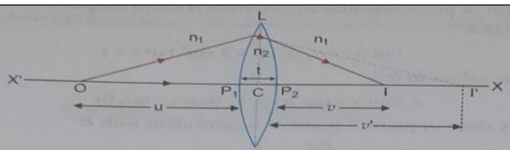
24.	(i) **Mirror Formula:** M_1M_2 is a concave mirror having pole P, focus F and centre of curvature C. An object AB is placed in front of mirror with point B on the principal axis. The image formed by mirror is $A'B'$. The perpendicular dropped from point of incidence D on principal axis is DN  In ΔABC and $\Delta A'B'C$ $\angle ABC = \angle A'B'C$ (each equal to 90°) $\angle ACB = \angle A'CB'$ (opposite angles) Both triangles are similar. $\therefore \frac{AB}{A'B'} = \frac{BC}{B'C}$ ...(i) Now in ΔDNF and $\Delta A'B'F$ $\angle DNF = \angle A'B'F$ (each equal to 90°) $\angle DFN = \angle A'FB'$ (opposite angles) $\therefore$ Both triangles are similar $\frac{DN}{A'B'} = \frac{FN}{B'F}$ or $\frac{AB}{A'B'} = \frac{FN}{B'F} (\because AB = DN)$ ...(ii) Comparing (i) and (ii), we get $\frac{BC}{B'C} = \frac{FN}{B'F}$ ...(iii) If aperture of mirror is very small, the point N will be very near to P, so $FN = FP$ $\therefore \frac{BC}{B'C} = \frac{FP}{B'F}$ or $\frac{PB-PC}{PC-PB'} = \frac{FP}{PB'-PF}$ ...(iv) By sign convention Distance of object from mirror $PB = -u$ Distance of image from mirror $PB' = -v$ Focal length of mirror $PF = -f$ Radius of curvature of mirror $PC = -R = -2f$ Substituting these values in (iv), we get $\frac{-u-(-2f)}{-2f-(-v)} = \frac{-f}{-v-(-f)}$ Magnification m = A'B'/AB = B'P/BP or m = - v/u = h'/h	1+1+1
25.	 $\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1}$ ...(i) The image I' acts as a virtual object for second surface and after refraction at second surface, the final image is formed at I. The distance of I from pole P_2 of second surface is v. The distance of virtual object (I') from pole P_2 is $(v' - t)$. For refraction at second surface, the ray is going from second medium (refractive index n_2) to first medium (refractive index n_1), therefore from refraction formula at spherical surface $\frac{n_1}{v} - \frac{n_2}{(v'-t)} = \frac{n_1 - n_2}{R_2}$ ...(ii) For a thin lens t is negligible as compared to v' therefore from (ii) $\frac{n_1}{v} - \frac{n_2}{v'} = -\frac{n_2 - n_1}{R_2}$ ...(iii) Adding equations (i) and (iii), we get $\frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ or $\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ *i.e.* $\frac{1}{v} - \frac{1}{u} = ({}_1n_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ ...(iv) where ${}_1n_2 = \frac{n_2}{n_1}$ is refractive index of second medium (*i.e.*, medium of lens) with respect to first medium. If the object O is at infinity, the image will be formed at second focus *i.e.*, if $u = \infty$, $v = f_2 = f$	1+1+1
26.	Here, $u_1 = -36$ cm, $f_1 = 24$ Image formed by first lens, L_1. Using lens formula, $\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1}$ $\Rightarrow \frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1} = \frac{1}{24} + \frac{1}{(-36)} = \frac{3-2}{72} = \frac{1}{72}$ Lens equation is -- by comparing the equations, $1/v - 1/u = (n-1)(1/R_1 - 1/R_2)$ and $1/f = (n-1)(1/R_1 - 1/R_2)$ we have, $1/v - 1/u = 1/f$ called lens equation.	1+1+1
27.	(a) Objective = 5D, Eyepiece = 10 D , This choice would give higher magnification as $M = f_0 / f_e = P_e / P_0$ (b) The aperture of the objective lens is preferred to be large that it may collect sufficient light to form a brighter image of a distant object.	1 + 1+1

28.

The mark O on the surface of glass sphere acts as object. The incident ray OA is in glass and refracted ray AB is in air. I is the image of O.

Thus, $n_1 = 1,\ n_2 = 1.5$

$u = -20$ cm (Minus sign is taken for refraction at concave surface)

As light passes from denser to rarer medium, so

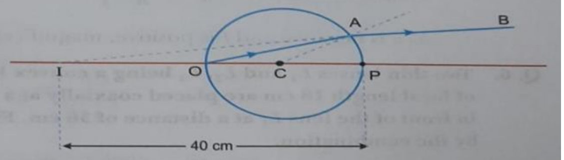
$$\frac{n_1}{v} - \frac{n_2}{u} = \frac{n_1 - n_2}{R}$$

$$\frac{1}{v} + \frac{1.5}{20} = \frac{1-1.5}{-10}$$

$$\frac{1}{v} = \frac{1}{20} - \frac{3}{40}$$

$$\frac{1}{v} = \frac{2-3}{40} = \frac{-1}{40}$$

$$v = -\mathbf{40\ cm}$$



Negative sign shows that the image is virtual. It is formed on the same side of the refracting surface as the object at a distance of 40 cm from the pole P.

OR

The ray incident perpendicularly on side AB, so it will pass out normally through AB.

On face AC, $i = 45°$

For total internal reflection to take place at face AC,

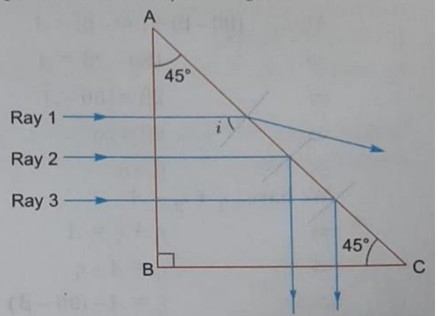
Angle of incidence > critical angle

$45° > i_c$

$\sin 45° > \sin i_c$

$\Rightarrow \quad \frac{1}{\sqrt{2}} > \frac{1}{n} \qquad \left[\because i_c = \sin^{-1}\left(\frac{1}{n}\right)\right]$

$\Rightarrow \quad \sqrt{2} < n \quad \Rightarrow 1.414 < n$

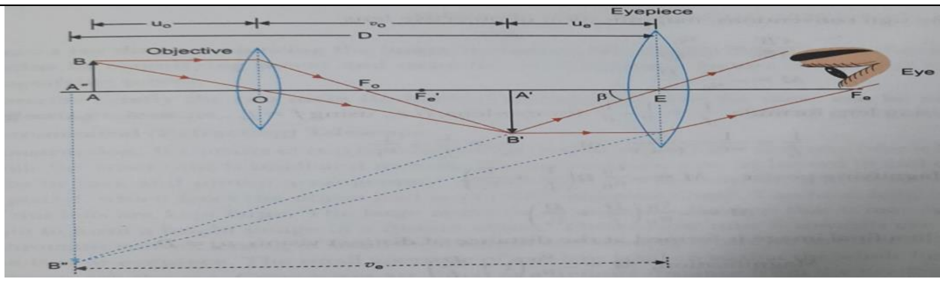


Hence, rays 2, 3 will undergo *TIR* and path of ray will be as shown.

Ray 1 is refracted from AC.

1+1+1

29.



Magnifying Power when final image is formed at least distance of distinct vision $M = -v_0/u_0\ (1 + D/f_e)$

Magnifying Power when final image is formed at infinity

$M = m_0 \times m_e = (L/f_0)\ (D/f_e)$

(ii) For grater magnification of a compound microscope, fe should be small. As $f_0 < f_e$, so f_0 is small. Hence, for greater magnification, both f_0 and f_e should be small with f_0 to be smaller of the two lenses.

OR

Here, $M = -20,\ m_e = 5,\ v_e = -20$ cm

For eyepiece, $m_e = \frac{v_e}{u_e}$

$\Rightarrow \quad 5 = \frac{-20}{u_e} \quad \Rightarrow \quad u_e = \frac{-20}{5} = -4$ cm

Using lens formula,

$$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e} \quad \Rightarrow \quad -\frac{1}{20} + \frac{1}{4} = \frac{1}{f_e}$$

$$\Rightarrow \quad \frac{-1+5}{20} = \frac{1}{f_e} \quad \Rightarrow \quad f_e = 5 \text{ cm}$$

Now, total magnification

$$M = m_e \times m_o$$

$$-20 = 5 \times m_o \quad \Rightarrow \quad m_o = -4$$

Also $\quad |v_o| + |u_e| = 14$

$$|v_o| + |-4| = 14$$

$$v_o = 14 - 4 = 10 \text{ cm}$$

$$m_o = 1 - \frac{v_o}{f_o} \quad \Rightarrow \quad -4 = 1 - \frac{10}{f_o}$$

$$-5 = -\frac{10}{f_o} \quad \Rightarrow \quad f_o = 2 \text{ cm.}$$

1½+2 +1½

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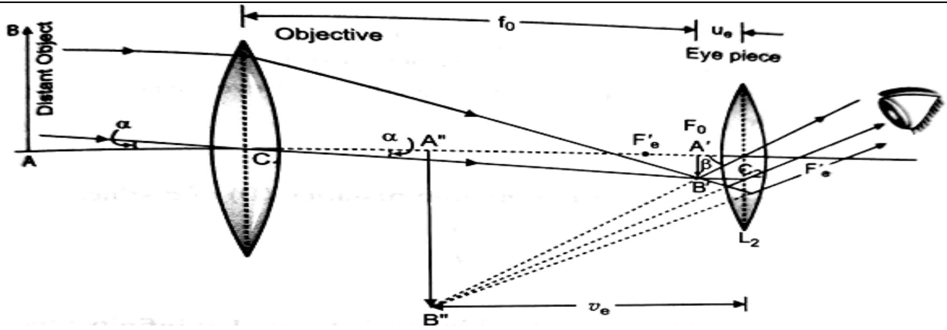
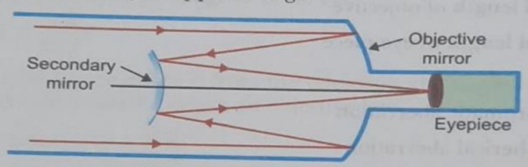


Labelled ray diagram with
(i) When final image is formed at LDDV then $M = -\,f_0/f_e\,(1 + f_e/D)$ and
Length of telescope $L = f_0 + u_e$
(ii) magnifying power $M = -\,f_0/f_e$ if image is formed at infinity and
Length of telescope $L = f_0 + f_e$
(iii) <u>Factors For Increasing The Magnifying Power :</u>
1- Increasing focal length of objective
2- Decreasing focal length of eye piece.

<u>OR</u>
(*a*) The main considerations taken into account while choosing the objective of astronomical telescope is:
(*i*) The aperture of objective lens is kept large so, that it may collect sufficient light to form a bright image of a distant object.
(*ii*) The focal length of objective is kept large so that the final image subtends a large angle at the eye and the object appears large.
(*b*)


If f_0 and f_e are the focal lengths of objective and eyepiece respectively, then magnifying power when the image is formed at the least distance of distinct vision,
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<td>2½+2
+1/2</td>
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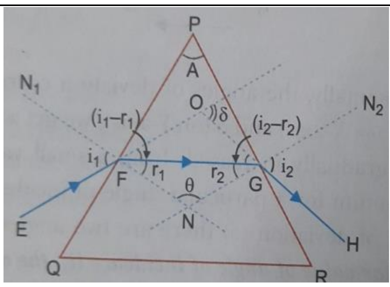

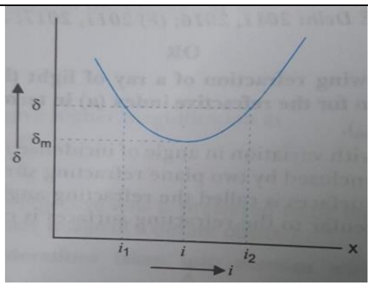

OR
Angle of prism, $A = 60°$ (Since prism is an equilateral glass prism)
We are given that
$$i = \frac{3}{4}A = \frac{3}{4}\times 60°$$
$\therefore$ $i = 45°$
At minimum deviation,
$$r = \frac{A}{2} = 30°$$
$$n = \frac{\sin i}{\sin r} = \frac{\sin 45°}{\sin 30°} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}} = \frac{2}{\sqrt{2}} = \sqrt{2}$$
Speed of light in the prism is given by
$$v = \frac{c}{n} = \frac{3\times 10^8}{\sqrt{2}} = 2.1\times 10^8 \text{ m/s}$$
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<td>1½+2
+1½</td>
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<tr>
<td>32. (i)
(ii)
(iii)
(iv)
(v)</td>
<td>(b) Away from normal
(a) 48.8^0
(a) Cladding
(b) 42^0
(c) Violet</td>
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33. (i) (ii) (iii) (iv) (v)	(b) Each half of the lens will form an image in the same plane. The optic axes of the lenses are displaced. (a) –26.7 cm (b) The bubble behaves like a diverging lens. (b) Convex lens is used in magnifying glass. (d) between F and optical center	4

Assignment - 2

<u>20 MCQs: Ray Optics and Optical Instruments</u> :

1. Answer: C) 1.5

2. Answer: B) 1.41

3. Answer: B) +5 D

4. Answer: B) Concave lens

5. Answer: A) 0°

6. Answer: B) Virtual, erect, magnified

7. Answer: B) Denser to rarer medium

8. Answer: B) 42°

9. Answer: B) f = infinite

10. Answer: C) 60°

11. Answer: C) 6

12. Answer: A) Angle of incidence = angle of emergence
13. Answer: A) Increases

14. Answer: C) 20 cm

15Answer: A) –25 cm

16. Answer: A) Greater than in air

17. Answer: C) Total internal reflection

18. Answer: D) Scattering

19. Answer: B) 10

20. Answer: A) 15 cm

21**Answer** B

22 **Answer A**

23.**Answer** C

24.**Answer** D

25.**Answer** C

26.**Answer** B

27.**Answer** D

28.**Answer** D

29.**Answer** D

30.**Answer** C

Assignment - 3

Assertion & Reason Questions :

Q1. Answer: C) A is true, R is false.

Q2. Answer: A) Both A and R are true, and R is the correct explanation of A.

Q3. Answer: A) Both A and R are true, and R is the correct explanation of A.

Q4. Answer: C) A is true, R is false.

Q5. Answer: A) Both A and R are true, and R is the correct explanation of A.

Q6. Answer: A) Both A and R are true, and R is the correct explanation of A.

Q7. Answer: C) A is true, R is false.

Q8. Answer: A) Both A and R are true, and R is the correct explanation of A.

Q9. Answer: A) Both A and R are true, and R is the correct explanation of A.
Q10. Answer: D) A is false, R is true.
Q11 **Answer:** A) Both A and R are true, and R is the correct explanation of A.
Q12 Answer: D) A is false, R is true.

Q13Answer: A) Both A and R are true, and R is the correct explanation of A.

Q14 Answer: C) A is true, R is false.
Q15 Answer: A) Both A and R are true, and R is the not correct explanation of A.

Assignment - 4

CASE STUDY – 01 :
ANSWERS :

1- (b) Each half of the lens will form an image in the same plane. The optic axes of the lenses are displaced.
2- (a) –26.7 cm
3- (b) The bubble behaves like a diverging lens.
4- (d) between F and optical center

CASE STUDY – 02 :

ANSWERS :

1- (b) –5 cm
2- (b) 2.5 cm
3- (a) : The intermediate image formed by the objective of a compound microscope is real, inverted and magnified.
4- (d) : Magnifying power of a compound microscope increases when fixed length of both objective and eye-piece are decreased.

Case Study - 03:

Answers:

1. C) The angle of incidence equals the angle of reflection.
2. B) The angle of incidence and the angle of refraction.
3. C) It bends.
4. B) 1/f = 1/v – 1/u

Case Study - 04:

Answers :

1 - d) 90°
2 - a) decreases
3 - b) Snell's law of refraction cannot be satisfied
4 - Optical fibres are used mainly for long distance transmission of signals. They are made up of high quality composite glass or quartz fibres which consists of core and cladding. The refractive index of core is higher than the cladding. So core acts as a rarer medium and cladding acts as the denser medium. The signal in the form of light is sended from one end of the fibre at a particular angel of incidence so that the light must get totally internally reflected. In such way, light get totally internally reflected many times along the length of the fibre and finally will be received at the other end without loss in intensity. In this way, by total internal reflection of light the long distance signal transmission is possible through optical fibres.

ASSIGNMENT-5 (BASED SHORT ANSWER AND LONG ANSWER QUESTIONS)

Subject: Physics

SHORT – ANSWER QUESTIONS :

Q 1. **Answer :** given magnifying power M = 30
Magnifying power of microscope $m = m_0 \times m_e$
But, me = $(1+D/f_e)$ = 1+25/5 =6 so, M = $m_0 \times 6 = 30$
or $m_0 = 30/6 = 5$

Q2. **Answer :** given, from ray diagram, u = -15 cm, f = 10cm of lens
By using lens formula 1/f = 1/v – 1/u or 1/10 = 1/v – 1/-15 or v = 30 cm
Distance of image formed by lens means object distance from the mirror = 50 cm – 30 cm
= 20 cm
According to question it is given that, the final image is to be formed at the same point 'O' where this object lies so, radius of curvature = 20 cm
Also, radius of curvature of mirror R = 2 f thus, focal length of mirror f = 20/2 = 10 cm

Q3. **Answer :** using, 1/f = 1/f1 + 1/f2 = 1/10 + 1/-5 = - 1/10
or combined focal length f = -10 cm

Power of combined lens P = 1/f = 1/- 0.1 = - 10 D

Q4. **Answer :**

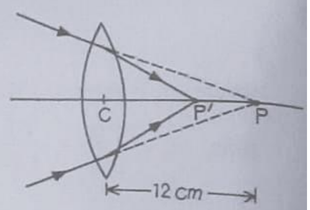
The point P on the right of lens works as a virtual source whose real image is formed at P'.

(i) For Convex Lens : $u = +12$ cm, $f = +20$ cm.

$$\therefore \quad \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

or $\quad \frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{12} + \frac{1}{20} = \frac{5+3}{60} = \frac{8}{60}$

or $\quad v = \frac{60}{8} = 7.5$ **cm.**

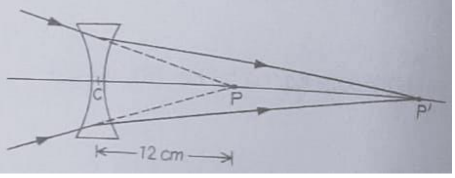


The beam converges at 7.5 cm from the lens.

(ii) For Concave Lens : $u = +12$ cm, $f = -16$ cm.

$$\frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{12} - \frac{1}{16} = \frac{1}{48}$$

$v = 48$ **cm.**



The beam diverges at 48 cm from the lens.

Q5. **Answer :** Let the object is placed at u metre infront of the lens.

The distance of image from the lens (u) = (3 - u) m

By using lens formula as, 1/v - 1/u = 1/f now, put the values of u

1/(3 - u) – 1/-u = 1/f or, 1/(3 - u) + 1/u = 1/f

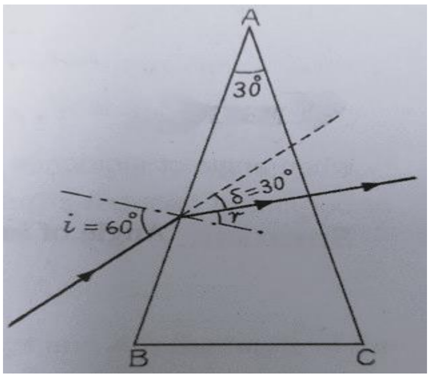
or, (u+3-u) / u (3 – u) = 1/f or, 3f = 3u – u^2

or, $u^2 – 3u + 3f = 0$

For real u, discriminant ≥ 0 i.e. $9 – 12f \geq 0$ or, $f \leq ¾$ or, $f \leq 0.75$ m

Q6. **Answer :**

(i)



(ii) Let I and r be the angles of incidence and refraction at the first face of the prism and r' and I' be the angles of incidence and emergence at the second face.

If 'A' be the angle of prism, then the deviation produced by the prism is given by

δ = i + i' – A

put i = 60^0, A = 30^0 and δ = 30^0

so, i' = δ - i + A = $30^0 – 60^0 + 30^0 = 0$

this means, the emergent ray is normal to the second face of the prism, as shown in the fig.

so, from the geometry of the fig. we have, r = i – δ = $60^0 – 30^0 = 30^0$

by using Snell's law, the refractive index of the material of the prism is

n = Sin i / Sin r = Sin 60^0 / Sin 30^0 = √3

Q7. **Answer :** For convex lens L1, u = ∞ , f1 = 80 cm

Now, this image is serving as virtual object for concave lens.

Thus, for concave lens, u = 80 – 20 = 60 cm

Further, the rays after refraction from concave lens becomes parallel to its principal axis thus, for concave lens v = ∞

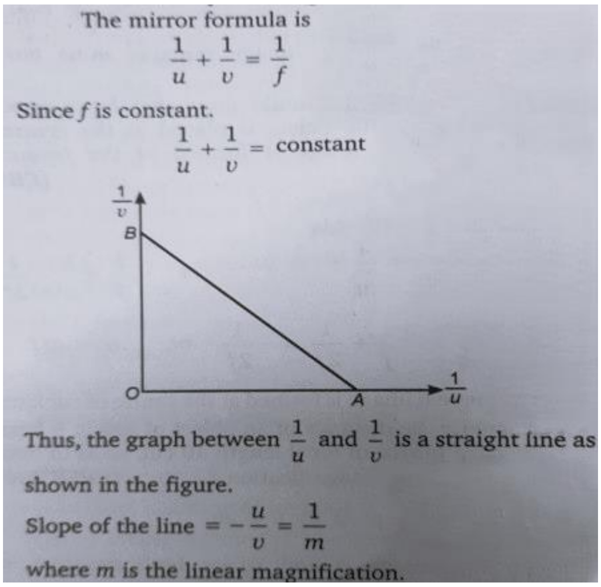
By using lens formula as, 1/f = 1/v – 1/u = 1/∞ - 1/60 or f = - 60 cm.

Q8. **Answer :** Since, the (absolute) refractive index of a medium is n = Sin i / Sin r = c/v

Where, c is the velocity of light in vacuum (constant) and v is velocity in the medium.
Thus, for the same angle of incidence (i) we have, $v = c \sin r / \sin i \;\alpha\; \sin r$
'v ' will be minimum for the medium in which sin r or angle of refraction is minimum. Thus, velocity of light is minimum in medium A.

Q9.
Answer : Correct NCERT derivation

Q10. **Answer :**


The mirror formula is

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Since f is constant.

$$\frac{1}{u} + \frac{1}{v} = \text{constant}$$

Thus, the graph between $\frac{1}{u}$ and $\frac{1}{v}$ is a straight line as shown in the figure.
Slope of the line $= -\frac{u}{v} = \frac{1}{m}$
where m is the linear magnification.

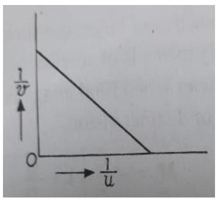
Q11. **Answer :**
When light goes from denser to rarer medium and incidence angle becomes greater than critical angle the light reflect In same medium
Condition
1. Angle i >Criticle Angle
2. Light go from denser to rarer medium

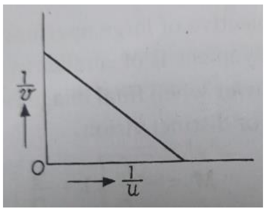
Q12. **Answer :**
Correct NCERT Diagram and relation

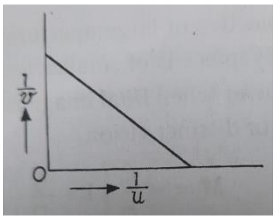
Q13 Correct ray diagrams

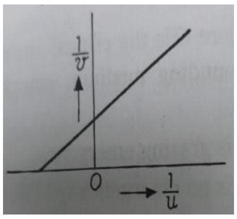
LONG – ANSWERS QUESTIONS :

Q1. **Answer :**

(i) 

(ii) 

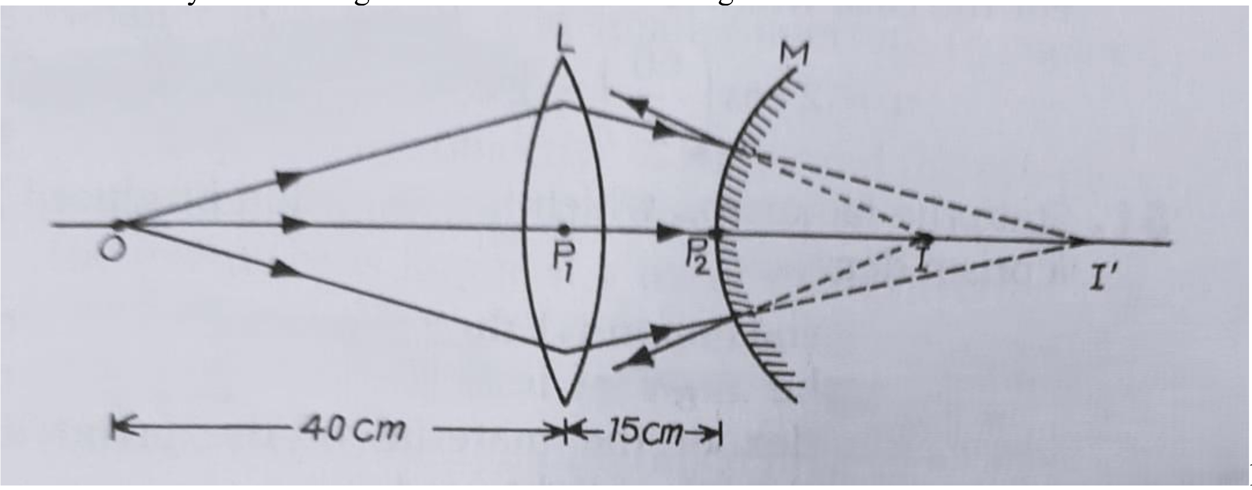
(iii) 

(iv) 

Q2. **Answer :** Given, $f_1 = f_2 = f_3 = 20$ cm
For the lens L_1, given that, $f_1 = 20$ cm, $u_1 = -40$ cm
By using lens formula as, $1/f = 1/v - 1/u$ we have, $1/v_1 - 1/-40 = 1/20$ so, $v_1 = 40$ cm.
This means, the image of object AB is formed at a distance of 40 cm from the lens L_1 on its right side.
Now, for lens L_3, final image is at its focus, this means, $v_3 = 20$ cm
Further, since, $f_3 = 20$ cm so, in compliance with lens formula it is possible only when object is at infinity for lens L_3 or $u_3 = \infty$.
Now, Since image of the object AB formed by convex lens L_2 is serving as virtual object for lens L_3, so, $v_2 = \infty$
Thus, for lens L_2, $u_2 = ?$, $f_2 = 20$ cm and $v_2 = \infty$ so, by using lens formula,
$1/v_2 - 1/u_2 = 1/f_2$ or, $1/\infty - 1/u_2 = 1/20$ so, $u_2 = -20$ cm
Thus, separation between lens L_1 and $L_2 = v_1 + (-u_2) = 40 + 20 = 60$ cm
Further, since, $v_2 = \infty$ and $u_3 = \infty$

So, lenses L_2 and L_3 are in contact or distance between lens L_2 and L_3 does not matter, it may take any value because image formed by lens L_2 is formed at infinity.

Q 3. **Answer :** Given, R = 20 cm (for mirror) so, f = R/2 =20/2 = 10 cm (for mirror)
For the convex lens, u = - 40 cm and f = 20 cm so, by lens eq. $1/f = 1/v - 1/u$
we have, $1/v = 1/20 – 1/40$ or $1/v = 1/40$ or v = 40 cm.
The image of object ‘ O ’ formed by convex lens that is ‘ I ‘ formed at adistance of 40 cm behind the convex lens serves as avirtual object for convex mirror whose final image is formed at ‘ I ‘ as shown in fig. so, for convex mirror u = (40 – 15) cm = 25 cm and f = 10 cm
By using mirror formula as, $1/f = 1/u + 1/v$ or $1/v = 1/10 – 1/25 = 3/50$ or v = 50/3 cm
Since, v = + 50/3 cm so, the image of object ‘O’ is formed at 50/3 cm from P2 behind the mirror .
The ray diagram of image formation is as fo



llows –

Q4 Correct NCERT Diagram and graphs

CHAPTER 10: WAVE OPTICS

ASSIGNMENT-1

PRACTICE QUESTION PAPER (CBSE PATTERN) — 2026-27

Subject: PHYSICS (Theory) Class: XII

Time Allowed: 3 Hours **Maximum Marks: 70**

General Instructions:

(i) There are 33 questions in all. All questions are compulsory.
(ii) This question paper has five sections: Section A, B, C, D and E.
(iii) In Section A – Questions no. 1 to 16 are Multiple Choice type questions. Each question carries 1 mark.
(iv) In Section B – Questions no. 17 to 21 are Very Short Answer type questions. Each question carries 2 marks.
(v) In Section C – Questions no. 22 to 28 are Short Answer type questions. Each question carries 3 marks.
(vi) In Section D – Questions no. 29 and 30 are Case Study-based questions. Each question carries 4 marks.
(vii) In Section E – Questions no. 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 a few questions in all the Sections except Section A.
(ix) Use of calculators is not allowed. Use the following values wherever necessary: speed of light in vacuum, $c = 3 \times 10^8$ m s^{-1}.

SECTION A

(Question Nos. 1 to 16 carry 1 mark each)

Q1. Two coherent sources of light have an intensity ratio of 4 : 1. The ratio of maximum to minimum intensity in the interference pattern produced by them is:
(a) 9 : 1 (b) 3 : 1 (c) 4 : 1 (d) 2 : 1

Q2. Assertion (A): In Young's double-slit experiment, the fringe width for the dark and the bright fringes is the same. Reason (R): Fringe width is given by $\beta = \lambda D/d$, which does not depend on the order of the fringe.
(a) Both A and R are true, and R is the correct explanation of A.
(b) Both A and R are true, but R is NOT the correct explanation of A.
(c) A is true, but R is false.
(d) A is false, and R is also false.

Q3. The shape of the wavefront of light diverging from a point source is:
(a) plane (b) spherical (c) cylindrical (d) elliptical

Q4. In a single-slit diffraction experiment, the first minimum of the diffraction pattern is obtained when the path difference between the wavelets from the two edges of the slit is:
(a) $\lambda/2$ (b) λ (c) $3\lambda/2$ (d) 2λ

Q5. The phase difference between the two superimposing waves that give rise to a bright spot in a Young's double-slit experiment is (nis an integer):
(A) $2n\pi$ (B) $2n\pi+\pi/2$ (C) $2n\pi+\pi/4$ (D) $2n\pi+\pi$

Q6. According to Huygens' principle, the amplitude of the secondary wavelets emanating from a wavefront is:
(a) equal in both the forward and the backward directions
(b) maximum in the forward direction and zero in the backward direction
(c) zero in the forward direction and maximum in the backward direction
(d) zero in both directions

Q7. In Young's double-slit experiment, a dark fringe is obtained at a point on the screen where the path difference between the two interfering waves is (n = 0, 1, 2, ...):

(a) $n\lambda$ (b) $(n + 1/2)\lambda$ (c) $2n\lambda$ (d) $n\lambda/2$

Q8. Light passes from a rarer medium (speed v_1) into a denser medium (speed v_2). Which of the following is correct?

(a) $v_1 < v_2$ (b) $v_1 > v_2$ (c) $v_1 = v_2$ (d) cannot be determined

Q9. Assertion (A): Two independent sodium lamps cannot act as coherent sources of light. Reason (R): Light emitted by an ordinary source undergoes abrupt, random phase changes in times of the order of 10^{-10} s.

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

Q10. In a single-slit diffraction experiment, if the width of the slit is doubled, the width of the central maximum becomes:

(a) double (b) half (c) four times (d) one-fourth

Q11. What property of light does this interference experiment demonstrate?

(A) Wave nature of light
(B) Particle nature of light
(C) Transverse nature of light
(D) Both wave nature and transverse nature of light

Q12. In Young's double-slit experiment, if the distance between the screen and the plane of the slits is doubled (all else unchanged), the fringe width becomes:

(a) half (b) double (c) four times (d) unchanged

Q13. When monochromatic light travels from air into glass, the quantity that remains unchanged is its:

(a) wavelength (b) speed (c) frequency (d) amplitude

Q14. Assertion (A): In interference and diffraction of light, energy that reduces in a dark region reappears in a bright region. Reason (R): This redistribution of energy is consistent with the principle of conservation of energy.

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

Q15. In a single-slit diffraction experiment, the width of the slit is halved. The width of the central maximum, in the diffraction pattern, will become:

(A) half
(B) twice
(C) four times
(D) one-fourth

Q16. Diffraction of sound waves is far more noticeable in everyday life than diffraction of light waves, mainly because:

(a) sound waves travel slower than light waves
(b) the wavelength of sound is comparable to the size of everyday obstacles/openings, unlike that of light
(c) sound waves are longitudinal while light waves are transverse
(d) sound waves do not obey Huygens' principle

SECTION B

(Question Nos. 17 to 21 carry 2 marks each)

Q17. State Huygens' principle. How did Huygens explain the absence of the backwave associated with a wavefront?

Q18. Write the conditions, in terms of the path difference between two interfering waves, for obtaining (i) a bright fringe, and (ii) a dark fringe, at a point on the screen in Young's double-slit experiment.

OR

State the two conditions that must be satisfied for two sources of light to act as coherent sources.

Q19. In Young's double-slit experiment, the two slits are separated by 0.5 mm and the screen is placed 1.0 m away from the slits. If the fringe width is found to be 1.2 mm, calculate the wavelength of light used.

Q20. Write any two points of difference between the interference pattern produced in Young's double-slit experiment and the diffraction pattern produced due to a single slit.

Q21. Unpolarised light of intensity I_0 is incident on a polaroid P_1. A second polaroid P_2 is placed after P_1 such that its pass axis makes an angle of 30° with the pass axis of P_1. Calculate the intensity of light emerging from P_2.

OR

Define the term 'linearly polarised light'. What should be the angle between the pass axes of two polaroids so that the intensity of the emergent light is zero?

SECTION C

(Question Nos. 22 to 28 carry 3 marks each)

Q22. Using Huygens' construction, draw a diagram to show the refraction of a plane wavefront at a plane interface separating a rarer medium (speed v_1) from a denser medium (speed v_2), when the wavefront travels from the rarer to the denser medium. Hence verify Snell's law of refraction.

Q23. In a Young's double-slit experiment, the slit separation is 1.0 mm and the screen is placed 1.0 m away from the slits. A beam of light consisting of two wavelengths, 600 nm and 480 nm, is used to obtain the interference pattern. Calculate: (a) the distance of the third bright fringe from the central maximum for the wavelength 600 nm. (b) the least distance from the central maximum where bright fringes due to both the wavelengths coincide.

Q24. Two coherent sources of light, each of amplitude 'a' and angular frequency 'ω', produce displacements $y_1 = a \cos \omega t$ and $y_2 = a \cos(\omega t + \varphi)$ at a point, where φ is the phase difference between them. Derive the expression for the resultant intensity at that point. Hence state the conditions on φ for (i) maximum, and (ii) minimum, intensity.

Q25. A parallel beam of monochromatic light of wavelength 500 nm is incident normally on a single slit of width 0.20 mm. Find the angular position, from the central maximum, of (i) the first minimum, and (ii) the first secondary maximum, of the diffraction pattern obtained on a distant screen.

OR

Using Huygens' construction, briefly explain how a diffraction pattern is formed on a screen due to a single narrow slit illuminated by a monochromatic source of light.

Q26. Two monochromatic waves emanating from two coherent sources have the displacements represented by $y1=a \cos\omega t$, and $Y2 = a\cos(\omega t+ø)$,where ø is the phase difference between the two displacements. Show that the resultant intensity at a point due to their superposition is given by $I = 4I0 \cos^2 ø /2$, where $Io \propto a^2$. Hence obtain the conditions for constructive and destructive interference.

Q27. Write three characteristic points of difference between the interference pattern obtained in Young's double-slit experiment and the diffraction pattern obtained due to a single slit.

Q28. In a Young's double-slit experiment using monochromatic light, the fringe width obtained on the screen is 0.4 mm. If the entire experimental set-up is now immersed in a transparent liquid of refractive index 1.6, without changing any other parameter, find the new fringe width. Will the position of the central maximum shift? Justify your answer.

SECTION D

(Question Nos. 29 and 30 are Case Study-based questions carrying 4 marks each)

Q29. Read the following passage and answer the questions that follow:

In Young's double-slit experiment, two coherent sources of light produce an interference pattern of equally spaced alternate bright and dark fringes on a screen. In a particular set-up, two slits, 2 mm apart, are illuminated by monochromatic light of wavelength 600 nm, and the interference pattern is observed on a screen kept 3 m away from the plane of the slits.

(a) Calculate the fringe width of the interference pattern obtained on the screen. (1)

(b) Find the distance of the fourth bright fringe from the central maximum. (1)

(c) What will happen to the fringe width if the screen is moved closer to the plane of the slits, other factors remaining unchanged? (1)

(d) If one of the two slits in this set-up is now completely closed, what type of pattern would be observed on the screen? (1)

Q30. Read the following passage and answer the questions that follow:

Diffraction is the phenomenon of bending of light around the edges of an obstacle or aperture whose size is comparable to the wavelength of light. In a single-slit diffraction experiment, a parallel beam of monochromatic light of wavelength λ is incident normally on a slit of width 'a', and the diffraction pattern is observed on a screen placed at a distance D from the slit.

(a) Write the condition for the position of the nth secondary minimum in this diffraction pattern. (1)

(b) How does the angular width of the central maximum change if the slit width 'a' is decreased, other factors remaining the same? (1)

(c) How does the intensity of the secondary maxima compare with the intensity of the central maximum? (1)

OR

(c) Two students standing on either side of a 5 m high wall, 8 m apart, are unable to see each other but can converse with each other easily. Explain why, giving reason based on the phenomenon of diffraction. (1)

SECTION E

(Question Nos. 31 to 33 carry 5 marks each)

Q31. (a) State Huygens' principle. Using Huygens' construction, show the reflection of a plane wavefront at a plane reflecting surface and hence verify law of refction. (3)

(b) The refractive index of glass is 1.5. Calculate the speed of light in glass. Is the speed of light in glass independent of the colour of light? If not, which of the two colours, red or violet, travels slower in a glass prism? Give reason. (2)

Q32. (a) Describe briefly, with the help of a labelled diagram, Young's double-slit experiment for producing an interference pattern, and derive the expression for the fringe width of the pattern obtained on the screen. (3)

(b) In a Young's double-slit experiment, the slits are separated by 0.28 mm and the screen is placed 1.4 m away. The distance between the central bright fringe and the fourth bright fringe is measured to be 1.2 cm. Determine the wavelength of light used. (2)

OR

(a) Derive an expression for the resultant intensity when two coherent waves of the same amplitude 'a' and a stable phase difference φ superpose at a point. Hence obtain the conditions for constructive and destructive interference. (3)

(b) In Young's double-slit experiment, the intensity of light at a point on the screen where the path difference is λ is K units. Find the intensity of light at a point where the path difference is $\lambda/3$. (2)

Q33. (a) Using Huygens' principle, explain the formation of the diffraction pattern due to a single narrow slit illuminated by a monochromatic source of light, and obtain the condition for the position of the minima. Explain briefly why the secondary maxima become weaker in intensity with increasing order n. (3)

(b) A slit of width 0.30 mm is illuminated normally by light of wavelength 600 nm. Find the linear width of the central maximum obtained on a screen placed 2 m away from the slit.

Assignment -2

Multiple Choice Questions (MCQs)

1. If one slit of Young's double slit apparatus is blocked, such that it transmits no light, which of the following will occur?

(a) Both the bright and the dark lines will increase in intensity
(b) The dark lines will increase in intensity and the bright lines will decrease in intensity
(c) The bright lines will increase in intensity and the dark lines will decrease in intensity
(d) Both the bright and the dark lines will decrease in intensity

2. In YDSE with white source of light, if one slit is covered with green filter and the other with red filter, what will be observed on the screen?

(a) Alternate red and green fringes
(b) Alternate bright and dark fringes
(c) No interference
(d) There shall be separate interference pattern for green and red

3. Red light is used in single slit diffraction experiment with slit width 0.1 mm. If red light is replaced by UV light then what will you observe?

(a) That the central maxima is narrower
(b) No diffraction pattern
(c) More number of fringes
(d) Less number of fringes

4. In the diffraction from a single slit if slit width is halved, the width of central maximum will become:

(a) twice
(b) half
(c) thrice
(d) one fourth

5. In Young's double-slit experiment, the wavelength of light was changed from 6000 Å to 3000 Å. While doubling the separation between the slits, which of the following is not true for this experiment?

(a) The width of fringes changes.
(b) The colour of bright fringes changes.
(c) The separation between successive bright fringes changes.
(d) The separation between successive dark fringes remains unchanged.

6. A Young's double slit experiment is performed with a mixture of three colours red, green and blue.

(a) The central fringe will be white.
(b) The central fringe will be red
(c) The central fringe will be green
(d) The central fringe will be blue

7. What will be the shape of interference fringe if we use two pin hole source in the place of two slits?

(a) circular
(b) straight line
(c) hyperbolic
(d) none of these

8. Which of the following phenomena is not explained by wave theory of light?

(a) Reflection
(b) Refraction
(c) Polarization
(d) Photoelectric effect

9. The principle of superposition of waves is applicable to:

(a) Longitudinal waves only

(b) Transverse waves only
(c) Both longitudinal and transverse waves
(d) Neither longitudinal nor transverse waves

10. In Young's double-slit experiment, the fringe width is:
(a) Directly proportional to the wavelength of light
(b) Inversely proportional to the wavelength of light
(c) Directly proportional to the slit separation
(d) Inversely proportional to the distance between slits and screen

11. When light is reflected its phase:
(a) does not change
(b) changes by π
(c) changes by 2π
(d) depends on speed

12. The angular width of the central maximum in a single-slit diffraction pattern is:
(a) Directly proportional to the slit width
(b) Inversely proportional to the slit width
(c) Directly proportional to the square of wavelength of light
(d) Inversely proportional to the wavelength of light

13. In a double-slit experiment, if the wavelength of light used is increased, the fringe separation:
(a) Increases
(b) Decreases
(c) Remains unchanged
(d) First increases, then decreases

14. Which of the following colours of light has the shortest wavelength?
(a) Red
(b) Yellow
(c) Green
(d) Blue

15. The term 'coherent sources' refers to sources that emit light waves which are:
(a) Of the same amplitude
(b) Of the same frequency
(c) In phase or have a constant phase difference
(d) Of the same speed

16. The intensity of light at a point in an interference pattern is directly proportional to:
(a) The amplitude of light waves
(b) The square of the amplitude of light waves
(c) The frequency of light waves
(d) The wavelength of light waves

17. The condition for constructive interference in thin films is that the path difference should be:
(a) An odd multiple of half-wavelength
(b) An even multiple of half-wavelength
(c) An odd multiple of quarter-wavelength
(d) An integral multiple of half-wavelength

18. When two non-coherent sources of intensity I_1 and I_2 superimpose, the resultant intensity at a general point will be:
(a) $I_1 + I_2$
(b) $I_1 - I_2$
(c) $I_1 . I_2$

(d) $I_1^2 + I_2^2$

19. In Young's double slit experiment if the slit widths are in the ratio 1:9, then the ratio of the intensity of maxima to minima will be:

(a) 9:1
(b) 3:1
(c) 4:1
(d) 25:16

20. If two coherent waves of same intensity I each superimpose then the intensity at a point where path difference is $\lambda/3$ will be:

(a) I
(b) 2I
(c) 3I
(d) I/3

21. Four independent waves are expressed as: (i) $y_1 = A_1 \sin \omega t$ (ii) $y_2 = A_2 \sin 2\omega t$ (iii) $y_3 = A_3 \cos \omega t$ (iv) $y_4 = A_4 \sin(\omega t + \pi/3)$. The interference between two of these waves is possible in:

(a) (i) and (iii) only
(b) (iii) and (iv) only
(c) (i), (iii) and (iv) only
(d) All of them

22. The shape of the interference fringes in Young's double-slit experiment, when the distance between the slit and the screen is very large as compared to the slit-separation, is nearly:

(a) straight
(b) parabolic
(c) circular
(d) hyperbolic

23. The angular width of interference fringes in Young's double-slit experiment depends on:

(a) distance between the slits and the screen only
(b) wavelength of light used only
(c) both wavelength of light used and the slits separation
(d) slits separation only

24. The phenomenon of interference is shown by:

(a) longitudinal mechanical wave only
(b) transverse mechanical wave only
(c) electromagnetic waves only
(d) all these waves

25. Assertion (A): Light added to light can produce darkness. Reason (R): When two coherent light waves interfere, there is darkness at the position of destructive interference.

