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1700+ Objective

Chapter-wise Question Bank for CBSE

PHYSICS

Class 12

with Case base, A/R & MCQs

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1 Electric Charges and Fields

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

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

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

(c) $180°, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{2L^2}$ (d) $180°, \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{L^2}$

2. Two equal point charges each of 3μC are separated by a certain distance in metres. If they are located at $(\hat{i}+\hat{j}+\hat{k})$ and $(2\hat{i}+3\hat{j}+\hat{k})$, then the electrostatic force between them is

(a) 9×10^3 N (b) 16×10^{-3} N

(c) 10^{-3} N (d) 9×10^{-2} N

3. A body is positively charged, it implies that

(a) there is only positive charge in the body

(b) there is positive as well as negative charge in the body but the positive charge is more than negative charge

(c) there is equal positive and negative charge in the body but the positive charge lies in the outer regions

(d) negative charge is displaced from its position

4. On rubbing, when one body gets positively charged and other negatively charged, the electrons transferred from positively charged body to negatively charged body are

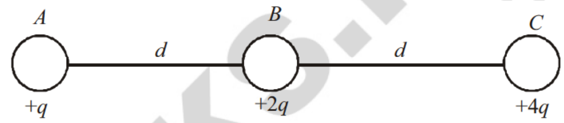
(a) valence electrons only

(b) electrons of inner shells

(c) both valence electrons and electrons of inner shell

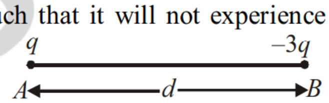
(d) yet to be established

5. Three charges $+q$, $+2q$ and $+4q$ are connected by strings as shown in the figure. What is ratio of tensions in the strings AB and BC ?



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

6. Two charge q and $-3q$ are placed fixed on x–axis separated by distance d. Where should a third charge $2q$ be placed such that it will not experience any force?



(a) $\frac{d-\sqrt{3}\,d}{2}$ (b) $\frac{d+\sqrt{3}\,d}{2}$

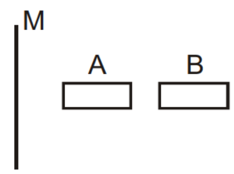
(c) $\frac{d+3d}{2}$ (d) $\frac{d-3d}{2}$

7. Two positive ions, each carrying a charge q, are separated by a distance d. If F is the force of repulsion between the ions, the number of electrons missing from each ion will be (e being the charge of an electron)

(a) $\frac{4\pi\varepsilon_0 Fd^2}{e^2}$ (b) $\sqrt{\frac{4\pi\varepsilon_0 Fe^2}{d^2}}$

(c) $\sqrt{\frac{4\pi\varepsilon_0 Fd^2}{e^2}}$ (d) $\frac{4\pi\varepsilon_0 Fd^2}{q^2}$

8. A large nonconducting sheet M is given a uniform charge density. Two uncharged small metal rods A and B are placed near the sheet as shown in figure. Then



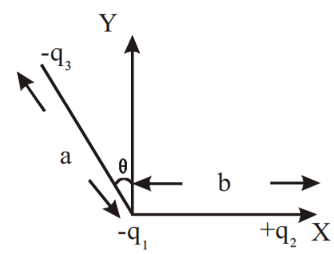
(a) M attracts A

(b) M attracts B

(c) A attracts B

(d) All of these

9. Three charges $-q_1$, $+q_2$ and $-q_3$ are place as shown in the figure. The x - component of the force on $-q_1$ is proportional to



(a) $\frac{q_2}{b^2}-\frac{q_3}{a^2}\cos\theta$

(b) $\frac{q_2}{b^2}+\frac{q_3}{a^2}\sin\theta$

(c) $\frac{q_2}{b^2}+\frac{q_3}{a^2}\cos\theta$

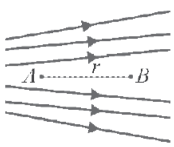
(d) $\frac{q_2}{b^2}-\frac{q_3}{a^2}\sin\theta$

10. A total charge Q is broken in two parts Q_1 and Q_2 and they are placed at a distance R from each other. The maximum force of repulsion between them will occur. when

(a) $Q_2 = \frac{Q}{R}, Q_1 = Q - \frac{Q}{R}$ (b) $Q_2 = \frac{Q}{4}, Q_1 = Q - \frac{2Q}{3}$

(c) $Q_2 = \frac{Q}{4}, Q_1 = \frac{3Q}{4}$ (d) $Q_1 = \frac{Q}{2}, Q_2 = \frac{Q}{2}$

11. Figure shows the electric lines of force emerging from a charged body. If the electric field at A and B are E_A and E_B respectively and if the displacement between A and B is r then



(a) $E_A > E_B$

(b) $E_A < E_B$

(c) $E_A = \frac{E_B}{r}$

(d) $E_A = \frac{E_B}{r^2}$

12. An electric dipole with dipole moment 4×10^{-9} cm is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^4 NC^{-1}. The torque acting on the dipole is

(a) 1×10^{-4} Nm (b) 5×10^{-8} Nm

(c) 11×10^{-12} Nm (d) 25×10^{-19} Nm

13. The electric field at a point on equatorial line of a dipole _________ to direction of the dipole moment.

(a) will be parallel
(b) will be in opposite direction
(c) will be perpendicular
(d) are not related

14. The electric field intensity just sufficient to balance the earth's gravitational attraction on an electron will be: (given mass and charge of an electron respectively are 9.1×10^{-31} kg and 1.6×10^{-19} C.)

(a) -5.6×10^{-11} N/C (b) -4.8×10^{-15} N/C

(c) -1.6×10^{-19} N/C (d) -3.2×10^{-19} N/C

15. Which one of the following is not a property of field lines

(a) Field lines are continuous curves without any breaks.
(b) Two field lines cannot cross each other.
(c) Field lines start at positive charge and end at negative charge
(d) They form closed loop

16. If a dipole of dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$, then torque acting on it is given by

(a) $\vec{\tau} = \vec{p}.\vec{E}$ (b) $\vec{\tau} = \vec{p} \times \vec{E}$

(c) $\vec{\tau} = \vec{p} + \vec{E}$ (d) $\vec{\tau} = \vec{p} - \vec{E}$

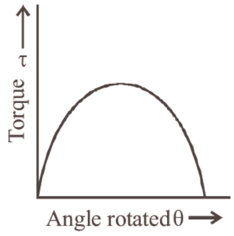
17. If E_a be the electric field strength of a short dipole at a point on its axial line and E_e that on the equatorial line at the same distance, then

(a) $E_e = 2E_a$ (b) $E_a = 2E_e$

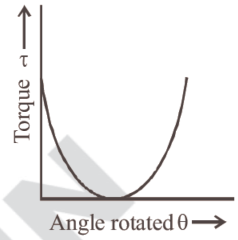
(c) $E_a = E_e$ (d) None of these

18. Which of the following graphs shows the correct variation in magnitude of torque on an electric dipole rotated in a uniform electric field from stable equillibrium to unstable equillibrium?

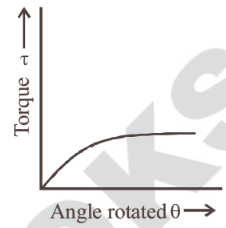
(a)



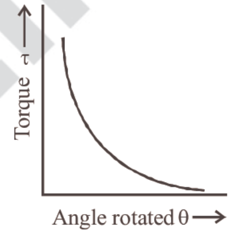
(b)



(c)



(d)



19. The electric intensity due to a dipole of length 10 cm and having a charge of 500 μC, at a point on the axis at a distance 20 cm from one of the charges in air, is

(a) 6.25×10^7 N/C (b) 9.28×10^7 N/C

(c) 13.1×10^{11} N/C (d) 20.5×10^7 N/C

20. A rod of length 2.4 *m* and radius 4.6 *mm* carries a negative charge of 4.2×10^{-7} C spread uniformly over it surface. The electric field near the mid–point of the rod, at a point on its surface is

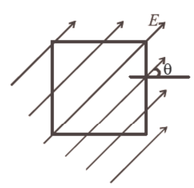
(a) -8.6×10^5 N C^{-1} (b) 8.6×10^4 N C^{-1}

(c) -6.7×10^5 N C^{-1} (d) 6.7×10^4 N C^{-1}

21. The total electric flux emanating from a closed surface enclosing an α-particle is (e-electronic charge)

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

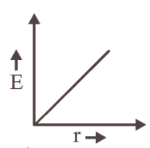
22. A square surface of side L meter in the plane of the paper is placed in a uniform electric field E (volt/m) acting along the same plane at an angle θ with the horizontal side of the square as shown in Figure. The electric flux linked to the surface, in units of volt. *m*, is



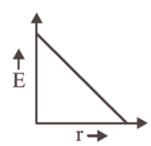
(a) EL^2
(b) $EL^2 \cos\theta$
(c) $EL^2 \sin\theta$
(d) zero

23. The E-r curve for an infinite linear charge distribution will be

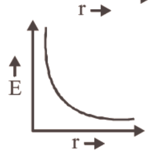
(a)



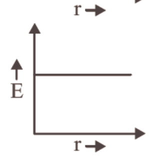
(b)



(c)



(d)



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

(a) Q/ε_o (b) $Q/3\varepsilon_o$ (c) $Q/4\varepsilon_o$ (d) $Q/6\varepsilon_o$

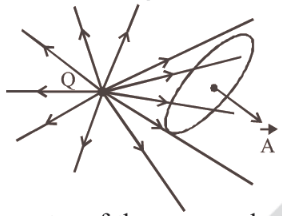
25. The Gaussian surface

(a) can pass through a continuous charge distribution.
(b) cannot pass through a continuous charge distribution.
(c) can pass through any system of discrete charges.
(d) can pass through a continuous charge distribution as well as any system of discrete charges.

26. In a region, the intensity of an electric field is given by $\vec{E} = 2\hat{i} + 3\hat{j} + \hat{k}$ in NC^{-1}. The electric flux through a surface $\vec{S} = 10\hat{i}\ m^2$ in the region is

(a) $5\ Nm^2C^{-1}$ (b) $10\ Nm^2C^{-1}$
(c) $15\ Nm^2C^{-1}$ (d) $20\ Nm^2C^{-1}$

27. In the figure the net electric flux through the area A is $\phi = \vec{E} \cdot \vec{A}$ when the system is in air. On immersing the system in water the net electric flux through the area



(a) becomes zero
(b) remains same
(c) increases
(d) decreases

28. A charge q is placed at the centre of the open end of a cylindrical vessel. The flux of the electric field through the surface of the vessel is

(a) zero
(b) q/ε_o
(c) $q/2\varepsilon_o$
(d) $2q/\varepsilon_o$

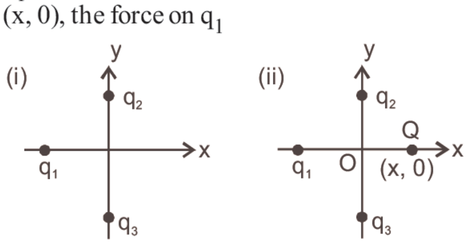
29. If the electric flux entering and leaving an enclosed surface respectively is ϕ_1 and ϕ_2, the electric charge inside the surface will be

(a) $(\phi_2 + \phi_2) \times \varepsilon_o$ (b) $(\phi_2 - \phi_2) \times \varepsilon_o$
(c) $(\phi_1 + \phi_2) \times \varepsilon_o$ (d) $(\phi_2 - \phi_1) \times \varepsilon_o$

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

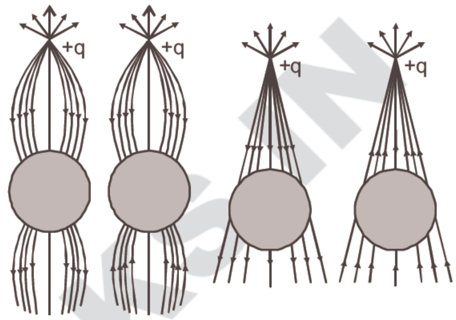
(a) no net charge is enclosed by the surface.
(b) uniform electric field exists within the surface.
(c) electric potential varies from point to point inside the surface.
(d) charge is present inside the surface.

31. 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



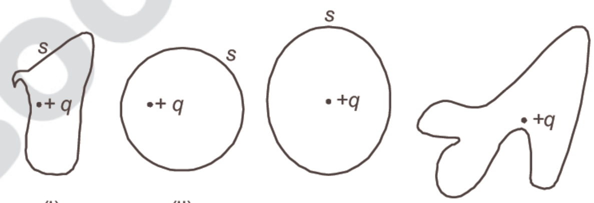
(a) shall increase along the positive x-axis
(b) shall decrease along the positive x-axis
(c) shall point along the negative x-axis
(d) shall increase but the direction changes because of the intersection of Q with q_2 and q_3

32. A point positive charge is brought near an isolated conducting sphere (figure). The electric field is best given by



(a) (b) (c) (d)

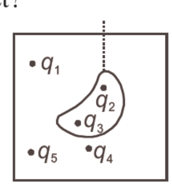
33. The electric flux through the surface



(i) (ii) (iii) (iv)

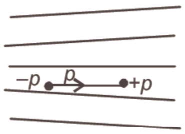
(a) in Fig. (iv) is the largest
(b) in Fig. (iii) is the least
(c) in Fig. (ii) is same as Fig. (iii) but is smaller than Fig. (iv)
(d) is the same for all the figures

34. Five charges q_1, q_2, q_3, q_4, and q_5 are fixed at their positions as shown in Figure, **S** is a Gaussian surface. The Gauss' law is given by $\int_s E.dS = \frac{q}{\varepsilon_0}$. Which of the following statements is correct?



(a) E on the LHS of the above equation will have a contribution from q_1, q_5 and q_1, q_5 and q_3 while q on the RHS will have a contribution from q_2 and q_4 only
(b) 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) 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.
(d) Both E on the LHS and q on the RHS will have contributions from q_2 and q_4 only

35. Figure shows electric field lines in which an electric dipole P is placed as shown. Which of the following statements is correct?



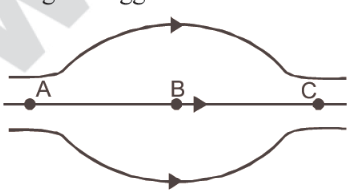
(a) The dipole will not experience any force
(b) The dipole will experience a force towards right
(c) The dipole will experience a force towards left
(d) The dipole will experience a force upwards

36. 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.

37. A hemisphere is uniformely 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

38. Among two discs A and B, first have radius 10 cm and charge 10^{-6} μC and second have radius 30 cm and charge 10^{-5}C. When they are touched, charge on both q_A and q_B respectively will, be
(a) $q_A = 2.75\mu C$, $q_B = 3.15\mu C$
(b) $q_A = 1.09\mu C$, $q_B = 1.53\mu C$
(c) $q_A = q_B = 5.5\mu C$
(d) None of these

39. Figure shows some of the electric field lines corresponding to an electric field. The figure suggests that



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

40. The surface density on the copper sphere is σ. The electric field strength on the surface of the sphere is
(a) σ (b) σ/2 (c) $\sigma / 2\varepsilon_o$ (d) Q / ε_o

41. When a body is charged by induction, then the body
(a) becomes neutral
(b) does not lose any charge
(c) loses whole of the charge on it
(d) loses part of the charge on it

42. Quantisation of charge implies
(a) charge cannot be destroyed
(b) charge exists on particles
(c) there is a minimum permissible charge on a particle
(d) charge, which is a fraction of a coulomb is not possible.

43. For an isolated system, it is possible to create or destroy charged particle, but it is not possible to create or destroy.
(a) net charge of the system
(b) charge on each particle
(c) charge distribution of system
(d) None of these

44. When some charge is transferred to ...*A*... it readily gets distributed over the entire surface of ... *A*... If some charge is put on ... *B*..., it stays at the same place. Here, A and B refer to
(a) insulator, conductor (b) conductor, insulator
(c) insulator, insulator (d) conductor, conductor

45. A positively charged rod is brought near an uncharged conductor. If the rod is then suddenly withdrawn, the charge left on the conductor will be
(a) positive (b) negative
(c) zero (d) cannot say

46. Two spheres A and B of exactly same mass are given equal positive and negative charges respectively. Their masses after charging
(a) remains unaffected (b) mass of A > mass of B
(c) mass of A < mass of B (d) Nothing can be said

47. Coulomb's law is true for
(a) atomic distances (= 10^{-11} m)
(b) nuclear distances (= 10^{-15} m)
(c) charged as well as uncharged particles
(d) all the distances

48. In annihilation process, in which an electron and a positron transform into two gamma rays, which property of electric charge is displayed?
(a) Additivity of charge
(b) Quantisation of charge
(c) Conservation of charge
(d) Attraction and repulsion

49. Which of the following statements is incorrect?
(a) The charge q on a body is always given by q = ne, where n is any integer, positive or negative.
(b) By convention, the charge on an electron is taken to be negative.
(c) The fact that electric charge is always an integral multiple of e is termed as quantisation of charge.
(d) The quatisation of charge was experimentally demonstrated by Newton in 1912.

50. Which of the following statements is incorrect? Study of charges, by scientists, concludes that
(a) there are two kinds of electric charges.
(b) bodies like plastic, fur acquire elecrtic charge on rubbing.
(c) like charges attract, unlike charges repel each other.
(d) the property which differentiates two kinds of charges is called the polarity of the charge.

51. What happens when some charge is placed on a soap bubble?
(a) Its radius decreases (b) Its radius increases
(c) The bubble collapses (d) None of these

52. Consider a neutral conducting sphere. A positive point charge is placed outside the sphere. The net charge on the sphere is then
(a) negative and distributed uniformly over the surface of the sphere
(b) negative and appears only at the point on the sphere closest to the point charge
(c) negative and distributed non-uniformly over the entire surface of the sphere
(d) zero

53. A charged particle is free to move in an electric field. It will travel
(a) always along a line of force
(b) along a line of force, if its initial velocity is zero
(c) along a line of force, if it has some initial velocity in the direction of an acute angle with the line of force
(d) none of the above

54. If one penetrates a uniformly charged spherical cloud, electric field strength
(a) decreases directly as the distance from the centre
(b) increases directly as the distance from the centre
(c) remains constant
(d) None of these

55. Electric lines of force about a negative point charge are
(a) circular anticlockwise (b) circular clockwise
(c) radial, inwards (d) radial, outwards

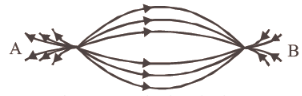
56. Electric lines of force
(a) exist everywhere
(b) exist only in the immediate vicinity of electric charges
(c) exist only when both positive and negative charges are near one another
(d) are imaginary

57. A region surrounding a stationary electric dipoles has
(a) magnetic field only
(b) electric field only
(c) both electric and magnetic fields
(d) no electric and magnetic fields

58. The electric field at a point on equatorial line of a dipole and direction of the dipole moment
(a) will be parallel
(b) will be in opposite direction
(c) will be perpendicular
(d) are not related

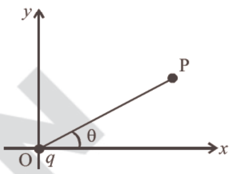
59. An electric dipole is placed at an angle of 30° to a non-uniform electric field. The dipole will experience
(a) a translational force only in the direction of the field
(b) a translational force only in the direction normal to the direction of the field
(c) a torque as well as a translational force
(d) a torque only

60. The spatial distribution of electric field due to charges (A, B) is shown in figure. Which one of the following statements is correct ?



(a) A is +ve and B –ve, |A| > |B|
(b) A is –ve and B +ve, |A| = |B|
(c) Both are +ve but A > B
(d) Both are –ve but A > B

61. In the figure, charge q is placed at origin O. When the charge q is displaced from its position the electric field at point P changes



(a) at the same time when q is displaced.
(b) at a time after $\frac{OP}{c}$ where c is the speed of light.
(c) at a time after $\frac{OP\cos\theta}{c}$.
(d) at a time after $\frac{OP\sin\theta}{c}$

62. An electric dipole is placed in a uniform electric field. The dipole will experience
(a) a force that will displace it in the direction of the field
(b) a force that will displace it in a direction opposite to the field.
(c) a torque which will rotate it without displacement
(d) a torque which will rotate it and a force that will displace it

63. On decreasing the distance between the two charges of a dipole which is perpendicular to electric field and decreasing the angle between the dipole and electric field, the torque on the dipole
(a) increases (b) decreases
(c) remains same (d) cannot be predicted.

64. A sphere of radius R has uniform distribution of electric charge in its volume. At a distance x from its centre for x <R, the electric field is directly proportional to
(a) $1/x^2$ (b) $1/x$ (c) x (d) x^2

65. In a medium of dielectric constant K, the electric field is $\vec{E}$. If ϵ_0 is permittivity of the free space, the electric displacement vector is
(a) $\frac{K\vec{E}}{\epsilon_0}$ (b) $\frac{\vec{E}}{K\epsilon_0}$ (c) $\frac{\epsilon_0\vec{E}}{K}$ (d) $K\epsilon_0\vec{E}$

66. Positive electric flux indicates that electric lines of force are directed
(a) outwards (b) inwards
(c) either (a) or (b) (d) None of these

67. If the flux of the electric field through a closed surface is zero, then
(a) the electric field must be zero everywhere on the surface
(b) the electric field may not be zero everywhere on the surface
(c) the charge inside the surface must be zero
(d) the charge in the vicinity of the surface must be zero

68. If the electric flux entering and leaving an enclosed surface respectively is ϕ_1 and ϕ_2, the electric charge inside the surface will be

(a) $(\phi_2 + \phi_2) \times \varepsilon_o$ (b) $(\phi_2 - \phi_2) \times \varepsilon_o$
(c) $(\phi_1 + \phi_2) \times \varepsilon_o$ (d) $(\phi_2 - \phi_1) \times \varepsilon_o$

69. The Gaussian surface

(a) can pass through a continuous charge distribution.
(b) cannot pass through a continuous charge distribution.
(c) can pass through any system of discrete charges.
(d) can pass through a continuous charge distribution as well as any system of discrete charges.

70. Gauss's law is true only if force due to a charge varies as

(a) r^{-1} (b) r^{-2} (c) r^{-3} (d) r^{-4}

71. For a given surface the Gauss's law is stated as $\oint \vec{E} \cdot d\vec{A} = 0$. From this we can conclude that

(a) E is necessarily zero on the surface
(b) E is perpendicular to the surface at every point
(c) the total flux through the surface is zero
(d) the flux is only going out of the surface

72. Total electric flux coming out of a unit positive charge put in air is

(a) ε_0 (b) ε_0^{-1} (c) $[4\pi\varepsilon_0]^{-1}$ (d) $4\pi\varepsilon_0$

73. A hollow sphere of charge does not produce an electric field at any

(a) interior point (b) outer point.
(c) beyond 2 m (d) beyond 10 m

74. A point charge +q is placed at mid point of a cube of side 'L'. The electric flux emerging from the cube is

(a) $\frac{q}{\varepsilon_0}$ (b) $\frac{6qL^2}{\varepsilon_0}$ (c) $\frac{q}{6L^2\varepsilon_0}$ (d) zero

75. It is not convenient to use a spherical Gaussian surface to find the electric field due to an electric dipole using Gauss's theorem because

(a) Gauss's law fails in this case
(b) This problem does not have spherical symmetry
(c) Coulomb's law is more fundamental than Gauss's law
(d) Spherical Gaussian surface will alter the dipole moment

76. An electric dipole is put in north-south direction in a sphere filled with water. Which statement is correct?

(a) Electric flux is coming towards sphere
(b) Electric flux is coming out of sphere
(c) Electric flux entering into sphere and leaving the sphere are same
(d) Water does not permit electric flux to enter into sphere

77. The electric field near a conducting surface having a uniform surface charge density is given by

(a) $\frac{\sigma}{\varepsilon_0}$ and is parallel to the surface
(b) $\frac{2\sigma}{\varepsilon_0}$ and is parallel to the surface
(c) $\frac{\sigma}{\varepsilon_0}$ and is normal to the surface
(d) $\frac{2\sigma}{\varepsilon_0}$ and is normal to the surface

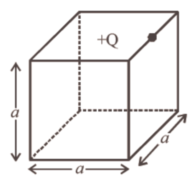
78. Select the correct statements from the following.

(a) The electric field due to a charge outside the Gaussian surface contributes zero net flux through the surface.
(b) The electgric flux of the electric field $\oint \vec{E} \cdot d\vec{A}$ is zero. The electric field is zero everywhere on the surface.
(c) Total flux linked with a closed body, not enclosing any charge will be zero.
(d) Total electric flux, if a dipole is enclosed by a surface is zero.

79. The number of electric lines of force that radiate outwards from one coulomb of charge in vacuum is

(a) 1.13×10^{11} (b) 1.13×10^{10}
(c) 0.61×10^{11} (d) 0.61×10^{9}

80. In figure + Q charge is located at one of the edge of the cube, then electric flux through cube due to + Q charge is



(a) $\frac{+Q}{\epsilon_0}$ (b) $\frac{+Q}{2\epsilon_0}$
(c) $\frac{+Q}{4\epsilon_0}$ (d) $\frac{+Q}{8\epsilon_0}$

81. A square frame of edge l cm is placed with its positive normal making an angle of 60° with a uniform electric field E. The flux of the electric field through the surface bounded by the frame is

(a) $El^2/2$ (b) $El^2/\sqrt{3}$ (c) $El^2/3$ (d) $2El^2$

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

A body can be charged by following methods.

(a) **By friction :** By rubbing two bodies together, both positive and negative charges in equal amounts appear simultaneously due to transfer of electrons from one body to the other.

(b) **By electrostatic induction :** If a charged body is brought near a neutral body, the charged body will attract opposite charge and repel similar charge present in the neutral body. As a result of this one side of neutral body becomes (+ ve) while the other (–ve). This process is called "electrostatic induction".

(c) **By conduction :** Take two conductors, one charged and other uncharged. Bring the conductors in contact with each other. The charge (whether – ve or + ve) under its own repulsion will spread over both the conductors. Thus the conductors will be charged with the same sign.

