SURE SHOT QUESTIONS

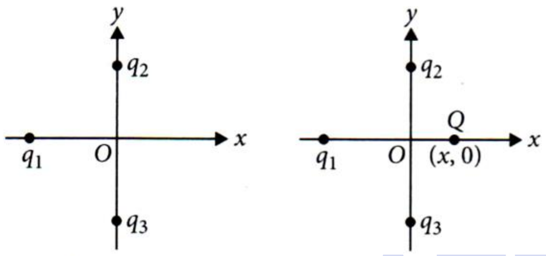
ARVIND ACADEMY

Chapter – 01

Electric Charges and Fields

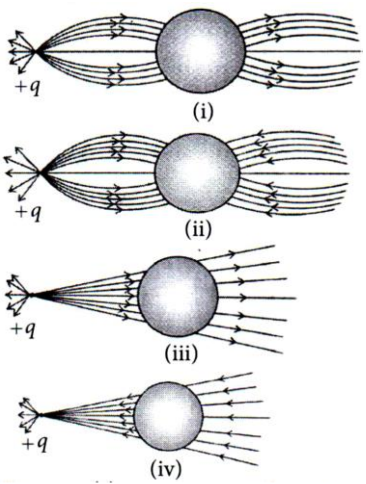
➢ MCQ (1 mark)

1. In figure, two positive charges, q_2 and q_3 fixed along the y axis, exert a net electric force in the +x direction on a charge q_1 fixed along the x axis. If a positive charge Q is added at (x, 0), the force on q_1



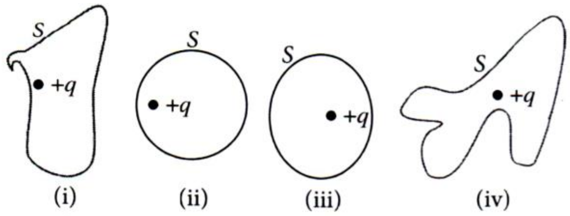
(a) Shall increase along the positive x-axis.
(b) Shall decrease along the positive x-axis.
(c) Shall point along the negative x-axis.
(d) Shall increase but the direction changes because of the intersection of Q with q_2 and q_3.

2. A point positive charge is brought near an isolated conducting sphere. The electric field is best given by



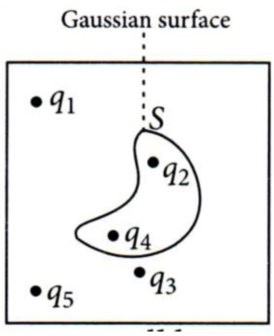
(a) Figure (i) (b) Figure (ii)
(c) Figure (iii) (d) Figure (iv).

3. The electric flux through the surface



(a) In figure (iv) is the largest
(b) In figure (iii) is the least
(c) In figure (ii) is same as in figure (iii) but is smaller than figure (iv)
(d) Is the same for all the figures.

4. Five charges q_1, q_2, q_3, q_4 and q_5 are fixed at their positions as shown in figure. S is Gaussian surface. The Gauss's law is given by $\oint_S \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$. Which of the following statements is correct?



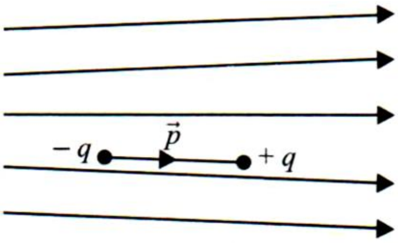
(a) $\vec{E}$ on the LHS of the above equation will have a contribution from q_1, q_5 and q_3 while q on the RHS will have a contribution from q_2 and q_4 only.

(b) $\vec{E}$ on the LHS of the above equation will have a contribution from all charges while q on the RHS will have a contribution from q_2 and q_4 only.

(c) $\vec{E}$ on the LHS of the above equation will have a contribution from all charges while q on the RHS will have a contribution from q_1, q_3 and q_5 only.

(d) Both $\vec{E}$ on the LHS and q on the RHS will have a contributions from q_2 and q_4 only.

5. Figure shows electric field lines in which an electric dipole $\vec{p}$ is placed as shown. Which of the following statements is correct?



(a) The dipole will not experience any force.
(b) The dipole will experience a force towards right.
(c) The dipole will experience a force towards left.
(d) The dipole will experience a force upwards.

6. A point charge +q, is placed at a distance d from an isolated conducting plane. The field at a point P on the other side of the plane is
(a) Directed perpendicular to the plane and away from the plane
(b) Directed perpendicular to the plane but towards the plane
(c) Directed radially away from the point charge
(d) Directed radially towards the point charge.

7. A hemisphere is uniformly charged positively. The electric field at a point on a diameter away from the centre is directed
(a) Perpendicular to the diameter
(b) Parallel to the diameter
(c) At an angle tilted towards the diameter
(d) At an angle tilted away from the diameter.

8. A negatively charged object X is repelled object X is repelled by another charged object Y. However, an object Z is attracted to object Y. Which of the following is the most possibility for the object Z?

[Term I 2021-22]

(a) Positively charged only.
(b) Negatively charged only.
(c) Neutral or positively charged.
(d) Neutral or negatively charged.

9. In an experiment three microscopic latex spheres are sprayed into a chamber and became charged with charges +3e, +5e and -3e respectively. All the three spheres came in contact simultaneously for a moment and got separated. Which one of the following are possible values for the final charge on the spheres? [Term I 2021 – 22]

(a) +5e, -4e, +5e
(b) +6e, +6e, -7e
(c) -4e, +3.5e, +5.5e
(d) +5e, -8e, +7e

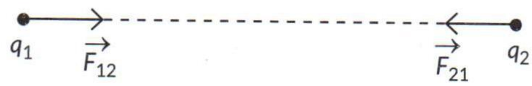
10. An object has charge of 1 C and gains 5.0×10^{18} electrons. The net charge on the object becomes

[Term I 2021 – 22]

(a) -0.80 C (b) +0.80 C
(c) +1.80 C (d) +0.20 C

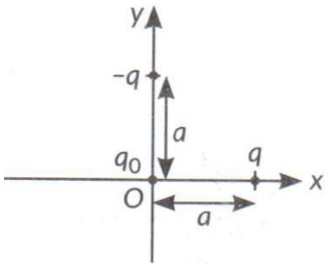
11. According to Coulomb's law, which is the correct relation for the following figure?

[2022-23]



(a) $q_1 q_2 > 0$ (b) $q_1 q_2 < 0$
(c) $q_1 q_2 = 0$ (d) $1 > q_1 / q_2 > 0$

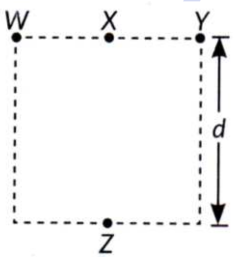
12. Three charges q, -q and q_0 are placed as shown in figure. The magnitude of the net force on the charge q_0 at point O is [Term I 2021 – 22]



(a) 0 (b) $\frac{2kqq_0}{a^2}$

(c) $\frac{\sqrt{2}kqq_0}{a^2}$ (d) $\frac{1}{\sqrt{2}}\frac{kqq_0}{a^2}$

13. Four objects W, X, Y and Z each with charge +q are held fixed at four points of a square of side d as shown in the figure. Object X and Z are on the midpoints of the sides of the square. The electrostatic force exerted by object W on object X is F. Then the magnitude of the force exerted by object W on Z is [Term I 2021 – 22]



(a) F/7 (b) F/5

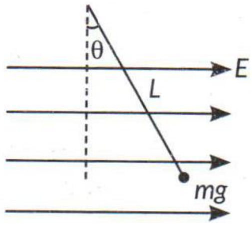
(c) F/3 (d) F/2

14. Two point charges +8q and -2q are located at x = 0 and x = L respectively. The point on x axis at which net electric field is zero due to these charges is [Term I 2021 – 22]

(a) 8 L (b) 4 L

(c) 2 L (d) L

15. A small object with charge q and weight mg is attached to one end of a straight of length 'L' attached to a stationary support. The system is placed in a uniform horizontal electric field 'E', as shown in the accompanying figure. In the presence of the field, the string makes a constant angle θ with the vertical. The sign and magnitude of q is [Term I 2021 – 22]



(a) Positive with magnitude mg/E

(b) Positive with magnitude $(mg / E)\tan\theta$

(c) Negative with magnitude $mg / E\tan\theta$

(d) Positive with magnitude $E\tan\theta / mg$

16. A square sheet of side 'a' is lying parallel to XY plane at z = a. The electric field in the region is $\vec{E} = cz^2\hat{k}$. The electric flux through the sheet is [Term I 2021 – 22]

(a) a^4c (b) $\frac{1}{3}a^3c$

(c) $\frac{1}{3}a^4c$ (d) 0

17. A cylinder of radius r and length l is placed in an uniform electric field parallel to the axis of the cylinder. The total flux for the surface of the cylinder is given by [Term I 2021 – 22]

(a) zero (b) πr^2

(c) Eπr^2 (d) 2Eπr^2

18. An electric dipole consisting of charges +q and -q separated by a distance L is in stable equilibrium in a uniform electric field. The $\vec{E}$ electrostatic potential energy of the dipole is [2020]

(a) qLE (b) zero

(c) -qLE (d) -2 qEL

19. An electric dipole of length 2 cm is placed at an angle of 30^0 with an electric field 2 x 10^5 N/C. If the dipole experiences a torque of 8 x 10^{-3} Nm, the magnitude of either charge of the dipole is [2023]

(a) 4 μ C (b) 7 μ C

(c) 8 mC (d) 2 Mc

20. An electric dipole placed in a non-uniform electric field can experience [2020]

(a) A force but not a torque
(b) A torque but not a force
(c) Always a force and a torque
(d) Neither a force nor a torque.

21. Which of the statement is true for Gauss law? [Term I 2021 – 22]

(a) All the charges whether inside or outside the gaussian surface contribute to the electric flux.
(b) Electric flux depends upon the geometry of the gaussian surface.
(c) Gauss theorem can be applied to non-uniform electric field.
(d) The electric field over the gaussian surface remains continuous and uniform at every point.

22. If the net electric flux through a closed surface is zero, then we can infer [2020]

(a) No net charge is enclosed by the surface
(b) Uniform electric field exists within the surface
(c) Electric potential varies from point to point inside the surface
(d) Charge is present inside the surface.

23. The electric flux through a closed Gaussian surface depends upon [2020]

(a) Net charge enclosed and permittivity of the medium
(b) Net charge enclosed, permittivity of the medium and size of the Gaussian surface
(c) Net charge enclosed only
(d) Permittivity of the medium only.

24. Two parallel large thin metal sheets have equal surface densities 26.4 x 10^{-12} C/m^2 of opposite signs. The electric field between these sheets is

[Term I 2021 – 22]

(a) 1.5 N/C (b) 1.5 x 10^{-16} N/C

(c) 3 x 10^{-10} N/C (d) 3 N/C

25. The magnitude of electric field due to a point charge 2q at distance r is E. Then the magnitude of electric field due to a uniformly charged thin spherical shell of radius R with total charge q at a distance $\frac{r}{2} (r >> R)$ will be

[Term I 2021 - 22]

(a) $\frac{E}{4}$ (b) 0

(c) 2E (d) 4E

➢ Assertion-Reasoning (1 mark)

Is Assertion (A) and Reason (R) type questions. Given below are the two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below.

26. Assertion (A): A negative charge in an electric field moves along the direction of the electric field.

Reason (R): On a negative charge a force acts in the direction of the electric field.

(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 correct explanation of (A).
(c) (A) is true, but (R) is false.
(d) (A) is false and (R) is also false.

[Term I 2021 – 22]

27. Assertion (A) : In a non-uniform electric field, a dipole will have translatory as well as rotatory motion

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

(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. [2020 – 21]

28. **Assertion (A):** Charging is due to transfer of electrons.
Reason (R): Mass of a body decreases slightly when it is negatively charged.

29. **Assertion (A):** The electric lines of forces diverges from a positive charge and converge at a negative charge.

Reason (A): A charged particle free to move in an electric field always move along an electric line of force.

30. **Assertion (A):** Three equal charges are situated on a circle of radius r such that they form on equilateral triangle, then the electric field intensity at the centre is zero.
Reason (R): The force on unit positive charge at the centre, due to the three equal charges are represented by the three sides of a triangle taken in the same order. Therefore, electric field intensity at centre is zero.

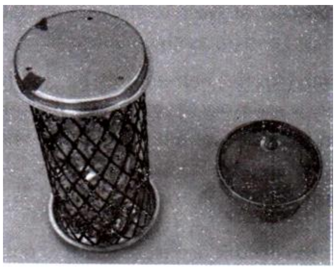
31. **Assertion (A):** The surface densities of two spherical conductors of different radii are equal. Then the electric field intensities near their surface are also equal.
Reason (R): Surface density is equal to charge per unit area.

32. **Assertion (A):** Sharper is the curvature of spot on a charged body lesser will be the surface charge density at that point
Reason (R): Electric field is non-zero inside a charged conductor.

33. **Assertion (A):** As force is a vector quantity, hence electric field intensity is also a vector quantity.
Reason (R): The unit of electric field intensity is newton per coulomb.

Case Study (4 marks)

34. 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 field within the enclosure is zero. These Faraday cages act as big hollow conductors you can put things in to shield them from electrical fields. Any electrical shocks the cage receives, pass harmlessly around the outside of the cage [2020 – 21]



(i) Which of the following material can be used to make a Faraday cage?

(a) Plastic (b) Glass

(c) Copper (d) Wood

(ii) Example of a real-world Faraday cage is

(a) car (b) plastic box

(c) lightning rod (d) metal rod

(iii) What is the electrical force inside a Faraday cage when it is struck by lightning?

(a) The same as the lightning

(b) Half that of the lightning

(c) Zero

(d) A quarter of the lighting

(iv) 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

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

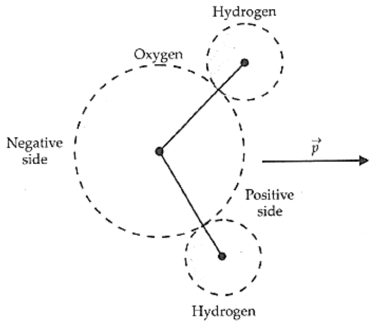
(a) $1.9\times10^5\ Nm^2/C$ entering the surface

(b) $1.9\times10^5\ Nm^2/C$ leaving the surface

(c) $2.0\times10^5\ Nm^2/C$ leaving the surface

(d) $2.0\times10^5\ Nm^2/C$ entering the surface

35. The electric field due to a charge configuration with total charge zero is not zero, but for distances large compared to the size of the configuration, its field falls off faster than $\frac{1}{r^2}$ typical of the field due to a single charge. An electric dipole is the simplest example of this fact. An electric dipole is a pair of equal and opposite charges + q and -q separated by some distance 2a. Its dipole moment vector $\underset{p}{\rightarrow}$ has magnitude 2qa and is in the direction of the dipole axis from -q to + q. The electric field of the pair of charges can be found out from Coulomb's law and the superposition principle. The magnitude and the direction of the dipole field depend not only on the distance r but also on the angle between the position vector $\underset{r}{\rightarrow}$ and the dipole moment $\underset{p}{\rightarrow}$. In some molecules, like $H2O$, the centres of -ve charges and of +ve charges do not coincide. So they have permanent dipole moment. Such molecules are called polar molecules.



QUESTIONS (Answer any four of the following questions)

(i) . What will be the value of electric field at the centre of the electric dipole?

(a) Zero

(b) Equal to the electric field due to one charge at centre

(c) Twice the electric field due to one charge at centre

(d) Half the value of electric field due to one charge at Centre

(ii) . If r is the distance of a point from the centre of a short dipole, then the electric field intensity due to the short dipole remains proportional to

(a) r^2 (a) r^{-3} (a) r^{-2} (a) r^{-3}

(iii) An electric dipole coincides on Z-axis and its midpoint is on origin of the coordinate system. The electric field at an axial point at a distance z from origin is E_2, and electric field at an equatorial point at a distance y from origin is E_y Here $z = y \gg a, so \frac{|E_2|}{|E_y|}$ is equal to

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

(iv) An electric dipole of moment $\underset{p}{\rightarrow}$ is placed in a uniform electric field $\underset{E}{\rightarrow}$. The maximum torque experienced by the dipole is

(a) pE (b) p/E

(c) E/p (d) $\underset{p}{\rightarrow}\cdot\underset{E}{\rightarrow}$

(v) The frequency of oscillation of an electric dipole having dipole moment p and rotational inertia I, oscillating in a uniform electric field E, is given by

(a) $\left(\frac{1}{2\pi}\right)\sqrt{I/pE}$ (b) $\left(\frac{1}{2\pi}\right)\sqrt{pE/I}$
(b) $(2\pi)\sqrt{pE/I}$ (d) $(2\pi)\sqrt{I/pE}$

➢ Questions

1. A particle of charge 2 μC and mass 1.6 g is moving with a velocity $4\hat{i}\, ms^{-1}$. At t = 0 the particle enters in a region having an electric field $\vec{E}$ (in N C^{-1}) = $80\hat{i}+60\hat{j}$. Find the velocity of the particle at t = 5s. [2/3, 2020]

36. A point charge (+Q) is kept in the vicinity of an uncharged conducting plate. Sketch the electric field lines between the charge and the plate.

[1/3, Foreign 2014]

37. Derive an expression for the electric field due to dipole of dipole moment $\vec{p}$ at a point on its perpendicular bisector. [2/3, Delhi 2019]

OR

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

[2/3, Delhi 2019]

OR

Find resultant electric field due to an electric dipole of dipole moment 2aq (2a being the separation between the charges $\pm q$) at a point distance x on its equator. [2/5, Foreign 2015]

38. (i)Define the term 'electric flux'. Write its SI unit.

(ii) What is the flux due to electric field $\vec{E} = 3\times10^{3}\hat{i}\, N/C$ through a square of side 10 cm, when it is held normal to $\vec{E}$? [AI 2015C]

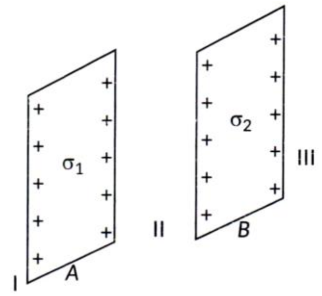
39. Two point charges of +1 μC and +4 μC are kept 30 cm apart. How far from the +1 μC charge on the

line joining the two charges, will the net electric field be zero? [2/5, 2020]

40. (a) Derive an expression for the electric field E due to a dipole of length '2a' at a point distance r from the centre of the dipole on the axial line.

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

41. Two infinitely large plane thin parallel sheets having surface charges densities σ_1 and σ_2 ($\sigma_1 > \sigma_2$) are shown in the figure. Write the magnitudes and directions of the net electric fields in the regions marked II and III. [Foreign 2014]



42. An electric field is uniform and acts along +x direction in the region of positive x. It is also uniform with the same magnitude but acts in -x direction in the region of negative x. The value of the field is E = 200 N C^{-1} for x > 0 and E = -200 N C^{-1} for x < 0. A right circular cylinder of length 20 cm and radius 5 cm has its centre at the origin and its axis along the x-axis so that one flat face is at x = +10 cm and the others is at x = -10 cm.

Find:

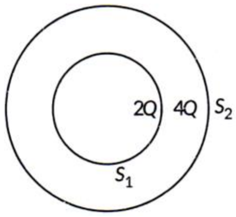
(i) The net outward flux through the cylinder.

(ii) The net charge present inside the cylinder. [2/5, 2020]

43. Consider two hollow concentric spheres S_1 and S_2, enclosing charges 2Q and 4Q respectively as shown in figure. [Al 2014]

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

(ii) How will the electric flux through the sphere S_1 change if a medium of dielectric constant 'ε_r' is introduced in the space inside S_1 in place of air? Deduce the necessary expression. [Al 2014]



44. State Gauss's law on electrostatics and derive an expression for the electric field due to a long straight thin uniformly charged wire (linear charge density λ, at a point lying at a distance r from the wire. [3/5, 2020]

45. Using Gauss law, derive expression for electric field due to a spherical shell of uniform charge distribution σ and radius R at a point lying at a distance x from the centre of shell, such that

[3/5, 2020]

46. Two large charged plane sheets of charge densities σ and -2σ C/m^2 are arranged vertically with a separation of d between them. Deduce expressions for the electric field at points (i) to the left of the first sheet, (ii) to the right of the second sheet, and (iii) between the two sheets.

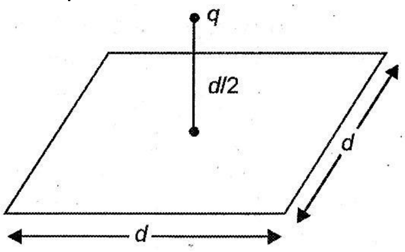
47. Consider a uniform electric field $\vec{E} = 3 \times 10^3 \hat{\imath} N/C$. Calculate the flux of this Field through a square surface of area 10 cm^2 when
(i) its plane is parallel to the $y - z$ plane

(ii) the normal to its plane makes a 60° angle with the $x - axis$.

48. (a) Derive an expression for the electric field at any point on the equatorial line of an electric dipole.
(b) The identical point charges, q each, are kept 2 m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q.

49. A charge is distributed uniformly over a ring of radius 'a'. Obtain an expression for the electric intensity E at a point on the axis of the ring. Hence show that for points at large distances from the ring, it behaves like a point charge.

50. (a)Define Electric flux. Is it a scalar or a vector quantity? A point charge q is at a distance of d/2 directly above the centre of a square of side d, as shown in figure. Use gauss's law to obtain the expression for the electric flux through the square.

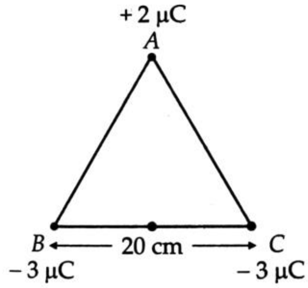


(b) If the point charge is now moved to distance 'd' from the centre of the square and the side of the square is doubled, explain how the electric flux will be affected.

51. State Coulomb's law and express it in vector form.

52. Two free point charges +4e and +e are placed at distance 'a' apart. Where should a third point charge q is placed between them such that the entire system may be in equilibrium? What should be the magnitude and sign of q? What type of equilibrium will it be?

53. Three point charges of $+2\mu C, -3\mu C$ and $-3\mu C$ are kept at the vertices A, B and C respectively of an equilateral triangle of side 20 cm as shown in figure. What should be the sign and magnitude of the charge to be placed at the midpoint (M) of side BC so that the charge at A remains in equilibrium?



54. Two point charges $+4\mu C$ and $+ 1\mu C$ are separated by 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?

55. Derive an expression for the electric field at a point on the axial position of an electric dipole.

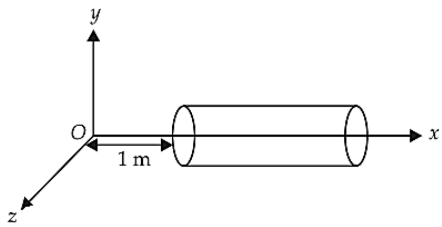
56. Find the expression for electric field intensity at a point on the axis of a uniformly charged ring.

57. Define electric flux. Write its SI unit.

58.Derive an expression for torque on an electric dipole in a uniform electric field.

59. State Gauss theorem and use it to find the electric field at a point due to an infinitely large thin plane sheet has a uniform surface charge density

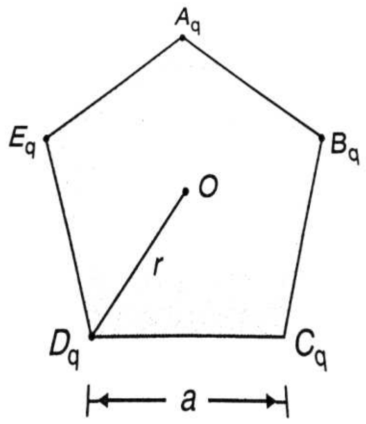
60. A hollow cylindrical box of length 1 m and area of cross-section 25 cm^2 is placed in a three dimensional coordinate system as shown in the figure. The electric field in the region is given by $\vec{E} = 50x\hat{\imath}$, where E is in NC^{-1} and x is in metres. Find
(i) net flux through the cylinder.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



61. A hollow cylindrical box of length 1 m and area of cross section 25 cm^2 is placed in a three dimensional coordinate system as shown in the figure. The electric field in the region is given by $\vec{E} = 5x\hat{i}$, where E is in NC^{-1} and x is in metres. Find
(i) Net flux through the cylinder.
(ii) Charge enclosed by the cylinder.

62. Derive an expression for the electric field due to an infinitely long straight uniformly charged wire.

63. Five Charges, q each are placed at the corners of a regular pentagon of side a.



(i) What will be the electric field at O if the charge from one of the corners say (A) is removed?
(ii) What will be the electric field at O if the charge q at A is replaced by -q?

64. Given a uniform field $\vec{E} = 5 \times 10^3 \hat{\imath}\ N/C$, Find the flux of this field through a square of side 10 cm on a side whose plane is parallel to the y-z plane. What would be the flux through the same square if the plane makes a 30^0 angle with the x axis?

65. A particle of mass 10^{-3} kg and charge 5 μC enters into a uniform electric field of $2 \times 10^5\ NC^{-1}$, moving with a velocity of $20\ ms^{-1}$ in a direction opposite to that of the field. Calculate the distance it would travel before coming to rest.

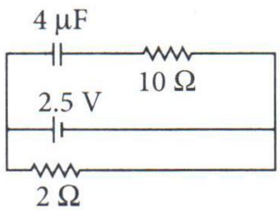
SURE SHOT QUESTIONS

Chapter – 02

Electrostatic Potential and Capacitance

MCQ

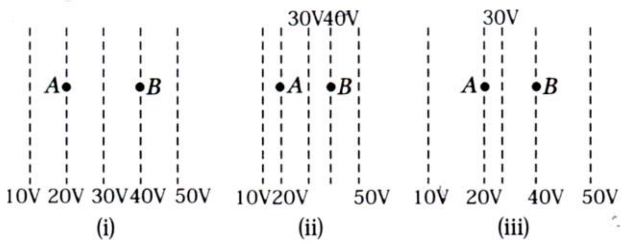
1. A capacitor of 4 μF is connected as shown in the circuit. The internal resistance of the battery is 0.5 Ω. The amount of charge on the capacitor plates will be



(a) 0 (b) 4 μC
(c) 16 μC (d) 8 μC

2. A positively charged particle is released from rest in a uniform electric field. The electric potential energy of the charge
(a) remains a constant because the electric field is uniform,
(b) increases because the charge moves along the electric field,
(c) decreases because the charge moves along the electric field,
(d) decreases because the charge moves opposite to the electric field.

3. Figure shows some equipotential lines distributed in space. A charged object is moved from point A to point B.

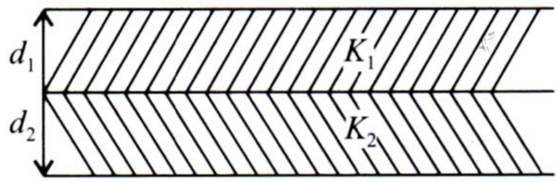


(a) The work done in figure (i) is the greatest,
(b) The work done in figure (ii) is the least,
(c) The work done is the same in figure (i), (ii) and (iii).
(d) The work done in figure (iii) is greater than figure (ii) but equal to that in figure (i).

4. The electrostatic potential on the surface of a charged conducting sphere is 100 V. Two statements are made in this regard
S_1 : At any point inside the sphere, electric intensity is zero.
S_2 : At any point inside the sphere, the electrostatic potential is 100 V.
Which of the following is a correct statement?
(a) S_1 is true but S_2 is false
(b) Both S_1 and S_2 are false
(c) S_1 is true, S_2 is also true and S_1 is the cause of S_2
(d) S_1 is true, S_2 is also true but the statements are independent.

5. Equipotentials at a great distance from a collection of charges whose total sum is not zero are approximately
(a) spheres (b) planes
(c) paraboloids (d) ellipsoids.

6. A parallel plate capacitor is made of two dielectric blocks in series. One of the blocks has thickness d_1 and dielectric constant K_1 and the other has thickness d_2 and dielectric constant K_2 as shown in figure. This arrangement can be thought as a dielectric slab of thickness d (= $d_1 + d_2$) and effective dielectric constant K. The K is



(a) $\frac{K_1d_1+K_2d_2}{d_1+d_2}$ (b) $\frac{K_1d_1+K_2d_2}{K_1+K_2}$

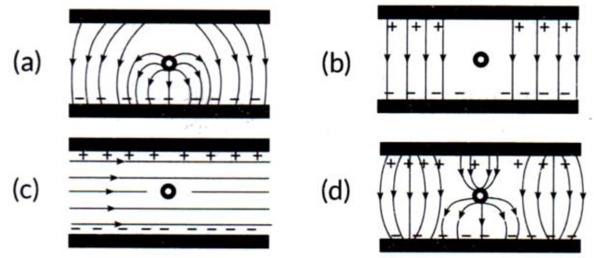
(c) $\frac{K_1K_2(d_1+d_2)}{K_2d_1+K_1d_2}$ (d) $\frac{2K_1K_2}{K_1+K_2}$

7. The electric potential V at any point (x, y, z) is given by $V = 3x^2$ where x is in metres and V in volts. The electric field at the point (1m, 0, 2m) is [Term I 2021 – 22]
   (a) 6 V m^{-1} along -x – axis
   (b) 6 V m^{-1} along +x – axis
   (c) 1.5 V m^{-1} along – x – axis
   (d) 1.5 V m^{-1} along +x – axis.

8. Equipotentials at a large distance from a collection of charges whose total sum is not zero are
   [Term I 2021 – 22]
   (a) spheres (b) planes
   (c) ellipsoids (d) paraboloids

9. A +3.0 nC charge Q is initially at rest at a distance of r_1 = 10 cm from a +5.0 nC charge q fixed at the origin. The charge Q is moved away from q to a new position at r_2 = 15 cm. In this process work done by position at r_2 = 15 cm. In this process work done by the field is [Term I 2021 – 22]
   (a) $1.29\times10^{-5}\ J$ (b) $3.6\times10^{5}\ J$
   (c) $-4.5\times10^{-7}\ J$ (d) $4.5\times10^{-7}\ J$

10. Which of the following correctly represents the electric field between two charged plates if a neutral conductor is placed in between the plates?
    [Term I 2021 – 22]



11. A charge particle is placed between the plates of a charged parallel plate capacitor. It experiences a force F. If one of the plates is removed, the force on the charge particle becomes [AI 2020C]
    (a) F (b) 2F
    (c) F/2 (d) Zero

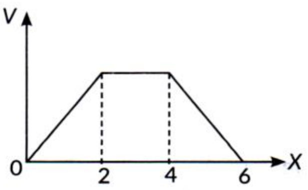
12. Two capacitors of capacitances C_1 and C_2 are connected in parallel. If a charge Q is given to the combination, the ratio of the charge on the capacitor C_1 to the charge on C_2 will be: [AI 2020]
    (a) C_1/C_2 (b) $\sqrt{\frac{C_1}{C_2}}$
    (c) $\sqrt{\frac{C_2}{C_1}}$ (d) $\frac{C_2}{C_1}$

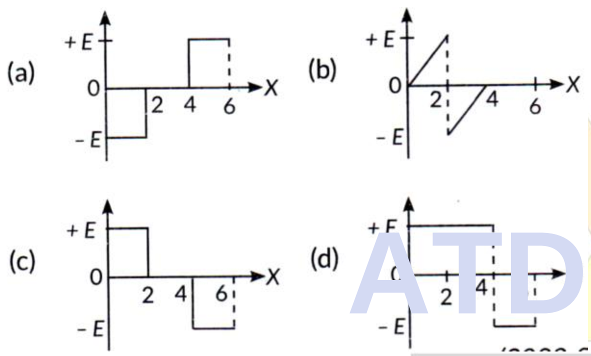
13. Three capacitors, each of 4 μF are to be connected in such a way that the effective capacitance of the combination is 6 μF . This can be achieved by connecting. [2023]
    (a) All three in parallel
    (b) All three in series
    (c) Two of them connected in series and the combination in parallel to the third.
    (d) Two of them connected in parallel and the combination in series to the third.

$$C_{eq}=\frac{4\times4}{4+4}$$
$$C_{eq}=2\mu F$$

14. A variable capacitor is connected to a 200 V battery. If its capacitance is changed from 2 μF to X μF , the decrease in energy of the capacitor is 2 x 10^{-2} J. The value of X is [Term I 2021 – 22]
    (a) 1 μF (b) 2 μF
    (c) 3 μF (d) 4 μF

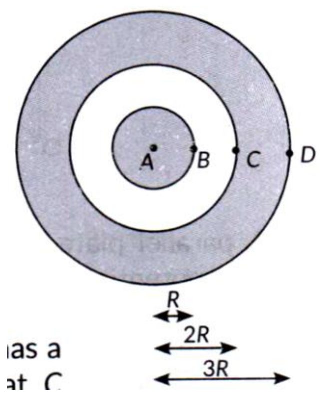
15. The electric potential V as a function of distance X is shown in the figure.





The graph of the magnitude of electric field intensity E as a function of X is [2022 – 23]

16. 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? [Term I 2021 – 22]



(a) The electric potential has a maximum magnitude at C and the electric field has a maximum magnitude at A.
(b) The electric potential has a maximum magnitude at D and the electric field has a maximum magnitude at B.
(c) The electric potential at A is zero and the electric field has a maximum magnitude at D.
(d) Both the electric potential and electric field achieve a maximum magnitude at B.

17. The electric potential on the axis of an electric dipole at a distance ‘r’ from it’s centre is V. Then the potential at a point at the same distance on its equatorial line will be [2022 – 23]
    (a) 2V (b) -V
    (c) $\frac{V}{2}$ (d) Zero

18. Three charges 2q, -q and -q lie at vertices of a triangle. The value of E and V at centroid of triangle will be [Term I 2021 – 22]
    (a) E $\neq$ 0 and V $\neq$ 0 (b) E = 0 and V = 0
    (c) E $\neq$ 0 and V = 0 (d) E = 0 and V $\neq$ 0

19. Which of the following is NOT the property of equipotential surface? [Term I 2021 – 22]
    (a) They do not cross each other.
    (b) The rate of change of potential with distance on them is zero.
    (c) For a uniform electric field they are concentric spheres.
    (d) They can be imaginary spheres.

20. An electric dipole of moment p is placed parallel to the uniform electric field. The amount of work done in rotating the dipole by 90^0 is [Term I 2021 – 22]

(a) 2pE (b) pE

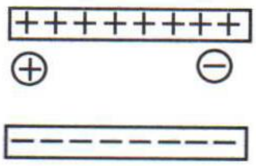
(c) pE/2 (d) zero

21. Three capacitors 2 μF , 3 μF and 6 μF are joined in series with each other. The equivalent capacitance is [Term I 2021 – 22]

(a) 1/2 μF (b) 1 μF

(c) 2 μF (d) 11 μF

22. A free electron and a free proton are placed between two oppositely charged parallel plates. Both are closer to the positive plate than the negative plate. [Term I 2021 – 22]



Which of the following statements is true?

I. The force on the proton is greater than the force on the electron.

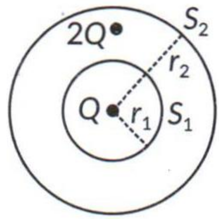
II. The potential energy of the proton is greater than that of the electron.

III. The potential energy of the proton and the electron is the same.

(a) I only (b) II only

(c) III and I only (d) II and I only

23. A capacitor plates are charged by a battery with 'V' volts. After charging battery is disconnected and a dielectric slab with dielectric constant 'K' is inserted between its plates, the potential across the plates of the capacitor will become [Term I 2021 – 22]



(a) zero (b) V/2

(c) V/K (d) KV

Assertion-Reasoning [1 Marks]

For question number 6, two statements are given one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below. [2020 – 21]

24. Assertion (A) : Electric field is always normal to equipotential surfaces and along the direction of decreasing order of potential.
Reason (R) : Negative gradient of electric potential is electric field.
(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 correct explanation of A.
(c) A is true, but R is false.
(d) A is false and R is also false.

25. Assertion (A): An electron has a high potential energy when it is at a location associated with a more negative value of potential, and a low potential energy when at a location associated with a more positive potential.
Reason (R): Electrons move from a region of higher potential to region of lower potential.
Select the most appropriate answer from the options 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. [Term I 2021 – 22]

26. Assertion (A) : Two adjacent conductors, carrying the same positive charge have no potential difference between them.
Reason (R): The potential of a conductor does not depend upon the charge given to it.

27. Assertion (A): The dielectric constant for metals is infinity.
Reason (R) : When a charged capacitor is filled completely with a metallic slab, its capacity becomes very large.

28. Assertion (A) : When air between the plates of a parallel plate condenser is replaced by an insulating medium of dielectric constant its capacity increases.
Reason (R): Electric field intensity between the plates with dielectric in between it is reduced.

29. Assertion (A): Capacity of a parallel plate capacitor increases when distance between the plates is decreased.
Reason (R): Capacitance of capacitor is inversely proportional to distance between them.

30. Assertion (A): Electric potential of the earth is zero.
Reason (R): The electric field due to the earth is zero.

31. Assertion (A): The whole charge of a conductor cannot be transferred to another isolated conductor.
Reason (R): The total transfer of charge from one to another is not possible.

32. Assertion (A): Positive charge always moves from a higher potential point to a lower potential point.
Reason (R): Electric potential is a vector quantity.

33. Assertion (A) : Lines of force are perpendicular to conductor surface.
Reason (R) : Generally electric field is perpendicular to equipotential surface.

Case Study [4 Marks]

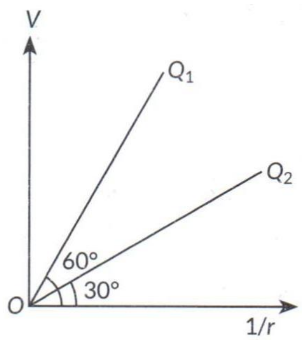
The following questions are source based/case based questions. Read the case carefully and answer the questions that follow.

34. Electrostatics deals with the study of forces, fields 9 and potentials arising from static charges. Force and electric field, due to a point charge is basically determined by Coulomb's law. For symmetric charge configurations. Gauss's law, which is also based on Coulomb's law, helps us to find the electric field. A charge/ a system of charges like a dipole experience a force/torque in an electric field. Work is required to be done to provide a specific orientation to a dipole with respect to an electric field.

Answer the following questions based on the above:

(a) Consider a uniformly charged thin conducting shell of radius R. Plot a graph showing the variation of $|\vec{E}|$ with distance r from the centre, for points $0 \le r \le 3R$.

(b) The figure shows the variation of potential V with $\frac{1}{r}$ for two points charges Q_1 and Q_2, where V is the potential at a distance r due to a point charge. Find $\frac{Q_1}{Q_2}$

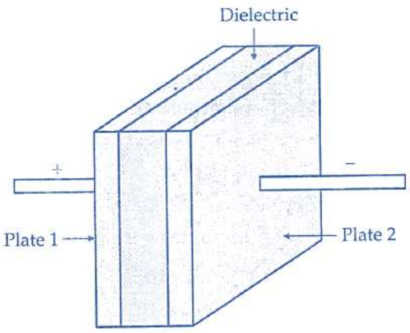


(c) An electric dipole of dipole moment of 6 x 10^{-7} C-m is kept is a uniform electric field of 10^4 N/C such that the dipole moment and the electric field are parallel. Calculate the potential energy of the dipole.

OR

An electric dipole of dipole moment $\vec{p}$ is initially kept in a uniform electric field $\vec{E}$ such that $\vec{p}$ is perpendicular to $\vec{E}$. Find the amount of work done in rotating the dipole to a position at which $\vec{p}$ becomes antiparallel to $\vec{E}$. [2023]

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



QUESTIONS (Answer any four of the following questions)

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

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

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

3. If n capacitors, each of capacitance C, are connected in series, then the equivalent capacitance of the combination will be
(a) nC (b)n^2C
(c) C/n (d) C/n^2

4. Three capacitors of 2.0,3.0 and 6.0 μF are connected in series to a 10 V source. The charge on the 3.0 μF capacitor is
(a) 5 μC (b) 10μC
(c) 12 μC (d) 15 μC

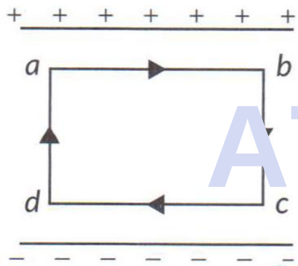
5. What is the potential difference across 2 μF capacitor in the circuit shown?
(a) 12 V (b) 4V
(c) 6V (d) 18 V

➢ Question

36. N small conducting liquid droplets, each of radius r, are charged to a potential V each. These droplets coalesce to form a single large drop without any charge leakage. Find the potential of the large drop. [2020]

37. Two point charges q and -2q are kept 'd' distance apart. Find the location of point relative to charge 'q' at which potential due to this system of charges is zero. [AI 2014C]

38. The electric field inside a parallel plate capacitor is E. Find the amount of work done in moving a charge q over a closed rectangular loop abcda. [Delhi 2014]

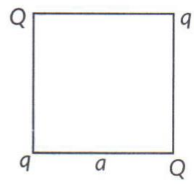


39. Establish the relation between electric field and electric potential at a point. Draw the equipotential surface for an electric field pointing in +Z direction with its magnitude increasing at constant rate along -Z direction. [2020 – 21]

40. Define an equipotential surface. Draw equipotential surfaces: [AI 2016]
    (i) In the case of a single point charge and
    (ii) In a constant electric field in Z – direction. Why the equipotential surface about a single charge are not equidistant?
    (iii) Can electric field exist tangential to an equipotential surface? Give reason.