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

26. The phase difference between the two superimposing waves that give rise to a bright spot in a Young's double-slit experiment is (n is an integer):

(a) $2n\pi$
(b) $2n\pi + \pi/2$
(c) $2n\pi + \pi/4$
(d) $2n\pi + \pi$

27. Assertion (A): In Young's double-slit experiment, the fringe width for dark and bright fringes is the same. Reason (R): Fringe width is given by $\beta = \lambda D/d$.

(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) Both A and R are false.

28. In a Young's double-slit experiment performed in a medium, when the whole apparatus is immersed in a liquid of refractive index greater than 1, the fringe pattern will:

(a) disappear
(b) become blurred
(c) be widened
(d) be compressed

29. Assertion (A): In double slit experiment if one slit is closed, diffraction pattern due to the other slit will appear on the screen. Reason (R): For interference, at least two waves are required.

(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) Both A and R are false.

30. Two coherent light waves, each having amplitude 'a', superpose to produce an interference pattern on a screen. The intensity of light as seen on the screen varies between:

(a) 0 and $2a^2$
(b) 0 and $4a^2$
(c) a^2 and $2a^2$
(d) $2a^2$ and $4a^2$

31. Two coherent waves, each of intensity I_0, produce an interference pattern on a screen. The average intensity of light on the screen is:

(a) zero
(b) I_0
(c) $2I_0$
(d) $4I_0$

32. Assertion (A): In interference and diffraction of light, light energy reduces in one region producing a dark fringe and increases in another producing a bright fringe. Reason (R): This happens because energy is not conserved in the phenomena of interference and diffraction.

(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 and R is false.
(d) Both A and R are false.

33. A Young's double-slit experimental set-up is kept in a medium of refractive index 3/2. Which maximum in this case will coincide with the 6th maximum obtained if the medium is replaced by air?

(a) 4th
(b) 6th
(c) 8th
(d) 10th

34. Assertion (A): In a Young's double-slit experiment, interference pattern is not observed when two coherent sources are infinitely close to each other. Reason (R): The fringe width is proportional to the separation between the two sources.

(a) Both A and R are true and R is 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) Both A and R are false.

35. In a Young's double-slit experiment in air, the fringe width is found to be 0.44 mm. If the entire setup is immersed in water ($\mu = 4/3$), the fringe width will be:

(a) 0.88 mm

(b) 0.59 mm

(c) 0.33 mm

(d) 0.44 mm

36. Assertion (A): The phase difference between any two points on a wavefront is zero. Reason (R): All points on a wavefront are at the same distance from the source and thus oscillate in the same phase.

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

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

(c) A is true, but R is false.

(d) A is false and R is also false.

37. A beam of light travels from air into a medium. Its speed and wavelength in the medium are 1.5×10^8 m/s and 230 nm respectively. The wavelength of light in air will be:

(a) 230 nm

(b) 345 nm

(c) 460 nm

(d) 690 nm

38. A plane wavefront is incident on a concave mirror of radius of curvature R. The radius of the reflected wavefront will be:

(a) 2R

(b) R

(c) R/2

(d) R/4

39. In an interference experiment, the third bright fringe is obtained at a point on the screen with light of 700 nm. What should be the wavelength of the light source in order to obtain the fifth bright fringe at the same point?

(a) 420 nm

(b) 750 nm

(c) 630 nm

(d) 500 nm

40. Assertion (A): In Young's double slit experiment all fringes are of equal width. Reason (R): The fringe width depends upon wavelength of light (λ), distance of screen from plane of slits (D), and slits separation (d).

(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 and R is false.

(d) A is false and R is also false.

Answer Key

1. d	2. c	3. a	4. a	5. d
6. a	7. c	8. d	9. c	10. a
11. b	12. b	13. a	14. d	15. c
16. b	17. d	18. a	19. d	20. a
21. c	22. a	23. c	24. d	25. a
26. a	27. a	28. d	29. c	30. b
31. c	32. c	33. a	34. b	35. c
36. a	37. c	38. c	39. c	40. a

Assignment -3

Assertion-Reason Type Questions

Directions: In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Choose the correct option from the codes given below.

Section A — Previous Year Questions (CBSE Board Papers)

1. Assertion (A): Light added to light can produce darkness.

Reason (R): When two coherent light waves interfere, there is darkness at the position of destructive interference.

(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.

[2026 • Set 55-2-1]

2. Assertion (A): In Young's double-slit experiment, the fringe width for dark and bright fringes is the same.

Reason (R): Fringe width is given by $\beta = \lambda D/d$, where symbols have their usual meanings.

(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.

[2026 • Set 55-5-1]

3. Assertion (A): In double slit experiment if one slit is closed, diffraction pattern due to the other slit will appear on the screen.

Reason (R): For interference, at least two waves are required.

(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.

[2025 • Set 55-4-1]

4. Assertion (A): In interference and diffraction of light, light energy reduces in one region producing a dark fringe. It increases in another region and produces a bright fringe.

Reason (R): This happens because energy is not conserved in the phenomena of interference and diffraction.

(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.

[2024 • Set 55-4-1]

5. Assertion (A): In a Young's double-slit experiment, interference pattern is not observed when two coherent sources are infinitely close to each other.

Reason (R): The fringe width is proportional to the separation between the two sources.

(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.

[2024 • Set 55-5-1]

6. Assertion (A): The phase difference between any two points on a wavefront is zero.

Reason (R): All points on a wavefront are at the same distance from the source and thus oscillate in the same phase.

(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.

[2023 • Set 55-1-1]

7. Assertion (A): In Young's double slit experiment all fringes are of equal width.

Reason (R): The fringe width depends upon wavelength of light (λ) used, distance of screen from plane of slits (D) and slits separation (d).

(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.

[2023 • Set 55-2-1]

Section B — Additional Practice Questions

(Composed in CBSE pattern for extra practice; not sourced from previous year board papers.)

8. Assertion (A): The angular width of the central maximum in a single-slit diffraction pattern increases when the slit width is decreased.

Reason (R): Diffraction effects become more pronounced when the slit width is decreased and made comparable to the wavelength of light.

(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.

9. Assertion (A): In Young's double-slit experiment, the fringe width is the same for successive bright and dark fringes.

Reason (R): The light used in the experiment is monochromatic.

(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.

10. Assertion (A): When white light is used in Young's double-slit experiment, the central fringe is white, with a few coloured fringes visible on either side before the pattern merges into general illumination.

Reason (R): Fringe width is directly proportional to the wavelength of light, so fringes of different colours have different widths and increasingly overlap away from the centre.

(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.

11. Assertion (A): The interference pattern in Young's double-slit experiment disappears if the widths of the two slits are made unequal.

Reason (R): Two slits of unequal width can no longer act as coherent sources.

(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.

12. Assertion (A): In Huygens' construction, the new wavefront is obtained as the envelope tangent to all the secondary wavelets.

Reason (R): In a homogeneous medium, the secondary wavelets originating from different points on a wavefront travel with different speeds.

(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.

Answer Key

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

Assignment -4

Case Study Based Questions

Case Study 1: Diffraction of Light at a Single Slit

Diffraction of light is the bending of light around the corners of an object whose size is comparable with the wavelength of light. Diffraction actually defines the limits of ray optics. This limit for optical instruments is set by the wavelength of light. An experimental arrangement is set up to observe the diffraction pattern due to a single slit.

Answer the following questions based on the above passage:

(a) How will the width of the central maximum be affected if the wavelength of light is increased? *[1]*

(b) Under what condition is the first minimum obtained in a single-slit diffraction pattern? *[1]*

(c) Write two points of difference between interference and diffraction patterns. *[2]*

OR

(c) Two students are separated by a 7 m partition wall in a room 10 m high. If both light and sound waves can bend around obstacles, how is it that the students are unable to see each other even though they can converse easily? *[2]*

[2023 • Set 55-3-1]

Case Study 2: Fringe Width in Young's Double Slit Experiment

(Composed in CBSE pattern for practice; not sourced from a previous year board paper.)

In Young's double slit experiment, two coherent sources derived from a single monochromatic source produce an interference pattern of alternate bright and dark fringes on a screen. The fringe width of this pattern depends on the wavelength of light used, the separation between the two slits, and the distance of the screen from the slits. Consider a Young's double slit experiment in which two slits separated by 1 mm are illuminated by monochromatic light of wavelength 500 nm, and the interference pattern is observed on a screen kept 1 m away from the slits.

Answer the following questions based on the above passage:

(a) Calculate the fringe width of the interference pattern obtained on the screen. *[1]*

(b) Find the distance of the 4th bright fringe from the central maximum. *[1]*

(c) If the entire experimental set-up is immersed in a liquid of refractive index 1.5, keeping all other parameters unchanged, find the new fringe width. *[2]*

OR

(c) If the width of one of the two slits is reduced so that it transmits less light than the other, how will the positions of the maxima and minima on the screen be affected? Justify your answer. *[2]*

Case Study 3: Coincidence of Fringes with Two Wavelengths

(Composed in CBSE pattern for practice; not sourced from a previous year board paper.)

When a beam of light containing two different wavelengths is used in Young's double slit experiment, each wavelength produces its own independent interference pattern with a fringe width proportional to that wavelength. At certain points on the screen, the bright fringes of both patterns coincide, producing an enhanced bright band; the least such distance from the central maximum can be found from the condition that the path differences for both wavelengths correspond to whole numbers of fringes. Consider a Young's double slit experiment where a beam of light consisting of two wavelengths, 600 nm and 750 nm, is incident on two slits separated by 0.5 mm, with the screen kept 1.5 m away from the slits.

Answer the following questions based on the above passage:

(a) Write the expression for the position of the nth bright fringe for a wavelength λ. *[1]*

(b) Find the fringe width for the wavelength 600 nm. *[1]*

(c) Calculate the least distance from the central maximum at which the bright fringes due to both the wavelengths coincide. *[2]*

OR

(c) What would happen to the interference pattern if the source of the two given wavelengths is replaced by a source of white light? *[2]*

Case Study 4: Huygens' Principle and Refraction of Wavefronts

(Composed in CBSE pattern for practice; not sourced from a previous year board paper.)

Huygens' principle states that every point on a wavefront acts as a source of secondary wavelets, which spread out in all directions with the speed of the wave in that medium. The new wavefront at any later instant is given by the envelope (forward surface of tangency) of these secondary wavelets. This principle can be used to derive and verify the laws of reflection and refraction of light without invoking a corpuscular picture of light. Consider a plane wavefront travelling in a rarer medium of refractive index n_1, incident obliquely on a plane surface separating it from a denser medium of refractive index n_2 ($n_2 > n_1$).

Answer the following questions based on the above passage:

(a) Define a wavefront. *[1]*

(b) What is the shape of the wavefront emerging from a convex lens when a plane wavefront is incident on it? *[1]*

(c) Using Huygens' construction of secondary wavelets, derive Snell's law of refraction for the situation described above. *[2]*

OR

(c) Why does the speed of light decrease when it travels from a rarer to a denser medium? Does this decrease in speed imply a reduction in the energy carried by the light wave? Explain. *[2]*

Answers

Case Study 1: Diffraction of Light at a Single Slit

(a) The width of the central maximum increases, since the angular width of the central maximum ($2\lambda/a$) is directly proportional to the wavelength λ.

(b) The first minimum is obtained when $a \sin\theta = \lambda$, i.e. when the path difference between waves from the two edges of the slit equals one wavelength.

(c) Any two: (i) In interference, all bright fringes are of equal intensity, whereas in diffraction the intensity of secondary maxima decreases rapidly with order. (ii) In interference, all fringes are of the same width, whereas in diffraction the central maximum is twice as wide as the secondary maxima.

OR (c) The wavelength of light ($\sim 10^{-7}$ m) is far smaller than the size of the partition wall, so diffraction of light around it is negligible and the students cannot see each other. The wavelength of sound (of the order of metres) is comparable to the size of the wall, so sound diffracts around it easily and they can converse.

Case Study 2: Fringe Width in Young's Double Slit Experiment

(a) $\beta = \lambda D/d = (500 \times 10^{-9} \times 1) / (1 \times 10^{-3}) = 5 \times 10^{-4}$ m = 0.5 mm.

(b) $x_4 = n\beta = 4 \times 0.5$ mm = 2 mm.

(c) New fringe width = β/μ = 0.5 mm / 1.5 ≈ 0.33 mm.

OR (c) The positions of the maxima and minima remain unchanged, since these depend only on the path difference (geometry of the set-up), not on the intensities of the two beams. However, the contrast of the pattern reduces — the minima are no longer perfectly dark, since I_{min} is no longer zero when the two interfering amplitudes are unequal.

Case Study 3: Coincidence of Fringes with Two Wavelengths

(a) $x_n = n\lambda D/d$, where n is the order of the bright fringe.

(b) $\beta_1 = \lambda_1 D/d = (600 \times 10^{-9} \times 1.5) / (0.5 \times 10^{-3}) = 1.8 \times 10^{-3}$ m = 1.8 mm.

(c) Coincidence requires $n_1\lambda_1 = n_2\lambda_2$, i.e. $n_1(600) = n_2(750)$, giving $n_1 : n_2 = 5 : 4$ (smallest integers). Least distance $x = n_1\lambda_1 D/d = (5 \times 600 \times 10^{-9} \times 1.5) / (0.5 \times 10^{-3}) = 9 \times 10^{-3}$ m = 9 mm.

OR (c) With white light, the central fringe remains white (all wavelengths interfere constructively at zero path difference). A few coloured fringes are seen on either side of it, and beyond that the fringes of different colours overlap and the pattern merges into general (uniform) illumination.

Case Study 4: Huygens' Principle and Refraction of Wavefronts

(a) A wavefront is the locus of all points of a medium that are vibrating in the same phase at a given instant of time.

(b) A spherical wavefront, converging towards the focal point of the lens.

(c) Using Huygens' construction for the incident wavefront AB, with secondary wavelets travelling at speeds v_1 (medium 1) and v_2 (medium 2) during time t, geometry of the resulting refracted wavefront gives $\sin i / \sin r = v_1 / v_2 = n_2 / n_1$, which is Snell's law: $n_1 \sin i = n_2 \sin r$.

OR (c) The speed decreases because light interacts with the atoms/molecules of the denser medium, which absorb and re-emit the wave with a time delay, effectively slowing its net progress. This decrease in speed does NOT imply a reduction in energy — the frequency of light remains unchanged on entering a new medium, and no energy is lost; only the wavelength and speed change.

Assignment -5

Assignment: Short Answer & Long Answer Questions

15 Short Answer Questions (2 marks each) • 5 Long Answer Questions (5 marks each)

Section A — Short Answer Type Questions

1. In a Young's double-slit experimental set-up with slit separation 0.6 mm, a beam of light consisting of two wavelengths 440 nm and 660 nm is used to obtain an interference pattern on a screen kept 1.5 m in front of the slits. Find the least distance of the point from the central maximum where the bright fringes due to both the wavelengths coincide. *[2]*

[2026 • Set 55-1-1]

2. In a Young's double-slit experiment, a beam of light consisting of two wavelengths 500 nm and 600 nm is used. The interference fringes are observed on a screen placed 1.8 m away from the plane of slits (slit separation 0.3 mm). Calculate the least distance from the central maximum where the bright fringes due to both the wavelengths coincide. *[2]*

[2026 • Set 55-2-1]

3. Explain why diffraction of sound is more common in daily experience than that of light. *[2]*

[2026 • Set 55-3-1]

4. In Young's double slit experiment, the central maximum is bright in the interference pattern obtained on a screen. What will happen when (a) light waves emitted from slits S_1 and S_2 have an initial phase difference of π radian? (b) one of the slits is closed? Justify your answers. *[2]*

[2026 • Set 55-3-3]

5. In a Young's double-slit experiment, two waves each of intensity I superpose on each other and produce an interference pattern. Prove that the resultant intensities at maxima and minima are 4I and zero respectively. *[2]*

[2026 • Set 55-5-2]

6. When monochromatic light is incident on a surface separating two media, the refracted and reflected light both have the same frequency as the incident frequency, but the wavelength of the refracted light is different. Explain why. *[2]*

[2026 • Set 55-5-3]

7. 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]*

[2025 • Set 55-2-3]

8. Write two differences between the patterns of a double-slit interference experiment and a single-slit diffraction experiment. *[2]*

[2025 • Set 55-7-1]

9. Light waves from two pinholes illuminated by two sodium lamps do not produce an interference pattern. Explain why. *[2]*

[2025 • Set 55-7-1]

10. The ratio of the intensities at maxima to minima in Young's double-slit experiment is 25 : 9. Calculate the ratio of intensities of the interfering waves. *[2]*

[2025 • Set 55-7-2]

11. In a Young's double-slit experiment, the intensity at the central maximum in the interference pattern on the screen is I_0. Find the intensity at a point on the screen where the path difference between the interfering waves is $\lambda/3$. *[2]*

[2025 • Set 55-7-3]

12. A beam of light consisting of a known wavelength 520 nm and an unknown wavelength λ, used in Young's double slit experiment, produces two interference patterns such that the fourth bright fringe of the unknown wavelength coincides with the fifth bright fringe of the known wavelength. Find the value of λ. *[2]*

[2024 • Set 55-1-1]

13. Write two points of difference between interference and diffraction of light. *[2]*

[2024 • Set 55-3-2]

14. What is a sustained or stable interference pattern? What are the conditions for obtaining such an interference pattern? *[2]*

[2024 • Set 55-3-3]

15. Two coherent monochromatic light beams of intensities I and 4I superpose each other. Find the ratio of the maximum and minimum intensities in the resulting beam. *[2]*

[2023 • Set 55-1-1]

Section B — Long Answer Type Questions

1. (i) A parallel beam of monochromatic light falls normally on a single slit of width 'a' and a diffraction pattern is observed on a screen placed at distance D from the slit. Explain: (I) the formation of maxima and minima in the diffraction pattern, and (II) why the maxima go on becoming weaker and weaker with increasing order (n). (ii) Write any two points of difference between the interference pattern due to a double-slit and the diffraction pattern due to a single-slit. *[5]*

[2026 • Set 55-5-1]

2. (i) Differentiate between a wavefront and a ray. (ii) State Huygens' principle and verify the laws of reflection using a suitable diagram. (iii) In Young's double slit experiment, the slits S_1 and S_2 are 3 mm apart and the screen is placed 1.0 m away from the slits. It is observed that the fourth bright fringe is at a distance of 5 mm from the second dark fringe. Find the wavelength of light used. *[5]*

[2024 • Set 55-4-1]

3. (i) A plane light wave propagating from a rarer into a denser medium is incident at an angle i on the surface separating the two media. Using Huygens' principle, draw the refracted wave and hence verify Snell's law of refraction. (ii) In a Young's double slit experiment, the slits are separated by 0.30 mm and the screen is kept 1.5 m away. The wavelength of light used is 600 nm. Calculate the distance between the central bright fringe and the 4th dark fringe. *[5]*

[2024 • Set 55-5-1]

4. (i) Write two points of difference between an interference pattern and a diffraction pattern, and name any two factors on which the fringe width in a Young's double-slit experiment depends. (ii) In Young's double-slit experiment, the two slits are separated by a distance equal to 100 times the wavelength of light that passes through the slits. Calculate: (1) the angular separation in radians between the central maximum and the adjacent maximum, and (2) the distance between these two maxima on a screen 50 cm from the slits. *[5]*

[2023 • Set 55-1-1]

5. Describe any two characteristic features which distinguish between interference and diffraction phenomena. Derive the expression for the intensity at a point of the interference pattern in Young's double slit experiment. *[5]*

[2019 • Set 55-1-1]

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PRACTICE QUESTION PAPER (CBSE PATTERN) — 2026-27

Subject: PHYSICS (Theory) | Class: XII

CHAPTER 10: WAVE OPTICS — MARKING SCHEME / STEPWISE SOLUTIONS

Maximum Marks: 70

SECTION A — Multiple Choice Questions (1 mark each) : Q1–Q16

Q1. Intensity ratio 4:1 → ratio of Imax to Imin

Given $I_1 : I_2 = 4 : 1$. Since intensity ∝ (amplitude)², the amplitude ratio is:

$a_1/a_2 = \sqrt{I_1/I_2} = \sqrt{4/1} = 2/1$

$I_{max}/I_{min} = (a_1 + a_2)^2 / (a_1 - a_2)^2$

$= (2+1)^2 / (2-1)^2 = 9/1$

Answer: (a) 9 : 1

Q2. Assertion–Reason: fringe width same for bright & dark fringes

Fringe width $\beta = \lambda D/d$ is a constant that depends only on λ, D and d — it does not depend on the fringe order n. Hence consecutive bright and dark fringes are equally spaced, i.e., A is true. R correctly explains why A is true.

Answer: (a) Both A and R are true, and R is the correct explanation of A.

Q3. Shape of wavefront from a point source

A point source emits light equally in all directions, so all points at a given instant that have travelled equal distance from the source lie on a sphere.

Answer: (b) spherical

Q4. Path difference for first minimum (single slit)

For the first minimum in single-slit diffraction, the wavelets from the two edges of the slit must have a path difference equal to one full wavelength (each half of the slit then cancels the other half point-by-point, with a phase difference of π between corresponding points).

Answer: (b) λ

Q5. Phase difference for a bright spot in YDSE

A bright fringe (constructive interference) occurs when the two waves arrive in phase, i.e., the phase difference is an integral multiple of 2π.

Answer: (A) 2nπ

Q6. Amplitude of secondary wavelets (Huygens' principle)

Huygens postulated (and it is confirmed by diffraction theory) that the amplitude of secondary wavelets is maximum in the forward direction and zero in the backward direction — this is why no back-wave is observed.

Answer: (b) maximum in the forward direction and zero in the backward direction

Q7. Path difference for a dark fringe in YDSE

A dark fringe (destructive interference) occurs when the path difference is an odd multiple of half a wavelength.

Answer: (b) (n + 1/2)λ

Q8. Light going from rarer (v1) to denser (v2) medium

Speed of light is higher in a rarer medium and lower in a denser medium (refractive index of denser medium is higher, and $v = c/n$).

Answer: (b) $v_1 > v_2$

Q9. Assertion–Reason: independent sodium lamps as coherent sources

Ordinary sources (like two separate sodium lamps) emit light with random, abrupt phase changes roughly every 10^{-10} s, so no fixed/stable phase relationship can exist between them. Hence they cannot act as coherent sources — A is true, and R correctly explains A.

Answer: (a) Both A and R are true, and R is the correct explanation of A.

Q10. Effect of doubling slit width on central maximum (diffraction)

Angular width of central maximum ∝ 1/a (slit width). Linear width on screen ∝ 2λD/a. If a is doubled, the width becomes half.

Answer: (b) half

Q11. Property of light demonstrated by the interference experiment

Interference (superposition producing alternating bright and dark fringes) can only be explained if light behaves as a wave; it is a direct demonstration of the wave nature of light.

Answer: (A) Wave nature of light

Q12. Effect of doubling screen distance D on fringe width

$\beta = \lambda D/d \;\Rightarrow\; \beta \propto D$

If D is doubled (d and λ unchanged), β also doubles.

Answer: (b) double

Q13. Quantity unchanged when light travels from air to glass

When light passes from one medium to another, its speed and wavelength change ($v = c/n$, $\lambda = \lambda 0/n$), but the frequency is determined by the source and remains unchanged.

Answer: (c) frequency

Q14. Assertion–Reason: energy redistribution in interference/diffraction

No energy is destroyed in interference/diffraction; energy that appears to be 'missing' from dark regions is simply transferred to and reappears in the bright regions, so total energy is conserved. R correctly explains A.

Answer: (a) Both A and R are true, and R is the correct explanation of A.

Q15. Effect of halving slit width on central maximum (diffraction)

Linear width of central maximum ∝ 1/a. If a is halved, the width doubles.

Answer: (B) twice

Q16. Why diffraction of sound is more noticeable than that of light

Diffraction becomes significant only when the size of the obstacle/opening is comparable to the wavelength. Sound waves have wavelengths of the order of metres (comparable to doors, walls, furniture), while light waves have wavelengths of the order of 10^{-7} m — far smaller than everyday objects — so light shows negligible diffraction in daily life.

Answer: (b) the wavelength of sound is comparable to the size of everyday obstacles/openings, unlike that of light

SECTION B — Very Short Answer Type (2 marks each) : Q17–Q21

Q17. Huygens' principle and absence of the back-wave

Huygens' Principle: (i) Every point on a wavefront acts as a source of new secondary wavelets, which spread out in all directions with the speed of the wave in that medium. (ii) The forward envelope (tangent surface) of these secondary wavelets at any later instant gives the new position of the wavefront.

Absence of back-wave: Huygens postulated that the amplitude of the secondary wavelets is maximum in the forward direction and zero in the backward direction. Since the amplitude in the backward direction is zero, no backward-travelling wavefront (back-wave) is formed.

Q18. Conditions for bright and dark fringes (in terms of path difference)

Let Δ be the path difference between the two interfering waves at a point on the screen, and n = 0, 1, 2, … :

(i) Bright fringe (constructive interference): $\Delta = n\lambda$

(ii) Dark fringe (destructive interference): $\Delta = (n + 1/2)\lambda$

OR

Two conditions for coherent sources:

1. The two sources must emit continuous light waves of the same frequency (or wavelength).
2. The two sources must maintain a constant (zero or otherwise fixed) phase difference with time.

(In practice this is achieved by deriving both sources from a single source, by division of wavefront or division of amplitude.)

Q19. Wavelength of light used, given d, D and β

Given: $d = 0.5$ mm $= 0.5 \times 10^{-3}$ m, $D = 1.0$ m, $\beta = 1.2$ mm $= 1.2 \times 10^{-3}$ m

$\beta = \lambda D/d \Rightarrow \lambda = \beta d/D$

$\lambda = (1.2 \times 10^{-3} \times 0.5 \times 10^{-3}) / 1.0$

$\lambda = 0.6 \times 10^{-6}$ m

Final Answer: $\lambda = 6 \times 10^{-7}$ m = 600 nm

Q20. Two differences: interference (YDSE) vs single-slit diffraction pattern

1. In interference, all bright fringes are (nearly) of the same intensity and equal width; in diffraction, the central maximum is much more intense and twice as wide as the secondary maxima, whose intensity falls off rapidly.
2. Interference occurs due to superposition of waves from two separate coherent sources (two narrow slits); diffraction occurs due to superposition of secondary wavelets originating from different parts of the same (single) wavefront.

Q21. Intensity after two polaroids with pass axes at 30°

Unpolarised light of intensity I0 passes through polaroid P1. The intensity emerging from the first polaroid is halved:

$I1 = I0 / 2$

This linearly polarised light of intensity I1 now falls on P2, whose pass axis is at $\theta = 30°$ to that of P1. By Malus' Law:

$I2 = I1 \cos^2\theta = (I0/2) \cos^2 30°$

$\cos 30° = \sqrt{3}/2 \Rightarrow \cos^2 30° = 3/4$

$I2 = (I0/2) \times (3/4) = 3I0/8$

Final Answer: I2 = 3I0 / 8

OR

Linearly polarised light: Light in which the electric field vector vibrates only along one fixed direction (a single straight line), perpendicular to the direction of propagation, is called linearly (plane) polarised light.

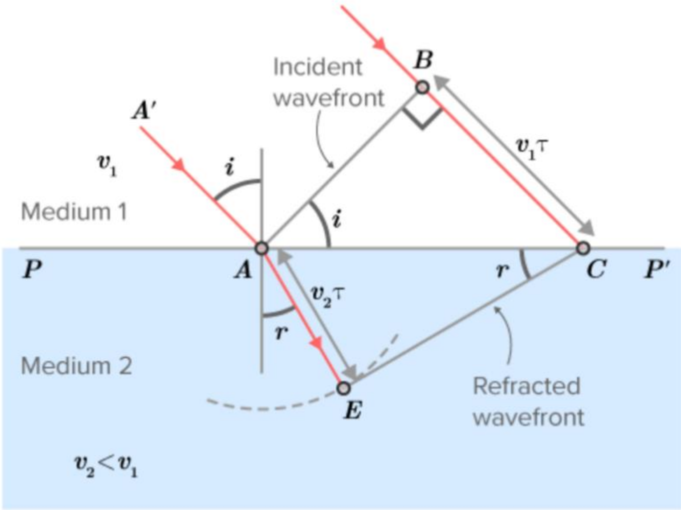
For zero emergent intensity, by Malus' Law, $I = I0 \cos^2\theta = 0$, which requires $\cos\theta = 0$, i.e.

Final Answer: θ = 90° (pass axes of the two polaroids must be mutually perpendicular / crossed)

SECTION C — Short Answer Type (3 marks each) : Q22–Q28

Q22. Huygens' construction for refraction — verification of Snell's law

Let PP' be a plane interface separating a rarer medium (speed v1) from a denser medium (speed v2), and let AB be a plane wavefront incident on it at angle i, as shown below.



Huygens' construction for refraction of a plane wavefront

The new refracted wavefront CD is the tangent (envelope) drawn from C to the secondary wavelet of radius v2t centred at B, so BD = v2t.

From right triangle ABC: sin i = BC / AC = v1t / AC

From right triangle BCD (with r = angle of refraction): sin r = BD / AC = v2t / AC

⇒ sin i / sin r = v1 / v2 = constant = n21 (refractive index of medium 2 with respect to medium 1)

Since v1 and v2 are constants for the two given media, sin i / sin r is a constant for the pair of media — this is exactly Snell's law of refraction.

Q23. YDSE with two wavelengths (600 nm and 480 nm)

Given: d = 1.0 mm = 1.0×10^{-3} m, D = 1.0 m, λ1 = 600 nm, λ2 = 480 nm

(a) Distance of the 3rd bright fringe for λ1 = 600 nm

xn = nλD/d

x3 = $(3 \times 600 \times 10^{-9} \times 1.0) / (1.0 \times 10^{-3}) = 1800 \times 10^{-6}$ m

Final Answer: x3 = 1.8×10^{-3} m = 1.8 mm

(b) Least distance where bright fringes of both wavelengths coincide

Bright fringes coincide when: n1λ1 = n2λ2 ⇒ n1 × 600 = n2 × 480 ⇒ n1/n2 = 480/600 = 4/5

Smallest integers satisfying this ratio: n1 = 4, n2 = 5

x = n1λ1D/d = $(4 \times 600 \times 10^{-9} \times 1.0) / (1.0 \times 10^{-3}) = 2400 \times 10^{-6}$ m

Final Answer: x = 2.4×10^{-3} m = 2.4 mm

Q24. Resultant intensity of two coherent waves — derivation

Given: y1 = a cos ωt and y2 = a cos(ωt + φ). By the principle of superposition:

y = y1 + y2 = a cos ωt + a cos(ωt + φ)

This can be written in the form y = A cos(ωt + θ), where, expanding cos(ωt+φ) and collecting cos ωt and sin ωt terms:

A cosθ = a(1 + cosφ)   and   A sinθ = a sinφ

Squaring and adding:

$A^2 = a^2(1+\cos\varphi)^2 + a^2 \sin^2\varphi = a^2[2 + 2\cos\varphi] = 2a^2(1+\cos\varphi)$

Using the identity $1 + \cos\varphi = 2\cos^2(\varphi/2)$:

$A^2 = 4a^2 \cos^2(\varphi/2)$

Since intensity $I \propto (\text{amplitude})^2$, and $I_0 \propto a^2$ is the intensity due to each wave acting alone:

Final Answer: $I = 4I_0 \cos^2(\varphi/2)$

(i) Condition for maximum intensity: $\cos^2(\varphi/2) = 1 \Rightarrow \varphi/2 = n\pi \Rightarrow \varphi = 2n\pi$ ($n = 0, \pm1, \pm2, \ldots$), giving $I_{max} = 4I_0$

(ii) Condition for minimum intensity: $\cos^2(\varphi/2) = 0 \Rightarrow \varphi/2 = (2n+1)\pi/2 \Rightarrow \varphi = (2n+1)\pi$, giving $I_{min} = 0$

Q25. Single-slit diffraction — angular positions of first minimum and first secondary maximum

Given: $\lambda = 500$ nm $= 5 \times 10^{-7}$ m, $a = 0.20$ mm $= 2 \times 10^{-4}$ m

(i) First minimum

$a \sin\theta = \lambda \Rightarrow \sin\theta = \lambda/a$

$\sin\theta = (5 \times 10^{-7})/(2 \times 10^{-4}) = 2.5 \times 10^{-3}$

Since θ is very small, $\sin\theta \approx \theta$ (in radians)

Final Answer: $\theta_1 = 2.5 \times 10^{-3}$ rad

(ii) First secondary maximum

$a \sin\theta = (n + 1/2)\lambda$, with $n = 1 \Rightarrow a \sin\theta = 3\lambda/2$

$\sin\theta = 3\lambda/2a = (3 \times 5 \times 10^{-7})/(2 \times 2 \times 10^{-4}) = (15 \times 10^{-7})/(4 \times 10^{-4})$

Final Answer: $\theta = 3.75 \times 10^{-3}$ rad

OR

Formation of diffraction pattern (Huygens' construction, single slit): When a plane wavefront falls normally on a narrow slit AB of width a, every point of the unblocked wavefront within the slit acts as a source of secondary wavelets (Huygens' principle). These wavelets travelling straight ahead ($\theta = 0$) all reach the screen in phase and reinforce to give a bright central maximum.

For wavelets travelling at an angle θ to the normal, the wavelets from different parts of the slit travel different path lengths to reach a point on the screen. When the path difference between wavelets from the two edges of the slit equals λ (i.e. $a \sin\theta = \lambda$), the slit can be divided into two halves such that corresponding points in the two halves have a path difference of $\lambda/2$ and cancel each other pairwise — producing the first minimum. Similarly, minima occur at $a \sin\theta = n\lambda$, and secondary (weaker) maxima appear roughly midway between successive minima, where the cancellation is incomplete.

Q26. Brewster's angle and refractive index

$y_1 = a \cos \omega t$, $y_2 = a \cos(\omega t + \varphi)$

Resultant displacement (superposition):

$y = y_1 + y_2 = 2a \cos(\varphi/2) \cdot \cos(\omega t + \varphi/2)$

So resultant amplitude $R = 2a \cos(\varphi/2)$

Intensity ($I \propto \text{amplitude}^2$, with $I_0 \propto a^2$):

$I \propto R^2 = 4a^2\cos^2(\varphi/2)$

$\mathbf{I = 4I_0 \cos^2(\varphi/2)}$

Constructive interference ($I_{max} = 4I_0$):

$\cos^2(\varphi/2) = 1 \Longrightarrow \varphi = 2n\pi \Longrightarrow$ path difference $\mathbf{\Delta = n\lambda}$ ($n = 0, 1, 2, \ldots$)

Destructive interference ($I_{min} = 0$):

$\cos^2(\varphi/2) = 0 \Longrightarrow \varphi = (2n+1)\pi \Longrightarrow$ path difference $\mathbf{\Delta = (n + \frac{1}{2})\lambda}$

Q27. Three differences: YDSE interference pattern vs single-slit diffraction pattern

Interference (YDSE)	Diffraction (single slit)
All bright fringes are of (nearly) equal width and equal intensity.	The central maximum is much brighter and twice as wide as the secondary maxima; intensity of secondary maxima falls off rapidly.
Arises from superposition of waves from two separate coherent sources (two narrow slits).	Arises from superposition of secondary wavelets from different parts of the same (single) wavefront.
Minima are perfectly dark (zero intensity) at all points where path difference = $(n+1/2)\lambda$.	Minima are also dark, but the region between minima (secondary maxima) never regains the brightness of the central maximum.

Q28. Fringe width when YDSE set-up is immersed in a liquid

Given: fringe width in air, $\beta = 0.4$ mm; refractive index of liquid, $\mu = 1.6$

When the set-up is immersed in a medium of refractive index μ, the wavelength of light decreases:

$\lambda' = \lambda/\mu$

Since $\beta = \lambda D/d$, the new fringe width is:

$\beta' = \lambda' D/d = (\lambda/\mu)(D/d) = \beta/\mu$

$\beta' = 0.4 \text{ mm} / 1.6$

Final Answer: $\beta' = 0.25$ mm

Shift of central maximum: The central maximum occurs where the path difference between the two waves is zero — this condition (equal path lengths from S1 and S2) is unaffected by changing the surrounding medium, since both paths change by the same factor. Hence the position of the central maximum does not shift.

SECTION D — Case Study Based Questions (4 marks each) : Q29–Q30

Q29. YDSE case study — d = 2 mm, λ = 600 nm, D = 3 m

Given: $d = 2 \text{ mm} = 2 \times 10^{-3}$ m, $\lambda = 600 \text{ nm} = 6 \times 10^{-7}$ m, $D = 3$ m

(a) Fringe width

$\beta = \lambda D/d = (6 \times 10^{-7} \times 3) / (2 \times 10^{-3})$

$\beta = (18 \times 10^{-7}) / (2 \times 10^{-3}) = 9 \times 10^{-4}$ m

Final Answer: $\beta = 0.9$ mm

(b) Distance of 4th bright fringe from central maximum

$x4 = 4\beta = 4 \times 0.9 \text{ mm}$

Final Answer: x4 = 3.6 mm

(c) Effect of moving the screen closer

Since $\beta = \lambda D/d$, $\beta \propto D$. If the screen is moved closer, D decreases, so the fringe width decreases (fringes come closer together).

(d) One slit completely closed

With only one slit open, there are no longer two coherent sources to interfere. The pattern on the screen changes from an interference pattern (equally spaced fringes) to a single-slit diffraction pattern — a wide, bright central maximum flanked by much weaker, unequally spaced secondary maxima.

Q30. Single-slit diffraction case study

(a) Condition for the nth secondary minimum

Final Answer: $a \sin\theta n = n\lambda$, where n = 1, 2, 3, …

(b) Effect of decreasing slit width 'a' on angular width of central maximum

Angular width of central maximum = 2λ/a, i.e., it is inversely proportional to a. If a is decreased, the angular width of the central maximum increases (the pattern spreads out more).

(c) Intensity of secondary maxima compared to central maximum

The secondary maxima are much less intense than the central maximum, and their intensity decreases rapidly as the order n increases (the intensity of the central maximum is roughly 20 times that of the first secondary maximum, and falls further for higher orders).

OR

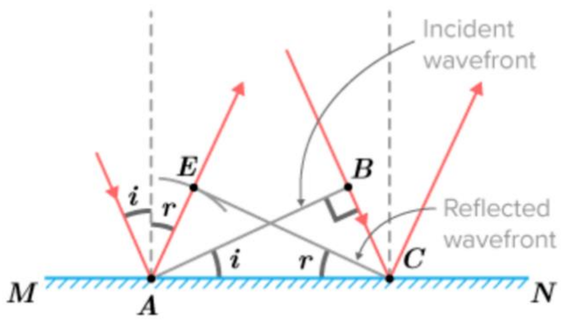
(c) Why two students can converse but not see each other across the wall

Sound waves have wavelengths of the order of metres — comparable to the height/width of the wall and gap between the students — so sound diffracts (bends) strongly around the wall and reaches both students, allowing them to hear each other.

Light waves have a wavelength of only about 5×10^{-7} m, which is negligibly small compared to the size of the wall. Diffraction of light around such a large obstacle is insignificant, so light travels essentially in straight lines and cannot bend around the wall — hence the students cannot see each other.

SECTION E — Long Answer Type (5 marks each) : Q31–Q33

Q31 (a). Huygens' principle, reflection construction (3 marks)



Let v be the speed of the wave in this medium. Suppose the wavefront advances from B to C during time τ, so

$$BC = v\tau.$$

To construct the reflected wavefront, we draw a sphere of radius $v\tau$ from point A. From point C, draw a tangent CE to this sphere. The new reflected wavefront is CE.

To prove that the **law of reflection** holds, we consider the triangles BAC and ECA.

- Both triangles have right angles:
$$\angle ABC = \angle CEA = 90°,$$
since wavefronts are perpendicular to the direction of propagation.
- Side AC is common to both triangles.
- By construction,
$$BC = AE = v\tau,$$
which is the distance travelled by the wavefront from B to C and by the secondary wavelet from A to E during time τ.

By the **RHS (Right-angle, Hypotenuse, Side)** congruence rule,

$$\triangle BAC \cong \triangle ECA.$$

Therefore, the corresponding angles are equal.

The angle of incidence is

$$i = \angle BAC,$$

and the angle of reflection is

$$r = \angle ECA.$$

Hence,

$$\angle BAC = \angle ECA$$

or,

$$i = r.$$

This is the **law of reflection**, which states that the angle of incidence is equal to the angle of reflection.

Q31 (b). Speed of light in glass; dispersion (2 marks)

Given $\mu = 1.5$, $c = 3 \times 10^8$ m/s

$v = c/\mu = (3 \times 10^8)/1.5$

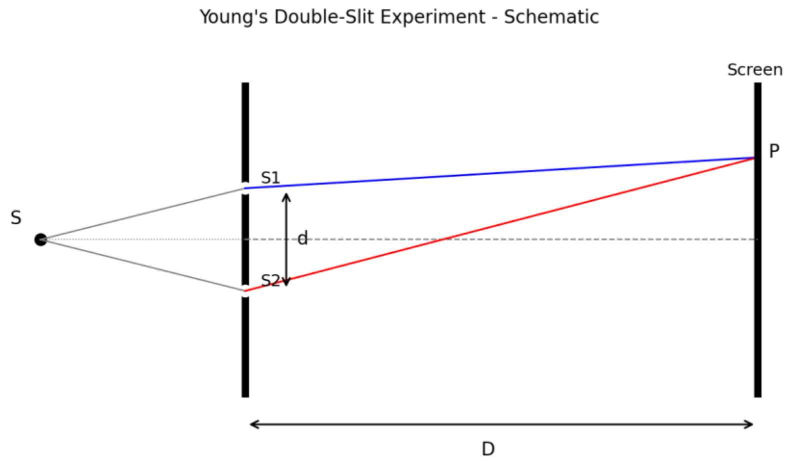
Final Answer: $v = 2 \times 10^8$ m/s

The speed of light in glass is NOT independent of colour, because the refractive index of glass depends on wavelength (a phenomenon called dispersion). Refractive index is higher for violet light than for red light (shorter wavelength → higher μ). Since $v = c/\mu$, a higher μ means a lower speed.

Final Answer: Violet light travels slower than red light in a glass prism (since $\mu_{violet} > \mu_{red}$).

Q32 (a). Young's double-slit experiment — description and derivation of fringe width (3 marks)

Description: Monochromatic light from a narrow source S falls on two narrow, closely spaced, parallel slits S1 and S2 (separation d), which act as coherent sources (since both are illuminated by the same wavefront). The light from S1 and S2 overlaps on a screen placed at distance D from the slits, producing alternating bright and dark fringes due to constructive and destructive interference.