82. When a body is charged by induction, then the body
(a) becomes neutral
(b) does not lose any charge
(c) loses whole of the charge on it
(d) loses part of the charge on it

83. On charging by conduction, mass of a body may
(a) increase (b) decreases
(c) increase or decrease (d) None of these

84. If a body is positively charged, then it has
(a) excess of electrons (b) excess of protons
(c) deficiency of electrons (d) deficiency of neutrons

85. A clyindrical conductor is placed near another positively charged conductor. The net charge acquired by the cylindrical conductor will be
(a) positive only (b) negative only
(c) zero (d) either positive or negative

86. A positive point charge Q is brought near an isolated metal cube then
(a) the cube becomes negatively charged.
(b) the cube becomes positively charged.
(c) the interior becomes positively charged and the surface becomes negatively charged.
(d) the interior remains charge free and the surface gets nonuniform charge distribution.

Case/Passage-II

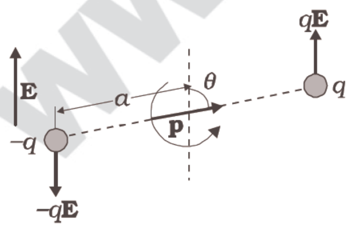
Electric dipole is a pair of equal and opposite point charges separated by a small distance.

Dipole moment is the product of the magnitude of either charge and the distance between them,

Dipole moment $= \left|\overrightarrow{p}\right| = q \times 2a$

It is directed from negative to positive charge.

Dipole in a uniform external field : There is a force q**E** on q and a force –q**E** on –q. The net force on the dipole is zero, since **E** is uniform. However, the charges are separated, so the forces act at different points, resulting in a torque on the dipole. When the net force is zero, the torque (couple) is independent of the origin.



87. An electric dipole has a pair of equal and opposite point charges q and $-q$ separated by a distance $2x$. The axis of the dipole is
(a) from positive charge to negative charge
(b) from negative charge to positive charge
(c) perpendicular to the line joining the two charges drawn at the centre and pointing upward direction
(d) perpendicular to the line joining the two charges drawn at the centre and pointing downward direction

88. The electric field at a point on equatorial line of a dipole and direction of the dipole moment
(a) will be parallel
(b) will be in opposite direction
(c) will be perpendicular
(d) are not related

89. An electric dipole is placed at an angle of 30° to a non-uniform electric field. The dipole will experience
(a) a translational force only in the direction of the field
(b) a translational force only in the direction normal to the direction of the field
(c) a torque as well as a translational force
(d) a torque only

90. Intensity of an electric field (E) depends on distance r, due to a dipole, is related as
(a) $E \propto \frac{1}{r}$ (b) $E \propto \frac{1}{r^2}$ (c) $E \propto \frac{1}{r^3}$ (d) $E \propto \frac{1}{r^4}$

91. On decreasing the distance between the two charges of a dipole which is perpendicular to electric field and decreasing the angle between the dipole and electric field, the torque on the dipole
(a) increases (b) decreases
(c) remains same (d) cannot be predicted

Case/Passage-III

Electric flux over an area in an electric field is the total number of electric lines of force crossing this area.

It is measured by the product of surface area and the corresponding component of electric field normal to the area.

$$\phi = \oint \overrightarrow{E}.d\vec{s}$$

It is a scalar quantity. Its SI unit is volt metre (Vm) or Nm^2/C. Dimensions : $[ML^3T^{-3}A^{-1}]$

92. For a given surface the Gauss's law is stated as $\oint \vec{E}.d\vec{A} = 0$. From this we can conclude that
(a) E is necessarily zero on the surface
(b) E is perpendicular to the surface at every point
(c) the total flux through the surface is zero
(d) the flux is only going out of the surface

93. In a region of space having a uniform electric field E, a hemispherical bowl of radius r is placed. The electric flux ϕ through the bowl is
(a) $2\pi RE$ (b) $4\pi R^2E$ (c) $2\pi R^2E$ (d) πR^2E

94. A cylinder of radius R and length ℓ is placed in a uniform electric field E parallel to the axis of the cylinder. The total flux over the curved surface of the cylinder is
(a) zero (b) πR^2E (c) $2\pi R^2E$ (d) $E/\pi R^2$

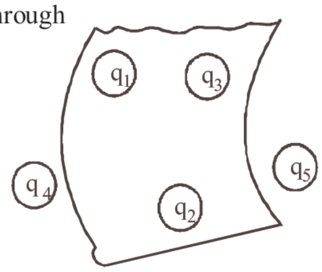
95. Electric flux over a surface in an electric field may be
(a) positive (b) negative
(c) zero (d) All of these

96. Electric charges are distributed in a small volume. The flux of the electric field through a spherical surface of radius 1 m surrounding the total charge is 100 V-m. The flux over the concentric sphere of radius 2 m will be
(a) 25V-m (b) 50V-m (c) 100V-m (d) 200V-m

Case/Passage-IV

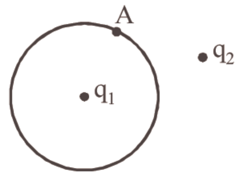
Figure shows five charged lumps of plastic. The cross-section of Gaussian surface S is indicated. Assuming $q_1 = q_4 = 3.1$ nC, $q_2 = q_5 = -5.9$ nC, and $q_3 = -3.1$ nC.

97. Find the net electric flux through the surface is



(a) -670 Nm^2/C
(b) $+670$ Nm^2/C
(c) -360 Nm^2/C
(d) $+360$ Nm^2/C

98. Electric field at point A depends on __________ charge.



(a) q_1
(b) q_2
(c) both q_1 and q_2
(d) None of these

99. The surface density on the copper sphere is σ. The electric field strength on the surface of the sphere is

(a) σ (b) $\sigma/2$ (c) $\sigma / 2\varepsilon_o$ (d) σ / ε_o

100. A charge q is placed at the centre of the open end of a cylindrical vessel. The flux of the electric field through the surface of the vessel is

(a) zero
(b) q/ε_o
(c) $q/2\varepsilon_o$
(d) $2q/\varepsilon_o$

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

(a) Q / ε_o (b) $Q / 3\varepsilon_o$ (c) $Q / 4\varepsilon_o$ (d) $Q / 6\varepsilon_o$

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

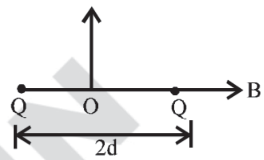
(a) If both **Assertion** and **Reason** are **correct** and the Reason is the **correct explanation** of the Assertion.
(b) If both **Assertion** and **Reason** are correct but Reason is **not the correct explanation** of the Assertion.
(c) If the **Assertion** is **correct** but **Reason** is **incorrect**.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

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

103. Assertion : Coulomb force and gravitational force follow the same inverse-square law.
Reason : Both laws are same in all aspects.

104. Assertion : The property that the force with which two charges attract or repel each other are not affected by the presence of a third charge.
Reason : Force on any charge due to a number of other charge is the vector sum of all the forces on that charge due to other charges, taken one at a time.

105. Assertion : Consider two identical charges placed distance 2d apart, along x-axis.
The equilibrium of a positive test charge placed at the point O midway between them is stable for displacements along the x-axis.



Reason: Force on test charge is zero.

106. Assertion : If a proton and an electron are placed in the same uniform electric field. They experience different acceleration.
Reason : Electric force on a test charge is dependent of its mass.

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

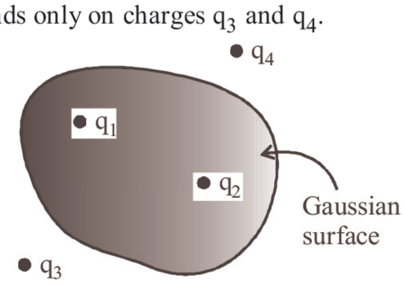
108. Assertion : A point charge is brought in an electric field, the field at a nearby point will increase or decrease, depending on the nature of charge.
Reason : The electric field is independent of the nature of charge.

109. Assertion : Electric field is always normal to equipotential surfaces and along the direction of decreasing order of potential.
Reason : Negative gradient of electric potential is electric field. **[CBSE Sample 2021]**

110. Assertion : On disturbing an electric dipole in stable equillibrium in an electric field, it returns back to its stable equillibrium orientation.
Reason : A restoring torque acts on the dipole on being disturbed from its stable equillibrium.

111. Assertion : On going away from a point charge or a small electric dipole, electric field decreases at the same rate in both the cases.
Reason : Electric field is inversely proportional to square of distance from the charge or an electric dipole.

112. Assertion : Four point charges q_1, q_2, q_3 and q_4 are as shown in figure. The flux over the shown Gaussian surface depends only on charges q_3 and q_4.



Reason : Electric field at all points on Gaussian surface depends only on charges q_1 and q_2.

113. **Assertion :** The surface charge densities of two spherical conductor of different radii are equal. Then electric field intensity near their surfaces are also equal.
Reason : Surface charge density is equal to charge per unit area.

114. **Assertion :** A uniformly charged disc has a pin hole at its centre. The electric field at the centre of the disc is zero.
Reason : Disc can be supposed to be made up of many rings. Also electric field at the centre of uniformly charged ring is zero.

115. **Assertion :** On bringing a positively charged rod near the uncharged conductor, the conductor gets attracted towards the rod.
Reason : The electric field lines of the charged rod are perpendicular to the surface of conductor.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

116.

Column I	Column II
(A) Linear charge density	(1) $\frac{\text{Charge}}{\text{Volume}}$
(B) Surface charge density	(2) $\frac{\text{Charge}}{\text{Length}}$
(C) Volume charge density	(3) $\frac{\text{Charge}}{\text{Area}}$
(D) Discrete charge distribution	(4) System consisting of ultimate individual charges

(a) A → (2), B → (3), C → (1), D → (4)
(b) A → (1), B → (3), C → (1), D → (4)
(c) A → (3), B → (1), C → (2), D → (4)
(d) A → (3), B → (2), C → (1), D → (4)

117. Match the entries of column I with that of Column II.

Column I	Column II
(A) Coulomb's law	(1) Total electric flux through a closed surface.
(B) Gauss's law	(2) Vector sum of forces.
(C) Principle of superposition	(3) Force is inversely proportional to square of distance
(D) Quantisation of charge	(4) Discrete nature of charge

(a) (A) → (2), (B) → (3), (C) → (1), (D) → (4)
(b) (A) → (3), (B) → (1), (C) → (2), (D) → (4)
(c) (A) → (1), (B) → (4), (C) → (3), (D) → (2)
(d) (A) → (1), (B) → (2), (C) → (3), (D) → (4)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

118. 1μC charge contains n units of basic charge e, where n is _______.

119. When an electric dipole $\vec{P}$ is placed in a uniform electric field $\vec{E}$ then angle between $\vec{P}$ and $\vec{E}$ the value of torque will be maximum is _______.

120. If the electric flux entering and leaving a closed surface are 6×10^6 and 9×10^6 S.I. units respectively, then the charge inside the surface of permittivity of free space ε_0 is _______.

121. The magnitude of the average electric field normally present in the atmosphere just above the surface of the Earth is about 150 N/C, directed inward towards the center of the Earth. This gives the total net surface charge carried by the Earth to be _______.
[Given $\varepsilon_o = 8.85 \times 10^{-12}$ C^2/N-m^2, $R_E = 6.37 \times 10^6$ m]

122. If the electric field is given by $(5\hat{i} + 4\hat{j} + 9\hat{k})$. The electric flux through a surface of area 20 units lying in the Y-Z plane will be _______.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

123. The positive charge particle is placed in front of a spherical uncharged conductor. The number of lines of forces terminating on the sphere will be more than those emerging from it.

124. The surface charge density at a point on the sphere nearest to the point charge will be negative and maximum in magnitude compared to other points on the sphere.

125. The property that the force with which two charges attract or repel each other are not affected by the presence of a third charge.

126. Force on any charge due to a number of other charge is the vector sum of all the forces on that charge due to other charges, taken one at a time.

ANSWER KEY & SOLUTIONS

1. (a) In the absence of gravitational force, the only force acts on the spheres is electrostatic repulsion and so the angle between two suspension becomes 180°. So force between the sphere

$$F = \frac{1}{4\pi \in_0} \frac{Q^2}{(2L)^2}$$

2. (b) Here, $r_1 = \hat{i} + \hat{j} + \hat{k} \Rightarrow r_2 = 2\hat{i} + 3\hat{j} + \hat{k}$

$\therefore \quad \vec{r} = \vec{r}_2 - \vec{r}_1 = (2\hat{i} + 3\hat{j} + \hat{k}) - (\hat{i} + \hat{j} + \hat{k}) = \hat{i} + 2\hat{j}$

$$|\vec{r}| = \sqrt{(1)^2 + (2)^2} = \sqrt{5}$$

By Coulomb's law,

$$F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} = \frac{9 \times 10^9 \times 3 \times 10^{-6} \times 3 \times 10^{-6}}{(\sqrt{5})^2}$$

$= \frac{81}{5} \times 10^{-3}$ N, Nearest answer is 16×10^{-3} N.

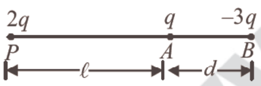
3. (b) When we say that a body is charged, we always mean that the body is having excess of electrons (negatively charged) or is of deficient of electrons (positively charged).

4. (a) Valence electrons are outermost electrons these can get transferred on rubbing.

5. (b) $T_{AB} = \frac{kq \cdot 2q}{d^2} + \frac{kq \cdot 4q}{(2d)^2} = \frac{3kq^2}{d}$

$$T_{BC} = \frac{k \cdot 4q \cdot 2q}{d^2} + \frac{kq \cdot 4q}{(2d)^2} = \frac{9kq^2}{d^2}$$

6. (b)



Let a charge $2q$ be placed at P, at a distance I from A where charge q is placed, as shown in figure.

The charge $2q$ will not experience any force, when force, when force of repulsion on it due to q is balanced by force of attraction on it due to $-3q$ at B where AB = d

or $\frac{(2q)(q)}{4\pi\varepsilon_0 \ell^2} = \frac{(2q)(-3q)}{4\pi\varepsilon_0 (\ell + d)^2}$

$(\ell + d)^2 = 3\ell^2$ or $2\ell^2 - 2\ell d - d^2 = 0$

$\therefore \quad \ell = \frac{2d \pm \sqrt{4d^2 + 2d^2}}{4} = \frac{d}{2} \pm \frac{\sqrt{3}d}{2}$

$$\ell = \frac{d + \sqrt{3}d}{2}$$

7. (c) Let n be the number of electrons missing.

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{d^2} \Rightarrow q = \sqrt{4\pi\varepsilon_0 d^2 F} = ne$$

$$\therefore \quad n = \sqrt{\frac{4\pi\varepsilon_0 F d^2}{e^2}}$$

8. (d)

9. (b) Force on charge q_1 due to q_2 is

$$F_{12} = k\frac{q_1 q_2}{b^2}$$

Force on charge q_1 due to q_3 is

$$F_{13} = k\frac{q_1 q_3}{a^2}$$

The X - component of the force (F_x) on q_1 *is* $F_{12} + F_{13} \sin\theta$

$\therefore \quad F_x = k\frac{q_1 q_2}{b^2} + k\frac{q_1 q_2}{a^2}\sin\theta$

$\therefore \quad F_x \propto \frac{q_2}{b^2} + \frac{q_3}{a^2}\sin\theta$

10. (d) $Q_1 + Q_2 = Q$ … (i) and $F = k\frac{Q_1 Q_2}{r^2}$ … (ii)

From (i) and (ii) $F = \frac{kQ_1(Q - Q_1)}{r^2}$

For F to be maximum $\frac{dF}{dQ_1} = 0 \Rightarrow Q_1 = Q_2 = \frac{Q}{2}$

11. (a) Figure indicates the presence of some positive charge to the left of A.

$\therefore \quad E_A > E_B \; (\because r_A < r_B)$

12. (a) Given,

Dipole moment, $p = 4 \times 10^{-9}$ Cm

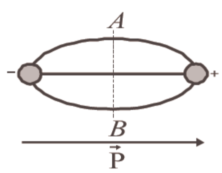
Electric field, $E = 5 \times 10^4 \, NC^{-1}$

Torque is given by

$\tau = p.E \sin\theta$

$= 4 \times 10^{-9} \times 5 \times 10^4 \times \sin 30° = 1 \times 10^{-4}$ Nm

13. (b) The direction of electric field at equatorial point A or B will be in opposite direction, as that of direction of dipole moment.



14. (a) $-eE = mg$

$$\vec{E} = -\frac{9.1 \times 10^{-31} \times 10}{1.6 \times 10^{-19}} = -5.6 \times 10^{-11} \, N/C$$

15. (d) Electric field lines do not form closed loop. This follows from the conservative nature of electric field.

16. (b) Given : Dipole moment of the dipole = $\vec{p}$ and uniform electric field = $\vec{E}$. We know that dipole moment (p) = q.a (where q is the charge and a is dipole length). And when a dipole of dipole moment $\vec{p}$ is placed in uniform electric field $\vec{E}$, then Torque (τ) = Either force × perpendicular distance between the two forces = qa E sin θ or $\tau = pE \sin\theta$ or $\vec{\tau} = \vec{p} \times \vec{E}$ (vector form)

17. **(b)** We have $E_a = \frac{2kp}{r^3}$ and $E_e = \frac{kp}{r^3}$; $\therefore E_a = 2E_e$

18. **(a)**

19. **(a)** **Given :** Length of the dipole $(2l) = 10\text{cm} = 0.1\text{m}$ or $l = 0.05\text{m}$

Charge on the dipole (q) = 500 μC = 500×10^{-6} C and distance of the point on the axis from the mid-point of the dipole (r) = 20 + 5 = 25 cm = 0.25 m.

We know that the electric field intensity due to dipole on the given point (E)

$$= \frac{1}{4\pi\varepsilon_0} \times \frac{2(q.2l)r}{(r^2 - l^2)^2}$$

$$= 9 \times 10^9 \times \frac{2(500 \times 10^{-6} \times 0.1) \times 0.25}{[(0.25)^2 - (0.05)^2]^2}$$

$= 6.25 \times 10^7\ N/C$ (k = 1 for air)

20. **(c)** Here, $\ell = 2.4\ m$, $r = 4.6\ mm = 4.6 \times 10^{-3}\ m$
$q = -4.2 \times 10^{-7}$ C

Linear charge density, $\lambda = \frac{q}{\ell}$

$$= \frac{-4.2 \times 10^{-7}}{2.4} = -1.75 \times 10^{-7}\ \text{C m}^{-1}$$

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

$$= \frac{-1.75 \times 10^{-7}}{2 \times 3.14 \times 8.854 \times 10^{-12} \times 4.6 \times 10^{-3}}$$

$= -6.7 \times 10^5$ N C^{-1}

21. **(a)** According to Gauss's law total electric flux through a closed surface is $\frac{1}{\varepsilon_0}$ times the total charge inside that surface.

Electric flux, $\phi_E = \frac{q}{\varepsilon_0}$

Charge on α-particle = 2e $\quad \therefore \phi_E = \frac{2e}{\varepsilon_0}$

22. **(d)** Electric flux, $\phi = EA\cos\theta$, where θ = angle between E and normal to the surface.

Here $\theta = \frac{\pi}{2} \Rightarrow \phi = 0$

23. **(c)** The field due to infinite linear charge distribution

$$E = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r} \Rightarrow E \propto \frac{1}{r}$$

So curve is hyperbolic.

24. **(d)** According to Gauss' Law

$$\oint E.ds = \frac{Q_{\text{enclosed by closed surface}}}{\varepsilon_o} = \text{flux}$$

so total flux = Q/ε_o

Since cube has six face, so flux coming out through one wall or one face is $Q/6\varepsilon_o$.

25. **(a)** Gaussian surface cannot pass through any discrete charge because electric field due to a system of discrete charges is not well defined at the location of the charges. But the Gaussian surface can pass through a continuous charge distribution.

26. **(d)** Here, $\vec{E} = 2\hat{i} + 3\hat{j} + \hat{k}\ \text{NC}^{-1}, \vec{S} = 10\hat{i}\ \text{m}^2$

Electric flux, $\phi = \vec{E}.\vec{S}$

$$= (2\hat{i} + 3\hat{j} + \hat{k}\ \text{NC}^{-1}).(10\hat{i}\ \text{m}^2)$$
$$= 20\ \text{Nm}^2\text{C}^{-1}$$

27. **(d)** Since electric field $\vec{E}$ decreases inside water, therefore flux $\phi = \vec{E} \cdot \vec{A}$ also decreases.

28. **(a)** The flux is zero according to Gauss' Law because it is a open surface which enclosed a charge q.

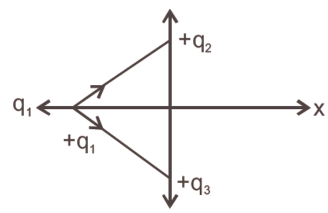
29. **(d)**

30. **(a)** According to Gauss's theorem

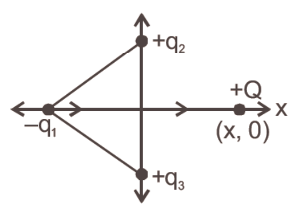
$$\phi = \frac{\Sigma q_{en}}{\varepsilon_0}$$

So, net charge enclosed by the surface is zero if the net electric flux through a closed surface is zero.

31. **(a)** The force on q_1 depend on the force acting between q_1 and q_2 and q_1 and q_3 so that the net force acting on q_1 by q_2 and q_1 by q_3 is along the + x-direction, so the force acting between q_1, q_2 and q_1, q_3 is attractive force as shown in figure :



The attractive force between these charges states that q_1 is a negative charge (since, q_2 and q_3 are positive). Then the force acting between q_1 and charge Q (positive) is also know as attractive force and then the net force on q_1 by q_2, q_3 and Q are along the same direction as shown in the figure.

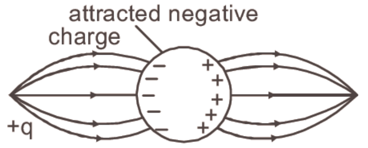


The figure shows that the force on q_1 shall increase along the positive x-axis due to the positive charge Q.

32. **(a)** If a positive point charge is brought near an isolated conducting sphere without touching the sphere, then the free electrons in the sphere are attracted towards the positive Charge and electric field passes through a charged body. This leaves an excess of positive charge on the (right) surface of sphere due to the induction process.

Both type of charges are bound in the (isolated conducting) sphere and cannot escape. They, therefore, reside on the surface.

Thus, the left surface of sphere has an excess of negative charge and the right surface of sphere has an excess of positive charge as shown in figure.



An electric field lines start from positive charge and ends at negative charge.

Also, electric field line emerges from a positive charge, in case of single charge and ends at infinity shown in figure (a).

33. **(d)** **By Gauss's law :** The total of the electric flux out of a closed surface is equal to the charge enclosed devided by the permittivity i.e., $\phi = \frac{Q}{\varepsilon_0}$.

Thus, electric flux through a surface doesn't depend on the shape, size or area of a surface but it depends on the number of charges enclosed by the surface. So all the given figures have same electric flux as all of them also has same single positive charge.

34. **(b)** Gauss's law states that total electric flux of an enclosed surface is given by, $\oint_s E.dS = \frac{q}{\varepsilon_0}$, includes the sum of all charges enclosed by the surface.

The charges may be located anywhere inside the surface, and out side the surface. Then, the electric field on the left side of equation is due to all the charges, both inside and outside S.

So, E on 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.

35. **(c)** The electric field lines, are directed away from positively charged source and directed toward negatively charged source. In electric field force are directly proportional to the electric field strength hence, higher the electric field strength greater the force and vice-versa. The space between the electric field lines is increasing, from left to right so strength of electric field decreases with the increase in the space between electric field lines. Then the force on charges also decreases from left to right. Thus, the force on charge $-q$ is greater than force on charge $+q$ in turn dipole will experience a force towards left.

36. **(a)** When a positive point charge +q is placed near an isolated conducting plane, some negative charge developes on the surface of the plane towards the charge and an equal positive charge developes on opposite side of the plane. This is called induction process and the electric field on a isolated conducting plane at point is directly projected in a plane perpendicular to the field and away from the plane.

37. **(a)** Consider a point on diameter away from the centre of hemisphere uniformly positively charged, then the electric field is perpendicular to the diameter and the component of electric intensity parallel to the diameter cancel out.

38. **(c)** The charge on disc A is 10^{-6} μC. The charge on disc B is 10×10^{-6} μC. The total charge on both = 11 μC. When touched, this charge will be distributed equally *i.e.*, 5.5 μC on each disc.

39. **(c)**

40. **(d)** According to Gauss's theorem,

$$E\oint ds = \frac{q}{\epsilon_0}\left[\text{Here} \oint ds = 4\pi R^2\right]$$

$$\therefore E = \frac{q/4\pi R^2}{\epsilon_0} \quad [\because q/4\pi R^2 = \sigma]$$

$$\text{or } E = \sigma/\varepsilon_0$$

41. **(b)** **42.** **(d)**

43. **(a)** The charge of an isolated system is conserved.

44. **(b)** When some charge is given to conductor it spreads on its surface. When some charge is given to insulator, it remains there, it do not spread, Free charges in conductor interact with added charge, so added charge spreads on surface to be in equilibrium.

45. **(c)** **46.** **(c)** **47.** **(d)**

48. **(c)** Electron having a charge of -1.6×10^{-19}C undergoes annihilation with it's antiparticle positron having a charge of $+1.6 \times 10^{-19}$C as $e^- + e^+ \rightarrow \gamma + \gamma$

Net charge before annihilation

$= -1.6\times10^{-19}C + 1.6\times10^{-19}C = 0$

Net charge after annihilation $= 0 + 0 = 0$

i.e., net charge remains same.

49. **(d)** Milikan demonstrated the quantisation of charge experimentally. Charge on electron = – e = -1.6×100^{-19}C. Addition of charge can occur in integral multiples of *e*.

50. **(c)** Like charges repel $\longleftarrow \oplus \oplus \longrightarrow$

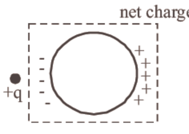
Unlike charges attract $\oplus \longrightarrow \longleftarrow \ominus$

To specify particular charge on body, term used is polarity.

On rubbing, plastic rod acquires negative charge, cat's fur acquires positive charge. There are only two kinds of charges: +, –.

51. **(b)**

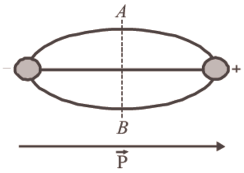
52. **(d)** When a positive point charge is placed outside a conducting sphere, a rearrangement of charge takes place on the surface. But the total charge on the sphere is zero as no charge has left or entered the sphere.