41. (a) Two point charges $+Q_1$ and $-Q_2$ are placed r distance apart. Obtain the expression for the amount of work done to place a third charge Q_3 at the midpoint of the line joining the two charges.
    (a) At what distance from charge $+Q_1$ on the line joining the two charges (in terms of Q_1, Q_2 and r) will this work done be zero.

42. Four point charges Q, q, Q and q are placed at the corners of a square of side 'a' as shown in the figure. Find the [2018]



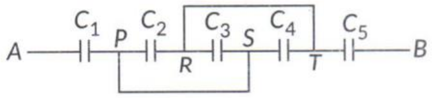
    (a) Resultant electric force on a charge Q, and
    (b) Potential energy of this system.

43. (a) Three point charges q, -4q and 2q are placed at the vertices of an equilateral triangle ABC of side 'l' as shown in the figure. Obtain the expression for the magnitude of the resultant electric force acting on the charge q.
    (c) Find out the amount of the work done to separate the charges at infinite distance.

44. In a parallel plate capacitor with air between the plates, each plate has an area of 6×10^{-3} m^2 and the separation between the plates is 0.3 mm.
    (i) Calculate the capacitance of the capacitor.
    (ii) If this capacitor is connected to 100 V supply, what would be the charge on each plate?
    (iii) How would charge on the plates be affected, if a 3 mm thick mica sheet of K = 6 is inserted between the plates while the

voltage supply remains connected?
[Foreign 2014]

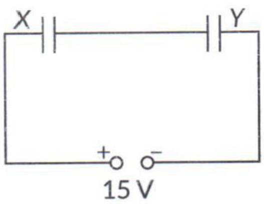
45. (i) Find the equivalent capacitance between A and B in the combination given below. Each capacitor is of 2 μF capacitance.



(i) If a dc source of 7 V is connected across AB, how much charge is drawn from the source and what is the energy stored in the network? [Delhi 2017]

46. A 12 pF capacitor is connected to a 50 V battery. How much electrostatic energy is stored in the capacitor? If another capacitor of 6 pF is connected in series with it with the same battery connected across the combination, find the charge stored and potential difference across each capacitor.
[Delhi 2017]

47. 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 of $\varepsilon_r = 4$. [Delhi 2016]



(i) Calculate 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.

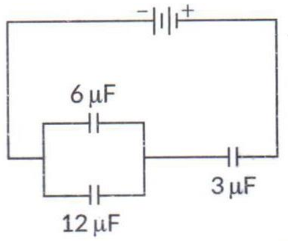
(iii) Estimate the ratio of electrostatic energy stored in X and Y.

48. In the following arrangement of capacitors, the energy stored in the 6 μF capacitor is E. Find the value of the following [Foreign 2016]

(i) Energy stored in 12 μF capacitor

(ii) Energy stored in 3 μF capacitor

(iii) Total energy drawn from the battery

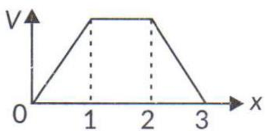


49. The magnitude of electric field (in N C^{-1}) in a region varies with the distance r (in m) as

$E = 10r + 5$

By how much does the electric potential increase in moving from point at r = 1 m to a point at r = 10 m. [2/5, 2020]

50. The electric potential as a function of distance 'x' is shown in the figure. Draw a graph of the electric field E as a function of x. [1/5, AI 2019]



51. Derive an expression for the potential energy of an electric dipole in a uniform electric field. Explain conditions for stable and unstable equilibrium.
[3/5, AI 2019]

52. If two similar large plates, each of area A having surface charge densities + σ and - σ are separated by a distance d in air, find the expressions for

(a) Field at points between the two plates and on outer side of the plates. Specify the direction of the field in each case.

(b) The potential difference between the plates.

(c) The capacitance of the capacitor so formed.

[3/5, AI 2016]

53. (a) Define an ideal electric dipole. Give an example.

(b) Derive an expression for the torque experienced by an electric dipole in a uniform electric field. What is net force acting on this dipole?

(c) An electric dipole of length 2 cm is placed with its axis making an angle of 60^0 with respect to uniform electric field of 10^5 N/C. If it experiences a torque of $8\sqrt{3}$ N/m, calculate the magnitude of charge on the dipole, and its potential energy.

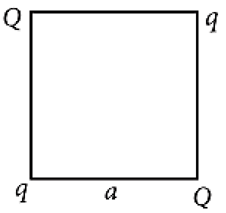
[2020 – 21]

54. Four point charges Q, q, Q and q are placed at the corners of a square of side 'a' as shown in the figure.

Find the

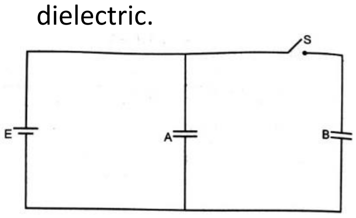
(a) resultant electric force on a charge Q, and

(b) potential energy of this system.



55. Show that the capacitance of a spherical conductor is $4\pi\varepsilon_0$ times the radius of the spherical conductor.

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

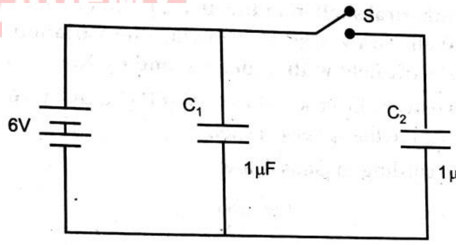


57. A 100 μF parallel plate capacitor having plate separation of 4 mm is charged by200 V dc. The source is now disconnected. When the distance between the plates is doubled and dielectric slab of thickness 4 mm and dielectric constant 5 is introduced between the plates, how will (i) its capacitance, (ii) the electric field between the plates, and (iii) energy density of the capacitor get affected? Justify your answer in each case.

58. (a) Derive the expression for the energy stored in a parallel plate capacitor. Hence obtain the expression for the energy density of the electric field.

(b) A fully charged parallel plate capacitor is connected across an uncharged identical capacitor. Show that the energy stored in the combination is less than that stored initially in the single capacitor.

59. Figure shows two identical capacitors, C_1 and C_2 each of 1 μF capacitance connected to a battery of 6 V. Initially switch 'S' is closed. After sometime 'S' is left open and dielectric slabs of dielectric constant K = 3 are inserted to fill completely the space between the plates of the capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted?



60. Define electric potential at a point & derive an expression for the electrostatic potential at a point due to point charge

61. Derive the expression for the electric potential due to an electric dipole at a point on (i) its axial position (ii) at an equatorial point

62. Two tiny spheres carrying charges 1.5 μC and 2.5 μC are located 30 cm apart. Find the potential and the electric field

a. At the mid-point of the line joining the two charges, and

b. At a point 10 cm from this mid-point in a plane normal to the line and passing through the mid-point.

63. Define an equipotential surface. Draw equipotential surfaces :

i. In the case of the single point charge and

ii. In a constant electric field in Z-direction. Why the equipotential surfaces about a single charge are not equidistant ?

iii. Can electric field exist tangential to an equipotential surface? Give reason.

64. Derive a relation between electric field & potential & explain significance of –ve sign.

65. Find Potential energy of a Dipole in a uniform external electric field.

66. An electric dipole of length 4 cm, when placed with its axis making an angle of 60° with a uniform electric field experiences a torque of $4\sqrt{3}$ Nm. Calculate (i) magnitude of the electric field, (ii) potential energy of the dipole, if the dipole has charges of $\pm 8\ nC$.

67. Two particles have equal masses of 5.0 g each and opposite charges of +4 x 10^{-5} C and -4 x 10^{-5} C. They are released from rest with a separation of 1.0 m between them. Find the speeds of the particles when the separation is reduced to 50 cm.

68. (i) Define the capacitance of a capacitor. Obtain the expression for the capacitance of a parallel plate capacitor in vacuum, in terms of plate area A and separation d between the plates.

(ii) A slab of material of dielectric constant K has the same area as the plates of a parallel plate capacitor but has a thickness 3d/4. Find the ratio of the capacitance with dielectric inside it to its capacitance without the dielectric

69. Two capacitors with capacitances C_1 and C_2 are charged to potentials V_1 and V_2 respectively and then connected in parallel. Calculate the common potential across the combination, the charge on each capacitor, the electrostatic energy stored in the system and the change in electrostatic energy from its initial value.

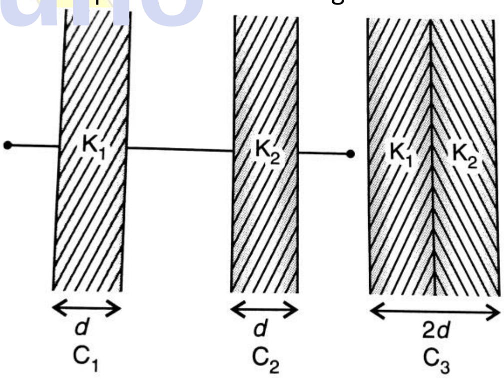
70. In a hydrogen atom, the electron and proton are bound at a distance of about 0.53Å.

(a) Estimate the potential energy of the system in eV, taking the zero of potential energy at infinite separation of electron from proton.

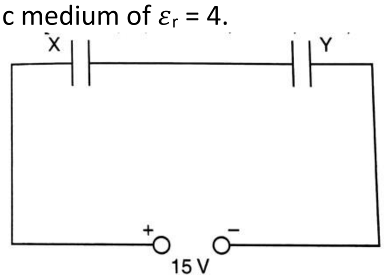
(b) What is the minimum work required to free the electron, given that its kinetic energy in the orbit is half the magnitude of potential energy obtained in (a) ?

(c) What are the answers to (a) and(b) above if the zero of potential energy is taken at 1.06 Å separation?

71. The capacitors C_1 and C_2 having plates of area A each, are connected in series, as shown. Compare the capacitance of this combination with the capacitor C_3, again having plates of area A each, but filled up as shown in the figure.



72. 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 of ε_r = 4.

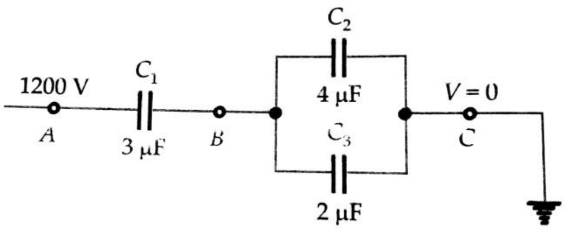


(i) Calculate capacitance of each capacitor if equivalent capacitance of the combination is 4 μF.

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

(iii) Estimate the ratio of electrostatic energy stored in X and Y.

73.In the circuit shown in the Fig., if the point C is earthed and point A is given a potential of +1200 V, find the charge on each capacitor and the potential at the point B

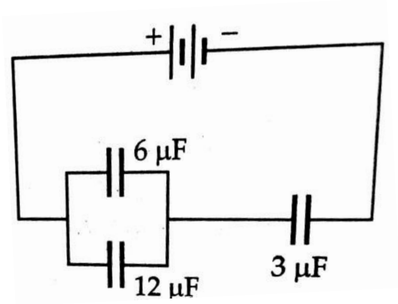


74.In the following arrangements of capacitors, the energy stored in the 6 μF capacitor is E. Find the value of the following :

(i) Energy stored in 12 μF capacitor.

(ii) Energy stored in 3 μF capacitor.

(iii) Total energy drawn from the battery.



75. Explain Electrostatic shielding.

76.Find capacitance of a parallel Plate capacitor with a dielectric slab.

77.What are dielectrics? Distinguish polar and non-polar dielectrics.

78.Compare the individual dipole moment and the specimen dipole moment for H_2O molecule and O_2 molecule when placed in

(a) Absence of external electric field.

(b) Presence of external electric field.

Justify your answer.

SURE SHOT QUESTIONS

ARVIND ACADEMY

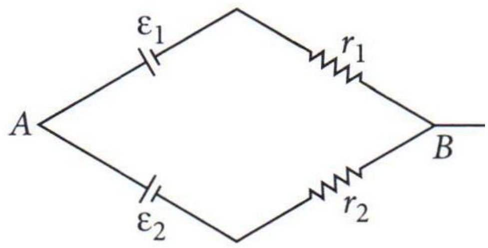
Chapter – 03

Current Electricity

MCQ (1 mark)

1. Consider a current carrying wire (current I) in the shape of a circle. Note that as the current progresses along the wire, the direction of $\vec{J}$ (current density) changes in an exact manner, while the current I remains unaffected. The agent that is essentially responsible for it is
   (a) Source of e.m.f.
   (b) Electric field produced by charges accumulated on the surface of wire.
   (c) The charges just behind a given segment of wire which push them just right way by repulsion.
   (d) The charges ahead.

2. Two batteries of emf ε_1 and $\varepsilon_2 (\varepsilon_2 > \varepsilon_1)$ and internal resistance r_1 and r_2 respectively are connected in parallel as shown in figure.



   (a) The equivalent emf ε_{eq} of the two cells is between ε_1 and ε_2, i.e., $\varepsilon_1 < \varepsilon_{eq} < \varepsilon_2$.
   (b) The equivalent emf ε_{eq} is smaller than ε_1.
   (c) The ε_{eq} is given by $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$ always.
   (d) ε_{eq} is independent of internal resistances r_1 and r_2.

3. A resistance R is to be measured using a meter bridge. Student chooses the standard resistance S to be 100 Ω. He finds the null point at $l_1 = 2.9$ cm. He is told to attempt to improve the accuracy. Which of the following is a useful way?
   (a) He should measure l_1 more accurately.
   (b) He should changes S to 1000 Ω and repeat the experiment.
   (c) He should change S to 3 Ω and repeat the experiment.
   (d) He should give up hope of a more accurate measurement with a meter bridge.

4. Two cells of emf's approximately 5V and 10 V are to be accurately compared using a potentiometer of length 400 cm.
   (a) The battery that runs the potentiometer should have voltage of 8 V.
   (b) The battery of potentiometer can have a voltage of 15 V and R adjusted so that the potential drop across the wire slightly exceeds 10 V.
   (c) The first portion of 50 cm of wire itself should have a potential drop of 10 V.
   (d) Potentiometer is usually used for comparing resistances and not voltages.

5. A metal rod of length 10 cm and a rectangular cross-section of $1cm \times \frac{1}{2}$ cm is connected to a battery across opposite faces. The resistance will be
   (a) Maximum when the battery is connected across 1 cm $\times \frac{1}{2}$ cm faces.
   (b) Maximum when the battery is connected across 10 cm x 1 cm faces.

(c) Maximum when the battery is connected across $10\,cm \times \frac{1}{2}\,cm$ faces.
(d) Same irrespective of the three faces.

6. Which of the following characteristics of electrons determines the current in a conductor?
(a) Drift velocity alone
(b) Thermal velocity alone
(c) Both drift velocity and thermal velocity
(d) Neither drift nor thermal velocity

7. A potential difference of 200 V is maintained across a conductor of resistance 100 Ω. The number of electrons passing through it in 1 s is [Term I 2021 – 22]
(a) 1.25×10^{19} (b) 2.5×10^{18}
(c) 1.25×10^{18} (d) 2.5×10^{16}

8. The ratio of current density and electric field is called [2020]
(a) resistivity (b) conductivity
(c) drift velocity (d) mobility
OR
In a current carrying conductor, the ratio of the electric field and the current density at a point is called [2020]
(a) resistivity (b) conductivity
(c) resistance (d) mobility

9. If n, e, τ and m have their usual meanings, then the resistance of a wire of length l and cross-sectional area A is given by [Term I 2021 – 22]
(a) $\frac{ne^2A}{2m\tau l}$ (b) $\frac{ml}{ne^2\tau A}$
(c) $\frac{m\tau A}{ne^2 l}$ (d) $\frac{ne^2\tau A}{2ml}$

10. The potential difference applied across a given conductor is doubled. The mobility of the electrons in the conductor [AI 2019]
(a) Is doubled
(b) Is halved
(c) Remains unchanged
(d) Becomes four times

11. The resistance of a metal wire increases with increasing temperature on account of [2020]
(a) Decrease in free electron density
(b) Decrease in relaxation time
(c) Increase in mean free path
(d) Increase in the mass of electron.

12. Resistivity of a given conductor depends upon [2020]
(a) Temperature
(b) Length of conductor
(c) Area of cross-section
(d) Shape of the conductor.

13. Which of the following has negative temperature coefficient of resistivity? [Term I 2021 – 22]
(a) Metal
(b) Metal and semiconductor
(c) Semiconductor
(d) Metal and alloy.

14. The electric power consumed by a 220 V – 100 W bulb when operated at 110 V is [Term I 2021 – 22]
(a) 25 W (b) 30 W
(c) 35 W (d) 45 W

15. Two resistors R_1 and R_2 of $4\,\Omega$ and $6\,\Omega$ are connected in parallel across a battery. The ratio of power dissipated in them, $P_1 : P_2$ will be [AI 2020]

(a) 4 : 9 (b) 3 : 2

(c) 9 : 4 (d) 2 : 3

16. In a dc circuit the direction of current inside the battery and outside the battery respectively are [Term I 2021 – 22]

(a) positive to negative terminal and negative to positive terminal

(b) positive to negative terminal and positive to negative terminal

(c) negative to positive terminal and positive to negative terminal

(d) negative to positive terminal and negative to positive terminal.

17. A cell of internal resistance r connected across an external resistance R can supply maximum current when [2020]

(a) R = r (b) R > r

(c) R = r/2 (d) R = 0

18. Two sources of equal emf are connected in series. This combination is, in turn connected to an external resistance R. The internal resistance of two sources are r_1 and r_2 ($r_2 > r_1$).If the potential difference across the source of internal resistance r_2 is zero, then R equals to [Term I 2021 – 22]

(a) $\frac{r_1 + r_2}{r_2 - r_1}$ (b) $r_2 - r_1$

(c) $\frac{r_1 r_2}{r_2 - r_1}$ (d) $\frac{r_1 + r_2}{r_1 r_2}$

19. Kirchhoff's first rule $\sum I = 0$ and second rule $\sum IR = \sum E$ (where the symbols have their usual meanings) are respectively based on [Term I 2021 – 22]

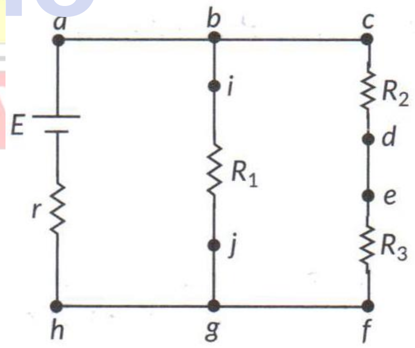
(a) conservation of momentum and conservation of charge

(b) conservation of energy, conservation of charge

(c) conservation of charge, conservation of momentum

(d) conservation of charge, conservation of energy.

20. An experiment was set up with the circuit diagram shown in figure. Given that $R_1 = 10\Omega,\ R_2 = R_3 = 5\Omega, r = 0\Omega$ and E = 5 V



(i) The point with the same potential are –

(a) b,c,d (b) f,h,j

(c) d,e,f (d) a,b,j

(ii) The current through branch bg is

(a) 1 A (b) $\frac{1}{3}A$

(c) $\frac{1}{2}A$ (d) $\frac{2}{3}A$

(iii) The power dissipated in R_1 is

(a) 2 W (b) 2.5 W

(c) 3 W (d) 4.5W

(iv) The potential difference across R_3 is

(a) 1.5 V (b) 2 V

(c) 2.5 V (d) 3 V

[Term I 2021 – 22]

21. Kirchhoff's first rule at a junction in an electrical network, deals with conservation of [2020]

(a) Energy

(b) Charge

(c) Momentum

(d) Both energy and charge

22. A battery is connected to the conductor of non-uniform cross section area. The quantities or quantity which remains constants is [Term I 2021 – 22]

(a) Electric field only

(b) Drift speed and electric field

(c) Electric field and current

(d) Current only.

23. If the potential difference V applied across a conductor is increased to 2 V with its temperature kept constant, the drift velocity of the free electrons in a conductor will

(a) Remains the same.

(b) Becomes half of its previous value.

(c) Be double of its initial value.

(d) Become zero. [Term I 2021 – 22]

24. The temperature (T) dependence of resistivity of material A and material B is represented by figure (i) and figure (ii) respectively. Identify material A and material B. [Term I 2021 – 22]

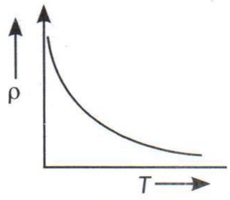


fig (i)

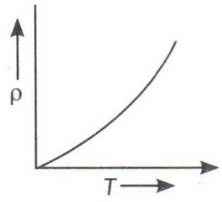


fig (ii)

(a) Material A is copper and material B is germanium

(b) Material A is germanium and material B is copper

(c) Material A is nichrome and material B is germanium

(d) Material A is copper and material Bis nichrome

25. An electric current is passed through a circuit containing two wires of same material, connected in parallel. If the lengths and radii of the wires are in the ratio of 3 : 2 and 2 : 3, then the ratio of the current passing through the wire will be [Term I 2021 – 22]

(a) 2 : 3 (b) 3 : 2

(c) 8 : 27 (d) 27 : 8

26. We use alloys for making standard resistors because they have [Term I 2021 – 22]

(a) low temperature coefficient of resistivity and high specific resistance

(b) high temperature coefficient of resistivity and low specific resistance

(c) low temperature coefficient of resistivity and low specific resistance

(d) high temperature coefficient of resistivity and high specific resistance.

27. A constant voltage is applied between the two ends of a uniform metallic wire, heat 'H' is developed in it. If another wire of the same

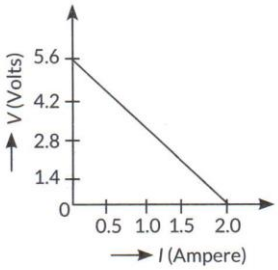
material, double the radius and twice the length as compared to original wire is used then the heat developed in it will be [Term I 2021 – 22]

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

28. Three resistors having values R_1, R_2 and R_3 are connected in series to a battery. Suppose R_1 carries a current of 2.0 A, R_2 has a resistance of 3.0 ohms, and R_3 dissipates 6.0 watts of power. Then the voltage across R_3 is [Term I 2021 – 22]

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

29. A straight line plot showing the terminal potential difference (V) of a cell as a function of current (I) drawn from it, is shown in the figure. The internal resistance of the cell would be then
[Term I 2021 – 22]



(a) 2.8 ohms
(b) 1.4 ohms
(c) 1.2 ohms
(d) Zero

Assertion-Reasoning (1 mark)

30. Assertion: kWhr is a commercial unit used for expressing consumed electric energy.
Reason: Kilo-watt hour is the unit of electric power.

31. Assertion: Material used in the construction of a standard resistance is constantan or manganin.
Reason: Temperature coefficient of constantan is very small.

32. Assertion: The temperature coefficient of resistance is always positive only for metals.
Reason: On increasing the temperature, the resistance of metals and alloys increases.

33. Assertion : If the length of the conductor is doubled, the drift velocity will become half of the original value
(keeping potential difference unchanged).
Reason : At constant potential difference, drift velocity is inversely proportional to the length of the conductor.

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

35. Assertion: The current flowing through a conductor is directly proportional to the drift velocity.
Reason: As the drift velocity increases the current flowing through the conductor decreases.

36. Assertion: Chemical reactions involved in primary cells are irreversible and in secondary cells are reversible.
Reason : Primary cells can be recharged, but secondary cells can not be recharged.

37. Assertion: The average thermal velocity of the electrons in a conductor is zero.
Reason: Direction of motion of electrons are randomly oriented.

38. Assertion (A): In a Metre Bridge experiment, the null point for an unknown resistance is [1] measured. Now, the unknown resistance is put inside an enclosure maintained at a higher temperature. The null point can be obtained at the same point as before by decreasing the value of the standard resistance.
Reason (R): Resistance of metal remains constant with an increase in temperature.

a) Both A and R are true and R is the

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

c) A is true but R is false

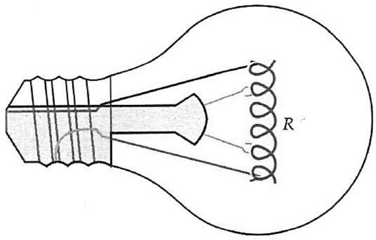
d) A is false and R is also 14. Assertion: In II-atom, according to Bohr's theory election revolves around the nucleus in [1]

39. Assertion: When current through a bulb decreases by 0.5 %, the glow of bulb decreases by 1 %. Reason: Glow (Power) which is directly proportional to square of current.

Case Study

PARAGRAPH 1: Electric Resistance

40. Electrons move more easily through some conductors than others when a potential difference is applied. The opposition of a conductor to current is called its resistance. Collisions are the basic cause of collision. When a p.d. is applied across the ends of a conductor, its free electrons get accelerated. On their way, they frequently collide with the positive metal ions, i.e., their motion is opposed and this opposition to the flow of electrons is called resistance. The number of collisions that the electrons make with atoms/ions depends on the arrangement of atoms or ions in a conductor. So the resistance depends on the nature of the material of the conductor. A long wire offers more resistance than short wire because there will be more collisions in the long wire.



A thick wire offers less resistance than a thin wire because in a thick wire, more area of cross-section is available for the flow of electrons. The resistance of metals increases when their temperature increases. Certain alloys such as constantan and manganin show very small changes of resistance with temperature and are used to make standard resistors. The resistance of semiconductors and insulators decreases as their temperature increases.

QUESTIONS (Answer any four of the following questions)

1. The resistance of a conductor is

(a) inversely proportional to the length
(b) directly proportional to the square of the radius
(c) inversely proportional to the square of the radius
(d) directly proportional to the square root of the length.

2. The dimensions of a block are 1cm x 1cm x 100cm. If the specific resistance of the material is $3 \times 10^{-7}\Omega m$, then the resistance between two opposite rectangular bases is
(a) $3 \times 10^{-9}\Omega$ (b) $3 \times 10^{-7}\Omega$
(c) $3 \times 10^{-5}\Omega$ (d) $3 \times 10^{-1}\Omega$

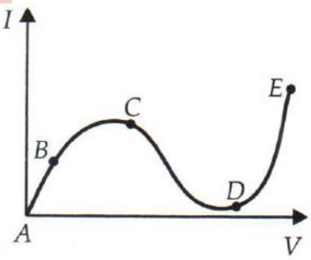
3. Two wires of the same material have lengths l and $2l$ and areas of cross-section $4A$ and A respectively. The ratio of their specific resistances would be

(a) 1: 2 (b) 8:1
(c) 1: 8 (c) 1: 1

4. A wire of resistance R is stretched to twice of its original length. Its new resistance will be

(a)4R (b) $\frac{R}{9}$ (c)3R (d) $\frac{R}{3}$

5. From the graph between current I and voltage V, identify the portion corresponding to the negative Resistance

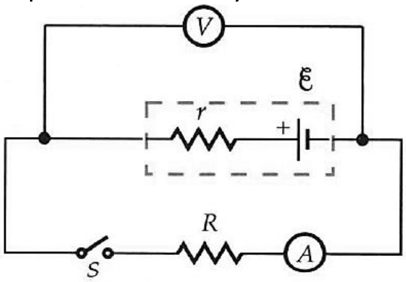


(a) AB (b) BC (c) CD (d) DE

PARAGRAPH 2: Internal Resistance of a Cell

41. Any source of emf has some internal resistance itself, called internal or source resistance. When we connect the terminals of a cell, a current flow in the wire from positive terminal of the cell towards the negative terminal. But inside the electrolyte of the cell, the positive ions flow from the lower to the higher potential (or negative ions from the higher to the lower potential) against the background of other ions and neutral atoms of the electrolyte. So the electrolyte offers some resistance to the flow of current inside the cell. The resistance offered by the electrolyte to the flow of current between its electrodes is called the

internal resistance of the cell. It depends on nature and concentration of electrol5rte, separation and common area of the electrodes dipped in the electrolyte, and temperature of the electrolyte. Internal resistance causes energy loss which occurs inside a battery when a current is driven round an external circuit. The greater the current, the greater the energy loss and the small is the terminal p.d. of the battery.



The internal resistance of a battery increases with age and so reduces the current it can drive.
The knowledge of internal resistance becomes important when we consider how a source of emf can deliver maximum power to an appliance connected to it. According to maximum power theorem this occurs when the internal resistance of the source equals the resistance of the appliance.

QUESTIONS (Answer any four of the following questions)

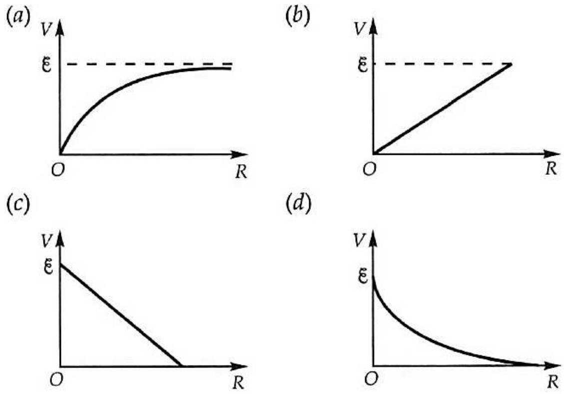
6. The internal resistance of a cell

(a) always acts in the cell in open circuit
(b) acts only in closed circuit and it reduces the EMF
(c) acts only in closed circuit and it reduces the current
(d) none of these.

7. A battery of emf 10 V and internal resistance 3 Ω is connected to a resistor. The current in the circuit is 0.5 A. The terminal voltage of the battery when the circuit is closed is

(a) $10\ V$ (b) $zero$
(c) $1.5\ V$ (d) $8.5\ V$

8. A cell of emf 6 and internal resistance r is connected across an external resistance R. The graph showing the variation of $P.D.$ across R versus R is



9. The maximum power drawn out of the cell from a source is given by

(a) $\frac{\xi^2}{2r}$ (b) $\frac{\xi^2}{4r}$
(c) $\frac{\xi^2}{r}$ (d) $\frac{\xi^2}{3r}$

where r is internal resistance of the cell.

10. A battery of 16 V and internal resistance 2 Ω is connected to an external resistance R. Find the value of current so that power in circuit is maximum.

(a)8 A (b)2A
(c) 16 A (d) 4 A

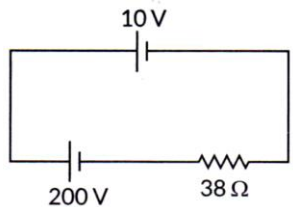
Question

42. Define the term 'drift velocity' of electrons in a current carrying conductor. Obtain the relationship between the current density and the drift velocity of electrons. [2020]

43. Define the term 'mobility' of charge carriers in a current carrying conductor. Obtain the relation for mobility in terms of relaxation time.

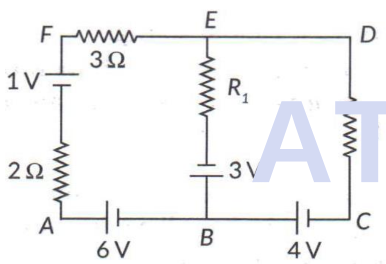
44. Using the concept of drift velocity of charge carriers in a conductor, deduce the relationship between current density and resistivity of the conductor. [Delhi 2015C]

45. A 10 V cell of negligible internal resistance is connected in parallel across a battery of emf 200 V and internal resistance 38 Ω as shown in the figure. Find the value of current in the circuit. [2018]

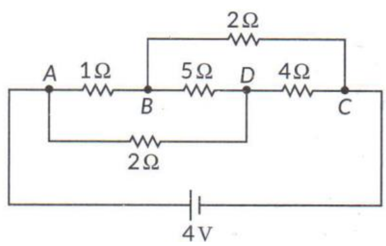


46. A cell of emf 'E' and internal resistance 'r' is connected across a variable resistor 'R'. Plot a graph showing variation of terminal voltage 'V' of the cell versus the current 'I'. Using the plot, show how the emf of the cell and its internal resistance can be determined. [AI 2014]

47. Use Kirchhoff's rules to determine the potential difference between the points A and D when no current flows in the BE of the electric network shown in the figure. [AI 2015]

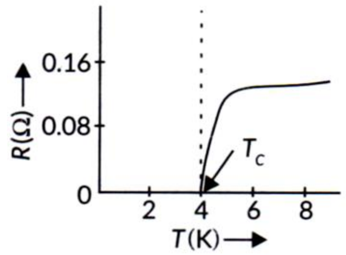


48. Calculate the current drawn from the battery by the network of resistors shown in the figure. [AI 2015C]

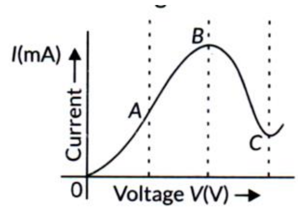


49. A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor : current, current density, electricity field, drift speed? [1/3, Delhi 2015C]

50. (i) The graph between resistance (R) and temperature (T) for Hg is shown in the figure. Explain the behaviour of Hg near 4 K.



(ii) In which region of the graph shown in the figure is the resistance negative and why?

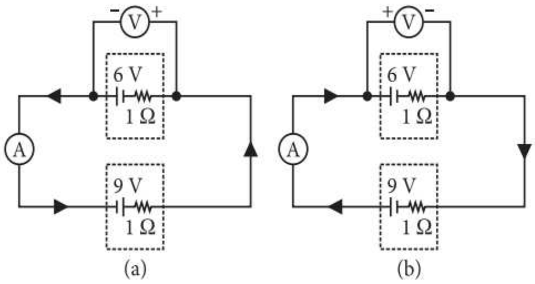


51. A cell of emf 'E' and internal resistance 'r' is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the current I. It is found that when R = 4 Ω, the current is 1 A and when R is increased to 9 Ω, the current reduces to 0.5 A. Find the values of the emf E and internal resistance r. [Delhi 2015]

52. (a) Two cells of emf E_1 and E_2 have their internal resistances r_1 and r_2 respectively. Deduce an expression for the equivalent emf and internal resistance of their parallel combination when connected across an external resistance R. Assume that the two cells are supporting each other.
(b) In case the two cells are identical, each of emf E = 5 V and internal resistance r = 2 Ω, calculate voltage across the external resistance R = 10 Ω. [2020]

53. A variable resistor R is connected across a cell of emf E and internal resistance r. [2020 – 21]
    (a) Draw the circuit diagram.
    (b) Plot the graph showing variation of potential drop across R as function of R.
    (c) At what value of R current in circuit will be maximum.

54. In the two electric circuits shown in the figure, determine the readings of ideal ammeter (A) and the ideal voltmeter (V).



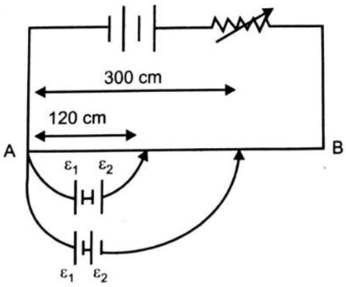
55. A steady current flows in a metallic conductor of non- uniform cross-section. Which of these quantities is constant along the conductor : current, current density, electric field, drift speed?

56. Write a relation between current and drift velocity of electrons in a conductor. Use this relation to explain how the resistance of a conductor changes with the rise in temperature.

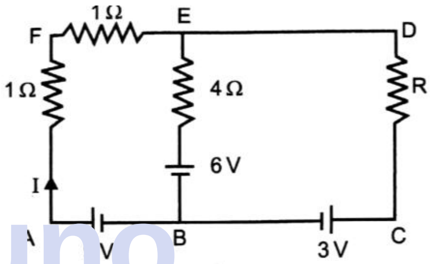
57. (a) Define the term drift velocity.
    (b) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of conductor depend?
    (c) Why alloys like constantan and manganic are used for making standard resistors?

58. A potentiometer wire of length 1 m has a resistance of 10Ω. It is connected to a 6 V battery in series with resistance of 5 Ω. Determine the emf of the primary cell which gives a balance point at 40 cm.

59. In the figure, a long uniform potentiometer wire AB is having a constant potential gradient along its length. The null points for the two primary cells of emfs ε_1 *and* ε_2 connected in the manner shown are obtained at a distance of 120 cm and 300 cm from the end A. Find (i) $\varepsilon_1/\varepsilon_2$ and (ii) position of null point for the cell ε_1.
    How is the sensitivity of a potentiometer increased?



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



61. Define drift Velocity & Relaxation Time

62. Deduce Ohm's law using the concept of drift Velocity.

63. Establish a relation between electric current and drift velocity.

64. Define the term current density of a metallic conductor. Deduce the relation connecting current density (J) and the conductivity σ of the conductor, when an electric field E, is applied to it.

65. What is conductivity & mobility? Derive an expression for conductivity in terms of mobility.

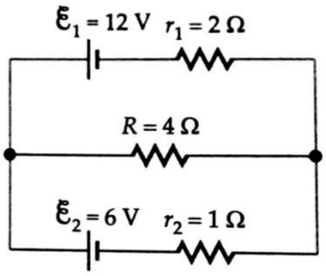
66. Two cells of emfs 1.5 V and 2.0 V and internal resistances 0.2 Ω and 0.3 Ω respectively are

connected in parallel. Calculate the emf and internal resistance of the equivalent cell.

67. State Kirchhoff's rules. Explain briefly how these rules are justified.

68. Use Kirchhoff's rules to obtain conditions for the balance condition in a Wheatstone bridge.

69. Find the potential difference across each cell and the rate of energy dissipation in R.



70. Two cells of emfs 1.5 V and 2.0 V and internal resistances 1 Ω and 2 Ω respectively are connected in parallel so as to send current in the same direction through an external resistance of 5Ω.

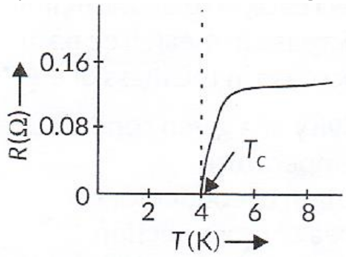
i. Draw the circuit diagram.

ii. Using Kirchhoff's laws, calculate

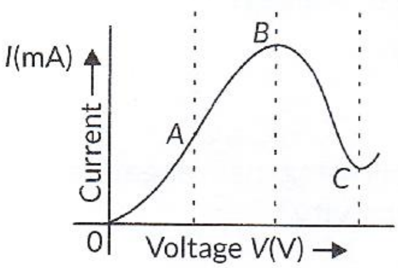
a. Current through each branch of the circuit.

b. P.d. across the 5 Ω resistance.

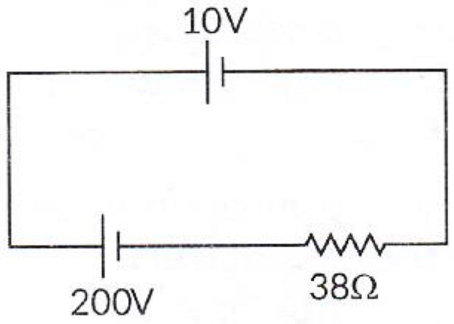
71. (i) The graph between resistance (R) and temperature (T) for Hg is shown in the figure. Explain the behaviour of Hg near 4 K.



(ii) In which region of the graph shown in the figure is the resistance negative and why?

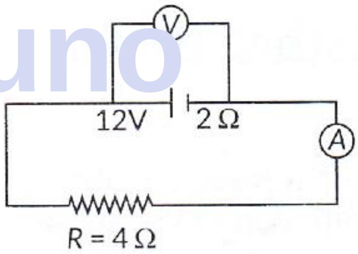


72. A 10 V cell of negligible internal resistance is connected in parallel across a battery of emf 200 V and internal resistance 38 Ω as shown in the figure. Find the value of current in the circuit.



73. (a) The potential difference applied across a given resistor is altered so that the heat produced per second increases by a factor of 9. By what factor does the applied potential difference change?

(b) In the figure shown, an ammeter A and a resistor of 4 Ω are connected to the terminals of the source. The emf of the source is 12 V having an internal resistance of 2 Ω. Calculate the voltmeter and ammeter readings.



74. (a) Two cells of emf E_1 and E_2 have their internal resistances r_1 and r_2, respectively. Deduce an expression for the equivalent emf and internal resistance of their parallel combination when connected across an external resistance R. Assume that the two cells are supporting each other.

(b) In case the two cells are identical, each of emf $E = 5\,V$ and internal resistance $r = 2\,\Omega$, calculate voltage across the external resistance $R = 10\,\Omega$.

ARVIND ACADEMY

For Solutions

Download Arvind Academy App

Click Link: http://bit.ly/2kTWbkj

SURE SHOT QUESTIONS

ARVIND ACADEMY

Chapter – 04

Moving Charges and Magnetism

MCQ (1 mark)

1. Two charged particles traverse identical helical paths in a completely opposite sense in a uniform magnetic field $\vec{B} = B_0 \hat{k}$.
   (a) They have equal z-components of momenta.
   (b) They must have equal charges.
   (c) They necessarily represent a particle-antiparticle pair.
   (d) The charge to mass ratio satisfy:
   $$\left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0.$$

2. Biot – Savart law indicates that the moving electrons (velocity $\vec{v}$) produce a magnetic field $\vec{B}$ such that
   (a) $\vec{B} \perp \vec{v}$
   (b) $\vec{B} \parallel \vec{v}$
   (c) It obeys inverse cube law.
   (d) It is along the line joining the electron and point of observation.

3. A current carrying circular loop of radius R is placed in the x-y plane with centre at the origin. Half of the loop with x > 0 is now bent so that it now lies in the y-z plane.
   (a) The magnitude of magnetic moment now diminishes.
   (b) The magnetic of $\vec{B}$ at (0, 0, z), z >> R increases.
   (c) The magnitude of $\vec{B}$ at (0, 0, z), z >> R is unchanged.