Schematic of Young's Double-Slit Experiment

Derivation of fringe width: Let P be a point on the screen at distance x from the central point O (on the perpendicular bisector of S1S2). For D >> d, x, the path difference between the two waves reaching P is:

$\Delta = S_2P - S_1P \approx xd/D$

For the nth bright fringe, $\Delta = n\lambda$:

$x_n = n\lambda D/d$

Fringe width = distance between two consecutive bright (or dark) fringes:

$\beta = x_{(n+1)} - x_n = \lambda D/d$

Q32 (b). Wavelength from YDSE data (2 marks)

Given: $d = 0.28$ mm $= 2.8 \times 10^{-4}$ m, $D = 1.4$ m, $x_4 = 1.2$ cm $= 1.2 \times 10^{-2}$ m (distance of 4th bright fringe from centre)

$x_4 = 4\lambda D/d \Rightarrow \lambda = x_4 \cdot d / (4D)$

$\lambda = (1.2 \times 10^{-2} \times 2.8 \times 10^{-4}) / (4 \times 1.4)$

$\lambda = (3.36 \times 10^{-6}) / 5.6$

Final Answer: $\lambda = 6 \times 10^{-7}$ m = 600 nm

Q32 OR (a). Resultant intensity of two coherent waves — derivation (3 marks)

(Derivation identical in method to Q24.) For two coherent waves of the same amplitude a and phase difference φ:

$y = y_1 + y_2 = A \cos(\omega t + \theta)$, with $A^2 = 2a^2(1 + \cos\varphi) = 4a^2\cos^2(\varphi/2)$

Since intensity $I \propto (\text{amplitude})^2$, and $I_0 \propto a^2$ is the intensity due to one wave alone:

Final Answer: $I = 4I_0 \cos^2(\varphi/2)$

Constructive interference (maximum): $\varphi = 2n\pi$ ($n = 0, 1, 2, \ldots$), giving $I_{max} = 4I_0$

Destructive interference (minimum): $\varphi = (2n+1)\pi$, giving $I_{min} = 0$

Q32 OR (b). Intensity at path difference λ/3, given intensity K at path difference λ (2 marks)

At path difference λ, phase difference $\varphi_1 = (2\pi/\lambda) \times \lambda = 2\pi$ (fully constructive)

$I(\varphi_1) = 4I_0 \cos^2(\pi) = 4I_0 = K \Rightarrow I_0 = K/4$

At path difference $\lambda/3$, phase difference $\varphi_2 = (2\pi/\lambda) \times (\lambda/3) = 2\pi/3$

$I = 4I_0 \cos^2(\varphi_2/2) = 4I_0 \cos^2(\pi/3)$

$\cos(\pi/3) = 1/2 \Rightarrow \cos^2(\pi/3) = 1/4$

$I = 4I_0 \times (1/4) = I_0 = K/4$

Final Answer: $I = K/4$

Q33 (a). Single-slit diffraction — Huygens' explanation, minima condition, and weakening of secondary maxima (3 marks)

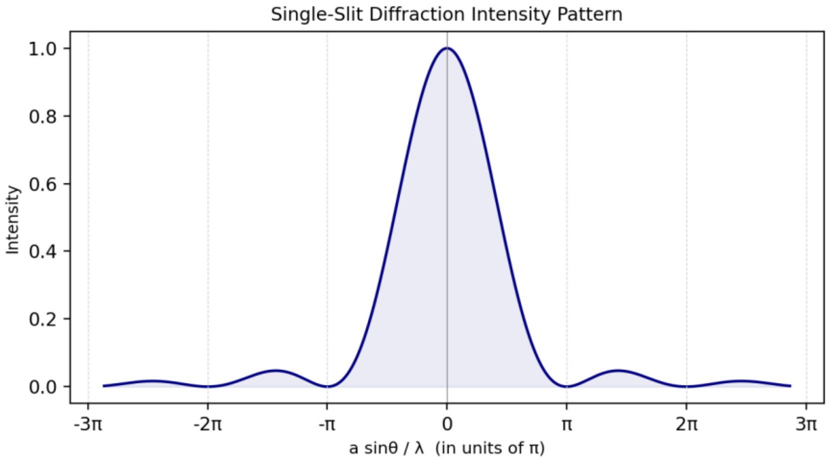
Formation of the pattern: When a plane wavefront falls normally on a narrow slit of width a, every point of the wavefront within the slit becomes a source of secondary wavelets (Huygens' principle), which spread out and superpose on a distant screen.

Straight-ahead wavelets ($\theta = 0$) all travel equal path lengths and arrive in phase, reinforcing to give an intense central maximum.

For wavelets diffracted at angle θ, consider the path difference between wavelets from the two edges of the slit: $a \sin\theta$. If $a \sin\theta = \lambda$, the slit can be divided into two equal halves such that, for every point in the upper half, there is a corresponding point in the lower half whose path difference is $\lambda/2$ — these pairs cancel completely, producing a minimum. In general:

Final Answer: Minima occur at: $a \sin\theta_n = n\lambda$, $n = 1, 2, 3, \ldots$

Weakening of secondary maxima: At larger angles corresponding to secondary maxima, the slit can be divided into 3, 5, 7, … (odd number of) equal parts. Wavelets from adjacent parts are out of phase and cancel in pairs, leaving only the contribution of one unpaired part as the net (uncancelled) amplitude. As the order n increases, the slit is divided into more parts, so a progressively smaller fraction of the amplitude remains uncancelled — hence the intensity of secondary maxima decreases rapidly with increasing order n.



Intensity distribution in single-slit diffraction — central maximum and weakening secondary maxima

Q33 (b). Linear width of central maximum (2 marks)

Given: $a = 0.30$ mm $= 3 \times 10^{-4}$ m, $\lambda = 600$ nm $= 6 \times 10^{-7}$ m, $D = 2$ m

Linear width of central maximum:

$W = 2\lambda D/a$

$W = (2 \times 6 \times 10^{-7} \times 2) / (3 \times 10^{-4})$

$W = (24 \times 10^{-7}) / (3 \times 10^{-4})$

Final Answer: $W = 8 \times 10^{-3}$ m $= 8$ mm

— END OF SOLUTIONS —

Class XII Physics — Wave Optics

MCQ Solutions with Detailed Reasoning

1. If one slit of Young's double slit apparatus is blocked, such that it transmits no light, which of the following will occur?

Solution: With one slit blocked, there are no longer two coherent waves to interfere, so the interference pattern (alternating bright and dark fringes) disappears. Light now reaches the screen only from the single open slit, producing a broad single-slit diffraction pattern with fairly uniform illumination. The bright fringes lose the extra constructive build-up they had from two-slit interference, so their intensity decreases; the dark fringes, which were dark only because of destructive interference, now receive light from the open slit, so their intensity increases.

Correct Answer: (b) The dark lines will increase in intensity and the bright lines will decrease in intensity

2. In YDSE with white source of light, if one slit is covered with green filter and the other with red filter, what will be observed on the screen?

Solution: Sustained interference requires the two waves reaching a point to have the same frequency (wavelength) with a constant phase relationship. Red and green light have different wavelengths, so the two beams can never maintain a fixed phase relationship suitable for interference. Hence no stable interference fringes are formed; the screen simply shows a mixed illumination from the two independent beams.

Correct Answer: (c) No interference

3. Red light is used in single slit diffraction experiment with slit width 0.1 mm. If red light is replaced by UV light then what will you observe?

Solution: The angular half-width of the central maximum in single-slit diffraction is given by $\sin\theta = \lambda/a$, so the width of the central maximum is directly proportional to the wavelength λ. UV light has a much shorter wavelength than red light, so for the same slit width the central maximum becomes narrower.

Correct Answer: (a) That the central maxima is narrower

4. In the diffraction from a single slit if slit width is halved, the width of central maximum will become:

Solution: The linear width of the central maximum on the screen is given by $2\lambda D/a$, which is inversely proportional to the slit width a. If the slit width a is halved, the width of the central maximum doubles.

Correct Answer: (a) twice

5. In Young's double-slit experiment, the wavelength of light was changed from 6000 Å to 3000 Å, while doubling the separation between the slits. Which of the following is not true for this experiment?

Solution: Fringe width is $\beta = \lambda D/d$, and this same formula gives the spacing of both bright and dark fringes (dark fringes lie exactly midway between consecutive bright fringes, so they share the same periodicity β). Here λ is halved (6000→3000 Å) and d is doubled, so the new fringe width becomes $\beta' = (\lambda/2)D/(2d) = \beta/4$ — one-quarter of the original. Since β decreases, the spacing of the bright fringes changes, the colour of the fringes changes (due to the changed wavelength), and — because dark fringes use the same β — their separation changes too. Therefore the statement that the separation between successive dark fringes 'remains unchanged' is false.

Correct Answer: (d) The separation between successive dark fringes remains unchanged.

6. A Young's double slit experiment is performed with a mixture of three colours red, green and blue.

Solution: At the central point of the screen, the path difference for light coming from the two slits is zero for every wavelength simultaneously. Since zero path difference means constructive interference regardless of λ, red, green and blue all form a bright fringe exactly at the centre, and their superposition is perceived as white light.

Correct Answer: (a) The central fringe will be white.

7. What will be the shape of interference fringe if we use two pin hole sources in the place of two slits?

Solution: A slit is effectively a line source, so loci of constant path difference from two slits are straight lines (nearly), giving straight-line fringes. A pinhole, however, is a point source in all directions, so the locus of points having a constant path difference from two point sources is a hyperbola (with the screen usually intersecting these hyperbolic surfaces to give near-circular fringes on a screen perpendicular to the axis). Two-pinhole interference fringes are therefore circular (concentric rings) rather than straight lines.

Correct Answer: (a) circular

8. Which of the following phenomena is not explained by wave theory of light?

Solution: Reflection, refraction, and polarization are all fully explained using the wave picture of light (Huygens' principle explains reflection/refraction, and polarization is a direct proof that light is a transverse wave). The photoelectric effect, however, requires that light be treated as discrete quanta (photons) — the instantaneous emission of photoelectrons and the existence of a threshold frequency cannot be explained by the classical wave theory, which predicts a time lag and no threshold frequency.

Correct Answer: (d) Photoelectric effect

9. The principle of superposition of waves is applicable to:

Solution: The principle of superposition states that when two or more waves overlap in a medium, the resultant displacement at any point is the vector (or scalar, for one dimension) sum of the displacements due to each wave acting alone. This principle follows from the linearity of the wave equation and holds for any type of wave — mechanical or electromagnetic, transverse or longitudinal.

Correct Answer: (c) Both longitudinal and transverse waves

10. In Young's double-slit experiment, the fringe width is:

Solution: Fringe width is given by $\beta = \lambda D/d$, where λ is the wavelength of light, D is the distance from slits to screen, and d is the slit separation. From this formula, β is directly proportional to λ, and inversely proportional to d (not directly proportional to it), and directly proportional to D (not inversely).

Correct Answer: (a) Directly proportional to the wavelength of light

11. When light is reflected its phase:

Solution: By Stokes' treatment of reflection (and as required for energy conservation at an interface), when light reflects off a medium of higher refractive index (an optically denser medium), it undergoes an abrupt phase change of π (equivalent to a path difference of $\lambda/2$). This is the basis of the extra path difference used in analysing thin-film interference and Newton's rings for reflected light. (No such phase change occurs on reflection from a rarer medium.)

Correct Answer: (b) changes by π

12. The angular width of the central maximum in a single-slit diffraction pattern is:

Solution: The angular half-width of the central maximum satisfies $\sin\theta = \lambda/a$, so the (angular) width $2\theta \approx 2\lambda/a$ for small θ. This shows the angular width is directly proportional to wavelength λ and inversely proportional to the slit width a.

Correct Answer: (b) Inversely proportional to the slit width

13. In a double-slit experiment, if the wavelength of light used is increased, the fringe separation:
Solution: Fringe separation is $\beta = \lambda D/d$. Since D and d are fixed by the experimental setup, β is directly proportional to λ. Increasing the wavelength therefore increases the fringe separation.
Correct Answer: (a) Increases

14. Which of the following colours of light has the shortest wavelength?
Solution: In the visible spectrum, wavelength increases in the order violet < blue < green < yellow < orange < red. Among the given options (red, yellow, green, blue), blue has the shortest wavelength.
Correct Answer: (d) Blue

15. The term 'coherent sources' refers to sources that emit light waves which are:
Solution: Two sources are called coherent if they maintain a constant phase difference between the waves they emit (they need not necessarily have exactly the same amplitude). This constant phase relationship is essential for the formation of a stable, observable interference pattern, since a randomly varying phase difference would wash out the fringes over time.
Correct Answer: (c) In phase or have a constant phase difference

16. The intensity of light at a point in an interference pattern is directly proportional to:
Solution: For a wave, the energy transported (and hence the intensity observed) is proportional to the square of the amplitude of oscillation, i.e., $I \propto A^2$. This relationship is the basis of the intensity formula used in interference, $I = I_1 + I_2 + 2\sqrt{(I_1 I_2)}\cos\varphi$.
Correct Answer: (b) The square of the amplitude of light waves

17. The condition for constructive interference in thin films is that the path difference should be:
Solution: For thin-film interference (as commonly analysed at the level of this chapter, accounting for the phase reversal that occurs on reflection at the film's upper, denser-medium surface), the effective optical path difference for constructive (bright-fringe) interference works out to an integral multiple of half the wavelength.
Correct Answer: (d) An integral multiple of half-wavelength

18. When two non-coherent sources of intensity I_1 and I_2 superimpose, the resultant intensity at a general point will be:
Solution: For coherent sources the resultant intensity includes an interference term: $I = I_1 + I_2 + 2\sqrt{(I_1 I_2)}\cos\varphi$. For non-coherent sources, the phase difference φ varies randomly and rapidly with time, so the average value of the $\cos\varphi$ term over any observation time is zero. The resultant (time-averaged, observed) intensity therefore simply reduces to the sum of the individual intensities, with no interference pattern.
Correct Answer: (a) $I_1 + I_2$

19. In Young's double slit experiment if the slit widths are in the ratio 1:9, then the ratio of the intensity of maxima to minima will be:
Solution: The amplitude of light diffracted from a slit is proportional to the slit width, so widths in ratio 1:9 give amplitudes in ratio $a_1:a_2 = 1:9$. At a maximum the amplitudes add; at a minimum they subtract: $I_{max}/I_{min} = (a_1+a_2)^2/(a_1-a_2)^2 = (1+9)^2/(9-1)^2 = 100/64 = 25/16$.
Correct Answer: (d) 25:16

20. If two coherent waves of same intensity I each superimpose then the intensity at a point where path difference is $\lambda/3$ will be:
Solution: Phase difference corresponding to a path difference of $\lambda/3$ is $\varphi = (2\pi/\lambda)(\lambda/3) = 2\pi/3$. For two waves of equal intensity I, the resultant intensity is $I_R = 4I \cos^2(\varphi/2) = 4I \cos^2(\pi/3) = 4I \times (1/2)^2 = 4I \times 1/4 = I$.
Correct Answer: (a) I

21. Four independent waves are expressed as: (i) $y_1 = A_1\sin \omega t$ (ii) $y_2 = A_2\sin 2\omega t$ (iii) $y_3 = A_3\cos \omega t$ (iv) $y_4 = A_4\sin(\omega t + \pi/3)$. The interference between two of these waves is possible in:

Solution: Sustained interference requires the waves to have the same frequency and a constant (time-independent) phase difference. Waves (i), (iii), and (iv) all have the same angular frequency ω, so any pair among them maintains a fixed phase difference and can interfere. Wave (ii) has a different angular frequency (2ω), so it cannot maintain a constant phase relationship with any of the others and cannot show sustained interference with them.

Correct Answer: (c) (i), (iii) and (iv) only

22. The shape of the interference fringes in Young's double-slit experiment, when the distance between the slit and the screen is very large as compared to the slit-separation, is nearly:

Solution: In general, loci of constant path difference from two point/line sources are hyperbolas. However, when the screen distance D is very large compared to the slit separation d, the curvature of these hyperbolic loci over the small region of the screen actually illuminated becomes negligible, and the fringes appear as (nearly) straight, equally-spaced parallel lines — which is exactly the standard YDSE approximation used to derive $\beta = \lambda D/d$.

Correct Answer: (a) straight

23. The angular width of interference fringes in Young's double-slit experiment depends on:

Solution: Angular fringe width is $\theta = \beta/D = (\lambda D/d)/D = \lambda/d$. This depends only on the wavelength λ of light used and the slit separation d — the screen distance D cancels out of the angular width, even though it affects the linear fringe width β.

Correct Answer: (c) both wavelength of light used and the slits separation

24. The phenomenon of interference is shown by:

Solution: Interference results purely from the superposition of coherent waves, a property of wave motion in general. It is not restricted to any particular type of wave — it is observed with mechanical longitudinal waves (e.g., sound), mechanical transverse waves (e.g., waves on a string or water surface), and electromagnetic waves (e.g., light), as long as coherent sources are available.

Correct Answer: (d) all these waves

25. Assertion (A): Light added to light can produce darkness. Reason (R): When two coherent light waves interfere, there is darkness at the position of destructive interference.

Solution: Both statements are correct physics: at points of destructive interference, two coherent light waves arrive out of phase (path difference = odd multiple of $\lambda/2$) and their amplitudes cancel, producing darkness even though light is being added from two sources. This directly demonstrates Assertion A, and the Reason correctly explains why it happens.

Correct Answer: (a) Both A and R are true and R is the correct explanation of A.

26. The phase difference between the two superimposing waves that give rise to a bright spot in a Young's double-slit experiment is (n is an integer):

Solution: A bright fringe (constructive interference) occurs when the path difference between the two waves is an integral multiple of the wavelength, i.e., $\Delta x = n\lambda$. Converting to phase difference using $\varphi = (2\pi/\lambda)\Delta x$ gives $\varphi = 2n\pi$, i.e., an integral multiple of 2π (the waves arrive exactly in phase).

Correct Answer: (a) $2n\pi$

27. Assertion (A): In Young's double-slit experiment, the fringe width for dark and bright fringes is the same. Reason (R): Fringe width is given by $\beta = \lambda D/d$.

Solution: Bright and dark fringes alternate at equal intervals, each separated by $\beta = \lambda D/d$, because both bright fringes (path difference $n\lambda$) and dark fringes (path difference $(2n+1)\lambda/2$) are equally spaced with the same periodicity β on the screen. So Assertion A is true, and the formula in Reason R correctly explains why this uniform spacing arises.

Correct Answer: (a) Both A and R are true and R is the correct explanation of A.

28. In a Young's double-slit experiment performed in a medium, when the whole apparatus is immersed in a liquid of refractive index greater than 1, the fringe pattern will:

Solution: The wavelength of light inside a medium of refractive index μ reduces to $\lambda\_medium = \lambda\_air/\mu$. Since fringe width $\beta = \lambda D/d$, and only λ changes here (D and d are geometrical and unaffected), β decreases by the same factor μ. A smaller β means the fringes are more closely spaced, i.e., the fringe pattern gets compressed.

Correct Answer: (d) be compressed

29. Assertion (A): In double slit experiment if one slit is closed, diffraction pattern due to the other slit will appear on the screen. Reason (R): For interference, at least two waves are required.

Solution: Assertion A is correct: with only one slit open, light from that slit alone produces the familiar single-slit diffraction pattern (a broad central maximum with weaker side maxima), not a two-slit interference pattern. Reason R, while stating a fact about interference in general, does not correctly explain why closing one slit produces a diffraction (not interference) pattern — the appearance of diffraction from a single slit has nothing to do with the two-wave requirement for interference, so R does not logically account for A. On strict reading in this context R is taken as not a valid explanation here.

Correct Answer: (c) A is true, but R is false.

30. Two coherent light waves, each having amplitude 'a', superpose to produce an interference pattern on a screen. The intensity of light as seen on the screen varies between:

Solution: For two coherent waves of equal amplitude a, the resultant amplitude ranges from $(a - a) = 0$ at points of complete destructive interference to $(a + a) = 2a$ at points of complete constructive interference. Since intensity $\propto$ (amplitude)^2, the intensity varies from $0^2 = 0$ to $(2a)^2 = 4a^2$.

Correct Answer: (b) 0 and $4a^2$

31. Two coherent waves, each of intensity I_0, produce an interference pattern on a screen. The average intensity of light on the screen is:

Solution: The intensity at a general point is $I = I_0 + I_0 + 2\sqrt{(I_0 I_0)}\cos\varphi = 2I_0(1 + \cos\varphi)$. Averaged over all values of the phase difference φ (i.e., over the whole fringe pattern), the average of $\cos\varphi$ is zero, so the average intensity is $2I_0$ — simply the sum of the two individual intensities, confirming that interference redistributes energy but conserves the total on average.

Correct Answer: (c) $2I_0$

32. Assertion (A): In interference and diffraction of light, light energy reduces in one region producing a dark fringe and increases in another producing a bright fringe. Reason (R): This happens because energy is not conserved in the phenomena of interference and diffraction.

Solution: Assertion A correctly describes the observed effect: interference and diffraction redistribute light energy, taking it away from dark regions and concentrating it in bright regions. However, Reason R is false — total energy is always conserved; interference and diffraction merely redistribute the energy in space, they do not create or destroy it (the average intensity over the pattern still equals the sum of the individual intensities, as seen in the previous question).

Correct Answer: (c) A is true and R is false.

33. A Young's double-slit experimental set-up is kept in a medium of refractive index 3/2. Which maximum in this case will coincide with the 6th maximum obtained if the medium is replaced by air?

Solution: Wavelength in the medium is $\lambda\_m = \lambda\_air/\mu$. Since a maximum occurs at a fixed path difference equal to (order number) × (wavelength in that medium), matching the position of a given order between the two cases requires n_medium × λ_m = n_air × λ_air. Using the ratio of orders needed for the same location on the screen, n_medium = n_air/μ = 6/(3/2) = 4. So the 4th maximum in the medium coincides with the 6th maximum in air.

Correct Answer: (a) 4th

34. Assertion (A): In a Young's double-slit experiment, interference pattern is not observed when two coherent sources are infinitely close to each other. Reason (R): The fringe width is proportional to the separation between the two sources.

Solution: As the slit separation d becomes very small, the fringe width $\beta = \lambda D/d$ relates to d, and as $d \to 0$ the fringes become so widely spaced that only a single very broad bright region is seen — the closely packed fringe pattern effectively disappears from a practical field of view, supporting Assertion A. Reason R correctly states the formula relating β and d, but by itself it is not a full logical explanation of why the pattern is not seen (that also involves the practical size of the screen/field of view), so R, although a true relation, is not considered the direct explanation of A.

Correct Answer: (b) Both A and R are true, but R is not the correct explanation of A.

35. In a Young's double-slit experiment in air, the fringe width is found to be 0.44 mm. If the entire setup is immersed in water (μ = 4/3), the fringe width will be:

Solution: Since $\beta = \lambda D/d$ and only λ changes on immersion in water (λ_water = λ_air/μ), the new fringe width is β_water = β_air/μ = 0.44 mm ÷ (4/3) = 0.44 × 3/4 = 0.33 mm.

Correct Answer: (c) 0.33 mm

36. Assertion (A): The phase difference between any two points on a wavefront is zero. Reason (R): All points on a wavefront are at the same distance from the source and thus oscillate in the same phase.

Solution: By definition, a wavefront is the locus of all points that are in the same phase of oscillation, so the phase difference between any two points on it is indeed zero, confirming Assertion A. This is precisely because, for a wave spreading out from a source, every point on a given wavefront has travelled the same distance from the source in the same time, so Reason R is both true and the correct explanation of A.

Correct Answer: (a) Both A and R are true and R is the correct explanation of A.

37. A beam of light travels from air into a medium. Its speed and wavelength in the medium are 1.5 × 10^8 m/s and 230 nm respectively. The wavelength of light in air will be:

Solution: The refractive index of the medium is $n = c/v = (3\times10^8)/(1.5\times10^8) = 2$. Since wavelength in a medium is λ_medium = λ_air/n, the wavelength in air is λ_air = n × λ_medium = 2 × 230 nm = 460 nm.

Correct Answer: (c) 460 nm

38. A plane wavefront is incident on a concave mirror of radius of curvature R. The radius of the reflected wavefront will be:

Solution: A plane wavefront reflecting from a concave mirror converges to the mirror's focal point, becoming a converging spherical wavefront. The radius of this spherical wavefront, at the moment of reflection, equals the mirror's focal length, f = R/2.

Correct Answer: (c) R/2

39. In an interference experiment, the third bright fringe is obtained at a point on the screen with light of 700 nm. What should be the wavelength of the light source in order to obtain the fifth bright fringe at the same point?

Solution: A bright fringe forms wherever the path difference equals an integral multiple of the wavelength used, and this path difference is fixed by the geometry (slit separation, screen distance, and position on the screen) — it does not depend on which wavelength is being used. So if the third bright fringe of 700 nm and the fifth bright fringe of the new wavelength λ both fall at the same point, they correspond to the same path difference: 3×700 nm $= 5 \times \lambda$, giving $\lambda = 2100/5 = 420$ nm.

Note: applying the standard bright-fringe condition $n_1\lambda_1 = n_2\lambda_2$ gives 420 nm here, which corresponds to option (a) rather than the (c) 630 nm listed in the answer key of the original question bank — this appears to be a transcription slip in that key, and 420 nm is the value obtained from the calculation shown above.

Correct Answer: (a) 420 nm [see note above regarding the source answer key]

40. Assertion (A): In Young's double slit experiment all fringes are of equal width. Reason (R): The fringe width depends upon wavelength of light (λ), distance of screen from plane of slits (D), and slits separation (d).

Solution: All bright and dark fringes in YDSE are equally spaced because the fringe width $\beta = \lambda D/d$ is a constant for a given experimental setup — it does not depend on the fringe order n, so consecutive fringes are always separated by the same distance β, confirming Assertion A. Reason R states exactly this formula and correctly explains why the fringe width (and hence the equal spacing) comes out to be a fixed value depending only on λ, D, and d.

Correct Answer: (a) Both A and R are true and R is the correct explanation of A.

Class XII Physics — Wave Optics

Assertion–Reason: Complete Solutions with Reasoning

Companion solution sheet to the 12-question Assertion-Reason worksheet

Each solution below evaluates the Assertion (A) and the Reason (R) independently, checks whether R correctly explains A, and states the matching option code. Section A questions are drawn from actual CBSE board papers and have been cross-checked against official board answer keys; Section B questions are practice questions evaluated on first principles.

SECTION A — PREVIOUS YEAR QUESTIONS (CBSE BOARD PAPERS)

Question 1 — Correct Answer: (a)

Assertion (A): *Light added to light can produce darkness.*
Reason (R): *When two coherent light waves interfere, there is darkness at the position of destructive interference.*

Assertion: TRUE

Reason: TRUE

Reasoning:
By the principle of superposition, when two coherent waves of (nearly) equal amplitude meet with a path difference of $(n + ½)\lambda$, they arrive out of phase by 180°. The crest of one wave coincides with the trough of the other, so their displacements cancel and the resultant intensity drops to (near) zero — a dark fringe. This is exactly what "light added to light producing darkness" means, so A is a correct and non-trivial statement about interference.
R states precisely this mechanism — destructive interference of coherent sources creating darkness — so R correctly explains A.

Conclusion:
Both A and R are true, and R is the correct explanation of A → option (a).

Question 2 — Correct Answer: (a)

Assertion (A): *In Young's double-slit experiment, the fringe width for dark and bright fringes is the same.*
Reason (R): *Fringe width is given by $\beta = \lambda D/d$, where symbols have their usual meanings.*

Assertion: TRUE

Reason: TRUE

Reasoning:
The position of the nth bright fringe is $y_n = n\lambda D/d$, and the position of the nth dark fringe is $y_n = (2n - 1)\lambda D/2d$. The spacing between two consecutive bright fringes works out to $\lambda D/d$, and the spacing between two consecutive dark fringes also works out to $\lambda D/d$. So bright and dark fringes are equally and alternately spaced across the whole pattern — the fringe width does not change from one fringe to the next.
Since $\beta = \lambda D/d$ contains only constants (λ, D, d) for a given experimental setup, it directly explains why every fringe — bright or dark — has the same width.

Conclusion:
Both A and R are true, and R is the correct explanation of A → option (a).

Question 3 — Correct Answer: (c)

Assertion (A): *In double slit experiment if one slit is closed, diffraction pattern due to the other slit will appear on the screen.*

Reason (R): *For interference, at least two waves are required.*

Assertion: TRUE

Reason: FALSE — true as a stand-alone fact, but not accepted as the explanation here — see note

Reasoning:
When one slit is blocked, light from the single remaining slit still spreads out and produces its own single-slit diffraction pattern (a broad central maximum with weaker secondary maxima) on the screen. So A is true.
R — "interference needs at least two waves" — is true as a general statement of physics. However, the official CBSE marking scheme does not accept it as a valid explanation of A: A is about diffraction appearing from a single open slit, while R talks about the condition for interference (a different phenomenon). Since R does not causally account for why diffraction appears, it is marked false in the context of explaining this particular assertion.

Conclusion:
A is true, but R is false (as an explanation of A) → option (c). This exact question appeared in the 2025 board paper (Set 55/4/1), where the official answer key confirms option (c).

Question 4 — Correct Answer: (c)
Assertion (A): *In interference and diffraction of light, light energy reduces in one region producing a dark fringe. It increases in another region and produces a bright fringe.*
Reason (R): *This happens because energy is not conserved in the phenomena of interference and diffraction.*

Assertion: TRUE

Reason: FALSE

Reasoning:
Interference and diffraction do redistribute light energy in space — intensity is below average at dark fringes and above average at bright fringes. So A correctly describes what is observed.
However, this redistribution does not violate energy conservation. The energy that seems to "disappear" from the dark regions reappears at the bright regions; averaged over a full fringe pattern, the total energy equals the sum of the energies of the individual waves. Energy is conserved — it is merely redistributed, not created or destroyed. So R is false.

Conclusion:
A is true, but R is false → option (c).

Question 5 — Correct Answer: (c)
Assertion (A): *In a Young's double-slit experiment, interference pattern is not observed when two coherent sources are infinitely close to each other.*
Reason (R): *The fringe width is proportional to the separation between the two sources.*

Assertion: TRUE

Reason: FALSE

Reasoning:
Since $\beta = \lambda D/d$, as the slit separation $d \to 0$, the fringe width $\beta \to \infty$. Practically, this means the fringes become so wide that no distinct fringe pattern can be observed on a screen of finite size — one just sees a broad, uniform patch of illumination. So A is true.

R states that fringe width is "proportional to" (i.e. directly proportional to) the separation d. This is the opposite of the correct relation: $\beta = \lambda D/d$ shows that fringe width is inversely proportional to d, not directly proportional. As worded, R is therefore false.

Conclusion:
A is true, but R is false → option (c).

Question 6 — Correct Answer: (a)
Assertion (A): *The phase difference between any two points on a wavefront is zero.*
Reason (R): *All points on a wavefront are at the same distance from the source and thus oscillate in the same phase.*

Assertion: TRUE

Reason: TRUE

Reasoning:
A wavefront is, by definition, the locus of all points in the medium that are in the same phase of oscillation at a given instant. Hence any two points lying on the same wavefront necessarily have zero phase difference between them — A is true.
For a wave spreading out from a point source in a homogeneous medium, all points on a given (spherical) wavefront are equidistant from the source. Since they have travelled the same path length in the same time, they reach that phase simultaneously — this is exactly why they share a common phase. R correctly explains A.

Conclusion:
Both A and R are true, and R is the correct explanation of A → option (a).

Question 7 — Correct Answer: (a)
Assertion (A): *In Young's double slit experiment all fringes are of equal width.*
Reason (R): *The fringe width depends upon wavelength of light (λ) used, distance of screen from plane of slits (D) and slits separation (d).*

Assertion: TRUE

Reason: TRUE

Reasoning:
As shown in Q2 above, consecutive fringes (bright-to-bright or dark-to-dark) are always separated by $\beta = \lambda D/d$, independent of the fringe's order number n. So every fringe in the pattern has the same width — A is true.
Because λ, D and d are all fixed once the experimental setup is chosen, β itself is a single fixed number for the whole pattern — which is precisely why the fringe width does not vary from fringe to fringe. R correctly explains A.

Conclusion:
Both A and R are true, and R is the correct explanation of A → option (a).

SECTION B — ADDITIONAL PRACTICE QUESTIONS

Question 8 — Correct Answer: (a)
Assertion (A): *The angular width of the central maximum in a single-slit diffraction pattern increases when the slit width is decreased.*

Reason (R): *Diffraction effects become more pronounced when the slit width is decreased and made comparable to the wavelength of light.*

Assertion: TRUE

Reason: TRUE

Reasoning:
The angular half-width of the central maximum in single-slit diffraction is $\theta = \lambda/a$ (so the full angular width is $2\lambda/a$), where a is the slit width. As a decreases, θ increases — so the central maximum spreads out more. A is true.
This spreading is the diffraction effect itself: diffraction becomes pronounced precisely when the obstacle/aperture size becomes comparable to the wavelength ($a \sim \lambda$). Making the slit narrower pushes a/λ closer to 1, which is why the bending and spreading of light (and hence the angular width) increases. R correctly explains A.

Conclusion:
Both A and R are true, and R is the correct explanation of A → option (a).

Question 9 — Correct Answer: (b)
Assertion (A): *In Young's double-slit experiment, the fringe width is the same for successive bright and dark fringes.*
Reason (R): *The light used in the experiment is monochromatic.*

Assertion: TRUE

Reason: TRUE — true, but not the reason for A

Reasoning:
As established in Q2, the fringe width $\beta = \lambda D/d$ is the same between any two consecutive fringes, bright or dark — so A is true.
It is also true that YDSE is normally performed with monochromatic light (a single, well-defined λ). But monochromaticity is not what makes the bright and dark fringe spacing equal — that equality follows purely from the geometry of path differences ($n\lambda$ for bright, $(2n-1)\lambda/2$ for dark) for whatever single wavelength is used. Even using a different single wavelength would still give equal spacing; what monochromaticity actually ensures is that the pattern is sharp and undistorted (avoiding the overlap of fringes of different colours, as in Q10). So R is true in itself, but it does not explain why the fringe width is uniform.

Conclusion:
Both A and R are true, but R is not the correct explanation of A → option (b).

Question 10 — Correct Answer: (a)
Assertion (A): *When white light is used in Young's double-slit experiment, the central fringe is white, with a few coloured fringes visible on either side before the pattern merges into general illumination.*
Reason (R): *Fringe width is directly proportional to the wavelength of light, so fringes of different colours have different widths and increasingly overlap away from the centre.*

Assertion: TRUE

Reason: TRUE

Reasoning:
At the centre of the screen (zero path difference), every wavelength present in white light interferes constructively at the same point, so all colours superpose to give a white central fringe. Moving away from the centre, fringes of different colours (each governed by its own $\beta = \lambda D/d$) drift out of step with each other,

so only a few distinguishable coloured fringes survive before the pattern washes out into uniform illumination. A is true.
Since $\beta \propto \lambda$, red fringes (longer λ) are wider than violet fringes (shorter λ). Close to the centre the fringes of all colours nearly coincide, but as the order n increases, the accumulated mismatch between the differently-spaced colour patterns grows until they overlap so much that no distinct fringes remain visible. R correctly explains A.

Conclusion:
Both A and R are true, and R is the correct explanation of A → option (a).

Question 11 — Correct Answer: (d)
Assertion (A): *The interference pattern in Young's double-slit experiment disappears if the widths of the two slits are made unequal.*
Reason (R): *Two slits of unequal width can no longer act as coherent sources.*

Assertion: FALSE

Reason: FALSE

Reasoning:
Making the two slits unequal in width changes the amplitudes (and hence intensities) of the two interfering waves, but it does not remove interference. Bright and dark fringes still form; only the contrast (visibility) changes — the minima are no longer perfectly dark, since the two unequal amplitudes cannot cancel completely, and the maxima are correspondingly less bright than in the equal-slit case. The pattern persists in a lower-contrast form rather than disappearing. So A is false.
Coherence between the two sources in YDSE comes from the fact that both slits are illuminated by wavefronts derived from the same single primary source, keeping a constant phase relationship between them. This has nothing to do with how wide the two slits are; unequal slit widths only affect the amplitude (intensity) of light passing through each slit, not the phase relationship. So R is also false.

Conclusion:
Both A and R are false → option (d).

Question 12 — Correct Answer: (c)
Assertion (A): *In Huygens' construction, the new wavefront is obtained as the envelope tangent to all the secondary wavelets.*
Reason (R): *In a homogeneous medium, the secondary wavelets originating from different points on a wavefront travel with different speeds.*

Assertion: TRUE

Reason: FALSE

Reasoning:
This is the definition of Huygens' construction: every point on a wavefront acts as a source of secondary spherical wavelets, and the surface tangential to (the envelope of) all these wavelets at a later instant gives the new wavefront. A is true.
A homogeneous medium is, by definition, one whose properties (and hence wave speed) are the same at every point. So secondary wavelets originating from different points on the same wavefront in a homogeneous medium travel outward with the same speed, not different speeds — it is exactly this equal speed that keeps the envelope a well-defined, undistorted wavefront (e.g. a plane remains a plane, a sphere remains a sphere). R is therefore false.

Conclusion:

A is true, but R is false → option (c).

VERIFIED ANSWER KEY

All answers below match the source worksheet's key except Q5 (see the highlighted note under Question 5).

Q1	Q2	Q3	Q4	Q5	Q6
(a)	(a)	(c)	(c)	(c)*	(a)
Q7	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**
(a)	(a)	(b)	(a)	(d)	(c)

Class XII Physics — Wave Optics

Case Study Based Questions — Solutions

Case Study 1: Diffraction of Light at a Single Slit

(a) Effect on central maximum width if wavelength increases

Width increases — angular width of central maximum ($2\lambda/a$) is directly proportional to λ.

(b) Condition for first minimum in single-slit diffraction

$a \sin\theta = \lambda$ (path difference from the two edges of the slit equals one wavelength).

(c) Two differences between interference and diffraction

1. In interference all bright fringes have equal intensity; in diffraction secondary maxima intensity falls off rapidly with order.
2. In interference all fringes are equally wide; in diffraction the central maximum is twice as wide as the secondary maxima.

OR (c) Why can't the students see each other but can hear?

Light's wavelength ($\sim10^{-7}$ m) is far smaller than the wall, so it barely diffracts around it. Sound's wavelength (~metres) is comparable to the wall size, so it diffracts around it easily.

Case Study 2: Fringe Width in Young's Double Slit Experiment

(a) Fringe width β

$\beta = \lambda D/d = (500\times10^{-9} \times 1)/(1\times10^{-3}) = 5\times10^{-4}$ m = 0.5 mm.

(b) Distance of 4th bright fringe from centre

$x_4 = n\beta = 4 \times 0.5$ mm = 2 mm.

(c) New fringe width in liquid of μ = 1.5

$\beta' = \beta/\mu = 0.5/1.5 \approx 0.33$ mm.

OR (c) Effect of unequal slit widths on maxima/minima positions

Positions stay unchanged — they depend only on path difference (geometry), not intensity. Only the contrast reduces, since I_{min} is no longer exactly zero when the two amplitudes are unequal.

Case Study 3: Coincidence of Fringes with Two Wavelengths

(a) Position of nth bright fringe
$x_n = n\lambda D/d$

(b) Fringe width for λ = 600 nm
$\beta_1 = \lambda_1 D/d = (600\times10^{-9} \times 1.5)/(0.5\times10^{-3}) = 1.8\times10^{-3}$ m = 1.8 mm.

(c) Least distance where bright fringes of both wavelengths coincide
$n_1\lambda_1 = n_2\lambda_2 \rightarrow n_1(600) = n_2(750) \rightarrow n_1:n_2 = 5:4$ (smallest integers).
$x = n_1\lambda_1 D/d = (5 \times 600\times10^{-9} \times 1.5)/(0.5\times10^{-3}) = 9\times10^{-3}$ m = 9 mm.

OR (c) Pattern with white light instead of two wavelengths
Central fringe stays white (zero path difference for all λ). A few coloured fringes appear near the centre; farther out, fringes of different colours overlap into general uniform illumination.

Case Study 4: Huygens' Principle and Refraction of Wavefronts

(a) Define a wavefront
The locus of all points in a medium vibrating in the same phase at a given instant.

(b) Shape of wavefront emerging from a convex lens (plane wave incident)
A spherical wavefront, converging towards the lens's focal point.

(c) Derive Snell's law using Huygens' construction
For incident wavefront AB, secondary wavelets travel at v_1 (medium 1) and v_2 (medium 2) over time t. Geometry of the refracted wavefront gives $\sin i/\sin r = v_1/v_2 = n_2/n_1$, i.e. $n_1 \sin i = n_2 \sin r$ (Snell's law).

OR (c) Why does speed decrease in a denser medium? Does energy reduce?
Speed decreases because light interacts with the medium's atoms, which absorb and re-emit it with a time delay, slowing its net progress. No energy is lost — frequency stays constant on entering a new medium; only wavelength and speed change.

CLASS XII PHYSICS — WAVE OPTICS

Assignment: Short Answer & Long Answer Questions

STEPWISE SOLUTIONS

15 Short Answer Questions (2 marks each) • 5 Long Answer Questions (5 marks each)

SECTION A — Short Answer Type Questions (2 marks each)

Q1. Least distance where bright fringes of 440 nm & 660 nm coincide

Given: $d = 0.6$ mm $= 6 \times 10^{-4}$ m, $\lambda 1 = 440$ nm, $\lambda 2 = 660$ nm, $D = 1.5$ m

Bright fringes of the two wavelengths coincide when: $n1\lambda 1 = n2\lambda 2$

$n1 \times 440 = n2 \times 660 \;\Rightarrow\; n1/n2 = 660/440 = 3/2$

Smallest integers satisfying this ratio: $n1 = 3$, $n2 = 2$

$x = n1\lambda 1D/d = (3 \times 440 \times 10^{-9} \times 1.5) / (6 \times 10^{-4})$

$x = (1980 \times 10^{-9}) / (6 \times 10^{-4}) = 3.3 \times 10^{-3}$ m

Final Answer: $x = 3.3 \times 10^{-3}$ m $= 3.3$ mm

Q2. Least distance where bright fringes of 500 nm & 600 nm coincide

Given: $\lambda 1 = 500$ nm, $\lambda 2 = 600$ nm, $D = 1.8$ m, $d = 0.3$ mm $= 3 \times 10^{-4}$ m

$n1 \times 500 = n2 \times 600 \;\Rightarrow\; n1/n2 = 600/500 = 6/5$

Smallest integers: $n1 = 6$, $n2 = 5$

$x = n1\lambda 1D/d = (6 \times 500 \times 10^{-9} \times 1.8) / (3 \times 10^{-4})$

$x = (5400 \times 10^{-9}) / (3 \times 10^{-4}) = 1.8 \times 10^{-2}$ m

Final Answer: $x = 1.8 \times 10^{-2}$ m $= 18$ mm $= 1.8$ cm

Q3. Why diffraction of sound is more common than that of light

Noticeable diffraction requires the size of the obstacle/opening to be comparable to the wavelength of the wave. Sound waves have wavelengths of the order of metres (comparable to doors, walls, furniture encountered daily), so they diffract strongly around such obstacles.

Light waves, however, have wavelengths of only about $4–7 \times 10^{-7}$ m, which is negligibly small compared to the size of everyday objects. Hence light shows no perceptible diffraction in daily life and appears to travel in straight lines, while sound diffracts noticeably.

Q4. Effect of (a) initial phase difference π, (b) closing one slit

(a) Initial phase difference of π between S1 and S2

Normally the central point O has zero path difference, so both waves arrive in phase (total phase difference = 0) giving a bright central fringe.

If the sources themselves start with an initial phase difference of π, then at O the total phase difference becomes $\pi + 0 = \pi$, which is the condition for destructive interference.

Final Answer: The central point will now show a dark fringe instead of a bright one (the entire fringe pattern shifts by half a fringe width).

(b) One of the slits is closed

With only one slit open, there is only a single source of light — no two coherent waves are available to superpose, so interference cannot occur.

Final Answer: The interference pattern (equally spaced bright/dark fringes) disappears; instead, a single-slit diffraction pattern is observed — a broad central maximum with much weaker, unevenly spaced secondary maxima.

Q5. Prove Imax = 4I and Imin = 0 for two waves each of intensity I

Let the two coherent waves each have intensity I (i.e., $I_1 = I_2 = I$), and phase difference φ. The resultant intensity in interference is:

$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\varphi = I + I + 2I \cos\varphi = 2I(1 + \cos\varphi)$

At maxima (constructive interference): φ = 0, 2π, 4π, … so cosφ = 1

$I_{max} = 2I(1 + 1) = 4I$

At minima (destructive interference): φ = π, 3π, … so cosφ = −1

$I_{min} = 2I(1 - 1) = 0$

Final Answer: Hence $I_{max} = 4I$ and $I_{min} = 0$, as required — proved.

Q6. Why frequency stays the same but wavelength changes on refraction

Frequency is determined solely by the source — it equals the number of oscillations produced by the source per second. Since the source itself does not change when light enters a new medium, the frequency of the wave (in both the refracted and reflected parts) remains exactly equal to the incident frequency.

Speed of light, however, is a property of the medium: $v = c/n$, where n is the refractive index. As light passes into a denser medium its speed decreases.

Since $v = \nu\lambda$ and ν (frequency) is fixed, a decrease in speed v must be accompanied by a proportional decrease in wavelength λ. This is why wavelength changes on refraction even though frequency does not.