53. **(b)** If charge particle is put at rest in electric field, then it will move along line of force.

54. **(a)** **55.** **(c)** **56.** **(d)** **57.** **(b)**

58. **(b)** The direction of electric field at equatorial point *A* or *B* will be in opposite direction, as that of direction of dipole moment.



59. **(c)** The electric field will be different at the location of force on the two charges. Therefore the two charges will be unequal. This will result in a force as well as torque.

60. **(a)** Since lines of force starts from A and ends at B, so A is +ve and B is –ve. Lines of forces are more crowded near A, so A > B.

61. **(b)** The electric field around a charge propagates with the speed of light away from the charge. Therefore the required time $= \frac{\text{distance}}{\text{speed}} = \frac{OP}{c}$.

62. **(c)** When a dipole is placed in a uniform electric field, two equal and opposite forces act on it. Therefore, a torque acts which rotates the dipole.

63. **(b)** Since $\tau = pE \sin\theta$ on decreasing the distance between the two charges, and on decreasing angle θ between the dipole and electric field, $\sin\theta$ decreases therefore torque decreases.

64. **(c)** Since $x < R$, that is the point is inside the sphere electric field $E \propto x$. as $E = \frac{kq}{R^3}x$

65. **(d)** Electric displacement vector, $\vec{D} = \varepsilon\vec{E}$

As, $\varepsilon = \varepsilon_0 K$ $\quad\therefore\ \vec{D} = \varepsilon_0 K\vec{E}$

66. **(a)** **67.** **(c)** **68.** **(d)**

69. **(a)** Gaussian surface cannot pass through any discrete charge because electric field due to a system of discrete charges is not well defined at the location of the charges. But the Gaussian surface can pass through a continuous charge distribution.

70. **(b)**

71. **(c)** $\oint \vec{E}.d\vec{A} = 0$, represents charge inside close surface is zero. Electric field as any point on the surface may be zero.

72. **(b)** Total flux coming out from unit charge

$$\phi = \vec{E}.\vec{ds} = \frac{1}{\varepsilon_0} \times 1 = \varepsilon_0^{-1}$$

73. **(a)** At the interior point of a hollow sphere, the electric field is zero.

74. **(a)** By Gauss theorem

$$\text{Total electric flux} = \frac{\text{Total charge inside cube}}{\varepsilon_0} = \frac{q}{\varepsilon_0}$$

75. **(b)**

76. **(c)** If electric dipole, the flux coming out from positive charge is equal to the flux coming in at negative charge *i.e.* total charge on sphere = 0. From Gauss law, total flux passing through the sphere = 0.

77. **(c)** Electric field near the conductor surface is given by $\frac{\sigma}{\varepsilon_0}$ and it is perpendicular to surface.

78. **(d)**

79. **(a)** Here, $q = 1$ C, $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2N^{-1}m^{-2}$
Number of lines of force = Electric force

$$= \frac{q}{\varepsilon_0} = \frac{1}{8.85 \times 10^{-12}} = 1.13 \times 10^{11}$$

80. **(c)**

81. **(a)** $\text{Flux}(\phi) = \vec{E}\cdot\Delta\vec{A} = E\Delta A\cos 60° = El^2/2$

82. **(b)** Charging by induction involves transfer of charges from one part to the other of the body. No loss of charge is involved.

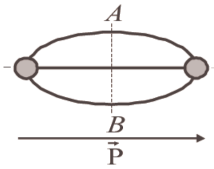
83. **(c)** On charging by conduction, body may gain mass, if it acquires negative charge. It may lose mass, if it acquires positive charge.

84. **(c)** Positive charge is due to deficiency of electrons.

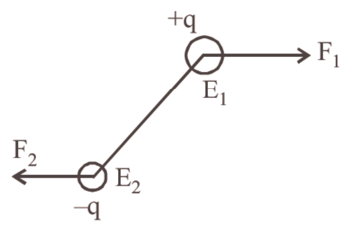
85. **(c)** Net charge acquired by induction is zero, as there is only transfer of electrons from one part of body to the other.

86. **(a)** **87.** **(b)**

88. **(b)** The direction of electric field at equatorial point *A* or *B* will be in opposite direction, as that of direction of dipole moment.



89. **(c)**



The electric field will be different at the location of force on the two charges. Therefore the two charges will be unequal. This will result in a force as well as torque.

90. **(c)** Intensity of electric field due to a Dipole

$$E = \frac{p}{4\pi\varepsilon_0 r^3}\sqrt{3\cos^2\theta + 1} \Rightarrow E \propto \frac{1}{r^3}$$

91. **(b)** Since $\tau = pE\sin\theta$ on decreasing the distance between the two charges, and on decreasing angle θ between the dipole and electric field, $\sin\theta$ decreases therefore torque decreases.

92. **(c)** $\oint \vec{E}\cdot d\vec{A} = 0$, represents charge inside close surface is zero. Electric field as any point on the surface may be zero.

93. **(c)** $\phi = E(ds)\cos\theta = E(2\pi r^2)\cos 0° = 2\pi r^2 E$.

94. **(a)** For the curved surface, $\theta = 90°$

$\therefore\ \phi = E\ ds\cos 90° = 0$.

95. **(d)**

96. **(c)** Flux does not depend on the size and shape of the close surface, and so, it remains same.

97. **(a)** $\phi = \frac{\Sigma q}{\epsilon_0} = \frac{-5.9\times10^{-9}}{8.85\times10^{-12}} = -670\ Nm^2/C$

98. **(c)** Electric field at any point depends on all the charges.

99. **(d)** According to Gauss's theorem,

$$E\oint ds = \frac{q}{\epsilon_0}\left[\text{Here} \oint ds = 4\pi R^2\right]$$

$$\therefore\ E = \frac{q/4\pi R^2}{\epsilon_0}\quad [\because q/4\pi R^2 = \sigma]$$

or $E = \sigma/\varepsilon_o$

100. **(a)** The flux is zero according to Gauss' Law because it is a open surface which enclosed a charge q.

101. **(d)** According to Gauss' Law

$$\oint E.ds = \frac{Q_{\text{enclosed by closed surface}}}{\varepsilon_o} = \text{flux}$$

so total flux = Q/ε_o

Since cube has six face, so flux coming out through one wall or one face is $Q/6\varepsilon_o$.

102. **(a)** Conservation of electric charge states that the total charge of an isolated system remains unchanged with time.

103. **(c)** Coulomb force and gravitational force follow the same inverse-square law. But gravitational force is always attractive force, while coulomb force can be of both force attractive and repulsive.

104. **(b)** The individual force are unaffected due to presence of other charges. This is the principal of superposition of charges. Force on any charge due to a number of other charges is the vector sum of all the forces on that charge due to the other charges, taken one at a time.

105. **(b)** If +ve charge is displaced along x-axis, then net force will always act in a direction opposite to that of displacement and the test charge will always come back to its original position.

106. **(c)** Electron and proton have same amount of charge so they have same coulomb force. They have different acceleration because they have different masses.

107. **(a)** The electrostatic shielding is possible by metallic conductor.

108. **(c)** The electric field will increase if positive charge is brought in an electric field.

109. **(b)** $E = -\frac{dv}{dx}$

110. **(a)** The restoring torque brings it back to its stable equillibrium.

111. **(d)** The rate of decrease of electric field is different in the two cases. In case of a point charge, it decreases as $1/r^2$ but in the case of electric dipole it decreases more rapidly, as $E \propto 1/r^3$.

112. **(d)** Electric field at any point depends on presence of all charges.

113. **(b)** $\frac{q_1}{q_2} = \frac{r_1^2}{r_2^2}$ [Let r_1 and r_2 be two different radii]

so, $\frac{E_1}{E_2} = \frac{q_1}{4\pi\varepsilon_0 r_1^2}\cdot\frac{4\pi\varepsilon_0 r_2^2}{q_2} \Rightarrow \frac{q_1}{q_2}\times\frac{r_2^2}{r_1^2} = 1$

so $E_1 = E_2$

114. **(a)** The electric field due to disc is superposition of electric field due to its constituent ring as given in Reason.

115. **(b)** Though the net charge on the conductor is still zero but due to induction negatively charged region is nearer to the rod as compared to the positively charged region. That is why the conductor gets attracted towards the rod.

116. **(a)** 117. **(b)**

118. (6×10^{12}) $n = {}^{1\mu c}\!\Big/_{1.6\times10^{-19}C} \approx 6\times10^{12}$

119. (90°)

120. $(3\times10^6\times\varepsilon_0)$ By Gauss law, we know that

$\phi = \frac{q}{\varepsilon_0}$ Here, Net electric flux, $\phi = \phi_2 - \phi_1$

$= 9\times10^6 - 6\times10^6 = \frac{q}{\varepsilon_0} \Rightarrow q = 3\times10^6\times\varepsilon_0.$

121. (–680) Given,

Electric field E = 150 N/C

Total surface charge carried by earth q = ?

According to Gauss's law.

$\phi = \frac{q}{\epsilon_0} = EA$ or, $q = \epsilon_0 EA = \epsilon_0 E\pi r^2$.

$= 8.85\times10^{-12}\times150\times(6.37\times10^6)^2 \simeq 680$ Kc

As electric field directed inward hence q = – 680 Kc

122. (100) Here, E must be perpendicular to Y-Z plane, i.e., area must be parallel to X-plane,

so $d\vec{s} = 20\hat{i}$ units

$\therefore$ electric flux = $\vec{E}.d\vec{s} = (5\hat{i}+4\hat{j}+9\hat{k}).(20\hat{i}) = 100$ units

123. (False) No. of lines entering the surface = No. of lines leaving the surface.

124. (True)

125. (True) The individual force are unaffected due to the presence of other charges.

126. (True) Force on any charge due to a number of other charges is the vector sum of all the forces on that charge due to the other charges, taken one at a time.

2 Electrostatic Potential and Capacitance

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. The electric potential inside a conducting sphere
(a) increases from centre to surface
(b) decreases from centre to surface
(c) remains constant from centre to surface
(d) is zero at every point inside

2. In a region of constant potential
(a) the electric field is uniform
(b) the electric field is zero
(c) the electric field shall necessarily change if a charge is placed outside the region
(d) None of these

3. It becomes possible to define potential at a point in an electric field because electric field
(a) is a conservative field
(b) is a non-conservative field
(c) is a vector field
(d) obeys principle of superposition

4. Which of the following about potential at a point due to a given point charge is true ?
The potential at a point P due to a given point charge
(a) is a function of distance from the point charge.
(b) varies inversely as the square of distance from the point charge.
(c) is a vector quantity
(d) is directly proportional to the square of distance from the point charge.

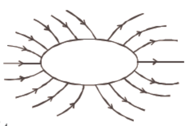
5. A cube of a metal is given a positive charge Q. For this system, which of the following statements is true?
(a) Electric potential at the surface of the cube is zero
(b) Electric potential within the cube is zero
(c) Electric field is normal to the surface of the cube
(d) Electric field varies within the cube

6. There are two metallic spheres of same radii but one is solid and the other is hollow, then
(a) solid sphere can be given more charge
(b) hollow sphere can be given more charge
(c) they can be charged equally (maximum)
(d) None of the above

7. The electric potential due to the pair of charges (+ 10μc and + 20 μc the middle of the line joing them is [if sepration is 2 cm]
(a) 27 MV (b) 35 MV (c) 37 MV (d) 40 MV

8. Potential due to electric dipole along equatorial line is.
(a) maximum (b) increasing
(c) zero (d) None of these

9. Figure below shows a hollow conducting body placed in an electric field. Which of the quantities are zero inside the body?



(a) Electric field and potential
(b) Electric field and charge density
(c) Electric potential and charge density.
(d) Electric field, potential and charge density.

10. The positive terminal of 12 V battery is connected to the ground. Then the negative terminal will be at
(a) – 6 V (b) + 12 V (c) zero (d) – 12 V

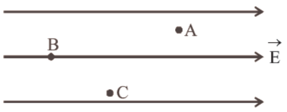
11. Let V be the electric potential at a given point. Then the electric field E_x along x-direction at that point is given by
(a) $\int_0^\infty V dx$ (b) $\frac{dV}{dx}$ (c) $-\frac{dV}{dx}$ (d) $-V\frac{dV}{dx}$

12. The electric field is along the direction in which the potential
(a) increases at max^m rate
(b) decreases at max^m rate
(c) increases at min^m rate
(d) None of these

13. Potential at any point inside a charged hollow sphere
(a) increases with distance
(b) is a constant
(c) decreases with distance from centre
(d) is zero

14. A solid sphere of radius R has uniform volume charge density. The electric potential at a points (r <R) is
(a) due to the charge inside a sphere of radius r only
(b) due to the entire charge of the sphere
(c) due to the charge in the spherical sheel of inner and outer radii r and R, only
(d) independent of r

15. A, B and C are three points in a uniform electric field. The electric potential is



(a) maximum at B
(b) maximum at C
(c) same at all the three points A, B and C
(d) maximum at A

16. Identify the false statement.
(a) Inside a charged or neutral conductor, electrostatic field is zero
(b) The electrostatic field at the surface of the charged conductor must be tangential to the surface at any point
(c) There is no net charge at any point inside the conductor
(d) Electrostatic potential is constant throughout the volume of the conductor

17. Three charges 2 q, – q and – q are located at the vertices of an equilateral triangle. At the centre of the triangle
(a) the field is zero but potential is non-zero
(b) the field is non-zero, but potential is zero
(c) both field and potential are zero
(d) both field and potential are non-zero

18. The electrostatic potential energy of a system of two charges is negative when
(a) both the charges are positive
(b) both the charges are negative
(c) one charge is positive and other is negative
(d) both the charges are separated by infinite distance

19. Two conducting spheres of radii R_1 and R_2 having charges Q_1 and Q_2 respectively are connected to each other. There is
(a) no change in the energy of the system
(b) an increase in the energy of the system
(c) always a decrease in the energy of the system
(d) a decrease in the energy of the system unless $Q_1R_2 = Q_2R_1$

20. A ball of mass 1 g carrying a charge 10^{-8} C moves from a point A at potential 600 V to a point B at zero potential. The change in its K.E. is
(a) -6×10^{-6} erg (b) -6×10^{-6} J
(c) 6×10^{-6} J (d) 6×10^{-6} erg

21. On moving a charge of 20 coulomb by 2 cm, 2 J of work is done, then the potential difference between the points is
(a) 0.1 V (b) 8 V (c) 2 V (d) 0.5 V.

22. Two points *P* and *Q* are maintained at the potentials of 10 V and – 4 V, respectively. The work done in moving 100 electrons from *P* to *Q* is:
(a) 9.60×10^{-17} J (b) -2.24×10^{-16} J
(c) 2.24×10^{-16} J (d) -9.60×10^{-17} J

23. A and B are two points in an electric field. If the work done in carrying 4.0C of electric charge from A to B is 16.0 J, the potential difference between A and B is
(a) zero (b) 2.0 V (c) 4.0 V (d) 16.0 V

24. A system of three positive charges placed at the vertices of an equilateral triangle. To decrease the potential energy of the system,
(a) a positive charge should be placed at centroid
(b) a negative charge should be placed at centroid.
(c) distance between the charges should be decreased.
(d) it should be rotated by an angle of $\frac{\pi}{2}$ radian.

25. The work done in carrying a charge q once around a circle of radius *r* with a charge *Q* placed at the centre will be
(a) $Qq(4\pi\varepsilon_0 r^2)$ (b) $Qq/(4\pi\varepsilon_0 r)$
(c) zero (d) $Qq^2/(4\pi\varepsilon_0 r)$

26. On decreasing the distance between the plates of a parallel plate capacitor, its capacitance
(a) remains unaffected
(b) decreases
(c) first increases then decreases.
(d) increases

27. A sheet of aluminium foil of negligible thickness is introduced between the plates of a capacitor. The capacitance of the capacitor
(a) decreases (b) remains unchanged
(c) becomes infinite (d) increases

28. The potential gradient at which the dielectric of a condenser just gets punctured is called
(a) dielectric constant (b) dielectric strength
(c) dielectric resistance (d) dielectric number

29. When air in a capacitor is replaced by a medium of dielectric constant *K*, the capacity
(a) decreases *K* times (b) increases *K* times
(c) increases K^2 times (d) remains constant

30. Capacitors are used in electrical circuits where appliances need more
(a) voltage (b) current
(c) resistance (d) power

31. A parallel plate capacitor is charged by connecting it to a battery. Now the distance between the plates of the capacitor is increased. Which of the following remains constant ?
(a) Capacitance
(b) Charge on each plate of the capacitor.
(c) Potential difference between the plates of capacitor
(d) Energy stored in the capacitor.

32. A parallel plate condenser is immersed in an oil of dielectric constant 2. The field between the plates is
(a) increased, proportional to 2
(b) decreased, proportional to $\frac{1}{2}$
(c) increased, proportional to – 2
(d) decreased, proportional to $-\frac{1}{2}$

33. Capacitance (in F) of a spherical conductor with radius 1 m is
(a) 1.1×10^{-10} (b) 10^6
(c) 9×10^{-9} (d) 10^{-3}

34. A parallel plate capacitor is charged to a certain voltage. Now, if the dielectric material (with dielectric constant k) is removed then the
(a) capacitance increases by a factor of k
(b) electric field reduces by a factor k
(c) voltage across the capacitor decreases by a factor k
(d) None of these.

35. A dielectric slab is inserted between the plates of an isolated charged capacitor. Which of the following quantities remain unchanged ?
(a) The charge on the capacitor
(b) The stored energy in the Capacitor
(c) The potential difference between the plates
(d) The electric field in the capacitor

36. The capacitors of capacity C_1 and C_2 are connected in parallel, then the equivalent capacitance is
(a) $C_1 + C_2$ (b) $\frac{C_1C_2}{C_1 + C_2}$ (c) $\frac{C_1}{C_2}$ (d) $\frac{C_2}{C_1}$

37. A conductor carries a certain charge. When it is connected to another uncharged conductor of finite capacity, then the energy of the combined system is
(a) more than that of the first conductor
(b) less than that of the first conductor
(c) equal to that of the first conductor
(d) uncertain

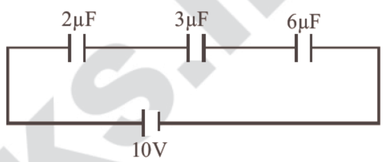
38. In a charged capacitor, the energy resides
(a) in the positive charges.
(b) in both the positive and negative charges.
(c) in the field between the plates.
(d) around the edges of the capacitor plates.

39. To obtain 3 μF capacity from three capacitors of 2 μF each, they will be arranged.
(a) all the three in series
(b) all the three in parallel
(c) two capacitors in series and the third in parallel with the combinatioin of first two
(d) two capacitors in parallel and the third in series with the combinatioin of first two

40. Three capacitors each of capacitance C and of breakdown voltage V are joined in series. The capacitance and breakdown voltage of the combination will be
(a) $3C, \frac{V}{3}$ (b) $\frac{C}{3}, 3V$ (c) $3C, 3V$ (d) $\frac{C}{3}, \frac{V}{3}$

41. A 5.0 μF capacitor is charged to a potential difference of 800 V and discharged through a conductor. The energy given to the conductor during the discharge is
(a) 1.6×10^{-2} joule (b) 3.2 joule
(c) 1.6 joule (d) 4.2 joule

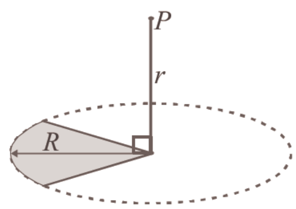
42. In the given figure, the charge on 3 μF capacitor is
(a) 10μC
(b) 15μ
(c) 30μC
(d) 5μC



43. A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. The potential at a distance of 2 cm from the centre of the sphere is
(a) zero (b) 10 V (c) 4 V (d) 10/3 V

44. Four point charges $-Q$, $-q$, $2q$ and $2Q$ are placed, one at each corner of the square. The relation between Q and q for which the potential at the centre of the square is zero is
(a) $Q = -q$ (b) $Q = -\frac{1}{q}$ (c) $Q = q$ (d) $Q = \frac{1}{q}$

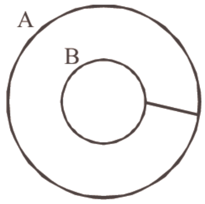
45. A plastic disc is charged on one side with a uniform surface charge density σ and then three quadrant of the disk are removed. The remaining quadrant is shown in figure, with $V = 0$ at infinity, the potential due to the remaining quadrant at point P is



(a) $\frac{\sigma}{2 \epsilon_0}[(r^2 + R)^{1/2} - r]$ (b) $\frac{\sigma}{2 \epsilon_0}[R - r]$
(c) $\frac{\sigma}{8 \epsilon_0}[(r^2 + R^2)^{1/2} - r]$ (d) None of these

46. Consider the following statements and select the true/false.
I. Electric field lines are always perpendicular to equipotential surface.
II. No two equipotential surfaces can intersect each other.
III. Electric field lines are in the direction of tangent to an equipotential surface.
(a) T, F, F (b) F, T, F
(c) T, T, F (d) T, T, T

47. Figure shows two hollow charged conductors A and B having same positive surface charge densities. B is placed inside A and does not touches it. On connecting them with a conductor

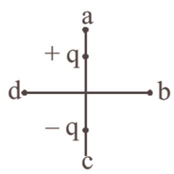


(a) charge will flow from A to B
(b) charge will flow from B to A
(c) charge oscillates between A and B
(d) no charge will flow.

48. Two equally charged spheres of radii a and b are connected together. What will be the ratio of electric field intensity on their surfaces?

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

49. Four points a, b, c and d are set at equal distance from the centre of a dipole as shown in figure. The electrostatic potential V_a, V_b, V_c, and V_d would satisfy the following relation:

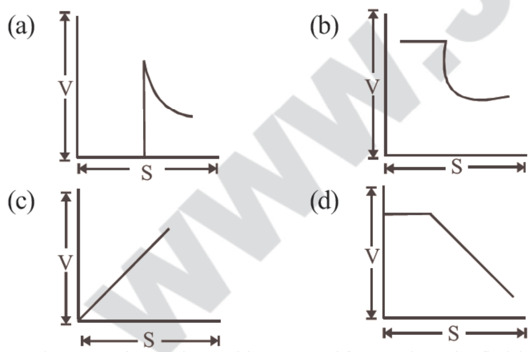


(a) $V_a > V_b > V_c > V_d$
(b) $V_a > V_b = V_d > V_c$
(c) $V_a > V_c = V_b = V_d$
(d) $V_b = V_d > V_a > V_c$

50. The electric potential at a point (x, y) in the x – y plane is given by V = –kxy. The field intensity at a distance r from the origin varies as

(a) r^2 (b) r (c) $\frac{1}{r}$ (d) $\frac{1}{r^2}$

51. In a hollow spherical shell, potential (V) changes with respect to distance (s) from centre as



52. A charge q is projected into a uniform electric field E, work done when it moves a distance y is,

(a) q E y (b) q y/E (c) q E/ y (d) y/q E

53. Consider the following statements and select the true/ false statements

I. In an external electric field, the positive and negative charges of a non–polar molecule are displaced in opposite directions.
II. In non –polar molecules displacement stops when the external force on the constituent charges of the molecule is balanced by the restoring force.
III. The non–polar molecule develops an induced dipole moment.

(a) T, T, F (b) F, T, T (c) T, F, T (d) T, T, T

54. Which of the following about potential difference between any two points, are true/false.

I. It depends only on the initial and final position.
II. It is the work done per unit positive charge in moving from one point to other.
III. It is more for a positive charge of two units as compared to a positive charge of one unit.

(a) T, F, F (b) F, T, F (c) T, T, F (d) T, T, T

55. On decreasing the distance between the plates of a parallel plate capacitor, its capacitance

(a) remains unaffected
(b) decreases
(c) first increases then decreases.
(d) increases

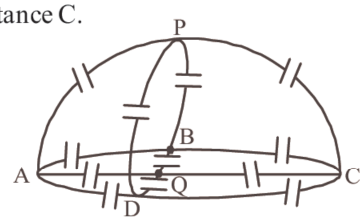
56. The potential energy of a charged parallel plate capacitor is U_0. If a slab of dielectric constant k is inserted between the plates, then the new potential energy will be

(a) U_0/k (b) U_0k^2 (c) U_0/k^2 (d) U_0^2

57. A capacitor is charged by using a battery which is then disconnected. A dielectric slab of dielectric k is then inserted between the plates, which results in

(a) Reduction of charge on the plates and increase of potential difference across the plates.
(b) Increase in the potential difference across the plate, reduction in stored energy, but no change in the charge on the plates.
(c) Decrease in the potential difference across the plates, reduction in the stored energy, but no change in the charge on the plates.
(d) None of these

58. Find the capacitance between P and Q (Fig). Each Capacitor has capacitance C.

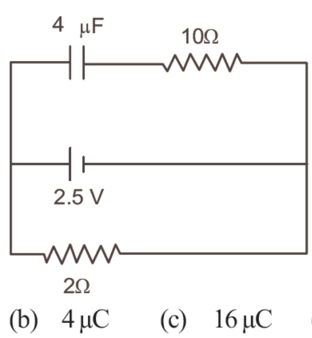


(a) 2C
(b) 3C
(c) 8C
(d) 6C

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

(a) qLE (b) zero (c) $-qLE$ (d) $-2\,qEL$

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



(a) 0 μC (b) 4 μC (c) 16 μC (d) 8 μC

61. A positively charged particle is released from rest in an 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

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

(a) The work done in Fig. (i) is the greatest

(b) The work done in Fig. (ii) is least

(c) The work done is the same in Fig. (i), Fig.(ii) and Fig. (iii)

(d) The work done in Fig. (iii) is greater than Fig. (ii) but equal to that in

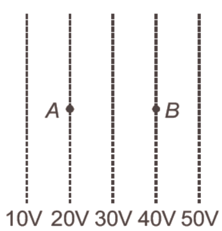


Fig. (i)

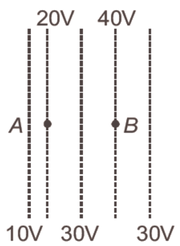


Fig. (ii)

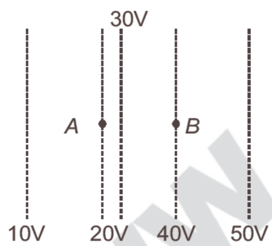


Fig. (iii)

63. The electrostatic potential on the surface of a charged conducting sphere is 100V. 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 100V. Which of the following is a correct statement?