4. An electron is projected with uniform velocity along the axis of a current carrying long solenoid. Which of the following is true?
   (a) The electron will be accelerated along the axis.
   (b) The electron path will be circular about the axis.
   (c) The electron will experience a force at 45^0 to the axis and hence execute a helical path.
   (d) The electron will continue to move with uniform velocity along the axis of the solenoid.

5. In a cyclotron, a charged particle
   (a) Undergoes acceleration all the time.
   (b) Speeds up between the dees because of the magnetic field.
   (c) Speeds up in a die.
   (d) Slows down within a dee and speeds up between dees.

6. A circular current loop of magnetic moment M is in an arbitrary orientation in an external magnetic field $\vec{B}$. The work done to rotate the loop by 30^0 about an axis perpendicular to its plane is
   (a) MB (b) $\sqrt{3}\frac{MB}{2}$
   (c) $\frac{MB}{2}$ (d) zero.

7. A straight conducting rod of length ℓ and mass m is suspended in a horizontal plane by a pair of flexible strings in a magnetic field of magnitude B. To remove the tension in the supporting

strings, the magnitude of the current in the wire is

[Term I 2021 – 22]

(a) $\frac{mgB}{\ell}$ (b) $\frac{mg\ell}{B}$

(c) $\frac{mg}{\ell B}$ (d) $\frac{\ell B}{mg}$

8. A current carrying wire kept in a uniform magnetic field will experience a maximum force when it is [Term I 2021 – 22]

(a) Perpendicular to the magnetic field
(b) Parallel to the magnetic field
(c) At an angle of 45^0 to the magnetic field
(d) At an angle of 60^0 to the magnetic field

9. A particle of mass m and charge -q is moving with a uniform speed v in a circle of radius r, with another charge q at the centre of the circle. The value of r is [2023]

(a) $\frac{1}{4\pi\varepsilon_0 m}\left(\frac{q}{v}\right)$ (b) $\frac{1}{4\pi\varepsilon_0 m}\left(\frac{q}{v}\right)^2$

(c) $\frac{m}{4\pi\varepsilon_0}\left(\frac{q}{v}\right)$ (d) $\frac{m}{4\pi\varepsilon_0}\left(\frac{q}{v}\right)^2$

10. A charge particle after being accelerated through a potential difference 'V' enters in a uniform magnetic field and moves in a circle of radius r. If V is doubled, the radius of the circle will become

[2020]

(a) 2r (b) $\sqrt{2}\,r$

(c) 4r (d) $r/\sqrt{2}$

11. Two particles of masses m_1 and m_2 have equal charges. They are accelerated from rest through a potential difference V and then enter in a region of uniform magnetic field $\vec{B}$. If they describe circular paths of radii r_1 and r_2, respectively, then the value of m_1/m_2 is [AI 2020C]

(a) $\left(\frac{r_2}{r_1}\right)^2$ (b) $\frac{r_1 V}{r_2 B}$

(c) $\left(\frac{r_1}{r_2}\right)^2$ (d) $\frac{r_1^2 V}{r_2^2 B}$

12. An electron is released from rest in a region of uniform electric and magnetic fields acting parallel to each other. The electron will [2020]

(a) Move in a straight line.
(b) Move in a circle.
(c) Remain stationary
(d) Move in a helical path.

13. Two horizontal thin long parallel wires, separated by a distance r carry current I each in the opposite directions. The net magnetic field at a point midway between them, will be [2023]

(a) Zero
(b) $\left(\frac{\mu_0 I}{2\pi r}\right)$ vertically downward
(c) $\left(\frac{2\mu_0 I}{r}\right)$ vertically upward
(d) $\left(\frac{\mu_0 I}{\pi r}\right)$ vertically downward

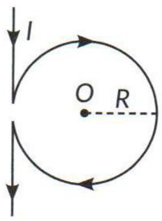
14. The magnetic field at the centre of a current carrying circular loop of radius R is B_1. The magnetic field at a point on its axis at a distance

R from the center of the loop is B_2. Then the ratio (B_1/B_2) is [Term I 2021 – 22]

(a) $2\sqrt{2}$ (b) $\frac{1}{\sqrt{2}}$

(c) $\sqrt{2}$ (d) 2

15. A current I flows through a long straight conductor which is bent into a circular loop of radius R in the middle as shown in the figure. The magnitude of the net magnetic field at point O will be [AI 2020]



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

(c) $\frac{\mu_0 I}{4\pi R}$ (d) $\frac{\mu_0 I}{2R}\left(1-\frac{1}{\pi}\right)$

16. Two long parallel wires kep 2 m apart carry 3A current each, in the same direction. The force per unit length on one wire due to the other is [2023]

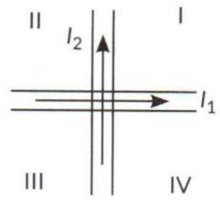
(a) $4.5\times10^{-5}\ Nm^{-1}$, attractive

(b) $4.5\times10^{-7}\ Nm$, repulsive

(c) $9\times10^{-7}\ Nm$, repulsive

(d) $9\times10^{-5}\ Nm$, attractive

17. Two wires carrying currents I_1 and I_2 lie, one slightly above the other, in a horizontal plane as shown in figure. The region of vertically upward strongest magnetic field is [Term I 2021 – 22]



(a) I (b) II

(c) III (d) IV

18. Two parallel conductors carrying current of 4.0 A and 10.0 A are placed 2.5 cm apart in vacuum. The force per unit length between them is [Term I 2021 – 22]

(a) 6.4×10^{-5} N m^{-1} (b) 6.4×10^{-2} N m^{-1}

(c) 4.6×10^{-4} N m^{-1} (d) 3.2×10^{-4} N m^{-1}

19. The magnetic dipole moment of a current carrying coil does not depend upon [2020]

(a) Number of turns of the coil

(b) Cross-sectional area of the coil

(c) Current flowing in the coil

(d) Material of the turns of the coil.

20. If an ammeter is to be used in place of a voltmeter,then we must connect with the ammeter a [Term I 2021 – 22]

(a) low resistance in parallel

(b) low resistance in series

(c) high resistance in parallel

(d) high resistance in series.

21. Two wires of the same length are shaped into asquare of side 'a' and a circle with radius 'r'. If theycarry same current, the ratio of their

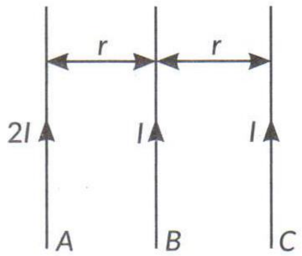
magnetic moment is [Term I 2021 – 22]

(a) $2:\pi$ (b) $\pi:2$

(c) $\pi:4$ (d) $4:\pi$

22. Three infinitely long parallel straight current carrying wires A, B and C are kept at equal distance from each other as shown in the figure. The wire C experiences net force F. The net force on wire C, when the current in wire A is reversed will be

[Term I 2021 – 22]



(a) zero (b) F/2

(c) F (d) 2F

23. The coil of a moving coil galvanometer is woundover a metal frame in order to

[Term I 2021 – 22]

(a) reduce hysteresis

(b) increase sensitivity

(c) increase moment of inertia

(d) provide electromagnetic damping

24. The current sensitivity of a galvanometer increasesby 20%. If its resistance also increases by 25%, the voltage sensitivity will [Term I 2021 – 22]

(a) Decrease by 1%

(b) Increased by 5%

(c) Increased by 10%

(d) Decrease by 4%

Assertion-Reasoning (1 mark)

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

25. Assertion (A): A current carrying square loop made of a wire of length L is placed in a magnetic field. It experiences a torque which is greater than the torque on a circular loop made of the same wire carrying the same current in the same magnetic field.

Reason (R): A square loop occupies more area than a circular loop, both made of wire of the same length. [2023]

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

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

(c) Assertion (A) is true, but Reason (R) is false.

(d) Assertion (A) is false and Reason (R) is also false.

26. Assertion (A): The deflecting torque acting on a current carrying loop is zero when its plane is perpendicular to the direction of magnetic field.

Reason (R): The deflecting torque acting on a loop of magnetic moment $\vec{m}$ in a magnetic field $\vec{B}$ is given by the dot product of $\vec{m}$ and $\vec{B}$.

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

27. Assertion (A): When radius of a current carrying loop is doubled, its magnetic moment becomes four times.
Reason (R) : The magnetic moment of a current carrying loop is directly proportional to the area of the loop. [Term I 2021 – 22]
(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 correct explanation of (A).
(c) (A) is true, but (R) is false.
(d) (A) is false and (R) is also false.

28. Assertion (A): Higher the range, lower is the resistance of an ammeter.
Reason (R) : To increase the range of an ammeter additional shunt is added in series to it.
(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 correct explanation of (A).
(c) (A) is true, but (R) is false.
(d) (A) is false and (R) is also false.
[Term I 2021 – 22, 2021C]

29. Assertion (A): A proton and an electron, with same momenta, enter in a magnetic field in a direction at right angles to the lines of the force. The radius of the paths followed by them will be same. Reason (R): Electron has less mass than the proton. Select the most appropriate answer from the options 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.
[Term I 2021 – 22]

30. Assertion (A): To increase the range of an ammeter, we must connect a suitable high resistance in series to it.
Reason (R) : The ammeter with increased range should have high resistance. Select the most appropriate answer from the options 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.
[Term I 2021 – 22]

31. Assertion (A): On increasing the current sensitivity of a galvanometer by increasing the number of turns, may not necessarily increase its voltage sensitivity.
Reason (R) : The resistance of the coil of the galvanometer increases on increasing the number

of turns. Select the most appropriate answer from the options given below: [Term I 2021 – 22]

(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.

32. Assertion (A): An ammeter is connected in series in the circuit.
Reason (R): An ammeter is a high resistance galvanometer.

33. Assertion (A): In a conductor, free electrons keep on moving but no magnetic force acts on a conductor in a magnetic field.
Reason (R) : Force on free electron due to magnetic field always acts perpendicular to its direction of motion.

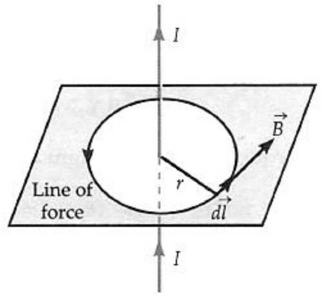
34. Assertion (A) : The magnetic field intensity at the centre of a circular coil carrying current changes, if the current through the coil is doubled.
Reason (R): The magnetic field intensity is dependent on current in conductor.

35. Assertion (A): When a charged particle moves perpendicular to magnetic field then its kinetic energy and momentum gets affected.
Reason (R): Force changes velocity of charged particle.

Case study Question

PARAGRAPH 1: Ampere's Circuital Law

36. Just as Gauss's law is an alternative form of Coulomb's law in electrostatics, similarly we have Ampere's circuital law as an alternative form of Biot-Savart law in magnetostatics. Ampere found that the magnetic lines of force of a straight current carrying conductor are concentric circles in a plane perpendicular to the conductor. Ampere's law stated with reference to the loops of magnetic lines of force. We consider a loop to be made up of a number of small line elements. Consider one such element of length dl. Let B_t be the tangential component of field $\vec{B}$ at this element. We multiply it by the element length dl. We add all such products. When the lengths of these elements becomesmall and their number gets larger, this summation tends to an integral. Ampere's law states that the line integral of the magnetic field$\vec{B}$ around any closed loop is equal to μ_0 times the net current I passing through the closed loop.



$$\oint \vec{B}\,.\vec{dl} = \mu_0\, I$$

The closed loop is called Amperean loop. Ampere's law is valid for any arbitrary closed loop and holds only

for steady currents. However, Ampere's law is useful only for calculating the magnetic field only in highlysymmetrical situations where $\vec{B}$is tangential to loop and has a non-zero constant B, or $\vec{B}$ is normal to the

loop, or B vanishes.

QUESTIONS (Answer any four of the following questions)

1. Only the current inside the Amperean loop

contributes in

(a) finding magnetic field at any point on theAmperean loop

(b) line integral of magnetic field

(c) in both of the above
(d) in neither (a) nor (b).

2. An electriccurrent passes through a long wire. At adistance 5 cm from the wire, the magnetic field is B. Thefield at 20 cm from the wire would be

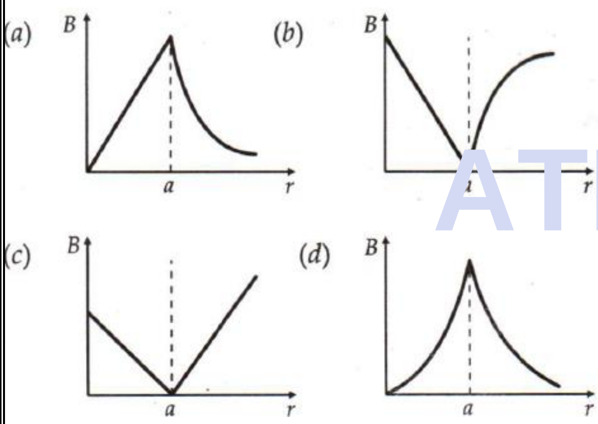
(a) B/2 (b) B/3
(c) B/4 (d) B/5

3. 1 A current flows through an infinitely long straightwire. The magnetic field produced at a point 1 m awayfrom it is

(a) $2 \times 10^{-3} T$ (b) $2\pi \times 10^{-3} T$

(c) $2 \times 10^{-7} T$ (d) $2\pi \times 10^{-7} T$

4. A long straight wire of circular cross-section (radiusa) carries a steady current I and the current I is uniformlydistributed across this cross-section. Which of the followingplots represents the variation of magnitude of magneticfield B with distance r from the centre of the wire?



5. A steady electric current is flowing through a cylindrical conductor.

(a) The magnetic field in the vicinity of the conductoris zero

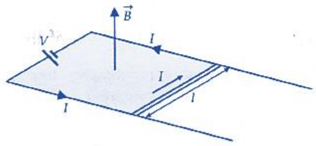
(b) The electric field in the vicinity of the conductoris zero

(c) The magnetic field at the axis of the conductoris zero

(d) The electric field at the axis of the conductoris zero.

PARAGRAPH 2: Force on a Current-Carrying Conductor in a Magnetic Field

37. When a conductor carrying a current is placed in an external magnetic field, it experiences a mechanicalforce. A current is an assembly of moving charges and a magnetic field exerts a force on a moving charge.That is why a current-carrying conductor when placed in a magnetic field experiences a sideways force asthe force experienced by the moving electrons is transmitted to the conductor as a whole. A conductor of length l carrying a current I held in a magnetic field $\vec{B}$ at an angle θ with it, experiences a force given by $F = \Pi B\ sin\ 0$.



In vector form, $\vec{F} = I(\vec{l} \times \vec{B})$

The direction of $\vec{F}$ is perpendicular to both $\vec{l}$ and $\vec{B}$ and is given by Fleming's left hand rule. A conducting bar with mass m and length l slides over horizontal rails that are connected to voltage source V. The sourcemaintains a constant current I in the rails and bar, and a uniform magnetic field $\vec{B}$, acting vertically upwards, acts in the region between the rails.

QUESTIONS (Answer any four of the following questions)

6. Ignoring friction, air resistance and electricalresistances, the magnitude and direction of the net forceon the conducting bar is

(a) IlB, to the right

(b) IlB, to the left

(c) 2 IlB, to the right

(d) 2 IlB, to the left

7. If the bar has mass m, find the distance d that thebar must move along the rails from rest to attain speed v.

(a) $\frac{3v^2m}{2\Pi B}$ (b) $\frac{5v^2m}{2\Pi B}$

(c) $\frac{v^2m}{\Pi B}$ (d) $\frac{v^2m}{2\Pi B}$

8. A force acting on a conductor of length 5 m carrying a current of 8 A kept perpendicular to the magnetic fieldof 1.5 T is

(a) 100 N (b) 60 N (c) 50 N (d) 75 N

9. A straight wire of mass 200 g and length 1.5 m carries a current of 2 A. It is suspended in mid air by a uniform horizontal magnetic field B. The magnitude of B(in tesla) is (assume that $g = 9.8ms^{-2}$)

(a) 2 (b) 1.5 (c) 0.55 (d) 0.65

10. A wire of length l carries a current i along x-axis. A magnetic field exists given by

$$B = B_0(\hat{\imath} + \hat{\jmath} + \hat{k})T$$

The magnitude of the magnetic force acting on the wire is

(a) ilB_0 (b)$\sqrt{3}\ ilB_0$

(c) $2ilB_0$ (d) $\sqrt{2}\ ilB_0$

Questions

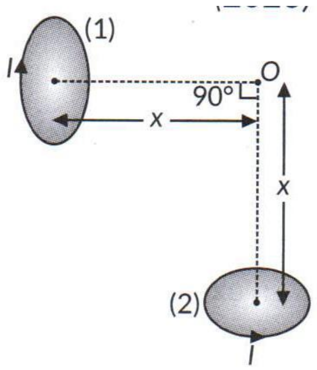
38. A straight wire of mass 200 g and length 1.5 m carries a current of 2A. It is suspended in mid air by a uniform magnetic field B. What is the magnitude of the magnetic field?

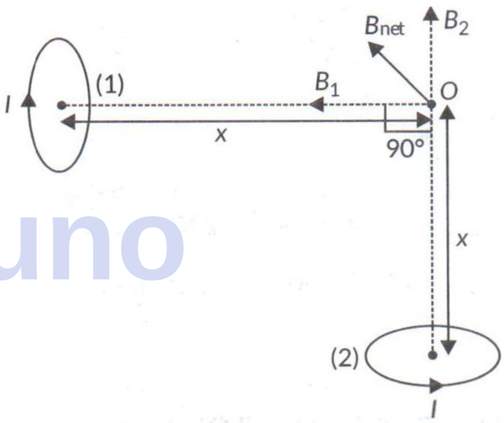
[2/3, Foreign 2015]

39. A charged particle q is moving in the presence ofa magnetic field B which is inclined to an angle 30°with the direction of the motion of the particle.Draw the trajectory followed by the particle in thepresence of the field and explain how the particledescribes this path.

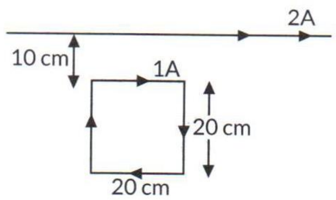
[Delhi 2019]

40. Two very small identical circular loops, (1) and (2), carrying equal currents I are placed vertically (with respect to the plane of the paper) with their geometrical axes perpendicular to each other as shown in the figure. Find the magnitude and direction of the net magnetic field produced at the point O. [2017C, Foreign 2014]





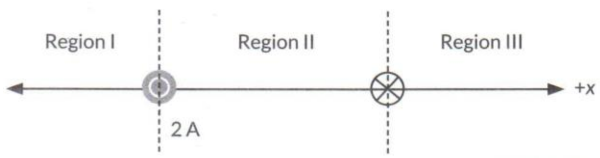
41. A square loop of side 20 cm carrying current of 1 A is kept near an infinite long straight wire carrying a current of 2 A in the same plane as shown in the figure.



Calculate the magnitude and direction of the net force exerted on the loop due to the current carrying conductor. [AI 2015C]

42. An ammeter of resistance 0.8 Ω can measure a current upto 1.0 A. Find the value of shunt resistance required to convert this ammeter to measure a current upto 5.0 A. [2020]

43. Two straight infinitely long wires are fixed in space so that the current in the left wire is 2 A and directed out of the plane of the page and the current in the right wire is 3 A and directed into the plane of the page. In which region(s) is/are there a point on the x-axis, at which the magnetic field is equal to zero due to these currents carrying wires? Justify your answer.



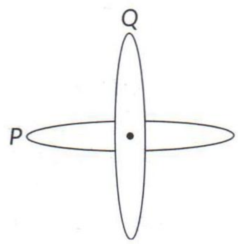
44. A proton, a deuteron and an alpha particle are accelerated through the same potential difference and then subjected to a uniform magnetic field $\vec{B}$, perpendicular to the direction of their motions. [AI 2019]

Compare

(i) Their kinetic energies, and

(ii) If the radius of the circular path described by proton is 5 cm, determine the radii of the path described by deuteron and alpha particle.

45. Two identical loops P and Q each of radius 5 cm are lying in perpendicular planes such that they have a common centre as shown in the figure. Find the magnitude and direction of the net magnetic field at the common centre of the two coils, if they carry currents equal to 3 A and 4 A respectively. [AI 2017]



46. Two infinitely long straight wires A_1 and A_2 carrying currents I and 2I flowing in the same directions are kept 'd' distance apart. Where should a third straight wire A_3 carrying current 1.5 I be placed between A_1 and A_2 so that it experiences no net force due to A_1 and A_2? Does the net force acting on A_3 depend on the current flowing through it? [Delhi 2019]

47. (a) Write an expression of magnetic moment associated with a current (I) carrying circular coil of radius r having N turns.

(b) Consider the above mentioned coil placed in YZ plane with its centre at the origin. Derive expression for the value of magnetic field due to it at point (x, 0, 0). [2020]

48. (a) Define current sensitivity of a galvanometer. Write its expression.

(b) A galvanometer has resistance G and shows full scale deflection for current I_g.

(i) How can it be converted into an ammeter to measure current upto $I_0 (I_0 > I_g)$?

(iii) What is the effective resistance of this ammeter? [2020]

49. (a) Briefly explain how a galvanometer isconverted into an ammeter.

(b) A galvanometer coil has a resistance of 15 Ω and it shows full scale deflection for a current of4 mA. Convert it into an ammeter of range 0 to 6A.

[AI 2019]

50. A circular loop of radius R carries a current I. Obtain an expression for the magnetic field at a point on its axis at a distance x from its centre. [3/5, 2020]

OR

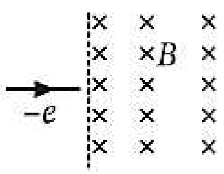
Write, using Biot – Savart law, the expression for the magnetic field $\vec{B}$ due to an element $d\vec{l}$ carrying current I at a distance $\vec{r}$ from it in a vector form. Hence derive the expression for the magnetic field due to a current carrying loop of radius R at a point P distant x from its centre along the axis of the loop. [AI 2015]

51. Derive the expression for the torque acting on therectangular current carrying coil of a galvanometer.Why is the magnetic field made radial? [3/5, 2020]

OR

Obtain the expression for the deflecting torqueacting on the current carrying rectangular coil of agalvanometer in a uniform magnetic field. Why is aradial magnetic field employed in the moving coil galvanometer? [3/5, 2020]

52. An electron moving horizontally with a velocity of $4 \times 10^4 m/s$ enters a region of uniform magnetic field of 10^{-5} T acting vertically upward as shown in the figure. Draw its trajectory and find out the time it takes to come out of the region of magnetic field.



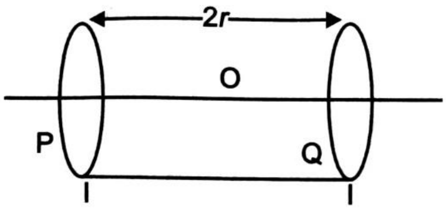
53. (a) How is a toroid different from a solenoid?
(b) Use Ampere's circuital law to obtain the magnetic field inside a toroid.
(c) Show that in an ideal toroid, the magnetic field (i) inside the toroid and (ii) outside the toroid at any point in the open space is zero.

54. (a) Write the expression for the force $\vec{F}$ acting on a particle of mass m and charge q moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. Under what conditions will it move in (i) a circular path and (ii) a helical path?
(b) Show that the kinetic energy of the particle moving in Magnetic field remains constant.

55. Two long straight parallel conductors carry steady current I_1 and I_2 separated by a distance d. if the currents are flowing in the same direction, show how the magnetic fields set up if one produces an attractive force on the other. Obtain the expression for this force. Hence define one ampere.

56. (a) Write the expression for the force $\vec{F}$, acting on a charged particle of charge 'q', moving with a velocity $\vec{v}$ in the presence of both electric field $\vec{E}$ and magnetic field $\vec{B}$. Obtain the condition under which the particle moves undeflected through the fields.
(b) A rectangular loop of size $l \times b$ carrying a steady current I is placed in a uniform magnetic field $\vec{B}$. Prove that the torque $\vec{\tau}$ acting on the loop is given by, $\vec{\tau} = \vec{m} \times \vec{B}$ where $\vec{m}$ is the magnetic moment of the loop.

57. Two identical circular loops, P and Q, each of radius r and carrying equal currents are kept in the parallel planes having a common axis passing through O. the direction of current in P is clockwise and in Q is anti – clockwise as seen from O which is equidistant from the loops P and Q. find the magnitude of the net magnetic field at O.



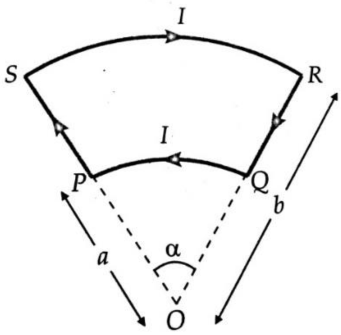
58. A rectangular coil of sides ‘*l*’ and ‘b’ carrying a current I is subjected to a uniform magnetic field $\overrightarrow{B}$, acting perpendicular to its plane. Obtain the expression for the torque acting on it.

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

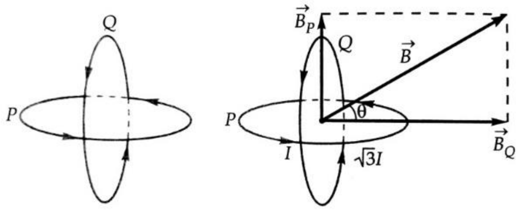
60. State Bio-Savart’s law, Write in vector form.

61. Derive the expression for the magnetic field in the vector form at a point on the axis of a circular current carrying loop.

62. Fig., shows a current loop having two circular segments and joined by two radial lines. Find the magnetic field at the centre O.



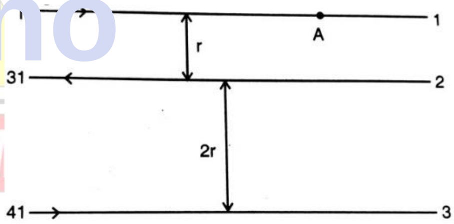
63. Two identical coils P and Q each of radius R are lying in perpendicular places such that they have a common centre. Find the magnitude and direction of the magnetic fields at the common centre of the two coils, if they carry currents equal to *I* and $\sqrt{3}I$.



64. State Ampere’s circuital law. Use this law to obtain the expression for the magnetic field inside an air cored straight solenoid having turn density n and current I.

65. What is Lorentz Force? Write the proper expression for it.

66. The figure shows three infinitely long straight parallel current carrying conductors. Find the
i. Magnitude and direction of the net magnetic field at point A lying on conductor 1,
ii. Magnetic force on conductor 2.



67. An electron of mass m_e revolves around a nucleus of charge $+Z_e$. Show that it behaves like a tiny magnetic dipole. Hence, prove that the magnetic moment associated with it is expressed as $\vec{\mu} = -\frac{e}{2m_e}\vec{L}$, where $\vec{L}$ is the orbital angular momentum of the electron. Give the significance of negative sign.

68. Draw a labelled diagram of a moving coil galvanometer. Describe briefly its principle & working. How will you convert galvanometer into (i) ammeter (ii) Voltmeter.

69. Explain Current & Voltage sensitivity of galvanometer

70. A rectangular coil having each turn of length 5 cm and breadth 2 cm is suspended freely in a radial magnetic field of induction 2.5 x 10^{-2}Wb m^{-2}, torsional constant of the suspension fibre is 1.5 x 10^{-8} Nm rad^{-1}. The coil deflects through an angle of 0.2 radian when a current of 2 μA is passed through it. Find the number of turns of the coil.

71. An ammeter of resistance 0.80Ω can measure currents upto 1.0 A. (i) What must be the shunt resistance to enable the ammeter to measure current upto 5.0 A? (ii) What is the combined resistance of the ammeter and the shunt?

72. A galvanometer can be converted into a voltmeter of certain range by connecting a resistance of 980Ω in series with it. When the resistance is 470Ω connected in series, the range is halved. Find the resistance of the galvanometer.

SURE SHOT QUESTIONS

ARVIND ACADEMY

Chapter – 05

Magnetism and Matter

MCQ (1 mark)

1. The magnetic field of the earth can be modelled by that of a point dipole placed at the centre of the Earth. The dipole axis makes an angle of 11.3^0 with the axis of the earth. At Mumbai, declination is nearly zero. Then,
   (a) The declination varies between 11.3^0 W to 11.3^0E.
   (b) The least declination is 0^0.
   (c) The plane defined by dipole axis and the earth axis passes through Greenwich.
   (d) Declination averaged over the earth must be always negative.

2. In a permanent magnet at room temperature
   (a) magnetic moment of each molecule is zero
   (b) the individual molecules have non-zero magnetic moment which are all perfectly aligned
   (c) domains are partially aligned
   (d) domains are all perfectly aligned.

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

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

   (a) Case (i) contradicts Gauss's law for electrostatic fields.
   (b) Case (ii) contradicts Gauss's law for magnetic fields.
   (c) Case (i) agrees with $\oint \vec{E}.d\vec{l} = 0$.
   (d) Case (ii) contradicts $\oint \vec{H}.d\vec{l} = I_{en}$.

4. A paramagnetic sample shows a net magnetization of 8 A m^{-1} when placed in an external magnetic field of 0.6 T at a temperature of 4 K. When the same sample is placed in an external magnetic field of 0.2 T at a temperature of 16 K, the magnetization will be
   (a) $\frac{32}{3} Am^{-1}$ (b) $\frac{2}{3} Am^{-1}$
   (c) $6Am^{-1}$ (d) $2.5\ Am^{-1}$

5. A bar magnet has magnetic dipole moment $\vec{M}$. Its initial position is parallel to the direction of uniform magnetic $\vec{B}$. In this position, the magnitudes of torque and force acting on it respectively are [Term I 2021 – 22]
   (a) 0 and MB (b) MB and MB
   (c) 0 and 0 (d) $|\vec{M} \times \vec{B}|$ and 0

6. Which of the following statements is correct? [Term I 2021 – 22]
   (a) Magnetic field lines do not form closed loops.
   (b) Magnetic field lines start from north pole and end at south pole of a magnet.

(c) The tangent at a point on a magnetic field line represents the direction of the magnetic field at that point.

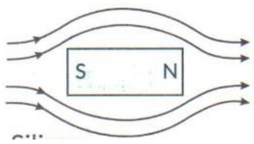
(d) Two magnetic field lines may intersect each other.

7. Which of the following has its permeability less than that of free space? [2023]

(a) Copper (b) Aluminium

(c) Copper chloride (d) Nickel

8. Which of the following cannot modify an external magnetic field as shown in the figure? [2023]



(a) Nickel (b) Silicon

(c) Sodium Chloride (d) Copper

9. Which one of the following has relative magnetic permeability between 0 and 1? [2023]

(a) Aluminium (b) Alnico

(c) Water (d) Sodium

10. Above Curies temperature, a [AI 2020]

(a) ferromagnetic material become diamagnetic

(b) ferromagnetic material become paramagnetic

(c) paramagnetic material become ferromagnetic

(d) paramagnetic material become diamagnetic

11. If the magnetizing field on a ferromagnetic material is increased, its permeability [2022 – 23]

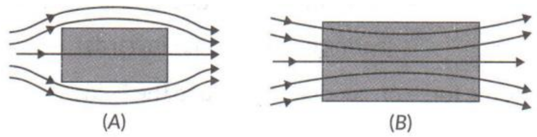
(a) Decreases

(b) Increases

(c) Remains unchanged

(d) First decreases and then increases.

12. A uniform magnetic field gets modified as shown in figure when two specimens A and B are placed in it. [2022 – 23]



(i) Identify the specimen A and B.

(ii) How is the magnetic susceptibility of specimen A different from that of specimen B?

Assertion-Reasoning (1 mark)

Question No. is Assertion (A) and Reason (R) type questions. Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below.

13. Assertion (A): The poles of a bar magnet cannot be separated.

Reason (R): Magnetic monopoles do not exist.

(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 correct explanation of (A).

(c) (A) is true, but (R) is false.

(d) (A) is false and (R) is also false.

14. Assertion (A): Earth's magnetic field does not affect the working of a moving coil galvanometer.

Reason (R): The earth's magnetic field is quite weak as compared to magnetic field produced in the moving coil galvanometer.

15. Assertion (A): Actinic lines on the magnetic map represents lines of equal dip.
Reason (R): When the horizontal and vertical components of the earth's magnetic field are equal, the angle
of dip is 60°.

16. Assertion (A): The true geographic north direction is found by using a compass needle.
Reason (R): The magnetic meridian of the earth is along the axis of rotation of the earth.

17. Assertion (A): There is only one neutral points on a horizontal board when a magnet is held vertically on the board.
Reason (R): At the neutral point the net magnetic field due to the magnetic and magnetic field of the earth is zero.

18. Assertion (A): The earth's magnetic field is due to iron present in its core.
Reason (R): At a low temperature magnet losses its magnetic property or magne is n.

19. Assertion (A): The ends of a magnet suspended freely point out always along north south.
Reason (R): Earth behaves as a huge magnet.

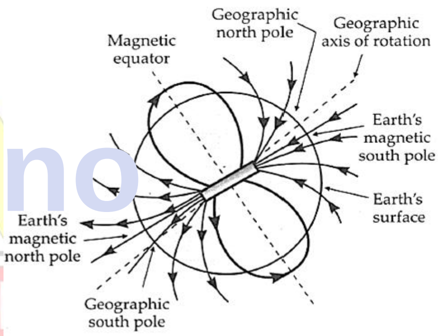
20. Assertion (A) : A compass needle when placed on the magnetic north pole of the earth rotates in vertical
direction.
Reason (R): The earth has only horizontal component of its magnetic field at the north poles.

21. Assertion (A): At neutral point, a compass needle point out in any arbitrary direction.
Reason (R): Magnetic field of earth is balanced by field due to magnets at the neutral points.
Activate
Go to Sett

22. Assertion (A): Magnetic moment is measured in joule/tesla or amp m^2.
Reason (R): Joule/tesla is equivalent to amp m^2.

➢ Case Study Question

23. The earth's magnetic field is not due to a huge bar magnet inside it. The core of the earth is so hot that a permanent magnet cannot exist there. The earth's magnetism is the result of circulating electric currents
induced in the molten liquid and other material inside the earth. With the rotation of the earth, charged metallic fluid in the core of earth also rotates resulting in the currents in the core of the earth. This is equivalent to a current-carrying loop which behaves like a magnetic dipole. Moreover, the outer layers of earth's atmosphere (ionosphere) are in ionised state.



As earth's rotates, strong electric currents are set up due to movement of these charges. This can also be one of the causes of the earth's magnetism. The earth's magnetic field resembles that of a (hypothetical) magnetic dipole located at the centre of the earth. The pole near the geographic north pole of the earth is called the south magnetic pole. Similarly, the pole near the geographic south pole is called the north magnetic pole. The dipole is aligned making a small angle with the magnetic axis of the earth. The magnitude of the magnetic field on the earth's surface is nearly $10^{-4}T$. Three parameters are needed to specify the magnetic field of the earth on its surface — the horizontal component, the magnetic declination, and the magnetic dip. These are known as elements of the earth's magnetic field.

QUESTIONS (Answer any four of the following questions)

1. The plane at which the earth's magnetic field is horizontal is

(a) plane through magnetic meridian

(b) plane through magnetic equator

(c) plane through magnetic poles

(d) it is not horizontal anywhere.

2. The angle of dip at a place on the earth gives

(a) the horizontal component of the earth's magnetic field

(b) the location of geographic meridian

(c) the vertical component of the earth' field

(d) the direction of the earth's magnetic field.

3. Angle of dip is 90° at

(a) poles

(b) equator

(c) both (a) and (b)

(d) none of the these.

4. The earth's magnetic field at a certain place has a horizontal component of 0.3 G and total strength 0.5 G. Find angle of dip in tan^{-1}.

(a) $\delta = tan^{-1}\frac{4}{3}$

(b) $\delta = tan^{-1}\frac{3}{4}$

(c) $\delta = tan^{-1}\frac{5}{3}$

(d) $\delta = tan^{-1}\frac{3}{5}$

5. A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It

(a) will become rigid showing no movement

(b) will stay in any position

(c) will stay in north-south direction only

(d) will stay in east-west direction only.

PARAGRAPH 2: Magnetic Behaviour of Materials

24. Before nineteenth century, scientists believed that magnetic properties were confined to a few materials like iron, cobalt and nickel. But in 1846, Curie and Faraday discovered that all the materials in the universe are magnetic to some extent. These magnetic substances are categorized into two groups. Weak magnetic materials are called diamagnetic and paramagnetic materials. Strong magnetic materials are called ferromagnetic materials. According to the modern theory of magnetism, the magnetic response of any material is due to circulating electrons in the atoms. Each such electron has a magnetic moment in a direction perpendicular to the plane of circulation. In magnetic materials all these magnetic moments due to the orbital and spin motion of all the electrons in any atom, vectorially add upto a resultant magnetic

moment. The magnitude and direction of these resultant magnetic moment is responsible for the behaviour of the materials. For diamagnetic materials χ is small and negative and for paramagnetic materials χ is small and positive. Ferromagnetic materials have large χ and are characterised by non-linear relation between $\vec{B}$ and $\vec{H}$.

QUESTIONS (Answer any four of the following questions)

6. The universal (or inherent) property among all substances is

(a) diamagnetism (b) paramagnetism

(c) ferromagnetism (d) both (a) & (b)

7. When a bar is placed near a strong magnetic field and it is repelled, then the material of bar is

(a) diamagnetic (b) ferromagnetic

(c) paramagnetic (d) anti-ferromagnetic.

8. Magnetic susceptibility of a diamagnetic substance

(a) decreases with temperature

(b) is not affected by temperature

(c) increases with temperature

(d) first increases then decreases with temperature.

9. For a paramagnetic material, the dependence of the magnetic susceptibility χ on the absolute temperature is given as

(a) $\chi \propto T$ (b) $\chi \propto \frac{1}{T^2}$

(c) (b) $\chi \propto \frac{1}{T}$ (d) independent.

10. The value of the magnetic susceptibility for a superconductor is

(a) zero (b) infinity (c) +1 (d)-l

➢ Question

25. Give two points to distinguish between a paramagnetic and a diamagnetic substance.

26. Write the four important properties of the magnetic field lines due to a bar magnet. [2/3, Delhi 2019]

27. A bar magnet of magnetic moment 6 J T^{-1} is aligned at 60^0 with a uniform external magnetic field of 0.44 T. Calculate (a) the work done in turning the magnet to align its magnetic moment (i) normal to the magnetic field, (ii) opposite to the magnetic field, and (b) the torque on the magnet in the final orientation in case (ii). [2018]

28. Write three points of differences between para-dia- and ferro- magnetic materials giving one example for each. [Delhi 2019]

29. The susceptibility of a magnetic material is 0.9853. Identify the type of magnetic material. Draw the modification of the field pattern on keeping a piece of this material in a uniform magnetic field. [AI 2018]

30. Show diagrammatically the behavior of magnetic field lines in the presence of (i) paramagnetic and (ii) diamagnetic substances. How does one explain this distinguishing feature. [AI 2014]

31. In what way is the behaviour of a diamagnetic material different from that of a paramagnetic, when kept in an external magnetic field? [AI 2016]

32. Depict the behaviour of magnetic field lines in the presence of a diamagnetic material. [Foreign 2016]

33. Relative permeability of a material $\mu_r = 0.5$. Identify the nature of the magnetic material and write its relation to magnetic susceptibility. [Delhi 2014C]

34. An iron ring of relative permeability μ_r has windings of insulated copper wire of n turns per metre. When the current in the windings is I, Find the expression for the magnetic field in the ring.

35. Write the four important properties of the magnetic field lines due to a bar magnet.

36. The magnetic susceptibility χ of magnesium at 300 K is 1.2×10^5. At what temperature will its magnetic susceptibility become 1.44×10^5?
Or
The magnetic susceptibility χ of a given material is – 0.5. identify the magnetic material.

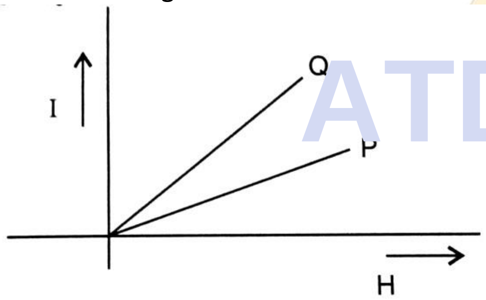
37. The susceptibility of a magnetic material is 0.9853. Identify the type of magnetic material. Draw the

modification of the field pattern on keeping a piece of this material in a uniform magnetic field.

38. A bar magnet of magnetic moment 6 J/T is aligned at 60^0 with a uniform external magnetic field of 0.44 T. Calculate (a) the work done in turning the magnet to align its magnetic moment (i) normal to the magnetic field, (ii) opposite to the magnetic field, and (b) the torque on the magnet in the final orientation in case (ii).

39. (a) State Gauss' law for magnetism. Explain its significance.
(b) Write the four important properties of the magnetic field lines due to a bar magnet.

40. The given graphs show the variation of intensity of magnetisation I with strength of applied magnetic field H for two magnetic materials P and Q.



i. Identify the materials P and Q.
ii. For a material P, plot the variation of intensity of magnetisation with temperature. Justify, your answer.

41. Define the terms (i) Magnetisation 'M' (ii) Magnetic Intensity 'H' (iii) Magnetic permeability 'μ' (iv) Magnetic Susceptibility 'χ_m'

42. What is Curie law, Curie temperature & Curie-Weiss law explain.

43. (i) Mention two properties of soft iron due to which it is preferred for making an electromagnet. (ii) State Gauss's law in magnetism. How it is different from Gauss's law in electrostatics and why?