Q7. Slit separation from angular fringe width

Given: angular fringe width θ = 0.2°, λ = 500 nm = 5×10^{-7} m

Angular fringe width is related to slit separation d by:

$\theta = \lambda/d \;\Rightarrow\; d = \lambda/\theta$

Converting θ to radians: $\theta = 0.2 \times (\pi/180) = 3.49 \times 10^{-3}$ rad

$d = (5 \times 10^{-7}) / (3.49 \times 10^{-3})$

Final Answer: $d \approx 1.43 \times 10^{-4}$ m = 0.143 mm

Q8. Two differences: double-slit interference vs single-slit diffraction pattern

1. In interference, all bright fringes are of nearly equal width and equal intensity; in diffraction, the central maximum is much wider and brighter than the secondary maxima, whose intensity falls off rapidly.
2. Interference arises from the superposition of waves from two separate coherent sources (two narrow slits); diffraction arises from the superposition of secondary wavelets from different parts of the same (single) wavefront.

Q9. Why two independent sodium lamps do not produce interference

For a sustained interference pattern, the two sources must be coherent — they must maintain a constant phase difference at all times.

Light from an ordinary source (such as a sodium lamp) is emitted by a very large number of independent atoms, each emitting light in random bursts (wave trains) that undergo abrupt, random phase changes roughly every 10^{-10} s. Two separate sodium lamps have no fixed phase relationship between their emissions.

As a result, the path difference — and hence the resultant intensity — at any point fluctuates randomly and extremely rapidly; the eye/detector only records the time-averaged intensity, which is just the simple sum $I_1 + I_2$ everywhere, i.e. uniform illumination with no stable pattern of fringes.

Q10. Intensity ratio of interfering waves, given Imax:Imin = 25:9

$I_{max}/I_{min} = (a_1+a_2)^2/(a_1-a_2)^2 = 25/9$

$\Rightarrow (a_1+a_2)/(a_1-a_2) = 5/3$

Cross-multiplying: $3(a_1+a_2) = 5(a_1-a_2) \Rightarrow 3a_1 + 3a_2 = 5a_1 - 5a_2 \Rightarrow 8a_2 = 2a_1$

$\Rightarrow a_1/a_2 = 4$

Since intensity ∝ (amplitude)²:

$I_1/I_2 = (a_1/a_2)^2 = 16$

Final Answer: $I_1 : I_2 = 16 : 1$

Q11. Intensity at path difference λ/3, given central intensity I0

At the central maximum (path difference = 0), the two waves interfere fully constructively, so I_0 represents the maximum intensity.

General intensity formula: $I = I_0 \cos^2(\varphi/2)$, where φ is the phase difference.

At path difference λ/3, the phase difference is:

$\varphi = (2\pi/\lambda) \times (\lambda/3) = 2\pi/3$

$I = I_0 \cos^2(\pi/3) = I_0 \times (1/2)^2 = I_0/4$

Final Answer: $I = I_0 / 4$

Q12. Unknown wavelength λ, given 4th bright fringe (unknown) coincides with 5th bright fringe (520 nm)

At the point of coincidence, both bright fringes lie at the same distance from the central maximum:

$4 \times \lambda = 5 \times 520$ nm *(since $x_n = n\lambda D/d$, and x for both patterns is equal)*

$\lambda = (5 \times 520) / 4$

Final Answer: λ = 650 nm

Q13. Two points of difference between interference and diffraction of light

1. Interference occurs due to superposition of waves from two (or more) coherent sources; diffraction occurs due to superposition of secondary wavelets originating from different parts of the same wavefront.
2. In interference, all bright fringes have nearly the same intensity and are equally spaced; in diffraction, the intensity of successive maxima decreases rapidly, and the central maximum is twice as wide as the other maxima.

Q14. Sustained (stable) interference pattern and its conditions

A sustained or stable interference pattern is one in which the positions of the bright and dark fringes (maxima and minima) do not change with time, i.e., the pattern remains fixed and observable.

Conditions required:

1. The two sources must be coherent, i.e., they must emit light of the same frequency (wavelength) and maintain a constant phase difference with time.
2. The amplitudes of the two interfering waves should be equal, or nearly equal, so that dark fringes have (near) zero intensity and the fringe contrast is good.
3. The two sources should be narrow and placed close to each other, and the light should ideally be monochromatic, so that fringes of adequate width and visibility are obtained.

Q15. Ratio of Imax to Imin for beams of intensity I and 4I

Amplitude ratio: $a_1/a_2 = \sqrt{(I_1/I_2)} = \sqrt{(I/4I)} = 1/2$, i.e., $a_2 = 2a_1$

$I_{max}/I_{min} = (a_1+a_2)^2/(a_1-a_2)^2 = (a_1+2a_1)^2/(a_1-2a_1)^2 = (3a_1)^2/(-a_1)^2$

$= 9a_1^2/a_1^2 = 9$

Final Answer: Imax : Imin = 9 : 1

SECTION B — Long Answer Type Questions (5 marks each)

Q1. Single-slit diffraction — maxima/minima formation, weakening of maxima, and interference vs diffraction differences

(i)(I) Formation of maxima and minima

When a plane wavefront falls normally on a narrow slit of width a, every point of the unblocked wavefront within the slit becomes a source of secondary wavelets (Huygens' principle), which spread out and superpose on a screen placed at distance D.

Wavelets travelling straight ahead ($\theta = 0$) all cover equal path lengths to the screen and arrive in phase — they reinforce to produce an intense central maximum.

For wavelets diffracted at angle θ, the path difference between wavelets from the two edges of the slit is a $\sin\theta$. When this path difference equals λ, the slit can be divided into two equal halves such that every point in one half has a corresponding point in the other half with a path difference of $\lambda/2$ — every such pair cancels, producing the first minimum. In general, minima occur at:

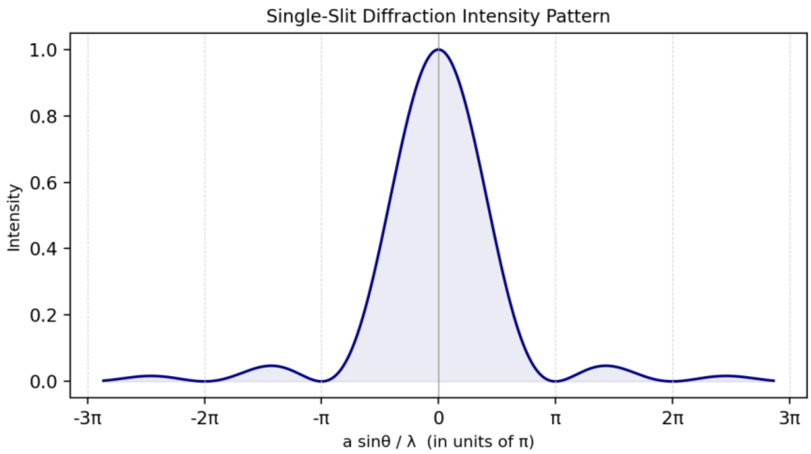
$a \sin\theta n = n\lambda$, $n = 1, 2, 3, \ldots$

Between consecutive minima, cancellation is incomplete and a weak secondary maximum appears, roughly at a $\sin\theta \approx (n + 1/2)\lambda$.

(i)(II) Why maxima become weaker with increasing order n

At larger angles corresponding to secondary maxima, the slit can be divided into 3, 5, 7, … (an odd number of) equal parts. Contributions from adjacent parts are out of phase and cancel pairwise, leaving only the contribution of one unpaired part as the net (uncancelled) amplitude.

As the order n increases, the slit gets divided into more parts, so a progressively smaller fraction of the total amplitude remains uncancelled — hence the intensity of successive secondary maxima decreases rapidly with increasing order n.



Intensity distribution in single-slit diffraction

(ii) Two differences: interference (double-slit) vs diffraction (single-slit)

1. In interference, all bright fringes are of (nearly) equal width and equal intensity; in diffraction, the central maximum is much brighter and twice as wide as the secondary maxima, whose intensity decreases rapidly.
2. Interference results from superposition of waves from two separate coherent sources; diffraction results from superposition of secondary wavelets from different parts of the same (single) wavefront.

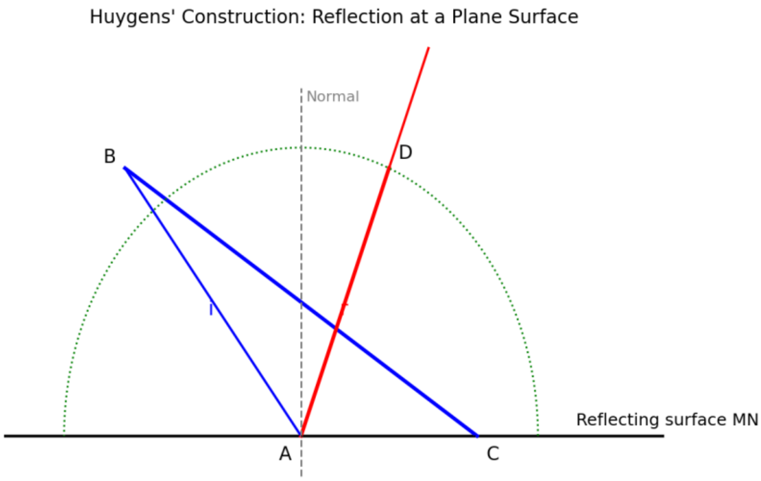
Q2. Wavefront vs ray; Huygens' principle & laws of reflection; YDSE numerical

(i) Difference between a wavefront and a ray

Wavefront	Ray
The locus of all points in a medium that are vibrating in the same phase at a given instant.	The straight-line path along which light energy travels; it represents the direction of propagation.
It is a surface (a line in 2-D diagrams) — plane, spherical, or cylindrical depending on the source.	It is a straight line, always perpendicular to the wavefront at the point it passes through.

(ii) Huygens' principle and verification of the laws of reflection

Huygens' Principle: (a) Every point on a wavefront acts as a source of new secondary wavelets which spread out with the speed of the wave in that medium. (b) The forward envelope (tangent surface) of these secondary wavelets at a later instant gives the new position of the wavefront.



Huygens' construction verifying the laws of reflection

Let AB be a plane wavefront incident on the reflecting surface MN at angle i, touching the surface first at A while B is still approaching it. Let B take time t to reach the surface at C, so BC = vt (v = speed of light in the medium).

By Huygens' principle, a secondary wavelet also starts from A at the instant the wavefront was at AB. In the same time t, this wavelet spreads out to radius AD = vt in the medium. The reflected wavefront CD is the tangent from C to this wavelet.

In right triangles ABC and ADC: BC = AD (both equal vt), and AC is common to both. By RHS congruence, $\Delta ABC \cong \Delta ADC$, so:

$\angle BAC = \angle DCA \Rightarrow$ *angle of incidence, i = angle of reflection, r*

Also, the incident ray, the reflected ray, and the normal at the point of incidence all lie in the same plane. These two results together constitute the laws of reflection.

(iii) Wavelength from YDSE data

Given: $d = 3$ mm $= 3 \times 10^{-3}$ m, $D = 1.0$ m; the 4th bright fringe is 5 mm from the 2nd dark fringe.

Position of nth bright fringe: $x_n = n\lambda D/d$. Position of mth dark fringe: $x'_m = (m - 1/2)\lambda D/d$

4th bright fringe: $x_4 = 4\lambda D/d$. 2nd dark fringe: $x'_2 = (2 - 1/2)\lambda D/d = 1.5\lambda D/d$

Distance between them:

$x_4 - x'_2 = (4 - 1.5)\lambda D/d = 2.5\lambda D/d = 5 \times 10^{-3}$ m

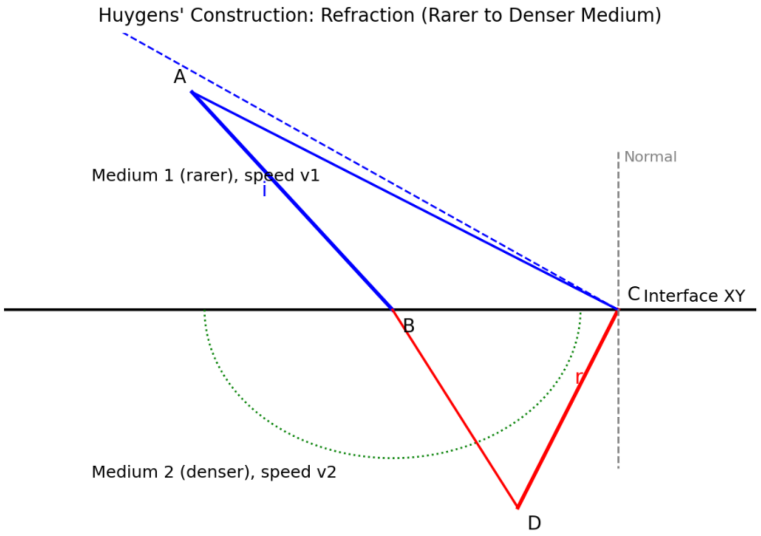
$\Rightarrow \lambda D/d = 2 \times 10^{-3}$ m (this is the fringe width β)

$\lambda = (2 \times 10^{-3} \times 3 \times 10^{-3}) / 1.0 = 6 \times 10^{-6}$ m

Final Answer: $\lambda = 6 \times 10^{-6}$ m = 6000 nm (as obtained from the given numerical data using $\beta = xd/D$)

Q3. Huygens' construction for refraction & Snell's law; distance to 4th dark fringe

(i) Refraction of a plane wave (rarer → denser) and verification of Snell's law



Huygens' construction for refraction of a plane wavefront

Let AB be a plane wavefront incident on interface XY at angle i, travelling from a rarer medium (speed v1) into a denser medium (speed v2). While the disturbance at A travels distance AC = v1t to reach the interface at C, the secondary wavelet from B (already at the interface) spreads into the denser medium with radius BD = v2t. The refracted wavefront CD is the tangent to this wavelet.

From right triangle ABC: sin i = BC/AC = v1t/AC. From right triangle BCD: sin r = BD/AC = v2t/AC

⇒ sin i / sin r = v1 / v2 = constant = n21

Since this ratio is constant for a given pair of media (independent of the angle of incidence), this is precisely Snell's law of refraction.

(ii) Distance between central bright fringe and 4th dark fringe

Given: d = 0.30 mm = 3×10^{-4} m, D = 1.5 m, λ = 600 nm = 6×10^{-7} m

Position of the nth dark fringe:

$y_n = (n - 1/2)\, \lambda D/d$

For n = 4: $y_4 = 3.5 \times \lambda D/d$

$\lambda D/d = (6 \times 10^{-7} \times 1.5)/(3 \times 10^{-4}) = 3 \times 10^{-3}$ m

$y_4 = 3.5 \times 3 \times 10^{-3}$ m

Final Answer: $y_4 = 10.5 \times 10^{-3}$ m = 10.5 mm

Q4. Differences & fringe-width factors; angular separation and fringe distance when d = 100λ

(i) Two differences (interference vs diffraction) and factors affecting fringe width

Differences: (1) Interference fringes are equally spaced with nearly equal intensity; diffraction fringes have a much wider, brighter central maximum with rapidly weakening, unequally spaced secondary maxima. (2) Interference arises from two coherent sources; diffraction arises from a single wavefront (single slit).

Fringe width $\beta = \lambda D/d$ — it depends on: (a) the wavelength of light used (λ), and (b) the distance between the slits and the screen (D) — [it also depends inversely on the slit separation d].

(ii) Angular separation and linear fringe distance when d = 100λ

Given: $d = 100\lambda$, $D = 50$ cm $= 0.5$ m

(1) Angular separation between the central maximum and the adjacent (first) maximum:

$\Delta\theta = \lambda/d = \lambda/(100\lambda) = 1/100$

Final Answer: $\Delta\theta = 0.01$ rad $= 10^{-2}$ rad

(2) Distance between these two maxima on the screen:

$y = \Delta\theta \times D = 0.01 \times 0.5$

Final Answer: $y = 5 \times 10^{-3}$ m $= 5$ mm

Q.5. Distinguishing features of interference/diffraction; derivation of intensity in YDSE

Two characteristic features distinguishing interference from diffraction

1. Interference is due to superposition of light from two distinct coherent sources; diffraction is due to superposition of secondary wavelets from different parts of the same (single) wavefront.
2. In interference all bright fringes have nearly equal intensity and are equally spaced; in diffraction, the central maximum is far more intense and wider than the secondary maxima, whose intensities fall off rapidly with increasing order.

Derivation of intensity at a point in the YDSE interference pattern

Let the two waves arriving at a point P on the screen from S_1 and S_2 have amplitudes a_1 and a_2, and a phase difference φ between them:

$y_1 = a_1 \sin\omega t, \quad y_2 = a_2 \sin(\omega t + \varphi)$

By the principle of superposition, the resultant displacement is $y = y_1 + y_2$, which can be shown (by expanding and using compound-angle formulae) to take the form:

$y = A \sin(\omega t + \theta)$, where $A \cos\theta = a_1 + a_2 \cos\varphi$ and $A \sin\theta = a_2 \sin\varphi$

Squaring and adding these two relations:

$A^2 = a_1^2 + a_2^2 + 2a_1a_2 \cos\varphi$

Since intensity is proportional to the square of the amplitude ($I \propto A^2$), and writing $I_1 \propto a_1^2$, $I_2 \propto a_2^2$:

Final Answer: $I = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\varphi$

For maxima, $\varphi = 2n\pi$ ($\cos\varphi = 1$): $I_{max} = I_1 + I_2 + 2\sqrt{I_1I_2} = (\sqrt{I_1} + \sqrt{I_2})^2$

For minima, $\varphi = (2n+1)\pi$ ($\cos\varphi = -1$): $I_{min} = I_1 + I_2 - 2\sqrt{I_1I_2} = (\sqrt{I_1} - \sqrt{I_2})^2$

For two waves of equal intensity ($I_1 = I_2 = I_0$), this reduces to the familiar form $I = 4I_0 \cos^2(\varphi/2)$.

CHAPTER 11: DUAL NATURE OF RADIATION AND MATTER

Assignment -1

(CBSE Pattern — Chapter Test)

Time Allowed: 2 Hours **Maximum Marks: 70**

General Instructions:

(i) This question paper contains 33 questions. All questions are compulsory.
(ii) Section A: Q1–14 are MCQs and Q15–16 are Assertion-Reason questions, each of 1 mark.
(iii) Section B: Q17–21 are Very Short Answer questions of 2 marks each.
(iv) Section C: Q22–28 are Short Answer questions of 3 marks each.
(v) Section D: Q29–30 are case-study based questions of 4 marks each.
(vi) Section E: Q31–33 are Long Answer questions of 5 marks each, with an internal choice provided in each.
(vii) Use $h = 6.63 \times 10^{-34}$ J s, $c = 3 \times 10^{8}$ m/s, $e = 1.6 \times 10^{-19}$ C, me = 9.11×10^{-31} kg, mp = 1.67×10^{-27} kg, hc = 1240 eV·nm (12400 eV·Å) wherever required.

SECTION A

Q1. The work function of a metal is 4.2 eV. Its threshold wavelength is nearly: ***[1]***
(a) 2955 Å (b) 5955 Å (c) 4200 Å (d) 1240 Å

Q2. Photoelectric current is directly proportional to the: ***[1]***
(a) frequency of incident light (b) intensity of incident light (c) work function of metal (d) stopping potential

Q3. The slope of the stopping potential (V_0) versus frequency (ν) graph gives: ***[1]***
(a) e/h (b) h/e (c) h (d) φ_0/e

Q4. The de Broglie wavelength of a particle of momentum p is given by: ***[1]***
(a) $\lambda = h/p$ (b) $\lambda = p/h$ (c) $\lambda = hp$ (d) $\lambda = mc^2/h$

Q5. An electron and a proton are accelerated through the same potential difference. The ratio λ_e/λ_p of their de Broglie wavelengths is: ***[1]***
(a) 1 (b) $\sqrt{(m_p/m_e)}$ (c) $\sqrt{(m_e/m_p)}$ (d) m_p/m_e

Q6. Einstein's photoelectric equation is: ***[1]***
(a) $h\nu = \varphi_0 + KEmax$ (b) $h\nu = \varphi_0 - KEmax$ (c) $h\nu = KEmax - \varphi_0$ (d) $\varphi_0 = h\nu + KEmax$

Q7. Which of the following particles has zero rest mass? ***[1]***
(a) electron (b) proton (c) photon (d) neutron

Q8. The Davisson–Germer experiment demonstrated: ***[1]***
(a) the photoelectric effect (b) the wave nature of electrons (c) the particle nature of light (d) the Compton effect

Q9. The momentum of a photon of energy E is: ***[1]***
(a) E/c (b) Ec (c) E/c^2 (d) c/E

Q10. If the frequency of incident radiation is increased, keeping intensity constant, the number of photoelectrons emitted per second: ***[1]***
(a) increases (b) decreases (c) remains the same (d) becomes zero

Q11. For photoelectric emission to occur, the frequency of the incident radiation must be: ***[1]***
(a) equal to the threshold frequency (b) less than the threshold frequency (c) greater than or equal to the threshold frequency (d) independent of the threshold frequency

Q12. A photocell works on the principle of: ***[1]***
(a) photoelectric effect (b) Compton effect (c) thermionic emission (d) field emission

Q13. The de Broglie wavelength associated with a ball of mass 1 kg moving at 1 m/s is of the order of: ***[1]***
(a) 10^{-34} m (b) 10^{-24} m (c) 10^{-10} m (d) 10^{-6} m

Q14. Two metals A and B have threshold frequencies ν and 2ν respectively. The work function of A compared to that of B is: ***[1]***
(a) half (b) double (c) the same (d) four times

For Q15–16, two statements are given — Assertion (A) and Reason (R). Choose 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, but R is false.
(d) A is false, but R is true.

Q15. Assertion (A): Photoelectric effect cannot be explained on the basis of the wave theory of light.
Reason (R): According to the wave theory, energy is continuously distributed over the wavefront and does not depend on frequency. ***[1]***

Q16. Assertion (A): The de Broglie wavelength of a moving electron decreases with an increase in its speed.
Reason (R): The de Broglie wavelength is directly proportional to the momentum of the particle. ***[1]***

SECTION B

Q17. State two important features of the photon picture of electromagnetic radiation. ***[2]***
Q18. The threshold wavelength for photoelectric emission from a metal is 5200 Å. Calculate the work function of the metal in eV. ***[2]***
Q19. Why does the photoelectric current increase with an increase in the intensity of incident radiation, while the stopping potential remains unchanged? Explain. ***[2]***
Q20. Derive the expression for the de Broglie wavelength of an electron accelerated through a potential difference V. ***[2]***
Q21. Sketch a graph showing the variation of stopping potential with the frequency of incident radiation for two different photosensitive materials. What physical quantity does the slope of this graph represent? ***[2]***

SECTION C

Q22. State Einstein's photoelectric equation. Using it, explain: (i) why photoelectric current is independent of the frequency of incident light, and (ii) why there exists a threshold frequency for a given metal. ***[3]***
Q23. Light of wavelength 4000 Å falls on a metal surface of work function 2.0 eV. Calculate (i) the threshold frequency of the metal, and (ii) the maximum kinetic energy of the emitted photoelectrons. ***[3]***
Q24. Describe briefly, with the help of a diagram, the Davisson–Germer experiment. State its significance in the development of quantum mechanics. ***[3]***
Q25. An electron and a photon each have an energy of 100 eV. Find the de Broglie wavelength associated with each, and compare them. ***[3]***
Q26. The graph alongside shows the variation of photoelectric current with collector-plate potential for two intensities I_1 and I_2 ($I_2 > I_1$) of incident radiation of the same frequency. Explain why the saturation currents differ while the stopping potential remains the same in both cases. ***[3]***
Q27. Starting from the relation E = hν for a photon, derive an expression for its de Broglie wavelength and show that it is consistent with $\lambda = h/p$. ***[3]***
Q28. A metal surface is illuminated successively by light of wavelengths 300 nm and 400 nm. The maximum speeds of the photoelectrons in the two cases are found to be v_1 and v_2 respectively, with $v_1 = 2v_2$. Calculate the work function of the metal. ***[3]***

SECTION D (Case-Study Based Questions)

Q29. Case Study — Photoelectric Effect [4]

In an experiment to verify Einstein's photoelectric equation, the stopping potential V_0 was measured for different frequencies ν of light incident on a given photosensitive surface. The observations recorded were:

ν ($\times 10^{14}$ Hz):	5.0	6.0	7.0	8.0
V_0 (volts):	0.00	0.41	0.83	1.24

Answer the following:
(i) What is the threshold frequency of the given metal surface? [1]
(ii) Using the data, calculate the value of h/e. [1]
(iii) Find the work function of the metal in eV. [1]
(iv) If the frequency is increased further beyond 8×10^{14} Hz (intensity kept constant), what happens to the stopping potential and to the photoelectric current? [1]

Q30. Case Study — Matter Waves [4]

Louis de Broglie proposed that, like radiation, matter also exhibits a dual (wave–particle) character, and a particle of momentum p has an associated wavelength $\lambda = h/p$. This hypothesis was later confirmed experimentally by Davisson and Germer through diffraction of electrons from a nickel crystal.
Answer the following:
(i) Write the de Broglie relation connecting wavelength and momentum. [1]
(ii) An electron and a proton have the same kinetic energy. Which of the two has the longer de Broglie wavelength? Justify your answer. [1]
(iii) Calculate the de Broglie wavelength of an electron accelerated through a potential difference of 150 V. [2]

SECTION E

Q31. State the laws of photoelectric emission. Using Einstein's photoelectric equation, explain how each of these laws is accounted for. ***[5]***

OR

Derive Einstein's photoelectric equation. Draw graphs to show the variation of (i) photoelectric current with intensity of incident light (frequency kept constant), and (ii) stopping potential with frequency of incident light. [5]

Q32. The work function of caesium is 2.14 eV. (i) Find the threshold frequency for photoelectric emission from caesium. (ii) If light of frequency 6×10^{14} Hz is incident on the caesium surface, find the stopping potential and the maximum speed of the emitted photoelectrons. ***[5]***

OR

(i) Derive the expression for the de Broglie wavelength of an electron accelerated through a potential difference V. (ii) Calculate the de Broglie wavelength associated with an electron accelerated through 100 V. (iii) Compare it with the de Broglie wavelength of a proton accelerated through the same potential difference. [5]

Q33. What is meant by wave–particle duality of radiation and matter? Describe, with a labelled diagram, the Davisson–Germer experiment and explain how it confirms the wave nature of electrons. ***[5]***

OR

(i) Explain the photoelectric effect and write Einstein's photoelectric equation. (ii) A parallel beam of monochromatic light of wavelength 663 nm and power 3 mW is incident on a metal surface of work function 1.5 eV. Assuming 1% of the incident photons produce photoelectrons, calculate the number of photoelectrons emitted per second and the maximum kinetic energy of the photoelectrons. [5]

Assignment -2

CLASS XII — PHYSICS

CHAPTER 11: DUAL NATURE OF RADIATION AND MATTER

A Note on This Document

The 2017 CBSE Class XII Physics board papers did not include MCQs on this chapter — MCQs were introduced into the CBSE board exam pattern only from 2020–21 onward. The 2017 papers (Delhi, All India, and Compartment sets) consisted entirely of Very Short Answer, Short Answer, and Long Answer questions.

This document is therefore in two clearly separate parts: Part 1 contains 20 NCERT-based practice MCQs (not from any board paper) for MCQ practice. Part 2 contains genuine questions that were actually asked in the 2017 CBSE board papers on this chapter, in their original VSA/SA/LA format, with answers.

PART 1 — NCERT-Based Practice MCQs (20 Questions)

These are practice questions based on NCERT concepts. They were not part of the 2017 CBSE board exam.

1. The photoelectric effect was successfully explained by:
(a) Newton (b) Maxwell (c) Einstein (d) Planck

2. Work function of a metal is the minimum energy required to:
(a) Move an electron within the metal (b) Remove an electron from the metal surface (c) Ionise the metal atom (d) Excite an electron

3. The SI unit of work function is:
(a) Joule only (b) eV or Joule (c) Watt (d) eV/s

4. Photoelectric current depends on:
(a) Frequency of light (b) Intensity of light (c) Angle of incidence (d) Work function

5. Threshold frequency ν_0 is related to work function φ_0 by:
(a) $\varphi_0 = h\nu_0$ (b) $\varphi_0 = h/\nu_0$ (c) $\varphi_0 = \nu_0/h$ (d) $\varphi_0 = h + \nu_0$

6. If the intensity of incident light is increased, keeping frequency constant, the stopping potential:
(a) Increases (b) Decreases (c) Remains unchanged (d) Becomes zero

7. The de Broglie wavelength associated with a moving particle is given by:
(a) $\lambda = h/p$ (b) $\lambda = p/h$ (c) $\lambda = hp$ (d) $\lambda = h/mv^2$

8. For photons, the momentum p is related to energy E by:
(a) $p = E/c$ (b) $p = Ec$ (c) $p = c/E$ (d) $p = E^2/c$

9. An electron and an alpha particle are accelerated through the same potential difference. Which has a smaller de Broglie wavelength?
(a) Electron (b) Alpha particle (c) Both equal (d) Cannot be determined

10. The maximum kinetic energy of emitted electrons versus frequency graph is:
(a) A parabola (b) A straight line with positive slope (c) A straight line through origin (d) A hyperbola

11. Photoelectric effect shows no emission even with high intensity light, if frequency is below threshold:
(a) True for all metals (b) False for all metals (c) True only for alkali metals (d) False for alkali metals

12. The stopping potential in the photoelectric effect gives a measure of:
(a) Number of photoelectrons (b) Intensity of light (c) Maximum KE of photoelectrons (d) Work function only

13. Photocells are used in:
(a) Burglar alarms (b) Automatic light control (c) Counting devices (d) All of these

14. The wave nature of matter was experimentally verified by:
(a) Millikan's experiment (b) Davisson-Germer experiment (c) Compton experiment (d) Rutherford's experiment

15. The de Broglie wavelength of a particle is independent of its:
(a) Mass (b) Velocity (c) Charge (d) Momentum

16. If the accelerating potential of an electron is increased 4 times, its de Broglie wavelength changes by a factor of:

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

17. Photoelectric emission occurs instantaneously (within ~10^{-9} s) because:
(a) Wave theory predicts this (b) Photon energy is absorbed in a single collision (c) Electrons take time to accumulate energy (d) Intensity determines emission time

18. According to Einstein's photoelectric equation, KEmax vs ν graph has slope equal to:
(a) φ_0 (b) h (c) e (d) h/e

19. Which particle has the largest de Broglie wavelength if all have the same kinetic energy?
(a) Electron (b) Proton (c) Neutron (d) Alpha particle

20. Photoelectric effect is not observed with visible light for:
(a) Sodium (b) Potassium (c) Platinum (d) Caesium

PART 2 — Actual CBSE 2017 Board Questions (Dual Nature)

These questions were genuinely asked in the CBSE 2017 Delhi / All India / Compartment Class XII Physics papers on this chapter (original format: VSA/SA/LA, not MCQ), with answers below each.

Q1. *[VSA — Comptt. All India 2017 (1 mark)]*
State two properties of photons. For monochromatic radiation incident on a photosensitive surface, why do not all photoelectrons come out with the same energy?

Q2. *[VSA — Comptt. All India 2017 (1 mark)]*
A photon and a proton have the same de Broglie wavelength. Show, by calculation, which has more total energy.

Q3. *[SA-I — Delhi 2017 (2 marks)]*
(i) Explain photoelectric emission using Einstein's photoelectric equation. (ii) Work functions: Na = 2.75 eV, K = 2.3 eV, Mo = 4.17 eV, Ni = 5.15 eV. Which metal(s) will show no photoelectric emission for a laser of wavelength 3300 Å placed 1 m away? What happens if the source is moved to 50 cm?

Q4. *[SA-I — Delhi 2017 (2 marks)]*
State two important features of Einstein's photoelectric equation. Radiation of frequency 10^{15} Hz is incident on surfaces P and Q: no emission occurs from P, while emission occurs from Q with photoelectrons of zero kinetic energy. Find the work function of Q.

Q5. *[SA-II — All India 2017 (3 marks)]*
Using the photon picture of light, derive Einstein's photoelectric equation. State two features of the photoelectric effect that cannot be explained by the wave theory of light.

Q6. *[SA-II — All India 2017 (3 marks)]*
Explain, giving reasons: (a) photoelectric current increases with intensity of incident radiation; (b) stopping potential varies linearly with frequency with the same slope for all surfaces; (c) maximum kinetic energy of photoelectrons is independent of intensity.

Q7. *[SA-II — Comptt. Delhi 2017 (3 marks)]*
Sketch the graph of de Broglie wavelength λ versus accelerating potential V for a particle of charge q and mass m. A proton and a deuteron have the same de Broglie wavelength — which has more kinetic energy? Explain.

Q8. *[SA-II — Comptt. Delhi 2017 (3 marks)]*
An α-particle and a proton have the same de Broglie wavelength, equal to 1 Å. Explain, with calculation, which has more kinetic energy.

Q9. *[SA-II — Comptt. All India 2017 (3 marks)]*
The photon emitted during de-excitation from the first excited state to the ground state of a hydrogen atom is used to irradiate a photocathode; the resulting stopping potential is 5 V. Calculate the work function of the cathode.

Q10. *[SA-II — Comptt. All India 2017 (3 marks)]*
An electron microscope uses electrons accelerated through 50 kV. Find the de Broglie wavelength of the electrons, and compare the resolving power of this microscope with an optical microscope using 550 nm light (same numerical aperture).

Q11. *[LA — Comptt. All India 2017 (5 marks)]*
(a) State three features of the photoelectric effect that wave theory cannot explain, and show how Einstein's equation accounts for them. (b) A graph shows stopping potential V_0 vs frequency ν for two materials M1 and M2. Explain (i) why the slope of both lines is the same, and (ii) which material's electrons have greater kinetic energy for the same frequency.

Q12. *[LA — Comptt. All India 2017 (5 marks)]*
Describe briefly how the wave nature of electrons was established experimentally. Also, find the ratio of de Broglie wavelengths of deuterons and α-particles accelerated from rest through the same potential V.

Assignment -3

CLASS XII — PHYSICS

CHAPTER 11: DUAL NATURE OF RADIATION AND MATTER

Assertion-Reason Questions (NCERT-Based, CBSE Pattern) with Answers

Note: Assertion-Reason (AR) questions were introduced into the CBSE board exam pattern only from 2020–21 onward. I could not verify these 8 questions as having appeared verbatim in a specific past CBSE board paper on this chapter, so they are presented here as NCERT-based CBSE-pattern practice questions rather than attributed to any particular year.

For each question, two statements are given — Assertion (A) and Reason (R). Choose 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, but R is false.
(d) A is false, but R is true.

Q1. Assertion (A): In the process of photoelectric emission, all emitted electrons do not have the same kinetic energy.
Reason (R): The energy of the incident photons is randomly distributed among all the free electrons in the metal.

Q2. Assertion (A): Photoelectric current remains unchanged when the frequency of incident radiation is increased, provided the intensity is kept constant and the frequency stays above the threshold value.
Reason (R): Photoelectric current depends only on the number of photons incident per second, i.e., on the intensity of radiation, not on the frequency.

Q3. Assertion (A): The stopping potential for a photosensitive surface depends only on the frequency of incident radiation, not on its intensity.
Reason (R): Maximum kinetic energy of photoelectrons, $KEmax = h\nu - \varphi_0$, depends only on frequency and work function.

Q4. Assertion (A): No photoelectric emission takes place if the frequency of incident radiation is less than the threshold frequency, however high the intensity of radiation may be.
Reason (R): Below the threshold frequency, a single photon does not carry enough energy to overcome the work function of the metal.

Q5. Assertion (A): The de Broglie wavelength of a moving electron decreases as its speed increases.
Reason (R): The de Broglie wavelength is directly proportional to the momentum of the particle.

Q6. Assertion (A): A proton and an electron, accelerated through the same potential difference, have different de Broglie wavelengths.
Reason (R): The de Broglie wavelength depends on the mass of the particle in addition to the accelerating potential.

Q7. Assertion (A): The wave nature of electrons was experimentally confirmed by the Davisson–Germer experiment.
Reason (R): Diffraction is a characteristic phenomenon exhibited only by waves.

Q8. Assertion (A): The photoelectric effect cannot be explained on the basis of the wave theory of light.
Reason (R): According to the wave theory, the energy of a light wave is spread continuously over the wavefront and does not depend on its frequency.

Assignment -4
CLASS XII — PHYSICS

CHAPTER 11: DUAL NATURE OF RADIATION AND MATTER

Case Study Based Questions (NCERT-based)

Case Study 1: Photoelectric Effect — Threshold Frequency

When light of frequency ν falls on a clean metal surface, electrons are emitted only if ν exceeds a certain minimum value called the threshold frequency ν_0, which is characteristic of the metal. Below ν_0, no photoelectrons are emitted no matter how intense the light is. The maximum kinetic energy of the emitted electrons increases linearly with frequency once $\nu > \nu_0$.
(i) What is the physical significance of threshold frequency? [1]
(ii) Two metals A and B have work functions 2 eV and 5 eV respectively. Which has a higher threshold frequency? [1]

(iii) Why does photoelectric emission not occur below the threshold frequency even for very intense light? [2]

Case Study 2: Einstein's Photoelectric Equation

Einstein explained the photoelectric effect using the equation $KE_{max} = h\nu - \varphi_0$, where φ_0 is the work function. This equation was later verified experimentally by Millikan, who measured stopping potential against frequency and found a straight-line graph.

(i) What does the y-intercept of the V_0 vs ν graph represent? [1]

(ii) What does the slope of this graph represent, and what is its numerical value? [1]

(iii) If the work function of a metal is 2.5 eV, calculate the threshold wavelength. (hc = 12400 eV·Å) [2]

Case Study 3: de Broglie Hypothesis

Louis de Broglie proposed that all matter exhibits wave-like properties, with wavelength $\lambda = h/p$, where p is the momentum of the particle. This wavelength is significant only for very light, fast-moving particles like electrons, and is negligible for macroscopic objects.

(i) Write the de Broglie relation. [1]

(ii) Why is the wave nature of a moving cricket ball never observed in daily life? [1]

(iii) Calculate the de Broglie wavelength of an electron moving with a speed of 10^6 m/s. ($m_e = 9.11 \times 10^{-31}$ kg, $h = 6.63 \times 10^{-34}$ J s) [2]

Case Study 4: Davisson–Germer Experiment

Davisson and Germer accelerated electrons through a known potential and directed them at a nickel crystal. The scattered electron intensity, measured as a function of angle, showed a sharp peak at 50° for 54 V accelerating electrons — matching the diffraction pattern predicted for waves of de Broglie wavelength $\lambda = h/p$.

(i) What was the purpose of using a nickel crystal in this experiment? [1]

(ii) What key conclusion did this experiment establish about electrons? [1]

(iii) Explain how this experiment provided direct confirmation of de Broglie's hypothesis. [2]

Assignment -5

CLASS XII — PHYSICS

CHAPTER 11: DUAL NATURE OF RADIATION AND MATTER

Previous Year CBSE Board Short Answer Questions with Answers

Q1. *[Delhi 2017 — 2 marks]*
Explain photoelectric emission using Einstein's photoelectric equation. Given work functions Na = 2.75 eV, K = 2.3 eV, Mo = 4.17 eV, Ni = 5.15 eV, which metal(s) show no photoelectric emission for a laser of wavelength 3300 Å?

Q2. *[Delhi 2017 — 2 marks]*
State two important features of Einstein's photoelectric equation. Radiation of frequency 10^{15} Hz is incident on surfaces P and Q: no emission occurs from P, while Q emits electrons with zero kinetic energy. Find the work function of Q.

Q3. *[All India 2017 — 3 marks]*
Using the photon picture of light, derive Einstein's photoelectric equation. State two features of the photoelectric effect that cannot be explained by the wave theory of light.

Q4. *[All India 2017 — 3 marks]*
Explain, giving reasons, for the following: (a) photoelectric current increases with an increase in intensity of incident radiation; (b) stopping potential varies linearly with frequency, with the same slope for all photosensitive surfaces; (c) maximum kinetic energy of photoelectrons is independent of intensity.

Q5. *[Comptt. Delhi 2017 — 3 marks]*
A proton and a deuteron have the same de Broglie wavelength. Which of the two has more kinetic energy? Explain.

Q6. *[Comptt. Delhi 2017 — 3 marks]*
An α-particle and a proton have the same de Broglie wavelength, equal to 1 Å. Explain, with calculation, which of the two has more kinetic energy.

Q7. *[Comptt. All India 2017 — 3 marks]*
The photon emitted during de-excitation from the first excited state to the ground state of a hydrogen atom is used to irradiate a photocathode, producing a stopping potential of 5 V. Calculate the work function of the cathode.

Q8. *[Comptt. All India 2017 — 3 marks]*
An electron microscope uses electrons accelerated through 50 kV. Find the de Broglie wavelength of these electrons, and compare the resolving power of this microscope with an optical microscope using light of wavelength 550 nm (same numerical aperture).

Q9. *[Comptt. All India 2017 — 1 mark]*
State two properties of photons. For monochromatic radiation incident on a photosensitive surface, why do not all photoelectrons come out with the same energy?

Q10. *[Comptt. All India 2017 — 1 mark]*
A photon and a proton have the same de Broglie wavelength. Show, by actual calculation, which of the two has more total energy.

Assignment -6

SOLUTIONS OF QUESTION PAPER

Section A — MCQs & Assertion-Reason (1 mark each)

1. (a) — $\lambda_0 = hc/\varphi_0 = 12400/4.2 \approx 2952$ Å
2. (b) — Photoelectric current ∝ number of photons ∝ intensity.
3. (b) — $eV_0 = h\nu - \varphi_0 \Rightarrow V_0 = (h/e)\nu - \varphi_0/e$; slope = h/e.
4. (a)
5. (b) — $\lambda \propto 1/\sqrt{m}$ at same accelerating potential.
6. (a)
7. (c)

8. (b)
9. (a)
10. (c) — Current depends on intensity (photon number), not frequency.
11. (c)
12. (a)
13. (a) — $\lambda = h/mv = 6.63\times10^{-34}/1 \approx 6.63\times10^{-34}$ m.
14. (a) — $\varphi_0 = h\nu_0$, so $\varphi_A/\varphi_B = \nu/2\nu = 1/2$.
15. (a) — Both true; wave theory's frequency-independent energy distribution is exactly why it fails to explain the threshold-frequency and instantaneous-emission features.
16. (d) — A is true (higher speed → higher momentum → shorter λ), but R is false: λ is inversely proportional to momentum ($\lambda = h/p$), not directly proportional.

Section B (2 marks each)

17. (i) Radiation behaves as a stream of discrete energy packets called photons, each carrying energy $E = h\nu$. (ii) Photons travel with the speed of light and are not deflected by electric/magnetic fields; in a photon–particle collision, energy and momentum are conserved as in an elastic collision (any correct pair of features, 1 mark each).
18. $\varphi_0 = hc/\lambda_0 = 12400$ eV·Å / 5200 Å ≈ 2.38 eV.
19. Increasing intensity increases the number of photons falling per second, hence more photoelectrons are ejected per second, increasing current. But stopping potential depends only on the maximum KE of photoelectrons, which is set by $h\nu - \varphi_0$ — independent of the number of photons — so it stays unchanged.
20. $KE = eV = p^2/2m \Rightarrow p = \sqrt{2meV}$. de Broglie wavelength $\lambda = h/p = h/\sqrt{2meV}$.
21. Graph: straight lines for both materials, parallel to each other (same slope h/e), with different intercepts on the ν-axis (different threshold frequencies) — each line cutting the V_0-axis at different negative values $-\varphi_0/e$. The common slope equals h/e (Planck's constant divided by electronic charge), independent of the material.