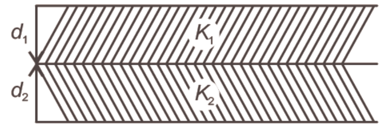
(a) S_1 is true but S_2 is false

(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 independant

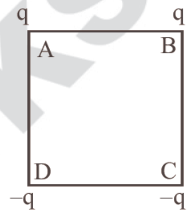
64. A parallel plate capacitor is made of two dielectric blocks in series. One of the blocks has thickness d_1 and dielectric constant K_1 and the other has thickness d_2 and dielectric constant K_2 as shown in figure. This arrangement can be thought as a dielectric slab of thickness d $(= d_1 + d_2)$ 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) $\frac{K_1K_2(d_1 + d_2)}{(K_1d_2 + K_2d_1)}$ (d) $\frac{2K_1K_2}{K_1 + K_2}$

65. Charges are placed on the vertices of a square as shown. Let $\vec{E}$ be the electric field and V the potential at the centre. If the charges on A and B are interchanged with those on D and C respectively, then



(a) $\vec{E}$ changes, V remains unchanged

(b) $\vec{E}$ remains unchanged, V changes

(c) both $\vec{E}$ and V change

(d) $\vec{E}$ and V remain unchanged

66. Two conducting spheres of radii R_1 and R_2 having charges Q_1 and Q_2 respectively are connected to each other. There is

(a) no change in the energy of the system

(b) an increase in the energy of the system

(c) always a decrease in the energy of the system

(d) a decrease in the energy of the system unless $Q_1R_2 = Q_2R_1$

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

Electrostatic potential energy of a system of point charges is the total amount of work done in bringing various charges to their respective positions from infinitely large mutual separations.

If two charges having charge q_1 and q_2 are placed at a distance r from each other, then the potential energy of the system is given by

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$$

The above potential energy is formed due to work done in bringing any one of the charge at the distance r of other charge from infinity so. $W = U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$

67. The potential energy of a system of two charges is negative when
(a) both the charges are positive
(b) both the charges are negative
(c) one charge is positive and other is negative
(d) both the charges are separated by infinite distance

68. The electric potential at point A is 1 V and at another point B is 5V. A charge 3 μC is released from B. What will be the kinetic energy of the charge as it passes through A ?
(a) 8×10^{-6} J (b) 12×10^{-6} J
(c) 12×10^{-9} J (d) 4×10^{-6} J

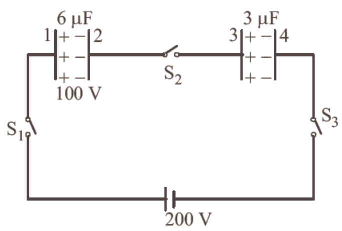
69. A square of side 'a' has charge Q at its centre and charge 'q' at one of the corners. The work required to be done in moving the charge 'q' from the corner to the diagonally opposite corner is
(a) zero (b) $\frac{Qq}{4\pi \epsilon_0 a}$
(c) $\frac{Qq\sqrt{2}}{4\pi \epsilon_0 a}$ (d) $\frac{Qq}{2\pi \epsilon_0 a}$

70. When a positive charge q is taken from lower potential to a higher potential point, then its potential energy will
(a) increase (b) decrease
(c) remain unchanged (d) become zero

71. If a unit charge is taken from one point to another over an equipotential surface, then
(a) work is done on the charge
(b) work is done by the charge
(c) work done on the charge is constant
(d) no work is done

Case/Passage-II

Two capacitors of capacity 6 μF and 3 μF are charged to 100 V and 50 V separately and connected as shown in figure. Now all the three switches S_1, S_2 and S_3 are closed.



72. Which plates form an isolated system?
(a) plate 1 and plate 4 separately
(b) plate 2 and plate 3 separately
(c) plate 2 and plate 3 jointly
(d) none of these

73. Charge on the 6 μF capacitor in steady state will be
(a) 400 μC (b) 700 μC (c) 800 μC (d) 250 μC

74. Charge on the 3 μF capacitor in steady state will be
(a) 400 μC (b) 700 μC (c) 800 μC (d) 250 μC

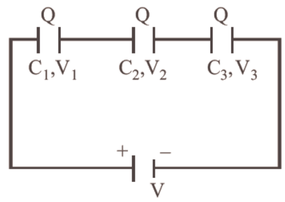
75. Suppose q_1, q_2 and q_3 be the magnitudes of charges flowing from charges S_1, S_2 and S_3 after they are closed. Then
(a) $q_1 = q_3$ and $q_2 = 0$ (b) $q_1 = q_3 = \frac{q_2}{2}$
(c) $q_1 = q_3 = 2q_2$ (d) $q_1 = q_2 = q_3$

76. A 2 μF capacitor is charged to 100 V and then its plates are connected by a conducting wire. The heat produced is
(a) 0.001 J (b) 0.01 J
(c) 0.1 J (d) 1J

Case/Passage-III

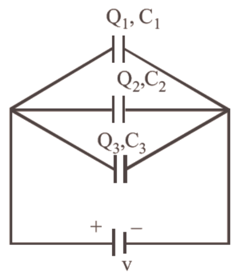
Combination of capacitors in series
Equivalent capacitance of capacitors

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_n}$$

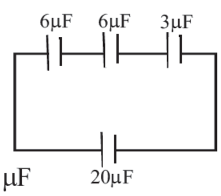


Combination of capacitors in parallel
Equivalent capacitance of capacitors,

$$C_P = C_1 + C_2 + C_3 + ... + C_n$$



77. The capacitor, whose capacitance is 6, 6 and 3μF respectively are connected in series with 20 volt line. Find the charge on 3μF.

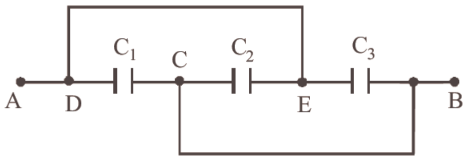


(a) 30 μc (b) 60 μF
(c) 15 μF (d) 90 μF

78. Three condensor each of capacitance 2F are put in series. The resultant capacitance is
(a) 6 F (b) 3/2 F
(c) 2/3 F (d) 5 F

79. To obtain 3 μF capacity from three capacitors of 2 μF each, they will be arranged.
(a) all the three in series
(b) all the three in parallel
(c) two capacitors in series and the third in parallel with the combinatioin of first two
(d) two capacitors in parallel and the third in series with the combinatioin of first two

80. A combination of parallel plate capacitors is maintained at a certain potential difference.



When a 3 mm thick slab is introduced between all the plates, in order to maintain the same potential difference, the distance between the plates is increased by 2.4 mm. Find the dielectric constant of the slab.

(a) 3 (b) 4 (c) 5 (d) 6

81. Two capacitors of capacitances 3μF and 6μF are charged to a potential of 12V each. They are now connected to each other, with the positive plate of each joined to the negative plate of the other. The potential difference across each will be

(a) zero (b) 4 V (c) 6 V (d) 12 V

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

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

(b) If both **Assertion** and **Reason** are correct but Reason is **not the correct explanation** of the Assertion.

(c) If the **Assertion** is **correct** but **Reason** is **incorrect**.

(d) If the **Assertion** is **incorrect** but the **Reason** is **correct**.

82. Assertion: The potential difference between any two points in an electric field depends only on initial and final position.
Reason: Electric field is a conservative field so the work done per unit positive charge does not depend on path followed.

83. Assertion : Polar molecules have permanent dipole moment.
Reason : In polar molecules, the centres of positive and negative charges coincide even when there is no external field.

84. Assertion : Dielectric polarisation means formation of positive and negative charges inside the dielectric.
Reason: Free electrons are formed in this process.

85. Assertion : In the absence of an external electric field, the dipole moment per unit volume of a polar dielectric is zero.
Reason : The dipoles of a polar dielectric are randomly oriented.

86. Assertion : A parallel plate capacitor is connected across battery through a key. A dielectric slab of dielectric constant k is introduced between the plates. The energy stored becomes k times.

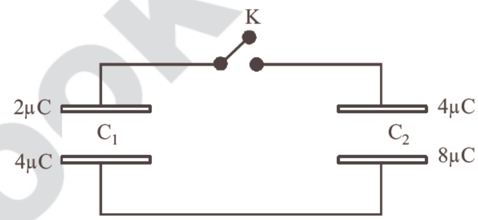
Reason : The surface density of charge on the plate remains constant.

87. Assertion : If two metal plates having charges $Q, -Q$ face each other at some separation are dipped into an oil tank, then electric field between the plates decreases.

Reason : Electric field between the plates, $E_{\text{med}} = \dfrac{E_{\text{air}}}{\kappa}$ due to polarization of dielectrical materials.

88. Assertion : A dielectric is inserted between the plates of a battery connected capacitor. The potential difference between the plates remains constant.
Reason : As the battery remains connected maintaining the same potential difference.

89. Assertion : Charges are given to plates of two plane parallel plate capacitors C_1 and C_2 (such that $C_2 = 2C_1$) as shown in figure. Then the key K is pressed to complete the circuit. Finally the net charge on upper plate and net charge on lower plate of capacitor C_1 is negative.



Reason : In a parallel plate capacitor both plates always carry equal and positive charge.

90. Assertion : Rate of change of potential is maximum at right angles to an equipotential surface.

Reason : There is no net force is acting on the dipole in a uniform electric field.

91. Assertion : A dielectric is inserted between the plates of a battery connected capacitor. The potential difference between the plates remains constant.
Reason : As the battery remains connected maintaining the same potential difference.

Match the Following

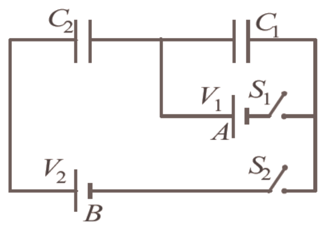
DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

92. Match the entries of Column I and Column II

Column I	Column II
(A) Inside a conductor placed in an external electric field.	(1) Potential energy = 0
(B) At the centre of a dipole	(2) Electric field = 0
(C) Dipole in stable equilibrium	(3) Electric potential = 0
(D) Electric dipole perpendicular to uniform electric field.	(4) Torque = 0

(a) (A) → (2); (B) → (4); (C) → (3); (D) → (1)
(b) (A) → (2); (B) → (3); (C) → (4); (D) → (1)
(c) (A) → (2); (B) → (3); (C) → (1); (D) → (4)
(d) (A) → (1); (B) → (3); (C) → (4); (D) → (2)

93. In the given circuit diagram, both capacitors are initially uncharged. The capacitance $C_1 = 2F$ and $C_2 = 4F$ emf of battery A and B are 2V and 4V respectively.



Column I	Column II
(A) On closing switch S_1 with S_2 open work done by battery A is	(1) $\frac{64}{3}$
(B) Switch S_1 is open and S_2 is closed, work done by battery B is	(2) 4
(C) Charge on capacitor C_2 is (after S_1 open and S_2 closed)	(3) 8
(D) Charge on C_1 when both are closed	(4) $\frac{16}{3}$

(a) (A) → (1); (B) → (2); (C) → (2); (D) → (4)
(b) (A) → (4); (B) → (3); (C) → (3); (D) → (1)
(c) (A) → (2); (B) → (3); (C) → (2); (D) → (1)
(d) (A) → (3); (B) → (1); (C) → (4); (D) → (2)

Fill in the Blanks

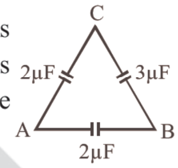
DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

94. The electric potential _______ inside a conducting sphere.

95. An electric dipole of moment $\vec{p}$ is placed normal to the lines of force of electric intensity $\vec{E}$, then the work done in deflecting it through an angle of 180° is _______.

96. Three capacitors each of capacitance C and break down voltage V are joined in series. The capacitance of the combination will be _______ and break down voltage of the combination will be _______.

97. Three capacitors are connected in the arms of a triangle ABC as shown in figure 5 V is applied between A and B. The voltage between B and C is _______.



98. The electric potential V is given as a function of distance × (metre) by
$V = (5x^2 + 10x - 4)$ volt. Value of electric field at x = 1 m is _______.

99. A dielectric of dielectric constant k is inserted in a capacitor after it is disconnected from the battery. As a result, the potential energy _______.

100. A parallel plate capacitor is made by stacking n equally spaced plates connected alternatively. If the capacitance between any two adjacent plates is 'C' then the resultant capacitance is _______.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

101. Electric potential and electric potential energy are different quantities.

102. For a system of positive test charge and point charge electric potential energy = electric potential.

103. When a dielectric slab is pulled out slowly from an isolated charged parallel plate capacitor, its energy increases.

104. Work done by external force is negative.

105. Electric potential due to dipole $\propto \frac{1}{r}$.

106. Electric potential due to a point charge $\propto \frac{1}{r^2}$.

107. For a non-uniformly charged thin circular ring with net charge is zero, the electric field at any point on axis of the ring is zero.

108. For a non-uniformly charged thin circular ring with net charge zero, the electric potential at each point on axis of the ring is maximum.

ANSWER KEY & SOLUTIONS

1. **(c)** Electric potential inside a conductor is constant and it is equal to that on the surface of the conductor.
2. **(b)** 3. **(a)**
4. **(a)** Since $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$, for a given point charge, q is constant, therefore V depends only on r. Hence V is a function of distance.
5. **(d)** Surface of metallic cube is an equipotential surface. Therefore, electric field is normal to the surface of the cube.
6. **(c)** Because in case of metallic spheres either solid or hollow, the charge will reside on the surface of the sphere. Since both spheres have same surface area, so they can hold equal maximum charge.
7. **(a)** 8. **(c)**
9. **(b)** Electric field is always zero inside a conductor. If there is any excess of charge on a hollow conductor it always resides on the outer surface of conductor. Therefore inside a hollow conductor there is no charge and hence charge density is zero.
10. **(d)** When negative terminal is grounded, positive terminal of battery is at +12 V. When positive terminal is grounded, the negative terminal will be at –12 V.
11. **(c)** The component of electric field in any direction is negative of the rate of change of electric potential with distance in that direction.

$$\therefore\ E_x = -\frac{dV}{dx}$$

12. **(b)**
13. **(b)** As, $E = -\frac{dV}{dr}$ or, $0 = -\frac{dV}{dr}$ because electric field inside a charged hollow sphere is zero.
or, v = constant
14. **(a)**
15. **(a)** Potential at B, V_B is maximum
$V_B > V_C > V_A$
As in the direction of electric field potential decreases.
16. **(b)**
17. **(b)** Potential at the centre of the triangle,

$$V = \frac{\Sigma q}{4\pi\varepsilon_0 r} = \frac{2q - q - q}{4\pi\varepsilon_0 r} = 0$$

Obviously, $E \neq 0$
18. **(c)** The potential energy is negative whenever there is attraction. Since a positive and negative charge attract each other therefore their energy is negative. When both the charges are separated by infinite distance, they do not attract each other and their energy is zero.
19. **(d)** When $\frac{Q_1}{R_1} - \frac{Q_2}{R_2}$; current will flow in connecting wire so that energy decreases in the form of heat through the connecting wire.
20. **(c)** As work is done by the field, K.E. of the body increases by

$$K.E. = W = q(V_A - V_B)$$
$$= 10^{-8}(600 - 0) = 6\times10^{-6}\ J$$

21. **(a)** We know that $\frac{W_{AB}}{q} = V_B - V_A$

$$\therefore\ V_B - V_A = \frac{2\,J}{20\,C} = 0.1\ J/C = 0.1V$$

22. **(c)** $\frac{W_{PQ}}{q} = (V_Q - V_P)$

$$\Rightarrow\ W_{PQ} = q(V_Q - V_P)$$
$$= (-100\times1.6\times10^{-19})(-4-10)$$
$$= +2.24\times10^{-16} J$$

23. **(c)** Since $W_{A\to B} = q(V_B - V_A)$

$$\Rightarrow\ V_B - V_A = \frac{16}{4} = 4V$$

24. **(c)** Potential energy decreases whenever there is attraction. A negative charge placed at centroid causes attraction.
25. **(c)** In a round trip, displacement is zero. Hence, work done is zero.
26. **(d)** Since capacitance $C = \frac{\varepsilon_0 A}{d}$, as d decreases capacitance increases.
27. **(b)** 28. **(b)**
29. **(b)** $C_{medium} = K \times C_{air}$
30. **(b)**
31. **(c)** As the capacitor remains connected to the battery, the potential difference provided by the battery remains constant.
32. **(b)** In oil, C becomes twice, V becomes half. Therefore, E = V/d becomes half.
33. **(a)** Capacitance of spherical conductor = $4\pi\varepsilon_0 a$ where a is radius of conductor.

Therefore, $C = \frac{1}{9\times10^9}\times1 = \frac{1}{9}\times10^{-9}$
$= 0.11\times10^{-9}\ F = 1.1\times10^{-10}\ F$

34. **(d)**

35. **(a)** Due to insertion of a dielectric slab capacitance increase by K times. The potential difference, the electric field and the stored energy decreases by $\frac{1}{K}$ times.

36. **(a)** In parallel grouping of capacitors
$C_{eq} = C_1 + C_2 + \ldots\ldots\ldots\ldots C_n$

37. **(b)** Energy will be lost during transfer of charge (heating effect).

38. **(c)**

39. **(c)** $C = \frac{2 \times 2}{2+2} + 2 = 3\,\mu F$

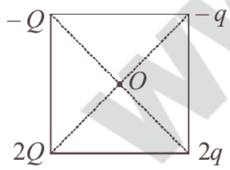
40. **(b)** In series combination of capacitors
$V_{eff} = V + V + V = 3V$
$\frac{1}{C_{eff}} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} \Rightarrow C_{eff} = \frac{C}{3}$
Thus, the capacitance and breakdown voltage of the combination will be $\frac{C}{3}$ and 3V.

41. **(c)** Energy of given to conductor, $U = \frac{1}{2}CV^2$
or $U = \frac{1}{2} \times 5 \times 10^{-6} \times (800)^2 = 1.6$ joule

42. **(a)** C = equivalent capacitance
$\therefore \frac{1}{C} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6} \Rightarrow \therefore C = 1\mu F$
Charge in series circuit will be same.
$\therefore q = CV = (1 \times 10^{-6}) \times 10 = 10\mu C$
$\therefore$ Charge across '3μF' capacitor will be 10μC.

43. **(b)** Potential at any point inside the sphere = potential at the surface of the sphere = 10V.

44. **(a)** Let the side length of square be 'a' then potential at centre O is



$$V = \frac{k(-Q)}{\left(\frac{a}{\sqrt{2}}\right)} + \frac{k(-q)}{\frac{a}{\sqrt{2}}} + \frac{k(2q)}{\frac{a}{\sqrt{2}}} + \frac{k(2Q)}{\frac{a}{\sqrt{2}}} = 0 \text{ (Given)}$$

$= -Q - q + 2q + 2Q = 0 = Q + q = 0 \Rightarrow Q = -q$

45. **(c)** The potential at P due to whole disc is
$$V = \frac{\sigma}{2\epsilon_0}\left[\sqrt{R^2+r^2} - r\right]$$
Now potential due to quarter disc,
$$V = \frac{V}{4} = \frac{\sigma}{8\epsilon_0}\left[\sqrt{R^2+r^2} - r\right]$$

46. **(c)** Electric field lines are always perpendicular to equipotential surface so, they cannot be in a direction of tangent to an equipotential surface.

47. **(b)** Irrespective of the charges on the inner and outer conductors, the inner conductor is always at a higher potential as long as the charge on inner conductor is not zero. Therefore charge flows from B to A. When the whole charge of B flows to A and charge on B becomes zero then A and B are at same potential.

48. **(c)**

Let charge on each sphere $= q$
when they are connected together their potential will be equal.
Now let charge on a = q_1 and on b = $2q - q_1$

$\Rightarrow V_a = V_b$ or $\frac{1}{4\pi\varepsilon_o}\frac{q_1}{a} = \frac{1}{4\pi\varepsilon_o}\frac{2q - q_1}{b}$

$\Rightarrow \frac{q_1}{2q - q_1} = \frac{a}{b}$

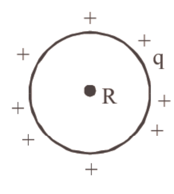
$$\frac{E_a}{E_b} = \frac{\frac{1.}{4\pi\varepsilon_o}\frac{q_1}{a^2}}{\frac{1}{4\pi\varepsilon_o}\frac{q_2}{b^2}} = \left(\frac{q_1}{2q - q_1}\right)\frac{b^2}{a^2}$$

$= \frac{a}{b}.\frac{b^2}{a^2} = \frac{b}{a} = b : a$

49. **(b)**

50. **(b)** $\vec{E} = \frac{\partial v}{\partial x}\hat{i} + \frac{\partial v}{\partial y}\hat{j}$ $\quad \therefore |\vec{E}| = k(\sqrt{x^2 + y^2}) = kr$
Given $v = -kxy$ $\quad E \propto r$
$\therefore \vec{E} = ky\hat{i} + kx\hat{j}$

51. **(b)** In shell, q charge is uniformly distributed over its surface, it behaves as a conductor.



V = potential at surface $= \frac{q}{4\pi\varepsilon_0 R}$
and inside $V = \frac{q}{4\pi\varepsilon_0 R}$
Because of this it behaves as an equipotential surface.

52. **(a)** Force on a charge q in a uniform electric field E is, F = q E, work done = force × distance = qEy.

53. **(d)** In an external electric field, the positive and negative charges of a non-polar molecule are displaced in opposite directions. The displacement stops when the external force on the constituent charges of the molecule is balanced by the restoring force (due to internal fields in the molecule). The non-polar molecule thus develops an induced dipole moment. The dielectric is said to be polarised by the external field.

54. **(c)** Since $V = \frac{W}{Q}$, more work will be done for a positive charge of two units as compared to positive charge of one unit, but the ratio $\frac{W}{Q}$ is same. Therefore potential difference is same.

55. **(d)** Since capacitance $C = \frac{\varepsilon_0 A}{d}$, as d decreases capacitance increases.

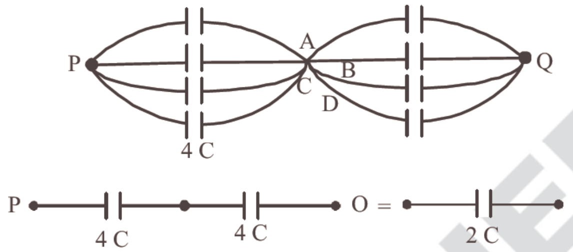
56. **(a)** PE, $U_0 = Q^2/2C$

When a slab of dielectric constant k is inserted, then $C' = Ck$

$$U' = \frac{Q^2}{2C'} = \frac{Q^2}{2Ck} = \frac{U_0}{k}$$

57. **(c)** Battery is disconnected so Q will be constant as $C \propto k$. So with introduction of dielectric slab capacitance will increase using $Q = CV$, V will decrease and using $U = \frac{Q^2}{2C}$, energy will decrease.

58. **(a)** A, B, C and D are equipotential points (see fig.)



59. **(c)** Potential energy of a dipole in external field *U* is

$$U = -\vec{P} \cdot \vec{E}$$

for stable equilibrium $\theta = 0°$

$$U = -pE\cos 0° = -pE$$

$$\therefore \quad U = -qLE$$

60. **(d)** As capacitor offers infinite resistance in dc-circuit. So, current flows through 2Ω resistance from left to right, given by

$$I = \frac{V}{R + r} = \frac{2.5V}{2 + 0.5} = \frac{2.5}{2.5} = 1\text{ A}$$

So, the potential difference across 2Ω resistance

$V = IR = 1 \times 2 = 2$ volt.

Since, capacitor is in parallel with 2Ω resistance, so it also has 2V potential difference across it.

As current does not flow through capacitor branch so no potential drop will be accross 10Ω resistance. The charge on capacitor

$q = CV = (4\ \mu F) \times 2V = 8\ \mu C$

61. **(c)** The direction of electric field is always perpendicular to the direction of electric field and equipotential surface maintained at high electrostatic potential to other equipotential surface maintained at low electrostatic potential.

The positively charged particle experiences the electrostatic force in the direction of electric field i.e., from high electrostatic potential to low electrostatic potential. Thus, the work done by the electric field on the positive charge, so electrostatic potential energy of the positive charge decreases because speed of charged particle moves in the direction of field due to force $q\vec{E}$.

62. **(c)** The work done (in displacing a charge particle) by a electric force is given by $W_{12} = q(V_2 - V_1)$. Here initial and final potentials are same in all three cases are equal (20V) and same charge is moving from A to B, so work done is (ΔVq) same in all three cases.

63. **(c)** As we know that the relation between electric field intensity E and electric potential V is

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

Electric field intensity $E = 0$ then $\frac{dV}{dr} = 0$

This imply that V = constant

Thus, $E = 0$ inside the charged conducting sphere then the constant electrostatic potential 100V at every where inside the sphere and it verifies the shielding effect also.

64. **(c)** The capacitance of parallel plate capacitor filled with dielectric of thickness d_1 and dielectric constant K_1 is

$$C_1 = \frac{K_1 \varepsilon_o A}{d_1}$$

Similarly, capacitance of parallel plate capacitor filled with dielectric of thickness d_2 and dielectric constant K_2 is

$$C_2 = \frac{K_2 \varepsilon_o A}{d_2}$$

Since both capacitors are in series combination, then the equivalent capacitance is

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\text{or} \quad C = \frac{C_1 C_2}{C_1 + C_2} = \frac{\frac{K_1\varepsilon_0 A}{d_1}\frac{K_2\varepsilon_0 A}{d_2}}{\frac{K_1\varepsilon_0 A}{d_1} + \frac{K_2\varepsilon_0 A}{d_2}}$$

$$C = \frac{K_1 K_2 \varepsilon_0 A}{K_1 d_2 + K_2 d_1} \quad \text{... (i)}$$

So multiply the numerator and denominator of equation (i) with $(d_1 + d_2)$

$$C = \frac{K_1 K_2 \varepsilon_0 A}{(K_1 d_2 + K_2 d_1)} \times \frac{(d_1 + d_2)}{(d_1 + d_2)}$$

$$= \frac{K_1 K_2 (d_1 + d_2)}{(K_1 d_2 + K_2 d_1)} \times \frac{\varepsilon_0 A}{(d_1 + d_2)} \quad \text{... (ii)}$$

So, the equivalent capacitances is

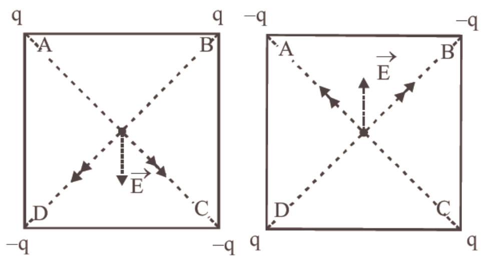
$$C = \frac{K\varepsilon_0 A}{(d_1 + d_2)} \quad \text{... (iii)}$$

Comparing, (ii) and (iii), the dielectric constant of new capacitor

$$K=\frac{K_1K_2(d_1+d_2)}{K_1d_2+K_2d_1}$$

65. **(a)** As shown in the figure, the resultant electric fields before and after interchanging the charges will have the same magnitude, but opposite directions.