44. Explain the terms retentively and coercivity.

45. In what way is the behaviour of a diamagnetic material different from that of a paramagnetic, when kept in an external magnetic field?

46. Depict the behaviour of magnetic field lines in the presence of a diamagnetic material.

47. Relative permeability of a material $\mu_r = 0.5$. Identify the nature of the magnetic material and write its relation to magnetic susceptibility.

48. Give two points to distinguish between a paramagnetic and a diamagnetic substance.

49. Depict the behaviour of magnetic field lines with (i) a diamagnetic material and (ii) a paramagnetic material placed in an external magnetic field. Mention briefly the properties of these materials which explain this distinguishing behaviour.

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

51. The susceptibility of a magnetic material is 0.9853. Identify the type of magnetic material. Draw the modification of the field pattern on keeping a piece of this material in a uniform magnetic field.

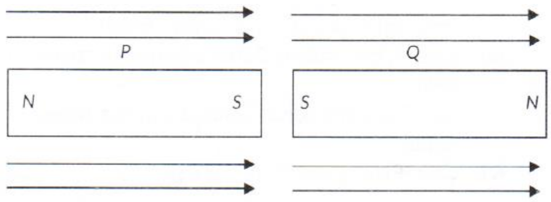
52. Show diagrammatically the behaviour of magnetic field lines in the presence of (i) paramagnetic and (ii) diamagnetic substances. How does one explain this distinguishing feature.

53. A sample of paramagnetic salt contains $2.0 \times 10^{+24}$ Atomic dipoles each of dipole moment $1.5 \times 10^{-23} JT^{-1}$ The sample is placed under a homogeneous magnetic
field of 0.84 T, and cooled to a temperature of 4.2 K. The degree of magnetic saturation achieved is equal to 20%. What is the total dipole moment of the sample for a magnetic field of 1.00 T and a temperature of 2.1 K? (Assume Curie's Law).

54. A short bar magnet of magnetic moment $M = 0.3JT^{-1}$ispiaced in a uniform external magnetic

field of 0.50 T. If the bar is free to rotate in the plane of the field, which orientations would correspond to its (i) stable and (ii) unstable equilibrium? What is the potential energy of the magnet in each case? What is the torque on magnet in each case?

55. Two identical bar magnets P and Q are placed in two identical uniform magnetic fields as shown in the figure. Justify that both the magnets are in equilibrium. Which one of these is in stable equilibrium? Give reasons for your answer.



56. What is the name given to the curves, the tangent to which at any point gives the direction of the magnetic field at that point? Can two such curves intersect each other? Justify your answer.

57. The magnetic needle has magnetic moment $6.7 \times 10^{-2}\ A\,m^2$ and moment of inertia $I = 7.5 \times 10^{-6}\ kg\,m^2$. It performs 10 oscillations in 6.70 s. What is the magnitude of the magnetic field?

SURE SHOT QUESTIONS

ARVIND ACADEMY

Chapter – 06

Electromagnetic Induction

MCQ (1 mark)

1. A square of side L meters lies in the x-y plane in a region, where the magnetic field is given by $\vec{B} = B_0(2\hat{i} + 3\hat{j} + 4\hat{k})\,\mathrm{T}$, where B_0 is constant. The magnitude of flux passing through the square is

(a) $2B_0L^2\,Wb$ (b) $3B_0L^2\,Wb$

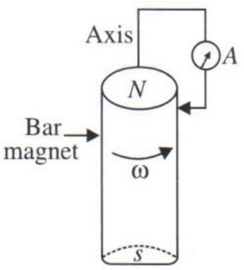
(c) $4B_0L^2\,Wb$ (d) $\sqrt{29}B_0L^2\,Wb$

2. A loop, made of straight edges has six corners at A(0, 0, 0), B(L, 0, 0), C(L,L,0), D(0, L, 0), E(0, L, L) and F(0, 0, L). A magnetic field $\vec{B} = B_0(\hat{i} + \hat{k})\,\mathrm{T}$ is present in the region. The flux passing through the loop ABCDEFA (in that order) is

(a) $B_0L^2\,Wb$ (b) $2\,B_0L^2\,Wb$

(c) $\sqrt{2}\,B_0L^2\,Wb$ (d) $4\,B_0L^2\,Wb$

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



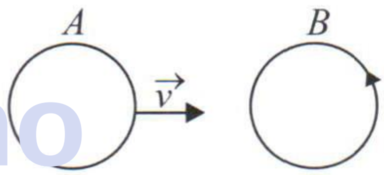
(a) A direct current flows in through the ammeter A.

(b) No current flows through the ammeter A.

(c) An alternating sinusoidal current flows through the ammeter A with a time period, $T = \frac{2\pi}{\omega}$.

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

4. There are two coils A and B as shown in the figure. A current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counterclockwise. B is kept stationary when A moves. We can infer that



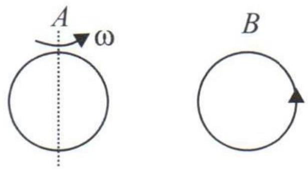
(a) There is a constant current in the clockwise direction of A.

(b) There is a varying current in A.

(c) There is no current in A.

(d) There is a constant current in the counter-clockwise direction in A.

5. Same as problem 4 except the coil A is made to rotate about a vertical axis. No current flows in B if A is at rest. The current in coil A, when the current in B (at t = 0) is counterclockwise and the coil A is as shown at this instant, t = 0, is



(a) Constant current clockwise.

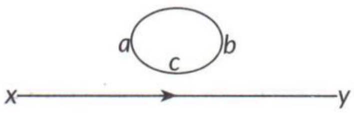
(b) Varying current clockwise.

(c) Varying current counterclockwise.

(d) Constant current counterclockwise.

6. The self inductance L of a solenoid of length l and area of cross-section A, with a fixed number of turns N increases as
(a) l and A increase.
(b) l decreases and A increases.
(c) l increases and A decreases.
(d) both l and A decrease.

7. The direction of induced current in the loop abc is: [2023]



(a) Along abc if I deceases
(b) Along acb if I increases
(c) Along abc if I constant
(d) Along abc if I increases.

8. 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 [2023]
(a) 0.1 V (b) 0.5 V
(c) 0.75 V (d) 1.0 V

9. A coil of area 100 cm^2 is kept at an angle of 30^0 with a magnetic field of 10^{-1} T. The magnetic field is reduced to zero in 10^{-4}s. The induced emf in the coil is [Term I 2021 – 22]
(a) $5\sqrt{3}V$ (b) $50\sqrt{3}V$
(c) 5.0 V (d) 50.0 V

10. 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
[Term I 2021 – 22]
(a) 50 V (b) 75 V
(c) 100 V (d) 220 V

11. 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 [Term I 2021 – 22]
(a) 95 mH (b) 90 mH
(c) 85 mH (d) 75 mH

12. A constant current is flowing through a solenoid. An iron rod is inserted in the solenoid along its axis. Which of the following quantities will not increase? [Term I 2021 – 22]
(a) The magnetic field at the centre.
(b) The magnetic flux linked with the solenoid.
(c) The rate of heating
(d) The self – inductance of the solenoid.

13. The magnetic flux linked with the coil (in Weber) is given by the equation [Term I 2021 – 22]

$\phi = 5t^2 + 3t + 16$

The induced EMF in the coil at time, t = 4s will be
(a) -27 V (b) -43 V
(c) -108 V (d) 210 V

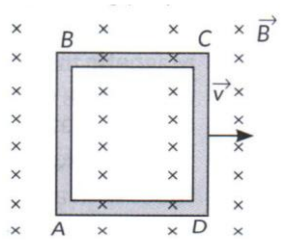
14. A rectangular, a square, a circular and an elliptical loop, all in the (x – y) plane, are moving out of a uniform magnetic field with a constant velocity $\vec{v} = v\hat{i}$. The magnetic field is directed along the negative z – axis direction. The induced emf, during the passage of these loops, out of the field region, will not remain constant for [2022 – 23]
(a) Any of the four loops
(b) The circular and elliptical loops

(c) The rectangular, circular and elliptical loops

(d) Only the elliptical loops

15. A conducting square loop of side 'L' and resistance 'R' moves in its plane with the 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 as shown in the figure. The current induced in the loop is

[Term I 2021 – 22]



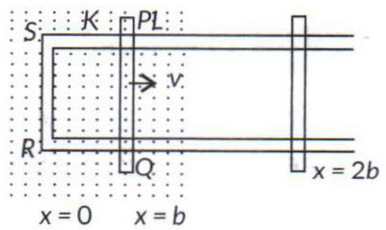
(a) BLv/R Clockwise

(b) BLv/R Anticlockwise

(c) 2BLv/R Anticlockwise

(d) Zero.

16. Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon the [Term I 2021 – 22]



(a) Rate at which current change in the two coils

(b) Elative position and orientation of the coils

(c) Rate at which voltage induced across two coils

(d) Currents in the two coils.

17. An air – cored solenoid with length 30 cm, area of cross-section 25 cm^2 and number of turns 800, carries a current of 2.5 A. The current is suddenly switched off in a brief time of 10^{-3}s. Ignoring the variation in magnetic field near the ends of the solenoid, the average back emf induced across the ends of the open switch in the circuit would be

[Term I 2021 – 22]

(a) Zero (b) 3.125 volts

(c) 6.54 volts (d) 16.75 volts

18. A circular loop of radius 0.3 cm lies parallel to much bigger circular loop of radius 20 cm. The centre of the small loop is on the axis of the bigger loop. The distance between their centres is 15 cm. If a current of 2.0 A flows through the smaller loop, then the flux liked with the bigger loop is

[Term I 2021 – 22]

(a) [illegible].3 × $10^{-[illegible]}$ weber

(b) 6×10^{-11} weber

(c) 6.6×10^{-9} weber

(d) 9.1×10^{-11} weber

19. If both the number of turns and core length of an inductor is doubled keeping other factors constant, then its self-inductance will be

[Term I 2021 – 22]

(a) unaffected (b) doubled

(c) halved (d) quadrupled

Assertion-Reasoning (1 mark)

Directions: In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

20. Assertion (A) : When number of turns in a coil doubled, coefficient of self-inductance of the coil becomes four times.
Reason (R): Coefficient of self-inductance is proportional to the square of number of turns.

21. Assertion (A): The coil in the resistance boxes are made by doubling the wire.
Reason (R): Thick wire is required in resistance box.

22. Assertion (A): The resistance of a coil for direct current is 5 ohms. An alternating current is sent through it. The resistance will remain same.
Reason (R): The resistance of a coil does not depend upon nature of current.

23. Assertion (A): Induced e.m.f. depends on number of turns and area of the coil.
Reason (R): Induced e.m.f. increases with increase in number of turns of coil.

24. Assertion (A): Inductance coil are made of copper.
Reason (R): Induced current is more in wire having less resistance.

25. Assertion (A): Self-inductance is called the inertia of electricity.
Reason (R): 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 with the coil.

26. Assertion (A) : An induced current is developed when the number of magnetic lines of force associated with conductor is changed.
Reason (R): An induced current develop in a conductor moved in a direction parallel to the magnetic field.

27. Assertion (A): A copper sheet is placed in a magnetic field. If we pull it out of the field or push it into the field, we experience an opposing force.
Reason (R): According to Lenz's law, eddy current produced in sheet opposes the motion of the sheet.

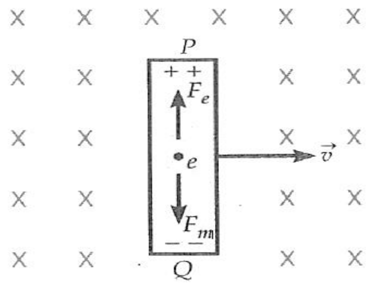
28. Assertion (A): Changing magnetic flux can produce induced e.m.f.
Reason (R): Faraday established induced e.m.f. experimentally.

29. Assertion (A): Only a change of magnetic flux with time, will maintain an induced current in [1] the coil.
Reason (R): The presence of a large magnetic flux will maintain an induced current in the coil.
a) Both A and R are true and R is the
b) Both A and R are true but R is NOT correct explanation of A the correct explanation of A
c) A is true but R is false
d) A is false and R is also false

➢ Case Study Question

30. Consider a conductor PQ of length l moving towards right with velocity $\vec{v}$ perpendicular to a magnetic field $\vec{B}$, directed into the plane of paper. As the conductor PQ moves, its free electrons also move in the same direction and experience magnetic Lorentz force, $F_m = evB$. By Fleming's left hand rule, electrons move

from P to Q within the conductor. The end P becomes positive and end Q becomes negative. An electric field is set up in the conductor from P to Q.



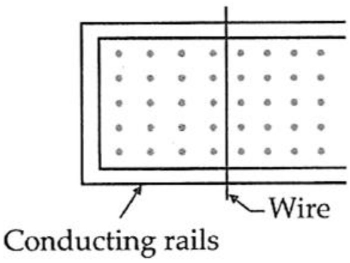
This field exerts a force, $F_e = eE$ on the free electrons. The accumulation of charges at the two ends continues till these two forces balance each other, i.e., $F_m = F_e$ or $evB = eE$ or $vB = E$. Potential difference between the ends P and Q, $V = El = vBl$. It is the magnetic

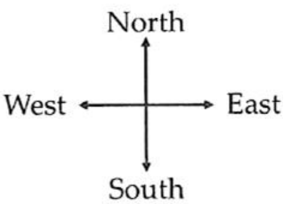
force on the free electrons that maintains p.d. and produces the emf, $\xi = Blv$. As this emf is produced due to the motion of a conductor, so it is called a motional emf.

QUESTIONS (Answer any four of the following questions)

A conducting wire sits on smooth metal rails, as shown in the figure. A variable magnetic field points out of the page. The strength of this magnetic field is

increased linearly from zero. Immediately after the field

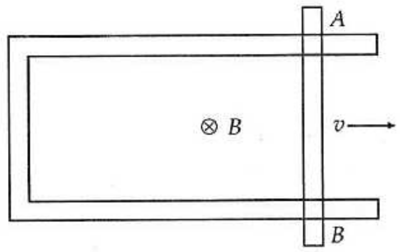




	Current in the wire	Motion of the wire
(a)	North	No motion
(b)	North	East
(c)	South	West
(d)	South	East

starts to increase, what will be the direction of the current in the wire and the direction of the wire's motion?

2. A 50 cm long bar AB is moved with a speed of 4 ms^{-1} in a magnetic field $B = 0.01\ T$ as shown in the figure.



The emf generated is

(a) 0.01 V (b) 0.02 V

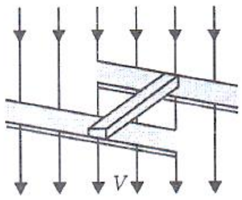
(c) 0.03 V (d) 0.04 V.

3. An aeroplane having a wing span of 35 m flies due north with the speed of 90 m/s, given $B = 4 \times 10^{-5} T$. The potential difference between the tips of the wings will be

(a) 0.126 V (b) 1.26 V

(c) 12.6 V (d) 0.013 V.

4. If the vertical component of earth's magnetic field be $6 \times 10^{-5}\ Wb/m^2$, then what will be the induced potential difference produced between the rails of a meter-gauge when a train is running on them with a speed of 36 km/h



(a) $2 \times 10^4\ V$ (b) $6 \times 10^{-4}\ V$

(c) $3 \times 10^{-4}\ V$ (d) $9 \times 10^{-4}\ V$.

5. A wheel with 10 metallic spokes each 0.5 m long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of earth's magnetic field B_H at a place. If B_H = 0.4 G at the place, the magnitude of induced emf between the axle and the rim of the wheel is

(a) $1.256 \times 10^{-3} V$

(b) $6.28 \times 10^{-4} V$

(c) $1.256 \times 10^{-4} V$

(d) $6.28 \times 10^{-5} V$.

PARAGRAPH 2: Eddy Currents

31. The motion of a copper plate is damped when it is allowed to oscillate between the magnetic pole-pieces. Magnetic flux associated with the plate keeps on changing as the plate moves in and out of the region between the magnetic poles. The changing flux sets up induced currents in the copper plate which flow along closed paths in planes perpendicular to the magnetic field. The currents look like eddies or whirlpools in water. So they are known as eddy currents. They also oppose the change in magnetic flux. Eddy currents develop heat at the cost of kinetic energy of the plate as the plate slows down. This is called electromagnetic damping. To reduce electromagnetic damping, one can cut slots in the plate which reduces the possible paths of eddy currents considerably.

QUESTIONS (Answer any four of the following questions

6. A metallic pendulum oscillating in a uniform magnetic field directed perpendicular to the plane of oscillation

(a) slows down (b) becomes faster

(c) remains unaffected

(d) oscillates with a changing frequency.

7. A metallic cylinder is held vertically. A small bar magnet dropped along its axis will fall with acceleration such that

(a) $a > g$ (b) $a < g$

(d) $a = 0$, constant velocity. (c) $a = g$

8. A coil is suspended in a uniform magnetic field, with the plane of the coil parallel to the magnetic lines of force. When a current is passed through the coil it starts oscillating; it is very difficult to stop. But if an aluminium plate is placed near to the coil, it stops. This is due to

(a) development of air current when the plate is placed

(b) induction of electrical charge on the plate

(c) shielding of magnetic lines of force as aluminium is a paramagnetic material

(d) electromagnetic induction in the aluminium plate giving rise to electromagnetic damping.

9. Eddy currents are produced when

(a) a metal is kept in a steady magnetic field

(b) a metal is kept in a varying magnetic field

(c) a circular coil is placed in a magnetic field

(d) a current is passed through a circular coil.

10. The core of a transformer is laminated so that

(a) rusting of iron core may be stopped

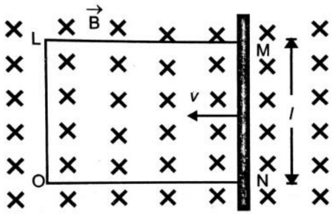
(b) ratio of voltage in the primary and secondary may be increased

(c) rate of change of flux is increased

(d) energy losses due to eddy currents may be reduced.

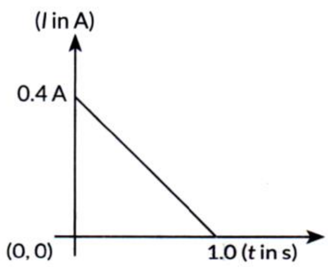
➢ Questions

32. A rectangular conductor LMNO is placed in uniform magnetic field of 0.5 T. the field is directed perpendicular to the plane of the conductor. When the arm MN of length of 20 cm is moved towards left with a velocity of 10 ms^{-1}, calculate the emf induced in the arm. Given the resistance of the arm to be 5 Ω (assuming that other arms are of negligible resistance) find the value of the current in the arm.



33. Starting from the expression for the energy $W = \frac{1}{2}LI^2$, stored in a solenoid of self-inductance L to build up the current I, obtain the expression for the magnetic energy in terms of the magnetic field B, area A and length l of the solenoid having n number of turns per unit length. Hence, show that the energy density is given by $B^2/2\mu_0$

34. When conducting loop of resistance 10 Ω and area 10 cm^2 is removed from an external magnetic field acting normally, the variation of induced current in the loop with time is shown in the figure.
[2020]



Find the
(i) Total charge passed through the loop.
(ii) Change in magnetic flux through the loop.
(iii) Magnitude of the magnetic field applied.

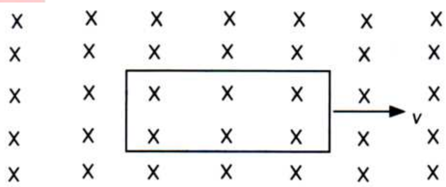
35. Define mutual inductance between a pair of coils. Derive an expression for the mutual inductance of two long coaxial solenoids of same length wound one over the other. [AI 2017]
OR
Define the term 'mutual inductance' between the two coils. Obtain the expression for mutual inductance of a pair of long coaxial solenoid each of length l and radii r_1 and r_2 ($r_2 >> r_1$). Total number of turns in the two solenoid are N_1 and N_2 respectively. [AI 2014]

36. (i) Define mutual inductance.
(ii) A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from O to 20 A in 0.5 s, what is the change of flux linkage with the other coil?
[Delhi 2016]

37. Define self – inductance of a coil. Obtain the expression for the energy stored in an inductor L connected across a source of emf. [AI 2017]
OR
Define the term self – inductance of a solenoid. Obtain the expression for the magnetic energy stored in an inductor of self – inductance L to build up a current I through it. [AI 2014]

38. The currents flowing in the two coils of self – inductance L_1 = 16 mH and L_2 = 12 mH are increasing at the same rate. If the power supplied to the two coils are equal, find the ratio of (i) induced voltages, (ii) the currents and (iii) the energies stored in the two coils at a given instant.
[Foreign 2014]

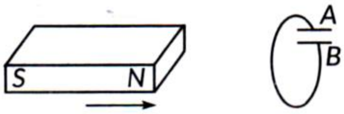
39. A rectangular loop which was initially inside the region of uniform and time – independent magnetic field, is pulled out with constant velocity v as shown in the figure. [2020 – 21]



(a) Sketch the variation of magnetic flux, the induced current, and power dissipated as Joule heat as function of time.
(b) If instead of rectangular loop, circular loop is pulled out; do you expect the same value of induced current? Justify your answer. Sketch the variation of flux in this case with time.
[2020 – 21]

40. State Lenz's law. Use it to predict the polarity of the capacitor in the situation given below:

[2/5, AI 2015C]



41. Describe a simple experiment (or activity) to show that the polarity of emf induced in a coil is always such that it tends to produce a current which opposes the change of magnetic flux that produces it. [2/5, Delhi 2014]

OR

State Lenz's law. Give one example to illustrate this law. "The Lenz's law is a consequence of the principle of conservation of energy". Justify this statement. [3/5, AI 2014]

42. State Lenz's law. A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an emf induced at its ends? Justify your answer.

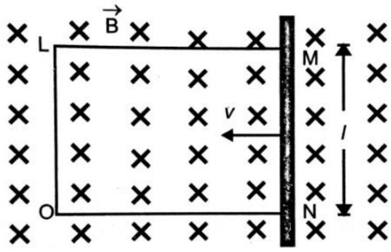
43. (a)Derive an expression for the induced emf developed when a coil of N turns, and area of cross-section A, is rotated at a constant angular speed ω in a uniform magnetic field B.

(b) A wheel with 100 metallic spokes each 0.5 m long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of the Earth's magnetic field. If the resultant magnetic field at that place is 4×10^{-4} T and the angle of dip at the place is 30^0, find the emf induced between the axle and the rim of the wheel.

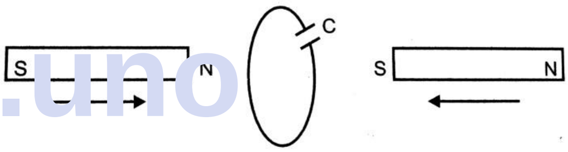
44. (a) State the principle of an ac generator and explain its working with the help of a labelled diagram. Obtain the expression for the emf induced in a coil having N turns each of cross-sectional area A, rotating with a constant angular speed $'\omega'$ in a magnetic field $\vec{B}$,directed perpendicular to the axis of rotation.

(b) An aeroplane is flying horizontally from west to eaxst with a velocity of 900 km/hour. Calculate the potential difference between the ends of its wings having a span of 20m . the horizontal component of the Earth's magnetic field is 5×10^{-4} T and the angle of dip is 30^0.

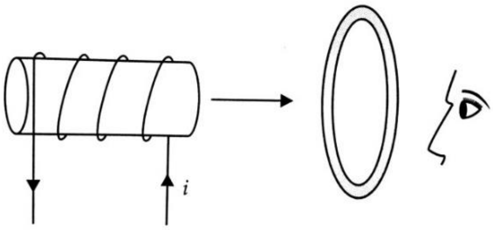
45. A rectangular conductor LMNO is placed in uniform magnetic field of 0.5 T. the field is directed perpendicular to the plane of the conductor. When the arm MN of length of 20 cm is moved towards left with a velocity of 10 ms^{-1}, calculate the emf induced in the arm. Given the resistance of the arm to be 5 Ω (assuming that other arms are of negligible resistance) find the value of the current in the arm.



46. Two bar magnets are quickly moved towards a metallic loop connected across a capacitor 'C' as shown in the figure. Predict the polarity of the capacitor.

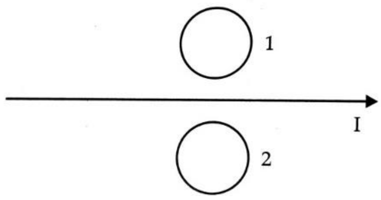


47. Figure shows a current carrying solenoid moving towards a conducting loop. Find the direction of the current induced in the loop.

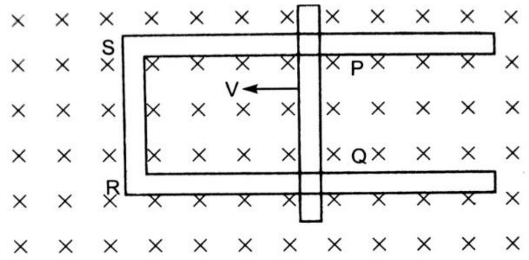


48. What is magnetic flux? Write its SI unit.

49. What is the direction of induced currents in metal rings 1 and 2 when current I in the wire is increasing steadily?



50. Figure shows a rectangular loop conducting PQRS in which the arm PQ is free to move. A uniform magnetic field acts in the direction perpendicular to the plane of the loop. Arm PQ is moved with a velocity v toward the arm RS. Assuming that the arms QR, RS and SP have negligible resistances and the moving arm PQ has the resistance r, obtain the expression for (i) the current in the loop (ii) the force and (iii) the power required to move the arm PQ



51. A metallic rod of length L is rotated at angular speed normal to a uniform magnetic field B. Derive expressions for the (i) emf induced in the rod (ii) current induced and (iii) heat dissipation, if the resistance of the rod is R.

52. State Lenz's Law. Explain, by giving examples that Lenz's Law is a consequence of conservation of energy

53. What is motional emf?

54. A light bulb and a solenoid are connected in series across an *ac* source of voltage. Explain, how the glow of the light bulb will be affected when an iron rod is inserted in the solenoid.

55. 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 by $\frac{1}{2}LI^2$

56. Starting from the expression for the energy W = $\frac{1}{2}LI^2$, stored in a solenoid of self-inductance L to build up the current I, obtain the expression for the magnetic energy in terms of the magnetic field B, area A and length l of the solenoid having n number of turns per unit length. Hence, show that the energy density is given by $B^2/2\mu_0$

57. Define Mutual inductance between a pair of coils. Derive an expression for the mutual inductance of two long coaxial solenoids of same length wound one over the other.

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

59. What are the factors affecting mutual inductance of a pair of coils? Define coefficient of coupling

60. What are the eddy currents? Write their two applications.

61. An air-cored solenoid with length 30 cm, area of cross-section 25 cm^2 and number of turns 500, carries a current of 2.5 A . The current is suddenly switched off in a brief time of 10^{-3} s . How much is the average back emf induced across the ends of the open switch in the circuit?

62. Distinguish between self-inductance and mutual inductance.

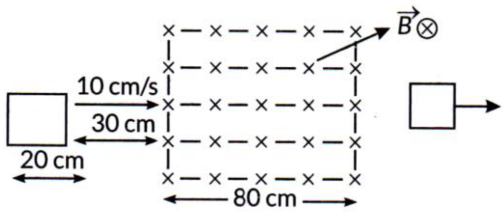
63. A conductor of length '/' is rotated about one of its ends at a constant angular speed 'ω' in a plane perpendicular to a uniform magnetic field B. Plot graphs to show variations of the emf induced across the ends of the conductor with (i) angular speed ω and (ii) length of the conductor l. [2/5, 2020]

64. A square loop of side 20 cm is initially kept 30 cm away from a region of uniform magnetic field of 0.1 T as shown in the figure. It is then moved towards the right with a velocity of 10 cm s^{-1} till it goes out of the field. [3/5, AI 2015C]
Plot a graph showing the variation of

(i) Magnetic flux (ϕ) through the loop with time (t).

(ii) Induced emf (ε) in the loop with time t.

(iii) Induced current in the loop if it has resistance of 0.1 Ω.



65. Two concentric circular loops of radius 1 cm and 20 cm are placed coaxially.

(i) Find mutual inductance of the arrangement.

(ii) If the current passed through the outer loop is changed at a rate of 5 A/ms, find the emf induced in the inner loop. Assume the magnetic field on the inner loop to be uniform. [2/5, 2020]

66. (a) Draw a schematic diagram for an ac generator. Explain its working and obtain the expression for the instantaneous value of the emf in terms of the magnetic field B, number of turns N of the coil of area A rotating with angular frequency ω.

Show how an alternating emf is generated by a loop of wire rotating in a magnetic field.

(b) A circular coil of radius 10 cm and 20 turns is rotated about its vertical diameter with angular speed of 50 rad s^{-1} in a uniform horizontal magnetic field of 3.0×10^{-2} T.

(i) Calculate the maximum and average emf induced in the coil.

(ii) If the coil forms a closed loop of resistance 10 Ω, calculate the maximum current in the coil and the average power loss due to Joule heating.

[AI 2019]

67. (a) Draw a labelled diagram of ac generator. Derive the expression for the instantaneous value of the emf induced in the coil.

(b) A circular coil of cross-sectional area 200 cm^2 and 20 turns is rotated about the vertical diameter with angular speed of 50 rad s^{-1} in a uniform magnetic field of magnitude 3.0×10^{-2} T. Calculate the maximum value of the current in the coil. [Delhi 2017]

SURE SHOT QUESTIONS

ARVIND ACADEMY

Chapter – 07

Alternating Current

MCQ (1 mark)

1. If the rms current in a 50 Hz ac circuit is 5A, the value of the current 1/300 seconds after its value becomes zero is

(a) $5\sqrt{2}\,A$ (b) $5\sqrt{\frac{3}{2}}A$

(c) $\frac{5}{6}$A (d) $\frac{5}{\sqrt{2}}$A

2. An alternating current generator has an internal resistance R_g and an internal reactance X_g. It is used to supply power to a passive load consisting of a resistance R_g and a reactance X_L. For maximum power to be delivered from the generator to the load, the value of X_L is equal to

(a) zero (b) X_g

(c) - X_g (d) R_g

3. When a voltage measuring device is connected to ac mains, the meter shows the steady input voltage of 220 V. This means
   (a) Input voltage cannot be ac voltage, but a dc voltage.
   (b) Maximum input voltage is 220 V.
   (c) The meter reads not V but $<V^2>$ and is calibrated to read $\sqrt{<V^2>}$.
   (d) The pointer of the meter is stuck by some mechanical defect.

4. To reduce the resonant frequency in an LCR series circuit with a generator
   (a) The generator frequency should be reduced.
   (b) Another capacitor should be added in parallel to the first.
   (c) The iron core of the inductor should be removed.
   (d) Dielectric in the capacitor should be removed.

5. Which of the following combinations should be selected for better tuning of an LCR circuit used for communication?
   (a) $R=20\Omega,\ L=1.5H,\ C=35\mu F$
   (b) $R=25\Omega,\ L=2.5H,\ C=45\mu F$
   (c) $R=15\Omega,\ L=3.5H,\ C=30\mu F$
   (d) $R=25\Omega,\ L=1.5H,\ C=45\mu F$

6. An inductor of reactance 1 Ω and a resistor of 2 Ω are connected in series to the terminals of a 6 V (rms) ac source. The power dissipated in the circuit is

(a) 8 W (b) 12 W

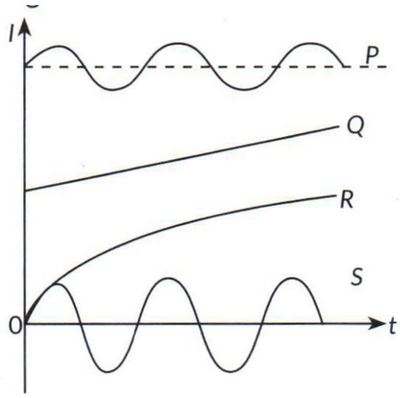
(c) 14.4 W (d) 18 W

7. The output of a step – down transformer is measured to be 24 V when connected to a 12 watt light bulb. The value of the peak current is

(a) $\frac{1}{\sqrt{2}}A$ (b) $\sqrt{2}A$

(c)2 A (d) $2\sqrt{2}A$

8. The figure shows variation of current (I) with time (t) in four devices P, Q, R and S. the device in which an alternating current flows is [2023]



(a) P (b) Q
(c) R (d) S

9. The rms current in a circuit connected to a 50 Hz ac source is 15 A. The value of the current in the circuit $\left(\frac{1}{600}\right)$s after the instant the current is zero, is [Term I 2021 – 22]

(a) $\frac{15}{\sqrt{2}}A$ (b) $15\sqrt{2}\,A$
(c) $\frac{\sqrt{2}}{15}A$ (d) 8 A

10. An ac voltage $v = v_0 \sin \omega t$ is applied to a series combination of a resistor R and an element X. The instantaneous current in the circuit is $I = I_0 \sin\left(\omega t + \frac{\pi}{4}\right)$. Then which of the following is correct? [2023]

(a) X is a capacitor and $X_C = \sqrt{2}R$
(b) X is an inductor and $X_L = R$
(c) X is an inductor and $X_L = \sqrt{2}R$
(d) X is a capacitor and $X_C = R$

11. Which of the following statements about a series LCR circuit connected to an ac source is correct?
(a) If the frequency of the source is increased, the impedance of the circuit first decreases and then increases.
(b) If the next reactance $(X_L - X_C)$ of circuit becomes equal to its resistance, then the current leads the voltage by 45^0.
(c) At resonance, the voltage drop across the inductor is more than that across the capacitor.
(d) At resistance, the voltage drop across the capacitor is more than that across the inductor. [2023]

12. What is the ratio of inductive and capacitive reactance in an ac circuit? [2023]
(a) $\omega^2 LC$ (b) LC^2
(c) $\frac{LC}{\omega^2}$ (d) $\omega^2 L$

13. In a circuit the phase difference between the alternating current and the source voltage is $\frac{\pi}{2}$. Which of the following cannot be the element(s) of the circuit? [Term I 2021 – 22]
(a) only C (b) only L
(c) L and R (d) L or C

14. The impedance of a series LCR circuit is [Term I 2021 – 22]
(a) $R + X_L + X_C$ (b) $\sqrt{\frac{1}{X_C^2} + \frac{1}{X_L^2} + R^2}$
(c) $\sqrt{X_L^2 - X_C^2 + R^2}$ (d) $\sqrt{R^2 + (X_L - X_C)^2}$

15. 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. The resultant voltage in the circuit is [Term I 2021 – 22]

(a) 5 V (b) 20 V

(c) 25 V (d) 65 V

16. A circuit is connected to an ac source of variable frequency. As the frequency of the source is increased, the current first increases and then decreases. Which of the following combinations of elements is likely to comprise the circuit? [Term I 2021 – 22]

(a) L, C and R (b) L and C

(c) L and R (d) R and C

17. 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 in the circuit are in phase, then the value of capacitance is [Term I 2021 – 22]

(a) 100 μF (b) 127 μF

(c) 142 μF (d) 160 μF

18. A 300 Ω resistor and a capacitor of $\left(\frac{25}{\pi}\right)\mu F$ are connected in series to a 200 V – 50 Hz ac source. The current in the circuit is [Term I 2021 – 22]

(a) 0.1 A (b) 0.4 A

(c) 0.6 A (d) 0.8 A

19. The selectivity of a series LCR a.c. current is large, when [2020]

(a) L is large and R is large

(b) L is small and R is small

(c) L is large and R is small

(d) L = R

20. When an alternating voltage $E = E_0 \sin \omega t$ is applied to a circuit, a current $I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$ flows through it. The average power dissipated in the circuit is [Term I 2021 – 22]

(a) $E_{rms} I_{rms}$ (b) $E_0 I_0$

(c) $\frac{E_0 I_0}{\sqrt{2}}$ (d) zero

21. The power factor of a series LCR circuit at resonance will be [2020]

(a) 1 (b) 0

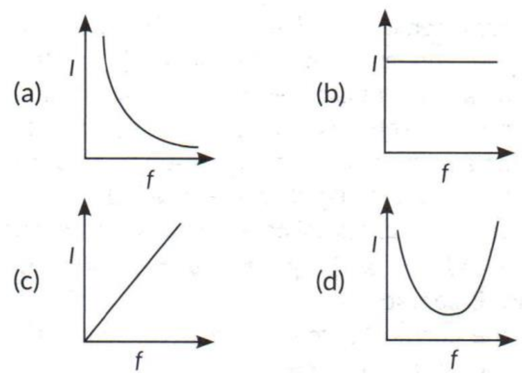
(c) ½ (d) $1/\sqrt{2}$

22. The core of transformer is laminated to reduce the effect of [Term I 2021 – 22]

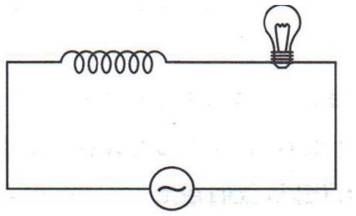
(a) flux leakage (b) copper loss

(c) hysteresis loss (d) eddy current.

23. Which of the following graphs represent the variation of current (I) with frequency (f) in an AC circuit containing a pure capacitor? [Term I 2021 – 22]



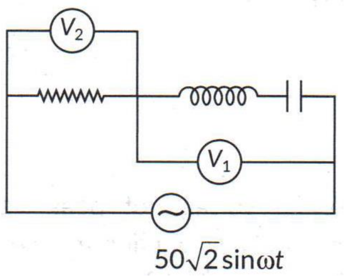
24. An iron cored coil is connected in series with an electric bulb with an AC source as shown in figure. When iron piece is taken out of the coil, the brightness of the bulb will [2022 – 23]



(a) decrease (b) increase

(c) remain unaffected (d) fluctuate

25. If the reading of the voltmeter V_1 is 40 V, then the reading of voltmeter V_2 is [2022 – 23]



(a) 30 V (b) 58V

(c) 29 V (d) 15 V

26. A 20 volt AC is applied to a circuit consisting of a resistance and a coil with negligible resistance. If the voltage across the resistance is 12 volt, the voltage across the coil is [Term I 2021 – 22]

(a) 16 V (b) 10 V

(c) 8 V (d) 6 V

27. The instantaneous values of emf and the current in a series ac are

$$E = E_0 \sin \omega t \ \ and \ \ I = I_0 \sin(\omega t + \pi / 3)$$

respectively, then it is [Term I 2021 – 22]

(a) Necessarily a RL circuit

(b) Necessarily a RC circuit

(c) Necessarily a LCR circuit

(d) Can be RC or LCR circuit.

28. An alternating voltage source of variable angular frequency 'ω' and fixed amplitude 'V' is connected in series with a capacitance C and electric bulb of resistance R (inductance zero). Wen 'ω' is increased [Term I 2021 – 22]

(a) The bulb glows dimmer

(b) The bulb glows brighter

(c) Net impedance of the circuit remains unchanged

(d) Total impedance of the circuit increases.

29. A sinusoidal voltage of peak value 283 V and frequency 50 Hz is applied to a series LCR circuit in which $R = 3\Omega,\ L = 25.48$ mH and $C = 796\mu F$, then the power dissipated at the resonant condition will be [Term I 2021 – 22]

(a) 39.70 kW (b) 26.70 kW

(c) 13.25 kW (d) zero

30. Which among the following, is not a cause for power loss in a transformer

[Term I 2021 – 22]

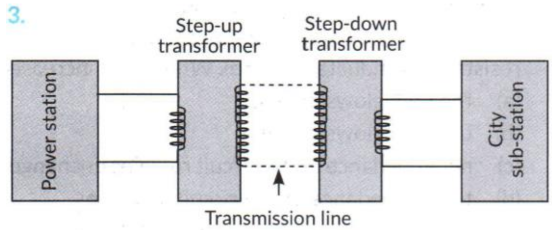


Figure : Long distance power transmissions

(a) Eddy currents are produced in the soft iron core of a transformer

(b) Electric flux sharing not properly done in primary and secondary coils

(c) Humming sound produced in the transformers due to magnetostriction

(d) Primary coil is made up of a very thick copper wire.

➢ Assertion-Reasoning (1 mark)

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

31. Assertion (A) : When three electric bulbs of power 200 W, 100 W and 50 W are connected in series to a source, the power consumed by the 50 W bulb is maximum.

Reason (R) : In a series circuit, current is the same through each bulb, but the potential difference across each bulb is different.

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

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

(c) Assertion (A) is true, but Reason (R) is false,

(d) Assertion (A) is false and Reason (R) is also false.

32. Assertion (A): When capacitive reactance is smaller than the inductive reactance in LCR series circuit, e.m.f. leads the current.
Reason (R) : The phase angle is the angle between the alternating e.m.f. and alternating current of the circuit.

33. Assertion (A): At resonance, LCR series circuit have a maximum current.
Reason (R): At resonance, in LCR series circuit, the current and e.m.f are in phase with each other.

34. Assertion (A): Long distance transmission of A.C. is carried out at extremely high voltage.
Reason (R): For large distance, voltage has to be large.

35. Assertion (A): An electric lamp connected in series with a variable capacitor and A.C. source, its brightness
increases with increase in capacitance.
Reason (R): Capacitive reactance decreases with increase in capacitance of capacitor.

36. Assertion (A): A transformer cannot work on D.C. supply.
Reason (R): D.C. changes neither in magnitude nor in direction.

37. Assertion (A) : The alternating current lags behind the e.m.f. by a phase angle of n/2, when A.C. flows through an inductor.
Reason (R): The inductive reactance increases as the frequency of A.C. source decreases.