Section C (3 marks each)

22. Einstein's equation: $h\nu = \varphi_0 + KE_{max}$, i.e., $KE_{max} = h\nu - \varphi_0$. (i) One photon interacts with one electron; increasing intensity increases photon number (hence photocurrent) but not the energy per photon, so KE_{max} and hence stopping potential are unaffected by intensity — current is governed only by photon number. (ii) Emission occurs only if $h\nu \geq \varphi_0$; below this, KE_{max} would be negative, which is not physical — hence a threshold frequency $\nu_0 = \varphi_0/h$ exists.
23. $E_{photon} = hc/\lambda = 12400/4000 = 3.1$ eV. (i) $\nu_0 = \varphi_0/h = (2.0 \times 1.6\times10^{-19})/(6.63\times10^{-34}) \approx 4.83\times10^{14}$ Hz. (ii) $KE_{max} = 3.1 - 2.0 = 1.1$ eV.
24. A beam of electrons accelerated through a known potential is directed at a nickel crystal; the intensity of scattered electrons is measured as a function of scattering angle. A pronounced peak was observed at 50° for 54 V electrons, matching the diffraction pattern expected for waves of de Broglie wavelength $\lambda = h/p$ — confirming the wave nature of electrons and providing the first direct experimental verification of de Broglie's hypothesis, a cornerstone of quantum mechanics.
25. Photon: $\lambda = hc/E = 12400/100 = 124$ Å. Electron: $\lambda = h/\sqrt{2m_eE}$; with $E = 100$ eV $= 1.6\times10^{-17}$ J, $\lambda \approx 1.23$ Å. So the photon's wavelength (~124 Å) is about 100 times longer than the electron's (~1.23 Å) for the same energy, because the electron's rest mass gives it much larger momentum at the same energy.
26. Both curves rise and flatten to a constant (saturation) value as collector potential increases; saturation current for I_2 is higher than for I_1 since more photons (higher intensity) eject more photoelectrons per second. Both curves cut the potential axis at the same negative value $-V_0$, since stopping potential depends only on frequency (same for both curves here), not on intensity.
27. For a photon, $E = h\nu = hc/\lambda$. Also, from relativity, $E = pc$ for a massless particle. Equating: $pc = hc/\lambda \Rightarrow p = h/\lambda \Rightarrow \lambda = h/p$ — identical in form to the de Broglie relation, showing photons are a special ($v = c$) case of matter waves.
28. $hc/\lambda_1 = \varphi_0 + \frac{1}{2}mv_1^2$; $hc/\lambda_2 = \varphi_0 + \frac{1}{2}mv_2^2$, with $v_1 = 2v_2$. $E_1 = 1240/300 = 4.133$ eV; $E_2 = 1240/400 = 3.10$ eV. Let $K_2 = \frac{1}{2}mv_2^2$, so $\frac{1}{2}mv_1^2 = 4K_2$. Subtracting: $E_1 - E_2 = 3K_2 \Rightarrow K_2 = 0.344$ eV. $\varphi_0 = E_2 - K_2 = 3.10 - 0.344 \approx 2.76$ eV.

Section D (Case Study — 4 marks each)

29. (i) The line cuts the ν-axis at $\nu_0 = 5.0 \times 10^{14}$ Hz — the threshold frequency. (ii) Slope = $\Delta V_0/\Delta\nu = (1.24 - 0)/((8.0-5.0)\times10^{14}) \approx 4.13\times10^{-15}$ V·s ≈ h/e. (iii) $\varphi_0 = h\nu_0$; in eV, $\varphi_0 = (h/e) \times \nu_0 = 4.13\times10^{-15} \times 5.0\times10^{14} \approx$ 2.07 eV. (iv) Stopping potential continues to increase linearly with frequency ($V_0 = (h/e)\nu - \varphi_0/e$); photoelectric current (at saturation) remains unchanged since intensity is unchanged.
30. (i) $\lambda = h/p$. (ii) For the same KE, $\lambda = h/\sqrt{2mKE}$, so $\lambda \propto 1/\sqrt{m}$. Since the proton is far more massive than the electron, the electron has the longer de Broglie wavelength. (iii) $\lambda = h/\sqrt{2meV} = 12.27/\sqrt{V}$ Å = $12.27/\sqrt{150} \approx 1.00$ Å.

Section E (5 marks each)

31. Laws of photoelectric emission: (a) For a given metal, photoelectric current ∝ intensity of incident light, above threshold frequency. (b) For a given metal there exists a threshold frequency below which no emission occurs, regardless of intensity. (c) Maximum KE of photoelectrons increases linearly with frequency and is independent of intensity. (d) Emission is instantaneous (no observable time lag). Einstein's equation $KEmax = h\nu - \varphi_0$ accounts for all four: (a) more photons ⇒ more photoelectrons ⇒ more current; (b) emission needs $h\nu \geq \varphi_0$, giving $\nu_0 = \varphi_0/h$; (c) KEmax depends linearly on ν as per the equation, not on intensity; (d) each photon is absorbed in a single quantum event transferring its entire energy instantly to one electron, with no time needed to accumulate energy.

OR — Derivation: each photon of energy hν gives up its entire energy to a single electron; part of this energy (φ_0) frees the electron from the metal surface, the rest appears as its kinetic energy: $h\nu = \varphi_0 + KEmax$, so $KEmax = h\nu - \varphi_0 = eV_0$. Graph (i): photocurrent vs intensity — straight line through the origin (linear relationship, frequency fixed). Graph (ii): stopping potential vs frequency — straight line with positive slope h/e, cutting the frequency axis at ν_0 and the V_0-axis at $-\varphi_0/e$.
32. $\nu_0 = \varphi_0/h = (2.14 \times 1.6\times10^{-19})/(6.63\times10^{-34}) \approx 5.16\times10^{14}$ Hz. For $\nu = 6\times10^{14}$ Hz: $E = h\nu = 6.63\times10^{-34} \times 6\times10^{14} = 3.978\times10^{-19}$ J = 2.486 eV. KEmax = 2.486 − 2.14 = 0.346 eV ⇒ stopping potential $V_0 \approx 0.346$ V. vmax: $\frac{1}{2}mv^2 = KEmax \Rightarrow v = \sqrt{2\times0.346\times1.6\times10^{-19}/9.11\times10^{-31}} \approx 3.49\times10^5$ m/s.

OR — (i) Derivation as in Q20: $\lambda = h/\sqrt{2meV}$. (ii) $\lambda = 12.27/\sqrt{100} \approx 1.227$ Å. (iii) $\lambda p = \lambda e \times \sqrt{me/mp} = 1.227 \times \sqrt{1/1836} \approx 0.0286$ Å — the proton's wavelength is about 43 times shorter than the electron's for the same accelerating potential.
33. Wave–particle duality: radiation (and matter) exhibits wave-like behaviour (interference, diffraction) in propagation, and particle-like behaviour (discrete quanta, photoelectric effect) in interaction with matter; neither picture alone is sufficient. Davisson–Germer experiment: a beam of electrons from an electron gun, accelerated through a known potential, is directed at a nickel crystal target; a movable detector measures the intensity of electrons scattered at different angles. A pronounced intensity peak was observed at a scattering angle of 50° for 54 V accelerating potential, matching the diffraction condition for waves of wavelength $\lambda = h/p$ — the same value predicted by de Broglie's formula — thereby confirming that electrons exhibit wave nature.

OR — (i) When light of suitable frequency falls on a metal surface, electrons are emitted; $h\nu = \varphi_0 + KEmax$. (ii) E_photon = hc/λ = 1240/663 ≈ 1.87 eV = $1.87\times1.6\times10^{-19} \approx 2.99\times10^{-19}$ J. Photons incident per second = P/E_photon = $3\times10^{-3}/2.99\times10^{-19} \approx 1.00\times10^{16}\ s^{-1}$. With 1% efficiency, photoelectrons emitted per second ≈ $1.00\times10^{14}\ s^{-1}$. KEmax = 1.87 − 1.5 = 0.37 eV.

: Dual Nature of Radiation and Matter

Assertion-Reason

Answer1: *(c) — A is true — photoelectrons are emitted with a range of kinetic energies up to a maximum value. But R is false: each photon transfers its entire energy to a single electron in one event (not shared among many electrons); the variation in KE arises because electrons from different depths lose different amounts of energy in collisions on their way out of the metal.*

Answer2: *(a) — Both true, and R correctly explains A: since current is set by how many photoelectrons are ejected per second, which in turn depends on the number of incident photons per second (intensity), current stays the same as frequency changes as long as intensity is unchanged; it is KEmax, not current, that depends on frequency.*

Answer3: *(a) — Both true, and R correctly explains A: since $eV_0 = KEmax = h\nu - \varphi_0$, stopping potential is fixed once frequency and the metal (hence φ_0) are fixed, independent of intensity.*

Answer4: *(a) — Both true, and R correctly explains A: since each photon interacts with only one electron and photon energies do not add up, no amount of intensity (i.e., number of photons) can compensate for insufficient energy per photon.*
Answer5: *(c) — A is true — since $\lambda = h/mv$, higher speed gives a smaller wavelength. R is false: de Broglie wavelength is inversely proportional to momentum ($\lambda = h/p$), not directly proportional.*
Answer6: *(a) — Both true, and R correctly explains A: $\lambda = h/\sqrt{2mqV}$; since the proton and electron have different masses (though the same charge magnitude and same V), their wavelengths differ.*
Answer7: *(a) — Both true, and R correctly explains A: the experiment showed a diffraction pattern for electrons scattered from a nickel crystal, matching the pattern predicted for waves of de Broglie wavelength $\lambda = h/p$ — and since diffraction is a wave phenomenon, this confirmed the wave nature of electrons.*
Answer8 : *(a) — Both true, and R correctly explains A: wave theory's frequency-independent, continuously-distributed energy is exactly what fails to predict the existence of a threshold frequency and the instantaneous nature of photoelectric emission, both of which are observed experimentally.*

SHORT -ANSWER QUESTION SOLUTION

Answer1 : A single photon transfers its entire energy $h\nu$ to one electron; part of this overcomes the work function φ_0, and the remainder becomes the electron's kinetic energy: $KE_{max} = h\nu - \varphi_0$. Photon energy at 3300 Å = $hc/\lambda = 12400/3300 \approx 3.76$ eV. Since this is less than the work functions of Mo (4.17 eV) and Ni (5.15 eV), these two metals show no emission; Na and K, having lower work functions, do emit photoelectrons.

Answer2: (i) KEmax depends linearly on the frequency of incident radiation and is independent of intensity. (ii) There exists a threshold frequency $\nu_0 = \varphi_0/h$ below which no emission occurs, regardless of intensity. Since Q emits electrons with exactly zero kinetic energy, the incident frequency equals Q's threshold frequency: $\nu_0(Q) = 10^{15}$ Hz. Hence $\varphi_0(Q) = h\nu_0 = 6.63\times10^{-34} \times 10^{15} \approx 6.63\times10^{-19}$ J ≈ 4.14 eV.

Answer3: *Each photon of energy $h\nu$ interacts with a single electron; part of the energy (φ_0) frees the electron from the metal surface, and the remainder appears as its kinetic energy: $h\nu = \varphi_0 + KE_{max}$. Two features wave theory cannot explain: (i) KEmax depends only on the frequency of incident light, not on its intensity, contrary to wave-theory predictions; (ii) a sharp threshold frequency exists for every metal, below which no emission occurs however intense the light — a fact wave theory does not predict.*

Answer 4: *(a) A higher intensity means more photons striking the surface per second, resulting in more photon–electron collisions and hence more photoelectrons emitted per second, provided the frequency exceeds the threshold. (b) From $eV_0 = h\nu - \varphi_0$, we get $V_0 = (h/e)\nu - \varphi_0/e$ — a straight line in ν whose slope h/e is the ratio of two universal constants, and is therefore the same for every material; only the intercept ($-\varphi_0/e$) varies with the surface. (c) Since $KE_{max} = h\nu - \varphi_0$ depends only on the frequency and the work function, not on how many photons arrive per second, it is independent of intensity.*

Answer5 : *Kinetic energy $K = h^2/(2m\lambda^2)$, so at a fixed de Broglie wavelength, $K \propto 1/m$. A deuteron (a proton bound to a neutron) is roughly twice as massive as a proton. Since the proton has the smaller mass, it has the greater kinetic energy for the same de Broglie wavelength.*

Answer6 : *Using $K = h^2/(2m\lambda^2)$: for the proton ($m \approx 1.67\times10^{-27}$ kg), $K_p \approx (6.63\times10^{-34})^2/(2 \times 1.67\times10^{-27} \times (10^{-10})^2) \approx 1.32\times10^{-20}$ J ≈ 0.082 eV. Since the α-particle's mass ($\approx 4m_p$) is about four times the proton's mass, and $K \propto 1/m$ at fixed λ, $K_\alpha \approx K_p/4 \approx 0.021$ eV. So the proton has roughly four times more kinetic energy than the α-particle.*

Answer7 : *Energy released in the transition $n = 2 \rightarrow n = 1$: $E = 13.6(1 - 1/4) = 13.6 \times 0.75 = 10.2$ eV. This is the energy of the incident photon. Since $eV_0 = KEmax = 5$ eV, the work function is $\varphi_0 = E - KEmax = 10.2 - 5 = 5.2$ eV.*

Answer8: *$\lambda = 12.27/\sqrt{V}$ Å $= 12.27/\sqrt{50000} \approx 0.055$ Å $\approx 5.5\times10^{-12}$ m. Since resolving power is inversely proportional to wavelength, the electron microscope's resolving power exceeds that of the optical microscope ($\lambda = 5500$ Å) by a factor of roughly $5500/0.055 \approx 10^5$ — about a hundred thousand times finer resolution.*

Answer9: *Two properties of photons: each carries energy $E = h\nu$; a photon is electrically neutral and travels at speed c irrespective of the intensity of radiation. All photoelectrons do not have the same energy because electrons originating from below the metal surface lose some energy in collisions on their way out, so only electrons emitted from the surface itself attain the maximum kinetic energy KEmax; others emerge with less.*

Answer10 : *For a photon, $E\_photon = pc$ (since $p = h/\lambda$). For a non-relativistic proton of the same momentum, $E\_proton = p^2/2m$. Their ratio is $E\_photon/E\_proton = pc/(p^2/2m) = 2mc/p = 2mc\lambda/h$. Since mc is extremely large compared with h/λ for any practically achievable wavelength, $E\_photon \gg E\_proton$ — the photon carries far greater total energy for the same de Broglie wavelength.*

Case Study Answers

Case Study 1 — Answers
(i) It is the minimum frequency of incident radiation required to just eject an electron from a given metal's surface (KE = 0 at ν_0).
(ii) Metal B — since $\nu_0 = \varphi_0/h$, a higher work function means a higher threshold frequency.
(iii) Each photon interacts with only one electron and transfers its entire energy $h\nu$ in a single event. If $h\nu < \varphi_0$, one photon cannot supply enough energy to free the electron, and photons do not add up their energies — increasing intensity only increases the number of photons striking the surface, not the energy carried by each one.

Case Study 2 — Answers
(i) The y-intercept (at $\nu = 0$) represents $-\varphi_0/e$.
(ii) The slope represents $h/e \approx 4.14 \times 10^{-15}$ V·s.
(iii) $\lambda_0 = hc/\varphi_0 = 12400/2.5 = 4960$ Å.

Case Study 3 — Answers
(i) $\lambda = h/p = h/(mv)$.
(ii) Because its mass is very large, its de Broglie wavelength ($\lambda = h/mv$) works out to be immeasurably small ($\sim10^{-34}$ m), far too small to produce any observable diffraction or interference effects.
(iii) $\lambda = h/(mv) = 6.63\times10^{-34} / (9.11\times10^{-31} \times 10^6) \approx 7.28 \times 10^{-10}$ m ≈ 7.28 Å.

Case Study 4 — Answers
(i) The regularly spaced atomic planes of the nickel crystal act as a diffraction grating for electron waves, similar to how a crystal diffracts X-rays.
(ii) It established that electrons exhibit wave nature, confirming the wave-particle duality of matter.
(iii) The observed diffraction peak's angle matched the value calculated using the de Broglie wavelength ($\lambda = h/p$) for the electrons' momentum at 54 V. Since diffraction is a wave phenomenon, this quantitative match between theory and experiment confirmed that electrons behave as waves under these conditions.

MCQ,SAnswer Key

1.c 2.b 3.b 4.b 5.a 6.c 7.a 8.a 9.b 10.b 11.a 12.c 13.d 14.b 15.c 16.c 17.b 18.b 19.a 20.c

S-A QUESTION ANSWER

Answer1: Two properties of photons: each carries energy $E = h\nu$; a photon is electrically neutral and travels at speed c irrespective of intensity. All photoelectrons do not have the same energy because, in addition to overcoming the work function, electrons originating from below the surface lose some energy in collisions on their way out, so only electrons emitted from the surface itself acquire the maximum kinetic energy KEmax; others come out with less.

Answer2: For a photon, $E_{photon} = pc$ (since $p = h/\lambda$). For a non-relativistic proton of the same momentum, $E_{proton} = p^2/2m$. Their ratio is $E_{photon}/E_{proton} = 2mc/p = 2mc\lambda/h$. Since mc is extremely large compared with h/λ for any practically achievable λ, $E_{photon} \gg E_{proton}$ — the photon carries far greater total energy for the same de Broglie wavelength.

Answer3: (i) A single photon transfers its entire energy $h\nu$ to one electron; part overcomes the work function φ_0, the rest becomes the electron's kinetic energy: $KEmax = h\nu - \varphi_0$. (ii) Photon energy at 3300 Å: $E = hc/\lambda = 12400/3300 \approx 3.76$ eV. Since 3.76 eV < 4.17 eV (Mo) and < 5.15 eV (Ni), these two metals will show no emission (Na and K, with lower work functions, will emit). Moving the source closer only increases intensity, not photon energy, so Mo and Ni still show no emission; for Na and K, KEmax is unchanged — only the photocurrent increases.

Answer4: Two features: (i) KEmax depends linearly on frequency, independent of intensity; (ii) there exists a threshold frequency $\nu_0 = \varphi_0/h$ below which no emission occurs regardless of intensity. Since no emission occurs from P, $\nu_0(P) > 10^{15}$ Hz. Since Q emits electrons with exactly zero KE, the incident frequency equals Q's threshold frequency: $\nu_0(Q) = 10^{15}$ Hz. So $\varphi_0(Q) = h\nu_0 = 6.63\times10^{-34} \times 10^{15} \approx 6.63\times10^{-19}$ J ≈ 4.14 eV.

Answer5: Each photon (energy $h\nu$) interacts with one electron; part of the energy (φ_0) frees the electron, the rest becomes its kinetic energy: $h\nu = \varphi_0 + KEmax$. Two features wave theory cannot explain: (i) KEmax should depend on intensity according to wave theory, but experimentally it depends only on frequency; (ii) wave theory predicts no threshold frequency should exist (since energy could accumulate over time at any frequency given enough intensity), but a sharp threshold frequency is observed for every metal.

Answer6: (a) Higher intensity means more photons per second, so more photon-electron collisions and hence more photoelectrons emitted per second (more current), for frequency above threshold. (b) From $eV_0 = h\nu - \varphi_0$, $V_0 = (h/e)\nu - \varphi_0/e$ — a straight line in ν with slope h/e, a universal constant independent of the material; only the intercept ($-\varphi_0/e$) differs between surfaces. (c) Since $KEmax = h\nu - \varphi_0$ depends only on frequency and work function, and each photon transfers a fixed amount of energy per collision regardless of how many photons arrive per second, KEmax does not depend on intensity.

Answer6: (a) Higher intensity means more photons per second, so more photon-electron collisions and hence more photoelectrons emitted per second (more current), for frequency above threshold. (b) From $eV_0 = h\nu - \varphi_0$, $V_0 = (h/e)\nu - \varphi_0/e$ — a straight line in ν with slope h/e, a universal constant independent of the material; only the intercept ($-\varphi_0/e$) differs between surfaces. (c) Since $KEmax = h\nu - \varphi_0$ depends only on frequency and work function, and each photon transfers a fixed amount of energy per collision regardless of how many photons arrive per second, KEmax does not depend on intensity.

Answer7: $\lambda = h/\sqrt{(2mqV)}$, so λ decreases as V increases (a curve resembling $1/\sqrt{V}$, flattening out at higher V). For the same λ, since $\lambda = h/\sqrt{(2mK)}$ (K = kinetic energy), $K = h^2/(2m\lambda^2)$, so $K \propto 1/m$. As the deuteron (proton + neutron) is roughly twice as massive as the proton, the proton — having the smaller mass — has the greater kinetic energy for the same de Broglie wavelength.

Answer8: $K = h^2/(2m\lambda^2)$. For the proton ($m \approx 1.67\times10^{-27}$ kg): $K_p = (6.63\times10^{-34})^2/(2\times1.67\times10^{-27}\times(10^{-10})^2) \approx 1.32\times10^{-20}$ J ≈ 0.082 eV. For the α-particle ($m \approx 4 \times 1.67\times10^{-27}$ kg): $K_\alpha \approx K_p/4 \approx 0.021$ eV. Since $K \propto 1/m$ at fixed λ, and the α-particle's mass is about four times the proton's, the proton has roughly four times more kinetic energy than the α-particle.

Answer9: Energy released (n=2 → n=1): $E = 13.6(1 - 1/4) = 13.6 \times 0.75 = 10.2$ eV. This is the photon energy incident on the cathode. Since $eV_0 = KEmax = 5$ eV, the work function is $\varphi_0 = E - KEmax = 10.2 - 5 = 5.2$ eV.

Answer10: $\lambda = 12.27/\sqrt{V}$ Å $= 12.27/\sqrt{50000} \approx 0.055$ Å $\approx 5.5\times10^{-12}$ m. Since resolving power is inversely proportional to wavelength, the electron microscope's resolving power exceeds that of the optical microscope ($\lambda = 5500$ Å) by a factor of roughly $5500/0.055 \approx 10^5$ — about a hundred thousand times better resolution.

Answer11: (a) Wave theory predicts KEmax should rise with intensity (observed: it doesn't, only with frequency); predicts no threshold frequency should exist (observed: a sharp threshold does exist for each metal); predicts a time lag for emission at low intensities (observed: emission is instantaneous). Einstein's equation KEmax = $h\nu - \varphi_0$ resolves all three, since one photon transfers its full energy to one electron instantly, and the process only occurs if $h\nu \geq \varphi_0$. (b) (i) The slope of the V_0–ν line equals h/e, the ratio of two universal constants — the same for every material. (ii) At the same frequency, the material with the higher V_0 (the line lying above the other) has electrons with greater kinetic energy, since KEmax = eV_0.

Answer12: In the Davisson–Germer experiment, electrons from a heated filament are accelerated through a known potential and directed at a nickel crystal target; a movable detector records the scattered electron intensity at various angles. A sharp intensity peak was observed at a scattering angle of 50° for 54 V accelerating electrons, matching the diffraction pattern expected for waves of the de Broglie wavelength calculated from $\lambda = h/p$ — directly confirming the wave nature of electrons. For the wavelength ratio: $\lambda = h/\sqrt{(2mqV)}$; using deuteron mass ≈ $2m_p$, charge e, and α-particle mass ≈ $4m_p$, charge 2e: $\lambda\_deuteron/\lambda\_alpha = \sqrt{[(m\alpha \cdot q\alpha)/(m\_d \cdot q\_d)]} = \sqrt{[(4m_p \times 2e)/(2m_p \times e)]} = \sqrt{4} = 2$. So the deuteron's de Broglie wavelength is twice that of the α-particle for the same accelerating potential.

CHAPTER 12: ATOMS

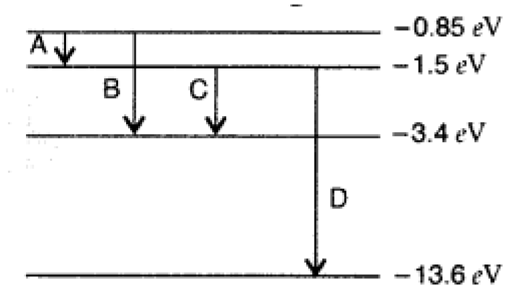
CLASS –XII
Assignment 1
QUESTION PAPER ON ATOM, AGRA REGION
SESSION: 2025-2026

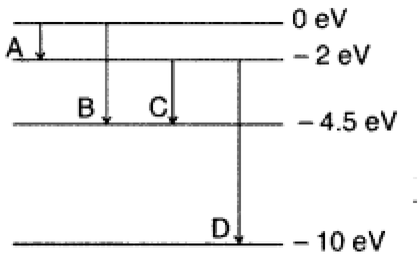
SUBJECT: PHYSICS Maximum Marks: 70 Marks

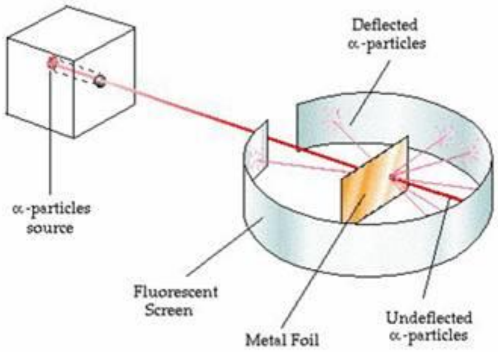
Time Allowed: 3 hours.

General Instructions:
(1) There are 33 questions in all. All questions are compulsory
(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
(3)**Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, **Section B** contains five questions of two marks each, **Section C** contains seven questions of three marks each, **Section D** contains two case study based questions of four marks each and **Section E** contains three long answer questions of five marks each
(4) There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.
6. You may use the following values of physical constants where ever necessary
i. $c = 3 \times 10^8$ m/s
ii. $m_e = 9.1 \times 10^{-31}$ kg
iii. $e = 1.6 \times 10^{-19}$ C
iv. $\mu_0 = 4\pi \times 10^{-7}$ Tm$\boldsymbol{A^{-1}}$
v. $h = 6.63 \times 10^{-34}$ Js
vi. $\varepsilon 0 = 8.854 \times 10^{-12}$ $\boldsymbol{C^2N^{-1}m^{-2}}$
vii. Avogadro's number = 6.023 X $\mathbf{10^{23}}$per gram mole

S N	SECTION A	MARKS
1	The magnetic field induction produced at the centre of orbit due to an electron revolving in n^{th} orbit of hydrogen atom is proportional to (1)n^{-3} (2)n^{-5} (3) n^5 (4)n	**1**
2	When an electron in hydrogen atom is taken from fourth excited state to ground state (1) Both kinetic energy and potential energy increases (2) Both kinetic energy and potential energy decreases (3) Kinetic energy will increase while potential energy will decrease (4) Kinetic energy will decrease while potential energy will increase	**1**
3	The speed of an electron in the orbit of hydrogen atom in the ground state is (1) c (2) c/10 (3) c/2 (4) c/137	**1**
4	Taking the Bohr radius as a_0= 53 pm, the radius of Li++ ion in its ground state, on the basis of Bohr's model, will be about (1) 53 pm (2) 27 pm (3) 18 pm (4) 13 pm	**1**
5	Which of the following transitions in a hydrogen atom emit photons of lowest frequency? (1) n = 2 to n = 1 (2) n = 4 to n = 2 (3) n = 4 to n = 3 (4) n = 3 to n = 1	**1**
6	Which of the following cannot be the value of ionisation energy for a hydrogen atom? (1) 0.85 eV (2) 3.4 eV (3) 1.51 eV (4) 0.27 eV	**1**
7	How many times does the electron go round the first Bohr orbit in a second? (1) 6.57×10^5 (2) 6.57×10^{10} (3) 6.57×10^{13} (4) 6.57×10^{15}	
8	When an electron is excited to nth energy state in hydrogen, the possible number of spectral lines emitted are (1) n (2) 2n (3) $(n^2-n)/2$ (4) $(n^2+n)/2$	**1**
9	The ratio of the energies of the hydrogen atom in its first excited state to second excited state is (1)1/4 (2) 4/9 (3) 9/4 (4) 4	**1**

10	Bohr's atomic model is applicable for (1) Hydrogen atom only (2) Uni -electron atomic system only (3) All atoms (4) All isotopes of hydrogen only	**1**
11	The total energy of an electron in the hydrogen atom in the ground state is –13.6 eV. The kinetic energy of this electron is (1) 13.6 eV (2) 0 (3) –13.6 eV (4) 6.8 eV	**1**
12	The speed of an electron in the 4th orbit of hydrogen atom is (1) c (2) c/137 (3) c/2192 (4) c/548	**1**
	Two statements are given-one labeled Assertion (A) and the other labeled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below. (a) Both A and R are true and R is the correct explanation of A. (b) Both A and R are true but R is NOT the correct explanation of A. (c) A is true but R is false. (d) A is false and R is also false.	
13	**Assertion** : According to Bohr's atomic model the ratio of angular momenta of an electron in first excited state and in ground state is 2 : 1. **Reason** : In a Bohr's atom the angular momentum of the electron is directly proportional to the principal quantum number.	**1**
14	**Assertion** :The positively charged nucleus of an atom has a radius of almost 10^{-15} m **Reason** :In α-particle scattering experiment, the distance of closest approach for α-particles is $\simeq 10^{-15}$ m	**1**
15	**Assertion** :According to classical theory, the proposed path of an electron in Rutherford atom model will be parabolic. **Reason** :According to electromagnetic theory an accelerated particle continuously emits radiation	**1**
16	**Assertion** : The Bohr model of the hydrogen atom does not explain the fine structure of spectral lines. **Reason** : The Bohr model does not take into account the spin of the electron.	**1**
	SECTION B	
17	The radius of innermost electron orbit of a hydrogen atom is 5.3 X 10^{-11} m. What is the radius of orbit in the second excited state ?	**2**
18	Of the various series of the hydrogen spectrum then state which one lies completely in the ultraviolet region and why? **OR** The electron, in a hydrogen atom, is in its second excited state. Calculate the wavelength of the lines in the Lyman series, that can be emitted through the permissible transitions of this electron. (Given the value of Rydberg constant, $R = 1.1 \times 10^7\ m^{-1}$ **)**	**2**
19	The energy level diagram of an element is given. Identify, by doing necessary calculations, which transition corresponds to the emission of a spectral line of wavelength 102.7 nm. 	**2**
20	The short wavelength limit for the Lyman series of the hydrogen spectrum is 913.4 A^0 Calculate the short wavelength limit for Balmer series of the hydrogen spectrum	**2**
21	Find the ratio between the wavelengths of the 'most energetic' spectral lines in the Balmer and Paschen series of the hydrogen spectrum	**2**

	SECTION C	
22	(a) The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. Calculate its radius in n = 2 orbit. (b) The total energy of an electron in the second excited state of the hydrogen atom is -1.51 eV. Find out its (i) kinetic energy and (ii) potential energy in this state **OR** The energy levels of a hypothetical atom are shown below. Which of the shown transitions will result in the emission of a photon of wavelength 275 nm? Which of these transitions correspond to emission of radiation of (i) maximum and (ii) minimum wavelength ? 	**3**
23	A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. Up to which energy level the hydrogen atoms would be excited? Calculate the wavelengths of the first member of Lyman and first member of Balmer series	**3**
24	Using Bohr's postulates, obtain the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence draw the energy level diagram showing how the line spectra corresponding to Balmer series occur due to transition between energy levels	**3**
25	The ground state energy of hydrogen atom is -13.6 eV. If an electron makes a transition from an energy level -0.85 eV to -3.4 eV, calculate the wavelength of the spectral line emitted. To which series of hydrogen spectrum does this wavelength belong?	**3**
26	In a Geiger-Marsden experiment, calculate the distance of closest approach to the nucleus of Z = 80, when an α-particle of 8 MeV energy impinges on it before it comes momentarily to rest and reverses its direction. How will the distance of closest approach be affected when the kinetic energy of the α-particle is doubled?	**3**
27	(a) Using Bohr's second postulate of quantization of orbital angular momentum show that the circumference of the electron in the nh orbital state in hydrogen atom is n times the de-Broglie wavelength associated with it. (b) The electron in hydrogen atom is initially in the third excited state. What is the maximum number of spectral lines which can be emitted when it finally moves to the ground state?	**3**
28	The ground state energy of hydrogen atom is -13.6 eV. (i) What is the potential energy of an electron in the 3rd excited state? (ii) If the electron jumps to the ground state from the 3rd excited state, calculate the wavelength of the photon emitted	**3**
	SECTION D	
29	A radioactive source emitting alpha particles was enclosed within a protective lead shield. The radiation was focused into a narrow beam after passing through a slit in a lead screen. A thin section of gold foil was placed in front of the slit, and a screen coated with zinc sulfide to render it fluorescent served as a counter to detect alpha particles. As each alpha particle struck the fluorescent screen, it produced a burst of light called a scintillation, which was visible through a viewing microscope attached to the back of the screen. The screen itself was movable, allowing to determine whether or not any alpha particles were being deflected by the gold foil.	**4**



(i) The particles which were deflected backwards in Rutherford's experiment were hit upon by
(a) Nucleus
(b) Empty space
(c) Electrons
(d) Protons

(ii) According to the Rutherford atomic model, the whole atom is
(a) Positively Charged
(b) Negatively Charged
(c) Neutral
(d) None of the above

(iii) Rutherford in his atomic model could not explain the behavior of which of the following
(a) Proton
(b) Neutron
(c) Electron
(d) Neutrino

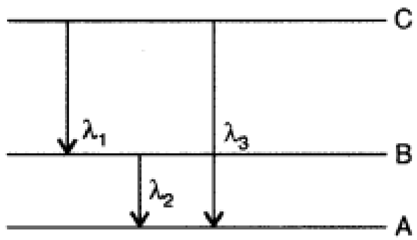
(iv) In Rutherford model -electron revolves around the nucleus in orbits which have
(a) variable energy
(b) fixed energy
(c) infinite energy
(d) zero energy

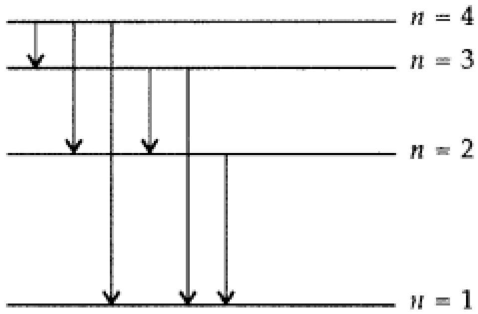
OR

According to Rutherford, most of the space occupied by the atom is
(a) filled
(b) partially filled
(c) empty
(d) none of above

30 THE LINE SPECTRA OF THE HYDROGEN ATOM

According to the third postulate of Bohr's model, when an atom makes a transition from the higher energy state with quantum number n_i to the lower energy state with quantum number n_f ($n_f < n_i$), the difference of energy is carried away by a photon of frequency v such that $hv = En_i – En_f$. Since both n_f and n_i are integers, this immediately shows that in transitions between different atomic levels, light is radiated in various discrete frequencies. For hydrogen spectrum, the Balmer formula corresponds to $n_f = 2$ and $n_i = 3, 4, 5$ etc. The results of the Bohr's model suggested the presence of other series spectra for hydrogen atom–those corresponding to transitions resulting from $n_f = 1$ and $n_i = 2, 3$, etc; $n_f = 3$ and $n_i = 4, 5$, etc. and so on. Such series were identified in the course of spectroscopic investigations and are known as the Lyman, Balmer, Paschen, Brackett, and Pfund series. The electronic transitions corresponding to these series are shown in Fig. The various lines in the atomic spectra are produced when electrons jump from higher energy state to a lower energy state and photons are emitted. These spectral lines are called emission lines. But when an atom absorbs a photon that has precisely the same energy needed by the electron in a lower energy state to make transitions to a higher energy state, the process is called absorption. Thus if

	photons with a continuous range of frequencies pass through a rarefied gas and then are analyzed with a spectrometer, a series of dark spectral absorption lines appear in the continuous spectrum. The dark lines indicate the frequencies that have been absorbed by the atoms of the gas. The explanation of the hydrogen atom spectrum provided by Bohr's model was a brilliant achievement, which greatly stimulated progress towards the modern quantum theory. (i). The series of spectrum when electron jumps from n = 5 to n = 3 is a) Lymen b) Balmer c) Paschen d) Bracket (ii). Balmer series is obtained when electron transits from a) n = 1,2,3, … to n = 5 b) n = 3,4,5 … to n = 2 c) n = 1,2,3, … to n = 4 d) n = 1,2,3, … to n = 6 (iii). From Fig. shown predict which series has waves of maximum frequency a) Lymen b) Balmer c) Paschen d) Bracket (iv) . What is the maximum energy of photon in emission spectrum of hydrogen atom a) 13.6 eV b) 1.36 eV c) 1.5 eV d) 1eV OR What is the minimum energy required to ionise a hydrogen atom that is already in its first excited state? a) 13.6 eV b) 10.2 eV c) 3.4 eV d) 1.51 eV	
	SECTION E	
31	(a) Draw a schematic arrangement of Geiger- Marsden experiment showing the scattering of a-particles by a thin foil of gold. Why is it that most of the a-particles go right through the foil and only a small fraction gets scattered at large angles? Draw the trajectory of the a-particle in the coulomb field of a nucleus. What is the significance of impact parameter and what information can be obtained regarding the size of the nucleus? (b) Estimate the distance of closest approach to the nucleus (Z = 80) if a 7.7 MeV a-particle before it comes momentarily to rest and reverses its direction **OR** (i) State Bohr's quantization condition for defining stationary orbits. How does de-Broglie hypothesis explain the stationary orbits? (ii) Find the relation between the three wave-lengths λ_1, λ_2 and λ_3 from the energy level diagram shown below:  	**5**
32	(i) A hydrogen atom initially in the ground state absorbs a photon which excites it to the n-4 level. Determine the wavelength of the photon.	**5**

	(ii) The radius of innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. Determine its radius in n = 4 orbit **OR** The figure shows energy level diagram of hydrogen atom  (a) Find out the transition which results in the emission of a photon of wavelength 496 nm. (b) Which transition corresponds to the emission of radiation of maximum wavelength? Justify your answer.	
33	(a)Define ionization energy. How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron but having the same charge? (b) An α-particle moving with initial kinetic energy K towards a nucleus of atomic number z approaches a distance 'd' at which it reverses its direction. Obtain the expression for the distance of closest approach 'd' in terms of the kinetic energy of α-particle K OR If a proton had a radius R and the charge was uniformly distributed, calculate using Bohr theory, the ground state energy of a H-atom when (i) R = 0.1 Å and (ii) R = 10 Å .	**5**

CHAPTER 12: ATOMS

Assignment 2 — Multiple Choice Questions

Maximum Marks: 30	**Time Allowed: 45 Minutes**

General Instructions:

1. This assignment contains 30 MCQs of 1 mark each. All questions are compulsory.
2. Each question has four options, out of which only one is correct.
3. Questions 21–30 have appeared (in the same or an adapted form) in CBSE board papers or NEET over the last five years, as marked.
4. Use the following values wherever required: $R = 1.097 \times 10^7\ m^{-1}$, $h = 6.63 \times 10^{-34}$ Js, $c = 3 \times 10^8$ m/s, 1 eV = 1.6×10^{-19} J, $E_n(H) = -13.6/n^2$ eV, $r_1 = 5.3 \times 10^{-11}$ m.

1. In the hydrogen atom, consider four electronic transitions: P (n = 4 → n = 1), Q (n = 4 → n = 3), R (n = 2 → n = 1), and S (n = 3 → n = 2). The transitions that emit photons of the shortest and the longest wavelength, respectively, are:

(a) P and Q respectively (b) R and S respectively (c) Q and P respectively (d) S and R respectively

2. An electron in Bohr's hydrogen atom has an energy of −3.4 eV. The angular momentum of the electron is:

(a) h/π (b) h/2π (c) nh/2π (n is an integer) (d) 2h/π

3. In a hydrogen atom, the binding energy of the electron in the nth state is E_n. The frequency of revolution of the electron in the nth orbit is:

(a) $2E_n/nh$ (b) $2E_nn/h$ (c) E_n/nh (d) E_nn/h

4. When a hydrogen atom is in its first excited state, its radius is:
(a) Four times its ground state radius (b) Twice its ground state radius (c) The same as its ground state radius (d) Half its ground state radius

5. If the electron in a hydrogen atom were in the energy level with n = 3, how much energy (in joule) would be required to ionise the atom? (Ionisation energy of the H atom from its ground state is 2.18×10^{-18} J)
(a) 6.54×10^{-19} (b) 1.43×10^{-19} (c) 2.42×10^{-19} (d) 3.14×10^{-20}

6. According to the Bohr theory of the H atom, the speed of the electron, its energy and the radius of its orbit vary with the principal quantum number n, respectively, as:
(a) $1/n$, n^2, $1/n^2$ (b) n, $1/n^2$, n^2 (c) n, $1/n^2$, $1/n^2$ (d) $1/n$, $1/n^2$, n^2

7. In a hydrogen atom, the electron is in the nth excited state. It may come down to the second excited state by emitting ten different wavelengths. The value of n is:
(a) 6 (b) 7 (c) 8 (d) 5

8. The simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons. This is because:
(a) The electrons are not subject to a central force (b) The electrons collide with each other (c) Of screening effects (d) The force between the nucleus and an electron is no longer given by Coulomb's law

9. For the ground state, the electron in the H atom has an angular momentum = ħ (= $h/2\pi$), according to the simple Bohr model. Angular momentum is a vector, and hence there should be infinitely many orbits with the vector pointing in all possible directions. In actuality this is not true,
(a) Because the Bohr model gives incorrect values of angular momentum (b) Because only one of these would have a minimum energy (c) Because angular momentum must be in the direction of spin of the electron (d) Because electrons go around only in horizontal orbits

10. In which of the following series does the 121.5 nm line of the hydrogen spectrum lie?
(a) Lyman series (b) Balmer series (c) Paschen series (d) Brackett series

11. In an experiment on the scattering of α-particles by a gold nucleus, the closest distance of approach is 30 fermi. If the velocity of the α-particle is doubled, the closest distance of approach will:
(a) Remain unaltered (b) Double (c) Reduce to half the original value (d) Reduce to (1/4)th the original value

12. In a hydrogen atom, which of the following electronic transitions involves the maximum energy change?
(a) n = 2 to n = 1 (b) n = 3 to n = 1 (c) n = 4 to n = 2 (d) n = 3 to n = 2

13. The ionisation potential of the hydrogen atom is 13.6 V. The energy required to remove an electron from the second orbit of hydrogen is:
(a) 3.4 eV (b) 6.8 eV (c) 13.6 eV (d) 27.2 eV

14. According to Bohr's model, the difference between the energies of an electron in two orbits is equal to:
(a) hν (b) hc/λ (c) Both (a) and (b) (d) Neither (a) nor (b)

15. An electron collides with a fixed hydrogen atom in its ground state. The hydrogen atom gets excited, and the colliding electron loses all its kinetic energy. Consequently, the hydrogen atom may emit a photon corresponding to the largest wavelength of the Balmer series. The minimum kinetic energy of the colliding electron will be:
(a) 10.2 eV (b) 1.9 eV (c) 12.1 eV (d) 13.6 eV

16. Which of the following did Rutherford consider to be supported by the results of the experiment in which α-particles were scattered by a gold foil?
(a) The nucleus of an atom is held together by forces much stronger than electrical or gravitational forces (b) The force of repulsion between an atomic nucleus and an α-particle varies with distance according to the inverse-square law (c) α-particles are nuclei of helium atoms (d) Atoms can exist with a series of discrete energy levels

17. The total energy of a hydrogen atom in its ground state is −13.6 eV. If the potential energy in the first excited state is taken as zero, the total energy in the ground state will be:
(a) −3.4 eV (b) 3.4 eV (c) −6.8 eV (d) 6.8 eV

18. Which of the following parameters is the same for all hydrogen-like atoms and ions in their ground states?
(a) Radius of the orbit (b) Speed of the electron (c) Energy of the atom (d) Orbital angular momentum of the electron

19. The radius of the second Bohr orbit of a singly ionised helium atom (He^+) is:
(a) 0.53 Å (b) 1.06 Å (c) 0.265 Å (d) 0.132 Å

20. The energy difference between the ground state and the first excited state of a hydrogen atom is 10.2 eV. The energy difference between the same two states in a doubly ionised lithium atom (Li^{2+}) is:
(a) 10.2 eV (b) 20.4 eV (c) 40.8 eV (d) 91.8 eV

21. The radius of the nth orbit in the Bohr model of the hydrogen atom is proportional to:
(a) n (b) n^2 (c) 1/n (d) $1/n^2$
[CBSE 2023, Delhi Set-1, adapted]

22. A hydrogen atom makes a transition from n = 5 to n = 1, emitting a photon of wavelength λ. The wavelength of the photon emitted for the transition n = 5 to n = 2 will be:
(a) Equal to λ (b) Less than λ (c) Greater than λ (d) Exactly half of λ
[CBSE 2024, Delhi Set-1, adapted]

23. Among the transitions n = 4 → 3, n = 3 → 2, n = 2 → 1 and n = 4 → 1 in a hydrogen atom, the one in which the emitted photon has the highest energy is:
(a) n = 4 → 3 (b) n = 3 → 2 (c) n = 2 → 1 (d) n = 4 → 1
[CBSE 2023, Delhi Set-1, adapted]

24. Let T_1 and T_2 be the total energies of the electron in the first and second excited states of the hydrogen atom, respectively. According to Bohr's model, the ratio $T_1 : T_2$ is:
(a) 4 : 9 (b) 9 : 4 (c) 1 : 4 (d) 4 : 1
[NEET 2023]

25. Let L_1 and L_2 be the orbital angular momenta of the electron in the first and second excited states of the hydrogen atom, respectively. According to Bohr's model, the ratio $L_1 : L_2$ is:
(a) 1 : 2 (b) 2 : 3 (c) 3 : 2 (d) 1 : 3
[NEET 2022]

26. The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. The radius of its third allowed (n = 3) Bohr orbit is:
(a) 1.6×10^{-10} m (b) 4.77×10^{-10} m (c) 15.9×10^{-10} m (d) 9×10^{-11} m
[NEET, previous years]

27. If 13.6 eV of energy is required to ionise the hydrogen atom from its ground state, the energy needed to ionise it from its second excited state is:

(a) 13.6 eV (b) 3.4 eV (c) 1.51 eV (d) 12.09 eV

[NEET, previous years]

28. The angular momentum of an electron in a certain Bohr orbit of the hydrogen atom is 1.5(h/π). The energy of the electron in that orbit is nearly:

(a) −13.6 eV (b) −3.4 eV (c) −1.5 eV (d) −0.85 eV

[NEET, previous years]

29. Bohr's atomic model provides a satisfactory explanation for the spectrum of:

(a) The hydrogen atom only (b) Any atom or ion containing only one electron (c) The hydrogen molecule (d) The solar spectrum

[NEET, previous years]

30. According to Bohr's theory, which of the following transitions in the hydrogen atom gives rise to the least energetic photon?