Also, the potential will be same in both cases as it is a scalar quantity.



66. **(d)** When $\frac{Q_1}{R_1}-\frac{Q_2}{R_2}$; current will flow in connecting wire so that energy decreases in the form of heat through the connecting wire.

67. **(c)** The potential energy is negative whenever there is attraction. Since a positive and negative charge attract each other therefore their energy is negative. When both the charges are separated by infinite distance, they do not attract each other and their energy is zero.

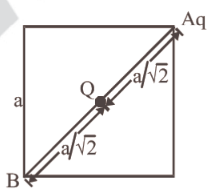
68. **(b)** When the charge is released to move freely, the work done by electric field is equal to change in kinetic energy

$\therefore\ W_{EF}=\Delta KE$

$-q\,\Delta V=\Delta KE$

$KE=-3\times10^{-6}(1-5)=12\times10^{-6}\,J$

69. **(a)** Here, $V_A=V_B=\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{a/\sqrt{2}}$



Hence, $V_A-V_B=0$

Work done, $W=q(V_A-V_B)=0$

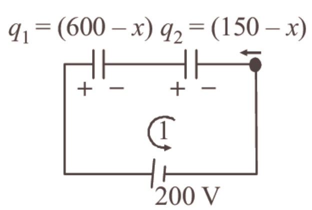
70. **(a)** **71.** **(d)**

72. **(c)** Plate 2 and plate 3 jointly.

$$\frac{(150-x)}{3}+\frac{(600-x)}{6}-200=0$$

73. **(b)** Hence, find charge on 6 μF capacitor is $q_1=700\ \mu C$

74. **(d)** Charge on 3 μF is $q_2=250\ \mu C$



75. **(d)** Plates 2 and 3 and plates 1 and 4 form isolated system. Hence $q_1=q_2=q_3=x=-100\ \mu C$

76. **(b)** Energy stored in capacitor will convert into heat.

$$=\frac{1}{2}CV^2=\frac{1}{2}\times2\times10^{-6}\times(100)^2=0.01\,J$$

77. **(a)** In series $\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$ and charge on each capacitor is same.

78. **(c)** Capacitance are in series

$$\frac{1}{c}=\frac{1}{2}+\frac{1}{2}+\frac{1}{2}\Rightarrow c=\frac{2}{3}F$$

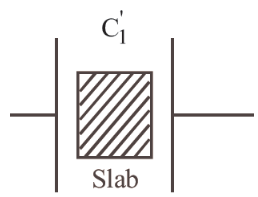
79. **(c)** $C=\frac{2\times2}{2+2}+2=3\ \mu F$

80. **(c)** Before introducing a slab capacitance of plates

$$C_1=\frac{\varepsilon_0A}{3}$$

If a slab of dielectric constant K is introduced between plates then

$C=\frac{K\varepsilon_0A}{d}$ then $C_1'=\frac{\varepsilon_0A}{2.4}$



C_1 and C_1' are in series hence,

$$\frac{\varepsilon_0A}{3}=\frac{k\frac{\varepsilon_0A}{3}\cdot\frac{\varepsilon_0A}{2.4}}{k\frac{\varepsilon_0A}{3}+\frac{\varepsilon_0A}{2.4}}$$

$3k=2.4k+3 \qquad 0.6k=3$

Hence, the dielectric constant of slap is given by,

$$k=\frac{30}{6}=5$$

81. **(b)**

82. **(a)** As $(V_B-V_A)=\frac{W_{AB}}{q}=-\int_A^B\vec{E}.\vec{d\ell}$

$$=kq\left[\frac{1}{r_A}-\frac{1}{r_B}\right]$$

Which depends on the initial and final position.

83. **(c)** **84.** **(c)** **85.** **(a)**

86. **(c)** $C'=kC$, and so, $U'=\frac{1}{2}(kC)V^2=kU$. Also $q'=C'V$ $=kCV=kq$, and so charge density increases.

87. **(a)**

88. **(a)** In the battery connected capacitor V remains constant while C increases with the introduction of dielectric.

89. **(d)**

90. **(b)** Since force on both the charges of a dipole is equal but opposite in direction, so net force = 0

91. **(a)** In the battery connected capacitor V remains constant while C increases with the introduction of dielectric

92. **(b)** $A \to (2); B \to (3); C \to (4); D \to (1)$

Electrice field is zero inside a conductor placed in an external field.

Electrice potential is zero at the centre of a dipole.

Torque is zero when a dipole in stable equilibrium.

Potential energy is zero if a electric dipole perpendicular to uniform electice field.

93. **(d)** $(A) \to (3); (B) \to (1); (C) \to (4); (D) \to (2)$

W.d. by battery A, $= 2\left(\frac{1}{2}C_1V_1^2\right) = 2 \times 2^2 = 8\text{J}$

W.d. by battery B, $= 2\left[\frac{1}{2}CV_2^2\right]$

$= 2\left[\frac{1}{2} \times \frac{4 \times 2}{4+2} \times 4^2\right] = \frac{64}{3}\text{J}$

$q_2 = CV_2 = \left(\frac{4 \times 2}{4+2}\right) \times 4 = \frac{16}{3}$

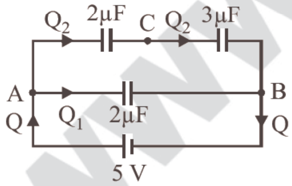
$q_1 = C_1V_1 = 2 \times 2 = 4$

94. Electric potential inside a conductor is constant and it is equal to that on the surface of the conductor.

95. Zero

96. $\frac{C}{3}$, 3V

97. (2v) The equivalent circuit diagram as shown in the figure.



The equivalent capacitance between A and B is

$$C_{eq} = \frac{2\mu F \times 3\mu F}{2\mu F + 3\mu F} + 2\mu F = \frac{16}{5}\mu F$$

Total charge of the given circuit is

$$Q = \frac{16}{5}\mu F \times 5V = 16\mu C$$

$$Q_1 = (2\mu F) \times 5V = 10\mu C$$

$\therefore$ $Q_2 = Q - Q_1 = 16\ \mu C - 10\ \mu C = 6\ \mu C$

$\therefore$ Voltage between B and C is

$$V_{BC} = \frac{Q_2}{3\mu F} = \frac{6\mu C}{3\mu F} = 2\text{ V}$$

98. (–20 V/m) $V = 5x^2 + 10x - 4$

$$E = \frac{-dV}{dx} = -(10x + 10).$$

At x = 1 m, E = –20 V/m.

99. (decreases)

100. $(n-1)\ C$ As n plates are joined, it means $(n-1)$ combination joined in parallel.

$\therefore$ resultant capacitance $= (n-1)\ C$

101. (True) Potential and potential energy are different quantities and cannot be equated.

102. (False)

103. (True) For an isolated capacitor, q is constant $U = \frac{q^2}{2C}$

When C decreases, U will increase

External force is outwards, hence work done is positive.

104. (False)

105. (False) $V_{dipole} = \frac{KP}{r^2}$

106. (True) $V_{point\ charge} = \frac{Kq}{r}$

107. (False)

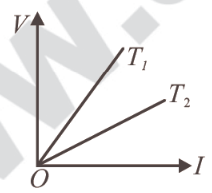
108. (True)

3 Current Electricity

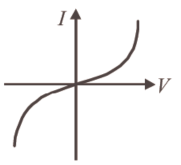
Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. In the equation AB = C, A is the current density, C is the electric field, Then B is
   (a) resistivity (b) conductivity
   (c) potential difference (d) resistance
2. A wire X has half the diameter and half the length of a wire Y of similar material. The ratio of resistance of X to that of Y is
   (a) 8 : 1 (b) 4 : 1
   (c) 2 : 1 (d) 1 : 1
3. The voltage V and current I graphs for a conductor at two different temperatures T_1 and T_2 are shown in the figure. The relation between T_1 and T_2 is
   (a) $T_1 > T_2$
   (b) $T_1 < T_2$
   (c) $T_1 = T_2$
   (d) $T_1 = \frac{1}{T_2}$



4. The I-V characteristics shown in figure represents
   (a) ohmic conductors
   (b) non-ohmic conductors
   (c) insulators
   (d) superconductors



5. If the resistance of a conductor is 5Ω at 50º C & 7Ω at 100º C, then mean temperature coefficient of resistance (of material) is
   (a) 0.013/ ºC (b) 0.004/ ºC
   (c) 0.006/ ºC (d) 0.008/ ºC
6. At what temperature will the resistance of a copper wire becomes three times its value at 0°C? (Temperature coefficient of resistance of copper is 4×10^{-3}/°C)
   (a) 550°C (b) 500°C
   (c) 450°C (d) 400°C
7. A potentiometer can measure emf of a cell because **[CBSE 2020]**
   (a) the sensitivity of potentiometer is large.
   (b) no current is drawn from the cell at balance.
   (c) no current flows in the wire of potentiometer at balance.
   (d) internal resistance of cell is neglected.
8. Two resistors R_1 and R_2 of 4 Ω and 6 Ω are connected in parallel across a battery. The ratio of power dissipated in them, $P_1 : P_2$ will be **[CBSE 2020]**
   (a) 4 : 9 (b) 3 : 2
   (c) 9 : 4 (d) 2 : 3
9. A wire of radius r and another wire of radius 2r, both of same material and length are connected in series to each other. The combination is connected across a battery. The ratio of the heats produced in the two wires will be
   (a) 4.00 (b) 2.00
   (c) 0.50 (d) 0.25
10. Emf of a cell is
    (a) the maximum potential difference between the terminals of a cell when no current is drawn from the cell.
    (b) the force required to push the electrons in the circuit.
    (c) the potential difference between the positive and negative terminal of a cell in a closed circuit.
    (d) less than terminal potential difference of the cell.
11. An energy source will supply a constant current into the load if its internal resistance is
    (a) very large as compared to the load resistance
    (b) equal to the resistance of the load
    (c) non-zero but less than the resistance of the load
    (d) zero
12. To draw a maximum current from a combination of cells, how should the cells be grouped?
    (a) Parallel
    (b) Series
    (c) Mixed grouping
    (d) Depends upon the relative values of internal and external resistances

13. A cell of internal resistance r is connected across an external resistance nr. Then the ratio of the terminal voltage to the emf of the cell is

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

14. If n cells each of emf ε and internal resistance r are connected in parallel, then the total emf and internal resistances will be

(a) $\varepsilon, \frac{r}{n}$ (b) ε, nr (c) $n\varepsilon, \frac{r}{n}$ (d) $n\varepsilon, nr$

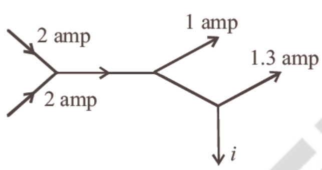
15. Under what condition will the strength of current in a wire of resistance R be the same for connection is series and in parallel of n identical cells each of the internal resistance r? When

(a) R = n r (b) R = r/n
(c) R = r (d) $R \to \infty, r \to 0$

16. The internal resistance of a 2.1 V cell which gives a current of 0.2 A through a resistance of 10 Ω is

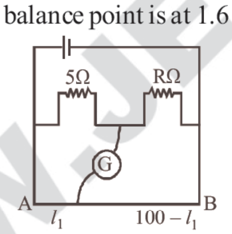
(a) 0.5 Ω (b) 0.8 Ω
(c) 1.0 Ω (d) 0.2 Ω

17. The figure below shows currents in a part of electric circuit. The current i is



(a) 1.7 amp
(b) 3.7 amp
(c) 1.3 amp
(d) 1 amp

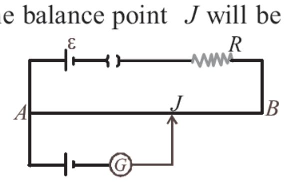
18. The resistances in the two arms of the meter bridge are 5Ω and RΩ, respectively. When the resistance R is shunted with an equal resistance, the new balance point is at 1.6 l_1. The resistance 'R' is :



(a) 10Ω
(b) 15Ω
(c) 20Ω
(d) 25Ω

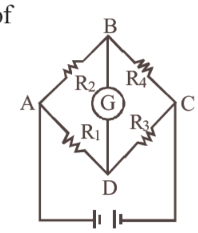
19. Sensitivity of potentiometer can be increased by
(a) increasing the e.m.f of the cell
(b) increasing the length of the potentiometer
(c) decreasing the length of the potentiometer wire
(d) None of these

20. AB is a wire of potentiometer with the increase in value of resistance R, the shift in the balance point J will be



(a) towards B
(b) towards A
(c) remains constant
(d) first towards B then back towards A

21. In the figure in balanced condition of wheatstone bridge



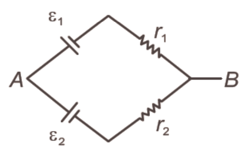
(a) B is at higher potential.
(b) D is at higher potential.
(c) Any of the two B or D can be at higher potential than other arbitrarily.
(d) B and D are at same potential.

22. The resistance of an ammeter is 13 Ω and its scale is graduated for a current upto 100 amps. After an additional shunt has been connected to this ammeter it becomes possible to measure currents upto 750 amperes by this meter. The value of shunt-resistance is

(a) 2 Ω (b) 0.2 Ω (c) 2 k Ω (d) 20 Ω

23. Consider a current carrying wire (current I) in the shape of a circle.
(a) source of emf
(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 the right way by repulsion
(d) the charges ahead

24. Two batteries of emf ε_1 and $\varepsilon_2 (\varepsilon_2 > \varepsilon_1)$ and internal resistances 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



25. A resistance R is to be measured using a meter bridge, student chooses the standard resistance S to be 100Ω. 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 I_1 more accurately
(b) He should change 5 to 1000Ω and repeat the experiment
(c) He should change S to 3Ω and repeat the experiment
(d) He should given up hope of a more accurate measurement with a meter bridge

26. Two cells of emfs approximately 5 V 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 8V
(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

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

(b) maximum when the battery is connected across 10 cm × 1 cm faces

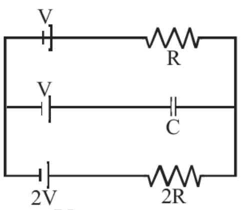
(c) maximum when the battery is connected across 10 cm × $\frac{1}{2}$ cm faces

(d) same irrespective of the three faces

28. 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

29. Two sources of equal emf are connected to an external resistance R. The internal resistance of the two sources are R_1 and R_2 ($R_2 > R_1$). If the potential difference across the source having internal resistance R_2 is zero, then
(a) $R = R_2 - R_1$
(b) $R = R_2 \times (R_1 + R_2)/(R_2 - R_1)$
(c) $R = R_1R_2/(R_2 - R_1)$
(d) $R = R_1R_2/(R_1 - R_2)$

30. In the circuit shown in figure, with steady current, the potential drop across the capacitor must be



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

31. The current in the primary circuit of a potentiometer wire is 0.5 A, ρ for the wire is 4×10^{-7} Ω–m and area of cross-section of wire is 8×10^{-6} m^2. The potential gradient in the wire would be
(a) 25 mV/meter (b) 2.5 mV/meter
(c) 25 V/meter (d) 10 V/meter

32. Kirchhoff's first law, *i.e.*, $\Sigma i = 0$ at a junction, deals with the conservation of
(a) charge (b) energy
(c) momentum (d) angular momentum

33. Drift velocity of electrons is due to
(a) motion of conduction electrons due to random collisions.
(b) motion of conduction electrons due to electric field $\vec{E}$.
(c) repulsion to the conduction electrons due to inner electrons of ions.
(d) collision of conduction electrons with each other.

34. For which of the following dependence of drift velocity v_d on electric field E, is Ohm's law obeyed?
(a) $v_d \propto E^2$ (b) $v_d = E^{1/2}$
(c) v_d = constant (d) $v_d = E$

35. When a potential difference V is applied across a conductor at a temperature T, the drift velocity of electrons is proportional to
(a) $\sqrt{V}$ (b) V (c) $\sqrt{T}$ (d) T

36. In the absence of an electric field, the mean velocity of free electrons in a conductor at absolute temperature (T) is
(a) zero (b) independent of T
(c) proportional to T (d) proportional to T^2

37. A current passes through a wire of nonuniform cross-section. Which of the following quantities are independent of the cross-section?
(a) The charge crossing (b) Drift velocity
(c) Current density (d) Free-electron density

38. If N, e, τ and m are representing electron density, charge, relaxation time and mass of an electron respectively, then the resistance of wire of length ℓ and cross-sectional area A is given by
(a) $\frac{m\ell}{Ne^2A^2\tau}$ (b) $\frac{2m\tau A}{Ne^2\ell}$ (c) $\frac{Ne^2\tau A}{2m\ell}$ (d) $\frac{Ne^2A}{2m\tau\ell}$

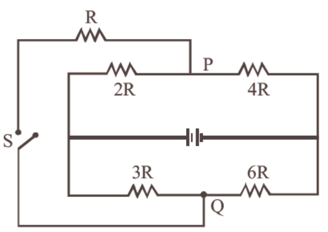
39. The example of non-ohmic resistance is
(a) diode (b) copper wire
(c) filament lamp (d) carbon resistor

40. The electric field intensity E, current density J and specific resistance k are related to each other through the relation
(a) E = J/k (b) E = Jk (c) E = k/J (d) k = JE

41. Nichrome or Manganin is widely used in wire bound standard resistors because of their
(a) temperature independent resistivity
(b) very weak temperature dependent resistivity.
(c) strong dependence of resistivity with temperature.
(d) mechanical strength.

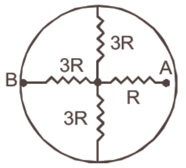
42. Two resistors A and B have resistances R_A and R_B respectively with $R_A < R_B$. The resistivities of their materials are ρ_A and ρ_B. Then
(a) $\rho_A > \rho_B$
(b) $\rho_A = \rho_B$
(c) $\rho_A < \rho_B$
(d) insufficient information to predict relation

43. The figure shows the circuit diagram of five resistors, a battery and a switch. If the switch S is closed then current drawn from the battery



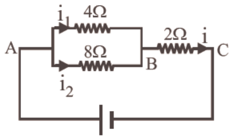
(a) increases
(b) decreases
(c) remains same
(d) initially increases and when the resistance *R* gets heated then decreases.

44. In the network shown below, the ring has zero resistance. The equivalent resistance between the point A and B is



(a) 2R
(b) 4R
(c) 7R
(d) 10R

45. In the circuit shown in Fig, the current in 4 Ω resistance is 1.2 A. What is the potential difference between B and C?



(a) 3.6 volt
(b) 6.3 volt
(c) 1.8 volt
(d) 2.4 volt

46. Kirchhoff's first and second laws for electrical circuits are consequences of
(a) conservation of electric charge and energy respectively
(b) conservation of electric charge
(c) conservation of energy and electric charge respectively
(d) conservation of energy

47. Emf of a cell is
(a) the maximum potential difference between the terminals of a cell when no current is drawn from the cell.
(b) the force required to push the electrons in the circuit.
(c) the potential difference between the positive and negative terminal of a cell in a closed circuit.
(d) less than terminal potential difference of the cell.

48. When potential difference is applied across an electrolyte, then Ohm's law is obeyed at
(a) zero potential (b) very low potential
(c) negative potential (d) high potential

49. To draw a maximum current from a combination of cells, how should the cells be grouped?
(a) Parallel
(b) Series
(c) Mixed grouping
(d) Depends upon the relative values of internal and external resistances.

50. A cell of internal resistance r is connected to an external resistance R. The current will be maximum in R, if
(a) R = r (b) R < r (c) R > r (d) R = r/2

51. Under what condition will the strength of current in a wire of resistance R be the same for connection is series and in parallel of n identical cells each of the internal resistance r? When
(a) R = n r (b) R = r/n
(c) R = r (d) $R \to \infty, r \to 0$

52. A capacitor is connected to a cell of emf E having some internal resistance r. The potential difference across the
(a) cell is < E (b) cell is E
(c) capacitor is > E (d) capacitor is < E

53. Two cells of the same emf E have different internal resistances r_1 and r_2. They are connected in series with an external resistance R and the potential difference across the first cell is found to be zero. Therefore, the external resistance R must be
(a) $r_1 - r_2$ (b) $r + r_2$ (c) $2r_1 - r_2$ (d) $r_1 - 2r_2$

54. If n cells each of emf ε and internal resistance *r* are connected in parallel, then the total emf and internal resistances will be
(a) $\varepsilon, \frac{r}{n}$ (b) ε, nr (c) $n\varepsilon, \frac{r}{n}$ (d) $n\varepsilon, nr$

55. An electric fan and a heater are marked as 100 W, 220 V and 1000 W, 220 V respectively. The resistance of heater is
(a) equal to that of fan (b) lesser than that of fan
(c) greater than that of fan (d) zero

56. Three resistances R, 2R and 3R are connected in parallel to a battery. Then
(a) the potential drop across 3R is maximum
(b) the current through each resistance is same
(c) the heat developed in 3R is maximum
(d) the heat developed in R is maximum.

57. A current of 30A is registered when the terminals of a dry cell of emf 1.5V are connected through an ammeter. (Neglect the ammeter resistance). The amount of heat produced in the battery in 20s is
(a) 450 J (b) 900 J (c) 1000 J (d) 50 J

58. The powers of two electric bulbs are 100 watt and 200 watt. Both of them are joined with 220 volt. The ratio of resistance of their filament will be
(a) 4 : 1 (b) 1 : 4 (c) 1 : 2 (d) 2 : 1

59. Forty electric bulbs are connected in series across a 220 V supply. After one bulb is fused the remaining 39 are connected again in series across the same supply. The illumination will be
(a) more with 40 bulbs than with 39
(b) more with 39 bulbs than with 40
(c) equal in both the cases
(d) in the ratio $40^2 : 39^2$

60. A heater boils a certain quantity of water in time t_1 Another heater boils the same quantity of water in time t_2. If both heaters are connected in parallel, the combination will boil the same quantity of water in time
(a) $\frac{1}{2}(t_1 + t_2)$ (b) $(t_1 + t_2)$
(c) $\frac{t_1 t_2}{t_1 + t_2}$ (d) $\sqrt{t_1 t_2}$

61. How much heat is developed in 210 watt electric bulb in 5 minutes? (Chemical equivalent of heat = 4.2 J/C)
(a) 30000 cal (b) 22500 cal (c) 15000 cal (d) 7500 cal

62. Why is the Wheatstone bridge better than the other methods of measuring resistances?
(a) It does not involve Ohm's law
(b) It is based on Kirchoff's law
(c) It has four resistor arms
(d) It is a null method

63. If in the experiment of Wheatstone's bridge, the positions of cells and galvanometer are interchanged, then balance point will
(a) change
(b) remain unchanged
(c) depend on the internal resistance of cell and resistance of galvanometer
(d) None of these

64. In meter bridge or Wheatstone bridge for measurement of resistance, the known and the unknown resistance are interchanged. The error so removed is
(a) end correction
(b) index error
(c) due to temperature effect
(d) random error

65. Potentiometer is based on
(a) deflection method (b) zero deflection method
(c) both (a) and (b) (d) None of these

66. In potentiometer a balance point is obtained, when
(a) the e.m.f. of the battery becomes equal to the e.m.f of the experimental cell
(b) the p.d. of the wire between the +ve end of battery to jockey becomes equal to the e.m.f. of the experimental cell
(c) the p.d. of the wire between +ve point of cell and jockey becomes equal to the e.m.f. of the battery
(d) the p.d. across the potentiometer wire becomes equal to the e.m.f. of the battery

67. In the experiment of potentiometer, at balance point, there is no current in the
(a) main circuit
(b) galvanometer circuit
(c) potentiometer circuit
(d) both main and galvanometer circuits

68. Sensitivity of potentiometer can be increased by
(a) increasing the e.m.f of the cell
(b) increasing the length of the potentiometer
(c) decreasing the length of the potentiometer wire
(d) None of these

69. Potentiometer measures potential more accurately because
(a) it measures potential in open circuit
(b) it uses sensitive galvanometer for null deflection
(c) it uses high resistance potentiometer wire
(d) it measures potential in closed circuit

70. For measuring voltage of any circuit, potentiometer is preferred to voltmeter because
(a) the potentiometer is cheap and easy to handle.
(b) calibration in the voltmeter is sometimes wrong.
(c) the potentiometer almost draws no current during measurement.
(d) range of the voltmeter is not as wide as that of the potentiometer.

71. The emf developed by a thermocouple is measured with the help of a potentiometer and not by a moving coil millivoltmeter because
(a) the potentiometer is more accurate than the voltmeter
(b) the potentiometer is more sensitive than voltmeter
(c) the potentiometer makes measurement without drawing any current from the thermocouple
(d) measurement using a potentiometer is simpler than with a voltmeter

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

The motion of free electrons in a conductor are continuous and random. They collide with positive metal ions and change direction during each collision. So thermal velocities are randomly distributed and average velocity is zero.