38. Assertion (A): Capacitor serves as a block for D.C. and offers an easy path to A.C.
Reason (R): Capacitive reactance is inversely proportional to frequency.

➢ Case Study Question

39. The large – scale transmission and distribution of electrical energy over long distance is done with the use of transformers. The voltage output of the generator is stepped – up. It is then transmitted over long distances to an area sub-station near the consumers. There the voltage is stepped down. It is further stepped down at distributing sub-stations and utility poles before a power supply of 240 V reaches our homes.

(i) Which of the following statement is true?

(a) Energy is created when a transformer steps up the voltage.

(b) A transformer is designed to convert an AC voltage to DC voltage.

(c) Step – up transformer increases the power for transmission.

(d) Step – down transformer decreases the AC voltage.

(ii) If the secondary coil has a greater number of turns than the primary,

(a) The voltage is stepped-up $(V_s > V_p)$ and arrangement is called a step – up transformer

(b) The voltage is stepped – down $(V_s < V_p)$ and arrangement is called a step – down transformer

(c) The current is stepped – up $(I_s > I_p)$ and arrangement is called a step – up transformer

(d) The current is stepped – down $(I_s < I_p)$ and arrangement is called a step - down transformer.

(iii) We need to step – up the voltage for power transmission, so that

(a) The current is reduced and consequently, the I^2R loss is cut down

(b) The voltage is increased, the power losses are also increased

(c) The power is increased before transmission is done

(d) The voltage is decreased so V^2/R losses are reduced.

(iv) A power transmission line feeds input power at 2300 V to a step down transformer with its primary windings having 4000 turns. The number of turns in the secondary in order to get output power at 230 V are [Term I 2021 – 22]

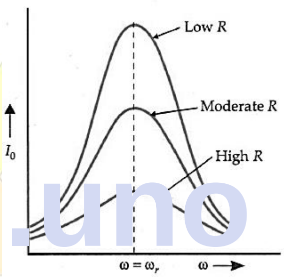
(a) 4 (b) 40

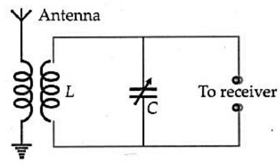
(c) 400 (d) 4000

40. An interesting characteristic of a series LCR-circuit is the phenomenon of resonance. The circuit exhibits resonance i.e., the amplitude of current is maximum at the resonant frequency, $\omega_r = 1/\sqrt{LC}$ The quality factor Q is an indicator of the sharpness of the resonance.

$$Q\text{-}factor = \frac{\text{Resonant frequency}}{\text{Bandwidth}} = \frac{\omega_r}{\omega_2 - \omega_1} = \frac{\omega_r L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

where ω_1 and ω_2 are the two frequencies on either side of ω_r such that at each frequency, the current amplitude becomes $1/\sqrt{2}$ times the value at resonant frequency. The higher value of Q indicates a sharper peak in current.





The sharpness of resonance is an important matter in radio reception of transmitting stations. If it is not sharp, other transmitting stations may produce a current I of the same value as the station required. Then interference will occur. If resistance R in the series LCR-circuit is small, then the resonance is sharp.

6. A transmitting station transmits radiowaves of wavelength 360 m. Find the inductance of the coil required with a condenser of capacity 1.20 μF in the resonant circuit.

(a) $1.25 \times 10^{-8} H$ (b) $3.07 \times 10^{-8} H$

(c) $2.25 \times 10^{-8} H$ (d) $1.9 \times 10^{-8} H$

7. Series a.c. circuit has inductance L, resistance R and angular frequency ω, the quality factor Q is

(a) $\left(\frac{\omega L}{R}\right)^2$ (b) $\frac{\omega L}{R}$

(c) $\frac{R}{\omega L}$ (d) $\left(\frac{R}{\omega L}\right)^2$

8. The values of L, C and R for a circuit are 1H, 9F and 3Ω. What is the quality factor for the circuit at resonance?

(a) 1 (b) 9 (c) $\frac{1}{9}$ (d) $\frac{1}{3}$

9. In a series LCR-circuit, the quality factor can be improved by

(a) decreasing L (b) increasing C

(c) decreasing R (d) decreasing R and L.

10. R, L and C represent the physical quantities resistance, inductance and capacitance respectively. Which one of the following combinations has dimension of frequency?

(a) $\frac{1}{\sqrt{RC}}$ (b) $\frac{R}{L}$ (c) $\frac{1}{LC}$ (d) $\frac{C}{L}$

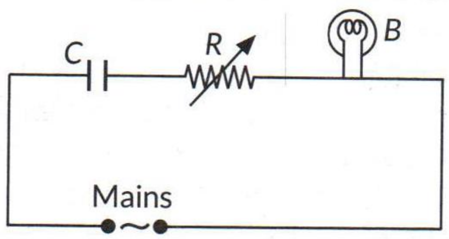
➢ Questions

41. An ac source of emf V = $V_0 \sin \omega t$ is connected to a capacitor of capacitance C. Deduce the expression for the current (I) flowing in it. Plot the graph of (i) V vs ωt, and (ii) I vs ωt. [2020]

OR

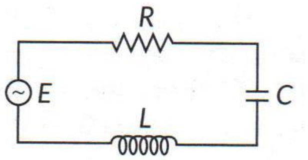
Show that the current leads the voltage in phase by $\pi/2$ in an ac circuit containing an ideal capacitor. [Foreign 2014]

42. A capacitor 'C', a variable resistor 'R' and a bulb 'B' are connected in series to the ac mains in circuit as shown. The bulb glows with some brightness.



How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistance R is increased keeping the same capacitance? [Delhi 2014]

43. The figure shows a series LCR circuit connected to a variable frequency 200 V source with L = 50 mH, C = 80 μF and R = 40 Ω.

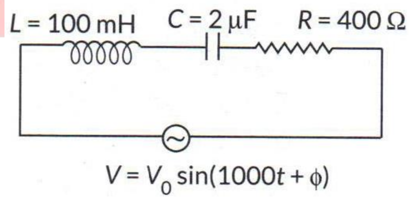


Determine [AI 2014C]

(i) The source frequency which derives the circuit in resonance.

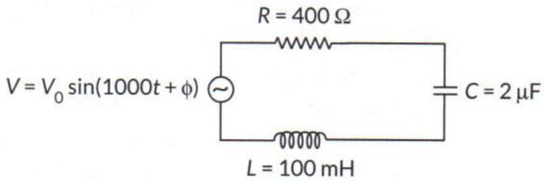
(ii) The quality factor (Q) of the circuit.

44. Find the value of the phase difference between the current and the voltage in the series LCR circuit shown below. Which one leads in phase: current or voltage? [2/3, Delhi 2017]



OR

Determine the value of phase difference between the current and the voltage in the given series LCR circuit. [2/3, AI 2015]



45. A device X is connected across an ac source of voltage $V = V_0 \sin \omega t$. The current through X is given as $I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$. [2018]

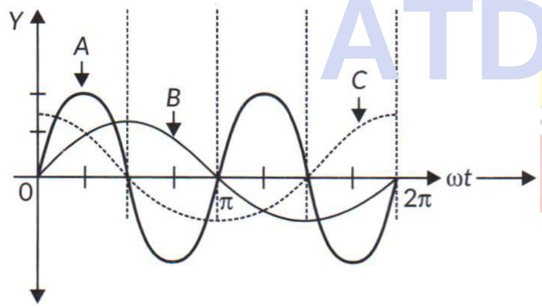
(a) Identify the device X and write the expression for its reactance.

(b) Draw graphs showing variation of voltage and current with time over one cycle of ac, for X.

(c) How does the reactance of the device X vary with frequency of the ac? Show this variation graphically.

(d) Draw the phasor diagram for the device X.

46. A device 'X' is connected to an ac source $V = V_0 \sin \omega t$. The variation of voltage, current and power in one cycle is shown in the following graph: [AI 2017]



(a) Identify the device 'X'.

(b) Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit? Justify your answer.

(c) How does its impedance vary with frequency of the ac source? Show graphically.

(d) Obtain an expression for the current in the circuit and its phase relation with ac voltage.

47. (a) In a series LCR circuit connected across an ac source of variable frequency, obtain the expression for its impedance and draw a plot showing its variation with frequency of the ac source.

(b) What is the phase difference between the voltages across inductor and the capacitor at resonance in the LCR circuit?

(c) When an inductor is connected to a 200 V dc voltage, a current of 1A flows through it. When the same inductor is connected to a 200 V, 50 Hz ac source, only 0.5 A current flows. Explain, why? Also, calculate the self inductance of the inductor.

48. With the help of a labelled diagram, explain the working of a step – up transformer. Give reasons to explain the following: [3/5, 2020]

(i) The core of the transformer is laminated.

(ii) Thick copper wire is used in windings.

49. (a) Draw the diagram of a device which is used to decrease high ac voltage into a low ac voltage and state its working principle. Write four sources of energy loss in this device.

(b) A small town with a demand of 1200 kW of electric power at 220 V is situated 20 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5 Ω per km. The town gets the power from the line through a 4000 – 220 V step – down transformer at a substation in the town. Estimate the line power loss in the form of heat. [Delhi 2019]

50. A lamp is connected in series with a capacitor. Predict your observation when this combination is connected in turn across
(i) ac source and
(ii) a dc battery. What change would you notice in each case if the capacitance of the capacitor is increased?

51. When an inductor is connected to 200 V dc voltage, a current of 1 A flows through it. When

the same inductor is connected to a 200 V, 50 Hz ac source, only 0.5 A current flows. Explain, why ? Also, calculate the self inductance of the inductor.

52. A small town with a demand of 1200 kW of electric power at 220V is situated 20 km away from an electric plant generating power at 440 V. the resistance of the two wire line carrying power is 0.5 Ω per km. the town gets the power from the line through a 4000-220 V step-down transformer at a sub-station in the town. Estimate the line power loss in the from of heat.

53. A device X is connected across an ac source of voltage $V = V_0 \sin \omega t$. The current through X is given as $I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$

(a) Identify the device X and write the expression for its reactance.

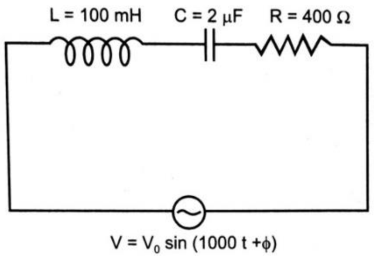
(b) Draw graphs showing variation of voltage and current with time over one cycle of ac, for X.

(c) How does the reactance of the device X vary with frequency of the ac? Show this variation graphically.

(d) Draw the phasor diagram for the device X.

54. (a) Find the value of the phase difference between the current and the voltage in the series LCR circuit shown below. Which one leads in phase: current or voltage?

(b) Without making any other change, find the value of the additional capacitor C_1, to be connected in parallel with capacitor C, in order to make the power factor of the circuit unity.



55. In a series LCR circuit connected to an ac source of variable frequency and voltage $v = v_m \sin \omega t$, draw a plot showing the variation of current (I) with angular frequency (ω) for two different values of resistance R_1 and $R_2 (R_1 > R_2)$. Write the condition under which the phenomenon of resonance occurs. For which value of the resistance out of the two curves, a sharper resonance is produced? Define Q-factor of the circuit and give its significance.

56. The power factor of an *ac* circuit is 0.5. What is the phase difference between voltage and current in the circuit?

57. Define rms value of AC & derive an expression for it.

58. Why is the use of *ac* voltage preferred over *dc* voltage? Give two reasons.

59. Show that the current leads the voltage in phase by $\pi/2$ in an a.c. circuit containing an ideal capacitor & also show that the average power supplied by the source over a complete cycle is Zero in this circuit.

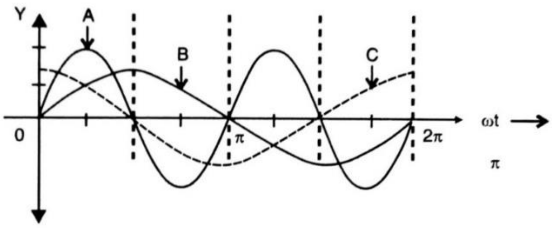
60. (i) Prove that current flowing through an ideal inductor connected across ac source, lags the voltage in phase by $\frac{\pi}{2}$.

(ii) An inductor of self-inductance 100mH and a bulb are connected in series with *ac* source of *rms* voltage 10 V, 50Hz. It is found that effective voltage of the circuit leads the current in phase by $\frac{\pi}{4}$. Calculate the inductance of the inductor used and average power dissipated in the circuit, if a current of 1A flows in the circuit.

61. Obtain the expression for the energy density of magnetic field B produced in the inductor.

62. A device 'X' is connected to an ac source $V = V_m \sin \omega t$.

The variation of voltage, current and power in one cycle is shown in the following graph:

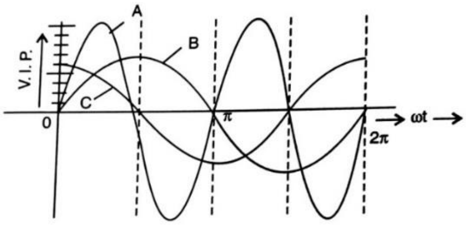


(i) identify the device 'X'.

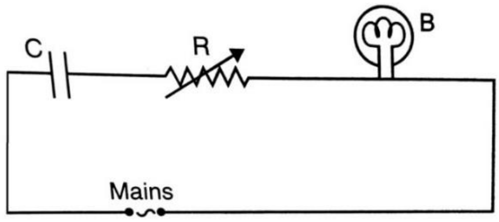
(ii) Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit? Justify your answer.
(iii) How does its impedance vary with frequency of the ac source? Show graphically.
(iv) Obtain an expression for the current in the circuit and its phase relation with ac voltage.

63. A device 'X' is connected to an ac source $V = V_0 \sin \omega t$. The variation of voltage, current and power in one complete cycle is shown in the following figure.

i. Which curve shows power consumption over a full cycle?
ii. Identify the device 'X'



64. A capacitor 'C', a variable resistor 'R' and a bulb 'B' are connected in series to the *ac* mains in circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistor R is increased keeping the same capacitance?



65. A 200 mH (pure) inductor and a 5 μF (pure) capacitor are connected one by one, across a sinusoidal ac voltage source of V = [70.7 sin (1000t)] voltage. Obtain the expressions for the current in each case.

66. An *ac* voltage $V = V_m \sin\omega t$ is applied to a series LCR circuit. Obtain an expression for the current in the circuit and voltage. What is resonance frequency?

67. (i) An *ac* source of voltage $V = V_0 \sin \omega t$ is connected to a series combination of L, C and R. Use the phasor diagram to obtain expressions for impedance of the circuit and phase angle between voltage and current. Find the condition when current will be in phase with the voltage. What is the circuit in this condition called?
(ii) In a series LR circuit $X_L = R$ and power factor of the circuit is P_1. When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2. Calculate $\frac{P_1}{P_2}$

68. (i) Describe, with the help of a suitable diagram, the working principle of a step-up transformer. Obtain the relation between input and output voltages in terms of the number of turns of primary and secondary windings and the currents in the input and output circuits.
(ii) Given the input current 15 A and the input voltage of 100 V for a step-up transformer having 90% efficiency, find the output power and the voltage in the secondary if the output current is 3 A.

69. (i) Write the function of a transformer. State its principle of working with the help of a diagram. Mention various energy losses in this device. (ii) The primary coil of an ideal step up transformer has 100 turns and transformation ratio is also 100. The input voltage and power are respectively 220 V and 1100 W. Calculate

a. Number of turns in secondary
b. Current in primary
c. voltage across secondary
d. Current in secondary
e. Power in secondary

70. You are given three circuit elements X, Y and Z. When the element X is connected across an *a.c.* source of a given voltage, the current and the voltage are in the same phase. When the element Y is connected in series with X across the source, Voltage is ahead of the current in phase by $\frac{\pi}{4}$. But the current is ahead of the voltage in phase by $\frac{\pi}{4}$ when Z is connected in series with X across the source. Identify the circuit elements X, Y and Z. When all the three elements are connected in series across the same source, determine the impedance of the circuit.

71. A circuit containing a 80 mH inductor and a 60 μF capacitor in series is connected to a 230 V, 50 Hz supply. The resistance of the circuit is negligible.
   a. Obtain the current amplitude and *rms* values.
   b. Obtain the rms values of potential drops across each element.
   c. What is the average power transferred to the inductor?
   d. What is the average power transferred to the capacitor?
   e. What is the total average power absorbed by the circuit?

SURE SHOT QUESTIONS

ARVIND ACADEMY

Chapter – 08

Electromagnetic Waves

MCQ (1 mark)

1. One requires 11eV of energy to dissociate a carbon monoxide molecule into carbon and oxygen atoms. The minimum frequency of the appropriate electromagnetic radiation to achieve the dissociation lies in
(a) visible region (b) infrared region
(c) ultraviolet region (d) microwave region

2. A linearly polarized electromagnetic wave given as $\vec{E} = E_0 \hat{i} \cos(kz - \omega t)$ is incident normally on a perfectly reflecting infinite wall at z = a. Assuming that the material of the wall is optically inactive, the reflected wave will be given as
(a) $\vec{E}_r = -E_0 \hat{i} \cos(kz - \omega t)$
(b) $\vec{E}_r = E_0 \hat{i} \cos(kz + \omega t)$
(c) $\vec{E}_r = -E_0 \hat{i} \cos(kz + \omega t)$
(d) $\vec{E}_r = E_0 \hat{i} \sin(kz - \omega t)$

3. Light with an energy flux of 20 W/cm^2 falls on a non – reflecting surface at normal incidence. If the surface has an area of 30 cm^2, the total momentum delivered (for complete absorption) during 30 minutes is
(a) 36 x 10^{-5} kg m/s
(b) 36 x 10^{-4} kg m/s
(c) 108 x 10^{4} kg m/s
(d) 1.08 x 10^{7} kg m/s

4. The electric field intensity produced by the radiations coming from 100 W bulb at a 3 m distance is E. The electric field intensity produced by the radiations coming from 50 W bulb at the same distance is
(a) $\frac{E}{2}$ (b) 2E
(c) $\frac{E}{\sqrt{2}}$ (d) $\sqrt{2}\ E$

5. If $\vec{E}$ and $\vec{B}$ represent electric and magnetic field vectors of the electromagnetic wave, the direction of propagation of electromagnetic wave is along
(a) $\vec{E}$ (b) $\vec{B}$
(c) $\vec{B} \times \vec{E}$ (d) $\vec{E} \times \vec{B}$

6. The ratio of contributions made by the electric field and magnetic field components to the intensity of an electromagnetic wave is
(a) c : 1 (b) c^2 : 1
(c) 1 : 1 (d) $\sqrt{c} : 1$

7. An electromagnetic wave radiates outwards from a dipole antenna, with E_0 as the amplitude of its electric field vector. The electric field E_0 which transports significant energy from the source falls off as
(a) $\frac{1}{r^3}$ (b) $\frac{1}{r^2}$
(c) $\frac{1}{r}$ (d) remains constant.

8. Displacement current exists only when [2020]

(a) Electric field is changing.
(b) Magnetic field is changing.
(c) Electric field is not changing.
(d) Magnetic field is not changing.

9. The oscillating electric and magnetic field vectors in an electromagnetic wave are
(a) perpendicular to each other and opposite in phase,
(b) parallel to each other and opposite in phase,
(c) perpendicular to each other and in the same phase,
(d) parallel to each other and in the same phase.

10. Name the electromagnetic waves also known as 'heat waves'. [2023]
(a) Radiowaves (b) Microwaves
(c) X-rays (d) Infrared waves

11. Which one of the following electromagnetic radiation has the least wavelength? [2023]
(a) Gamma rays (b) Microwaves
(c) Visible light (d) X – rays

12. A welder wears special glasses to protect his eyes mostly from the harmful effect of [2020]
(a) Very intense visible light
(b) Infrared radiation
(c) Ultraviolet rays
(d) Microwave.

13. Electromagnetic waves used as a diagnostic tool in medicine are [2020]
(a) X-rays (b) ultraviolet rays
(c) infrared radiation (d) ultrasonic waves.

14. Which of the following statement is NOT true about the properties of electromagnetic waves? [2022 – 23]
(a) These waves do not require any material medium for their propagation,
(b) Both electric and magnetic field vectors attain m the maxima and minima at the same time.
(c) The energy in electromagnetic wave is divided 4. equally between electric and magnetic fields,
(d) Both electric and magnetic field vectors are parallel to each other.

➢ Assertion-Reasoning (1 mark)

15. Assertion (A): When a charged particle moves in a circular path. It produces electromagnetic
Reason (R): Charged particle has acceleration.

16. Assertion (A): Electromagnetic waves exert pressure called radiation pressure.
Reason (R): Electromagnetic waves carries energy.

17. Assertion (A): Light is a transverse wave but not an electromagnetic wave.
Reason (R): Maxwell showed that speed of electromagnetic waves is related to the permittivity of the medium through which it travels.

18. Assertion (A): The electric field and magnetic field have equal average values in linearly polarized plane em wave.
Reason (R): The electric energy and magnetic energy have equal average values in linearly polarized plane em wave.

19. Assertion (A): Light can travel in vacuum whereas sound cannot do so.
Reason (R): Light has an electromagnetic wave nature whereas sound is mechanical wave.

20. Assertion (A): The microwaves are better carriers of signals than radio waves.
Reason (R): The electromagnetic waves do not required any material medium for propagation.

21. Assertion (A): Velocity of light is constant in all media.
Reason (R): Light is an electromagnetic wave which has constant velocity in all media.

22. Assertion (A): X-rays in vacuum travel faster than light waves in vacuum.
Reason (R): The energy of X-rays photon is less than that of light photon.

23. Assertion (A) : In an electromagnetic wave, magnitude of magnetic field vector is much smaller than the
magnitude of electric field vector.
Reason (R): Energy of electromagnetic waves is shared equally by the electric and magnetic fields.

24. Assertion (A): The electromagnetic waves are transverse in nature.
Reason (R): These waves propagate in straight lines.

➢ Case Study

PARAGRAPH 1: Sources of an Electromagnetic Wave

25. According to Maxwell, an accelerating charge produces electromagnetic waves. Consider a charge oscillating harmonically with time. This is an example of an accelerating charge. This charge produces an oscillating electric field in its neighbourhood. This field, in turn, produces an oscillating magnetic field in its neighbourhood. The process continues because the oscillating electric and magnetic fields act as sources of each other. Hence an electromagnetic wave originates from the oscillating charge. The frequency of the electromagnetic wave is equal to the frequency of oscillation of the charge. The energy carried by the wave comes from the source which makes the charge oscillating. An electric dipole is a basic source of electromagnetic waves. An LC-circuit containing inductance L and capacitance C produces electromagnetic waves of frequency, $\text{v} = 1/\ 2\pi\sqrt{LC}$.

QUESTIONS (Answer any four of the following questions)

1. Electromagnetic waves are produced by

(a) accelerated charged particle

(b) charge at rest

(c) charge in uniform motion

(d) none of these

2. Light can travel in vacuum due to its

(a) transverse nature

(b) electromagnetic nature

(c) longitudinal nature

(d) both (a) and (c).

3. If a source is transmitting electromagnetic wave of frequency 8.2×10^6 Hz , the wavelength of electro-magnetic wave transmitted from the source is

(a) 35.6 m (b) 18.8 m

(c) 42.8 m (d) 58 m

4. A plane electromagnetic wave travels in vacuum along $\hat{k}$ direction, where $\hat{i}, \hat{j}$ and $\hat{k}$ are unit vectors along the x, y and z directions. The directions along which the electric and the magnetic field vectors point may be respectively

(a) $\hat{i}$ and $\hat{j}$ (b) $\hat{i}$ and $-\hat{j}$

(c) $\hat{j}$ and $\hat{i}$ (d) $\hat{k}$ and $\hat{i}$

5. According to Maxwell's equation, the velocity of light in any medium is expressed as

(a) $\frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ (b) $\frac{1}{\sqrt{\mu \varepsilon}}$

(c) $\frac{1}{\sqrt{\mu/\varepsilon}}$ (d) $\sqrt{\frac{\mu_0}{\varepsilon}}$

PARAGRAPH 2: Electromagnetic Spectrum

26. All the known radiations form a big family of electromagnetic waves which stretch over a large range of wavelengths. The orderly distribution of electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is called electromagnetic spectrum. The main parts of the electromagnetic spectrum are γ-rays, X-rays, ultraviolet rays, visible light, infrared waves, microwaves and radiowaves in the order of increasing wavelength from 10^{-2}Å or 10^{-12} m to 10^{6} m. The wavelength of the e.m. wave is correlated with the characteristic size of the system that radiates. Thus, γ-rays having wavelength of 10^{-14}m to 10^{-15}m, typically originate from an atomic nucleus. X-rays are emitted from heavy atoms. Radiowaves are produced by accelerating electrons in a circuit. A transmitting antenna can most efficiently radiate waves having λ of about the same size as the antenna. Visible radiation emitted by atoms is, however, much longer in wavelength than atomic size.

6. The correct option, if speeds of gamma rays, x-rays and micro waves are v_g, v_x and v_m respectively, will be

(a) $v_g > v_x > v_m$ (b) $v_g < v_x < v_m$

(c) $v_g > v_x > v_m$ (d) $v_g = v_x = v_m$

7. In the order of increasing frequency, the electromagnetic spectrum may be arranged as:

(a) gamma rays. X-rays, visible light, radio waves

(b) X-rays, gamma rays, visible light, radio waves

(c) radio waves, visible light. X-rays, gamma rays

(d) radio waves, visible light, gamma rays. X-rays.

8. Microwave oven acts on the principle of

(a) giving rotational energy to water molecules

(b) giving vibrational energy to water molecules

(c) giving translational energy to water molecules

(d) transferring electrons from lower to higher energy levels in water molecule.

9. The condition under which a microwave oven heats up a food item containing water molecules most efficiently, is

(a) The frequency of the microwaves must match the resonant frequency of the water molecules

(b) The frequency of the microwaves has no relation with natural frequency of water molecules

(c) Microwaves are heat waves, so always produce heating

(d) Infrared waves produce heating in a microwave oven.

10. The structure of solids is investigated by using

(a) cosmic rays (b) X-rays

(c) γ-rays (d) infrared radiation.

➢ Question

27. A parallel plate capacitor of plate area A each and separation d, is being charged by an AC source. Show that the displacement current inside the capacitor is the same as the current charging the capacitor. [AI 2019]

28. How does Ampere – Maxwell law explain the flow of current through a capacitor when it is being charged by a battery? Write the expression for the displacement current in terms of the rate of change of electric flux. [Delhi 2017]

29. Write Maxwell's generalization of Ampere's circuital law. Show that in the process of charging a capacitor, the current produced within the plates of the capacitor is

$$i = \varepsilon_0 \frac{d\phi_E}{dt}$$

Where ϕ_E is the electric flux produced during charging of the capacitor plates. [Delhi 2016]

30. Write the expression for the speed of light in a material medium of relative permittivity ε_r and relative magnetic permeability μ_r. [1/3, 2020]

31. Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field. [2/3, Delhi 2019]

32. How are e.m. waves produced by oscillating charges ? Draw a sketch of linearly polarized e.m. waves propagating in the z-direction. Indicate the directions of the oscillating electric and magnetic fields. [Delhi 2016]

33. Write the wavelength range and name of the electromagnetic waves which are used in [2/3, 2020]
    (i) Radar systems for aircraft navigation, and
    (ii) Earth satellites to observe the growth of the crops.

34. Identify the part of the electromagnetic spectrum used in (i) radar and (ii) eye surgery. Write their frequency range. [1/3, Delhi 2019]

35. Identify the part of the electromagnetic spectrum which is: [2/3, AI 2016]
    (a) Suitable for radar system used in aircraft navigation,
    (b) Produced by bombarding a metal target by high speed electrons.

36. Answer the following questions:
    (a) Name the e.m. waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves,
    (b) If the Earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain,
    (c) An e.m. wave exerts pressure on the surface on which it is incident. Justify. [Delhi 2014]

37. Answer the following questions: [Delhi 2014C]
    (i) Show, by giving a simple example, how e.m. waves carry energy and momentum,
    (ii) How are microwaves produced? Why is it necessary in microwave ovens to select

the frequency of microwaves to match the resonant frequency of water molecules?

(iii) Write two important uses of infrared waves.

38. Answer the following questions:
(a) Name the e.m. waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.
(b) if the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.
(c) An e.m. wave exerts pressure on the surface on which it is incident. Justify.s

39. (a) When the oscillating electric and magnetic fields are along the x-and y-direction respectively.
(i) point out the direction of propagation of electromagnetic wave.
(ii) express the velocity of propagation in terms of the amplitudes of the oscillating electric and magnetic fields.
(b) How do you show that the e.m. wave carries energy and momentum?

40. Arrange the following electromagnetic waves in the descending order of their wavelengths:
(i) Microwaves
(ii) Infra-red rays
(iii) Ultra – violet – radiation
(iv) Gamma rays
(b) write one use each of any two of them.

41. Why are infrared waves often called heat waves? Explain.

42. What are the directions of electric and magnetic field vectors relative to each other and relative to the direction propagation of electromagnetic waves?

43. (a) An EM wave is travelling in a medium with a velocity $v = v\hat{\imath}$. Draw a sketch showing the propagation of the EM wave, indicating the direction of the oscillating electric and magnetic fields.
(b) How are the magnitudes of the electric and magnetic fields related to velocity of the EM wave?

44. Answer the following :
(a) Name the e.m. waves which are used for the treatment of certain forms of cancer. Write their frequency range.
(b) why is the amount of the momentum transferred by the e.m. waves incident on the surface so small?

45. Answer the following :
(a) Name the e.m. waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.
(b) If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.
(c) An e.m. wave exerts pressure on the surface on which it is incident. Justify.

46. How are e.m. waves produces produced by oscillating charges? Draw a sketch of linearly polarized e.m. waves propagating in the Z-direction. Indicate the direction of the oscillating electric and magnetic fields.

47. Which of the following radiations are (i) heat radiation and (ii) used for long distance transmission? Infrared rays, gamma rays, ultraviolet rays, microwaves.

48. Identify the part of the electromagnetic spectrum to which the following wavelengths belong:
(i) 10^{-1} m
(ii) 10^{-12} m

49. Why are Infra-red radiations referred to as heat waves? Name the radiations which are next to these radiations in the electromagnetic spectrum having (i) shorter wavelength (ii) longer wavelength.

50. What is the meant by the transverse nature of electromagnetic waves? Draw a diagram showing the propagation of an electromagnetic wave along X-direction, indicating clearly the directions of

oscillating electric and magnetic fields associated with it.

51. (a) Which one of the following electromagnetic radiations has the least frequency: Ultraviolet radiations, X-rays, Microwaves?
(b) How do you show that electromagnetic waves carry energy and momentum?
(c) Write the expression for the energy density of an electromagnetic wave propagating in free space.

52. Identify the following electromagnetic radiations as per the wavelengths given below:
(i) 10^{-3} nm
(ii) 10^{-3} m
(iii) 1 nm
Write one application of each

53. Which constituent radiation of the electromagnetic spectrum is used
(i) in RADAR
(ii) to photograph internal parts of a human body, and
(iii) for taking photographs of the sky during night and foggy conditions?
Give one reason for your answer in each case
Answer the following questions:
(i) Why is the thin ozone layer on top of the stratosphere crucial for human survival? Identify to which part of electromagnetic spectrum does this radiation belong and write one important application of the radiation.
(ii) Why are infrared waves referred to as heat waves? How are they produced? What role do they play in maintaining the earth's warmth through the green house effect?

54. (i) How are microwaves produced? Why is it necessary in microwave ovens to select the frequency of microwaves to match the resonant frequency of water molecules?
(ii) Write two important uses of infrared waves

55. In an electromagnetic wave in free space the root mean square value of the electric field is $E_{ems} = 6Vm^{-1}$ Find the peak value of the magnetic field.

56. A plane electromagnetic wave of frequency 25 MHz travels in free space along the x-direction. At a particular point in space and time, $\vec{E} = 6.3\hat{j}\ V/m.$ At this point find $\vec{B}$.

57. A plane electromagnetic wave travels in free space along x-direction. If the value of B (in tesla) at a particular point in space and time is $1.2 \times 10^{-8}\hat{k}$ What the value of $\vec{E}$ $(in\ V\ m^{-1})$ at that point is

SURE SHOT QUESTIONS

ARVIND ACADEMY

Chapter – 09

Ray Optics and Optical Instruments

MCQ (1 mark)

1. A ray of light incident at an angle θ on a refracting face of a prism emerges from the other face normally.
If the angle of the prism is 5^0 and the prism is made of a material of refractive index 1.5, the angle of incidence is
(a) 7.5^0 (b) 5^0
(c) 15^0 (d) 2.5^0

2. A short pulse of white light is incident from air to a glass slab at normal incidence. After travelling through the slab, the first colour to emerge is
(a) blue (b) green
(c) violet (d) red.

3. An object approaches a convergent lens from the left of the lens with a uniform speed 5 m s^{-1} and stops at the focus. The image
(a) Moves away from the lens with an uniform speed 5 m s^{-1}.
(b) Moves away from the lens with an uniform acceleration.
(c) Moves away from the lens with a non-uniform acceleration
(d) Moves towards the lens with a non-uniform acceleration.

4. A passenger in an aeroplane shall
(a) never see a rainbow,
(b) may see a primary and a secondary rainbow as concentric circles,
(c) may see a primary and a secondary rainbow as concentric arcs,
(d) shall never see a secondary rainbow.

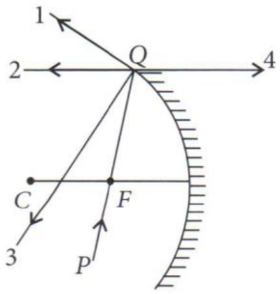
5. You are given four sources of light each one providing a light of a single colour - red, blue, green and yellow. Suppose the angle of refraction for a beam of yellow light corresponding to a particular angle of incidence at the interface of two media is 90°. Which of the following statements is correct, if the source of yellow light is replaced with that of other lights without changing the angle of incidence?
(a) The beam of red light would undergo total internal reflection.
(b) The beam of red light would bend towards normal while it gets refracted through the second medium,
(c) The beam of blue light would undergo total internal reflection.
(d) The beam of green light would bend away from the normal as it gets refracted through the second medium.

6. The radius of curvature of the curved surface of a plano-convex lens is 20 cm. If the refractive index of the material of the lens be 1.5, it will
(a) act as a convex lens only for the objects that lie on its curved side,
(b) act as a concave lens for the objects that lie on its curved side,
(c) act as a convex lens irrespective of the side on which the object lies,
(d) act as a concave lens irrespective of side on which the object lies.

7. The phenomena involved in the reflection of radio-waves by ionosphere is similar to
(a) reflection of light by a plane mirror,
(b) total internal reflection of light in air during a mirage,

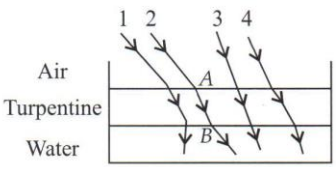
(c) dispersion of light by water molecules during the formation of a rainbow,
(d) scattering of light by the particles of air.

8. The direction of ray of light incident on a concave mirror is shown by PQ while directions in which the ray would travel after reflection is shown by four rays marked 1, 2, 3 and 4. Which of the four rays correctly shows the direction of reflected ray?



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

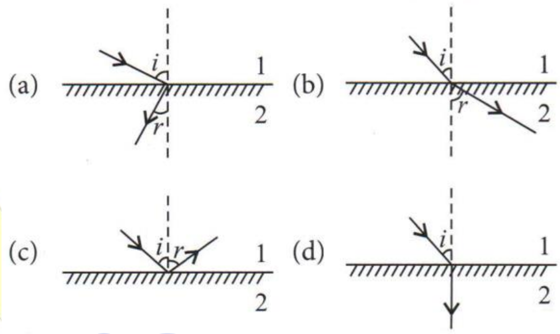
9. The optical density of turpentine is higher than that of water while its mass density is lower. Figure shows a layer of turpentine floating over water in a container. For which one of the four rays incident on turpentine in figure, the path shown is correct?



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

10. A car is moving with a constant speed of 60 km h^{-1} on a straight road. Looking at the rear view mirror, the driver finds that the car following him is at a distance of 100 m and is approaching with a speed of 5 km h^{-1}. In order to keep track of the car in the rear, the driver begins to glance alternatively at the rear and side mirror of his car after every 2 s till the other car overtakes. If the two cars were maintaining their speeds, which of the following statement (s) is/are correct?
(a) The speed of the car in the rear is 65 km h^{-1}.
(b) In the side mirror the car in the rear would appear to approach with a speed of 5 km h to the driver of the leading car.
(c) In the rear view mirror the speed of the approaching car would appear to decrease as the distance between the cars decreases,
(d) In the side mirror, the speed of the approaching car would appear to increase as the distance between the cars decreases.

11. There are certain material developed in laboratories which have a negative refractive index. A ray incident from air (medium 1) into such a medium (medium 2) shall follow a path given by



12. A window is provided in the middle of a wall. Its image is obtained on the opposite wall at a distance 'd' from it using a lens. If the window and its image are of the same size, then the focal length of the lens used is [2020]

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

(c) $-\frac{d}{4}$ (d) $-\frac{d}{2}$

13. A biconvex lens of glass having refractive index 1.47 is immersed in a liquid. It becomes invisible and behaves as a plane glass plate. The refractive index of the liquid is [2020]
(a) 1.47 (b) 1.62
(c) 1.33 (d) 1.51

14. A biconcave lens of power P vertically splits into two identical plano concave parts. The power of each part will be [2020]
   (a) 2P (b) P/2
   (c) P (d) $P/\sqrt{2}$

15. For a glass prism, the angle of minimum deviation will be smallest for the light of [2020]
   (a) red colour (b) blue colour
   (c) yellow colour (d) green colour

➢ Assertion-Reasoning (1 mark)

16. Given below are two statements labelled as assertion (A) and Reason (R).
   Assertion (A) : A convex mirror cannot form real images.
   Reason (R): Convex mirror converges the parallel rays that are incident on it.
   Select the most appropriate answer from the options given below: [2020 – 21]
   (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.

17. Given below are two statements labelled as assertion (A) and Reason (R).
   Assertion (A): A convex lens of focal length 30 cm can't be used as a simple microscope in normal setting.
   Reason (R): For normal setting, the angular magnification of simple microscope is M = D/F
   Select the most appropriate answer from the options given below: [2020 – 21]
   (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.

18. Assertion (A) : The angle of minimum deviation for a prism is lesser for red light than that for blue light.
   Reason (R): The refractive index of the material of a prism for blue light is greater than that for red light.
   (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. [2021]

19. Assertion (A): The light travelling from air to glass cannot suffer total internal reflection.
   Reason (R): Air is rarer than glass.

20. Assertion (A): By increasing the diameter of the objective of telescope, we can increase its range.
   Reason (R): The range of a telescope tells us how far away a star of some standard brightness can be spotted
   by telescope.

21. Assertion (A) : A convex lens is made of two different materials. A point object is placed on the principal
   axis. The number of images formed by the lens will be two.
   Reason (R): The image formed by convex lens is always virtual.

22. Assertion (A) : The illuminance of an image produced by a convex lens is greater in the middle and less
towards the edges.
Reason (R): The middle part of image is formed by undeflected rays while outer part by inclined rays.

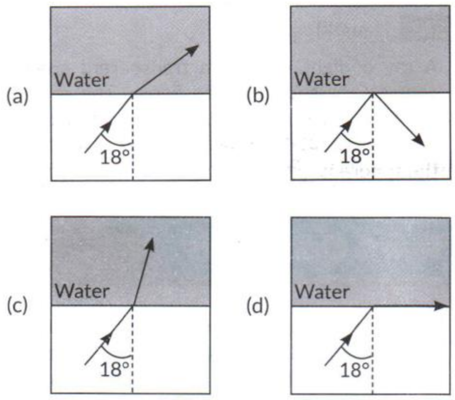
23. Assertion (A): A single lens produces a colored image of an object illuminated by white light.
Reason (R): The refractive index of the material of lens is different for different wavelengths of light.

24. Assertion (A): The minimum distance between an object and its real image formed by a convex lens is 2f.
Reason (R): The distance between an object and its real image is minimum when its magnification is two.

➢ Case Study (5 marks)

Here, question 12 (i) to (v) is a case study base question of 5 marks.

25. A ray of light travels from a denser to a rarer medium. After refraction, it bends away from the normal. When we keep increasing the angle of incidence, the angle of refraction also increases till the refracted ray grazes along the interference of two media. The angle of incidence for which it happens is called critical angle. If the angle of incidence is increased further the ray will not emerge and it will be reflected back in the denser medium. This phenomenon is called total internal reflection of light, (i) A ray of light travels from a medium into water at an angle of incidence of 18°. The refractive index of the medium is more than that of water and the critical angle for the interface between the two media is 20°. Which one of the following figures best represents the correct path of the ray of light?