(a) n = 6 to n = 1 (b) n = 5 to n = 4 (c) n = 6 to n = 5 (d) n = 5 to n = 3

[NEET, previous years]

CHAPTER 12: ATOMS

Assignment 3 (Revised) — Assertion–Reason Questions

Maximum Marks: 15	Time Allowed: 20 Minutes

General Instructions:

1. This assignment contains 15 Assertion–Reason questions of 1 mark each. All questions are compulsory.
2. Questions 9–15 are new additions, several adapted from CBSE board papers and CBSE-pattern practice material, as marked.
3. The hydrogen-spectra content in these questions is kept qualitative, in line with the 2026–27 syllabus note that hydrogen line spectra be treated qualitatively; no Rydberg-formula numerics are required.

For each question below, two statements are given — one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the options 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) Both Assertion (A) and Reason (R) are false.

1. Assertion (A): The total energy of an electron revolving in any stationary orbit of the hydrogen atom is negative.

Reason (R): The centripetal force required for the electron's circular motion is provided by the electrostatic (Coulomb) force of attraction.

[CBSE Physics 2025–26 Sample Question Paper, adapted]

2. Assertion (A): A hydrogen atom has only one electron, yet its emission spectrum has many lines.

Reason (R): Only the Lyman series is found in the absorption spectrum of hydrogen, whereas all the series are found in its emission spectrum.

3. Assertion (A): The wavelength of the first line of the Lyman series in He^+ is smaller than that in hydrogen.

Reason (R): The energy gap between corresponding levels in He^+ is larger, because Z = 2 for He^+.

4. Assertion (A): The energy of the electron in the nth orbit of hydrogen is inversely proportional to n^2.
Reason (R): The de Broglie wavelength of the electron in the nth orbit is directly proportional to n.

5. Assertion (A): The spectral lines of the hydrogen atom become more closely spaced as n increases.
Reason (R): The energy difference between consecutive levels decreases roughly as $1/n^3$ for large n.

6. Assertion (A): In the Bohr model, the electron's orbits are circular.
Reason (R): The classical Coulomb force of attraction between the electron and the nucleus provides the centripetal force needed for circular motion.

7. Assertion (A): Bohr's model fails to explain the fine structure of the hydrogen spectrum.
Reason (R): The fine structure arises due to relativistic corrections and spin–orbit interaction, neither of which is included in Bohr's model.

8. Assertion (A): For the scattering of α-particles at large angles, only the nucleus of the atom is responsible.
Reason (R): The nucleus is very heavy and its positive charge is highly concentrated, compared to the atom's electrons.

9. Assertion (A): Bohr postulated that electrons in stationary orbits around the nucleus do not radiate energy.
Reason (R): According to classical electromagnetic theory, all accelerated charges radiate energy.
[CBSE-pattern practice material]

10. Assertion (A): According to Bohr's atomic model, the ratio of the angular momenta of an electron in the first excited state to that in the ground state is 2 : 1.
Reason (R): According to Bohr's theory, the angular momentum of the electron is directly proportional to the principal quantum number n.
[CBSE-pattern practice material]

11. Assertion (A): In the Bohr model of the hydrogen atom, the angular momentum of the electron in the nth orbit is proportional to the square root of the orbit radius r_n.
Reason (R): According to Bohr's model, an electron can jump only to its nearest orbit.
[CBSE PYQ, adapted]

12. Assertion (A): The Balmer series in the hydrogen spectrum is formed when the electron jumps from a higher energy state directly to the ground state.
Reason (R): In Bohr's model of the hydrogen atom, the electron can jump only between successive (adjacent) orbits.
[CBSE PYQ, adapted]

13. Assertion (A): Rutherford concluded that the positive charge of the atom is concentrated in a nucleus, based on the fact that only a very small fraction of α-particles were scattered through large angles.
Reason (R): The size of the nucleus is about 10^{-5} times the size of the atom, so only a tiny fraction of incident α-particles pass close enough to it to be strongly scattered.
[CBSE PYQ, adapted]

14. Assertion (A): Electrons in an atom can occupy only certain discrete energy levels.
Reason (R): According to de Broglie, the electron waves interfere destructively unless the circumference of the orbit is an integral multiple of the electron's wavelength.

15. Assertion (A): Thomson's plum-pudding model could not explain the large-angle scattering of α-particles observed by Rutherford.

Reason (R): In Thomson's model, the positive charge is spread throughout the atom, so the maximum electrostatic force it can exert on an α-particle is too small to deflect it through a large angle.

CHAPTER 12: ATOMS

Assignment - 4 (Case-Study Based Questions)

Maximum Marks: 28	Time Allowed: 1 Hour

General Instructions:

1. There are 7 case-study-based questions. All are compulsory.
2. Each case study carries 4 marks and consists of a passage followed by four sub-questions of 1 mark each, in MCQ format. There is no internal choice.
3. Read each passage carefully before attempting the questions that follow it.
4. Use the following values wherever required: $R = 1.097 \times 10^7\ m^{-1}$, $h = 6.63 \times 10^{-34}$ Js, $c = 3 \times 10^8$ m/s, 1 eV $= 1.6 \times 10^{-19}$ J, ground state energy of hydrogen $E_1 = -13.6$ eV, Bohr radius $r_1 = 0.529$ Å.

Case Study 1	[4 Marks]

For a hydrogen-like ion (a single electron orbiting a nucleus of charge +Ze), Bohr's theory gives the following results for the nth orbit:

$$E_n = -13.6\ Z^2/n^2\ \text{eV} \qquad r_n = (0.529\ n^2/Z)\ \text{Å} \qquad v_n = (2.18 \times 10^6\ Z/n)\ \text{m/s}$$

Consider the ion He^+ (Z = 2) in various excited states, and compare it with the hydrogen atom (Z = 1).

(1) The energy required to excite an electron of He^+ from the ground state (n = 1) to n = 3 is:
(a) 12.1 eV (b) 13.6 eV (c) 40.8 eV (d) 48.4 eV

(2) The ratio of the radius of the 3rd orbit of He^+ to the radius of the 2nd orbit of H is:
(a) 3/2 (b) 9/4 (c) 9/8 (d) 3/4

(3) The ratio of the speed of the electron in the 2nd orbit of H to that in the 3rd orbit of He^+ is:
(a) 3 : 4 (b) 4 : 3 (c) 3 : 2 (d) 1 : 2

(4) The number of distinct spectral lines possible when an electron in He^+ de-excites from n = 4 to the ground state is:
(a) 4 (b) 5 (c) 6 (d) 10

Case Study 2	[4 Marks]

According to Bohr's third postulate, when an atom makes a transition from a higher energy state (quantum number n_i) to a lower energy state (quantum number n_f, with n_f < n_i), the energy difference is carried away by a photon of frequency ν such that $h\nu = E(n_i) - E(n\_f)$. Since both n_i and n_f are integers, light is radiated only at certain discrete frequencies. For the hydrogen atom, transitions ending on n_f = 1, 2, 3, 4 and 5 give rise to the Lyman, Balmer, Paschen, Brackett and Pfund series respectively, as summarised below.

Series	n_f	Spectral region
Lyman	1	Ultraviolet
Balmer	2	Visible
Paschen	3	Infrared
Brackett	4	Infrared
Pfund	5	Infrared

The Lyman series lies in the ultraviolet region while the Paschen, Brackett and Pfund series lie in the infrared region; the Balmer series alone has some lines in the visible region. Lines are called emission lines when electrons fall to a lower level, and absorption lines when electrons are raised to a higher level by absorbing a photon of exactly the required energy.

(1) The spectral series to which the emission line belongs when an electron jumps from n = 5 to n = 3 is the:
(a) Lyman series (b) Balmer series (c) Paschen series (d) Brackett series

(2) The Balmer series is obtained when the electron transits from:
(a) n = 1, 2, 3 ... to n = 5 (b) n = 3, 4, 5 ... to n = 2 (c) n = 1, 2, 3 ... to n = 4 (d) n = 1, 2, 3 ... to n = 6

(3) The maximum possible energy of a photon in the emission spectrum of the hydrogen atom is:
(a) 13.6 eV (b) 1.36 eV (c) 1.5 eV (d) 1 eV

(4) The shortest wavelength present in the Paschen series of the hydrogen spectrum is closest to:
(a) 820 nm (b) 740 nm (c) 610 nm (d) 720 nm

Case Study 3	[4 Marks]

In 1911, Ernest Rutherford performed his famous α-particle scattering experiment, directing a stream of α-particles (doubly charged helium nuclei) at a thin gold foil. He observed that: (1) most α-particles passed through undeflected; (2) some were deflected through small angles; (3) a very few (about 1 in 8000) were deflected through angles greater than 90°, some even bouncing almost straight back. From these observations, Rutherford proposed the nuclear model of the atom: a tiny, dense, positively charged nucleus (of size $\sim 10^{-15}$ m) at the centre, with electrons revolving around it, the atom itself being about 10^{-10} m in size — i.e., mostly empty space.

(1) The fact that most α-particles passed through the gold foil without deflection indicates that:
(a) Atoms are solid spheres (b) Atoms are mostly empty space (c) The nucleus occupies the whole atom (d) α-particles have very small mass

(2) The large-angle deflection of a few α-particles was due to:
(a) Elastic collisions with electrons (b) Repulsion from the gold foil surface (c) Electrostatic repulsion from the dense, positively charged nucleus (d) α-particles losing energy in the foil

(3) If the radius of the atom is $\sim 10^{-10}$ m and that of the nucleus is $\sim 10^{-15}$ m, the ratio of the size of the atom to that of the nucleus is about:
(a) 10^2 (b) 10^3 (c) 10^5 (d) 10^7

(4) Which of the following was NOT explained by Rutherford's nuclear model?
(a) Stability of the atom (b) Existence of the nucleus (c) Empty space within the atom (d) Large-angle scattering of α-particles

Case Study 4	[4 Marks]

Each element shows a specific emission or absorption line spectrum. The hydrogen spectrum consists of the Lyman, Balmer, Paschen, Brackett and Pfund series. According to Bohr's first postulate, electrons revolve in certain stable orbits without radiating energy. His second postulate states that these orbits are ones in which the angular momentum of the electron is an integral multiple of $h/2\pi$. His third postulate states that when an electron jumps from a higher to a lower energy state, it emits a photon of energy equal to the difference between the two energy levels. The energy of an electron in the nth orbit of hydrogen is given by $E_n = -13.6/n^2$ eV — the negative sign shows that the electron is bound to the nucleus. When n = 1, the corresponding energy is called the ground state energy. Bohr's model applies only to single-electron systems (hydrogen and hydrogen-like ions) and cannot be applied to multi-electron atoms such as neutral helium.

(1) In a hydrogen atom, the ground state energy is:

(a) +13.6 eV (b) −13.6 J (c) −13.6 kJ (d) −13.6 eV

(2) According to Bohr's second postulate, the angular momentum L of the electron is given by:
(a) $L = h/2\pi$ (b) $L = nh/2\pi$ (c) $L = 2\pi/h$ (d) $L = 2\pi/nh$

(3) The shortest wavelength in the Balmer series is close to:
(a) 656.3 nm (b) 364.6 nm (c) 486.1 nm (d) 91.2 nm

(4) For the ground state of the hydrogen atom, the value of the principal quantum number is:
(a) n = 2 (b) n = 0 (c) n = 1 (d) n = infinity

Case Study 5	**[4 Marks]**

In 1924, Louis de Broglie proposed that matter, like light, has a dual (particle-wave) nature, and that a particle of momentum p is associated with a wavelength $\lambda = h/p$. Applying this idea to the electron in a hydrogen atom, de Broglie showed that Bohr's postulate of quantised angular momentum has a simple physical meaning: an electron orbit is stable only if it is a whole number of de Broglie wavelengths in circumference, i.e. $2\pi r_n = n\lambda$. This was one of the first pieces of evidence for the wave nature of matter, and it paved the way for the development of quantum mechanics.

(1) According to de Broglie's hypothesis, the condition for a stable Bohr orbit of radius r_n is:
(a) $2\pi r_n = n\lambda$ (b) $\pi r_n = n\lambda$ (c) $2\pi r_n = \lambda/n$ (d) $r_n = n\lambda$

(2) The de Broglie wavelength of an electron of mass m moving with speed v is given by:
(a) $\lambda = hv$ (b) $\lambda = h/mv$ (c) $\lambda = mv/h$ (d) $\lambda = mvh$

(3) The de Broglie wavelength of the electron in the ground state of hydrogen ($r_1 = 5.3 \times 10^{-11}$ m) is closest to:
(a) 1.67×10^{-10} m (b) 3.33×10^{-10} m (c) 5.3×10^{-11} m (d) 1.06×10^{-10} m

(4) As the principal quantum number n increases, the de Broglie wavelength associated with the orbiting electron:
(a) Increases (b) Decreases (c) Remains constant (d) First increases, then decreases

Case Study 6	**[4 Marks]**

The minimum energy needed to remove an electron completely from an atom, taking it from its ground state to $n = \infty$, is called the ionisation energy. The energy needed to raise an electron from the ground state to a higher (excited) state is called the excitation energy. For hydrogen, the ground state energy is −13.6 eV, so its ionisation energy is 13.6 eV; once ionised, only a bare proton remains. These ideas explain how spectral lines are formed, and are also used, for example, to explain how solar radiation ionises gases in the upper atmosphere to form the ionosphere.

(1) The ionisation energy of a hydrogen atom in its ground state is:
(a) 3.4 eV (b) 10.2 eV (c) 13.6 eV (d) 27.2 eV

(2) The energy required to excite a hydrogen atom from its ground state to its first excited state is:
(a) 3.4 eV (b) 10.2 eV (c) 12.09 eV (d) 13.6 eV

(3) A hydrogen atom in the ground state absorbs a photon of energy 12.1 eV. It is excited to the state n =
(a) 2 (b) 3 (c) 4 (d) 5

(4) The minimum energy needed to ionise a hydrogen atom that is already in its first excited state is:
(a) 13.6 eV (b) 10.2 eV (c) 3.4 eV (d) 1.5 eV

Case Study 7	**[4 Marks]**

Bohr's model successfully explained the spectrum of hydrogen and other hydrogen-like (single-electron) ions, but it has significant limitations. It cannot explain the spectra of multi-electron atoms, the relative intensities of spectral lines, the fine structure of spectral lines (their splitting into closely spaced components), or the splitting of spectral lines in external magnetic fields (the Zeeman effect) and electric fields (the Stark effect). It also assumes that an electron moves in a well-defined circular orbit with a precisely known radius and momentum at the same time — an assumption in direct conflict with the wave nature of matter and the uncertainty principle. These shortcomings were later resolved by quantum mechanics.

(1) Bohr's model applies successfully to:
(a) All multi-electron atoms (b) Only hydrogen and hydrogen-like single-electron ions (c) Only noble gas atoms (d) All atoms of the periodic table

(2) Which of the following could NOT be explained by Bohr's model?
(a) Existence of discrete energy levels (b) Splitting of spectral lines in a magnetic field (Zeeman effect) (c) Wavelength of the Lyman series (d) Radius of the hydrogen atom's orbits

(3) Bohr's assumption of a well-defined circular orbit with simultaneously precise radius and momentum conflicts most directly with:
(a) Pauli's exclusion principle (b) Heisenberg's uncertainty principle (c) Bohr's own second postulate (d) Rutherford's nuclear model

(4) A key limitation of Bohr's theory is that it fails to explain the spectrum of:
(a) The hydrogen atom (b) The He^{+} ion (c) The Li^{2+} ion (d) The neutral helium atom (two electrons)

CHAPTER 12: ATOMS

Assignment -5 —(Short & Long Answer Questions)

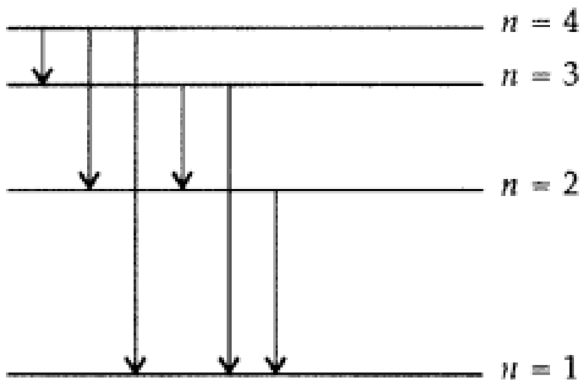
Maximum Marks: 29	**Time Allowed: 1 Hour**

General Instructions:
1. All questions are compulsory.
2. Section A contains 10 short-answer questions of 2 marks each.
3. Section B contains 3 long-answer questions of 3 marks each.
4. Use the value of Rydberg constant R = 1.097×10^{7} m^{-1} (approximated as 1.1×10^{7} m^{-1} where indicated), h = 6.63×10^{-34} Js, c = 3×10^{8} m/s, unless otherwise specified.
5. Show all formulas used and steps of calculation clearly.

SECTION A

(Short Answer Questions — 2 marks each)

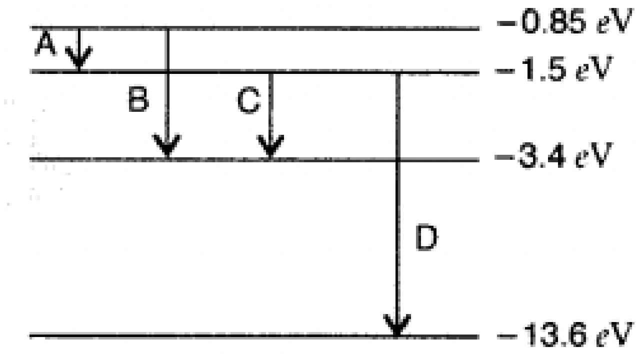
Q.No.	Question	Marks
1	(a) The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. Calculate the radius of its n = 3 orbit. (b) The total energy of an electron in the first excited state of the hydrogen atom is −3.4 eV. Find its (i) kinetic energy and (ii) potential energy in this state.	2
2	Calculate the wavelengths of the second member of the Lyman series and the second member of the Balmer series of the hydrogen spectrum. Identify the region of the electromagnetic spectrum to which each belongs.	2
3	Find the ratio of the energies of photons produced due to transition of an electron of a hydrogen atom from (i) its second permitted energy level to the first level, and (ii) the highest permitted energy level to the first permitted level.	2

Q.No.	Question	Marks
4	Using Bohr's postulates, derive an expression for the frequency of radiation emitted when an electron in a hydrogen atom undergoes a transition from a higher energy state (quantum number n_i) to a lower energy state (n_f). Hence, when an electron in a hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3$, 2 and 1, identify the spectral series to which each of the emission lines belongs.	2
5	The ground state energy of a hydrogen atom is −13.6 eV. What are the kinetic and potential energies of the electron in this state?	2
6	Find the de Broglie wavelength of the electron orbiting in the ground state of a hydrogen atom.	2
7	Calculate the shortest wavelength of light emitted in the Paschen series of the hydrogen spectrum. Which part of the electromagnetic spectrum does it belong to? (Given: Rydberg constant $R = 1.1 \times 10^7\ m^{-1}$)	2
8	Calculate the longest wavelength of the photons emitted in the Balmer series of the hydrogen spectrum. Which part of the electromagnetic spectrum does it belong to? (Given: Rydberg constant $R = 1.1 \times 10^7\ m^{-1}$)	2
9	When an electron in a hydrogen atom jumps from the third excited state to the ground state, how does the de Broglie wavelength associated with the electron change? Justify your answer.	2
10	The energy level diagram of a hydrogen atom is shown below. Find the transition which results in the emission of a photon of wavelength 496 nm. 	2

SECTION B

(Long Answer Questions — 3 marks each)

Q.No.	Question	Marks
1	(i) In a hydrogen atom, an electron undergoes a transition from the 2nd excited state to the first excited state, and then to the ground state. Identify the spectral series to which these two transitions belong. (ii) Find the ratio of the wavelengths of the radiations emitted in the two cases.	3
2	(i) Define the distance of closest approach. An α-particle of kinetic energy K is bombarded on a thin gold foil, and its distance of closest approach is r_c. What will be the distance of closest approach for an α-particle of double the kinetic energy? (ii) Calculate the shortest wavelength in the Balmer series of the hydrogen atom. In which region of the spectrum (infra-red, visible or ultraviolet) does this wavelength lie?	3

Q.No.	Question	Marks
3	(i) The energy level diagram of an element is given below. Identify, by doing the necessary calculations, which transition corresponds to the emission of a spectral line of wavelength 102.7 nm.  (ii) Consider two different hydrogen atoms, each with its electron in an excited state. Is it possible for the electrons to have different energies but the same orbital angular momentum, according to the Bohr model? Justify your answer.	3

Assignment- 6 (Answer Key)

ASSIGNMENT - 1

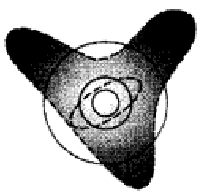
MARKING SCHEME OF SAMPLE PAPER-ATOM

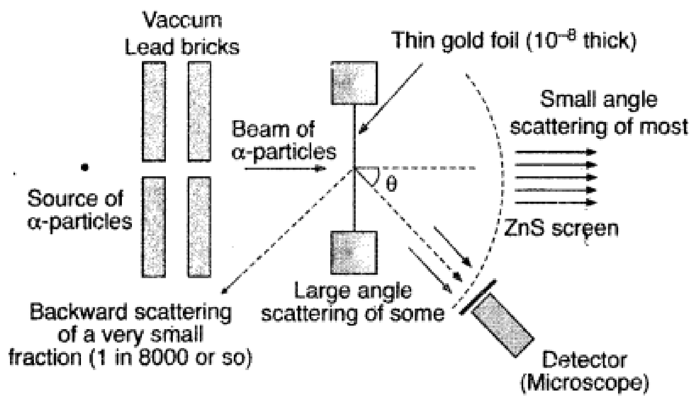
Class: XII SUBJECT: PHYSICS

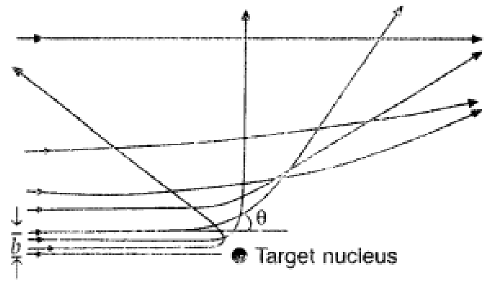
Q NO	SECTION A	MARKS
1	Answer (2)	1
2	Answer (3) Both U & K is inversely proportional to 1/r potential energy is negative whereas kinetic energy is positive.	1
3	Answer (4) The speed of electron in ground state of an hydrogen atom is about 2.2x 10^6 Which is approximately c / 137 where c is the speed of light	1
4	Answer (3) The atomic number (Z) of lithium is 3. As $r_n = a_0 \frac{n^2}{Z}$,	1
5	Answer (3) The pair for which the value $f=cR(1/n_f^2 - 1/n_i^2)$ is lowest is 4 and 3	1
6	Answer (4) Energy of different orbit is inversely proportional to n^2	1
7	Answer (4) 6.57×10^{15}	1
8	Answer (3) $^nC_1 = n(n-1)/2$	1
9	Answer (3) Energy in its 1st excited $=E_0/4$ Energy in its 2nd excited state $=E_0/9$ $E_1:E_2=9:4$	1
10	Answer (2)	1
11	Answer (1) $K=-E=13.6eV$	1
12	Answer (4) $V=V_0/n=c/548$	1
13	a	1

14	a	1
15	e	1
16	a.Fine structure of spectral lines is explained by Somerfield by using elliptical orbits of electrons, also the spin of the electron	1
	SECTION B	
17	For second excited state, n=2 By putting the value in general equation we obtain the desire result $r = n^2 r_0$	2
18	Since the Lyman series is the only series that emits light in the ultraviolet region. The difference in energy between consecutive energy levels keeps reducing it can easily predicted by the energy Transition equation of the line spectra, for hydrogen atom. Or **Given :** For second excited state, $n = 3$, $R = 1.1 \times 10^7\ m^{-1}$ Hence two possible transitions of the Lyman series : $3 \to 1$ and $2 \to 1$. (*i*) Wavelength for transition $3 \to 1$, $n_f = 1$, $n_i = 3$ $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ $\frac{1}{\lambda} = (1.1 \times 10^7)\left(\frac{1}{1} - \frac{1}{9}\right) = 1.1 \times 10^7 \left(\frac{8}{9}\right)$ $\Rightarrow \lambda = \frac{9}{8 \times (1.1 \times 10^7)} = 1.023 \times 10^{-7}$ $= \mathbf{102.3\ nm}$	2
19	Here $\lambda = 102.7$ nm $= 102.7 \times 10^{-9}$ m The energy of the emitted photon is, $E = \frac{hC}{\lambda} = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{102.7 \times 10^{-9}}$ $= \frac{19.878 \times 10^{-26}}{102.7 \times 10^{-9}} = 1.9355 \times 10^{-18}$ J $\therefore$ Energy corresponds $= \frac{1.9355 \times 10^{-18}}{1.6 \times 10^{-19}}$ eV $= 12.097$ eV $\approx$ **12.1 eV** This energy corresponds to the transition D for which the energy change $= -1.5 - (-13.6) = 12.1$ eV	2
20	**Given :** λ_{Limit} for Lyman series = 913.4 Å λ_{Limit} for Balmer series = ? We know $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ For Lyman series, $n_1 = 1$, $n_2 = \infty$ (for limiting value) $\therefore \frac{1}{\lambda_L} = R\left(\frac{1}{2^2} - \frac{1}{2^2}\right) = R$ $\therefore \lambda_L = \frac{1}{R}$ ...(*i*) For Balmer series $n_1 = 2$, $n_2 = \infty$ (for limiting value) $\frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - \frac{1}{\infty}\right) = \frac{R}{4}$ $\lambda_B = 4 \times \lambda_L = 4 \times 913.4 =$ **3653.6 Å**	2

21	As per Bohr's Model, the wavelengths are given by $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ [∵ **R = Rydberg's constant** For most energetic spectral lines, electron should jump from infinity. (*i*) For the most energetic line of Balmer Series : $\frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) \to \frac{R}{4}$ ...(*i*) $\because n_1 = 2$ (*ii*) Similarly for the Paschen Series : $\frac{1}{\lambda_P} = R\left(\frac{1}{3^2} - \frac{1}{\infty^2}\right) \to \frac{R}{9}$ ...(*ii*) $\because n_2 = 3$ $\therefore \frac{\lambda_P}{\lambda_B} = \frac{9}{4}$	2
	SECTION C	
22	(*a*) $r_0 = 5.3 \times 10^{-11}$ m $n = 2$ As $r_n = n^2 r_0$ $\therefore r_2 = (2)^2 \times (5.3 \times 10^{-11})$ m $= 4 \times 5.3 \times 10^{-11}$ m $= 21.2 \times 10^{-11}$ m $=$ **2.12×10^{-10} m** (*b*) $E_2 = -1.51$ eV (*i*) KE = – (Total energy) = – (– 1.51) eV = **+ 1.51 eV** (*ii*) PE = – 2 × KE = – 2 × (1.51) eV = **– 3.02 eV** OR Energy of photon wavelength 275 nm $E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{275 \times 10^{-9} \times 1.6 \times 10^{-19}}$ .eV = 4.5 eV This componds to transition 'B'. (*i*) *Element A* has radiation of maximum wavelength *621 nm*. (*ii*) *Element D* has radiation of minimum wavelength *155 nm*.	3
23	**Given :** Energy of electron beam = 12.5 eV Energy of hydrogen atom = (– 13.6) + 12.5 = – 1.1 eV Now $E_1 = -13.6$ eV $E_2 = \frac{-13.6}{(2)^2} = \frac{-13.6}{4} = -3.4$ eV $E_3 = \frac{-13.6}{(3)^2} = \frac{-13.6}{9} = -1.5$ eV $E_4 = \frac{-13.6}{(4)^2} = \frac{-13.6}{16} = -0.8.5$ eV Hydrogen atom will be excited up to third energy level, because energy of electron is less than that of 4^{th} energy level.	3

<table>
<tr><td></td><td>We know $\frac{1}{\lambda}=R\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$
where $R = 1.097 \times 10^7\ m^{-1}$
(a) *For Lyman series* : $n_1 = 1$, $n_2 = 2$ … for first member
$\frac{1}{\lambda}=1.097\times10^7\left(\frac{1}{1}-\frac{1}{4}\right) \Rightarrow \frac{1}{\lambda}=1.097\times10^7\times\frac{3}{4}$
$\therefore\ \lambda = \frac{4}{3\times1.097\times10^7} = 1.215 \times 10^{-7}$
$= 121.5 \times 10^{-9}$ m = **121.5 nm**
It lies in ultra-violet region.</td><td></td></tr>
<tr><td>24</td><td></td><td>3</td></tr>
<tr><td>25</td><td>Energy of emitted photon, $h\nu = E_2 - E_1$
$= -0.85 - (-3.4) = 2.55$ eV
$= 2.55 \times 1.6 \times 10^{-19}$ J
$\therefore\ \lambda\nu = \frac{hC}{E_2 - E_1} = \frac{hC}{2.55\times1.6\times10^{-19}}$
$= \frac{6.6\times10^{-34}\times3\times10^8}{2.55\times1.6\times10^{-19}} = \frac{19.8\times10^{-26}}{4.08\times10^{-19}}$
$= 4.853 \times 10^{-7}$ m = **4853 Å**
(ii) This wavelength belongs to Balmer series of hydrogen spectrum</td><td>3</td></tr>
<tr><td>26</td><td>$r_0 = \frac{2K\tau e^2}{K_\alpha}$ **where [$K_\alpha = 8 \times 1.6 \times 10^{-13}$ J]**
Atomic number, Z = 80
where [$K = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ NM^2C^{-2}$
$\therefore\ r_0 = \frac{2\times9\times10^9\times\cancel{80}^{10}\times[1.6\times10^{-19}]^2}{\cancel{8}\times1.6\times10^{-13}}$
$= \frac{18\times10^{10}\times\cancel{1.6}\times106\times10^{-38}}{\cancel{1.6}\times10^{-13}}$
$= 18 \times 1.6 \times 10^{10+13} \times 10^{-38}$
$= 18 \times 1.6 \times 10^{-38+23} = 18 \times 1.6 \times 10^{-15}$
$= 2.88 \times 10^{-14}$ m = **28.8 fm**
When kinetic energy of a-particle is doubled, then distance of closest approach becomes half
As $r_0 \propto \frac{1}{K_\alpha}$ $\Rightarrow K_\alpha' = 2K_\alpha$
$r_0' \propto \frac{1}{2K_\alpha}$ $\Rightarrow r_0' \propto \frac{1}{2}r_0$</td><td>3</td></tr>
<tr><td>27</td><td>(a) According to the de-Broglie hypothesis, this electron is also associated with wave character.
Hence a circular orbit can be taken to be a stationary energy state only if it contains an integral number of de- Broglie wavelengths i.e. we must have
$2\pi r = n\lambda$

But $\lambda = \frac{h}{mv}$
According to Bohr's-second postulate</td><td>3</td></tr>
</table>

	$mvr = n\frac{h}{2\pi}$ where $[n = 1, 2, 3]$ $2\pi r = n\frac{h}{mv}$ where $[\lambda = \frac{h}{mv}]$ $2\pi r = n\lambda$ Hence the circumference of the electron in the nth orbital state in hydrogen atom is n times the de-Broglie wavelength associated with it. (b) For third excited state n = 4 For ground state n = 1 Hence, possible transitions are : $n_i = 4$ to $n_f = 3, 2, 1$ $n_i = 3$ to $n_f = 2, 1$ $n_i = 2$ to $n_f = 1$ $\therefore$ Total number of transitions = 6	
28	Energy of an electron in nth orbit $= \frac{-13.6}{n^2}$eV (*i*) For 3rd excited state, $n = 4$ $\therefore\ E_4 = \frac{-13.6}{(4)^2} = \mathbf{-0.85\ eV}$ (*ii*) $\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = R\left(1 - \frac{1}{16}\right) = \frac{15}{16}R$ $\lambda = \frac{16}{15R} = \frac{160}{15 \times 1.1 \times 10^7} = \frac{160}{165} \times 10^{-7}$ $= \mathbf{0.97\ 10^{-7}\ m^{-1}}$	3
	SECTION D	
29	(i) (a) (ii) (c) (iii) (c) (iv)(a) OR (c)	4
30	Answer : (i) –(c) (ii) –(b) (iii) –(a) (iv) 4 – (a)	4
	SECTION E	
31	(*a*) (*i*) **Geiger-Marsden experiment**  (ii) For most of the α-particles, impact parameter is large, hence they suffer very small repulsion due to nucleus and go right through the foil. (iii) Trajectory of α-particles	5



It gives an estimate of the size of nucleus, that it relatively very small as compared to the size of atom.

(b) K.E. of the a-particle = Potential energy possessed by beam at distance of closest approach.

$$\frac{1}{2}mv^2 = \frac{1}{4\pi\epsilon_0}\cdot\frac{(2e)(Ze)}{r_0}$$

$$7.7 \times (1.6 \times 10^{-13}) = \frac{(9\times10^9)\times2\times(1.6\times10^{-19})^2\times80}{r_0}$$

$$r_0 = \frac{9\times10^9\times2\times2.56\times10^{-38}\times80}{7.7\times1.6\times10^{-13}}\ \text{m}$$

$$= 299 \times 10^{-16}\ \text{m}$$

$$= 29.9 \times 10^{-15}\ \text{m} \approx 30 \times 10^{-15}\ \text{m}$$

OR

(*i*) **Bohr's quantisation condition for stationary orbits :** Only those orbits are stable for which the angular momentum, of revolving electron, is an integral multiple of $\frac{h}{2\pi}$.

$L = \frac{nh}{2\pi}$ *i.e.* angular momentum of orbiting electron is quantized.

According to *de Broglie hypothesis*

Linear momentum $(p) = \frac{h}{\lambda}$

and for circular orbit $L = r_n p$

...**where**['r_n' is the radius of quantized orbits.

$$L = \frac{r_n h}{\lambda} \qquad \text{Also } L = \frac{nh}{2\pi}$$

$$\therefore \frac{r_n h}{\lambda} = \frac{nh}{2\pi} \qquad \Rightarrow 2\pi r_n = n\lambda$$

∴ **Circumference of permitted orbits are integral multiples of the wavelength λ.**

(*ii*) Let E_A, E_B and E_C be the energy of three given energy levels A, B and C respectively

$$E_C - E_B = \frac{hc}{\lambda_1} \qquad ...(i)$$

$$E_B - E_A = \frac{hc}{\lambda_2} \qquad ...(ii)$$

$$E_C - E_A = \frac{hc}{\lambda_3} \qquad ...(iii)$$

Adding (*i*) and (*ii*), we have

$$E_c - E_A = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} \qquad ...(iv)$$

Using equation (*iii*) and (*iv*), we havde

$$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} \Rightarrow \frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

32	(*i*) Energy of the ground state = −13.6 eV Energy of (n = 4) state = $\frac{E_0}{n^2} = \frac{E_0}{(4)^2} = \frac{-13.6}{16}$ eV ∴ Energy of the photon absorbed $= \left(\frac{-13.6}{16} - (-13.6)\right) = \left(\frac{-13.6}{16} + 13.6\right)$ eV $= \frac{15}{16} \times 13.6$ eV = 12.75 eV $= 12.75 \times (1.6 \times 10^{-19})$ J ∴ $E = \frac{hc}{\lambda} = 12.75 \times 1.6 \times 10^{-19}$ $\Rightarrow \lambda = \frac{hc}{12.75 \times 1.6 \times 10^{-19}}$ ∴ $\lambda = \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{12.75 \times (1.6 \times 10^{-19})}$ $= \frac{19.89}{20.400} \times 10^{-7}$ m $= 0.97 \times 10^{-7}$ m = **970 Å** or **97 nm** (*ii*) Radius of (n = 4) orbit = $(4)^2 \times (5.3 \times 10^{-11})$ m = **8.48 Å** OR (a) Transition emitting wavelength λ = 496 nm The given wavelength lies in visible region (Balmer series) when, $n_1 = 2,\ n_2 = 4$ $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ [$R = 1.097 \times 10^7\ m^{-1}$] $\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{4^2}\right) = 1.097 \times 10^7 \times \frac{3}{16}$ $\Rightarrow \lambda = \frac{16}{3} \times \frac{10^{-7}}{1.097} = 486$ nm ≈ 496 nm Hence the transition from, $n_2 = 4$ to $n_1 = 2$ (*b*) Transition corresponding to emission of maximum wavelength, $E = h\nu = \frac{hc}{\lambda}$ or $E \propto \frac{1}{\lambda}$ which means that the maximum wavelength emmission will be there when the energy level difference is minimum. From the given energy level diagram, it corresponds to : $n_2 = 4$ to $n_1 = 3$.	5
33	(a)Definition of ionization energy : "The minimum energy, required to free the electron from the ground state of the hydrogen atom, is known as Ionization Energy." The ionization energy is given by : $E_0 = \frac{me^4}{8 \epsilon_0^2 h^2}$ *i.e.*, $E_0 \propto m$ ∴Ionization Energy will become 200 times, ∵ the mass of given particle is 200 times. (b) At the distance d, the K.E. (K) gets converted into P.E. (P) of the system. ∴ P.E. at distance (d) = $\frac{1}{4\pi\varepsilon_0} \frac{2e \times Ze}{d}$ ∴ $\frac{1}{4\pi\varepsilon_0} \frac{2Ze^2}{d} = K$ ∴ $d = \frac{1}{4\pi\varepsilon_0} \frac{2Ze^2}{K}$	5

	OR In a H-atom in ground state, electron revolves round the point-size proton in a circular orbit of radius r_B (Bohr's radius). As $mvr_B = \hbar$ and $\frac{mv^2}{r_B} = \frac{-1 \times e \times e}{4\pi\varepsilon_0 r_B^2}$ $\frac{m}{r_B}\left(\frac{-\hbar^2}{m^2 r_B^2}\right) = \frac{e^2}{4\pi\varepsilon_0 r_B^{2\prime}}$ $r_B = \frac{4\pi\varepsilon_0}{e^2}\frac{\hbar^2}{m} = 0.53$ Å K.E. $= \frac{1}{2}mv^2 = \left(\frac{m}{2}\right)\left(\frac{\hbar}{mr_B}\right)^2$ $= \frac{\hbar^2}{2mr_P^2} = 13.6$ eV PE of the electron and proton, $U = \frac{1}{4\pi\varepsilon_0}\frac{e(-e)}{r_B} = -\frac{e^2}{4\pi\varepsilon_0 r_B} = -27.2$ eV	

Assignment 2

Constants used: $h = 6.63 \times 10^{-34}$ Js, $c = 3 \times 10^8$ m/s, 1 eV $= 1.6 \times 10^{-19}$ J, $R = 1.097 \times 10^7$ m^{-1}, $E_n(H) = -13.6/n^2$ eV, $r_1 = 5.3 \times 10^{-11}$ m.

1. Correct option: (c) Q and P respectively

Concept/Formula used: *Photon energy ∝ energy gap of the transition; shortest λ ↔ largest gap, longest λ ↔ smallest gap.*

E(P=4→1)=12.75 eV (largest); E(Q=4→3)=0.66 eV (smallest); E(R=2→1)=10.2 eV; E(S=3→2)=1.89 eV. So shortest λ ← P, longest λ ← Q, i.e. the pair is Q and P respectively.

2. Correct option: (a) h/π

Concept/Formula used: *$L = nh/2\pi$; identify n from the given energy using $E_n = -13.6/n^2$.*

-3.4 eV $= -13.6/n^2 \Rightarrow n = 2$. $L = 2 \times h/2\pi = h/\pi$.

3. Correct option: (a) $2E_n/nh$

Concept/Formula used: *Frequency of revolution $f = v/(2\pi r)$; combine with $mvr = nh/2\pi$ and KE $= E_n$ (binding energy) $\Rightarrow \frac{1}{2}mv^2 = E_n$.*

From $mv^2 = 2E_n$ and $r = nh/(2\pi mv)$: $f = v/(2\pi r) = mv^2/(nh) = 2E_n/(nh)$.

4. Correct option: (a) Four times its ground state radius

Concept/Formula used: *$r_n = n^2 r_1$; first excited state is $n = 2$.*

$r_2 = 2^2 r_1 = 4r_1$.

5. Correct option: (c) 2.42×10^{-19}

Concept/Formula used: *Energy needed to ionise from level n = (ionisation energy from ground state)/n^2.*

$E = 2.18 \times 10^{-18} / 9 = 2.42 \times 10^{-19}$ J.

6. Correct option: (d) $1/n, 1/n^2, n^2$

Concept/Formula used: *Bohr model results: $v_n \propto 1/n$, $|E_n| \propto 1/n^2$, $r_n \propto n^2$.*

7. Correct option: (b) 7

Concept/Formula used: *Number of spectral lines emitted from level n to level n_f = (n − n_f + 1)(n − n_f)/2.*
Second excited state: $n_f = 3$. Let $x = n - 3$: $x(x+1)/2 = 10 \Rightarrow x = 4 \Rightarrow n = 7$.

8. Correct option: (a) The electrons are not subject to a central force
Concept/Formula used: *In a multi-electron atom, each electron experiences forces from the nucleus and from every other electron, so the net force on it is not purely central (radial), unlike the single-electron case Bohr's model assumes.*

9. Correct option: (b) Because only one of these would have a minimum energy
Concept/Formula used: *Conceptual (NCERT Exemplar): among all possible orientations of the angular momentum vector, only the configuration of minimum energy is physically realised/stable.*

10. Correct option: (a) Lyman series
Concept/Formula used: *Lyman series ($n_f = 1$) lies in the ultraviolet; its longest-wavelength line ($n = 2 \rightarrow 1$, Lyman-α) is at 121.6 nm.*
121.5 nm ≈ 121.6 nm ⟹ Lyman series.

11. Correct option: (d) Reduce to (1/4)th the original value
Concept/Formula used: *Distance of closest approach $r_c \propto 1/K \propto 1/v^2$ ($K = \frac{1}{2}mv^2$).*
Doubling v ⟹ K becomes 4×, so r_c becomes $r_c/4$.

12. Correct option: (b) n = 3 to n = 1
Concept/Formula used: *Photon energy = $13.6(1/n_f^2 - 1/n_i^2)$ eV; compare all four options.*
(a) 10.2 eV; (b) 12.09 eV; (c) 2.55 eV; (d) 1.89 eV. Maximum is (b).

13. Correct option: (a) 3.4 eV
Concept/Formula used: *Energy to remove electron from orbit n = $|E_n| = 13.6/n^2$ eV.*
$n = 2$: $E = 13.6/4 = 3.4$ eV.

14. Correct option: (c) Both (a) and (b)
Concept/Formula used: *Bohr's third postulate: energy of emitted photon = $h\nu = hc/\lambda$; these are simply two equivalent expressions for the same photon energy.*

15. Correct option: (c) 12.1 eV
Concept/Formula used: *To emit the largest-wavelength Balmer line ($n = 3 \rightarrow 2$), the atom must first be excited to $n = 3$; minimum KE needed = $E_3 - E_1$.*
$E_3 - E_1 = -1.51 - (-13.6) = 12.09$ eV ≈ 12.1 eV.