When a potential difference is applied across the ends of a conductor, electrons are drifted towards the positive terminal of the field, this velocity is called drift velocity (v_d).

$$v_d = -\frac{e\vec{E}\tau}{m} = \frac{i}{neA}$$

72. If N, e, τ and m are representing electron density, charge, relaxation time and mass of an electron respectively, then the resistance of wire of length ℓ and cross-sectional area A is given by
(a) $\frac{m\ell}{Ne^2A^2\tau}$ (b) $\frac{2m\tau A}{Ne^2\ell}$
(c) $\frac{Ne^2\tau A}{2m\ell}$ (d) $\frac{Ne^2A}{2m\tau\ell}$

73. When a current I is set up in a wire of radius r, the drift velocity is v_d. If the same current is set up through a wire of radius 2 r, the drift velocity will be
(a) $4v_d$ (b) $2v_d$
(c) $v_d/2$ (d) $v_d/4$

74. A straight conductor of uniform cross-section carries a current I. If s is the specific charge of an electron, the momentum of all the free electrons per unit length of the conductor, due to their drift velocity only is
(a) I s (b) $\sqrt{I/s}$
(c) I/s (d) $(I/s)^2$

75. The resistance of a wire at room temperature 30°C is found to be 10 Ω. Now to increase the resistance by 10%, the temperature of the wire must be [The temperature coefficient of resistance of the material of the wire is 0.002 per °C]
(a) 36°C (b) 83°C
(c) 63°C (d) 33°C

76. The number of free electrons per 100 mm of ordinary copper wire is 2×10^{21}. Average drift speed of electrons is 0.25 mm/s. The current flowing is
(a) 5 A (b) 80 A
(c) 8 A (d) 0.8 A

Case/Passage-II

Heating Effect of Current: The electric energy consumed in a circuit is defined as *the total work done in maintaining the current in an electric circuit for a given time.*

Electric energy $= VIt = Pt = I^2Rt = V^2t/R$

The **S.I. unit** of electric energy is joule (denoted by J)

where 1 joule = 1 watt × 1 second = 1 volt × 1 ampere × 1 sec.

In **household circuits** the electrical appliances are connected in parallel and the electrical energy consumed is measured in kWh

77 An electric fan and a heater are marked as 100 W, 220 V and 1000 W, 220 V respectively. The resistance of heater is
(a) equal to that of fan
(b) lesser than that of fan
(c) greater than that of fan
(d) zero

78. Which of the following statement is false?

(a) Some of the energy produced by the light bulb takes the form of heat.
(b) The battery is the source of all the electrons flowing around the circuit.
(c) The current entering the light bulb equals the current leaving the light bulb.
(d) The potential in the wire to the left of the light bulb differs from the potential in the wire to the right of that bulb.

79. Resistance of conductor is doubled keeping the potential difference across it constant. The rate of generation of heat will

(a) become one fourth (b) be halved
(c) be doubled (d) become four times

80. The heating element of an electric heater should be made with a material, which should have

(a) high specific resistance and high melting point
(b) high specific resistance and low melting point
(c) low specific resistance and low melting point
(d) low specific resistance and high melting point

81. If R_1 and R_2 are respectively the filament resistances of a 200 watt bulb and a 100 watt bulb designed to operate on the same voltage

(a) R_1 is two times R_2 (b) R_2 is two times R_1
(c) R_2 is four times R_1 (d) R_1 is four times R_2

Case/Passage-III

Terminal potential difference of a cell is defining the potential difference between the two electrodes of a cell when the cell is in closed circuit i.e. current is withdrawn from it.

Electromotive force or e.m.f of a cell is the maximum potential difference between the two electrodes of a cell when the cell is in open circuit i.e. no current is taken from the cell.

$V = E - Ir \leftarrow$ when current is withdrawn from the cell
$V = E + Ir \leftarrow$ when the cell is charged.

The S.I. unit of emf and potential difference is same i.e., volt.

82. A cell of internal resistance r is connected to an external resistance R. The current will be maximum in R, if

(a) R = r (b) R < r (c) R > r (d) R = r/2

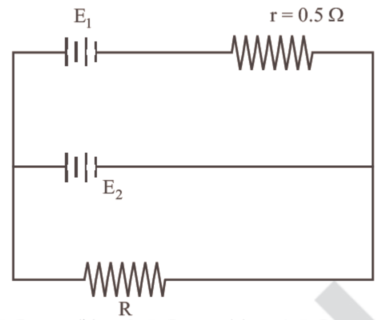
83. A capacitor is connected to a cell of emf E having some internal resistance r. The potential difference across the

(a) cell is < E (b) cell is E
(c) capacitor is > E (d) capacitor is < E

84. A primary cell has an e.m.f. of 1.5 volt. When short-circuited it gives a current of 3 ampere. The internal resistance of the cell is

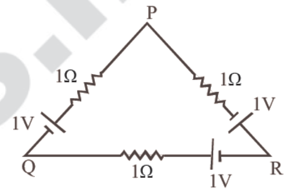
(a) 4.5 ohm (b) 2 ohm
(c) 0.5 ohm (d) (1/4.5) ohm

85. A dc source of emf E_1 = 100 V and internal resistance $r = 0.5\ \Omega$, a storage battery of emf E_2 = 90 V and an external resistance R are connected as shown in figure. For what value of R no current will pass through the battery ?



(a) 5.5 Ω (b) 3.5 Ω (c) 4.5 Ω (d) 2.5 Ω

86. Three batteries of emf 1V and internal resistance 1Ω each are connected as shown. Effective emf of combination between the points PQ is



(a) zero
(b) 1V
(c) 2V
(d) (2/3) V

Case/Passage-IV

Potentiometer: A potentiometer is an ideal voltmeter since a voltmeter draws some current through the circuit while potentiometer needs no current to work. A potentiometer works on the principle of emf comparison. In working condition, a constant current flows throughout the wire of a potentiometer using standard cell of emf e_1. The wire of potentiometer is made of uniform material and cross-sectional area, and it has uniform resistance per unit length. The potential gradient depends upon the current in the wire.

A potentiometer with a cell of emf 2 V and internal resistance 0.4 Ω is used across the wire *AB*. A standard cadmium cell of emf 1.02 V gives a balance point at 66 cm length of wire. The standard cell is then replaced by a cell of unknown emf *e* (internal resistance *r*), and the balance point found similarly turns out to be 88 cm length of the wire. The length of potentiometer wire *AB* is 1 m.

87. The value of *e* is

(a) 1.36 V (b) 2.63 V
(c) 1.83 V (d) None of these

88. The reading of the potentiometer, if a 4 V battery is used instead of *e*, is

(a) 88.3 cm (b) 47.3 cm
(c) 95 cm (d) cannot be calculated

89. If the resistance is connected across the cell *e*, the balancing length will

(a) increase (b) decrease
(c) remain same (d) None of these

90. The length of a wire of a potentiometer is 100 cm, and the emf of its standard cell is *E* volt. It is employed to measure the emf of a battery whose internal resistance is 0.5 Ω. If the balance point is obtained at l = 30 cm from the positive end, the emf of the battery is

(a) $\frac{30E}{100}$ (b) $\frac{30E}{100.5}$
(c) $\frac{30E}{(100-0.5)}$ (d) $\frac{30(E-0.5i)}{100}$

where i is the current in the potentiometer wire.

91. In a potentiometer experiment, the balancing with a cell is at length 240 cm. On shunting the cell with a resistance of 2 Ω, the balancing length becomes 120 cm. The internal resistance of the cell is

(a) 2 Ω (b) 4 Ω (c) 0.5 (d) 1 Ω

Case/Passage-V

It an instrument based on wheatstone bridge.

Principle:– The fall of potential across any portion of the wire is directly proportional to the length of that portion provided the wire of uniform cross-section and a constant current is flowing through it.

Theory : If A be the area of cross-section of the wire,

ρ be the specific resistance of the material of the wire.

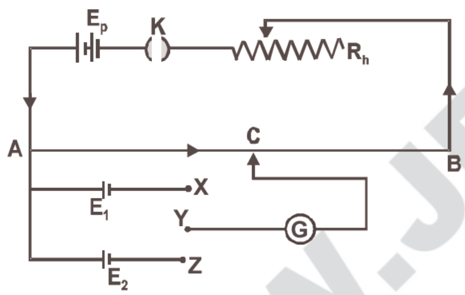
V be the potential difference across the portion of the wire whose length is ℓ and resistance R.

I be the current flowing through the wire then by Ohm's law,

$$V = IR = I\frac{\ell\rho}{A} = \left(\frac{I\rho}{A}\right)\ell = k\ell \quad \left[\text{where } k = \frac{\rho\ell}{A}\right]$$

$\therefore$ $V \propto \ell$ if A and I are constants

or, $\frac{V}{\ell} = k =$ Potential gradient or fall of potential/length of the wire.



92. If specific resistance of a potentiometer wire is $10^{-7}\Omega$m current flowing through it, is 0.1 amp and cross sectional area of wire is 10^{-6} m^2, then potential gradient will be

(a) 10^{-2} volt/m (b) 10^{-4} volt/m
(c) 10^{-6} volt/m (d) 10^{-8} volt/m

93. A cell when balanced with potentiometer gave a balance length of 50 cm. 4.5 Ω external resistance is introduced in the circuit, now it is balanced on 45 cm. The internal resistance of cell is

(a) 0.25 Ω (b) 0.5 Ω (c) 1.0 Ω (d) 1.5 Ω

94. A potentiometer consists of a wire of length 4m and resistance 10Ω. It is connected to a cell of e.m.f. 3V. The potential gradient of wire is

(a) 5V/m (b) 2V/m (c) 5V/m (d) 10V/m

95. In an experiment to measure the internal resistance of a cell, by a potentiometer, it is found that the balance point is at a length of 2 m, when the cell is shunted by a 5 Ω resistance and is at a length of 3 m when the cell is shunted by a 10 Ω resistance. The internal resistance of the cell is

(a) 1.5 Ω (b) 10 Ω (c) 15 Ω (d) 1 Ω

96. 125 cm of potentiometer wire balances the emf. of a cell and 100 cm of the wire is required for balance, if the poles of the cell are joined by a 2Ω resitor. Then the internal resistance of the cell is

(a) 0.25Ω (b) 0.5Ω (c) 0.75Ω (d) 1.25Ω

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

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

97. **Assertion :** The electric bulbs glows immediately when switch is on.

Reason : The drift velocity of electrons in a metallic wire is very high.

98. **Assertion:** For a conductor resistivity increases with increase in temperature.

Reason: Since $\rho = \frac{m}{ne^2\tau}$, when temperature increases the random motion of free electrons increases and vibration of ions increases which decreases τ.

99. **Assertion :** The current density $\vec{J}$ at any point in ohmic resistor is in direction of electric field $\vec{E}$ at that point.

Reason : A point charge when released from rest in a region having only electrostatic field always moves along electric lines of force.

100. **Assertion :** Free electrons always keep on moving in a conductor even then no magnetic force act on them in magnetic field unless a current is passed through it.

Reason : The average velocity of free electron is zero.

101. **Assertion :** Drift speed v_d is the average speed between two successive collisions.

Reason : If $\Delta\ell$ is the average distance moved between two collisions and Δt is the corresponding time, then $v_d = \lim_{\Delta t \to 0} \frac{\Delta\ell}{\Delta t}$.

102. **Assertion :** Fuse wire must have high resistance and low melting point.

Reason : Fuse is used for voltage stablisation only.

103. **Assertion :** The (100w, 220 v) bulb glow with more brightness than, (50w, 220v) bulb.

Reason : 100w bulb has more resistance than 50w bulb.

104. **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.

105. Assertion : Long distance power transmission is done at high voltage.

Reason : At high voltage supply power losses are less.

106. Assertion : A larger dry cell has higher emf.

Reason : The emf of a dry cell is proportional to its size.

107. Assertion : In a simple battery circuit, the point of the lowest potential is negative terminal of the battery.

Reason : The current flows towards the point of the higher potential, as it does in such a circuit from the negative to the positive terminal.

108. Assertion : Kirchoff's junction rule can be applied to a junction of several lines or a point in a line.

Reason : When steady current is flowing, there is no accumulation of charges at any junction or at any point in a line.

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

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

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

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

111. Assertion : A potentiometer of longer length is used for accurate measurment.

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

112. Assertion : Bending a wire does not effect electrical resistance.

Reason : Resistance of wire is proportional to resistivity of material.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

113. Match the Column I and Column II.

	Column I		Column II
(A)	Smaller the resistance greater the current	(1)	If the same voltage is applied and resistance are in series
(B)	Greater or smaller the resistance the current is same	(2)	If the same current is passed
(C)	Greater the resistance smaller the power	(3)	When resistances are connected in series
(D)	Greater the resistance greater the power	(4)	When resistances are connected in parallel

(a) (A) $\rightarrow$ (3) ; (B) $\rightarrow$ (1) ; (C) $\rightarrow$ (2) ; (D) $\rightarrow$ (4)
(b) (A) $\rightarrow$ (1) ; (B) $\rightarrow$ (3) ; (C) $\rightarrow$ (2) ; (D) $\rightarrow$ (4)
(c) (A) $\rightarrow$ (2) ; (B) $\rightarrow$ (1) ; (C) $\rightarrow$ (4) ; (D) $\rightarrow$ (3)
(d) (A) $\rightarrow$ (4) ; (B) $\rightarrow$ (3) ; (C) $\rightarrow$ (1) ; (D) $\rightarrow$ (2)

114. Match the entries of Column I with their correct mathematical expressions in Column II

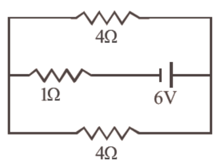
	Column I		Column II
(A)	Balanced condition of wheatstone bridge	(1)	$\frac{R_1}{R_2} = \frac{R_3}{R_4}$
(B)	Comparison of emf of two cells.	(2)	$\frac{R}{S} = \frac{l_1}{100 - l_1}$
(C)	Determination of internal resistance of a cell	(3)	$\frac{E_1}{E_2} = \frac{l_1}{l_2}$
(D)	Determination of unknown resistance by meter bridge	(4)	$r = R\left(\frac{l_1}{l_2} - 1\right)$

(a) (A) $\rightarrow$ (4); (B) $\rightarrow$ (2); C $\rightarrow$ (3); (D) $\rightarrow$ (1)
(b) (A) $\rightarrow$ (1); (B) $\rightarrow$ (3); C $\rightarrow$ (4); (D) $\rightarrow$ (2)
(c) (A) $\rightarrow$ (3); (B) $\rightarrow$ (4); C $\rightarrow$ (2); (D) $\rightarrow$ (1)
(d) (A) $\rightarrow$ (4); (B) $\rightarrow$ (3); C $\rightarrow$ (2); (D) $\rightarrow$ (1)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

115. The current in the 1Ω resistor shown in the circuit is _______ A.



116 A primary cell has an e.m.f. of 6. volt, when short-circuited it gives a current of 3 ampere. The internal resistance of the cells is _______ ohm.

117. A 5–ampere fuse wire can withstand a maximum power of 1 watt in the circuit. The resistance of the fuse wire is _______ ohm.

118. A heater of 220 V heats a volume of water in 5 minutes. The same heater when connected to 110 V heats the same volume of water in _______ minutes.

119. A battery of 10 V and internal resistance 0.5Ω is connected across a variable resistance R. The value of R for which the power delivered is maximum is equal to _______ Ω.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

120. Voltmeter is connected in parallel with the circuit.

121. Resistance of a voltmeter is very small.

122. The drift velocity of electrons in a metallic wire will decrease, if the temperature of the wire is increased.

123. On increasing temperature, conductivity of metallic wire inecreases.

ANSWER KEY & SOLUTIONS

1. **(a)** $J = \sigma E \Rightarrow J\rho = E$
J is current density, E is electric field
so B = ρ = resistivity.

2. **(c)** $R = \frac{\rho \ell}{A} \Rightarrow R = \frac{\rho \ell}{\pi r^2}$

Given, $\ell_x = \frac{\ell_y}{2}$

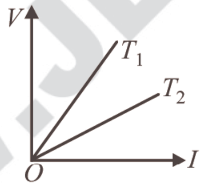
$r_x = \frac{r_y}{2}$

So, ratio of resistance of x to that of Y is,

$$\Rightarrow \frac{R_x}{R_y} = \frac{\ell_x}{\ell_y} \times \frac{r_y^2}{r_x^2} \Rightarrow \frac{(\ell_y/2)}{\ell_y} \times \frac{r_y^2}{\left(\frac{r_y^2}{2}\right)^2}$$

$$\Rightarrow \frac{\ell_y}{2\ell_y} \times \frac{\ell_y^2}{\ell_y^2} \times 4 \Rightarrow \frac{2}{1}$$

3. **(a)** The slope of *V–I* graph gives the resistance of a conductor at a given temperature.
From the graph, it follows that resistance of a conductor at temperature T_1 is greater than at temperature T_2 As the resistance of a conductor is more at higher temperature and less at lower temperature, hence $T_1 > T_2$.



4. **(b)** The figure is showing *I – V* characteristics of non ohmic or non linear conductors.

5. **(a)** [Hint $\Rightarrow R_t = R_o(1 + \alpha t)$]
$5\Omega = R_0(1 + \alpha \times 50)$ and $7\Omega = R_0(1 + \alpha \times 100)$
or $\frac{5}{7} = \frac{1+50\alpha}{1+100\alpha}$ or $\alpha = \frac{2}{150} = 0.0133/°C$

6. **(b)** $R_t = R_0(1+\alpha t)$ at t°C $R_t = 3R_0$
$\alpha = 4 \times 10^{-3}/°C$
$3R_0 = R_0(1 + 4 \times 10^{-3} \times t)$
$\therefore\ 3 - 1 = 4 \times 10^{-3} t$
$\therefore\ t = \frac{2}{4 \times 10^{-3}} = 500°C$

7. **(b)**

8. **(b)** $P_1 = \frac{V^2}{R_1}$ and $P_2 = \frac{V^2}{R_2}$ $\quad \therefore \frac{P_1}{P_2} = \frac{R^2}{R_1} = \frac{6}{4} = \frac{3}{2}$

9. **(a)** $H = I^2 Rt$. Here $R_1 = \rho\frac{\ell}{\pi r^2}$ and

$R_2 = \rho\frac{\ell}{\pi(2r)^2}$.

That is, $R_1 = 4R_2$. Hence, $\frac{H_1}{H_2} = 4$.

10. **(a)**

11. **(d)** $I = \frac{E}{R+r}$, Internal resistance (r) is zero,

$I = \frac{E}{R}$ = constant.

12. **(d)**

13. **(c)** Internal resistance = r, External resistance = nr.
Let terminal voltage = V

then $V = E - Ir \Rightarrow V = E - \frac{Er}{(n+1)r}$

$V = \frac{nE}{n+1} \Rightarrow \frac{V}{E} = \frac{n}{n+1}$

14. **(a)** In the parallel combination,

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

$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + ... + \frac{1}{r_n}$$

($\because\ \varepsilon_1 = \varepsilon_2 = \varepsilon_3 = ... = \varepsilon_n = \varepsilon$ and $r_1 = r_2 = r_3 = ... r$)

$$\therefore \quad \frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon}{r} + \frac{\varepsilon}{r} + ... + \frac{\varepsilon}{r} = n\frac{\varepsilon}{r} \qquad .... (i)$$

$$\frac{\varepsilon}{r_{eq}} = \frac{1}{r} + \frac{1}{r} + ... + \frac{1}{r} = \frac{n}{r} \quad r_{eq} = r/n \qquad ....(ii)$$

From (i) and (ii)

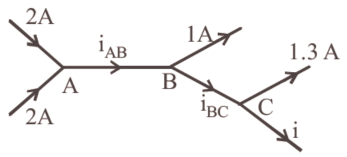
$$\varepsilon_{eq} = n\frac{\varepsilon}{r_{eq}} \times r_{eq} = n \times \frac{\varepsilon}{r} \times \frac{\varepsilon}{r} = \varepsilon$$

15. **(c)**

16. **(a)** Given : emf ε = 2.1 V
I = 0.2 A, R = 10Ω
Internal resistance r = ?

From formula.
$\varepsilon - Ir = V = IR$
$2.1 - 0.2r = 0.2 \times 10$
$2.1 - 0.2r = 2$ or $0.2r = 0.1$ $\Rightarrow r = \frac{0.1}{0.2} = 0.5\,\Omega$

17. **(a)** According to Kirchhoff's first law
At junction A, $i_{AB} = 2 + 2 = 4$ A
At junction B, $i_{AB} = i_{BC} + 1 \Rightarrow i_{BC} = 4 - 1 \Rightarrow 3$A



At junction C, $i = i_{BC} - 1.3 = 3 - 1.3 = 1.7$ A

18. **(b)** This is a balanced wheatstone bridge condition,
$$\frac{5}{R} = \frac{\ell_1}{100 - \ell_1} \text{ and } \frac{5}{R/2} = \frac{1.6\ell_1}{100 - 1.6\ell_1} \Rightarrow R = 15\,\Omega$$

19. **(b)**

20. **(a)** Due to increases in resistance *R* the current through the wire will decrease and hence the potential gradient also decreases, which results in increase in balancing length. So. *J* will shift towards *B*.

21. **(d)** In balance condition, since no current flows through the galvanometer therefore *B* and D are at the same potential.

22. **(a)** We know
$$\frac{I}{I_S} = 1 + \frac{G}{S}$$
$$\frac{750}{100} = 1 + \frac{13}{S}$$
$S \Rightarrow 2\Omega$

23. **(b)** As we know, electric current per unit area I/A, is called current density j i.e., $j = \frac{I}{A}$
The SI units of the current density are A/m^2.
The current density is also directed along E and is also a vector and the relationship is
$j = \sigma E$
Current density changes due to electric field produced by charges accumulated on the surface of wire.

24. **(a)** As we know the equivalent emf (ε_{eq}) in the parallel combination
$$\varepsilon_{eq} = \frac{\varepsilon_2 r_1 + \varepsilon_1 r_2}{r_1 + r_2}$$
So according to formula the equivalent emf ε_{eq} of the two cells in parallel combination is between ε_1 and ε_2. Thus ($\varepsilon_1 < \varepsilon_{eq} < \varepsilon_2$).

25. **(c)** Adjusting the blance point near the middle of the bridge, i.e.. when l_1 is close to 50 cm. requires a suitable choice of S, R is unknown resistance :

Since, $\frac{R}{S} = \frac{Rl_1}{R(100 - l_1)}$

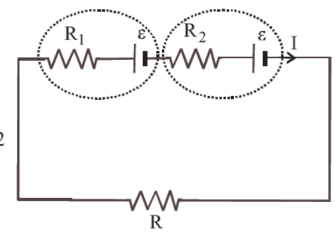
$$\frac{R}{S} = \frac{l_1}{100 - l_1} \quad \text{or} \quad R = S\left[\frac{l_1}{100 - l_1}\right]$$
$$R = S\left[\frac{2.9}{97.1}\right]$$
So, here, R : S = 2.9 : 97.1 implies that the S is nearly 33 times to that of R. In orded to make this ratio 1 : 1 it is necessary to reduce the value of S nearly $\frac{1}{33}$ times i.e., nearly $3\,\Omega$.

26. **(b)** The potential drop across wires of potentiometer should be more than emfs of primary cells. Here, values of emfs of two cells are given as 5V and 10V, so the potential drop along the potentiometer wire must be more than 10V. So battery should be of 15V and about 4V potential is droped by using variable resistance.

27. **(a)** As we known that the resistance of wire is $R = \rho\frac{l}{A}$
For maximum value of R, *l* must be higher and A should be lower and it is possible only when the battery is connected across area of cross section $= 1\text{cm} \times \left(\frac{1}{2}\right)$ cm.

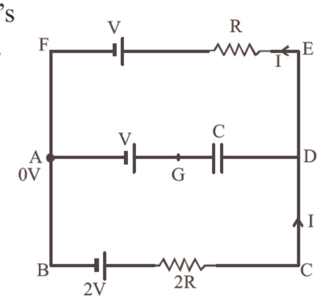
28. **(a)** We know that the relationship between current and drift speed is
$I = neAv_d$
Where, I is the current and V_d is the drift velocity.
So, $I \propto V_d$
Hence, only drift velocity determines the current in a conductor.

29. **(c)** $I = \frac{2\varepsilon}{R + R_1 + R_2}$



Pot. difference across second cell $= V = \varepsilon - IR_2$
$= 0$
$$\varepsilon = \frac{2\varepsilon}{R + R_1 + R_2}.R_2 = 0$$
$R + R_1 + R_2 - 2R_2 = 0$
$R + R_1 - R_2 = 0 \quad \therefore R = R_2 - R_1$

30. **(c)** Applying Kirchhoff's law in BCDEFAB we get,



$I = \frac{V}{3R}$
Let A be at 0 V. Then potential at G is V.
Applying Krichhoff's law for AFED, we get
$0 + V + IR = V_D$
$$\Rightarrow 0 + V + \frac{V}{3R} \times R = V_D \Rightarrow V_D = \frac{4V}{3}$$
$\therefore$ potential different across capacitor $= \frac{4V}{3} - V = \frac{V}{3}$

31. **(a)** Potential gradient of wire $= \frac{V}{\ell} = \left(\frac{\rho}{A}\right) \times I$

where ℓ & A are the length and cross-section of wire

so $\frac{V}{\ell} = \frac{4 \times 10^{-7}}{8 \times 10^{-6}} \times 0.5 = 25 mV / meter$

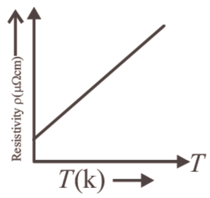
32. **(a)**

33. **(b)** Motion of conduction electrons due to random collisions has no preffered direction and average to zero. Drift velocity is caused due to motion of conduction electrons due to applied electric field $\vec{E}$.

34. **(d)** **35.** **(b)** **36.** **(a)** **37.** **(d)** **38.** **(a)**

39. **(a)** **40.** **(b)**

41. **(b)** These materials exhibit a very weak dependence of resistivity on temperature. Their resistance values would be changed very little with temperature as shown in figure.



Hence these materials are widely used as heating element.

42. **(d)** Resistivity depends on various other factors like temp.

43. **(c)** No current flows through the resistor *R* as *P* and *Q* are at same potential. Hence current drawn from battery will remain same on closing the switch.

44. **(a)** As the ring has no resistance, the three resistances of 3R each are in parallel.

$\Rightarrow \frac{1}{R'} = \frac{1}{3R} + \frac{1}{3R} + \frac{1}{3R} = \frac{1}{R} \Rightarrow R' = R$

$\therefore$ between point A and B equivalent resistance $= R + R = 2R$

45. **(a)** The potential difference across 4Ω resistance is given by $V = 4 \times i_1 = 4 \times 1.2 = 4.8$ volt

So, the potential across 8Ω resistance is also 4.8 volt.