(ii) A point source of light is placed at the bottom of a tank filled with water, of refractive index μ, to a depth d. The area of the surface of water through which light from the source can emerge, is:

(a) $\frac{\pi d^2}{2(\mu^2-1)}$ (b) $\frac{\pi d^2}{(\mu^2-1)}$

(c) $\frac{\pi d^2}{\sqrt{2}\sqrt{\mu^2-1}}$ (d) $\frac{2\pi d^2}{(\mu^2-1)}$

(iii) For which of the following media, with respect to air, the value of critical angle is maximum?
(a) Crown glass (b) Flint glass
(c) Water (d) Diamond

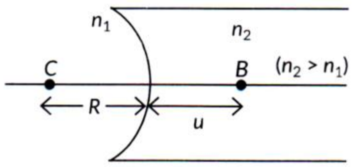
(iv) The critical angle for a pair of two media A and B of refractive indices 2.0 and 1.0 respectively is:
(a) 0^0 (b) 30^0
(c) 45^0 (d) 60^0

(v) The critical angle of pair of a medium and air is 30^0. The speed of light in the medium is:
(a) 1×10^8 m s^{-1} (b) 1.5×10^8 m s^{-1}
(c) 2.2×10^8 m s^{-1} (d) 2.8×10^8 m s^{-1}

26. Two transparent media of refractive indices n_1 and n_2 are separated by a spherical transparent surface. The rays of light incident on the surface get refracted into the medium on the other side. The laws of refraction are valid at each point of the

spherical surface. A lens is a transparent optical medium bounded by two surfaces, at least one of which should be spherical. The focal length of a lens is determined by the radii of curvature (R_1 and R_2) of its two surfaces and the refractive index(n) of the medium of the lens with respect to the surrounding medium. Depending on R_1 and R_2 a lens behaves as a diverging or a converging lens. The ability of a lens to diverge or converge a beam of light incident on it define its power.

(i) An object is placed at the point B as shown in the figure. The object distance (u) and the image distance (v) are related as



(a) $\frac{1}{v}-\frac{1}{u}=\left(\frac{n_2-n_1}{n_1}\right)\frac{1}{R}$

(b) $\frac{1}{v}-\frac{1}{u}=\left(\frac{n_1-n_2}{n_2}\right)\frac{1}{R}$

(c) $\frac{n_2}{v}-\frac{n_1}{u}=\frac{(n_2-n_1)}{R}$

(d) $\frac{n_1}{v}-\frac{n_2}{u}=\frac{(n_1-n_2)}{R}$

(ii) A point object is placed in air at a distance 'R' in front of a convex spherical refracting surface of radius of curvature R. If the medium on the other side of the surface is glass, then the image is

(a) Real and formed in glass.
(b) Real and formed in air.
(c) Virtual and formed in glass.
(d) Virtual and formed in air.

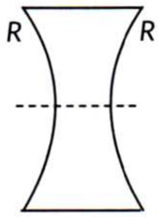
(iii) An object is kept at 2F in front of an equi – convex lens. The image formed is

(a) Real and of the size of the object.
(b) Virtual and of the size of the object.
(c) Real and enlarged.
(d) Virtual and diminished.

(iv) A thin converging lens of focal length 10 cm and a thin diverging lens of focal length 20 cm are placed coaxially in contact. The power of the combination is

(a) -5D (b) +5D
(c) +15D (d) -15D

(v) An equi – concave lens of focal length ‘f’ is cut into two identical parts along the dotted line as shown in the figure. The focal length of each part will be [Term II 2021 – 22]



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

27. The lens maker’s formula is useful to design lenses of desired focal lengths using surfaces of suitable radii of curvature. The focal length also depends on the refractive index of the material of the lens and the surrounding medium. The refractive index depends on the wavelength of the light used. The power of a lens is related to its focal length.

Answer the following questions based on the above.

(a) How will the power of a lens be affected with an increase of wavelength of light?

(b) The radius of curvature of two surfaces of a convex lens is R each. For what value of m of its material will its focal length become equal to R?

(c) The focal length of a concave lens of $\mu = 1.5$ is 20 cm in air. It is completely immersed in water of $\mu = \frac{4}{3}$. Calculate its focal length in water.

OR

(c) An object is placed in front of a lens which forms its erect image of magnification 3. The power of lens is 5D. Calculate the distance of the object and the image from the lens. [2023]

28. A compound microscope consists of two converging lenses. One of them, of smaller aperture and smaller focal length is called objective and the other of slightly larger aperture and slightly larger focal length is called eye-piece. Both the lenses are fitted in a tube with an arrangement to vary the distance between them. A tiny objects is placed in front of the objective at a distance slightly greater than its focal length. The objective produces the image of the object which acts as an object for the eye-piece. The eye piece, in turn produces the final magnified image.

(I) In a compound microscope the images formed by the objective and the eye-piece are respectively
(a) Virtual, real
(b) Real, virtual
(c) Virtual, virtual
(d) Real, real

(II) The magnification due to a compound microscope does not depend upon
(a) The aperture of the objective and the eye-piece
(b) The focal length of the objective and the eye-piece
(c) The length of the tube
(d) The colour of the light used

(III) Which of the following is not correct in the context of a compound microscope?
(a) Both the lenses are of short focal lengths.
(b) The magnifying power increases by decreasing the focal lengths of the two lenses.
(c) The distance between the two lenses is more than $(f_0 + f_e)$.
(d) The microscope can be used as a telescope by interchanging the two lenses.

(IV) A compound microscope consists of an objective of 10X and an eye – piece of 20X. The magnification due to the microscope would be
(a) 2 (b) 10
(c) 30 (d) 200

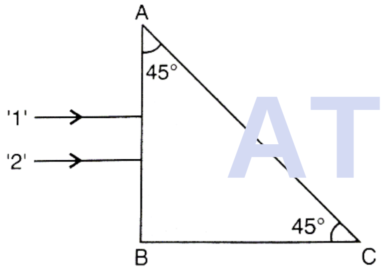
(V) The focal lengths of objective and eye - piece of a compound microscope are 1.2 cm and 3.0 cm respectively. The object is placed at a distance of 1.25 cm from the objective. If the final image is formed at infinity, the magnifying power of the microscope would be [2022C]
(a) 100 (b) 150
(c) 200 (d) 250

➢ Questions

29. An object is kept 20 cm in front of a concave mirror of radius of curvature 60 cm. Find the nature and position of the image formed.

30. An object is kept in front of a concave mirror of focal length 15 cm. The image formed is real and three times the size of the object. Calculate the distance of the object from the mirror. [AI 2019]

31. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.35 and 1.45. Trace the path of these rays after entering through the prism.



32. (a) Calculate the distance of an object of height h from a concave mirror of radius of curvature 20 cm, so as to obtain a real image of magnification 2. Find the location of image also,

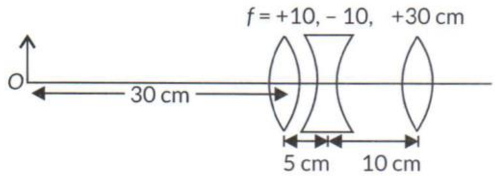
 (b) Using mirror formula, explain why does a convex mirror always produce a virtual image. [Delhi 2016]

33. An object is placed 30 cm in front of a plano – convex lens with its spherical surface of radius of curvature 20 cm. If the refractive index of the material of the lens is 1.5, find the position and nature of the image formed. [2/5, 2020]

34. (a) Using the ray diagram for a system of two lenses of focal lengths f_1 and f_2 in contact with each other, show that the two lens system can be regarded as equivalent to a single lens of focal length f, where $\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$.

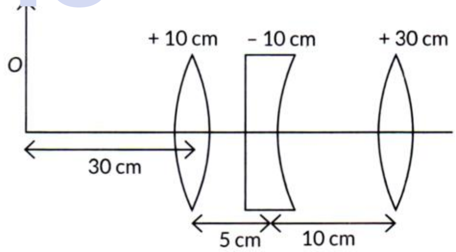
 Also write the relation for the equivalent power of the lens combination.

 (b) Determine the position of the image formed by the lens combination given in the figure.



[AI 2019]

 Three lenses of focal lengths +10 cm, -10 cm and +30 cm are arranged coaxially as in the figure given below. Find the position of the final image formed by the combination. [2/5, Delhi 2019]

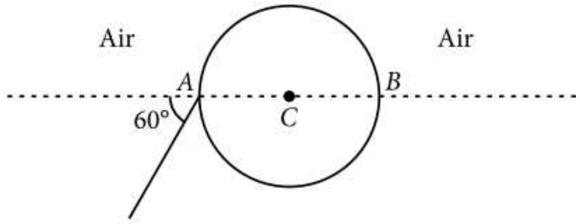


35. An astronomical telescope has an objective lens of focal length 20 m and eyepiece of focal length 1 cm.

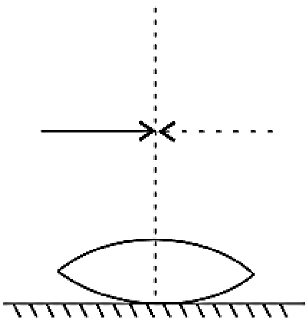
 (a) Find the angular magnification of the telescope.

 (b) If the telescope is used to view the Moon, find the diameter of the image formed by the objective lens. Given the diameter of the Moon is 3.5 x 10^6 m and radius of lunar orbit is 3.8 x 10^8 m. [2/5, 2020]

36. A ray of light falls on a transparent sphere with centre C as shown in the figure. The ray emerges from the sphere parallel to the line AB. Find the angle of refraction at A if refractive index of the material of the sphere is $\sqrt{3}$.

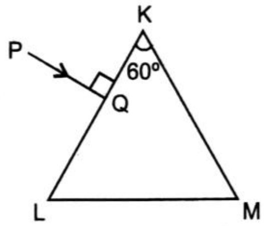


37. A symmetric biconvex lens of radius of curvature R and made of glass of refractive index 1.5, is placed on a layer of liquid placed on top of a plane mirror as shown in the figure. An optical needle with its tip on the principal axis of the lens is moved along the axis until its real, inverted image coincides with the needle from the lens is measured to be x. On removing the liquid layer and repeating the experiment, the distance is found to be y . Obtain the expression for the refractive index of the liquid in terms of x and y.



38. When a convex lens of focal length 30 cm is in contact with a concave lens of focal length 20 cm, find out if the system is converging or diverging.

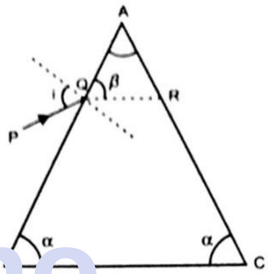
39. A triangular prism of refracting angle 60^0 is made of a transparent material of refractive index $2/\sqrt{3}$. A ray of light is incident normally on the face KL as shown in the figure. Trace the path of the ray as it passes through the prism and calculate the angle of emergence and angle of deviation.



40. Under which conditions can a rainbow be observed? Distinguish between a primary and a secondary rainbow.

41. Under what conditions does the phenomenon of total internal reflection take place? Draw a ray diagram showing how a ray of light deviates by 90^0 after passing through a right-angled isosceles prism.

42. A ray of light incident on the face AB of an isosceles triangular prism makes an angle of incidence (i) and deviates by angle β as shown in the figure. Show that in the position of minimum deviation $\angle\beta = \angle\alpha$. Also find out the condition when the refracted ray QR suffers total internal reflection.



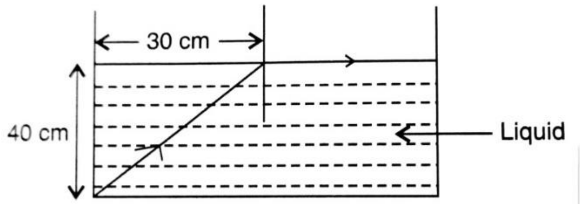
43. State, with the help of a ray diagram, the working principle of optical fibres. Write one important use of optical fibres.

44. A convex lens of focal length 20cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept 15cm apart. A point object is placed 60 cm in front of the convex lens. Draw a ray diagram to show the formation of the image by the combination. Determine the nature and the position of the image formed.

45. An object is placed in front of the convex lens made of glass. How does the image distance vary if the refractive index of the medium is increased in such a way that still it remains less than the glass?

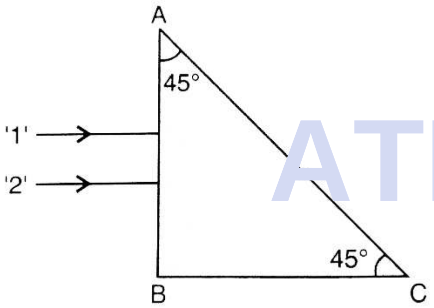
46. (i) Define refractive index of a medium.

(ii) In the following ray diagram, calculate the speed of light in the liquid of unknown refractive index.



47. (i) Why does white light disperse when passed through a glass prism?
(ii) Using lens maker's formula, show how the focal length of a given lens depends upon the colour of light incident on it.

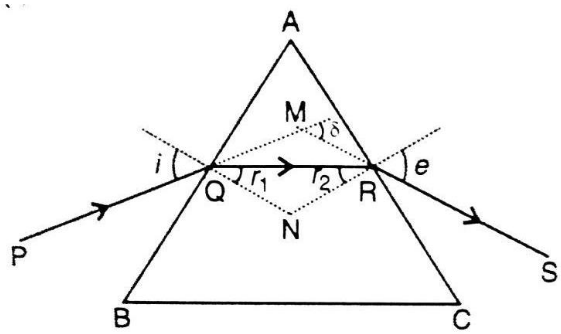
48. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.35 and 1.45. Trace the path of these rays after entering through the prism.



49. (i) Draw a ray diagram to show the image formation by a combination of two thin convex lenses in contact. Obtain the expression for the power of this combination in terms of the focal lengths of the lenses.
(ii) A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is $\frac{3}{4}th$ of the angle of prism.

50. (i) A point of object is placed on the principal axis of the convex spherical surface of the radius of curvature R, which separates the two media of refractive indices n_1 and n_2 ($n_2 > n_1$). Draw the ray diagram and deduce the relation between the object distance (u), image distance (v) and the radius of curvature (R) for refraction to take place at the convex spherical surface from rarer to denser medium.
(ii) A converging lens has a focal length of 20 cm in air. It is made of a material of refractive index 1.6. If it is immersed in a liquid of refractive index 1.3, find its new focal length.

51.



(i) Draw the ray diagram showing refraction of light through a glass prism and hence obtain the relation between the refractive index μ of the prism , angle of prism and angle of minimum deviation.
(ii) Determine the value of the angle of incidence for a ray of light travelling from a medium of refractive index $\mu_1 = 2$ into the medium of refractive index $\mu_2 = 1$, so that it just grazes along the surface of separation.

52. Define the magnifying power of a compound microscope when the final image is formed at infinity. Why must both the objective and the eyepiece of a compound microscope has a short focal lengths? Explain.

53. You are given two converging lens of focal lengths 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, find out the separation between the objective and the eyepiece.

54. Draw a labelled ray diagram of an astronomical telescope to show the image formation of a distant object. Write the main considerations required in selecting the objective and the eyepiece lenses in order to have large magnifying power and high resolution of the telescope.

55. (i) Draw a labelled ray diagram showing the image formation of a distant object by a refracting telescope. Deduce the expression for its magnifying power when the final image is formed at infinity.

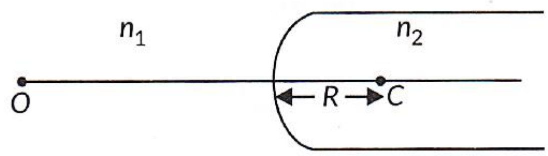
(ii) The sum of focal lengths of the two lenses of a refractive telescope is 105 cm. The focal length of one lens is 20 times that of the other. Determine the total magnification of the telescope when the final image is formed at infinity.

56. (i) State the condition under which a large magnification can be achieved in an astronomical telescope.
(ii) Give two reasons to explain why a reflecting telescope is preferred over a refracting telescope.

57. Why should the objective of a telescope have large focal length and large aperture? Justify your answer.

58. What is the difference in the construction of an astronomical telescope and a compound microscope? The focal lengths of the objective and eyepiece of a compound microscope are 1.25 cm and 5.0 cm, respectively. Find the position of the object relative to the objective in order to obtain an angular magnification of 30 when the final image is formed at the near point.

59. Figure shows a convex spherical surface with centre of curvature C, separating the two media of refractive indices n^ and n2. Draw a ray diagram showing the formation of the image of a point object O lying on the principal axis. Derive the relationship between the object and image distance in terms of refractive indices of the media and the radius of curvature R of the surface.



60. An illuminated object and a screen are placed 90 cm apart. Determine the focal length and nature of the lens required to produce a clear image on the screen, twice the size of the object.

SURE SHOT QUESTIONS

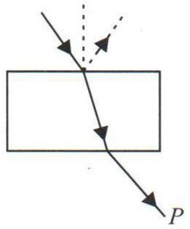
ARVIND ACADEMY

Chapter – 10

Wave Optics

MCQ (1 mark)

1. Consider a light beam incident from air to a glass slab at Brewster s angle as shown in figure. A polaroid is placed in the path of the emergent ray at point P and rotated about an axis passing through the centre and perpendicular to the plane of the polaroid.



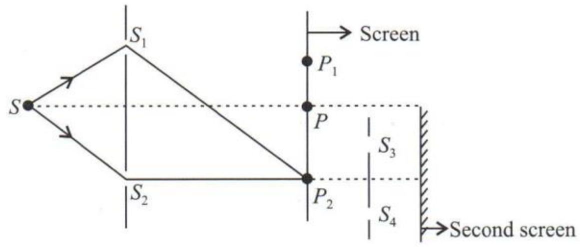
(a) For a particular orientation there shall be darkness as observed through the polaroid.
(b) The intensity of light as seen through the Polaroid shall be independent of the rotation,
(c) The intensity of light as seen through the Polaroid shall go through a minimum but not zero for two orientations of the polaroid.
(d) The intensity of light as seen through the Polaroid shall go through a minimum for four orientations of the polaroid.

2. Consider sunlight incident on a slit of width $10^4\ \overset{0}{\mathrm{A}}$. The image seen through the slit shall
(a) be a fine sharp slit, white in colour at the centre
(b) a bright slit, white at the centre diffusing to zero intensities at the edges
(c) a bright slit, white at the centre diffusing to regions of different colours
(d) only be a diffused slit, white in colour.

3. Consider a ray of light incident from air onto a slab of glass (refractive index n) of width d, at an angle θ. The phase difference between the ray reflected by the top surface of the glass and the bottom surface is
(a) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+\pi$
(b) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}$
(c) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+\frac{\pi}{2}$
(d) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+2\pi$

4. In a Young's double slit experiment, the source is white light. One of the holes is covered by a red filter and another by a blue filter. In this case
(a) there shall be alternate interference patterns of red and blue
(b) there shall be an interference pattern for red distinct from that for blue
(c) there shall be no interference fringes
(d) there shall be an interference pattern for red mixing with one for blue.

5. Figure shows a standard two slit arrangement with slits S_1, S_2, P_1, P_2 are the two minima points on either side of P. At P_2 on the screen, there is a hole and behind P_2 is a solenoid 2-slit arrangement with slits S_3, S_4 and a second screen behind them.



(a) There would be no interference pattern on the second screen but it would be lighted.

(b) The second screen would be totally dark.
(c) There would be a single bright point on the second screen.
(d) There would be a regular two slit pattern on the second screen.

6. According to Huygens principle, the amplitude of secondary wavelets is [2023]
 (a) Equal in both the forward and the backward directions.
 (b) Maximum in the forward direction and zero in the backward direction.
 (c) Large in the forward direction and small in the backward direction.
 (d) Small in the forward direction and large in the backward direction.

7. A plane wavefront is incident on a concave mirror of radius of curvature R. The radius of the refractive wavefront will be [2023]
 (a) 2R (b) R
 (c) $\frac{R}{2}$ (d) $\frac{R}{4}$

8. In a Young's double – slit experiment, the screen is moved away from the plane of the slits. What will be its effect on the following? [2023]
 (i) Angular separation of the fringes.
 (ii) Fringe – width.
 (a) Both (i) and (ii) remain constant
 (b) (i) remains constant, but (ii) decreases
 (c) (i) remains constant, but (ii) increases
 (d) Both (i) and (ii) increase.

9. In an interference experiment, third bright fringe is obtained at a point on the screen with a 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? [2023]
 (a) 420 nm (b) 750 nm
 (c) 630 nm (d) 500 nm

10. In a Young's double slit experiment, the fringe width is found to be β. If the entire apparatus is immersed in a liquid reference index μ, the new fringe width will be [2023]
 (a) β (b) $\mu\beta$
 (c) $\frac{\beta}{\mu}$ (d) $\frac{\beta}{\mu^2}$

11. In a Young's double slit experiment, the path difference at a certain point on the screen between two interfering waves is $\frac{1}{8}th$ of the wavelength. The ratio of intensity at this point to that at the centre of a bright fringe is close to [2022 – 23]
 (a) 0.80 (b) 0.74
 (c) 0.94 (d) 0.85

➢ Assertion-Reasoning (1 mark)

12. Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.
 (a) Both A and R are true and R is the correct explanation of A.
 (b) Both A and R are true and R is NOT the correct explanation of A.
 (c) A is true but R is false,
 (d) A is false and R is also false.

Assertion (A): In an interference pattern observed in Young's double slit experiment, if the separation (d) between coherent sources as well as the distance (D) of the screen from the coherent sources both are reduced to 1/3rd, then new fringe width remains the same.

Reason (R): Fringe width is proportional to (d/D).

[2022 – 23]

13. Assertion (A): We cannot get diffraction pattern from a wide slit illuminated by monochromatic light.
Reason (R): In diffraction pattern, all the bright bands are not of the same intensity.

14. Assertion (A): When a light wave travels from a rarer to a denser medium, it loses speed. The reduction in speed imply a reduction in energy carried by the light wave.
Reason (R): The energy of a wave is proportional to velocity of wave.

15. Assertion (A): The interference pattern is observed when source is monochromatic and coherent.
Reason (R): In Young's double slit experiment, we observe an interference pattern on the screen if both the slits are illuminated by two bulbs of same power.

16. Assertion (A): Young's double slit experiment can be performed using a source of white light.
Reason (R): The wavelength of red light is less than the wavelength of other colours in white light.

17. Assertion (A) : The film which appears bright in reflected system will appear dark in the transmitted light and vice-versa.
Reason (R) : The conditions for film to appear bright or dark in reflected light are just reverse to those in the transmitted light.

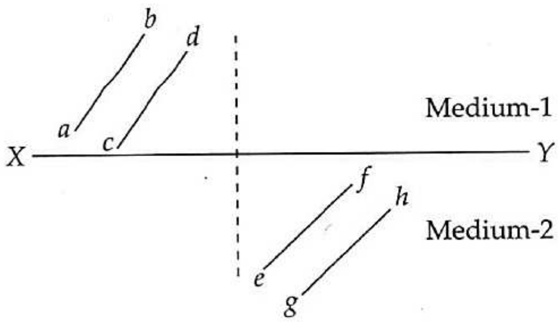
18. Assertion (A): In Young's double slit experiment, the fringes become indistinct if one of the slits is covered with cellophane paper.
Reason (R): The cellophane paper decrease the wavelength of light.

19. Assertion (A): One of the condition for interference is that the two source should be very narrow.
Reason (R): One broad source is equal to large number of narrow sources.

➢ Case Study

PARAGRAPH 1: Refraction of Light

20. Huygens' principle is the basis of wave theory of light. It tells how a wavefront propagates through a medium. According to the Huygen's principle, each point on a wavefront is a source of secondary waves, which add up to give a wavefront at any later time.



This principle can be used to prove the laws of refraction. The given figure shows a surface XY separating two transparent media —medium-1 and medium-2. The lines ab and cd represent wavefronts of a light wave travelling in medium-1 and incident on XY. The lines ef and gh represent wavefronts of the light wave in medium-2 after refraction.

QUESTIONS (Answer any four of the following questions)

1. Select the right option in the following:

(a) Christian Huygens, a contemporary of Newton's established the wave theory of light by assuming that light waves were transverse

{b) Maxwell provided the theoretical evidence that

light is transverse wave

(c) Thomas Young experimentally proved the wave

behaviour of light and Huygens' assumption

(d) All the statements given above, correctly answer

the question "What is light?"

2. Speed of light is

(a) same in medium-1 and medium-2

(b) larger in medium-1 than in medium-2

(c) larger in medium-2 than in medium-1

(d) different at *b* and *d*.

3. The phases of the light wave at c, d, e and f are Φ_c, Φ_d, Φ_e and Φ_f respectively. It is given that $\Phi_c = \Phi_f$

(a) Φ_c cannot be equal to Φ_d

(b) Φ_d cannot be equal to Φ_e

(c) $(\Phi_d - \Phi_f)$ is equal to $(\Phi_c - \Phi_e)$

(d) $(\Phi_d - \Phi_c)$ is not equal to $(\Phi_f - \Phi_e)$.

4. Light travels as a

(a) parallel beam in each medium

(b) convergent beam in each medium

(c) divergent beam in each medium

(d) divergent beam in one medium and convergent beam in the other medium.

5. Light waves travelling through air strike the surface

of water at an angle. Which of the following statements about the light's wave properties upon entering the water is correct?

(a) The light's speed, frequency and wavelength all stay the same

(b) The light's speed, frequency and wavelength all change

(c) The light's speed and frequency change, but the wavelength stays the same

(d) The light's wavelength and speed change, but the frequency stays the same.

PARAGRAPH 2: Interference in Light Waves

21. The principle of superposition is used to understand the phenomenon of interference of light waves. The principle states that at a particular point, the resultant displacement produced by a number of waves is the vector sum of the displacements produced by each wave. Light waves from two coherent sources produce interference pattern. Thomas Young devised a way to obtain two coherent sources using two identical pinholes (S_1 and S_2) illuminated by a single monochromatic pinhole source S. Using these sources in his experiment known as Young's double slit experiment. Young studied the interference pattern. The pattern consists of alternate bright and dark fringes. The distance between two successive bright or dark fringes depends on the distance between S_1 and S_2, the distance of the screen from the plane of S_1S_2 and the wavelength of light used.

QUESTIONS (Answer any four of the following questions)

6. Consider the following waves:

(*i*) $y_1 = a\sin\omega t$ (*ii*) $y_2 = a\sin 2\omega t$

(*iii*) $y_3 = a\sin(2\omega t + \Phi)$ (*iv*) $y_4 = a\sin(4\omega t + \frac{\pi}{2})$

Which pair of the waves coming from two sources S_1 and S_2 will produce interference

(a) (*i*) and (*ii*) (b) (*ii*) and (*iii*)

(c) (*iii*) and (*iv*) (d) (*iv*) and (*i*)

7. Two light waves of the same intensity I_0 each, having a path difference of $\lambda/4$ emanating from two

coherent sources, meet at a point. The resultant intensity at the point will be

(a) $zero$ (b) I_0 (c) $2I_0$ (d) $4I_0$

8. Vandana performs Young's double slit experiment by using orange, green and red lights successively. If the fringe widths measured in the three cases ω_1, ω_2, and ω_3 respectively, then which of the following is correct?

(a) $\omega_2 > \omega_1 > \omega_3$ (b) $\omega_2 > \omega_3 > \omega_1$

(c) $\omega_1 > \omega_2 > \omega_3$ (d) $\omega_3 > \omega_1 > \omega_2$

9. In a Yoimg's double slit experiment, the slit separation is 0.8 mm and the interference pattern is obtained on a screen kept 50 cm from the plane of the slits $S_1 and\ S_2$. If the first bright fringe is formed 0.4 mm from the central maximum, the wavelength of light used is

(a) 480 nm (b) 560 nm (c) 640 nm (d) 680 nm

10. Consider the effect on the angular separation of the fringes in a Young's double slit experiment due to the following operations:

(i) the screen is moved away from the plane of the slits,

(ii) the separation between the two slits is increased

(iii) fringes are observed

Which of the following option is correct?

(a) It remains constant in both cases.

(b) It decreases in both cases,

(c) It remains constant in (i) but decreases in (ii).

(d) It decreases in (i) but remains constant in (ii).

➢ Questions

22. Define wavefront of a travelling wave. Using Huygens principle, obtain the law of refraction at a plane interface when light passes from a rarer to a denser medium. [2020]

23. In a single slit diffraction experiment, the width of the slit is decreased. How will the (i) size (ii) intensity of the central bright band be affected. Justify your answer. [2020]

24. Draw the intensity pattern for single slit diffraction and double slit interference. Hence, state two differences between interference and diffraction patterns. [Al 2017]

25. A plane wavefront is propagating from a rarer into a denser medium. Use Huygens principle to show the refracted wavefront and verify Snell's law. [Term II 2021 – 22]

26. Define the term wavefront. Using Huygens wave theory, verify the law of reflection. [Delhi 2019]

27. Explain the following giving reasons:
   (i) When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency.
   (ii) When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a reduction in the energy carried by the wave? [2/3 Al 2016]

28. (a) If one of two identical slits producing interference in Young's experiment is covered with glass, so that the light intensity passing through it is reduced to 50%, find the ratio of the maximum and minimum intensity of the fringe in the interference pattern,
   (b) What kind of fringes do you expect to observe if white light is used instead of monochromatic light? [2018]

29. Answer the following questions: [Delhi 2015]

(a) In a double slit experiment using light of wavelength 600 nm, the angular width of the fringe formed on a distant screen is 0.1^0. Find the spacing between the two slits.

(b) Light of wavelength 500 $\overset{0}{A}$ propagating in air gets partly reflected from the surface of water. How will the wavelengths and frequencies of the reflected and refracted light be affected? [Delhi 2015]

30. Why cannot two independent monochromatic sources produce sustained interference pattern? [1/3, Foreign 2015]

31. What is a wavefront? How does it propagate? Using Huygens' principle, explain reflection of a plane wavefront from a surface and verify the laws of reflection. [2/5, 2020]

OR

Define a wavefront. Using Huygen's principle verify the laws of reflection at a plane surface.

[2018]

32. (a) Define a wavefront. How is it different from a ray?

(b) Depict the shape of a wavefront in each of the following cases.

(i) Light diverging from point source.

(ii) Light emerging out of a convex lens when a point source is placed at its focus.

(iii) Using Huygen's construction of secondary wavelets, draw a diagram showing the passage of a plane wavefront from a denser into a rarer medium. [Al 2015C]

33. In Young's double slit experiment, deduce the condition for (a) constructive, and (b) destructive interference at a point on the screen. Draw a graph showing variation of intensity in the interference pattern against position 'x' on the screen.

[4/5, Delhi 2016]

Ans. (a) Condition for constructive interference,

$$\cos\Delta\phi = +1$$

$$2\pi\frac{\Delta x}{\lambda} = 0, 2\pi, 4\pi......$$

$$or \quad \Delta x = n\lambda; \quad n = 0, 1, 2, 3, ...$$

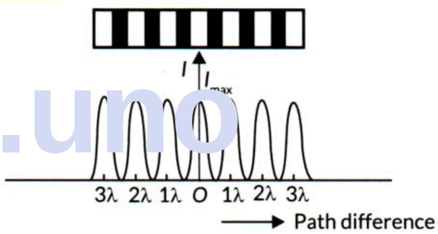
(b) Condition for destructive interference,

$$\cos\Delta\phi = -1$$

$$2\pi\frac{\Delta x}{\lambda} = \pi, 3\pi, 5\pi....$$

$$or \quad \Delta x = (2n-1)\lambda/2$$

Where n = 1, 2, 3.....



34. (a) If one of two identical slits producing interference in Young's experiment is covered with glass, so that the light intensity passing through it is reduced to 50%, find the ratio of the maximum and minimum intensity of the fringe in the interference pattern.

(b) What king of fringes do you expect to observe if white light is used instead of monochromatic light?

35. (a) Why are coherent sources necessary to produce a sustained interference pattern?

(b) In Young's double slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is $\lambda/3$.

36. A parallel beam of light of 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Calculate the width of the slit.

37. In the diffraction due to a single slit experiment, the aperture of the slit is 3 mm. if monochromatic light of wavelength 620 nm is incident normally on the slit, calculate the separation between the first order minima and the 3^{rd} order maxima on one side of the screen. The distance between the slit and the screen is 1.5 m.

38. Use Huygen's principle to verify the laws of refraction.

39. (i) Define a wavefront. How it is different from a ray?
(ii) Depict the shape of a wavefront in each of the following cases.
a. Light diverging from point source.
b. Light emerging out of a convex lens when a point source is placed at its focus.
c. Using Huygens construction of secondary wavelets, draw a diagram showing the passage of a plane wavefront from a denser into a rarer medium.

40. Use Huygens' Principle to explain the formation of diffraction pattern due to a single slit illuminated by a monochromatic source of light.
When the width of the slit is made double the original width, how would this affect the size and intensity of the central diffraction band?

41. Use Huygens' Principle to show how a plane wavefront propagates from a denser to a rarer medium. Hence, Verify Snell's law of refraction.

42. Define the term 'coherent sources' which are required to produce interference pattern in Young's double slit experiment.

43. Draw the intensity pattern for single slit diffraction and double slit interference. Hence, state two differences between interference and diffraction patterns.

44. Find the intensity at appoint on a screen in Young's double slit experiment where the interfering waves have a path difference of (i) $\lambda/6$, and (ii) $\lambda/2$.

45. Write the distinguishing features between a diffraction pattern due to a single slit and the interference fringes produced in Young's double slit experiment.

46. Yellow light (λ = 6000 Å) illuminates a single slit of width 1 x 10^{-4} m. Calculate : (i) the distance between the two dark lines on either side of central maximum, when the diffraction pattern is viewed on a screen kept 1.5 m away from the slit, (ii) The angular spread of the first diffraction minimum.

47. Give reasons:
i. When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency.
ii. When light travels from rarer to a denser medium, the speed decreases. Does this decrease in speed imply a reduction in the energy carried by the wave?
iii. In the wave picture of the light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light?

48. (a) What are coherent sources of light? State two conditions for two light sources to be coherent. Describe briefly how bright and dark fringes are obtained on the screen kept in front of a double slit.
Derive a mathematical expression for the width of interference fringes obtained in Young's double slit experiment with the help of a suitable diagram.

(b)The ratio of the intensities at minima to the maxima in the Young's double slit experiment is 9:25. Find the ratio of the widths of the two slits.

(c) If s is the size of the source and b its distance from the plane of the two slits, what should be the criterion for the interference fringe to be seen?

49. (a) In Young's double slit experiment, deduce the conditions for (i) constructive, and (ii) destructive interference at a point on the screen. Draw a graph showing variation of the resultant intensity in the interference pattern against pattern against position 'X' on the screen.

(a) Compare and contrast the pattern which is seen with two coherently illuminated narrow slits in Young's experiment with that seen for a coherently illuminated single slit producing diffraction.

50. What is interference of light? Write two essential conditions for sustained interference pattern to be produced on the screen.
Draw a graph showing the variation of intensity versus the position on the screen in Young's experiment when (a) both the slits are opened and (b) one of the slits is closed.
What is the effect on the interference pattern in Young's double slit experiment when:
i. Screen is moved closer to the plane of slits?
ii. Separation between two slits is increased?

Explain your answer in each case.

51. Use Huygens' Principle to explain the formation of diffraction pattern due to a single slit illuminated by a monochromatic source of light.
When the width of slit is made double the original width, how this affect the size and intensity of the central diffraction band?

52. In Young's double slit experiment using monochromatic light of wavelength λ, the intensity at a point on the screen where path difference is λ is K units. What is the intensity of light at a point where path difference is $\frac{\pi}{3}$?

53. Light of wavelength $6 \times 10^{-5}\ cm$ falls on a screen at a distance of 100 cm from a narrow slit. Find the width of the slit if the first minima lies 1 mm on either side of the central maximum.

54. In a single slit diffraction experiment first minimum for $\lambda_1 = 660\ nm$ coincides with first maxima for wavelength λ_2 Calculate λ_2.

55. Yellow light ($\lambda = 6000$ Å) illuminates a single slit of width 1×10^{-4} m. Calculate the distance between two dark lines on either side of the central maximum, when the diffraction pattern is viewed on a screen kept $1.5\ m$ away from the slit.

56. In Young's double slit experiment, the two slits 0.[illegible]5 mm apart are illuminated by monochromatic light of wavelength 450 nm. The screen is 1.0 m away from the slits. (a) Find the distance of the second (i) bright fringe, (ii) dark fringe from the central maximum.
(b) How will the fringe pattern change if the screen is moved away from the slits?

57. (a) Is Huygens principle valid for longitudinal sound waves?
(b) Why is the diffraction of sound waves more evident in daily experience than that of light wave?
(c) If one of the slits in Young's double slit experiment is fully closed, the new pattern has ______central maximum in angular size.

For Solutions

Download Arvind Academy App

Click Link: http://bit.ly/2kTWbkj

SURE SHOT QUESTIONS

ARVIND ACADEMY

Chapter – 11

Dual Nature of Radiation and Matter

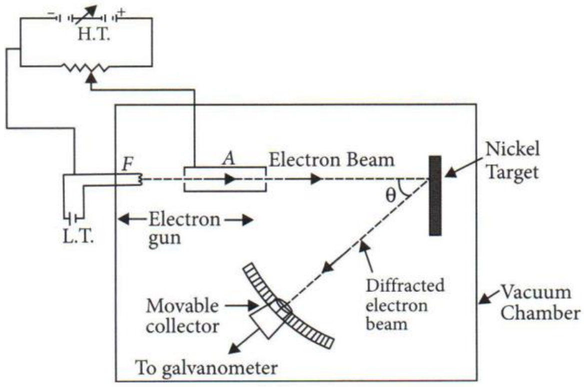
MCQ (1 mark)

1. A particle is dropped from a height H. The de Broglie wavelength of the particle as a function of height is proportional to
(a) H (b) $H^{1/2}$
(c) H^{0} (d) $H^{-1/2}$

2. The wavelength of a photon needed to remove a proton from a nucleus which is bound to the nucleus with 1 MeV energy is nearly
(a) 1.2 nm (b) 1.2×10^{-3} nm
(c) 1.2×10^{-6} nm (d) 1.2×10^{1} nm

3. Consider a beam of electrons (each electron with energy E_0) incident on a metal surface kept in an evacuated chamber. Then
(a) No electrons will be emitted as only photons can emit electrons.
(b) Electrons can be emitted but all with an energy E_0.
(c) Electrons can be emitted with any energy, with a maximum of $E_0 - \phi$ (ϕ is the work function).
(d) Electrons can be emitted with any energy, with a maximum of E_0.

4. Consider figure, Suppose the voltage applied to A is increased. The diffracted beam will have the maximum at a value of θ that



Davisson – Germer electron diffraction arrangement
(a) Will be larger than the earlier value
(b) Will be the same as the earlier value
(c) Will be less than the earlier value
(d) Will depend on the target

5. A proton, a neutron, an electron and an α-particle have same energy. Then their de Broglie wavelengths compare as
(a) $\lambda_p = \lambda_n > \lambda_e > \lambda_\alpha$
(b) $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$
(c) $\lambda_e < \lambda_p = \lambda_n > \lambda_\alpha$
(d) $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

6. An electron is moving with an initial velocity $\vec{v} = v_0 \hat{i}$ and is in a magnetic field $\vec{B} = B_0 \hat{j}$. Then it's de Broglie wavelength
(a) Remains constant
(b) Increases with time
(c) Decreases with time
(d) Increases and decreases periodically

7. An electron (mass m) with an initial velocity $\vec{v} = v_0 \hat{i} (v_0 > 0)$ is in an electric field $\vec{E} = -E_0 \hat{i}$ (E_0 = constant > 0). It's de Broglie wavelength at time t is give by

(a) $\frac{\lambda_0}{\left(1+\frac{eE_0 t}{mv_0}\right)}$ (b) $\lambda_0\left(1+\frac{eE_0 t}{mv_0}\right)$

(c) λ_0 (d) $\lambda_0 t$

8. An electron (mass m) with an initial velocity $\vec{v} = v_0 \hat{i}$ is in an electric field $\vec{E} = E_0 \hat{j}$. If $\lambda_0 = \frac{h}{mv_0}$, it's de Broglie wavelength at time t is given by

(a) λ_0 (b) $\lambda_0\sqrt{1+\frac{e^2E_0^2t^2}{m^2v_0^2}}$

(c) $\frac{\lambda_0}{\sqrt{1+\frac{e^2E_0^2t^2}{m^2v_0^2}}}$ (d) $\frac{\lambda_0}{\left(1+\frac{e^2E_0^2t^2}{m^2v_0^2}\right)}$

9. The energy of a photon of wavelength λ is [2023]

(a) hc λ (b) hc/ λ

(c) λ /hc (d) λ h/c

10. Photons of energy 3.2 eV are incident on a photosensitive surface. If the stopping potential for the emitted electrons is 1.5 V, the work function for the surface is [2023]

(a) 1.5 eV (b) 1.7 eV

(c) 3.2 eV (d) 4.7 eV

11. A light of frequency v is incident on a metal surface whose work function is W_0. The kinetic energy of emitted electron is K. If the frequency of the incident light is doubled then the kinetic energy of emitted electron will be [2023]

(a) 2 K

(b) More than 2K

(c) Between K and 2K

(d) Less than K

12. E, c and v represent the energy, velocity and frequency of a photon. Which of the following represents its wavelength? [2023]

(a) $\frac{hv}{c^2}$ (b) hv

(c) $\frac{hc}{E}$ (d) $\frac{hv}{c}$

13. Photons of energies 1 eV and 2 eV are successively incident on a metallic surface of work function 0.5 eV. The ratio of kinetic energy of most energetic photoelectrons in the two cases will be [2020]

(a) 1 : 2 (b) 1 : 1

(c) 1 : 3 (d) 1 : 4

14. Photons of energies 1 eV and 2 eV are successively incident on a metallic surface of work function 0.5 eV. The ratio of kinetic energy of most energetic photoelectrons in the two cases will be [2020]

(a) 2 : 3 (b) 3 : 4

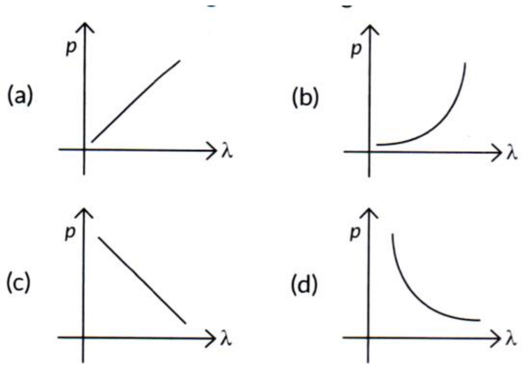
(c) 1 : 3 (d) $\sqrt{3} : \sqrt{2}$

15. A photon and an alpha particle have the same kinetic energy. The ratio of de Broglie wavelengths associated with the proton to that with the alpha particles is [2023]

(a) 1 (b) 2

(c) $2\sqrt{2}$ (d) $\frac{1}{2}$

16. Which of the following graphs correctly represents the variation of a particle momentum with its associated de – Broglie wavelength? [2023]



17. How will the de Broglie wavelength associated with an electron be affected when the (i) velocity of the electron decreases? And (ii) accelerating potential is increased? Justify your answer. [2023]

18. A heavy particle initially at rest splits spontaneously into two particles of masses m_1 and m_2 having non-zero velocities. The ratio of de Broglie wavelengths associated with the particles is [2020]

(a) m_1 / m_2 (b) m_2 / m_1

(c) 1 (d) $\sqrt{m_2} / \sqrt{m_1}$

19. Photoelectric emission from a given surface of metal can take place when the value of a 'physical quantity' is less than the energy of incident photon. The physical quantity is [2019 – 20]

(a) Threshold frequency
(b) Work function of surface
(c) Threshold wavelength
(d) Stopping potential

20. The work function for a metal surface is 4.14 eV. The threshold wavelength for this metal surface is [2022 – 23]

(a) 4125 $\overset{0}{A}$ (b) 2062.5 $\overset{0}{A}$

(c) 3000 $\overset{0}{A}$ (d) 6000 $\overset{0}{A}$

➢ Assertion-Reasoning (1 mark)

21. Two statements are given – one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true and R is NOT the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

Assertion (A): The photoelectrons produced by a monochromatic light beam incident on a metal surface have a spread in their kinetic energies.