16. Correct option: (b) The force of repulsion between an atomic nucleus and an α-particle varies with distance according to the inverse-square law
Concept/Formula used: *Rutherford derived the scattering-angle distribution assuming Coulomb's inverse-square repulsion between the nucleus and the α-particle; the excellent match with observed scattering data supported this specific law of force.*

17. Correct option: (c) −6.8 eV
Concept/Formula used: *Shifting the zero of potential energy shifts total energy by the same constant amount for every state.*
Normally at $n = 2$: KE = 3.4 eV, PE = −6.8 eV, E = −3.4 eV. Setting PE(n=2) = 0 adds +6.8 eV to all energies. New ground state energy = −13.6 + 6.8 = −6.8 eV.

18. Correct option: (d) Orbital angular momentum of the electron
Concept/Formula used: *r_n, v_n and E_n all depend on Z, but $L_n = nh/2\pi$ depends only on n (not Z); for the ground state ($n = 1$) this is $h/2\pi$ for every hydrogen-like species.*

19. Correct option: (b) 1.06 Å
Concept/Formula used: *$r_n = 0.529(n^2/Z)$ Å.*
He^+: Z = 2, n = 2: r = 0.529 × 4/2 = 1.058 Å ≈ 1.06 Å.

20. Correct option: (d) 91.8 eV
Concept/Formula used: *Energy differences between corresponding levels scale as Z^2.*
Li^{2+}: Z = 3, so ΔE = 10.2 × 3^2 = 10.2 × 9 = 91.8 eV.

21. Correct option: (b) n^2
Concept/Formula used: *$r_n = n^2 r_1$ — a direct consequence of Bohr's quantisation condition combined with the Coulomb force providing centripetal force.*

22. Correct option: (c) Greater than λ
Concept/Formula used: *Smaller energy gap ⟹ longer wavelength (E = hc/λ).*
ΔE(5→2) = 2.86 eV is much smaller than ΔE(5→1) = 13.06 eV, so λ(5→2) > λ(5→1) = λ.

23. Correct option: (d) n = 4 → 1
Concept/Formula used: *Photon energy = 13.6(1/n_f² − 1/n_i²) eV; the largest energy gap gives the highest photon energy.*
ΔE(4→3)=0.66eV; ΔE(3→2)=1.89eV; ΔE(2→1)=10.2eV; ΔE(4→1)=12.75eV — maximum is n = 4 → 1.

24. Correct option: (b) 9 : 4
Concept/Formula used: *$E_n = -13.6/n^2$ eV; first excited state n = 2, second excited state n = 3.*
$T_1 = -13.6/4 = -3.4$ eV; $T_2 = -13.6/9 \approx -1.51$ eV; $T_1 : T_2$ = 3.4 : 1.51 = 9 : 4.

25. Correct option: (b) 2 : 3
Concept/Formula used: *$L_n = nh/2\pi$; first excited state n = 2, second excited state n = 3.*
$L_1 : L_2$ = 2 : 3.

26. Correct option: (b) 4.77 × 10^{-10} m
Concept/Formula used: *$r_n = n^2 r_1$.*
$r_3 = 9 \times 5.3 \times 10^{-11} = 4.77 \times 10^{-10}$ m.

27. Correct option: (c) 1.51 eV
Concept/Formula used: *Energy needed to ionise from level n = $13.6/n^2$ eV; second excited state is n = 3.*
E = 13.6/9 = 1.51 eV.

28. Correct option: (c) −1.5 eV
Concept/Formula used: *$L_n = nh/2\pi$; identify n, then use $E_n = -13.6/n^2$ eV.*
1.5(h/π) = 3(h/2π) ⟹ n = 3. $E_3 = -13.6/9 = -1.51$ eV ≈ −1.5 eV.

29. Correct option: (b) Any atom or ion containing only one electron
Concept/Formula used: *Bohr's theory is derived for a single electron orbiting a nucleus of charge +Ze; it applies equally to H, He^+, Li^{2+}, etc.*

30. Correct option: (c) n = 6 to n = 5
Concept/Formula used: *Least energetic photon ↔ smallest energy gap between adjacent, high-n levels (levels are closest together at large n).*
ΔE(6→5) = 0.166 eV; ΔE(5→4) = 0.306 eV; ΔE(6→1) = 13.22 eV; ΔE(5→3) = 0.967 eV — minimum is 6 → 5.

Assignment 3

Options: (A) Both true, R is the correct explanation of A. (B) Both true, R is NOT the correct explanation of A. (C) A true, R false. (D) Both A and R false.

1. Correct option: (A)
Concept/Reasoning: Both are true. The electron is bound to the nucleus, and the Coulomb attraction supplies the centripetal force; solving this condition together with Bohr's quantisation gives KE = −E and PE = 2E, so the total energy E = KE + PE is negative — the Reason is exactly the physical starting point of that derivation, so it correctly explains the Assertion. (This is essentially CBSE's own 2025–26 Sample Paper Assertion–Reason question on this topic.)

2. Correct option: (B)
Concept/Reasoning: Both statements are true individually, but the Reason does not explain the Assertion. The real reason a single-electron atom's spectrum shows many lines is that a macroscopic sample contains a huge number of atoms, whose electrons sit in many different excited states and undergo many different transitions simultaneously — not the absorption/emission asymmetry between series.

3. Correct option: (A)
Concept/Reasoning: Both true, and R correctly explains A. For a hydrogen-like ion, $E_n = -13.6Z^2/n^2$ eV, so the energy gap (and hence photon energy) for any given transition scales as Z^2. For He^+ (Z = 2) this gap is 4× that of hydrogen, giving a proportionally shorter (smaller) wavelength for the corresponding Lyman line.

4. Correct option: (B)
Concept/Reasoning: Both statements are individually true ($E_n \propto 1/n^2$ and $\lambda_n = 2\pi r_n/n = 2\pi n\cdot r_1 \propto n$), but they describe two independent consequences of Bohr's model — the de Broglie wavelength result does not explain why the energy varies as $1/n^2$.

5. Correct option: (A)
Concept/Reasoning: Both true, and R is the correct explanation. Since $E_n = -13.6/n^2$ eV, the spacing between consecutive levels $E_{n+1} - E_n \approx |dE/dn| = 27.2/n^3$ eV, which shrinks rapidly as n grows — this is exactly why the lines bunch up (converge) at higher n.

6. Correct option: (A)
Concept/Reasoning: Both true, and R is the correct explanation: setting the Coulomb force equal to mv^2/r is precisely the physical assumption that fixes the electron's orbit as circular in Bohr's model.

7. Correct option: (A)
Concept/Reasoning: Both true, and R is the correct explanation: Bohr's model treats the electron non-relativistically and ignores electron spin entirely, so it cannot predict the fine splitting of spectral lines that these effects produce.

8. Correct option: (A)
Concept/Reasoning: Both true, and R is (part of) the correct explanation: the nucleus concentrates virtually all the atom's positive charge and mass in a tiny volume. Because it is so much heavier than the incoming α-particle, it barely recoils, allowing a close, nearly head-on encounter to reverse the α-particle's direction almost completely — something a light, spread-out charge (as in Thomson's model) could never do.

9. Correct option: (B)
Concept/Reasoning: Both statements are true, but R does not explain A — if anything, R describes the classical prediction that Bohr's postulate deliberately contradicts. Bohr's non-radiating-orbit postulate was an ad hoc departure from classical electromagnetism (introduced precisely because the classical prediction led to atomic collapse), not a consequence derived from it.

10. Correct option: (A)

Concept/Reasoning: Both true, and R is the correct explanation. $L_n = nh/2\pi$, so for the first excited state (n = 2) and the ground state (n = 1): $L_2 : L_1 = 2 : 1$, directly because $L \propto n$.

11. Correct option: (C)

Concept/Reasoning: A is true: since $r_n = n^2 r_1$ and $L_n = nh/2\pi \propto n$, we get $L_n \propto n \propto \sqrt{(n^2)} \propto \sqrt{r_n}$. R is false: in Bohr's model an electron can jump to any lower orbit (not just the nearest one) — this is exactly how the various spectral series (Lyman, Balmer, Paschen, …) arise from a single excited state.

12. Correct option: (D)

Concept/Reasoning: Both are false. The Balmer series is defined by transitions ending at n = 2, not the ground state (n = 1) — transitions to the ground state form the Lyman series instead. R is also false: Bohr's model places no restriction that electrons jump only between adjacent orbits; transitions can occur between any two allowed levels.

13. Correct option: (A)

Concept/Reasoning: Both true, and R is the correct explanation. Since the nucleus occupies only about $(10^{-5})^3$ of the atom's volume, the great majority of α-particles pass through the mostly-empty atom with little or no deflection, and only the rare ones aimed almost directly at the tiny nucleus undergo large-angle scattering.

14. Correct option: (A)

Concept/Reasoning: Both true, and R is the correct explanation: de Broglie's standing-wave condition $2\pi r_n = n\lambda$ shows that only orbits whose circumference is a whole number of electron wavelengths can support a stable (non-self-cancelling) wave, which is exactly why only discrete radii — and hence discrete energies — are allowed.

15. Correct option: (A)

Concept/Reasoning: Both true, and R is the correct explanation: in Thomson's model, the positive charge (and the compensating negative charge) is smeared over the entire atomic volume, so the electric field — and hence the maximum possible deflecting force on a passing α-particle — is far too weak to ever reverse its path, unlike Rutherford's concentrated nuclear charge.

Assignment 4 (Four Case based Questions)

Constants used: $h = 6.63 \times 10^{-34}$ Js, $c = 3 \times 10^8$ m/s, 1 eV = 1.6×10^{-19} J, $R = 1.097 \times 10^7\ m^{-1}$, $E_n(H) = -13.6/n^2$ eV, $r_1 = 0.529$ Å (5.3×10^{-11} m).

Case Study 1 — Answers

(1) Correct option: (d) 48.4 eV

Concept/Formula used: *$E_n = -13.6\ Z^2/n^2$ eV for a hydrogen-like ion.*

For He^+, Z = 2: $E_1 = -13.6 \times 4/1 = -54.4$ eV; $E_3 = -13.6 \times 4/9 = -6.04$ eV

$\Delta E = E_3 - E_1 = -6.04 - (-54.4) = 48.4$ eV

(2) Correct option: (c) 9/8

Concept/Formula used: *$r_n = (0.529\ n^2/Z)$ Å.*

$r(He^+, n=3) = 0.529 \times 9/2 = 2.38$ Å; $r(H, n=2) = 0.529 \times 4/1 = 2.12$ Å

Ratio = 2.38/2.12 = 9/8

(3) Correct option: (a) 3 : 4

Concept/Formula used: *$v_n = (2.18 \times 10^6\ Z/n)$ m/s, so $v \propto Z/n$.*

$v(H, n=2) \propto 1/2$; $v(He^+, n=3) \propto 2/3$

Ratio = $(1/2) \div (2/3) = 3/4 \implies 3 : 4$

(4) Correct option: (c) 6

Concept/Formula used: *Number of spectral lines from de-excitation of level n to ground state = n(n − 1)/2 (independent of Z).*
For n = 4: number of lines = 4 × 3 / 2 = 6

Case Study 2 — Answers

(1) Correct option: (c) Paschen series
Concept/Formula used: *A series is named by its lower (final) level n_f: n_f = 3 → Paschen series.*
Transition given: n = 5 → n = 3, so n_f = 3 ⟹ Paschen series

(2) Correct option: (b) n = 3, 4, 5 ... to n = 2
Concept/Formula used: *The Balmer series corresponds to all transitions ending at n_f = 2.*
So electrons from n = 3, 4, 5, ... fall to n = 2

(3) Correct option: (a) 13.6 eV
Concept/Formula used: *The maximum photon energy corresponds to the largest possible energy gap, i.e. the transition from n = ∞ to n = 1 (the series limit of the Lyman series), which equals the ionisation energy.*
E(max) = E(∞) − E(1) = 0 − (−13.6) = 13.6 eV

(4) Correct option: (a) 820 nm
Concept/Formula used: *Shortest wavelength in a series = series limit, i.e. transition from n = ∞ to the series' lower level (n_f = 3 for Paschen).* $1/\lambda = R(1/n_f^2 - 1/n_i^2)$.
$1/\lambda = R(1/9 - 0) = 1.097 \times 10^7/9 = 1.22 \times 10^6\ m^{-1}$
$\lambda = 8.2 \times 10^{-7}$ m ≈ 820 nm

Case Study 3 — Answers

(1) Correct option: (b) Atoms are mostly empty space
Concept/Formula used: *Rutherford's α-scattering experiment — undeflected particles imply very little matter obstructs their path.*
Since almost all α-particles passed straight through the foil, most of the atom's volume must be empty.

(2) Correct option: (c) Electrostatic repulsion from the dense, positively charged nucleus
Concept/Formula used: *Coulomb's law of repulsion between like charges (α-particle and nucleus, both positive).*
Only a concentrated positive charge (nucleus) could repel a fast α-particle strongly enough to reverse its path.

(3) Correct option: (c) 10^5
Concept/Formula used: *Simple ratio of given linear dimensions.*
Ratio = (radius of atom)/(radius of nucleus) = $10^{-10} / 10^{-15} = 10^5$

(4) Correct option: (a) Stability of the atom
Concept/Formula used: *Concept: an accelerating (orbiting) charge should radiate energy continuously as per classical electromagnetic theory, which would cause the electron to spiral into the nucleus — Rutherford's model could not explain why atoms are stable.*
This shortcoming was later addressed by Bohr's postulate of stable, non-radiating orbits.

Case Study 4 — Answers

(1) Correct option: (d) −13.6 eV

Concept/Formula used: *Ground state energy of hydrogen:* $E_1 = -13.6/1^2$ eV.

$E_1 = -13.6$ eV (the correct sign and unit together identify the ground state energy)

(2) Correct option: (b) L = nh/2π

Concept/Formula used: *Bohr's second postulate: angular momentum is quantised in integral multiples of h/2π.*

$L = nh/2\pi$, $n = 1, 2, 3, \ldots$

(3) Correct option: (b) 364.6 nm

Concept/Formula used: *Shortest wavelength of Balmer series = series limit:* $1/\lambda = R(1/4 - 1/n_i^2)$, $n_i \to \infty$.

$1/\lambda = R/4 = 1.097 \times 10^7/4 = 2.74 \times 10^6\ m^{-1}$

$\lambda = 3.65 \times 10^{-7}\ m \approx 364.6$ nm

(4) Correct option: (c) n = 1

Concept/Formula used: *By definition, the ground state is the lowest energy state, corresponding to the smallest allowed principal quantum number.*

$n = 1$ for the ground state of hydrogen

Case Study 5 — Answers

(1) Correct option: (a) $2\pi r_n = n\lambda$

Concept/Formula used: *De Broglie's explanation of Bohr's quantisation: a stable orbit must contain a whole number of electron de Broglie wavelengths.*

$2\pi r_n = n\lambda$ (orbit circumference = n × de Broglie wavelength)

(2) Correct option: (b) λ = h/mv

Concept/Formula used: *De Broglie's hypothesis:* $\lambda = h/p = h/mv$.

$\lambda = h/(mv)$

(3) Correct option: (b) 3.33×10^{-10} **m**

Concept/Formula used: *Combining* $mvr = nh/2\pi$ *with* $\lambda = h/mv$ *gives* $\lambda = 2\pi r/n$.

For the ground state, $n = 1$, $r_1 = 5.3 \times 10^{-11}$ m

$\lambda = 2\pi \times 5.3 \times 10^{-11} = 3.33 \times 10^{-10}$ m

(4) Correct option: (a) Increases

Concept/Formula used: *Since* $r_n = n^2 r_1$, $\lambda_n = 2\pi r_n/n = 2\pi n\, r_1$, *so* $\lambda \propto n$.

As n increases, λ increases proportionally.

Case Study 6 — Answers

(1) Correct option: (c) 13.6 eV

Concept/Formula used: *Ionisation energy = energy to take the electron from the ground state (n=1) to* $n = \infty$: $|E_1|$.

Ionisation energy = |−13.6| = 13.6 eV

(2) Correct option: (b) 10.2 eV

Concept/Formula used: *Excitation energy =* $E_2 - E_1$, *using* $E_n = -13.6/n^2$ eV.

$E_2 = -13.6/4 = -3.4$ eV; $E_1 = -13.6$ eV

$\Delta E = -3.4 - (-13.6) = 10.2$ eV

(3) Correct option: (b) 3

Concept/Formula used: *Absorbed photon energy = $E_n - E_1$; solve for n.*

$E_n = E_1 + 12.1 = -13.6 + 12.1 = -1.5$ eV

$-13.6/n^2 = -1.5 \implies n^2 \approx 9 \implies n = 3$

(4) Correct option: (c) 3.4 eV

Concept/Formula used: *Ionisation energy from a given state n = $|E_n|$ = $13.6/n^2$ eV.*

First excited state: n = 2, $E_2 = -13.6/4 = -3.4$ eV

Energy to ionise from n = 2 = $|E_2|$ = 3.4 eV

Case Study 7 — Answers

(1) Correct option: (b) Only hydrogen and hydrogen-like single-electron ions

Concept/Formula used: *Bohr's theory is derived for a single electron orbiting a nucleus of charge +Ze; it does not account for electron–electron interactions.*

It works for H, He^+, Li^{2+}, etc., but not for multi-electron atoms.

(2) Correct option: (b) Splitting of spectral lines in a magnetic field (Zeeman effect)

Concept/Formula used: *Bohr's model has no provision for the interaction of the atom's magnetic moment with an external magnetic field.*

It correctly gives discrete energy levels, the Lyman series wavelengths, and orbit radii, but not the Zeeman effect.

(3) Correct option: (b) Heisenberg's uncertainty principle

Concept/Formula used: *The uncertainty principle forbids simultaneous precise knowledge of position (hence orbit radius) and momentum of a particle.*

Bohr's well-defined circular orbits with exact radius and momentum contradict this principle.

(4) Correct option: (d) The neutral helium atom (two electrons)

Concept/Formula used: *Bohr's model applies only to single-electron (hydrogen-like) systems.*

Neutral helium has two electrons, so electron–electron repulsion makes Bohr's simple model inapplicable

Assignment 5 (Ten Short Questions and Three Long Questions)

SECTION A

Q1(a). Radius of n = 3 orbit

Concept/Formula used: *Bohr's quantisation of orbits — radius of the nth orbit is $r_n = n^2 r_1$, where r_1 is the radius of the innermost (n = 1) orbit.*

$$», r_n = n^2 \times r_1$$

$r_3 = (3)^2 \times 5.3 \times 10^{-11}$ m $= 9 \times 5.3 \times 10^{-11}$ m

Answer: $r_3 = 4.77 \times 10^{-10}$ m

Q1(b). Kinetic and potential energy in the first excited state

Concept/Formula used: *In the Bohr model, total energy E = KE + PE, and for Coulombic attraction PE = −2 × KE, so E = −KE, i.e. KE = −E and PE = 2E.*

$$», KE = -E \quad \text{and} \quad PE = 2E$$

Given E = −3.4 eV

KE = −(−3.4) = 3.4 eV

PE = 2 × (−3.4) = −6.8 eV

Answer: KE = 3.4 eV, PE = −6.8 eV

Q2. Second member of Lyman and Balmer series

Concept/Formula used: *Rydberg formula for hydrogen spectral lines: $1/\lambda = R(1/n_f^2 - 1/n_i^2)$. The second member of a series is the transition from the second-nearest higher level to the series' lower level (Lyman: $n_f = 1$, second member $n_i = 3$; Balmer: $n_f = 2$, second member $n_i = 4$).*

$$», 1/\lambda = R(1/n_f^2 - 1/n_i^2)$$

Lyman series, second member: $n_f = 1, n_i = 3$

$1/\lambda = R(1 - 1/9) = R \times 8/9 = 1.097 \times 10^7 \times 0.889 = 9.75 \times 10^6\ m^{-1}$

$\lambda = 1.03 \times 10^{-7}$ m ≈ 102.6 nm — this lies in the ultraviolet region.

Balmer series, second member: $n_f = 2, n_i = 4$

$1/\lambda = R(1/4 - 1/16) = R \times 3/16 = 1.097 \times 10^7 \times 0.1875 = 2.06 \times 10^6\ m^{-1}$

$\lambda = 4.86 \times 10^{-7}$ m ≈ 486 nm — this lies in the visible region (blue-green, the H_β line).

Answer: λ(Lyman, 2nd) ≈ 102.6 nm (UV); λ(Balmer, 2nd) ≈ 486 nm (visible)

Q3. Ratio of photon energies

Concept/Formula used: *Photon energy for a transition $n_i \to 1$ is $E = 13.6\ eV \times (1 - 1/n_i^2)$ (using $E_n = -13.6/n^2$ eV).*

$$», E \propto (1 - 1/n_i^2)$$

(i) $n_i = 2 \to 1$: $E_1 \propto (1 - 1/4) = 3/4$

(ii) $n_i = \infty \to 1$: $E_2 \propto (1 - 0) = 1$

Answer: $E_1 : E_2 = 3/4 : 1 = 3 : 4$

Q4. Derivation of frequency of emitted radiation + spectral series for n_i = 4

Concept/Formula used: *Bohr's postulates: (1) electron revolves in stationary orbits with quantised angular momentum $mvr = nh/2\pi$, (2) radiation is emitted only when the electron jumps from a higher to a lower energy orbit, with $h\nu = E_i - E_f$.*

From Bohr's theory, the energy of the nth orbit of hydrogen is:

$$», E_n = -(me^4)/(8\varepsilon_0^2h^2n^2) = -13.6/n^2\ \text{eV}$$

For a transition from n_i to n_f ($n_i > n_f$), the emitted photon energy is:

$$», h\nu = E_i - E_f = (me^4/8\varepsilon_0^2h^2)(1/n_f^2 - 1/n_i^2)$$

So the frequency of the emitted radiation is:

$$», \nu = (me^4)/(8\varepsilon_0^2h^3) \times (1/n_f^2 - 1/n_i^2)$$

For $n_i = 4$:

→ $n_f = 3$: Paschen series

→ $n_f = 2$: Balmer series

→ $n_f = 1$: Lyman series

Answer: $\nu = (me^4/8\varepsilon_0^2h^3)(1/n_f^2 - 1/n_i^2)$; transitions 4→3, 4→2, 4→1 belong to the Paschen, Balmer and Lyman series respectively.

Q5. KE and PE in the ground state

Concept/Formula used: *Same relation as Q1(b): KE = −E, PE = 2E.*

$$», KE = -E,\ \ PE = 2E$$

Given E = −13.6 eV

KE = 13.6 eV

PE = 2 × (−13.6) = −27.2 eV

Answer: KE = 13.6 eV, PE = −27.2 eV

Q6. de Broglie wavelength in the ground state

Concept/Formula used: *Bohr's quantisation condition $mvr = nh/2\pi$ combined with de Broglie's relation $\lambda = h/mv$ gives $\lambda = 2\pi r/n$, i.e. the orbit circumference equals n de Broglie wavelengths.*

», $\lambda = 2\pi r_n / n$

For the ground state, n = 1 and $r_1 = 5.3 \times 10^{-11}$ m

$\lambda = 2\pi \times 5.3 \times 10^{-11}$ m

Answer: $\lambda = 3.33 \times 10^{-10}$ m (3.33 Å)

Q7. Shortest wavelength of the Paschen series

Concept/Formula used: *The shortest wavelength (series limit) of a series corresponds to the transition from n = ∞ to the series' lower level, since this transition has the maximum photon energy.*

», $1/\lambda = R(1/n_f^2 - 1/n_i^2)$, with $n_f = 3$, $n_i = \infty$

$1/\lambda = R(1/9 - 0) = 1.1 \times 10^7 / 9 = 1.222 \times 10^6\ m^{-1}$

$\lambda = 8.18 \times 10^{-7}$ m = 818 nm

Answer: λ = 818 nm — this lies in the infrared region.

Q8. Longest wavelength of the Balmer series

Concept/Formula used: *The longest wavelength within a series corresponds to the smallest energy gap, i.e. the transition from the level immediately above the series' lower level.*

», $1/\lambda = R(1/n_f^2 - 1/n_i^2)$, with $n_f = 2$, $n_i = 3$

$1/\lambda = R(1/4 - 1/9) = 1.1 \times 10^7 \times 5/36 = 1.528 \times 10^6\ m^{-1}$

$\lambda = 6.55 \times 10^{-7}$ m = 655 nm

Answer: λ = 655 nm — this lies in the visible region (red, the H_α line).

Q9. Change in de Broglie wavelength (n = 4 → n = 1)

Concept/Formula used: *From Q6, $\lambda_n = 2\pi r_n/n$ and $r_n = n^2 r_1$, so $\lambda_n = 2\pi n\, r_1$, i.e. the de Broglie wavelength is directly proportional to n.*

», $\lambda_n \propto n$

Third excited state means n = 4 (n = 1 is ground, n = 2 first excited, n = 3 second excited, n = 4 third excited).

As the electron jumps from n = 4 to n = 1, $\lambda_4 : \lambda_1 = 4 : 1$

Answer: The de Broglie wavelength decreases and becomes one-fourth of its initial value, since λ ∝ n and the electron's speed increases as it falls to a lower orbit.

Q10. Transition emitting a photon of wavelength 496 nm

Concept/Formula used: *Photon energy E = hc/λ; compare with the energy differences read off the given energy level diagram ($E_n = -13.6/n^2$ eV for hydrogen).*

», E = hc/λ = 1240 / λ(nm) eV

E = 1240 / 496 ≈ 2.5 eV

From the diagram: $E_4 - E_2 = (-0.85) - (-3.4) = 2.55$ eV ≈ 2.5 eV

Answer: The transition is n = 4 → n = 2 (a line of the Balmer series).

SECTION B

LQ1(i). Spectral series for the two transitions

Concept/Formula used: *Ground state n = 1, first excited state n = 2, second excited state n = 3. A series is named by its lower (final) level: $n_f = 1$ → Lyman, $n_f = 2$ → Balmer, $n_f = 3$ → Paschen.*

Transition n = 3 → n = 2: Balmer series

Transition n = 2 → n = 1: Lyman series

Answer: 3 → 2 belongs to the Balmer series; 2 → 1 belongs to the Lyman series.

LQ1(ii). Ratio of wavelengths

Concept/Formula used: *Rydberg formula: $1/\lambda = R(1/n_f^2 - 1/n_i^2)$.*

$$», 1/\lambda_{32} = R(1/4 - 1/9) = 5R/36$$

$$», 1/\lambda_{21} = R(1 - 1/4) = 3R/4 = 27R/36$$

$\lambda_{32} / \lambda_{21} = (27R/36) / (5R/36) = 27/5$

Answer: $\lambda_{32} : \lambda_{21} = 27 : 5$ (i.e. $\lambda_{32} = 5.4 \times \lambda_{21}$)

LQ2(i). Distance of closest approach for doubled kinetic energy

Concept/Formula used: *The distance of closest approach r_c is the distance at which the α-particle's entire kinetic energy converts to electrostatic potential energy of repulsion (Rutherford scattering).*

$$», K = (1/4\pi\varepsilon_0) \times (2Ze^2)/r_c \implies r_c = (1/4\pi\varepsilon_0) \times 2Ze^2/K \implies r_c \propto 1/K$$

Definition: the distance of closest approach is the minimum distance from the nucleus that a bombarding α-particle can reach, at which point its kinetic energy is momentarily zero, having been fully converted into electrostatic potential energy.

Since $r_c \propto 1/K$, doubling K halves r_c.

Answer: New distance of closest approach = $r_c / 2$

LQ2(ii). Shortest wavelength in the Balmer series

Concept/Formula used: *Same as Q7's method but applied to the Balmer series: shortest wavelength = series limit, $n_i = \infty$, $n_f = 2$.*

$$», 1/\lambda = R(1/n_f^2 - 1/n_i^2), n_f = 2, n_i = \infty$$

$1/\lambda = R(1/4 - 0) = 1.097 \times 10^7 / 4 = 2.74 \times 10^6\ m^{-1}$

$\lambda = 3.65 \times 10^{-7}$ m = 365 nm

Answer: λ = 365 nm — this lies in the ultraviolet region.

LQ3(i). Transition for a spectral line of wavelength 102.7 nm

Concept/Formula used: *Photon energy $E = hc/\lambda$; compare with energy differences from the given diagram.*

$$», E = 1240 / \lambda(nm)\ \ eV$$

E = 1240 / 102.7 ≈ 12.07 eV

From the diagram: $E_3 - E_1 = (-1.51) - (-13.6) = 12.09$ eV ≈ 12.07 eV

Answer: The transition is n = 3 → n = 1 (a line of the Lyman series).

LQ3(ii). Same energy, different angular momentum?

Concept/Formula used: *In the Bohr model, both the energy $E_n = -13.6/n^2$ eV and the orbital angular momentum $L_n = nh/2\pi$ depend on the same quantum number n.*

If two electrons have different energies, they must be in states with different values of n (since energy depends uniquely on n).

Since angular momentum $L = nh/2\pi$ also depends only on n, a different n necessarily gives a different angular momentum.

Answer: No, it is not possible. Different energies imply different values of n, and since $L = nh/2\pi$ depends only on n, the two electrons must also have different orbital angular momenta.

CHAPTER 13: NUCLEI

Assignment - 1
QUESTION PAPER
CLASS - XII

MM -70 **TIME: 3 Hr**

SECTION A: MULTIPLE CHOICE QUESTIONS (1x16=16)

Q. 1.Two lithium nuclei in a lithium vapour at room temperature do not combine to form a carbon nucleus because:
(a) Carbon nucleus is an unstable particle
(b) it is not energetically favorable
(c) Nuclei do not come closer due to Coulomb repulsion
(d) Lithium nucleus is more tightly bound than a carbon nucleus

Q. 2 The curve of binding energy per nucleon as a function of atomic mass number and is constant for all nuclei, this implies that the helium nucleus is -
(a)Radioactive (b) unstable
(c) easily fissionable (d) more stable nucleus than its neighbours

Q. 3. Which of the following statements about nuclear forces is not true
a. The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few femtometre.
b. The nuclear force is much weaker than the coulomb force
c. The force is attractive for distances larger than 0.8 fm and repulsive if they are separated by distances less than 0.8 fm
d. The nuclear force between neutron-neutron , proton-neutron and proton - proton is approximately the same.

Q. 4. Heavy stable nucleus have more neutron than protons. This is because of the fact that
a. neutrons are heavier than protons
b. electrostatic force between protons is repulsive
c. neutrons decay into protons through beta decay
d. nuclear force between neutrons is weaker than that between protons.

Q. 5. Atomic mass unit (1u) is
(a) 1/12 of mass C-12 atom (b) 1/14 of mass C-14 atom
(c) 1/12 of mass C-14 atom (d) 1/6 of mass C-12 atom

Q. 6. Ratio of radius of an atom to the radius of its nucleus is around
(a) 10^{-2} (b) 10^{4} (c) 10^{12} (d) 10^{15}

Q. 7. The number of neutrons in a $_{84}Po^{218}$
(a) 84 (b) 218 (c) 222 (d) 134

Q. 8. If the nuclear radius of 27 Al is 3.6 fm, the approximate nuclear radius of 64 Cu in fm is
(a) 2.4 (b) 1.2 (c) 4.8 (d) 3.6

Q. 9. Energy equivalent of 2 gm of a substance is
(a) $18X10^{13}$ mJ (b) $18X10^{13}$ J (c) $9X10^{13}$ mJ (d) $9X10^{13}$ J

Q. 10. Given, m $_{26}$Fe(56) = 55.934939u and m $_{83}$Bi(209)=208.980388 u
m(neutron)=1.008665u , m(proton)=1.007825u
Then B.E. per nucleon of Fe is
(a) 8.790 MeV (b) 7.75 MeV (c) 7.5 MeV (d) Data insufficient

Q. 11. How much mass has to be converted into energy to produce electric power of 200 MW for one hour?
(a) $2x10^{-6}$kg (b) 8×10^{-6} kg
(c) 1×10^{-6} kg (d) 3 x 10-6 kg

Q. 12. Nature of nuclear force is
(a) electric (b) magnetic (c) gravitational (d) None of these

ASSERTION - REASON

Directions: Questions 13 to 16 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 incorrect.

Q. 13 ASSERTION: Nuclear density is very large as compared to ordinary matter

REASON : Nuclear density increases with the increase of mass number

Q. 14 ASSERTION: The nuclear force between neutron-neutron , proton-neutron and proton - proton is approximately the same.

REASON : The nuclear force does not depend on the electric charge

Q. 15 ASSERTION: Stable nuclei contains approximately same number of protons and neutrons

REASON : The stability of nucleus is determined by its neutron to proton ratio.

Q. 16 ASSERTION : Energy released in fusion process is much greater than that in fission process

REASON: Thermonuclear fusion is the source of energy in the stars

SECTION B: VERY SHORT ANSWER QUESTION [2 x 5 = 10]

Q. 17 What is the nuclear radius of ^{125}Fe if that of ^{27}Al is 3.6 fm ?

Q. 18 Draw a graph showing the variation of potential between a pair of nucleons as a function of their separation. Mark the regions where potential energy is (i) positive, and (ii) negative

Q. 19 Explain the processes of nuclear fusion by using the plot of binding energy per nucleon (BE/A) versus the mass number A.

Q. 20 Find the ratio of radii of two nuclei of mass number 27 and 64, respectively

Q. 21 Suppose that protons and neutrons have equal masses. Calculate how many times nuclear matter is denser than water? Take mass of nucleon = 1.67×10^{-27} kg and $R_o = 1.2 \times 10^{-15}$ m

SECTIONC: **SHORT ANSWER QUESTION [3 x 7 = 21]**

Q. 22 Find the binding energy per nucleon of $_{20}Ca^{40}$ nucleus. Given m(N) $_{20}Ca^{40}$ =39.962589u, m(n) = 1.008665 and m(p) = 1.007825 u.

Q. 23 How long can an electric lamp of 100 W be kept glowing by fusion of 2 kg of deuterium? Take the fusion reaction as Given Avogadro no. = 6.023×10^{23}

Q. 24 Four nuclei of an element undergo fusion to form a heavier nucleus, with release of energy. Which of the two the parent or the daughter nucleus would have higher binding energy per nucleon?

Q. 25 Distinguish between nuclear fission and nuclear fusion..

Explain the release of energy in nuclear fission and fusion on the basis of binding energy per nuclear curve.

Q. 26 How is size of nucleus found experimentally. Write the relation between the radius and mass number of a nucleus.

Prove that the density of nucleus is independent of mass number

Q. 27 Calculate the binding energy of an alpha particle in MeV. Given

mass of proton = 1.007825 u

mass of neutron = 1.008665 u

mass of He nucleus = 4.002800 u

1 u = 931 MeV/c²

Q. 28 If both the numbers of protons and neutrons are conserved in a nuclear reaction like

$_6C^{12} + _6C^{12}$----------$_{10}Ne^{20} + _2He^4$

In what ways is the mass converted into energy? Explain.

SECTION D: CASE BASED QUESTION [2 X 4 = 8]

Q. 29 Read the below case and answer the questions that follow:

GRAND UNIFICATION THEORY: There are four

Fundamental forces in the universe:

Gravitational force , Electromagnetic force, The weak nuclear force , The strong nuclear force

The weak and strong forces are effective only over a very short range and dominate only at the level of subatomic particles. Gravitational force and Electromagnetic force have infinite range.

The Four Fundamental Forces and their Strengths

(i) Gravitational Force - Weakest force; but has infinite range.

(ii) Weak Nuclear Force - Next weakest; but short range.

(iii) Electromagnetic Force - Stronger, with infinite range.

(iv) Strong Nuclear Force - Strongest; but short range.

Unification:

The weak nuclear force and electromagnetic force have been unified under the Standard Electroweak Theory, (Glashow, Weinberg and Salaam were awarded the Nobel Prize for this in 1979).

Grand unification theories attempt to treat both strong nuclear force and electroweak force under the same mathematical structure.

Theories that add gravitational force to the mix and try to unify all four fundamental forces into a single force are called Super-unified Theories. It has not yet been successful.

Q.1. What are the 4 fundamental forces?

(A) Gravitational force, electromagnetic force, nuclear force, tension force

(B) Gravitational force, electromagnetic force, nuclear force, frictional force

(C) Gravitational force, electromagnetic force, weak nuclear force, strong nuclear force

(D) Frictional force, electric force, nuclear force, magnetic force

Q.2. Which fundamental force is always attractive?

(A) Electric force (B) Magnetic force (C) Gravitational force (D) Strong Nuclear force

Q. 3. Which two fundamental forces have been unified by Standard Electroweak Theory?

(A) Weak nuclear force and electromagnetic force

(B) Strong nuclear force and electromagnetic force

(C) Gravitational force and electromagnetic force

(D) Weak nuclear force and strong nuclear force

Q.4. Which of the following forces have infinite ranges?

(A) Weak nuclear force and strong nuclear force

(B) Gravitational force and Electromagnetic force

(C) Weak nuclear force and Gravitational force

(D) All the forces

Q.30. The nucleus was first discovered in 1911 by Lord Rutherford and his associates by experiments on scattering of a-particles by atoms. He found that the scattering results could be explained, if atoms consist of a small, central, massive and positive core surrounded by orbiting electrons. The experimental results indicated that the size of the nucleus is of the order of 10-14 in and is thus 10000 times smaller than the size of atom.

(i) What is the ratio of mass of nucleus with mass of atom ?

(ii) If R is the radius and A is mass number, then, plot the graph between log R and logA.

(iii) What will be the ratio of masses of hydrogen, deuterium and tritium ?

(iv) What are the isotones?

SECTION E: LONG ANSWER QUESTION [5 X 3 = 15]

Q.31. Define Q value of a nuclear process when can a nuclear process not proceed simultaneously? If both the number of protons and the number of neutrons are conserved in a nuclear reaction, in what way is mass converted into energy or vice versa in nuclear reaction?

Q. 32 a) The mass of a nucleus in its ground state is always less than the total mass of its constituents – neutrons and protons. Explain.

b) Plot a graph showing the variation of potential energy of a pair of nucleons as a function of their separation.

Q. 33 Calculate and compare the energy released by

(i) fusion of 1 kg of hydrogen deep within sun (4 hydrogen nuclei fuse to form a helium nucleus with release of 26 MeV energy)and

(ii) the fusion of 1 kg $^{235}_{92}U$ in a fusion reactor energy released in one fission 200 MeV.

ASSIGNMENT NO. 2

MULTIPLE CHOICE QUESTIONS

Q. 1. Two nuclei have mass numbers in the ratio (1 : 8). What is the ratio of their nuclear radii?

(a) (1 : 2) (b) (1 : 4)

(c) (1 : 8) (d) (1 : 1

Q. 2. A nucleus with mass number 220 initially at rest emits an alpha particle. If the Q value of the reaction is 5.5 MeV . Calculate the kinetic energy.

(a) 4.4MeV (b) 5.4 MeV (c) 5.6 MeV (d) 6.5 MeV

Q. 3. The mass of a Li nucleus is 0.042u less than the masses of all its nucleons . The binding energy per nucleon of Li nucleus is nearby:

(a) 23MeV (b) 46 MeV (c) 5.6 MeV (d) 3.9 MeV

Q. 4. The binding energy per nucleon in a deuterium and Helium nuclei are 1.1MeV and 7.0 MeV , respectively. When two deuterium nuclei fuse to form a helium nucleus, the energy released in the fusion is :

(a) 23.6 MeV (b) 2,2 MeV (c) 28.0 MeV (D) 30.2 MeV

Q. 5. A match box with dimensions 5cm X 4cm X 1cm, when filled with nuclear matter , weights about:

(a) 2x10gm (b) 2×10^{8}gm (c) 2×10^{12} gm (d) 2×10^{16} gm

Q. 6. Number of neutrons emitted per fission is 1.6 when the energy released per fission is 200 MeV . The number of neutrons emitted per second when 20 MW power is generated will be :

(a) 3.9×10^{20} (b) 3.9×10^{19} (c) 10^{19} (d) 10^{18}

Q. 7. Percentage of mass which changes in to energy in fusion is of order of :

(a) 10% (b) 1% (c) 0.7% (d) 0.1%

Q. 8. If a star can convert all the He nuclei completely in to Oxygen nuclei, the energy released per Oxygen is {mass of He nucleus is 4.0026amu and mass of Oxygen nucleus is 15.994 amu}

(a) 7.6MeV (b) 56.12 Me V (C) 10.24 Me V (D) 23.9MeV

Q. 9. A nuclear reactor delivers a power of 10 W. Find fuel consumed by the reactor per hour, if its efficiency is 20%.

(a) 2×10^{-6} g/h (b) 9×10^{-12}g/h (c) 8×10^{-9} g/h (d) 2×10^{-9}g/h

Q. 10. Two lithium nuclei in a lithium vapour at room temperature do not combine to form a carbon nucleus because:

(a) Carbon nucleus is an unstable particle

(b) it is not energetically favorable

(c) Nuclei do not come closer due to Coulomb repulsion

(d) Lithium nucleus is more tightly bound than a carbon nucleus

Q. 11. Fusion reaction takes place at high temperature because:

(a) Molecules break up at high temperature

(b) Nuclei break up at high temperature

(c) Atoms gets ionized at high temperature

(d) Kinetic energy is high enough to overcome the Coulomb repulsion between nuclei

Q. 12. Monazite, found in plenty in India , is an ore containing

(a) Plutonium (b) uranium (c) thorium (d) thorium and uranium

Q. 13. Choose the correct statement

(a) Neutron do not interact with matter

(b) A free neutron is an stable as a free proton

(c) The e/m ratio of a charged particles is independent of its speed

(d) charge transfer from one body to another cannot take place without mass transfer

Q. 14. The heavier nuclei tend to have large N/Z ratio because

(a) a neutron is heavier than proton

(b) a neutron is an unstable particle

(c) a neutron does not exert electric repulsion
(d) Coulomb forces have larger range compared to the nuclear forces.

Q. 15. As the mass number A increases, which of the following quantities related to a nucleus do not change?
(a) mass (b) nucleus (c) density (d) binding energy

Q. 16. During a nuclear fusion reaction:
(a) a heavy nucleus breaks into two fragments by itself
(b) a light nucleus bombarded by thermal neutrons breaks up
(c) a heavy nucleus bombarded by thermal neutrons breaks up
(d) two light nuclei combine to give heavier nucleus and possibly other products

Q. 17. Obtain the binding energy in (MeV) of a Nitrogen (nucleus contain 7 proton , 7 neutron) nucleus from the following data in MeV.
m_p= 1.00783 u
m_n =1.00867 u
m_N= 14.00307 u
(a) 7.47MeV/nucleon (b) 104.67MeV/nucleon
(c) 7.8447MeV/nucleon (d) 8.7447MeV/nucleon

Q. 18. The potential energy between two nucleons inside a nucleus is minimum at a distance of about
(a) 0.8fm (b) 1.6 fm (c) 2.0 fm (d) 2.8 fm

Q. 19. The size of atom is proportional to
(a) A (b)$A^{1/3}$ (c)$A^{2/3}$ (d)$A^{-1/3}$

Q. 20. A nucleus is disintegrate in to two nuclear parts, which have their velocities in the ratio 2:1 . The ratio of their nuclear size is:
(a)$2^{1/3}$:1 (b) 1:$3^{1/2}$ (c) $3^{1/2}$:1 (d) 1:$2^{1:3}$

Q.21. The potential energy between two nucleons inside a nucleus is minimum at a distance of about
(a) 0.8 fm (b) 1.6 fm (c) 2.0 fm (d) 2.8 fm

Q.22. The curve of binding energy per nucleon as a function of atomic mass number has a sharp peak for helium nucleus. This implies that helium nucleus is
(a) radioactive (b) unstable
(c) easily fissionable (d) more stable nucleus than its neighbours

Q.23. The atomic number and mass number for a specimen are Z and A respectively. The number of neutrons in the atoms will be
(a) A (b) A (c) A + Z (d) A - Z

Q.24. The quantities, which remain conserved in a nuclear reaction
(a) Total charge (b) Angular momentum (c) Linear momentum (d) All the above

Q.25. The number of neutrons in an atom of $_{90}Th^{230}$
(a) 90 (b) 140 (c) 230 (d) 320

ASSIGNMENT NO. 3

ASSERTION – REASON QUESTIONS

Q. 1. Assertion (A) : Neutrons penetrate matter more readily as compared to Proton.
Reason (R) : Neutron are slightly more massive than Protons.