Current $i_2 = \frac{V}{8} = \frac{4.8}{8} = 0.6$ amp

Current in 2Ω resistance $i = i_1 + i_2$

$\therefore i = 1.2 + 0.6 = 1.8$ amp

Potential difference across 2Ω resistance

$V_{BC} = 1.8 \times 2 = 3.6$ volts

46. **(a)** Kirchhoff ' s first law deals with conservation of electrical charge & the second law deals with conservation of electrical energy.

47. **(a)** Because of internal resistance of cell.

48. **(d)** **49.** **(d)** **50.** **(a)** **51.** **(c)**

52. **(b)** In the given case cell is in open circuit (i = 0) so voltage across the cell is equal to its e.m.f.

53. **(a)**

54. **(a)** In the parallel combination,

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

$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + ... + \frac{1}{r_n}$$

($\because \varepsilon_1 = \varepsilon_2 = \varepsilon_3 = ... = \varepsilon_n = \varepsilon$ and $r_1 = r_2 = r_3 = ... r$)

$$\therefore \quad \frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon}{r} + \frac{\varepsilon}{r} + ... + \frac{\varepsilon}{r} = n\frac{\varepsilon}{r} \quad .... (i)$$

$$\frac{\varepsilon}{r_{eq}} = \frac{1}{r} + \frac{1}{r} + ... + \frac{1}{r} = \frac{n}{r} \quad r_{eq} = r/n \quad ...(ii)$$

From (i) and (ii)

$$\varepsilon_{eq} = n\frac{\varepsilon}{r_{eq}} \times r_{eq} = n \times \frac{\varepsilon}{r} \times \frac{\varepsilon}{r} = \varepsilon$$

55. **(b)** As $R \propto V^2/P$ or $R \propto 1/P$, so resistance of heater is less than that of fan.

56. **(d)** $H \propto \frac{1}{R}$ [as V = constant in parallel connection]

57. **(b)** $i = \frac{E}{r} \Rightarrow 30 = \frac{1.5}{r}$

$r = 0.05\,\Omega \Rightarrow H = i^2rt = (30)^2 \times 0.05 \times 20 = 900$ J

58. **(d)** As $R \times \frac{1}{\text{Power}}$ $\therefore R_1 : R_2 = 2 : 1$

59. **(b)** Since, the voltage is same for the two combinations, therefore $H \propto \frac{1}{R}$. Hence, the combination of 39 bulbs will glow more.

60. **(c)** If a heater boils m kg water in time t_1 and another heater boils the same water in t_2, then both connected in series will boil the same water in time $t_s = t_1 + t_2$ and if in parallel $t_p = \frac{t_1 t_2}{t_1 + t_2}$ [Use time taken $\propto$ Resistance]

61. **(c)** $H = P \times t = \frac{210 \times 5 \times 60}{4.2} = 15000$ cal.

62. **(d)**

63. **(b)** The deflection in galvanometer will not be changed due to interchange of cells and the galvanometer.

64. **(a)** In meter bridge experiment, it is assumed that the resistance of the *L* shaped plate is negligible, but actually it is not so. The error created due to this is called end error. To remove this the resistance box and the unknown resistance must be interchanged and then the mean reading must be taken.

65. **(b)** Potentiometer is based on zero deflection method.

66. **(b)** **67.** **(b)** **68.** **(b)** **69.** **(a)** **70.** **(c)**

71. **(c)** **72.** **(a)**

73. **(d)** $I = n A e v_d$ or $v_d \propto 1/\pi r^2$

74. **(c)**

75. **(b)** $R_t = R_0(1+\alpha t)$

Initially, $R_0(1+30\alpha) = 10\,\Omega$

Finally, $R_0(1+\alpha t) = 11\,\Omega$

$$\therefore \frac{11}{10} = \frac{1+\alpha t}{1+30\alpha}$$

or, $10 + (10 \times 0.002 \times t) = 11 + 330 \times 0.002$

or, $0.02t = 1 + 0.66 = 1.066$ or $t = \frac{1.66}{0.02} = 83°C$.

76. **(d)** $I = neAv_d = 2\times10^{21}\times1.6\times10^{-19}\times10\times0.25\times10^{-3}$

$$= 2\times1.6\times0.25 = \frac{8}{10} = 0.8\text{ A}$$

77. **(b)** As $R \propto V^2/P$ or $R \propto 1/P$, so resistance of heater is less than that of fan.

78. **(b)** Most of the charges flowing around the circuit are valence electrons stripped off the metal atoms in the wires and light bulbs. A battery doesn't "supply" all of the charges. It merely pushes around charges already present in the circuit.

Statements (c) and (d) are both true. All charges flowing into the light bulb also flow back out; no current gets " used up" But inside the bulb, those charges lose energy. This lost electrical energy converts into light and heat. So, the current has lower "potential" after flowing through the bulb.

79. **(b)** The rate of generation of heat, for a given potential difference is, $P = V^2/R$

80. **(a)** A heating wire should be such that it produces more heat when current is passed through it and also does not melt. It will be so if it has high specific resistance and high melting point.

81. **(b)** $R_1 = \frac{V^2}{P_1}$ and $R_2 = \frac{V^2}{P_2}$

$$\therefore \frac{R_2}{R_1} = \frac{P_1}{P_2} = \frac{200}{100} = 2 \quad (\because V = \text{constant})$$

$R_2 = 2R_1$

82. **(a)**

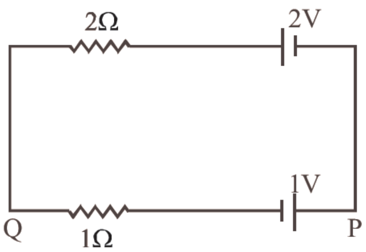
83. **(b)** In the given case cell is in open circuit (i = 0) so voltage across the cell is equal to its e.m.f.

84. **(c)** $r = E/I = 1.5/3 = 0.5$ ohm.

85. **(c)** $\frac{100}{R+r} = \frac{90}{R} \Rightarrow \frac{R+r}{R} = \frac{10}{9}$

$$\Rightarrow 1 + \frac{0.5}{R} = \frac{10}{9} \Rightarrow \frac{0.5}{R} = \frac{1}{9} \Rightarrow R = 4.5\,\Omega$$

86. **(a)**



$$E_{net} = \frac{E_1 r_2 - E_2 r_1}{r_1 + r_2} \text{ or } E_{net} = \frac{2-2}{2+1} = 0$$

87 **(a)** $\frac{e}{1.02} = \frac{88}{66}$

or $e = 1.36$ V

88. **(d)** 4 V is greater than applied emf 2 V, hence no balance point is obtained. On connecting the resistance across e, current will flow in e due to which terminal potential difference will be less than emf and the balancing length will decrease.

89. **(b)**

90. **(a)** $\because V \propto l \quad \therefore \frac{V}{E} = \frac{l}{L}$ or $V = \frac{l}{L}E = \frac{30}{100}E$

91. **(a)** $r = \frac{l_1 - l_2}{l_2}R = \frac{240-120}{120}\times 2 = 2\Omega$

92. **(a)** Potential gradient $= \frac{V_A - V_B}{\ell} = \frac{i\times\rho}{A} = \frac{0.1\times10^{-7}}{10^{-6}}$

$= 10^{-2}$ V/m

93. **(a)**

94. **(a)** Potential gradient $= \frac{\text{Pot. Difference}}{\text{length of wire}} = \frac{V_A - V_B}{\ell}$

95. **(b)** In case of internal resistance measurement by potentiometer,

$$\frac{V_1}{V_2} = \frac{\ell_1}{\ell_2} = \frac{\{ER_1/(R_1+r)\}}{\{ER_2/(R_2+r)\}} = \frac{R_1(R_2+r)}{R_2(R_1+r)}$$

Here $\ell_1 = 2$ m, $\ell_2 = 3$ m, $R_1 = 5\Omega$ and $R_2 = 10\Omega$

$$\therefore \frac{2}{3} = \frac{5(10+r)}{10(5+r)} \text{ or } 20 + 4r = 30 + 3r \text{ or } r = 10\,\Omega$$

96. **(b)** $r = \frac{\ell_1 - \ell_2}{\ell_2}\times R\Omega$

Here, $\ell_1 = 125$ cm, $\ell_2 = 100$ cm, $R = 2\Omega$.

$\therefore \quad r = 0.5\Omega$

97. **(c)**

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

99. **(c)** From relation $\vec{J} = \sigma\vec{E}$, the current density $\vec{J}$ at any point in ohmic resistor is in direction of electric field $\vec{E}$ at that point. In space having non-uniform electric field, charges released from rest may not move along ELOF. Hence Assertion is correct while Reason is incorrect.

100. **(a)** In the absence of the electric current, the free electrons in a conductor are in a state of random motion, like molecule in a gas. Their average velocity is zero. i.e. they do not have any net velocity in a direction. As a result, there is no net magnetic force on the free electrons in the magnetic field. On passing the current, the free electrons acquire drift velocity in a definite direction, hence magnetic force acts on them, unless the field has no perpendicular component.

101. **(c)** Drift speed is the average speed between two successive collisions.

102. **(c)**

103. **(c)**

104. **(a)** Glow = Power (P) = I^2R

$\therefore \frac{dP}{P} = 2\left(\frac{dI}{I}\right) = 2 \times 0.5 = 1\%$

105. **(a)** Power loss = $i^2R = \left(\frac{P}{V}\right)^2 R$

[P = Transmitted power]

106. **(d)** The e.m.f. of a dry cell is dependent upon the electrode potential of cathode and anode which in turn is dependent upon the reaction involved as well as concentration of the electrolyte. It has nothing to do with size of the cell.

107. **(c)** Positive terminal of a battery is point of highest potential and current flows from highest to lowest potential i.e. from +ve to –ve potential.

108. **(a)**

109. **(a)** Sensitivity $\propto \frac{1}{\text{Potential gradient}} \propto$ (Length of wire)

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

111. **(a)** Sensitivity $\propto \frac{1}{\text{Potential gradient}} \propto$ Length of wire.

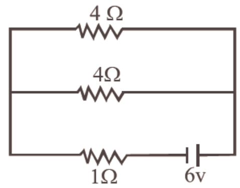
112. **(a)** Resistance wire $R = \rho\frac{\ell}{A}$, where ρ is resistivity of material which does not depend on the geometry of wire. Since when wire is bent resistivity, length and area of cross-section do not change, therefore resistance of wire also remain same.

113. **(c)** A → (2); B → (1); C → (4); D → (3)

114. **(b)** A → (1); B → (3); C → (4); D → (2)

115. (2A) Two 4Ω resistors are in parallel combination. Their equivalent resistance

$= \frac{4 \times 4}{4+4} = \frac{16}{8} = 2\Omega$



$\therefore$ Total resistance of the network = 2 + 1 = 3Ω

$\therefore$ Current through 1Ω resistor $= \frac{6}{3} = 2A$

116. (2Ω) Short circuit current

$i_{SC} = \frac{E}{r} \Rightarrow 3 = \frac{6}{r} \Rightarrow r = 2\Omega$

117. (0.04 Ω) $R = \frac{P}{I^2} = \frac{1}{25} = 0.04\Omega$

118. (20 min) W = Power × time $= \frac{V^2t}{R}$ R is the same.

$\therefore V^2t$ = constant. $V_1^2 t_1 = V_2^2 t_2 \Rightarrow 220^2 \times 5 = 110^2 t_2$

$\therefore t_2 = 20$ min.

119. (0.5 Ω) Power is maximum when $r = R$, $R = r = 0.5\Omega$.

120. (True) Voltmeter is a galvanometer with high resistance. It measures potential drop across any part of an electrical circuit. It is connected in parallel so that it does not draw any current itself (due to high resistance) and does not affect net resistance of the circuit.

121. (False)

122. (True) On increasing temperature of wire the kinetic energy of free electrons increase and so they collide more rapidly with each other and hence their drift velocity decreases.

123. (False) Also when temperature increases, resistivity increases and resistivity is inversely proportional to conductivity of material.

4 Moving Charges and Magnetism

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1 Magnetic field at the centre of a circular coil of radius r, through which a current I flows is
(a) directly proportional to r
(b) inversely proportional to I
(c) directly proportional to I
(d) directly proprotional to I^2

2. A long solenoid carrying a current produces a magnetic field B along its axis. If the current is double and the number of turns per cm is halved, the new value of the magnetic field is
(a) 4 B (b) B/2 (c) B (d) 2 B

3. The magnetic field around a long straight current carrying wire is
(a) spherical symmetry (b) cylindrical symmetry
(c) cubical symmetry (d) unsymmetrical

4. Magnetic field at the centre of a circular coil of radius r, through which a current I flows is
(a) directly proportional to r
(b) inverseley proportional to I
(c) directly proportional to I
(d) directly proprotional to I^2

5. Which of the following statements is/are correct?
I. The magnetic field in the open space inside the toroid is constant.
II. The magnetic field in the open space exterior to the toroid is constant.
III. The magnetic field inside the core of toroid is constant.
(a) I and II (b) II and III (c) III only (d) I only

6. A particle of mass m and charge q enters a magnetic field B perpendicularly with a velocity v. The radius of the circular path described by it will be
(a) Bq/mv (b) mq/Bv (c) mB/qv (d) mv/Bq

7. Which of the following statement(s) is/are true/false?
I. A charged particle moves perpendicular to the magnetic field. Its kinetic energy remains constant, but momentum changes.
II. Force acts perpendicular to the velocity of particle.
(a) F, F (b) F, T (c) T, T (d) T, F

8. In a region, steady and uniform electric and magnetic fields are present. These two fields are parallel to each other. A charged particle is released from rest in this region. The path of the particle will be a
(a) helix (b) straight line
(c) ellipse (d) circle

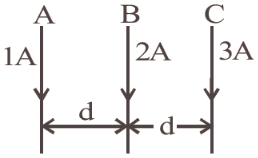
9. Direction of force due to magnetic field on a moving charged particle is
I. perpendicular to direction of velocity of charged particle.
II. perpendicular to direction of magnetic field.
III. parallel to direction of velocity of charged particle.
IV. parallel to the direction of magnetic field.
True/false statements are
(a) T, F, F, T (b) T, T, F, F
(c) T, F, T, F (d) F, F, T, T

10. Consider the following statements and select the true/false.
I. Force on the charged particle will be zero if it is at rest.
II. Direction of force on moving charge particle is given by Fleming's Left Hand Rule.
III. A charged particle enters a region of uniform magnetic field at an angle of 45° to the magnetic lines of force, the path of the particle is a circle.
IV. There is no change in the kinetic energy of a charged particle moving in a magnetic field although a magnetic force is acting on it.
(a) F, F, F, T (b) F, T, F, F
(c) T, T, F, T (d) F, F, T, T

11. A beam of electrons is moving with constant velocity in a region having simultaneous perpendicular electric and magnetic fields of strength 20 Vm^{-1} and 0.5 T respectively at right angles to the direction of motion of the electrons. Then the velocity of electrons must be
(a) 8 m/s (b) 20 m/s (c) 40 m/s (d) $\frac{1}{40}$ m / s

12. Two thin, long, parallel wires, separated by a distance 'd' carry a current of 'i' A in the same direction. They will
(a) repel each other with a force of $\mu_0 i^2/(2\pi d)$
(b) attract each other with a force of $\mu_0 i^2/(2\pi d)$
(c) repel each other with a force of $\mu_0 i^2/(2\pi d^2)$
(d) attract each other with a force of $\mu_0 i^2/(2\pi d^2)$

13. Three wires A, B and C are situated at the same distance. A current of 1A, 2A, 3A flows through these wires in the same direction. Then the resultant force on B is directed
(a) Towards A
(b) Towards C
(c) Perpendicular to the plane of paper and outward
(d) Perpendicular to the plane of paper and inward



14. The magnetic dipole moment of a current loop is independent of
(a) magnetic field in which it is lying
(b) number of turns
(c) area of the loop
(d) current in the loop

15. A current carrying loop is placed in a uniform magnetic field. The torque acting on it does not depend upon
(a) shape of the loop (b) area ot the loop
(c) value of the current (d) magnetic field

16. A square current carrying loop is suspended in a uniform magnetic field acting in the plane of the loop. If the force on one arm of the loop is $\vec{F}$, the net force on the remaining three arms of the loop is
(a) $3\vec{F}$ (b) $-\vec{F}$ (c) $-3\vec{F}$ (d) $\vec{F}$

17. The current sensitivity of a galvanometer is defined as
(a) the current flowing through the galvanometer when a unit voltage is applied across its terminals.
(b) current per unit deflection.
(c) deflection per unit current.
(d) dflection per unit current when a unit voltage is applied across its terminals.

18. The deflection in a moving coil galvanometer is
(a) directly proportional to the torsional constant
(b) directly proportional to the number of turns in the coil
(c) inversely proportional to the area of the coil
(d) inversely proportional to the current flowin g

19. The galvanometer cannot as such be used as an ammeter to measure the value of current in a given circuit. The following reasons are
I. galvanometer gives full scale deflection for a small current.
II. galvanometer has a large resistance.
III. a galvanometer can give inaccurate values.
The correct reasons are:
(a) I and II (b) II and III
(c) I and III (d) I, II and III

20. A galvanometer having a resistance of 80 ohms is shunted by a wire of resistance 2 ohms. If the total current is 1amp., the part of it passing through the shunt will be
(a) 0.25 amp (b) 0.8 amp
(c) 0.02 amp (d) 0.5 amp

21. The resistance of an ammeter is 13 Ω and its scale is graduated for a current upto 100 amps. After an additional shunt has been connected to this ammeter it becomes possible to measure currents upto 750 amperes by this meter. The value of shunt-resistance is
(a) 2 Ω (b) 0.2 Ω (c) 2 kΩ (d) 20 Ω

22. The magnetic dipole moment of a current carrying coil does ***not*** depend upon **[CBSE 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.

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

24. Biot-Savart law indicates that the moving electrons (velocity v) produce a magnetic field **B** such that
(a) B is perpendicular of v
(b) B is parallel to v
(c) it obeys inverse cube law
(d) it is along the line joining the electron and point of observationt.

25. 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 moment does not change
(c) The magnitude of B at (0, 0, z), z > R increases
(d) The magnitude of B at (0, 0, z), z >> R is unchanged

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

27. A galvanometer of resistance 100 Ω gives a full scale deflection for a current of 10^{-5} A. To convert it into a ammeter capable of measuring upto 1 A, we should connect a resistance of
(a) 1 Ω in parallel (b) 10^{-3} Ω in parallel
(c) 10^5 Ω in series (d) 100 Ω in series

28. An electric charge in uniform motion produces
(a) an electric field only
(b) a magnetic field only
(c) both electric and magnetic fields
(d) no such field at all

29. An electron having a charge e moves with a velocity v in X-direction. Magnetic field acts on it in Y-direction? The force on the electron acts in
(a) positive direction of Y-axis
(b) negative direction of Y-axis
(c) positive direction of Z-axis
(d) negative direction of Z-axis

30. An electron moves in a circular orbit with a uniform speed v. It produces a magnetic field B at the centre of the circle. The radius of the circle is proportional to

(a) $\sqrt{\frac{B}{v}}$ (b) $\frac{B}{v}$ (c) $\sqrt{\frac{v}{B}}$ (d) $\frac{v}{B}$

31. A charged particle of mass m and charge q travels on a circular path of radius r that is perpendicular to a magnetic field B. The time taken by the particle to complete one revolution is

(a) $\frac{2\pi q^2 B}{m}$ (b) $\frac{2\pi mq}{B}$ (c) $\frac{2\pi m}{qB}$ (d) $\frac{2\pi qB}{m}$

32. A charge q is moving with a velocity v parallel to a magnetic field B. Force on the charge due to magnetic field is

(a) q v B (b) q B/v (c) zero (d) B v/q

33. Consider a moving charged particle in a region of magnetic field. Which of the following statements are correct?

(a) If **v** is parallel to **B**, then path of particle is spiral.
(b) If **v** is perpendicular to **B**, then path of particle is a circle.
(c) If **v** has a component along **B**, then path of particle is zig-zag.
(d) If **v** is along **B**, then path of particle is a circle.

34. Which of the above statements is/are incorrect? A velocity selector; (a region of perpendicular electric and magnetic field)

(a) allows charged particles to pass straight when $v = E/B$.
(b) deflects particles in the direction of electric field when $v < E/B$.
(c) deflects particles in a direction perpendicular to both v and B, when $v < E/B$.
(d) deflects all particles in a direction perpendicular to both E and B.

35. Select the incorrect statement about Lorentz Force.

(a) In presence of electric field $\vec{E}(r)$ and magnetic field $\vec{B}(r)$ the force on a moving electric charge is $\vec{F} = q[\vec{E}(r) + v \times \vec{B}(r)]$
(b) The force, due to magnetic field on a negative charge is opposite to that on a positive charge.
(c) The force due to magnetic field become zero if velocity and magnetic field are parallel or antiparallel.
(d) For a static charge the magnetic force is maximum.

36. In the resonance condition

(a) the frequency of revolution of charged particle is equal to the frequency of A.C. voltage sources
(b) the frequency of revolution of charged particle is equal to the frequency of applied magnetic field
(c) the frequency of revolution of charged particle is equal to the frequency of rotation of earth
(d) the frequency of revolution of charged particle, frequency of A.C. source and frequency of magnetic field are equal

37. A charged particle enters in a uniform magnetic field with a certain velocity. The power delivered to the particle by the magnetic field depends on

(a) force exerted by magnetic field and velocity of the particle.
(b) angular speed ω and radius r of the circular path.
(c) angular speed ω and acceleration of the particle.
(d) None of these

38. A proton moving with a constant velocity passes through a region of space without any change in its velocity. If E and B represent the electric and magnetic fields respectively, this region of space may not have

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

39. A charged particle with charge q enters a region of constant, uniform and mutually orthogonal fields $\vec{E}$ and $\vec{B}$ with a velocity $\vec{v}$ perpendicular to both $\vec{E}$ and $\vec{B}$, and comes out without any change in magnitude or direction of $\vec{v}$. Then

(a) $\vec{v} = \vec{B} \times \vec{E} / E^2$ (b) $\vec{v} = \vec{E} \times \vec{B} / B^2$
(c) $\vec{v} = \vec{B} \times \vec{E} / B^2$ (d) $\vec{v} = \vec{E} \times \vec{B} / E^2$

40. If an electron and a proton having same momenta enter perpendicular to a magnetic field, then

(a) curved path of electron and proton will be same (ignoring the sense of revolution)
(b) they will move undeflected
(c) curved path of electron is more curved than that of the proton
(d) path of proton is more curved

41. A beam of electrons is moving with constant velocity in a region having simultaneous perpendicular electric and magnetic fields of strength 20 Vm^{-1} and 0.5 T respectively at right angles to the direction of motion of the electrons. Then the velocity of electrons must be

(a) 8 m/s (b) 20 m/s (c) 40 m/s (d) $\frac{1}{40}$ m / s

42. A charge moving with velocity v in X-direction is subjected to a field of magnetic induction in negative X-direction. As a result, the charge will

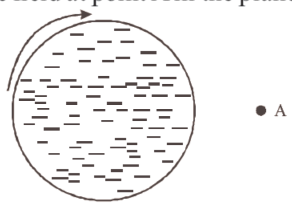
(a) remain unaffected
(b) start moving in a circular path Y–Z plane
(c) retard along X-axis
(d) move along a helical path around X-axis

43. A proton (mass m and charge + e) and an α-particle (mass 4m and charge + 2e) are projected with the same kinetic energy at right angles to the uniform magnetic field. Which one of the following statements will be true ?

(a) The α-particle will be bent in a circular path with a small radius that for the proton
(b) The radius of the path of the α-particle will be greater than that of the proton
(c) The α-particle and the proton will be bent in a circular path with the same radius
(d) The α-particle and the proton will go through the field in a straight line

44. A positively charged particle moving into east enters a region of uniform magnetic field directed vertically upwards. The particle will
(a) continue to move due east
(b) move in a circular orbit with its speed unchanged
(c) move in a circular orbit with its speed increased
(d) gets deflected vertically upwards.