Reason (R): The energy of electrons emitted from the metal surface, is lost in collision with the other atoms in the metal. [2022 – 23]

22. Assertion (A) : The de-Broglie wavelength of particle having kinetic energy K is λ.. If its kinetic energy becomes 4 K then its new wavelength would be $\lambda/2$.
Reason (R): The de-Broglie wavelength A is inversely proportional to square root of the kinetic energy.

23. Assertion (A): In photoemissive cell inert gas is used.

Reason (R): Inert gas in the photoemissive cell gives greater current.

24. Assertion (A): Photosensitivity of a metal is high if its work function is small.
Reason (R): Work function = $h\nu_0, where\ \nu_0$ is the threshold frequency.

25. Assertion (A): A photon has no rest mass, yet it carries definite momentum.
Reason (R): Momentum of photon is due to its energy and hence its equivalent mass.

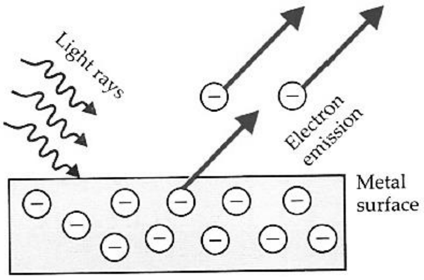
26. Assertion (A): Mass of moving photon varies inversely to the wavelength.
Reason (R): Energy of the particle = $Mass\ x\ (Speed\ of\ light)2$

27. Assertion (A): An electron microscope can achieve better resolving power than an optical microscope.
Reason (R): The de-Broglie wavelength of the electrons emitted from an electron gun with velocity 500 m/s is much less than 500 nm.

➢ Case Study

PARAGRAPH 1: Photoelectric Effect

28. The phenomenon of emission of electrons from a metal surface, when electromagnetic radiations of sufficiently high frequency are incident on it, is called photoelectric emission. The photo-generated electrons called photoelectrons. The wave theory of e.m. radiation fails to explain some experimentally observed facts on photoelectric effect such as its instantaneous nature, independence of the maximum K.E. of photoelectrons from intensity of incident radiation, and the existence of threshold frequency for every



photoemitter. According to the photon picture of radiation, in its interaction with matter, the radiation behaves as if it consists of quanta or small packets of energy, each of energy $h\nu$. This photon picture leads to the Einstein's photoelectric equations: $K_{max} = eV_0 = h\nu - W_0$ This equation correctly explains all the experimentally observed features of photoelectric effect.

QUESTIONS (Answer any four of the following questions)

1. Which one of the following statements is not true about photoelectric emission?

(a) For a given emitter illuminated by light of a given frequency the number of photoelectrons emitted per second is proportional to the intensity of incident light

(b) For every emitter there is a definite threshold frequency below which no photoelectrons are emitted, no matter what the intensity of light is

(c) Above the threshold frequency, the maximum kinetic energy of photoelectrons is proportional to the frequency of incident light

(d) The saturation value of the photoelectric current is independent of the intensity of incident light.

2. When photons of energy $h\nu$ are incident on the surface of photosensitive material of work function $h\nu_0$,

then

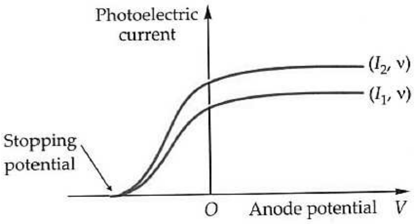
(a) the kinetic energy of all emitted electrons $is\ h\nu$^

(b) the kinetic energy of all emitted electrons is $h(\mathrm{v} - \mathrm{v}_0)$

(c) the kinetic energy of all fastest electrons is $h(\text{v} - \text{v}_0)$

(d) the kinetic energy of all emitted electrons is $h\text{v}$.

3. Following graphs show the variation of photoelectric current with anode potential for two light beams of same frequency but of different intensities.

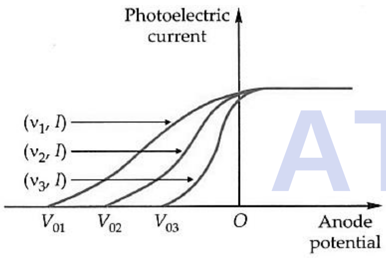


Then

(a) $I_1 > I_2$ (b) $I_1 = I_2$ (c) $I_1 < I_2$

(d) no relation between I_1 and I_2

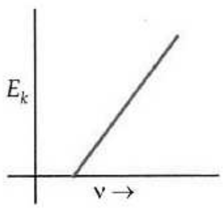
4. Identify the correct relation for frequencies v_1, v_2 and v_3 for the incident radiation of given intensity I



(a) $\text{v}_1 = \text{v}_2 = \text{v}_3$ (b) $\text{v}_1 > \text{v}_2 > \text{v}_3$

(c) $\text{v}_1 < \text{v}_2 < \text{v}_3$ (d) $\text{v}_1 = 2\text{v}_2 = 3\text{v}_3$

5. The graph of kinetic energy of emitted electron with frequency of incident radiation is plotted as shown in the figure.

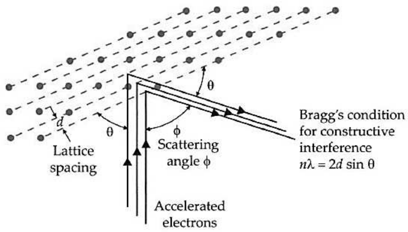


The slope of curve is

(a) h/v (b) h (c) hv (d) h/e

PARAGRAPH 2 Dual Nature of Matter

29. Light has dual nature. It manifests itself as a wave in diffraction, interference and polarisation, while it shows up particle nature in photoelectric effect, compton scattering, etc. So far no single experiment has been devised which shows both wave and particle behaviour of radiation at the same time. In 1924, the French physicist Louis Victor de-Broglie put forward the bold hypothesis that moving particles (Like protons, neutrons, electrons, etc.) of matter should display wave like properties under suitable conditions.



His argument was based on the fact that nature was symmetrical and the two physical quantities-matter and energy must have symmetrical character. If adiation shows due aspect so should matter. The waves associated with the moving particles were called matter waves. The de-Broglie wavelength of a particle of mass m moving with velocity v is given by

$\lambda = \frac{h}{p} = \frac{h}{mv}$, where h = Planck's constant

The de-Broglie wavelength is independent of charge and mass of the material particles. It has significant value for sub-atomic particles like electrons, protons, etc., due to their small masses. For macroscopic objects of everyday life, the de-Broglie wavelength is extremely small. The electron diffraction experiment of Davisson and Germer verified and confirmed the wave-nature of electrons.

QUESTIONS (Answer any four of the following questions)

6. If an electron and proton are propagating in the form of waves having the same A, it implies that they have the same

(a) energy (b) momentum

(c) velocity (d) angular momentum.

7. The de-Broglie wavelength of a particle with mass m and kinetic energy K is

(a) $\frac{h}{\sqrt{2mK}}$ (b) $\frac{h}{K}$ (c) $\frac{hK}{2mc}$ (d) $\frac{hc}{2mK}$

8. What is de-Broglie wavelength of electron having energy 10 keV?

(a) 0.12 A (b) 1.2 A (c) 12.2 A

(d) none of these.

9. A proton and an α-particle are accelerated through the same potential difference. The ratio of de-Broglie wavelength of proton to the de-Broglie wavelength of alpha particle will be

(a) 1 : 2 (b) $2\sqrt{2}$: 1

(c) 2 : 1 (d) 1 : 1

10. If K_e, K_p, K_n and K_d are the respective kinetic energies of electron, proton, neutron and deuteron having same de-Broglie wavelength λ, then

(a) $K_e > K_p > K_n > K_d$ (b) $K_e < K_p < K_n < K_d$

(c) $K_e = K_p = K_n = K_d$ (d) $K_e > K_p \approx K_n > K_d$

➢ Questions

30. (i) Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. Estimate the number of photons emitted per second on an average by the source.

(ii) Draw a plot showing the variation of photoelectric current versus the intensity of incident radiation on a given photosensitive surface. [Delhi 2014]

31. Draw a graph showing variation of photocurrent with the anode potential of a photocell. [1/2, 2020]

32. (a) Define the terms, (i) threshold frequency and (ii) stopping potential in photoelectric effect.

(b) Plot a graph of photocurrent versus anode potential for a radiation of frequency v and intensities I_1 and $I_2 (I_1 < I_2)$ [Delhi 2019]

33. What are matter waves? A proton and an alpha particle are accelerated through the same potential difference. Find the ratio of the de Broglie wavelength associated with the proton to that with the alpha particle. [Term II 2021 – 22]

34. (a) Calculate the energy and momentum of a photon in a monochromatic beam of wavelength 331.5 nm.

(b) How fast should a hydrogen atom travel in order to have the same momentum as that of the photon in part (a)? [Term II 2021 – 22]

35. An α -particle and a proton are accelerated through the same potential difference. Find the ratio of their de Broglie wavelengths. [Delhi 2017]

36. Plot a graph showing the variation of photoelectric current with intensity of light. The work function for the following metals is given.

Na : 2.75 eV and Mo : 4.175 eV.

Which of these will not give photoelectron emission for a radiation of wavelength 3300 $\overset{0}{A}$ from a laser beam? What happens if the source of laser beam is brough closer? [Foreign 2016]

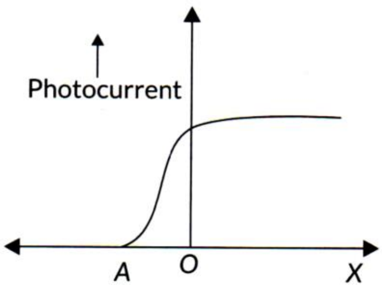
37. A beam of monochromatic radiation is incident on a photosensitive surface. Answer the following questions giving reasons.

(a) DO the emitted photoelectrons have the same kinetic energy?

(b) Does the kinetic energy of the emitted electrons depend on the intensity of incident radiation?

(c) On what factors does the number of emitted photoelectrons depend? [Foreign 2015]

38. The following graph shows the variation of photocurrent for a photosensitive metal:



(a) Identify the variable X on the horizontal axis.

(b) What does the point A on the horizontal axis represent?

(c) Draw this graph for three different values of frequencies of incident radiation v_1, v_2 and v_3 $(v_1 > v_2 > v_3)$ for same intensity.

(d) Draw this graph for three different values of intensities of incident radiation l_1, l_2 and l_3 $(l_1 > l_2 > l_3)$ having same frequency. [AI 2017]

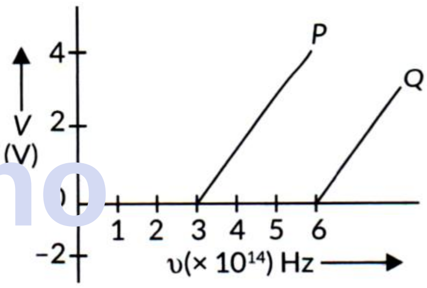
39. (a) Give an example each of a metal from which photoelectric emission takes place when irradiated by (i) UV light, (ii) visible light.

(b) The work function of a metal is 4.50 eV. Find the frequency of light to be used to eject electrons from the metal surface with a maximum kinetic energy of 6.06 x 10^{-19} J. [Term II 2021 – 22]

40. (i) State two important features of Einstein's photoelectric equation.

(i) Radiation of frequency 10^{15} Hz is incident on two photosensitive surfaces P and Q. There is no photoemission from surface P. Photoemission occurs from surface Q but photoelectrons have zero kinetic energy. Explain these observations and find the value of work function for surface Q. [Delhi 2017]

41. In the study of a photoelectric effect the graph between the stopping potential V and frequency v of the incident radiation on two different metals P and Q is shown in:



(i) Which one of the two metals has higher threshold frequency?

(ii) Determine the work function of the metal which has greater value.

(iii) Find the maximum kinetic energy of electron emitted by light of frequency 8 x 10^{14} Hz for this metal. [Delhi 2017]

42. In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light? [2/3, AI 2016]

43. (a) Write the important properties of photons which are used to establish Einstein's photoelectric equation. [Al 2015]
    (a) Use this equation to explain the concept of (i) Threshold frequency and (ii) stopping potential.

44. Obtain an expression for the ratio of the accelerating potentials required to accelerate a proton and an α -particle to have the same de-Broglie wavelength associated with them.
[2/3, Al 2019]

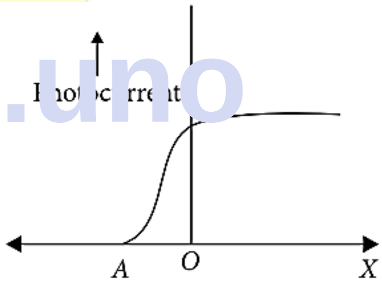
45. (a) An electron and a proton are accelerated through the same potential. Which one of the two has [Al 2019]
    (i) Greater value of de-Broglie wavelength associated with it, and
    (ii) Lesser momentum?
    Justify your answer in each case.
    (iii) How is the momentum of a particle related with its de-Broglie wavelength? Show the variation on a graph.

46. State the main implications of observations obtained from various photoelectric experiments. Can these implications be explained by wave nature of light? Justify your answer.
[2020 – 21]

47. Light of wavelength 2000 $\overset{0}{A}$ falls on a metal surface of work function 4.2 eV.
[Term II 2021 – 22]
    (a) What is the kinetic energy (in eV) of the fastest electrons emitted from the surface?
    (b) What will be the change in the energy of the emitted electrons if the intensity of light with same wavelength is doubled?
    (c) If the same light falls on another surface of work function 6.5 eV, what will be the energy of emitted electrons? [Term II 2021 – 22]

48. (a) Explain de-Broglie argument to propose his hypothesis. Show that de-Broglie wavelength of photon equals electromagnetic radiation.
    (b) If, deuterons and alpha particle are accelerated through same potential, find the ratio of the associated de-Broglie wavelengths of two. [2020 – 21]

49. The following graph shows the variation of photocurrent for a photosensitive metal:



(a) Identify the variable X on the horizontal axis.
(b) What does the point A on the horizontal axis represent?
(c)Draw this graph for three different values of frequencies of incident radiation $\upsilon_1 \upsilon_2 and\ \upsilon_3 (\upsilon_1 > \upsilon_2 > \upsilon_3)$ for same intensity.
(d) Draw this graph for three different values of intensities of incident radiation $I_1, I_2\ and\ I_3 (I_1 > I_2 > I_3)$ having same frequency.

50. A photon and a proton have the same de-Broglie wavelength λ. Prove that the energy of the photon is $(2m\lambda\ c/h)$ times the kinetic energy of the proton.

51. Draw a plot showing the variation of photoelectric current with collector plate potential for two different frequencies, $\nu_1 > \nu_2$, of incident radiation

having the same intensity. In which case will be stopping potential be higher? Justify your answer.

52. State de-Broglie hypothesis.

53. A proton and an electron have same kinetic energy. Which one has smaller de-Broglie wavelength and why?

54. Define the terms (i) 'Cut – off voltage' and (ii) 'threshold frequency' in relation to the phenomenon of photoelectric effect. Using Einstein's photoelectric equation show how the cut-off voltage and threshold frequency for a give photosensitive material can be determined with the help of a suitable plot/graph.

55.(a) Why photoelectric effect cannot be explained on the basis of wave nature of light? Give reasons.
(b) Write the basic features of photon picture of electro-magnetic radiation on which Einstein's photoelectric equation is based.

56. A deuteron and an alpha particle are accelerated with the same accelerating potential. Which one of the two has
(1) greater value of de-Broglie wavelength, associated with it, and
(2) less kinetic energy? Explain.

57. Plot a graph showing variation of de Broglie wavelength (λ) associated with a charged particle of a mass m, versus $1/\sqrt{V}$, where V is the potential difference through which the particle is accelerated. How does this graph give us the information regarding the magnitude of the charge of the particle ?

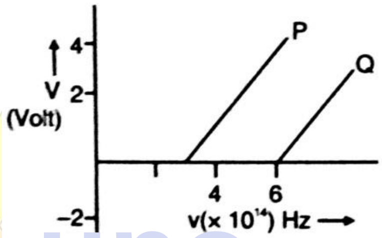
58. Write Einstein's photoelectric equation. Explain the terms (i) threshold frequency and (ii) stopping potential.

59. The work function (ω) of a metal X, equals 3 x 10^{-19} J. Calculate the number (N) of photons of light of wavelength 26.52 nm, whose total energy equals ω.

60. A monochromatic source emitting light of wavelength 600 nm has a power output of 66 W. Calculate the number of photons emitted by this source in 2 minutes.

61. (i) Draw a graph showing the variation of photoelectric current with collector potential for different frequencies but same intensity incident radiation.
(ii) Use Einstein's photoelectric equation to explain the observations from this graph.
(iii) What change will you observe if intensity of incident radiation is changed but the frequency remains the same?

62. In the study of photoelectric effect the graph between the stopping potential V and frequency of the incident radiation on two different metals P and Q is shown below:



i. Which one of the two metals has higher threshold frequency?
ii. Determine the wok function of the metal. Which has the greater value?
iii. Find the maximum kinetic energy of the electron emitted by the light of frequency 8 x 10^{-4} Hz for this metal.

63. Define the term "cut off frequency" in photoelectric emission. The threshold frequency of a metal is f. When the light of frequency 2f is incident on the metal plate, the maximum velocity of photo-electrons is v_1.
When the frequency of the incident radiation is increased to 5f, the maximum velocity of photo-electrons is v_2. Find the ratio of $v_1 : v_2$

64. An α - particle and a proton are accelerated through the same potential. Find the ratio of their de-Broglie wavelengths.

65. Write two characteristic features observed in photoelectric effect which support the photon picture of electromagnetic radiation. Draw a graph between the frequency of incident radiation (ν) and the maximum kinetic energy of the electrons emitted from the surface of a photosensitive material. State clearly how this graph can be used to determine (i) Planck's constant and (ii) work function of the material.

66. A proton and an alpha particle are accelerated through the same potential. Which one of the two has (i) greater value of de-Broglie wavelength associated with it and (ii) less kinetic energy? Give reasons to justify your answer.

67. Deduce de-Broglie wavelength of electrons accelerated by a potential of V volt. Draw a schematic diagram of a localized wave describing the wave nature of moving electron.

68. How did de-Broglie hypothesis lead to Bohr's quantum condition of atomic orbits?

69. A photon and an electron, each has a wavelength of 1.00 nm. Find

a. Their momenta
b. The energy of the photon
c. The kinetic energy of the electron.

70. The energy and momentum of an electron are related to frequency and wavelength of the associated matter (de-Broglie) wave by the relation

$E = h\nu$, p = $\frac{h}{\lambda}.s$

Then why is the value of λ physically significant but the value of frequency ν (and therefore, the value of phase speed $u = \nu\lambda$) has no physical significance?

71. Two monochromatic radiations, blue and violet, of the same intensity, are incident on a photosensitive surface and cause photoelectric emission. Would (i) the number of electrons emitted per second and (ii) the maximum kinetic energy of the electrons, be equal in the two cases? Justify your answer.

72. In an experiment on photoelectric emission, following observations were made
Wavelength of the incident light = $2 \times 10^{-7} m$. 2. Stopping potential = $3\ V$
Find kinetic energy of photoelectrons with maximum speed.

73. Sun gives light at the rate of $1400\ W\ m^{-2}$ of area perpendicular to the direction of light. Assume λ (sunlight) = $6000 Å$. Calculate the
(a) number of photons/sec arriving at $1\ m^2$ area at that part of the earth, and
(b) number of photons emitted from the sun/sec.
Assuming the average radius of earth's orbit is $1.49 \times 10^{11} m$.

SURE SHOT QUESTIONS

ARVIND ACADEMY

Chapter – 12

Atoms

MCQ (1 mark)

1. 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
   (a) 53 pm (b) 27 pm
   (c) 18 pm (d) 13 pm

2. The binding energy of a H – atom, considering an electron moving around a fixed nuclei (proton), is $B = -\frac{me^4}{8n^2\varepsilon_0^2h^2}$ (m = electron mass). If one decides to work in a frame of reference where the electron is at rest, the proton would be moving around it. By similar arguments, the binding energy would be $B = -\frac{Me^4}{8n^2\varepsilon_0^2h^2}$ (M = proton mass)
   This last expression is not correct because
   (a) n would not be integral
   (b) Bohr-quantisation applies only to electron
   (c) The frame in which the electron is at rest is not inertial.
   (d) The motion of the proton would not be in circular orbits, even approximately

3. The simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons. This is because
   (a) of the electrons not being subject to a central force
   (b) of the electrons colliding with each other
   (c) of screening effects
   (d) the force between the nucleus and an electron will no longer be given by Coulomb's law.

4. For the ground state, the electron in the H-atom has an angular momentum = -h, according to the simple Bohr model. Angular momentum is a vector and hence there will be infinitely many orbits with the vector pointing in all possible directions. In actuality this is not true,
   (a) because Bohr model gives incorrect values of angular momentum
   (b) because only one of these would have a minimum energy
   (c) angular momentum must be in the direction of spin of electron
   (d) because electrons go around only in horizontal Orbits

5. O_2 molecule consists of two oxygen atoms. In the molecule, nuclear force between the nuclei of the two atoms
   (a) Is not important because nuclear forces are short-ranged
   (b) Is as important as electrostatic force for binding the two atoms
   (c) Cancels the repulsive electrostatic force between the nuclei
   (d) Is not important because oxygen nucleus has equal number of neutrons and protons

6. Two H atoms in the ground state collide inelastically. The maximum amount by which their combined kinetic energy is reduced is
   (a) 10.2 eV (b) 20.4 eV
   (c) 13.6 eV (d) 27.2 eV

7. A set of atoms in an excited state decays

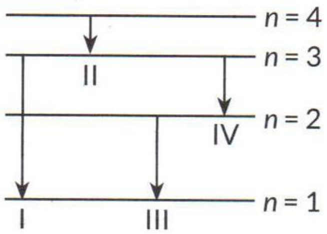
(a) in general to any of the states with lower energy
(b) into a lower state only when excited by an external electric field
(c) all together simultaneously into a lower state
(d) to emit photons only when they collide

8. Which of the following statements is not correct according to Rutherford model? [2020]
   (a) Most of the space inside an atom is empty.
   (b) The electrons revolve around the nucleus under the influence of coulomb force acting on them.
   (c) Most part of the mass of the atom and its positive charge are concentrated at its centre.
   (d) The stability of atom was established by the model.

9. The radius of the nth orbit in Bohr model of hydrogen atom is proportional to [2023]
   (a) n^2 (b) $\frac{1}{n^2}$
   (c) n (d) $\frac{1}{n}$

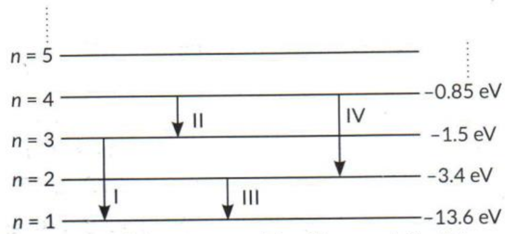
10. The potential energy of an electron in the second excited state in hydrogen atom is [2023]
   (a) -3.4 eV (b) -3.02 eV
   (c) -1.51 eV (d) -6.8 eV

11. The diagram shows four energy level of an electron in Bohr model of hydrogen atom. Identify the transition in which the emitted photon will have the highest energy. [2023]



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

12. The figure shows the energy level diagram of hydrogen atom with few transitions. Which transition shows the emission of photon with maximum energy? [2020]



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

13. The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. The radius of the n = 3 orbit is [2022 – 23]
   (a) 1.01×10^{-10} m (b) 1.59×10^{-10} m
   (c) 2.12×10^{-10} m (d) 4.77×10^{-10} m

14. A photon beam of energy 12.1 eV is incident on a hydrogen atom. The orbit to which electron of H – atom be excited is [2019 – 20]
   (a) 2nd (b) 3rd
   (c) 4th (d) 5th

➢ Assertion-Reasoning (1 mark)

DIRECTIONS

In the following questions, a statement of assertion (A) is followed by a corresponding statement of Reason (R), mark the correct answer as:

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

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

(c) If assertion is true but reason is false

(d) If both assertion and reason are false.

15. **Assertion.** Balmer series lies in the visible region of electromagnetic spectrum.
Reason. $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$,
where n = 3, 4, 5.

16. **Assertion.** Total energy of an electron in a hydrogen atom is negative.
Reason. Electron is bounded to the nucleus.

17. **Assertion.** Electrons in an atom are held by Coulombian forces.
Reason. The atom is stable because the centripetal force due to Coulomb's law is balanced by the centrifugal force.

18. Assertion (A): For the scattering of α-particles at a large angles, only the nucleus of the atom is responsible.
Reason (R): Nucleus is very heavy in comparison to electrons.

19. Assertion (A): It is essential that all the lines available in the emission spectrum will not be available in the absorption spectrum.
Reason (R): The spectrum of hydrogen atom is only absorption spectrum.

20. Assertion (A) : According to classical theory, the proposed path of an electron in Rutherford atom model will be circular.
Reason (R): According to electromagnetic theory an accelerated particle continuously emits radiation.

21. Assertion (A): Hydrogen atom consists of only one electron but its emission spectrum has many lines.
Reason (R) : Only Lyman series is found in the absorption spectrum of hydrogen atom whereas in the emission spectrum, all the series are found.

22. Assertion (A) : Between any two given energy levels, the number of absorption transitions is always less than the number of emission transitions.
Reason (R) : Absorption transitions start from the lowest energy level only and may end at any higher energy level. But emission transitions may start from any higher energy level and end at any energy level below it.

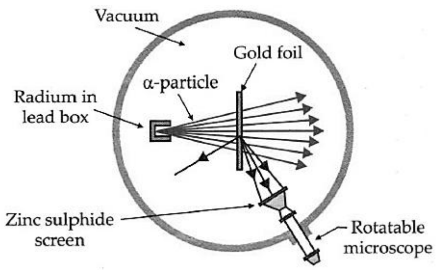
23. Assertion (A) : Smoky flame of Bunsen burner gives continuous spectrum whereas its blue flame gives band spectrum.
Reason (R): The band spectrum consists of coloured bands of light on a dark background.

24. Assertion (A): Bohr had postulated that the electrons in stationary orbits around the nucleus do not radiate.
Reason (R): According to classical physics all moving electrons radiate.

➢ Case Study

PARAGRAPH 1 Rutherford's Model of on Atom

25. Geiger and Marsden performed experiments an scattering of α-particles from metal foils. A collimated beam of 5.5 MeV of α -particles was allowed to fall on a 2.1×10^{-3} m thin gold foil. The scattered α-particles produced scientillations on a ZnS screen, which were counted at different angles (θ) from the direction of the beam. It was found that most of the α-particles passed undeviated through thin foils but some of them were scattered through very large angles.



From the results of these experiments, Rutherford proposed an atomic model. In Rutherford's model, most of the mass of the atom and all its positive charge are concentrated in a tiny nucleus, and the electrons revolved around it. Rutherford successfully determined an upper limit to the size of the nucleus. But this model failed to explain the stability of atoms and the emission of Une spectra of atoms of different elements.

QUESTIONS (Answer any four of the following questions)

This is because

(a) a-particles are positively charged

(b) a-particles are much massive than electrons

(c) most of the space within the atoms is empty

(d) a-particles move with high velocity

2. The given figure shows the path of four a-particles of the same energy being scattered by the nucleus of an atom simultaneously. Which of these are/is not physically possible?

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

3. A beam of fast moving a-particles was directed towards a thin foil of gold. The parts A', B' and C of the transmitted and reflected beams corresponding parts A, B and C of the beam are shown in the figure. The number of a -particles m

(a) B' will be maximum and in C' maximum

(b) A' will be maximum and in B' minimum

(c) A' will be minimum and in B' maximum

(d) C' will be minimum and in B' minimum.

4. An elementary particle of mass m and charge $+e$ is projected with velocity v at a much more massive particle of charge Ze, where $Z > 0$. What is the closest possible approach of the incident particle?

(a) $Ze^2/2\pi\varepsilon_0 mv^2$ (b) $Ze^2/4\pi\varepsilon_0 r_n$

(c) $Ze^2/8\pi\varepsilon_0 r_n$ (d) $-Ze^2/8\pi\varepsilon_0 r_n$.

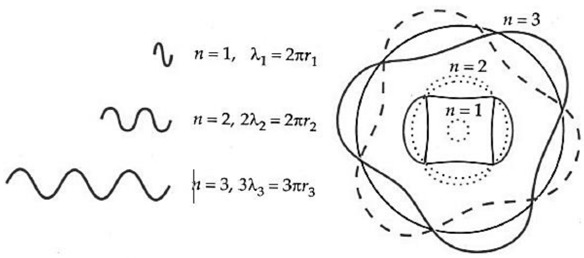
5. The radius of an atomic nucleus is of the order of

(a) $10^{-8}\ m$ (b) $10^{-10}\ m$

(c) $10^{-12}\ m$ (d) $10^{-15}\ m$

PARAGRAPH 2: Bohr's Theory of Hydrogen Atom

26. To explain the line spectra emitted by atoms, as well as the stability of atoms, the Danish physicist Neil's Bohr proposed a model for hydrogenic (single electron) atoms. Bohr proposed that electrons do not radiate energy as they orbit the nucleus, but exist in states of constant energy which he called stationary states. In stationary orbits, the angular momentum of an electron is an integral multiple of $h/2\pi$ $i.L = nh/2\pi$ where an is an integer called principal quantum number. An atom can emit or absorb radiation in the form of discrete photons only when an electron jumps from higher to a lower orbit or from a lower to a higher orbit. The frequency v of the emitted or absorbed photon is given by $hv = E_2, -E_1$,. As a result of the quantisation condition of angular momentum, the electrons can revolve around the nucleus in orbits of certain specific radii given by



$$r_n = \frac{n^2h^2}{4\pi^2 mkZe^2}$$

Moreover, the total energy of electrons in different orbits is also quantised:

$$E_n = \frac{2\pi^2 mk^2Z^2e^4}{n^2h^2} = \frac{13.6Z^2}{n^2} eV$$

Bohr's theory of the hydrogen atom was unable to predict the energy levels in complex atoms, which had many electrons.

QUESTIONS (Answer any four of the following questions)

6. Bohr's atom model assumes

(a) the nucleus is of infinite mass and is at rest

(b) electrons in a quantized orbit will not radiate energy

(c) mass of electron remains constant

(d) all the above conditions.

7. $\frac{h}{2\pi}$ has the dimensions of

(a) velocity (b) momentum

(c) energy (d) angular momentum.

8. The ratio between the first three Bohr radii is

(a) 1 : 2 : 3 (b) 2 : 4 : 6

(c) 1 : 4 : 9 (d) 1 : 3 : 5

9. Energy E of a hydrogen atom with principal quantum number n is given by $E_n = -\frac{13.6}{n^2} eV$. The energy of a photon ejected when the electron jumps from $n = 3$ state to $n = 2$ state of hydrogen, is approximately

(a) 1.5 eV (b) 0.85 eV
(c) 3.4 eV (d) 1.9 eV

10. Which spectral series of hydrogen lies in the UV region?

(a) Paschen (b) Lyman (c) Brackett (d) Balmer.

➢ Questions

27. What result do you expect if α -particle scattering experiment is repeated using a thin sheet hydrogen in place of a gold foil? Explain. (Hydrogen is a solid at temperature below 14K)
[Term II 2021 – 22]

28. Define the distance of closest approach. An α -particle of kinetic energy 'K' is bombarded on a thin gold foil. The distance of the closest approach is 'r'. What will be the distance of closest approach for an α -particle of double the kinetic energy?
[Delhi 2017]

29. Write two important limitations of Rutherford nuclear model of the atom. [Delhi 2017]

30. Using Bohr's atomic model, derive the expression for the radius of nth orbit of the revolving electron in a hydrogen atom.[2020]
OR
Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom. [Delhi 2015]
OR
Using Bohr's postulates of the atomic model, derive the expression for the radius of nth electron orbit. Hence obtain the expression for Bohr's radius [AI 2014]

31. Write shortcomings of Rutherford atomic model. Explain how these were overcome by the postulates of Bohr's atomic model. [2020]

32. State Bohr's quantization condition of angular momentum. Calculate the shortest wavelength of the Brackett series and state to which part of the electromagnetic spectrum does it belong.
[Delhi 2019]

33. The ground state energy of hydrogen atom is -13.6 eV. If an electron makes a transition from an energy level -1.51 eV to -3.4 eV, calculate the wavelength of the spectral line emitted and name the series of hydrogen spectrum to which it belongs. [AI 2017]

34. The short wavelength limit for the Lyman series of the hydrogen spectrum is 913.4 $\overset{0}{\text{A}}$. Calculate the short wavelength limit for the Balmer series of the hydrogen spectrum. [2022 – 23]

35. (a) In Geiger – Marsden experiment, calculate the distance of closest approach for an alpha particle with energy 2.56 x 10^{-12} J. Consider that the particle approaches gold nucleus (Z = 79) in head – on position. (b) If the above experiment is repeated with a proton of the same energy, then what will be the value of the distance of closest approach? [Term II 2021 – 22]

36. A hydrogen atom initially in the ground state absorbs a photon which excites it to the n = 4 level. Estimate the frequency of the photon. [1/3, 2018]

37. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited? [Delhi 2014]
Calculate the wavelengths of the first member of Lyman and first member of Balmer series.

38. Calculate the de-Broglie wavelength associated with the electron in the 2^{nd} excited state of hydrogen atom. The ground state energy of the hydrogen atom is 13.6 eV. [2020]

39. Derive an expression for the frequency of radiation emitted when a hydrogen atom de-excites from level n to level (n – 1). Also show that for large values of n, this frequency equals to classical frequency of revolution of an electron. [Term II 2021 – 22, 2020 – 21]

40. (a) Write two important limitations of Rutherford model which could not explain the observed features of atomic spectra. How were these explained in Bohr's model of hydrogen atom?
(b) Using Bohr's postulates, obtain the expression for the radius of the nth orbit in hydrogen atom. [4/5, Delhi 2015C]

41. Using Bohr's postulates, derive the expression for the total energy of the electron in the secondary states of the hydrogen atom. [3/5, Foreign 2014]

42. State the basic assumption of the Rutherford model of the atom. Explain, in brief, why this model cannot account for the stability of an atom.

43. State Bohr's quantization condition of angular momentum. Calculate the shortest wavelength of the Brackett series and state to which part of the electromagnetic spectrum does it belong.

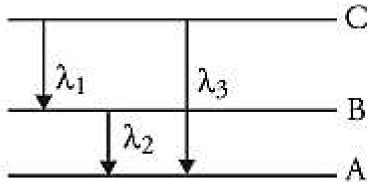
44. A hydrogen atom in the ground state is excited by an electron beam 12.5 eV energy. Find out the maximum number of lines emitted by atom from its excited state.

45. How is the stability of hydrogen atom in Bohr model explained by de-Broglie's Hypothesis?

46. (a) Draw the energy level diagram for the line spectra representing Lyman series and Balmer series in the spectrum of hydrogen atom.
(b) Using the Rydberg formula for the spectrum of hydrogen atom, calculate the largest and shortest wavelengths of the emission lines of the Balmar series in the spectrum of hydrogen atom. (Use the value of Rydberg constant $R = 1.1 \times 10^7 m^{-1}$.

47. Find out the wavelength of the electron orbiting in the ground state of hydrogen atom.

48. (a) state Bohr's quantization condition for defining stationary orbits. How does de-Broglie hypothesis explain the stationary orbits?
(b)Find the relation between the three wavelengths λ_1, λ_2 *and* λ_3 from the energy level diagram shown below.



49. 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.

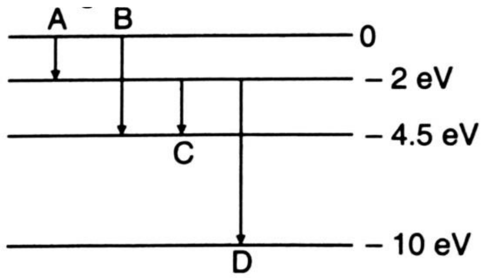
50. The ground state energy of hydrogen atom is $-13.6\ eV$. If an electron makes a transition from an energy level $-1.51\ eV$ to $-3.4\ eV$, calculate the wavelength of the spectral line emitted and the series of hydrogen spectrum to which it belongs.

51. Write two important limitations of Rutherford nuclear model of the atom.

52. Define the distance of closest approach. An α-particle of kinetic energy 'K' is bombarded on a thin gold foil. The distance of the closest approach is 'r'. What will be the distance of closest approach for an α-particle of double the kinetic energy?

53. Define ionization energy.
How would the ionization energy change when electron in hydrogen atom is replaced by the particle of mass 200 times that of the electron but having the same charge? [Given Rydberg constant, R = 10^{-7} m^{-1}]

54. The energy levels of a hypothetical atom are given below. Which of the shown transitions will result in the emission of photon of wavelength 275 nm?



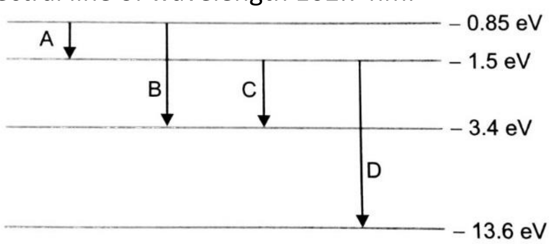
55. The electron, in a hydrogen atom, is in its second excited state.
Calculate the wavelength of the lines in the Lyman series that can be emitted through the permissible transitions of this electron. [Given the value of Rydberg constant, R = 1.1 x 10^7 m^{-1}]

$$\Rightarrow \qquad \lambda = 212\,nm$$

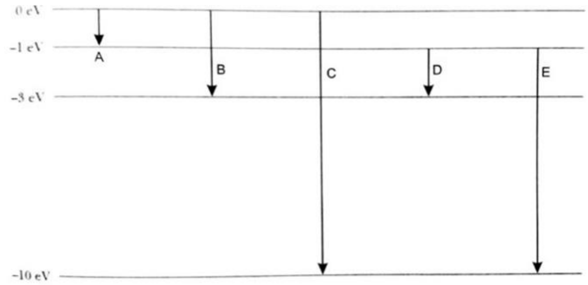
56. Using Rutherford model of the atom, derive the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron?

57. (i) State Bohr postulate of hydrogen atom that gives the relationship for the frequency of emitted photon in a transition.
(ii) An electron jumps from fourth to first orbit in an atom. How many maximum numbers of spectral lines can be emitted by the atom? To which series these lines correspond?

58. The energy level diagram of an element is given below. Identify, by doing necessary calculations, which transition corresponds to the emission of a spectral line of wavelength 102.7 nm.



59. The energy levels of an atom are given below in the diagram.



Which of the transitions belong to Lyman and Balmer series? Calculate the ratio of the shortest wavelengths of the Lyman and the Balmer series of the spectra.

60. (i) The radius of the innermost electron orbit of a hydrogen atom is 5.3 x 10^{-11} m. Calculate its radius in n = 3 orbit.
(ii) The total energy of an electron in the first excited state of the hydrogen atom is $-3.4\ eV$. Find out its (a) kinetic energy and (b) Potential energy in this state.

61. (i) In Rutherford scattering experiment, draw the trajectory traced by –particles in the coulomb field of target nucleus and explain how this led to estimate the size of the nucleus.
(ii) Describe briefly how wave nature of moving electrons was established experimentally.
(iii) Estimate the ratio of de-Broglie wavelengths associated with deuterons and α-particles when they are accelerated from rest through the same accelerating potential V.

62. (i) Draw a schematic arrangement of Geiger-Marsden experiment showing the scattering of α-particles by a thin foil of gold. Why is it that most of the α-particles go right through the foil and only a small fraction gets scattered at large angles?
Draw the trajectory of the α-particle in the coulomb field of a nucleus. What is the significance of impact parameter and what information can be obtained regarding the size of the nucleus?
(ii) Estimate the distance of closest approach to the nucleus (Z = 80) if a 7.7 MeV α-particle before it comes momentarily to rest and reverses its direction.