Q.2 Assertion (A) : Force acting between Proton-Proton (fpp), Proton – Neutron(fpn) and Neutron – Neutron (fnn)are such that fpp<fpn=fnn.
Reason (R) : Electrostatics force of repulsion between two protons reduces net nuclear forces between them.

Q.3 Assertion (A): Mass is not conserved , but mass and energy are conserved as a single entity called mass energy.
Reason (R) : Mass and energy are inter-convertible in accordance with Einstein's relation , $E=mc^2$.

Q.4 Assertion (A) : Thermonuclear fusion reactions may become the sources of unlimited power for the mankind.

Reason (R) : A single fusion event involving isotopes of hydrogen produces more nuclear fission of ^{235}U .

Q.5. Assertion (A) : positive value of packing fraction implies a large value of binding energy.

Reason (R) : The difference between the mass of nucleus and the mass number of the nucleus is called packing fraction.

Q.6. Assertion (A) Nuclear density is very large as compared to ordinary matter.

Reason (R) Nuclear density increases with the increase of mass number.

Q. 7. Assertion (A) The curve between the binding energy per nucleon versus mass number drops at high mass numbers (30 < A<170) as well as at low mass numbers (A <30).

Reason (R) Nuclei with middle mass numbers (30A170) have higher binding energy per nucleon.

Q.8. Assertion (A) Nuclear force between neutron-neutron, proton-neutron and 14 proton-proton is approximately the same.

Reason (R) The nuclear force does not depend on the electric charge.

Q.9. Assertion (A) Higher the binding energy of nucleon, more stable is the nucleus.

Reason (R) The stability of nucleus is determined by the value of its binding energy per nucleon.

Q. 10.Assertion (A) Stable nuclei contain approximately same number of protons and neutrons.

Reason (R) The stability of nucleus is determined by its neutron to proton ratio.

Q.11. Assertion (A) An uncontrolled chain reaction can become highly explosive.

Reason (R) In uncontrolled chain reaction, neutrons released in fission reaction are again and again absorbed by the fissile isotopes.

Q.12. Assertion (A) Naturally, thermonuclear fusion reaction is not possible on earth.

Reason (R) For thermonuclear fusion to take Place, extreme conditions of temperature and pressure are required

Q.13. Assertion (A) Density of all the nuclei is the same

Reason (R) Radius of the nucleus is directly proportional to the cube root of mass number

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Assignment No. 4:
Case-Based Questions

Read the paragraph given below and answer the questions that follow:

CASE STUDY.1.

A student is analyzing the binding energy curve of nuclei. She observes that the binding energy per nucleon varies with the mass number A. She notes that lighter nuclei tend to have lower binding energies per nucleon compared to medium-sized nuclei, while very heavy nuclei again show a decrease in binding energy per nucleon due to the effects of instability.

i) Which of the following statements is true about the binding energy per nucleon for stable nuclei?

A) It increases monotonically with mass number A.

B) It peaks around A≈56 (Iron-56) and then decreases for heavier nuclei.

C) It remains constant for all nuclei regardless of mass number.

D) It is highest for very light nuclei such as helium.

ii) What is the significance of the binding energy of a nucleus?

A) It determines the mass of the nucleus.

B) It indicates the stability of the nucleus; higher binding energy means greater stability.

C) It represents the total energy of the nucleus.

D) It is the energy required to create the nucleus from free nucleons.

iii) According to the binding energy curve, which of the following elements would be expected to be the most stable?

A) Hydrogen (H) B) Iron (Fe) C) Uranium (U) D) Lithium (Li)

iv) When a heavy nucleus undergoes fission, what happens to the total binding energy?

A) It decreases. B) It remains constant. C) It increases. D) It becomes negative.

CASE STUDY. 2.

The nucleus is composed of protons and neutrons. The mass of a nucleus is always less than the sum of the individual masses of its constituent protons and neutrons. This difference in mass is called the mass defect . and is converted into energy, which holds the nucleus together. This is known as nuclear binding energy . The binding energy per nucleon is a crucial indicator of nuclear stability; elements with a higher binding energy per nucleon are more stable. The curve of binding energy per nucleon peaks around (A approx 56) (Iron). Beyond this, heavy nuclei become unstable and can undergo nuclear fission to become more stable.

Questions:

1. What is meant by mass defect? Express it mathematically.
2. If the mass of a proton is m_P, the mass of a neutron is m_N and the mass of a nucleus $M_{NUCLEUS}$. what is the formula for binding energy?
3. What does a higher value of binding energy per nucleon signify?
4. Why do heavy nuclei (A > 200) tend to undergo nuclear fission?

   OR
5. Two lighter nuclei (A < 10) join together to form a relatively heavier nucleus. In this specific process (Nuclear Fusion):
   (A) Binding energy per nucleon decreases, and energy is absorbed.
   (B) Binding energy per nucleon increases, and energy is released.
   (C) Mass defect becomes zero.
   (D) Total number of nucleons changes.

CASE STUDY.3.

Neutrons and protons are identical particle in the sense that their masses are nearly the same and the force, called nuclear force, does into distinguish them. Nuclear force is the strongest force. Stability of nucleus is determined by the neutron proton ratio or mass defect or packing fraction. Shape of nucleus is calculated by quadrupole moment and spin of nucleus depends on even and odd mass number. Volume of nucleus depends on the mass number. Whole mass of the atom (nearly 99%) is centered at the nucleus.

1. **The correct statements about the nuclear force is/are**
   (a) charge independent
   (b) short range force
   (c) non-conservative force
   (d) all of these.
2. **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
3. **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
4. **Two protons are kept at a separation of 40 A^0. F_n is the nuclear force and F_e is the electrostatic force between them. Then**
   (a) $F_n << F_e$

(b) $F_n = F_e$
(c) $F_n >> F_e$
(d) $F_n \approx F_e$

OR

5. All the nucleons in an atom are held by
(a) Nuclear force
(b) vander waal's forces
(c) tensor forces
(d) coulomb forces

CASE STUDY 4.
The nucleus was first discovered in 1911 by Lord Rutherford and his associates by experiments on scattering of a-particles by atoms. He found
that the scattering results could be explained, if atoms consists of a small, central, massive and positive core surrounded by orbiting electrons. The experimental results indicated that the size of the nucleus is of the order of 10-14 in and is thus 10000 times smaller than the size of atom.
1. The ratio of mass of nucleus with mass of atom is approximately
a) 1 (b) 10 (c) 10^3 (d) 10^{10}
2. if R is radius and A is mass number, then, the graph between log R and log A will be
a) a straight line (b) a parabola (c) an ellipse (d) None of these
3. The masses of hydrogen, deuterium and tritium are in the ratio -
a) 1 : 2 : 3 (b) 1 : 1 : 1 (c) 1 : 1 : 2 (d) 1 : 2 : 4
4. The ratio of gold isotope silver isotope ${}_{79}Ag^{197}$ and gold isotope ${}^{107}{}_{47}Au$
a) 1.23 (b) 0.216 (c) 2.13 (d) 3.46

CASE STUDY 5.
In the year 1939 German scientist auto Haar and stress man discovered that when an uranium isotope was bombarded with a neutron It Breaks into two intermittent mass fragment it was observed that the sum of the masses of new fragments formed were less than the mass of the original nuclei this difference in the mass appeared as the energy released in the process does the phenomenon of splitting of a heavy nucleus usually A> 230 into two or more lighter nuclei by the bombardment of proton, neutron, alpha particle etc with liberation of energy is called Nuclear Fission reaction resulting from the absorption of neutron is known as induced fission

1. Fission of nucleus is possible because the binding energy per nucleon in them
a) increases with mass number at high mass numbers
b) decreases with mass number at high mass numbers
c) increases with mass number at low mass numbers
d) decreases with mass number at low mass number
2. For sustaining the nuclear fission chain reaction in a sample of small size of Uranium 235 it is desirable to slow down fast neutrons by
a) friction
b) elastic damping/scattering
c) absorption
d) None of the above
3. If A nucleus with mass number A =240 with binding energy equal to 7.6 MeV breaks into two fragments of A= 120 and binding energy =8.5 MeV then released energy is around
a)216 MeV
b) 200 MeV
c) 100 MeV
d) cannot be estimated from given data
4. In any fission process ratio of mass of daughter nucleus to mass of parent nucleus is
a) less than 1 b) greater than 1 c) equal to 1 d) depends on the mass of parent nucleus

CASE STUDY 6.

Nuclear Holocaust: A nuclear holocaust, nuclear apocalypse or atomic holocaust is a theoretical scenario where the mass detonation of nuclear weapons causes globally widespread destruction and radioactive fall out. Under such scenario, large parts of the earth are made uninhabitable by nuclear warfare, potentially causing the collapse of civilization. In a single uranium fission about 0.9 * 235 MeV (≈ 200 MeV) of energy is liberated. If each nucleus of about 50 kg of ${}_{92}U^{235}$ undergoes fission, the amount of energy involved is about 4 * 10^15 J. This energy is equivalent to about 20,000 tons of TNT, enough for a super explosion. Uncontrolled release of large nuclear energy is called an atomic explosion.

In a nuclear reactor, moderators slow down the neutrons which comes out in a fission process.

1. The Moderator used, have light nuclei. Heavy nuclei will not serve the purpose because
(a) substance with heavy nuclei do not occur in liquid or gaseous state at room temperature
(b) the net weight of the reaction would be unbearably high
(c) elastic collision of neutrons with heavy nuclei will not slow down the neutrons
(d) they will break up

2. In an atomic bomb, the energy is released due to
(a) chain reaction of neutrons and ${}_{92}U^{240}$
(c) chain reaction of neutrons and ${}_{92}U^{236}$
(b) chain reaction of neutrons and ${}_{92}U^{238}$
(d) chain reaction of neutrons and ${}_{92}U^{235}$

3. Energy released in nuclear fission is due to
(a) total binding energy of fragments is more than the binding energy of parental element
(b) total binding energy of fragments is less than the binding energy of parental element
(c) total binding energy of fragments is equal to the binding energy of parental element
(d) some mass is converted into energy

4. Solar energy is mainly caused due to
(a) gravitational contraction
(c) fission of uranium present in the sun
(b) fusion of proton during synthesis of heavier e
(d) burning of hydrogen in the oxygen

CASE STUDY 7.

Nuclear forces are the strong forces of attraction which hold together the nucleons (neutrons and protons) in the tiny nucleus of atom, inspite of strong electrostatic forces of repulsion between protons. Nuclear force is strongest force. It is 100 times that of electrostatic forces and 103 times that of gravitational forces between nucleons. It is independent of charge, short range, non-conservative force and not obeying inverse-square law.

(i) If the nuclear force between two neutrons is F, then what will be the nuclear force between a proton and a neutron?
(ii) If the electrostatic force between nucleons is F. then what is the nuclear force of nucleons?
(iii) Out of nuclear force, electrostatic force and gravitational force, which one is not obeying inverse-square law.
(iv) Which force is responsible to hold all the nucleons in an atom?

****

ASSIGNMENT NO. 5
SHORT ANSWER QUESTIONS

Q. 1 What do you mean by Nuclear Fission and Fusion reaction?

Q. 2 Write three characteristic properties of nuclear force.

Q. 3 Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions that can be drawn from the graph.

Q. 4 What is nuclear fission? Explain how a chain reaction can occur in a fissionable material?

Q. 5 A chain reaction dies out sometimes. Why?

Q. 6 How is the size of a nucleus estimated? Write the relation between the radius of a nucleus and its mass number

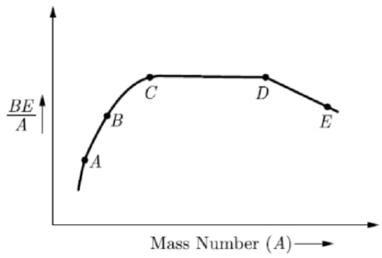
Q. 7 (i)Why is the binding energy per nucleon found to be constant for nuclei in the range of mass

(ii) When a heavy nucleus with mass number A = 240 breaks into two nuclei, A = 120, energy is released in the process.

Q. 8 (i) What characteristic property of nuclear force explains the constancy of binding energy per nucleon (BE/A) in the range of mass number A lying between 30 and 170?

(ii) Show that the density of nucleus over a wide range of nuclei is constant independent of mass number A.

Q. 9 (i) The figure shows the plot of binding energy (BE) per nucleon as a function of mass number A. The letters A,B,C,D and E represent the positions of typical nuclei on the curve. Point out, giving reasons, the two process (in terms of A,B,C,D and E), one of which can occur due to nuclear fission and the other due to nuclear fusion.



(ii) Identify the nature of the radioactive radiations emitted in each step of the decay .

Q. 10 (a) In the following nuclear reaction assign the values of Z and A.

${}_{Z}X^{A}$------------${}_{Z-2}Y^{A-2}$ ----${}_{Z-1}W^{A-4}$

(b) If both the number of protons and the number of neutrons are conserved in each nuclear reaction, in what way is the mass converted into energy? Explain.

LONG ANSWER QUESTIONS

Q. 1. Give reason for :

(a) Lighter elements are better moderators for a nuclear reactor than heavier elements.

(b) In a natural uranium reactor, heavy water is preferred moderator as compared to ordinary water.

(c) Cadmium rods are provided in a reactor.

(d) Very high temperature as those obtained in the interior of the sun are required for fusion reaction

Q. 2. Define the term binding energy. The binding energy of a nucleus ${}^{A}X_{Z}$ is given by the formula: B.E.=$[Zm_H+(A-Z)m_N-m({}_{Z}X^{A})]C^2$

Where, $m({}_{Z}X^{A})$ is the atomic mass of X . Derive this equation, state clearly the Approximation involved and say it is very safe approximation.

Q. 3(a) Calculate the binding energy of an α -particle in MeV.

Given,

mp (mass of proton) = 1.007825 amu

mn (mass of neutron) = 1.008665 amu

Mass of He nucleus = 4.002800 amu

1 amu = 931MeV

3 (b). Atomic weight of boron is 10.81 and it has two isotopes ${}_{5}B^{10}$ and ${}_{5}B^{11}$. What is the ratio of atomic weights of ${}_{5}B^{10}$ to ${}_{5}B^{11}$

****

MARKING SCHEME

SSIGNMENT - 1

Question paper

Q.NO.

MCQ

1- C

2- D

3- B

4- B

5- A

6- B

7- D

8- C

9 B

10 A

11 B

12 D

13 C

14 A

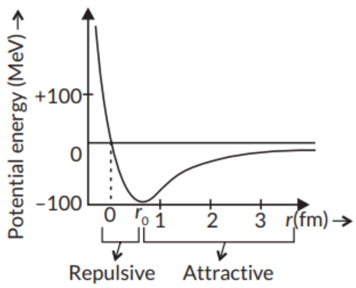
15 A

16 B

VERY SHORT ANSWER QUESTION

17 R2 :R1 = [A2/A1]⅓ Hence R2 = 6 fm
The nuclear radius of Fe is = **6 fm** , as calculated using the empirical relationship between a nucleus's radius and its atomic mass number.

18. The potential energy (U) between two nucleons varies with their separation distance (r) in femtometers (fm) as shown below.



(i) For distance less than 0.8 fm negative PE decreases to zero and then becomes positive

(ii) for distance larger than 0.8 fm negative PE goes on decreasing

19. From the plot, we can conclude that, a very heavy nucleus A = 240 has lower E(bn) compared to that of a nucleus with A = 120 Thus, if a nucleus A = 240 breaks into two A = 120 nuclei, nucleons get more tightly bound. Energy would be released in this process which is known as nuclear fission. Also, when two light nuclei ($A \leq 10$) join to form a heavier nucleus, E_n of fused heavier nuclei is more than the E(bn) of lighter nuclei. Energy would be released in this process, which is known as nuclear fusion.

20 The radius (R) of nucleus of an atom depends on the mass number (A) as $R=R_oA^{1/3}$, where Ro is constant for all nuclei

The ratio of the radii of the two nuclei is **3:4.**

21. Nuclear matter is approximately **2.31 x 10 ^{14} times** denser than water

22. No. of protons = 20

No. of neutrons = 20

B.E. = 341.873441 MeV

B.E. per nucleon = 341.873441 / 40 = 8.547 MeV

23. According to the question fusion reaction is given as ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + n + 3.27$.MeV Energy released in fusion of two deuterium atoms + 3.27 MeV

No. of atoms present in 2 kg of deuterium = $6 \times 10^{23} \times 10^3 = 6 \times 10^{26}$

The total energy E generated by all reactions is:

E(total)=n E reaction

The 100W electric lamp can be kept glowing for **1.58 x 10^{12} seconds**

24. As the daughter nucleus is a heavier nucleus as compared to the parent nuclei, which are more stable than lighter nuclei, hence daughter nucleus has more binding energy per nucleon than parent nuclei.

25. Differences between Nuclear Fission and Nuclear Fusion

a. Fission is the splitting of large nucleus into two or more smaller ones, on the other hand, fusion is the combining of two or more lighter nuclei to form a heavier more stable nucleus.

b. Fission does not normally occur in nature but fusion occurs in stars such as the sun.

c. Fission requires critical mass of the substance and high speed neutrons but in fusion, high density and high temperature environment are required.

d. Uranium is the primary fuel for fission reaction and hydrogen isotopes are the primary fuel in nuclear fusion reaction.

e. In fission, energy released is million times greater than in chemical reactions, but lower than energy released by nuclear fusion.

26. (i) The size of a atomic nucleus is found experimentally using **Rutherford's alpha-particle scattering experiment** or high-energy **electron scattering experiments**

(ii) Density of nucleus is independent of mass number as-

27. MASS DEFECT = MASS OF PROTONS + MASS OF NEUTRONS

- MASS OF HELIUM NUCLEUS

Mass defect = 2 x 1.007825 + 2 x 1.008665 - 4.002800 u = 0.03018 u

B.E. = 0.03018 x 931MeV

28. The sum of masses of nuclei of product element is less than sum of masses of reactants and hence loss of mass takes place during the reaction this difference of mass of product element and reactant gets converted into energy and is liberated in the form of heat here sum of masses of $_{10}Ne^{20}$ and $_{2}He^{4}$ less than the sum of two C-12 and conversion of this Mass defect is used to produce energy

CASE BASED QUESTIONS

29. (i) C

(ii) C

(iii)A

(iv) C

30. (i) The ratio of the mass of a nucleus to the mass of its atom is **approximately 1.**

(ii) plot between R and log A.

(iii) The mass ratio of hydrogen (protium), deuterium, and tritium is approximately **1:2:3**. This is because each isotope shares the same number of protons . (1) but increases in mass as neutrons are added:

(iv) Isotones are atoms of different elements that have the same number of neutrons but different numbers of protons.

LONG ANSWER QUESTION

31. "Q-value here refer to the energy released in the nuclear process, which can be determined using Einstein's mass-energy relation, $E = mc^2$.

The Q-value is equal to the difference of mass of products and reactants multiplied by square of velocity of light. The Energy released per fission of ${}^{235}_{92}U$ is 200.4 MeV. The fragment nuclei produced in fission are highly unstable. They are highly radioactive and emit ß-particles in succession until each reaches to a stable end product.

In fact the number of protons and number of neutrons are same before and after nuclear reaction, but the binding energies of nuclei present before and after a nuclear reaction are different. This difference is called mass defect. This mass defect appears as energy of reaction. In this sense, a nuclear reaction is an example of mass-energy inter conversion"

32. (a) When nucleons approach each other to form a nucleus, they strongly attract each other. Their potential energy decreases and becomes negative. It is this potential energy which holds the nucleons together in the nucleus. The decrease in' potential energy results in the decrease in the mass of the nucleons inside the nucleus.
(b) plot

33(i) In sun, 4 hydrogen nuclei fuse to form a helium nucleus with release of 26 MeV energy.
(ii) The complete fission of 1 kg of Uranium-235 releases a massive **8.2×10^{13}** J

ASSIGNMENT - 2 – MCQs

1. (c) (1 : 8)
2. (b) 5.4 Mev

3. (c) 5.6 MeV

4. (a) 23.6 MeV

5. (d) 2×10^{16} gm

6. (d) 10^{18}

7. (c) 0.7%

8. (C) 10.24 Me V

9. (d) 2x10 $^{-9}$g/h

10. (c) Nuclei do not come closer due to Coulomb repulsion

11. (c) Atoms gets ionized at high temperature

12. (d) thorium and uranium

13. (d) charge transfer from one body to another cannot take place without mass transfer

14. (d) Coulomb forces have larger range compared to the nuclear forces.

15. (c) density

16. (d) two light nuclei combine to give heavier nucleus and possibly other products

17.(a)7.47MeV/nucleon

18. (a) 0.8fm

19. (b)$A^{1/3}$

20. (d)$1:2^{1:3}$
21.(a)

22.(d) 23.(d) 24.(d) 25.(b)

ASSIGNMENT -3

ASSERTION-REASON

- ANSWER 1
- **Assertion (A):** Neutrons penetrate matter more readily compared to protons. (**True**)
  - Explanation*:* Neutrons are electrically neutral, meaning they do not experience electrostatic repulsion or attraction when passing near atomic nuclei or electrons. This allows them to penetrate deeply into matter.
- **Reason (R):** Neutrons are slightly more massive than protons. (**True**)

- **Conclusion:** Both statements are true, but the high penetration power is due to the neutron's lack of charge, not its mass difference.
- **Correct Option: (b)**

ANSWER 2.

- **Assertion (A): (True)**
  - *Explanation:* The strong nuclear force itself is charge-independent However, protons also experience a repulsive electrostatic force, which reduces the total net attractive force between them.
- **Reason (R):** Electrostatic force of repulsion between two protons reduces net nuclear forces between them. (**True**)
  - *Explanation:* This perfectly explains why the net attractive force between two protons is smaller.
- **Correct Option: (a)**

ANSWER 3.

- **Assertion (A):** Mass is not conserved, but mass and energy are conserved as a single entity called mass-energy. (**True**)
  - *Explanation:* In nuclear processes, some mass is converted into energy (known as mass defect), meaning mass alone is not conserved, but total mass-energy is.
- **Reason (R):** Mass and energy are inter-convertible in accordance with Einstein's relation, $E=Mc^2$ (**True**)
  - *Explanation:* This equation defines the exact conversion mechanism supporting the assertion.
- **Correct Option: (a)**

ANSWER 4

- **Assertion (A):** Thermonuclear fusion reactions may become the sources of unlimited power for mankind. (**True**)
  - *Explanation:* Nuclear fusion uses abundant light isotopes (like Hydrogen from water) and produces immense energy with minimal long-term radioactive waste.
- **Reason (R):** A single fusion event involving isotopes of hydrogen produces more nuclear fission... (**False**)
  - *Explanation:* A single fission event of a heavy nucleus like U^{235} releases roughly (approx 200 MeV), while a single D-T fusion event releases (approx 17.6 MeV). Fusion yields more energy *per unit mass* (per nucleon), but not per single atomic event.
- **Correct Option: (c)**

ANSWER 5

- **Assertion (A):** A positive value of packing fraction implies a large value of binding energy. (**False**)
  - *Explanation:* A positive packing fraction indicates that the isotopic mass (M) is greater than the mass number (A). This signifies a less stable nucleus with a **lower** binding energy per nucleon.
- **Correct Option: (d)**

ANSWER 6 Correct option : (c)

ANSWER 7. Correct option : (b)

ANSWER 8. Correct option : (a)

ANSWER 9. Correct option : (a)

ANSWER 10. Correct option : (a)

ANSWER 11. Correct option : (a)

ANSWER 12. Correct option: (a)

ANSWER 13.. Correct option: (b)

ASSIGNMENT -4 CASE BASED QUESTIONS

CASE STUDY 1. ANSWER KEY

Question 1 (i)

Answer: B) It peaks around A≈56 (Iron-56) and then decreases for heavier nuclei.

Explanation: The binding energy per nucleon curve increases sharply for light nuclei, reaches a maximum value of about (8.8 MeV) at Iron , and then gradually drops for heavier elements.

Question 1 (ii)

Answer: B) It indicates the stability of the nucleus; higher binding energy means greater stability.

Explanation: Binding energy measures how tightly nucleons are held together. A larger binding energy value means more energy is required to break the nucleus apart, signifying high stability.

Question 1 (iii)

Answer: B) Iron (Fe)

Explanation: Iron Fe sits at the absolute peak of the binding energy curve. This gives it the highest binding energy per nucleon among all elements, making it exceptionally stable.

Question 1 (iv)

Answer: C) It increases.

Explanation for Fission: Heavy nuclei have lower binding energy per nucleon. When they split into medium-sized nuclei, the product nuclei sit higher on the curve. This means they are more tightly bound, causing the total binding energy to **increase** and release energy.
OR
Answer for Fusion: C) It increases.
Explanation for Fusion: Very light nuclei have low binding energy per nucleon. When they fuse to form a heavier, more stable nucleus, the nucleons move to a higher position on the curve, resulting in an **increase** in total binding energy.

CASE STUDY 2. Answers/Explanations:

1. Mass defect is the difference between the rest mass of a nucleus and the sum of the rest masses of its constituent nucleons. Formula: $\Delta m =\{ [Z\, m_P + (A-Z)\, m_N] – M_{NUCLEUS})\}$

2. Binding Energy (BE) = $([Z\, m_P + (A-Z)\, m_N - M]c^2)$.

3. A higher **binding energy per nucleon** represents greater nuclear stability. It means more energy is required to pull the nucleons apart.

4. Heavy nuclei tend to undergo fission to split into smaller, more stable fragments. This is because lighter nuclei have a higher binding energy per nucleon than heavier ones, releasing energy in the process (getting closer to the peak of the binding energy.

5. (B) Binding energy per nucleon increases, and energy is released.

CASE STUDY NO.3 ANSWER KEY

(i) d
Explanation: All options are basic properties of nuclear forces. So, all options are correct.
(ii) d
Explanation: The nuclear force is of short range and the range of nuclear force is the order of 1.4×10^{-14}m.Now, volume α R^3 α A
(iii) d (iv) a (v) a

CASE BASED QUESTION - 4

(i) a (ii) a (iii) a (iv) a

CASE BASED QUESTION - 5

(i) b (ii) b (iii) d (iv) a

CASE BASED QUESTION - 6

(i) c (ii) d (iii) a (iv) (c)

CASE BASED QUESTION - 7

i) The nuclear force acting between a pair of neutrons, a pair of protons and also between a neutron-proton pair will be of same strength.

If nuclear force between two neutrons = F

Then , Nuclear force between a proton and a neutron = F

(ii) If electrostatic force between nucleons = Fe.

Then, Nuclear force between nucleons = 100 Fe

(iii)The nuclear force does not obey the inverse square law.

(iv) The strong nuclear force is responsible to hold all the nucleons in an atom.

ANSWER KEY ASSIGNMENT 5.

SHORT ANSWER

1 The phenomenon of splitting of heavy nuclei (mass number > 120) into smaller nuclei of nearly equal masses is known as nuclear fission. In nuclear fission, the sum of the masses of the product is less than the sum of masses of the reactants. This difference of mass gets converted into energy $E = mc^2$ and hence ample amount of energy is released in a nuclear fission

2 Characteristic properties of nuclear force are as follows :

(i) Nuclear force act between a pair of neutrons, a pair of protons and also between a neutron-proton pair, with the same strength. This shows that nuclear forces are independent of charge.

(ii) The nuclear forces are dependent on spin or angular momentum of nuclei.

(iii) Nuclear forces are non-central forces. This shows that the distribution of nucleons in a nucleus is not spherically symmetric.

3 **correct plot ,**From the plot, it is concluded that

(i) The potential energy is minimum at a distance r0(= 0.8 fm) which means that the force is attractive for distance larger than 0.8 fm and repulsive for the distance less than 0.8 fm between the nucleons.

(ii) Nuclear forces are negligible when the distances between the nucleons is more than 10 fm.

4. Nuclear fission is a peculiar type of reaction which, besides the other fission products, produces the same kind of particles that initiate it, viz., neutrons. When a single $_{92}U^{235}$ nucleus captures a neutron, its fission produces neutrons. These freshly produced neutrons can further cause the fission of more uranium nuclei, producing still more neutrons, which can further cause the fission of a larger number of nuclei and so on. The

number of fissions taking place at each successive stage goes on increasing at a rapid rate (rather in a geometric progression).

5. A chain reaction may die out due to any of the following causes:

1. Excessive neutron leakage if the size of the fissionable material is smaller than the critical size

2. Fast neutrons may escape the fissionable material without causing further fissions.

3. Some neutrons may suffer non-fission capture by ${}_{92}U^{238}$ nuclei.

6. A nucleus can be considered to be spherical in shape. By performing scattering experiments using high energy electrons, we can determine its radius accurately. Experimental observations show that the volume of a nucleus is directly proportional to its mass number. If R is the radius of a nucleus having mass number A, then

Thus, the radius R of a nucleus is proportional to the cube root of its mass number. The value of constant R_0 depends on the nature of probe particles

7. (i). The binding energy per nucleon for nucleus of range, 30 < A < 170 is close to its maximum value. So, the nucleus belongs to this region is highly stable and does not show radioactivity.
(ii). Binding energy per nucleon is smaller for heavier nuclei than the middle ones, i.e.,heavier nuclei are less stable. When a heavier nucleus such as nucleus of mass number 240 splits into lighter nuclei (mass number 120), the BE/nucleon changes from 7.6MeV to 8.4MeV. Greater BE of the product nuclei result in the liberation of energy.

8.(i) The saturation property of nuclear forces explains the constancy of binding energy per nucleon (BE/A) for mass numbers between 30 and 170.

(ii) The **nuclear density is constant and entirely independent of the mass number A** because both the mass and the volume of a nucleus scale linearly with \(A\), canceling each other out during division.

9. (i) Nuclear fission of E to D and C ; as there is an increase in binding energy per nucleon. Nucleon fusion of A and B into C ; as there is an increase in binding energy per nucleon.

10. Mass number of the reactant and product nuclides are same but there is an actual mass defect. This difference in the total mass of the nuclei on both sides gets converted into energy, i.e.,

▲E =mc²

ANSWER KEY : LONG ANSWER.

Q.1 (a) A good moderator has two properties. It slows down neutrons by elastic collision and it dose not remove them form the core by absorbing them. That is why ligther elements are better moderators.

(b) Heavy water is used in reactors using natural uranium as fuel. This is becuase it has lesser absorption probability of neutrons than ordinary water.

(C) Cadmium rods have a high cross section for neutron ansorption. They are used for controlling the nuclear chanin reaction responsible for producing nuclear energy.

(d) for fusion reactions, very high temperatures are required. It enables protons to have enough kinetic energy and overcome their mutual electrostatic repulsion and come closer than the range of nuclear forces of attraction.

Q.2. Binding energy is the minimum energy required to completely disassemble a nucleus into its individual protons and neutrons. It represents the energy equivalent of the mass lost when nucleons bind together.

Derivation of the Formula

Mass Defect: A stable nucleus weighs less than its isolated parts. This difference is mass defect.

Nuclear Equation: .B.E.=$[Zm_H+(A-Z)m_N-m(_ZX^A)]C^2$

Q.3. (a) Calculation of The binding energy of the alpha-particle is **28.098 MeV**

(b) Let the percentage of $5B^{10}$ be x%.
Therefore, the percentage of $5B^{11}$ will be (100 - x)%

Set up the average atomic weight formula**:**
Average Atomic eigh}={(10x)+((100-x)x11) /100

· Substitute the given average weight (10.81)**:**
10.81={10x+1100-11x}{100}

· Solve for :x

1081=1100-x, x=19%

$5B^{10}$ =19% and $5B^{11}$=81%

****

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c.Nuclear forces are non-central forces. This shows that the distribution of nucleons in a nucleus is not spherically symmetric.

(iv) correct plot

From the plot, it is concluded that

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8-

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CHAPTER 14: SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS

CASE STUDY BASED QUESTIONS

QUESTION 1

SEMICONDUCTOR - A pure semiconductor germanium or silicon, free of every impurity is called intrinsic semiconductor. At room temperature, a pure semiconductor has very small number of current carriers (electrons and holes) .Hence its conductivity is low. When the impurity atoms of valance five or three are doped in a pure semiconductor, we get respectively n-type or p- type extrinsic semiconductor. Where ne and n_h are the number density of electron and hole charge carriers in a pure semiconductor. The conductivity of extrinsic semiconductor is much higher than that of intrinsic semiconductor.

Answer the following questions:

Q (1). Which of the following statements is not true?

a. The resistance of intrinsic semiconductor decreases with increase of temperature.
b. Doping pure Si with trivalent impurities gives p- type semiconductors.
c. The majority charges in n- type semiconductors are holes.
d. A p-n junction can act as semiconductor diode.

Q (2). The impurity atoms with which pure Si should be doped to make a p- type semiconductor is

a Phosphorus b Boron c arsenic d Antimony

Q (3). Holes are majority charge carriers in

a intrinsic semiconductor b ionic solid c p-type semiconductor d metals

Q (4). At absolute zero, Si acts as

a Non- metals b Metals c Insulators d None of these.

QUESTION 2

PN JUNCTION – p-n junction is a semiconductor diode. It is obtained by bringing p-type semiconductor in close contact with n- type semiconductor. A thin layer is developed at the p- n junction which is devoid of any charge carrier but has immobile ions. It is called depletion layer. At the junction a potential barrier appears which does not allow the movement of majority charge carriers across the junction in the absence of any biasing of the junction. p-n junction offers low resistance when forward biased and high resistance when reverse biased.

Q (1). In the middle of depletion layer of reverse biased p- n junction, the

a electric field is zero

b potential is zero

c electric field is maximum

d potential is maximum

Q(2).The energy band gap is maximum in

a. Metals

b. Superconductors

c. Insulators

d. Semiconductors

QUESTION 3

Rectifiers: A semiconductor device is used as a rectifier that allows the voltage to flow in positive direction and very small value in the reverse direction. Now days, there is a problem of supply of less voltage that damages the household appliances.

Q (1). In the depletion region of a diode which is wrong

a. There are no mobile charges

b. Recombination of holes and electrons has taken place.

c. Immobile charge ion exist.

d. None of these

Q(2).When a p-n junction diode is reverse biased then

a. No Current flows

b. The depletion region is increased

c. The depletion reason is reduced

d. Height of potential barrier is reduced

Q(3). Diode is used as

a. Oscillator

b. Amplifier

c. Rectifier

d. Modulator

Q(4).Which one statement is incorrect?

a. Diode is used as rectifier

b. Diode is used as half wave rectifier

c. Diode is used as Amplifier

d. Diode is used as full wave rectifier

Assignment -2

1. If the conductivity of a semiconductor is only due to break of the covalent band due to the thermal excitation, then the semiconductor is called:
   (a) intrinsic
   (b) extrinsic
   (c) Acceptor
   (d) none of these
2. The conductivity of semiconductors like Ge and Si:
   (a) increases when it is doped with pentavalent impurity.
   (b) increases when it is doped with trivalent impurity.
   (c) increases when it is doped with pentavalent or trivalent impurity.
   (d) none
3. Which of following statements is not true?
   (a) Resistance of an intrinsic semiconductor decreases with increase in temperature.
   (b) Doping pure Si with trivalent impurities gives p-type semiconductor.
   (c) The majority carriers in n-type semiconductor are holes.
   (d) A p-n junction can act as semiconductor diode.
4. Ge. is doped with As due to doping (2024)
   (a) The structure of Ge. Lattice is distorted.
   (b) The number of conduction of electrons is increased
   (c) The number of holes increase
   (d) The number of conduction electrons is decreased
5. The impurity atoms with which pure silicon may be doped to make it a p-type semiconductor are those of
   (a) phosphorus (b) boron (c) antimony (d) nitrogen
6. The electrical conductivity of pure germanium can be increased by
   (a) increasing the temperature
   (b) doping acceptor impurities
   (c) doping donor impurities
   (d) All of the above
7. The resistivity of a semiconductor at room temperature is in between
   (a) 10^{-2} to 10^{-5} Ω cm (b) 10^{-3} to 10^{6} Ω cm (c) 10^{6} to 10^{8} Ω cm (d) 10^{10} to 10^{12} Ω cm
8. Number of electrons in the valence shell of a pure semiconductor is
   (a) 1 (b) 2 (c) 3 (d) 4
9. In a semiconductor, the forbidden energy gap between the valence band and the conduction band is of the order is
   (a) 1 MeV (b) 0.1 Mev (c) 1 eV (d) 5 Ev
10. The forbidden energy gap for germanium crystal at 0 K is
    (a) 0.071 eV (b) 0.71 eV (c) 2.57 eV (d) 6.57 eV
11. In an insulator, the forbidden energy gap between the valence band and conduction band is of the order of
    (a) 1 MeV (b) 0.1 MeV (c) 1 eV (d) 5 eV
12. In an n-type semiconductor, which of the following statements is true?
    a. Electrons are majority carriers and trivalent atoms are the dopants
    b. Electrons are minority carriers and pentavalent atoms are the dopants
    c. Holes are minority carriers and pentavalent atoms are the dopants
    d. Holes are majority carriers and trivalent atoms are the dopants.
13. In an unbiased p-n junction, holes diffuse from the p-region to n-region because:
    a. free electrons in the n-region attract them
    b. they move across the junction by the potential difference

c. hole concentration in p-region is more as compared to n-region
d. All of the above

14. When a p-n junction diode is forward biased:
 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.
15. When a p-n junction diode is subjected to reverse biasing:
 a. the barrier height decreases and the depletion region widens.
 b. the barrier height increases and the depletion region widens.
 c. the barrier height decreases and the depletion regions shrinks.
 d. the barrier height increases and the depletion region shrinks.
16. When the resistance measured between p and n ends of a p-n junction diode is high, it can act as a/an:
 a. resistor b. inductor c. capacitor d. switch
 ANSWER - A p-n junction diode exhibits different resistance characteristics depending on its biasing. When the resistance measured between the p and n ends of a p-n junction diode is high, it indicates that the diode is in a state where it significantly opposes the flow of current. This high resistance state is characteristic of a reverse-biased diode, where a large depletion region is formed, effectively blocking current flow. In this condition, the diode behaves like an open circuit, which is the fundamental characteristic of a switch in its "off" position.

17. Potential barrier developed in a junction diode opposes the flow of:
 a. minority carrier in both regions
 b. majority carriers only
 c. electrons in p-region
 d. holes in p-region
18. Which of the following statement is incorrect for the depletion region of a diode?
 a. There the mobile charges exist.
 b. Equal number of holes and electrons exist, making the region neutral.
 c. Recombination of holes and electrons has taken place.
 d. None of the above
19. If a p-n junction diode is reverse biased:
 a. the potential barrier is lowered
 b. the potential barrier remains unaffected
 c. the potential barrier is raised
 d. the current is mainly due to majority carriers
20. Rectifier is used to:
 a. convert AC voltage to DC voltage
 b. convert DC voltage to AC voltage
 c. convert high voltage to low voltage
 d. All of the above

Assignment- 3

Assertion and Reason

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 (A):** Electron has higher mobility than hole in a semiconductor.
 Reason (R): Mass of electron is less than the mass of hole.
 Answer – (a). Explanation the ratio of the velocity of the applied field is called the mobility. Science electron is higher than holes. They move faster in applied field than holes.
2. **Assertion (A):** In a semiconductor diode the thickness of depletion layer is not fixed.

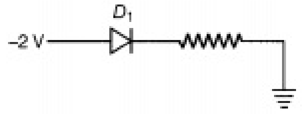
Reason (R): Thickness of depletion layer in a semiconductor device depends upon many factors such as biasing of the semiconductor.
Answer – (a)

3. **Assertion (A):** In a semiconductor, the electrons in the conduction band have lesser energy than those in the valence band.
Reason (R): Donor energy level is just above the valence band in a semiconductor.
Answer – (d) In a semiconductor, the electrons in the conduction band have higher energy than those the valence band, which is why they are free to move and conduct electricity. The donor energy level is just below the conduction band, not above the valence band. Donor levels donate electrons to the conduction band, enhancing conductivity.
4. **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.
Reason (R): In a p-type semiconductor, n >> n while in a n-type semiconductor, n_2 <<n
(CBSE 2025)
Answer - (c) A p-n junction diode cannot be formed just by joining p-type and n-type semiconductors physically due to lack of diffusion and formation of a depletion region. In a p-type semiconductor n >> n, while in a n-type semiconductor n_2>> n
5. **Assertion :** A pure semiconductor has negative temperature coefficient of resistance.
Reason : In a semiconductor on raising the temperature, more charge carriers are released, conductance increases and resistance decreases.
Answer- (a) In semiconductors, by increasing temperature, covalent bond breaks and conduction hole and electrons increase.
6. **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. R (CBSE 2023)
Answer -(a)
7. **Assertion (A):** Putting p-type semiconductor slab directly in physical contact with n-type semiconductor slab cannot form the p-n junction. Reason (R): The roughness at contact will be much more than interatomic crystal spacing and continuous flow of charge carriers is not possible. R (CBSE SOP 2023-24)
Answer -(a)
8. **Assertion (A):** The half wave rectifier work only for positive half cycle of AC.
Reason (R): In half wave rectifier, only one diode is used. R
Answer -(a) in half wave rectifier, only one diode is used. Diode is biased only when AC is in positive half cycle. For negative half AC cycle, the diode is reversed biased and there is no output corresponding to that. Since for only one-half cycle, we get a voltage output, because of which it is called half wave rectifier.

Assignment- 4

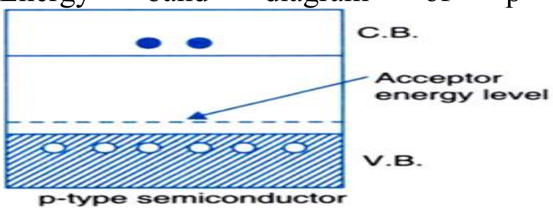
SHORT ANSWER QUESTIONS

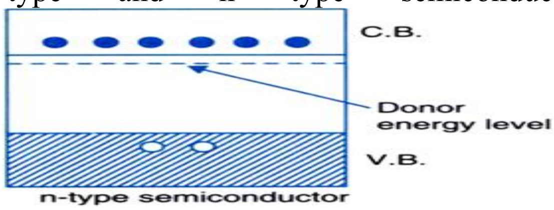
1. Write the difference between intrinsic and extrinsic semiconductors.
2. What are the limitations of intrinsic semiconductor when we use them for developing semiconductor devices?
3. How does the forbidden energy gap of an intrinsic semiconductor vary with increase in temperature??
4. What is meant by the term doping of an intrinsic semiconductor? How does it affect the conductivity of a semiconductor?
5. Draw the energy band diagram of an intrinsic semiconductor.
6. Name the two factors on which electrical conductivity of a pure semiconductor at a given temperature depends.
7. Name the two important processes that occur during the formation of a p-n junction.
8. Draw energy band diagram of n-type and p-type semiconductor at temperature T > OK. Mark the donar and acceptor energy level with their energies.
9. When Ge crystal is doped with phosphorus atoms, which type of semiconductor it become?
10. Which type of biasing is there in the following diode?



ANSWERS

1. An intrinsic semiconductor is a pure semiconductor material, whereas an extrinsic semiconductor is an impure semiconductor created by doping impurities into a pure material to enhance its electrical properties. There is no classification of intrinsic semiconductor. While the extrinsic semiconductors are of two types viz. P-type semiconductor and N-type semiconductor.
2. Intrinsic semiconductors have limited applications in devices due to their low and uncontrolled electrical conductivity
3. No effect
4. Deliberate adding of desired impurity to a semiconductor to increase its conductivity is called doping.
   Conductivity of a semiconductor increases due to doping.
5.
6. (i) The width of the forbidden band
   (ii) Intrinsic charge carrier concentration
7. **Ans.** (i) Diffusion (ii) drift.
8. Energy band diagram of p type and n type semiconductor is :





9. It becomes n – type semiconductor.
10. Reverse biased

LONG ANSWER QUESTIONS

1. (i) With the help of circuit diagrams, distinguish between forward biasing and reverse biasing of a p-n junction diode.
   (ii) Draw V-I characteristics of a p-n junction diode in
   (a) forward bias,
   (b) reverse bias.

   OR

   Draw V-I characteristics of a p-n junction diode.
   Answer 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?
2. (i)State briefly the processes involved in the formation of p-n junction, explaining clearly how the depletion region is formed.
   (ii)Using the necessary circuit diagrams, show how the V-I characteristics of a p-n junction are obtained in (a) forward biasing (b) reverse biasing How are these characteristics made use of in rectification?
3. Draw a labeled diagram of a full wave rectifier circuit. State its working principle. Show the input-output waveforms. Draw a labeled diagram of a half wave rectifier circuit. State its working principle. Show the input-output waveforms.