63. Using Bohr's second postulate of quantization of orbital angular momentum show that the circumference of the electron in the orbital state in hydrogen atom is n times the de-Broglie wavelength associated with it.

64. In hydrogen atom, electron excites from ground state to higher energy state and its orbital velocity is reduced to $\left(\frac{1}{3}\right)^{rd}$ of its initial value. The radius of the orbit in the ground state is R. Find the radius of the orbit in that higher energy state.

65. (a) Explain Bohr's quantization condition of angular momentum.
(b) The electron in a given Bohr orbit has a total energy of $-1.5\ eV$. Calculate its
(i) kinetic energy.
(ii) potential energy.
(iii) wavelength of radiation emitted, when this electron makes a transition to the ground state.
[Given : Energy in the ground state $= \ -13.6\ eV$ and Rydberg's constant $= \ 1.09\ \times 10^7 m^{-1}$]

66. In a hydrogen atom an electron jumps from 4th orbit to 2nd orbit. If $R\ =\ 10^7 m^{-1}$, then calculate the frequency of the emitted radiation.

SURE SHOT QUESTIONS

ARVIND ACADEMY

Chapter – 13

Nuclei

MCQ (1 mark)

1. Suppose we consider a large number of containers each containing initially 10000 atoms of a radioactive material with a half life of 1 year. After 1 year,
   (a) All the containers will have 5000 atoms of the material.
   (b) All the containers will contain the same number of atoms of the material but that number will only be approximately 5000.
   (c) The containers will in general have different number of the atoms of the material but their average will be close to 5000.
   (d) None of containers can have more than 5000 atoms.

2. The gravitational force between a H – atom and another particle of mass m will be given by Newton's law : $F = G\frac{M.m}{r^2}$, where r is in km and
   (a) $M = m_{proton} + m_{electron}$
   (b) $M = m_{proton} + m_{electron} - \frac{B}{c^2}(B = 13.6eV)$.
   (c) M is not related to the mass of the hydrogen atom.
   (d) $M = m_{proton} + m_{electron} - \frac{|V|}{c^2}$
   (|V| = magnitude of the potential energy of electron in the H-atom).

3. When a nucleus in an atom undergoes a radioactive decay, the electronic energy levels of the atom
   (a) Do not change for any type of radioactivity.
   (b) Change for α and β radioactivity but not for γ-radioactivity.
   (c) Change for α-radioactivity but not for others.
   (d) Change for β-radioactivity but not for others.

4. M_x and M_y denote the atomic masses of the parent and the daughter atom respectively in a radioactive decay. The Q-value for a β^- decay is Q_1 and that for a β^+ decay is Q_2. If m_e denotes the mass of an electron, then which of the following statements is correct?
   (a) $Q_1 = (M_x - M_y)c^2$ and
   $Q_2 = (M_x - M_y - 2m_e)c^2$
   (b) $Q_1 = (M_x - M_y)c^2$ and $Q_2 = (M_x - M_y)c^2$
   (c) $Q_1 = (M_x - M_y - 2m_e)c^2$ and
   $Q_2 = (M_x - M_y + 2m_e)c^2$
   (d) $Q_1 = (M_x - M + 2m_e)c^2$ and
   $Q_2 = (M_x - M_y + 2m_e)c^2$

5. Tritium is an isotope of hydrogen whose nucleus triton contains 2 neutrons and 1 proton. Free neutrons decay into $p + e^- + \bar{v}$. If one of the neutrons in triton decays, it would transform into He^3 nucleus. This does not happen. This is because
   (a) Triton energy is less than that of a He^3 nucleus.
   (b) The electron created in the beta decay process cannot remain in the nucleus.
   (c) Both the neutrons in triton have a decay simultaneously resulting in a nucleus with 3 protons, which is not a He^3 nucleus.

(d) Because free neutrons decay due to external perturbations which is absent in a triton nucleus.

6. Heavy stable nuclei have more neutrons than protons. This is because of the fact that
(a) neutrons are heavier than protons,
(b) electrostatic force between protons are repulsive,
(c) neutrons decay into protons through beta decay,
(d) nuclear forces between neutrons are weaker than that between protons.

7. In a nuclear reactor, moderators slow down the neutrons which come out in a fission process. The moderator used have light nuclei. Heavy nuclei will not serve the purpose because
(a) they will break up.
(b) elastic collision of neutrons with heavy nuclei will not slow them down,
(c) the net weight of the reactor would be unbearably high.
(d) substances with heavy nuclei do not occur in liquid or gaseous state at room temperature.

8. The ratio of the nuclear densities of two nuclei having mass numbers 64 and 125 is [2023]

(a) $\frac{64}{125}$ (b) $\frac{4}{5}$

(c) $\frac{5}{4}$ (d) 1

9. The difference in mass of ^{7}X nucleus and total mass of its constituent nucleons is 21.00 u. The binding energy per nucleon for this nucleus is equal to the energy equivalent of [2023]
(a) 3 u (b) 3.5 u
(c) 7 u (d) 21 u

10. When two nuclei ($A \leq 10$) fuse together to form a heavier nucleus, the [2020]
(a) binding energy per nucleon increases
(b) binding energy per nucleon decreases
(c) binding energy per nucleon does not change
(d) total binding energy decreases.

11. Which of the following statements is not true for nuclear forces. [2023]
(a) They are stronger than Coulomb forces.
(b) They have about the same magnitude for different pairs of nucleons.
(c) They are always attractive
(d) They saturate as the separation between two nucleons increases.

12. 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 femtometres.
(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. [2022 – 23]

➢ Assertion-Reasoning (1 mark)

DIRECTIONS

In the following questions (1 to 9), 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 assertion.

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

(c) If assertion is true but reason is false

(d) If both assertion and reason are false.

13. **Assertion.** Nuclei having mass number about 60 are most stable.
Reason. When two or more light nuclei are combined into a heavier nucleus, then the binding energy per nucleon will increase.

14. **Assertion.** On a decay daughter nucleus shifts two places to the left from the parent nucleus.
Reason. An alpha particle carries four units of mass.

15. **Assertion.** In a radioactive disintegration, an electron is emitted by the nucleus.
Reason. Electrons are present inside the nucleus.

16. **Assertion.** A beam of charged particles is employed in the treatment of cancer.
Reason. Charged particles on passing through a material medium lose their energy by causing ionization of the atoms along their path.

17. **Assertion.** Forces acting between proton-proton (f_{pp}), proton-neutron and neutron-neutron are such that $f_{pp} < f_{pn} = f_{nn}$
Reason. Electrostatic force of repulsion between two protons reduces net nuclear force between them.

18. **Assertion.** Heavy water is used as moderator in nuclear reactor.
Reason. Water cools down the fast neutron.

19. **Assertion.** Unlike electric forces and gravitational forces, nuclear force has limited range.
Reason. Nuclear forces do not obey inverse square

20. **Assertion.** Thermonuclear fusion reactions may become the source of unlimited power for the mankind.
Reason. A single fusion event involving isotopes of hydrogen produces more energy than energy from nuclear fission of $^{235}_{93}U$.

21. **Assertion.** Mass is not conserved, but mass and energy are conserved as a single entity called mass-energy.
Reason. Mass and energy are inter-convertible in accordance with Einstein's relation, $E = mc^2$.

➢ Case Study (5 marks)

22. In Rutherford's nuclear model of the atom, the entire positive charge and most of the mass of the atom are concentrated in the nucleus. The electrons move in orbits around the nucleus. The nucleus is made of protons and neutrons. Because the nucleus is extremely small as compared to the atom, most of an atom is empty space. The protons and the neutrons are held together in the nucleus by very strong nuclear forces,

(i) The radius R of a nucleus of mass number A is given by

(a) $R = R_0 A^3$ (b) $R = R_0 A^{1/3}$

(c) $R = R_0^3 A$ (d) $R = R_0^3 A^{1/3}$

(ii) The ratio of nuclear density of nuclei X^{27} to Y^8 is

(a) 3 : 2 (b) 27 : 8

(c) 1 : 1 (d) 2 : 3

(iii) In the following nuclear reaction

$$^{238}_{92}U + n \rightarrow ^{Y}_{X}Np + e^- + \bar{v} + Q,$$

The values of X and Y are

(a) X = 92 ; Y = 238

(b) X = 92 ; Y = 239

(c) X = 93 ; T = 239

(d) X = 93 ; Y = 238

(iv) The saturation property of the nuclear forces is due to the fact that they are

(a) Charge independent forces.

(b) Non-central forces.

(c) Spin – dependent forces.

(d) Short – range forces.

(v) In Geiger – Marsden scattering experiment, then gold foil is used to scatter alpha particles because alpha particles will [2020C]

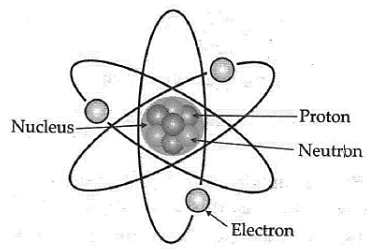
(a) not suffer more than one scattering and gold nucleus is 50 times heavier than alpha particle,

(b) not suffer more than one scattering and gold nucleus is lighter than alpha particle,

(c) not suffer more than few scattering and gold nucleus is 25 times heavier than alpha particle,

(d) suffer more than one scattering and gold nucleus is 25 times heavier than alpha particle.

23. The discovery of neutrons by Chadwick, led Heisenberg to propose proton-neutron hypothesis in 1932. According to this hypothesis, protons and neutrons are the main building blocks of all atoms. The protons are positively charged particles while neutrons are electrically neutral. The magnitude of the charge on a proton is equal to that on an electron and can be represented as (+ *e*). The number of protons in the nucleus is called atomic number *Z*. The total number of protons and neutrons is called mass number *A*. Hence (*A*-*Z*) gives the number of neutrons and is called neutron number *N*. A nuclear species or a nuclide is represented as ${}^{A}_{Z}X$, where X is the chemical symbol of the species.



Nuclides with same atomic number *Z,* but different neutron number *N* are called isotopes. Nuclides with same mass number A are isobars and those with the same neutron number *N* are isotones. As most of the elements are the mixture of two or more isotopes, the atomic mass of an element is the weighted average of the masses of its isotopes.

QUESTIONS (Answer any four of the following questions)

1. The mass number of a nucleus is

(a) always less than its atomic number

(b) always more than its atomic number

(c) sometimes equal to its atomic number

(d) sometimes less than and sometimes more than its atomic number.

2. In the nucleus of ${}_{11}\mathrm{Na}^{23}$ the number of protons, neutrons and electrons are

(a) 11,12, 0 (b) 23,12,11

(c) 12, 11, 0 (d) 23, 11,12

3. The nuclei ${}_{6}\mathrm{C}^{13}$ and ${}_{7}\mathrm{N}^{14}$ can be described as

(a) isotones (b) isobars

(c) isotopes of carbon (d) nitrogen.

4. Which one of the following pairs of nuclei are isotones?

(a) ${}_{34}\mathrm{Se}^{74}, {}_{31}\mathrm{Ga}^{71}$ (b) ${}_{38}\mathrm{Sr}^{84}, {}_{38}\mathrm{Sr}^{86}$

(c) ${}_{42}\mathrm{Mo}^{92}, {}_{40}\mathrm{Zr}^{92}$ (d) ${}_{20}\mathrm{Ca}^{40}, {}_{16}\mathrm{S}^{32}$

5. Atomic weight of Boron is 10.81 and it has two isotopes and ${}_{5}\mathrm{B}^{10}$ and ${}_{5}\mathrm{B}^{11}$ Then the ratio of ${}_{5}\mathrm{B}^{10}:{}_{5}\mathrm{B}^{11}$ in nature would be.

(a) 15 :16 (b) 10 : 11 (c) 19 : 81 (d) 81 : 19

➢ Questions

24. If both the number of protons and neutrons in a nuclear reaction is conserved, in what way is mass converted into energy (or vice versa)? Explain giving one example. [Delhi 2015C]

25. (a) Differentiate between nuclear fission and nuclear fusion.

    (b) Deuterium undergoes fusion as per the reaction.

    $${}_{1}^{2}H + {}_{1}^{2}H \rightarrow {}_{2}^{3}He + {}_{0}^{1}n + 3.27\,MeV$$

    Find the duration for which an electric bulb of 500 W can be kept glowing by the fusion of 100 g of deuterium. [Term – II 2021 – 22]

26. Calculate for how many years will the fusion of 2.0 kg deuterium keep 800 W electric lamp glowing. Take the fusion reaction as [2020]

    $${}_{1}^{2}H + {}_{1}^{2}H \rightarrow {}_{2}^{3}He + {}_{0}^{1}n + 3.27\,MeV$$

27. Show that density of nucleus is independent of its mass number A. [1/3, Delhi 2019]

28. In the study of Geiger – Marsden experiment on scattering of α-particles by a thin foil of gold, draw the trajectory of α-particles in the coulomb field of target nucleus. Explain briefly how one gets the information on the size of the nucleus from this study.

    From the relation R = $R_0 A^{1/3}$, where R_0 is constant and A is the mass number of the nucleus, show that nuclear matter density is independent of A. [Delhi 2015]

29. Draw a graph showing the variation of binding energy per nucleon with mass number of different nuclei. Write any two salient features of the curve. How does this curve explain the release of energy both in the processes of nuclear fission and fusion? [AI 2019]

    OR

    Explain the processes of nuclear fission and nuclear fusion by using the plot of binding energy per nucleon (BE/A) versus the mass number A. [2018]

    OR

    Draw a plot of B.E./A versus mass number A for 2 < A < 170. Use this graph to explain the release of energy in the process of nuclear fusion of two light nuclei. [Delhi 2014C]

30. (a) Explain the processes of nuclear fission and nuclear fusion by using the plot of binding energy per nucleon (BE/A) versus the mass number A. (b) A radioactive isotope has a half-life of 10 years. How long will it take for the activity to reduce to 3.125%?

31. A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy Q released per fission in MeV.

32. Calculate the energy in fusion reaction : ${}_{2}^{1}H + {}_{1}^{2}H \rightarrow {}_{2}^{3}He + n$, where BE of ${}_{1}^{2}H = 2.23\ MeV$ and of ${}_{2}^{3}He = 7.73\ MeV$.

33. (i) Explain the processes of nuclear fission and nuclear fusion by using the plot of binding energy per nucleon (BE/A) versus the mass number A.
    (ii) A radioactive isotope has a half-life of 10 years. How long will it take for the activity to reduce to 3.125%?

34. Distinguish between nuclear fission and nuclear fusion. Show how in both these processes energy is released.
Calculate the energy released in MeV in the deuterium-tritium fusion reaction

$$^2_1H + ^3_1H \rightarrow ^4_2He + n$$

Using the data :

$m\ (^2_1H)$ = 2.014102 μ
$m\ (^3_1H)$ = 3.016049 μ
$m\ (^4_2He)$ = 4.002603 μ
m_n = 1.008665 μ
1 amu = 931.5 MeV/c^2

35. The radius of a spherical nucleus as measured by electron scattering is 3.6 fm. What is the likely mass number of the nucleus?

36. If both the number of protons and the number of neutrons are conserved in a nuclear reaction like
$^{12}_6C + ^{12}_6C \rightarrow ^{20}_{10}Ne + ^4_2He$
In what way is mass converted into energy? Explain.

37. Draw a graph showing the variation of potential energy between a pair of nucleons as a function of their separation. Indicate the regions in which the nuclear force is (i) attractive, (ii) repulsive.

38. A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy of two nucleons is 8.5. Calculate the energy Q released per fission in MeV.

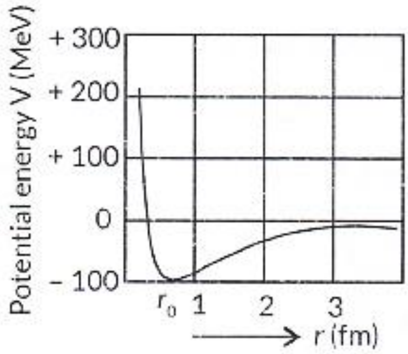
39. (a) Draw the plot of binding energy per nucleon (B.E./A) as a function of mass number A. Write two important conclusions that can be drawn regarding the nature of nuclear force.
(b) Use this graph to explain the release of energy in both the processes of nuclear fusion and fission.

(AI 2013)

40. When four hydrogen nuclei combine to form a helium nucleus estimate the amount of energy in MeV released in this process of fusion (Neglect the masses of electrons and neutrons). Given:
(i) Mass of $^1_1H = 1.007825\ u$
(ii) Mass of Helium Nucleus = $4.002603\ u$, $1u = 931\ MeV/c^2$

41. Calculate binding energy per nucleon of $_{85}Bi^{209}$
Given m $(_{85}Bi^{209}) = 208.980388\ amu$. Mass of neutron = 1.008665 amu and mass of proton = 1.007825 amu.

42. The potential energy (V) of a pair of nucleons varies with the separation (r) between them, in the manner shown. Use this graph to explain why the force between the nucleons must be regarded as
(i) strongly repulsive for separation values less than r_0
(ii) attractive nuclear force ($r > r_0$)



43. The fission properties of $^{239}_{94}Pu$ are very similar to those of $^{235}_{92}U$. The average energy released per fission is 180 MeV. How much energy, in MeV, is released if all the atoms in 1 kg of pure $^{239}_{94}Pu$ undergo fission?

44. A star converts all its hydrogen into helium achieving 100% helium composition. It then converts helium to carbon via the reaction. $^4_2He + ^4_2He + ^4_2He \rightarrow ^{12}_6C + 7.27\ MeV$ The mass of the star is $5.0 \times 10^{32}\ kg$ and it generates energy at the rate of 5×10^{30} watt. How long will it take to convert all the helium to carbon at this rate?

45. Obtain the binding energy of the nuclei $^{56}_{26}Fe$ and $^{209}_{83}Bi$ in units of MeV from the following data :
m($^{56}_{26}Fe$) = 55.934939 u m($^{209}_{83}Bi$) = 208.980388 u

46. Calculate and compare the energy released by (a) fusion of 1.0 kg of hydrogen deep within the Sun and (b) the fission of 1.0 kg of 235U in a fission reactor.

ARVIND ACADEMY

For Solutions

Download Arvind Academy App

Click Link: http://bit.ly/2kTWbkj

SURE SHOT QUESTIONS

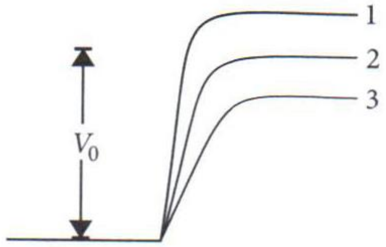
Chapter – 14

Semiconductor Electronics: Materials, Devices and Simple Circuits

MCQ (1 mark)

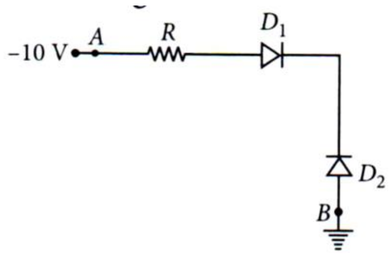
1. The conductivity of a semiconductor increases with increase in temperature because
(a) number density of free current carriers increases,
(b) relaxation time increases,
(c) both number density of carriers and relaxation time increase,
(d) number density of current carriers increases, relaxation time decreases but effect of decrease in relaxation time is much less than increase in number density.

2. In fig. V_0 is the potential barrier across a p-n junction, when no battery is connected across the junction.



(a) 1 and 3 both correspond to forward bias of junction
(b) 3 corresponds to forward bias of junction and 1 corresponds to reverse bias of junction
(c) 1 corresponds to forward bias and 3 corresponds to reverse bias of junction
(d) 3 and 1 both correspond to reverse bias of junction.

3. In figure, assuming the diodes to be ideal,

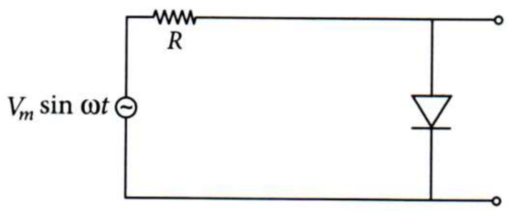


(a) D_1 is forward biased and D_2 is reverse biased and hence current flows from A to B.
(b) D_2 is forward biased and D_1 is reverse biased and hence no current flows from B to A and vice versa.
(c) D_1 and D_2 are both forward biased and hence current flows from A to B.
(d) D_1 and D_2 are both reverse biased and hence no current flows from A to B and vice versa.

4. A 220 V ac supply is connected between point A and B as shown in figure. What will be the potential difference V across the capacitor?
(a) 220 V (b) 110 V
(c) 0 V (d) $220\sqrt{2}\,V$

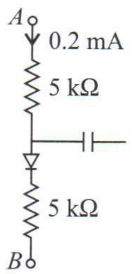
5. Hole is
(a) An anti-particle of electron.
(b) A vacancy created when an electron leaves a covalent bond.
(c) Absence of free electrons.
(d) An artificially created particle.

6. The output of the given circuit in figure



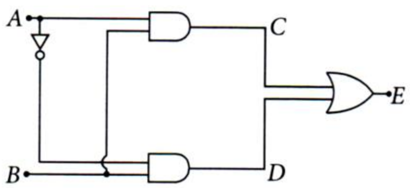
(a) Would be zero at all times.
(b) Would be like a half wave rectifier with positive cycles in output.
(c) Would be like a half wave rectifier with negative cycles in output.
(d) Would be like that of a full wave rectifier.

7. In the circuit shown in figure, if the diode forward voltage drop is 0.3 V, the voltage difference between A and B is



(a) 1.3 V (b) 2.3 V
(c) 0 (d) 0.5 V

8. Truth table for the given circuit in figure is



(a)

A	B	E
0	0	1
0	1	0
1	0	1
1	1	0

(b)

A	B	E
0	0	1
0	1	0
1	0	0
1	1	1

(c)

A	B	E
0	0	0
0	1	1
1	0	0
1	1	1

(d)

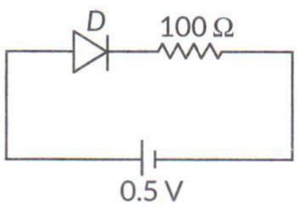
A	B	E
0	0	0
0	1	1
1	0	1
1	1	0

9. The energy required by an electron to jump the forbidden band in silicon at room temperature is about [2023]
(a) 0.01 eV (b) 0.05 eV
(c) 0.79 eV (d) 1.1 eV

10. In an n-type semiconductor, the donor energy level lies [2020]
(a) at the centre of the energy gap.
(b) just below the conduction band,
(c) just above the valance band,
(d) in the conduction band.

11. When the temperature of an n-type semiconductor is increased, then the
(a) number of free electrons increases while that of the holes decreases,
(b) number of holes increases while that of the free electrons decreases,
(c) number of free electrons and holes remains unchanged,
(d) number of both the free electrons and the holes increase equally. [2020C]

12. The threshold voltage for a p-n junction diode used in the circuit is 0.7 V. The type of biasing and current in the circuit are [2023]



(a) Forward biasing, 0 A
(b) Reverse biasing, 0 A
(c) Forward biasing, 5mA
(d) Reverse biasing, 2 mA

13. At equilibrium, in a p-njunction diode the net current is [2020]
(a) due to diffusion of majority charge carriers,
(b) due to drift of minority charge carriers,

(c) zero as diffusion and drift currents are equal and opposite,

(d) zero as no charge carriers cross the junction.

Assertion-Reasoning (1 mark)

14. Assertion (A): The resistance of an intrinsic semiconductor decreases with increases in its temperature.

Reason (R): The number of conduction electrons as well as hole increase in an intrinsic semiconductor with rise in its temperature.

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

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

(c) Assertion (A) is true, but Reason (R) is false.

(d) Assertion (A) is false, but Reason (R) is true.

[2023]

15. Assertion (A): IN 'n' type semiconductor, number density of electrons is greater than the number density of holes but the crystal maintains overall charge neutrality.

Reason (R): The charge of electrons donated by donor atoms is just equal and opposite to that of the ionized donor. [2023]

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

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

(c) Assertion (A) is true, but Reason (R) is false,

(d) Assertion (A) is false and Reason (R) is also false.

16. Assertion (A) : The electrical conductivity of a semiconductor increases on doping.

Reason (R): Doping always increases the number of electrons in the semiconductor,

(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. [2022 – 23]

17. Assertion (A): At absolute zero the conductivity of semiconductor is zero.

Reason (R): In a semiconductor there are no free electrons at any temperature.

18. Assertion (A): Light Emitting Diode (LED) emit spontaneous radiation.

Reason (R): LED are forward-biased p-n junction.

19. Assertion (A) : In a semiconductor diode, the reverse biased current is due to drift of free electrons and holes.

Reason (R): The drift of electrons and holes is due to thermal excitations.

20. Assertion (A) : The resistance of p-n junction is low when forward biased and is high when reverse biased.

Reason (R): In reversed biased, the depletion layer is reduced.

21. Assertion (A): The dominant mechanism for motion of charge carriers in forward and reverse biased silicon p-n junction are drift in both forward and reverse bias.

Reason (R): In reverse biased, no current flow through the junction.

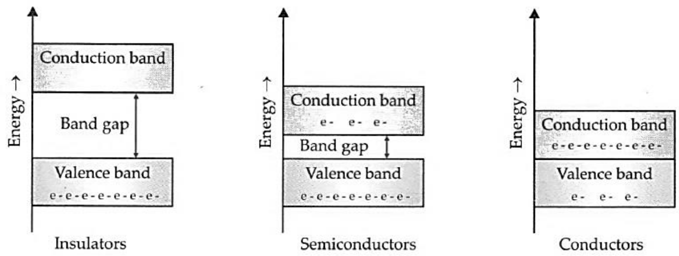
22. Assertion (A): Diamond behaves like an insulator.
Reason (R): There is a large energy gap between valence band and conduction band of diamond.

23. Assertion (A) : The probability of electrons to be found in the conduction band of an intrinsic semiconductor at a finite temperature decrease exponentially with increasing band gap.
Reason (R) : It will be more difficult for the electron to cross over the large band gap while going from valence band to conduction band.

➢ Case Study

PARAGRAPH 1: Energy Bonds in Solids

24. In case of isolated atoms, there are discrete energy levels. But when we take a solid as a whole there are bonds between atoms. For a particular atom in the solid, neighbouring atoms influence the energies of the outer electrons. These discrete levels spread into continuous bands of energies. The highest filled band is called valence band. The next higher unfilled band is called conduction band. The valence band and conduction band are usually separated by forbidden energy region called forbidden energy gap. In case of metallic conductors, valence band overlaps conduction band and electrons are readily available for conduction. Hence, they are good conductors. In case of insulators, there is large energy gap between valence and conduction bands.



Therefore, conductivity is negligible. In case of semiconductors, the energy gap is small and at room temperature some of the electrons of valence band cross the energy gap and reach the conduction band to contribute some electrical conductivity.

QUESTIONS (Answer any four of the following questions)

1. In semiconductors at a room temperature

(a) the valence band is partially empty and the conduction band is partially filled

(b) the valence band is completely filled and the conduction band is partially filled

(c) the valence band is completely filled

(d) the conduction band is completely empty.

2. In insulators

(a) valence band is partially filled with electrons

(b) conduction band is partially filled with electrons

(c) conduction band is filled with electrons and valence band is empty

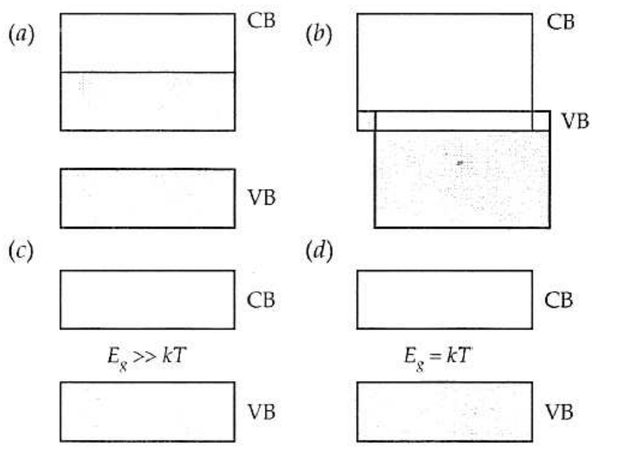
(d) conduction band is empty and valence band is completely filled with electrons.

3. In an insulator, the forbidden energy gap between a valence band and conduction band is of the order of

(a) 1 MeV (b) 1 keV

(c) 1 eV (d) 5 eV

4. Which of the energy band diagrams shown in the figure corresponds to that of a semiconductor?



5. In a germanium crystal, the forbidden energy gap in

joule is

(a) 1.6×10^{-19} (b) $zero$

(c) 1.12×10^{-19} (d) 1.76×10^{-19}

PARAGRAPH 2: Junction Diode

25. A p-n junction is the key to all semiconductor devices. When such a junction is made, a depletion layer is formed consisting of immobile ion-cores devoid of their electrons or holes. This is responsible for a junction potential barrier. By changing the external applied voltage, junction barrier can be changed. In forward bias, the barrier is decreased while the barrier increases in reverse bias. Hence, forward bias current is more (mA) while it is very small (μA) in reverse biased junction diode. The given figure shows a germanium semiconductor device.

QUESTIONS (Answer any four of the following questions)

6. In the diagram, section A represents the

(a) n-type germanium (b) p-type germanium

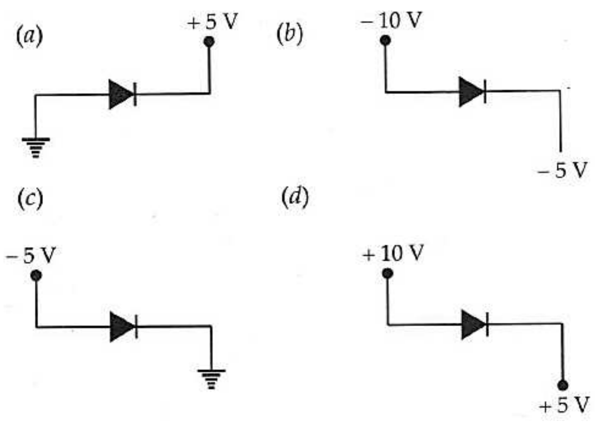
(c) anode (d) diode.

7. The bias of the p-n junction shown in the diagram is

(a) C to D (b) E to F

(d) forward (c) reverse

8. Which of the following p-n junction is forward biased?



9. In an unbiased p-n junction, holes diffuse from the p-region to the n-region because

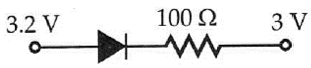
(a) free electrons in the n-region attract them

(b) they move across the junction due to potential difference

(c) hole concentration in p-region is more as compared to n-region

(d) all the above

10. The current in the circuit shown in the figure considering ideal diode is



(a) $20\ A$ (b) $2 \times 10^{-3} A$

(c) $200 A$ (d) $2 \times 10^{-4} A$

➢ Questions

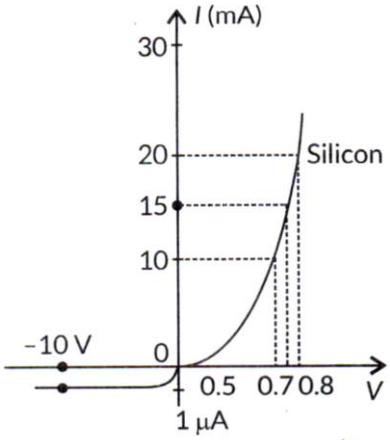
26. What is meant by energy band gap in a solid? Draw the energy band diagrams for a conductor, an insulator and a semiconductor. [Term II 2021 – 22]

27. Distinguish between a metal and an insulator on the basis of energy band diagrams. [Foreign 2014]

28. Explain the term 'depletion layer' and 'potential barrier' in a p-n junction diode. How are the (a) width of depletion layer, and (b) value of potential barrier affected when the p-n junction is forward biased? [2020]

29. Draw V-I characteristics of a p-n junction diode. Explain, why the current under reverse bias is almost independent of the applied voltage up to the critical voltage. [2020]

30. The V-I characteristic of a silicon diode is as shown in the figure. Calculate the resistance of the diode at (i)/= 15 mA and (ii) V=-10V [Foreign 2015]



31. Give two difference between a half wave rectifier and a full wave rectifier. [Term II 2021 – 22]

32. Write any two distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams.

33. Answer the following, giving reasons:

(a) The resistance of a p-n junction is low when it is forward biased and is high when it is reversed biased.

(b) Doping of intrinsic semiconductors is necessity for making electronic devices. [Term II 2021 – 22]

34. Write the two processes that take place in the formation of a p-n junction. Explain with the help of a diagram, the formation of depletion region and barrier potential in a p-n junction. [Delhi 2017]

OR

Explain with the help of the diagram the formation of depletion region and barrier potential in a p-n junction [2/3, AI 2016]

OR

Write briefly the important processes that occur during the formation of p-n junction. With the help of necessary diagrams, explain the term barrier potential. [Foreign 2015]

35. Draw V – I characteristics of a p-n junction diode. Answer the following giving reasons: [2022C]

(a) Why is the reverse bias current almost independent of applied voltage up to breakdown voltage?

(b) Why does the reverse current show a sudden increase at breakdown voltage?

36. State briefly the processes involved in the formation of p-n junction explaining clearly how the depletion region is formed. [2/5, Delhi 2014]

OR

Explain with the help of diagram, how a depletion layer and barrier potential are formed in a junction diode. [3/5, Delhi 2014C]

37. Explain briefly with the help of necessary diagrams, the forward and the reverse biasing of a p-n junction diode. Also draw their characteristic curves in the two cases. [Delhi 2017]

OR

Using the necessary circuit diagrams, show how the V-I characteristics of a p-n junction are obtained in [Delhi 2014]

(i) Forward biasing

(ii) Reverse biasing.

OR

Draw the circuit arrangement for studying the V-I characteristics of a p-n junction diode in (i) forward and (ii) reverse bias. Briefly explain how the typical V-I characteristics of a diode are obtained and draw these characteristics.

[AI 2014C]

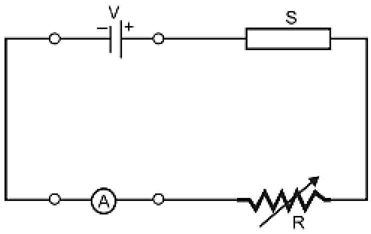
38. Draw the circuit diagram of a half wave rectifier and explain its working. [AI 2016]

39. Explain briefly with the help of necessary diagrams, the forward and the reverse biasing of a p-n junction diode. Also draw their characteristic curves in the two cases.

40. (a) Three photo diodes D_1, D_2 and D_3 are made of semiconductors having band gaps of 2.5 eV, 2eV and 3 eV respectively. Which of them will not be able to detect light of wavelength 600 nm?
(b) Why photodiodes are required to operate in reverse bias? Explain.

41. Draw the circuit diagram of a full wave rectifier. Explain its working principle. Show the input waveforms gives to the diode D_1 and D_2 and the corresponding output waveforms obtained at the load connected to the circuit.

42. (a) In the following diagram 'S' is a semiconductor. Would you increase or decrease the value of R to keep the reading of the ammeter A constant when S is heated? Give reason for your answer.
(b) Draw the circuit diagram of a photodiode and explain its working. Draw its $I - V$ characteristics.

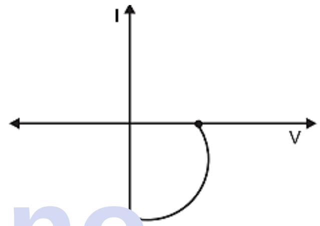


43. Draw V-I characteristics of a p-n junction diode. Answer the following questions, giving reasons:
(i) Why is the current under reverse bias almost independent of the applied potential upto a critical voltage?
(ii) Why does the reverse current show a sudden increase at the critical voltage?
Name any semiconductor device which operates under the reverse bias in the breakdown region.

44. What happens to the width of depletion layer of a p-n junction when it is (i) forward biased, (ii) reverse biased?

45. How is forward biasing different from reverse biasing is a p-n junction diode?

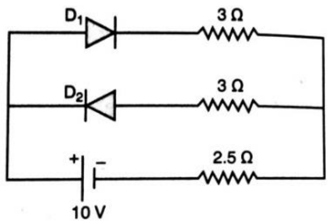
46. Name the junction diode whose I-V characteristics are drawn below:



47. Write any two distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams.

48. Explain with the help of a circuit diagram, the working of a p-n junction diode as a half-wave rectifier.

49. Assuming that the two diodes D_1 and D_2 used in the electric circuit shown in the figure are ideal, find out the value of the current flowing through 2.5 Ω resistor.



50. Explain the two processes involved in the formation of a p-n junction diode. Hence define the term 'barrier potential'.

51. (i) Explain with the help of a diagram the formation of depletion region and barrier potential in a p-n junction.
(ii) Draw the circuit diagram of a half wave rectifier and explain its working.

52. (a) Distinguish between an intrinsic semiconductor and a p-type semiconductor. Give reasons why a p-type semiconductor is electrically neutral, although $n_h >> n_e$
(b) Explain, how the heavy doping of both p-n junction diode results in the electric field of the junction being extremely high even with a reverse bias voltage of a few volts.

53. A semiconductor has equal electron and hole concentration of 6 x 10^8 / m^3. On doping with certain impurity, electron concentration increases to 9 x 10^{12} / m^3
(i) Identify the new semiconductor obtained after doping.
(ii) Calculate new hole concentration.

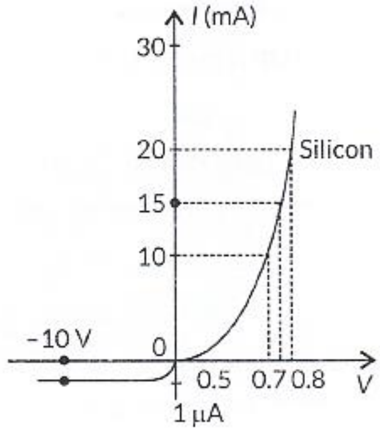
54. Answer the following, giving reason :
(a) The resistance of a p-n junction is low when it is forward. biased and is high when it is reversed biased.
(b) Doping of intrinsic semiconductors is a necessity for making electronic devices.

55. Distinguish between an intrinsic semiconductor and a p-type semiconductor. Give reason why a p-type semiconductor is electrically neutral, although $n_h >> n_e$.

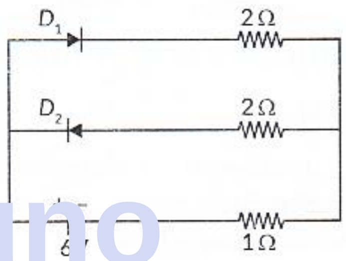
56. Explain the term 'depletion layer' and 'potential barrier' in a p-n junction diode. How are the (a) width of depletion layer, and (b) value of potential barrier affected when the p-n junction is forward biased?

57. Draw V-I characteristics of a p-n junction diode. Explain, why the current under reverse bias is almost independent of the applied voltage up to the critical voltage.

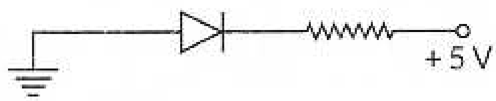
58. The V-I characteristic of a silicon diode is as shown in the figure. Calculate the resistance of the diode at
(i) I = 15 mA and (ii) V=-10V



59. Assuming that the two diodes D_1 and D_2 used in the electric circuit shown in the figure are ideal, find out the value of the current flowing through 1 Ω. resistor.

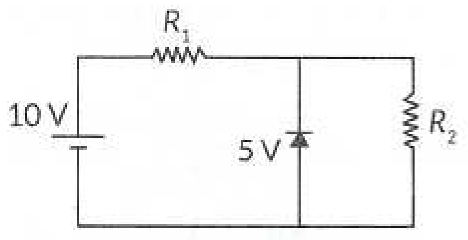


60. In the following diagram, is the junction diode forward biased or reverse biased?



61. Pure silicon at 300 K has equal electron and hole concentrations of $1.5\ 10^{16} m^{-3}$. Doping by indium increases the hole concentration to $4.5 \times 10^{22} m^{-3}$. Calculate the new electron concentration in the doped silicon.

62. What is the current flowing in R_2 in the circuit shown in figure?
Given : $R_1 = 500\ Q\ and\ R_2 = 1\ k\Omega$

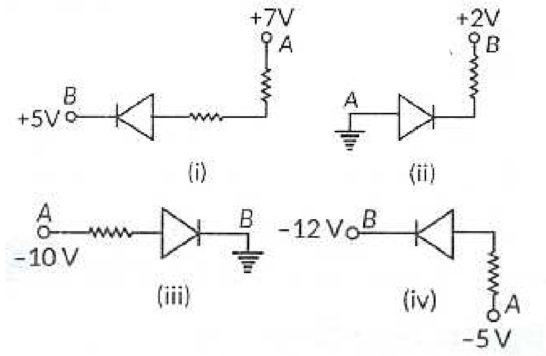


63. The following table provides the set of values, of V and I, obtained for a given diode:

	V	I
Forward Biasing	2.0 V	60 mA
	2.4 V	80 mA
Reverse Biasing	0 V	0 μA
	-2 V	-0.25 μA

Assuming the characteristics to be nearly linear, over this range, calculate the forward and reverse bias resistance of the given diode.

64. In the following diagrams, indicate which of the diodes are forward biased and which are reverse biased?



65. The forbidden energy gap in semiconductors, insulators and metals are E_s, E_i and E_m respectively. Arrange these in descending order. The band gap in silicon is 1.12 eV. What is the maximum wavelength of light that can be emitted by it?