45. The negatively and uniformly charged nonconducting disc as shown is rotated clockwise.
The direction of the magnetic field at point A in the plane of the disc is
(a) into the page
(b) out of the page
(c) up the page
(d) down the page



46. A proton (mass = 1.67×10^{-27} kg and charge = 1.6×10^{-19} C) enters perpendicular to a magnetic field of intensity 2 weber/m^2 with a velocity 3.4×10^7 m/sec. The acceleration of the proton should be
(a) 6.5×10^{15} m/sec^2 (b) 6.5×10^{13} m/sec^2
(c) 6.5×10^{11} m/sec^2 (d) 6.5×10^{9} m/sec^2

47. The magnetic field around a long straight current carrying wire is
(a) spherical symmetry (b) cylindrical symmetry
(c) cubical symmetry (d) unsymmetrical

48. A current is passed through a straight wire. The magnetic field established around it has its lines of force
(a) circular and endless (b) oval in shape and endless
(c) straight (d) All of the above

49. A current carrying coil is subjected to a uniform magnetic field. The coil will orient so that its plane becomes
(a) inclined at 45° to the magnetic field
(b) inclined at any arbitrary angle to the magnetic field
(c) parallel to the magnetic field
(d) perpendicular to the magnetic field

50. A small current element of length $d\ell$ and carrying current is placed at (1, 1, 0) and is carrying current in '+z' direction. If magnetic field at origin be $\vec{B}_1$ and at point (2, 2, 0) be $\vec{B}_2$ then
(a) $\vec{B}_1 = \vec{B}_2$ (b) $|\vec{B}_1| = |2\vec{B}_2|$
(c) $\vec{B}_1 = -\vec{B}_2$ (d) $\vec{B}_1 = -2\vec{B}_2$

51. A current I flows along the length of an infinitely long, straight, thin walled pipe. Then
(a) the magnetic field at all points inside the pipe is the same, but not zero
(b) the magnetic field is zero only on the axis of the pipe
(c) the magnetic field is different at different points inside the pipe
(d) the magnetic field at any point inside the pipe is zero

52. If a copper rod carries a direct current, the magnetic field associated with the current will be
(a) only inside the rod
(b) only outside the rod
(c) both inside and outside the rod
(d) neither inside nor outside the rod

53. Biot-Savart law indicates that the moving electrons velocity (V) produce a magnetic field B such that
(a) B PV (b) $B \perp V$
(c) it obeys inverse cube law
(d) it is along the line joining electron and point of observation

54. Ampere's circuital law is equivalent to
(a) Biot-Savart law (b) Coulomb's law
(c) Faraday's law (d) Kirchhoff's law

55. A solenoid of length 1.5 m and 4 cm diameter possesses 10 turns per cm. A current of 5A is flowing through it, the magnetic induction at axis inside the solenoid is
($\mu_0 = 4\pi \times 10^{-7}$ weber amp^{-1} m^{-1})
(a) $4\pi \times 10^{-5}$ gauss (b) $2\pi \times 10^{-5}$ gauss
(c) $4\pi \times 10^{-5}$ tesla (d) $2\pi \times 10^{-5}$ tesla

56. The magnetic field B at a point on one end of a solenoid having n turns per metre length and carrying a current of i ampere is given by
(a) $\frac{\mu_0 ni}{e}$ (b) $\frac{1}{2}\mu_0 ni$ (c) $4\pi\mu_0 ni$ (d) ni

57. A long solenoid has 200 turns per cm and carries a current i. The magnetic field at its centre is 6.28×10^{-2} Weber/m^2. Another long solenoid has 100 turns per cm and it carries a current $\frac{i}{3}$. The value of the magnetic field at its centre is
(a) 1.05×10^{-2} Weber/m^2 (b) 1.05×10^{-5} Weber/m^2
(c) 1.05×10^{-3} Weber/m^2 (d) 1.05×10^{-4} Weber/m^2

58. Two concentric circular coils of ten turns each are situated in the same plane. Their radii are 20 and 40 cm and they carry respectively 0.2 and 0.4 ampere current in opposite direction. The magnetic field in weber/m^2 at the centre is
(a) $\mu_0/80$ (b) $7\mu_0/80$ (c) $(5/4)\mu_0$ (d) zero

59. A coil of one turn is made of a wire of certain length and then from the same length a coil of two turns is made. If the same current is passed in both the cases, then the ratio of the magnetic inductions at their centres will be
(a) 2 : 1 (b) 1 : 4 (c) 4 : 1 (d) 1 : 2

60. Magnetic field intensity at the centre of a coil of 50 turns, radius 0.5 m and carrying a current of 2 A is
(a) 0.5×10^{-5} T (b) 1.25×10^{-4} T
(c) 3×10^{-5} T (d) 4×10^{-5} T

61. A coil carrying electric current is placed in uniform magnetic field, then
(a) torque is formed (b) e.m.f is induced
(c) both (a) and (b) are (d) None of these

62. Two long wires are hanging freely. They are joined first in parallel and then in series and then are connected with a battery. In both cases which type of force acts between the two wires?
(a) Attraction force when in parallel and repulsion force when in series
(b) Repulsion force when in parallel and attraction force when in series
(c) Repulsion force in both cases
(d) Attraction force in both cases

63. A moving coil galvanometer has N number of turns in a coil of effective area A, it carries a current I. The magnetic field B is radial. The torque acting on the coil is

(a) NA^2B^2I (b) $NABI^2$ (c) N^2ABI (d) $NABI$

64. A conducting circular loop of radius r carries a constant current i. It is placed in a uniform magnetic field $\vec{B}_0$ such that $\vec{B}_0$ is perpendicular to the plane of the loop. The magnetic force acting on the loop is

(a) $ir B_0$ (b) $2\pi ir B_0$ (c) zero (d) $\pi ir B_0$

65. Two long conductors, separated by a distance d carry current I_1 and I_2 in the same direction. They exert a force F on each other. Now the current in one of them is increased to two times and its direction is reversed. The distance is also increased to $3d$. The new value of the force between them is

(a) $-\frac{2F}{3}$ (b) $\frac{F}{3}$ (c) $-2F$ (d) $-\frac{F}{3}$

66. A current of 5 ampere is flowing in a wire of length 1.5 metres. A force of 7.5 N acts on it when it is placed in a uniform magnetic field of 2 tesla. The angle between the magnetic field and the direction of the current is

(a) 30° (b) 45° (c) 60° (d) 90°

67. A straight wire of length 0.5 metre and carrying a current of 1.2 ampere is placed in uniform magnetic field of induction 2 tesla. The magnetic field is perpendicular to the length of the wire. The force on the wire is

(a) 2.4 N (b) 1.2 N (c) 3.0 N (d) 2.0 N

68. An electric current of 30 ampere is flowing in each of two parallel conducting wires placed 5 cm apart. The force acting per unit length on either of the wires will be

(a) 3.6×10^{-3} N/m (b) 3.6×10^{-3} dyne/cm
(c) 3.6×10^{-5} N/m (d) 3.6×10^{-2} N/m

69. The distance between the wires of electric mains is 12 cm. These wires experience 4 mg wt. per unit length. The value of current flowing in each wire will be

(a) 4.85 A (b) 0
(c) 4.85×10^{-2} A (d) 4.85×10^{-4} A

70. A current carrying conductor placed in a magnetic field experiences maximum force when angle between current and magnetic field is

(a) $3\pi/4$ (b) $\pi/2$ (c) $\pi/4$ (d) zero

71. A current of 3 A is flowing in a linear conductor having a length of 40 cm. The conductor is placed in a magnetic field of strength 500 gauss and makes an angle of 30º with the direction of the field. It experiences a force of magnitude

(a) 3×10^{-4} N (b) 3×10^{-2} N
(c) 3×10^{2} N (d) 3×10^{4} N

72. Two straight horizontal parallel wires are carrying the same current in the same direction, d is the distance between the wires. You are provided with a small freely suspended magnetic needle. At which of the following positions will the orientation of the needle be independent of the magnitude of the current in the wires ?

(a) At a distance $d/2$ from any of the wires
(b) At a distance $d/2$ from any of the wires in the horizontal plane
(c) Anywhere on the circumference of a vertical circle of radius d and centre halfway between the wires
(d) At points halfway between the wires in the horizontal plane

73. Two long parallel wires are at a distance of 1 metre. Both of them carry 5 ampere of current. The force of attraction per unit length between the two wires is

(a) 50×10^{-7} N/m (b) 2×10^{-8} N/m
(c) 5×10^{-8} N/m (d) 10^{-7} N/m

74. A and B are two conductors carrying a current i in the same direction. x and y are two electron beams moving in the same direction. Then

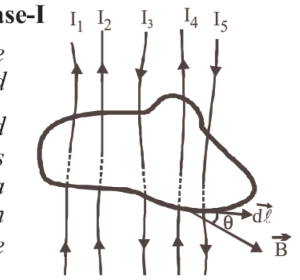
(a) there will be repulsion betwen A and B, attraction between x and y
(b) there will be attraction between A and B, repulsion between x and y
(c) there will be repulsion between A and B and also x and y
(d) there will be attraction between A and B and also x and y

Case/Passage Based Questions

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

Passage/Case-I

Ampere's circuital law states that *the line integral of magnetic field induction $\vec{B}$ around any closed path in vacuum is equal to μ_0 times the total current crossing the area bounded by the closed path provided the electric field inside the loop remains constant.*



i.e., $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 \sum I$ here $\sum I = I_1 + I_2 - I_3 + I_4 - I_5$

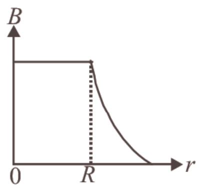
75. The magnetic field B at a point on one end of a solenoid having n turns per metre length and carrying a current of i ampere is given by

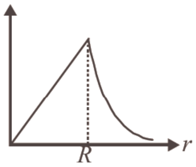
(a) $\frac{\mu_0 ni}{e}$ (b) $\frac{1}{2}\mu_0 ni$
(c) $4\pi\mu_0 ni$ (d) ni

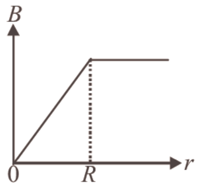
76. If a long hollow copper pipe carries a direct current, the magnetic field associated with the current will be

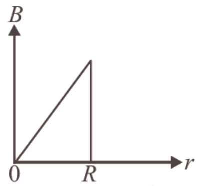
(a) only inside the pipe
(b) only outside the pipe
(c) neither inside nor outside the pipe
(d) both inside and outside the pipe

77. The correct plot of the magnitude of magnetic field $\vec{B}$ vs distance r from centre of the wire is, if the radius of wire is R

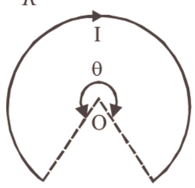
(a) 

(b) 

(c) 

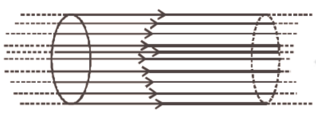
(d) 

78. A current of I ampere flows in a wire forming a circular arc of radius r metres subtending an angle θ at the centre as shown. The magnetic field at the centre O in tesla is



(a) $\frac{\mu_0 I\theta}{4\pi r}$ (b) $\frac{\mu_0 I\theta}{2\pi r}$ (c) $\frac{\mu_0 I\theta}{2r}$ (d) $\frac{\mu_0 I\theta}{4r}$

79. The figure shows n (n being an even number) wires placed along the surface of a cylinder of radius r. Each wire carries current i in the same direction. The net magnetic field on the axis of the cylinder is



(a) $\mu_0 ni$ (b) $\frac{\mu_0 ni}{2\pi r}$ (c) zero (d) $\frac{\mu_0 ni}{4\pi r}$

Passage/Case-II

The moving charged particle will experience **electric force** $\vec{F}_e = q\vec{E}$ and **magnetic force** $\vec{F}_m = q(\vec{v} \times \vec{B})$

Net force on the charged particle $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$ "Lorentz-force"

Depending on the direction of $\vec{v}$, $\vec{E}$ and $\vec{B}$ various situations are possible and the motion in general is quite complex.

80. An electron having a charge e moves with a velocity v in X-direction. An electric field acts on it in Y-direction? The force on the electron acts in
(a) positive direction of Y-axis
(b) negative direction of Y-axis
(c) positive direction of Z-axis
(d) negative direction of Z-axis

81. Lorentz force is
(a) electrostatic force acting on a charged particle.
(b) magnetic force acting on a moving charged particle.
(c) the vector sum of electrostatic and magnetic force acting on a moving charged particle.
(d) the vector sum of gravitational and magnetic force acting on a moving charged particle.

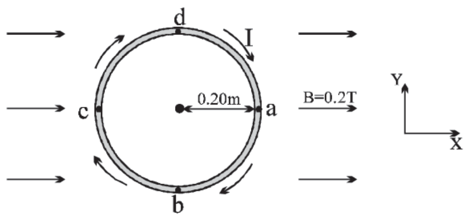
82. A certain region has an electric field $\vec{E} = (2\hat{i} - 3\hat{j})$ N/C and a uniform magnetic field $\vec{B} = (5\hat{i} + 3\hat{j} + 4\hat{k})$ T. The force experienced by a charge 1C moving with velocity $(\hat{i} + 2\hat{j})$ ms^{-1} is
(a) $(10\hat{i} - 7\hat{j} - 7\hat{k})$ (b) $(10\hat{i} + 7\hat{j} + 7\hat{k})$
(c) $(-10\hat{i} + 7\hat{j} + 7\hat{k})$ (d) $(10\hat{i} + 7\hat{j} - 7\hat{k})$

83. A proton moving with a constant velocity passes through a region of space without any change in its velocity. If E and B represent the electric and magnetic fields respectively, this region of space may not have
(a) $E = 0, B = 0$ (b) $E = 0, B \neq 0$
(c) $E \neq 0, B = 0$ (d) $E \neq 0, B \neq 0$

84. A charged particle with velocity 2×10^3 m/s passes undeflected through electric and magnetic field. Magnetic field is 1.5 tesla. The electric field intensity would be
(a) 2×10^3 N/C (b) 1.5×10^3 N/C
(c) 3×10^3 N/C (d) $4/3 \times 10^{-3}$ N/C

Passage/Case-III

A rigid circular loop has a radius of 0.20 m and is in the x-y plane. A clockwise current I is carried by the loop, as shown. The magnitude of the magnetic moment of the loop is 0.75 A-m^2. A uniform external magnetic field, $B = 0.20$ T in the positive x-direction, is present



85. In figure, the magnitude of the magnetic torque exerted on the loop is closest to
(a) 0.55 N-m (b) 0.15 N-m (c) 0.45 N-m (d) 0.35 N-m

86. In figure the loop is released from rest. The initial motion of the loop is described by
(a) point a moves out of the plane, point c moves into the plane
(b) points a, b, c and d move counterclockwise
(c) point a, b, c and d move clockwise
(d) point c moves out of the plane, point a moves into the plane

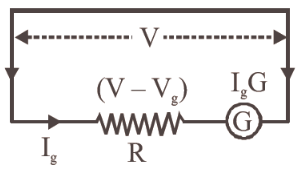
87. In figure, an external torque changes the orientation of loop from one of lowest potential energy to one of highest potential energy. The work done by the external torque is closest to
(a) 0.5 J (b) 0.2 J (c) 0.3 J (d) 0.4 J

88. A wire is placed parallel to the lines of force in a magnetic field and a current flows in the wire. Then
(a) the wire will experience a force in the direction of the magnetic field
(b) the wire will not experience any force at all
(c) the wire will experience a force in a direction opposite to the field
(d) it experiences a force in a direction perpendicular to lines of force

89. A current carrying coil is subjected to a uniform magnetic field. The coil will orient so that its plane becomes
(a) inclined at 45° to the magnetic field
(b) inclined at any arbitrary angle to the magnetic field
(c) parallel to the magnetic field
(d) perpendicular to the magnetic field

Passage/Case-IV

(a) A galvanometer is converted to voltmeter by putting a high resistance in series with it.
Total resistance of voltmeter = G + R where G is the galvonometer resistance.
R is the resistance added in series.

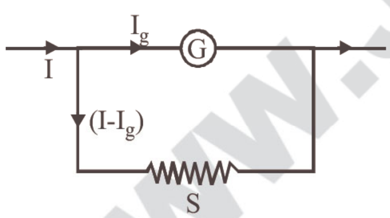


Current through the galvanometer, $I_g = \frac{V}{G+R}$
where V is the potential difference across the voltmeter.

And resistance, $R = \frac{V}{I_g} - G$

(b) A galvanometer is converted into an ammeter by connecting a low resistance (shunt) in parallel with it.

Shunt $S = \left(\frac{I_g}{I - I_g}\right)G$ where G is the galvanometere resistance.



I is the total current through the ammeter.
I_g is the current through the ammeter.

Effective resistance of the ammeter $R = \frac{GS}{G+S}$
The range of an ammeter can be increased N times by reducing shunt S = G/N – 1
An ideal ammeter has zero resistance.

90. A galvanometer of resistance, G is shunted by a resistance S ohm. To keep the main current in the circuit unchanged, the resistance to be put in series with the galvanometer is
(a) $\frac{S^2}{(S+G)}$ (b) $\frac{SG}{(S+G)}$ (c) $\frac{G^2}{(S+G)}$ (d) $\frac{G}{(S+G)}$

91. A galvanometer having a coil resistance of 60 Ω shows full scale deflection when a current of 1.0 amp passes through it. It can be converted into an ammeter to read currents upto 5.0 amp by
(a) putting in series a resistance of 15Ω
(b) putting in series a resistance of 240Ω
(c) putting in parallel a resistance of 15Ω
(d) putting in parallel a resistance of 240Ω

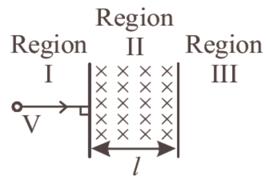
92. A milli voltmeter of 25 milli volt range is to be converted into an ammeter of 25 ampere range. The value (in ohm) of necessary shunt will be
(a) 0.001 (b) 0.01 (c) 1 (d) 0.05

93. A moving coil galvanometer of resistance 100Ω is used as an ammeter using a resistance 0.1Ω. The maximum deflection current in the galvanometer is 100μA. Find the minimum current in the circuit so that the ammeter shows maximum deflection
(a) 100.1 mA (b) 1000.1 mA
(c) 10.01 mA (d) 1.01 mA

94. A galvanometer of resistance 5 ohms gives a full scale deflection for a potential difference of 10 mV. To convert the galvanometer into a voltmeter giving a full scale deflection for a potential difference of 1V, the size of the resistance that must be attached to the voltmeter is
(a) 0.495 ohm (b) 49.5 ohm
(c) 495 ohm (d) 4950 ohm

Passage/Case-V

A particle of mass *m* and charge *q*, moving with velocity *V* enters Region II normal to the boundary as shown in the figure. Region II has a uniform magnetic field *B* perpendicular to the plane of the paper. The length of the Region II is *l*.



95. (a) The particle enters Region III only if its velocity $V > \frac{qB}{m}$
(b) The particle enters Region III only if its velocity $V < \frac{qlB}{m}$
(c) The particle enters Region III only if its velocity $V = \frac{qlB}{m}$
(d) All of the above

96. Path length of the particle in Region II is maximum when
(a) velocity $V = \frac{qlB}{2m}$ (b) velocity $V = \frac{2qlB}{m}$
(c) velocity $V = \frac{qlB}{m}$ (d) velocity $V = \frac{4qlB}{m}$

97. Time spent in Region II as long as the particle returns to Region I is
(a) two times if velocity *V* is doubled
(b) halved if velocity is doubled
(c) halved if velocity is halved
(d) same for any value of *V*

98. If the direction of the initial velocity of the charged particle is neither along nor perpendicular to that of the magnetic field, then the orbit will be
(a) a straight line (b) an ellipse
(c) a circle (d) a helix

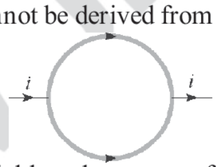
99. A charged particle moves with velocity $\vec{V}$ in a uniform magnetic field $\vec{B}$. The magnetic force experienced by the particle is
(a) always zero
(b) never zero
(c) zero, if $\vec{B}$ and $\vec{V}$ are perpendicular
(d) zero, if $\vec{B}$ and $\vec{V}$ are parallel

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*
(a) If both **Assertion** and **Reason** are **correct** and the Reason is the **correct explanation** of the Assertion.
(b) If both **Assertion** and **Reason** are correct but Reason is **not the correct explanation** of the Assertion.
(c) If the **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If the **Assertion** is **incorrect** but the **Reason** is **correct**.

100. **Assertion:** Ampere's circuital law is analogous of Biot-Savart's law.
Reason: Ampere's circuital law cannot be derived from the Biot-savart's law.

101. **Assertion :** Figure shows a current carrying circular loop. The magnetic field at the centre of loop is zero.



Reason : Magnitude of magnetic field at the centre of circular loop carrying current i is given by $B = \frac{\mu_0 ni}{R}$.

102. **Assertion :** A current I flows along the length of an infinitely long straight and thin walled pipe. Then the magnetic field at any point inside the pipe is zero.
Reason : $\oint \vec{B}.\vec{d\ell} = \mu_0 I$ and $\sum I_{in} = 0$

103. **Assertion :** The magnetic field at the end of a very long current carrying solenoid is half of that at the center.
Reason : If the solenoid is sufficiently long, the field within it is uniform.

104. **Assertion :** Magnetic field interacts with a moving charge and not with a stationary charge.
Reason : A moving charge produces a magnetic field.

105. **Assertion :** If a charged particle is released from rest in a region of uniform electric and magnetic fields parallel to each other, it will move in a straight line.
Reason : The electric field exerts no force on the particle but the magnetic field does.

106. **Assertion :** A charged particle moves in a uniform magnetic field. The velocity of the particle at some instant makes an acute angle with the magnetic field. The path of the particle is a helix with constant pitch.
Reason : The force on the particle is given by $\vec{F} = q\left(\vec{v}.\vec{B}\right)$.

107. **Assertion:** The work done by magnetic force on a moving charged particle is zero.
Reason: The work done by magnetic force on a charged particle is zero as the force is always parallel to velocity of particle.

108. **Assertion :** A direct current flows through a thin conductor produces magnetic field only outside the conductor.
Reason : There is no flow of charge carriers inside the conductor.

109. **Assertion :** The net charge in a current carrying wire is zero and so magnetic force on the wire in magnetic field is zero.
Reason : The force on a current carrying wire is given by $F = qVB \sin\theta$ [where q = charge, V = potential difference, B = field, θ = angle]

110. **Assertion:** Electron moving perpendicular to $\vec{B}$ will perform circular motion ?
Reason: Force by magnetic field is perpendicular to velocity

111. **Assertion :** If the current in a solenoid is reversed in direction while keeping the same magnitude, the magnetic field energy stored in the solenoid remains unchanged.
Reason : Magnetic field energy density is proportional to the magnetic field.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

112. Match Column I and Column II.

	Column I		Column II
(A)	Biot-Savart's law	(1)	$\frac{\mu_0 I_1 I_2}{2\pi d}$
(B)	Ampere's circuital law	(2)	$q[\vec{E} + (\vec{V} \times \vec{B})]$
(C)	Force between two parallel current carrying conductors	(3)	$\oint \vec{B}.\vec{dl} = \mu_0 \Sigma i$
(D)	Lorentz force	(4)	$\vec{B} = \frac{\mu_0 i}{4\pi}\int \frac{dl \sin\theta}{r^2}\hat{n}$

(a) (A) → (4) ; (B) → (3) ; (C) → (1) ; (D) → (2)
(b) (A) → (2) ; (B) → (2) ; (C) → (4) ; (D) → (3)
(c) (A) → (4) ; (B) → (3) ; (C) → (2) ; (D) → (1)
(d) (A) → (2) ; (B) → (1) ; (C) → (4) ; (D) → (3)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

113. Lorentz force is _________ charged particle.

114. An electric charge $+q$ moves with velocity $\vec{v} = 3\hat{i} + 4\hat{j} + \hat{k}$ in an electromagnetic field given by $\vec{E} = 3\hat{i} + \hat{j} + 2\hat{k}$ and $\vec{B} = \hat{i} + \hat{j} - 3\hat{k}$. The y-component of the force experienced by $+q$ is _______.

115. If m is magnetic moment and B is the magnetic field, then the torque is given by _______.

116. An 8 cm long wire carrying a current of 10 A is placed inside a solenoid perpendicular to its axis. If the magnetic field inside the solenoid is 0.3 T, then magnetic force on the wire is _______.

117. The magnetic induction at a point P which is at a distance of 4 cm from a long current carrying wire is 10^{-3} T. The field of induction at a distance 12 cm from the current will be _______ tesla.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

118. A charged particle undergoes uniform circular motion in a uniform magnetic field. The only force acting on the particle is that exerted by the uniform magnetic field. If now the speed of the same particle is somehow doubled keeping its charge and external magnetic field constant, then the centripetal force on the particle becomes four times.

119. The magnitude of centripetal force on a particle of mass m moving in a circle of radius R with uniform speed v is mv^2/R.

120. The magnetic field on the axis of a solenoid is non-uniform.

121. When a charged particle is projected along the axis of current carrying solenoid, the path of the particle is not changed.

122. A current carrying closed loop remains in equilibrium in a uniform and constant magnetic field parallel to its axis. Consider forces only due to this magnetic field.

123. Torque on a current carrying closed loop due to a magnetic field is maximum when the plane of the coil is parallel to the direction of the magnetic field.

ANSWER KEY & SOLUTIONS

1. **(c)** Field at the center of a circular coil of radius r is $B = \dfrac{\mu_0 I}{2r}$

2. **(c)** $B = \mu_0 N_0 i; B_1 = (\mu_0)\left(\dfrac{N_0}{2}\right)(2\ i) = \mu_0 N_0 i = B$
$\Rightarrow B_1 = B$

3. **(b)** Magnetic field is given by $B = \dfrac{\mu_0 i}{2\pi r}$ *i.e.*, $B \propto \dfrac{1}{r}$ which implies that field has cylindrical symmetry.

4. **(c)** Field at the center of a circular coil of radius r is
$B = \dfrac{\mu_0 I}{2r}$

5. **(c)**

6. **(d)** Force, $F = qVB = \dfrac{mv^2}{R}$ $\therefore R = \dfrac{mv}{Bq}$

7. **(c)** A force which always perpendicular to velocity of the particle does no work on the particle, but changes the direction of momentum of the particle.

8. **(b)** The charged particle will move along the lines of electric field (and magnetic field). Magnetic field will exert no force. The force by electric field will be along the lines of uniform electric field. Hence the particle will move in a straight line.

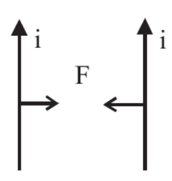
9. **(b)** (i) Lorentz force depends on q, **v** and **B** (charge of the particle, the velocity and the magnetic field). Force on a negative charge is opposite to that on a positive charge.
(ii) The magnetic force $q\ [\mathbf{v} \times \mathbf{B}]$ includes a vector product of velocity and magnetic field. The vector product makes the force due to magnetic field vanish (become zero) if velocity and magnetic field are parallel or anti-parallel. The force acts in a (sideways) direction perpendicular to both the velocity and the magnetic field. Its direction is given by the screw rule.

10. **(c)** When charged particle enters perpendicularly in a magnetic field, it moves in a circular path with a constant speed. Hence its kinetic energy also remains constant.

11. **(c)** The electron moves with constant velocity without deflection. Hence, force due to magnetic field is equal and opposite to force due to electric field.

$$qvB = qE \Rightarrow v = \frac{E}{B} = \frac{20}{0.5} = 40 \text{ m/s}$$

12. **(b)** When the direction of currents are same, the force is attractive. Hence, both the wires will attract each other Force per unit length.



$$\frac{F}{\ell} = \frac{\mu_0 i_1 i_2}{2\pi d} = \frac{\mu_0 i^2}{2\pi d}$$

13. **(b)** $F \propto i_1 i_2$, so force on B due to C will be greater than that due to A. Hence net force on B acts towards C.

14. **(a)** Current loop acts as a magnetic dipole. Its magnetic moment is given by
$M = NIA$
where N = number of turns, I = current in a loop,
A = area of the loop
From the above relation, we can conclude that magnetic dipole moment of a current loop is independent of magnetic field in which it is lying.

15. **(a)** Because $\tau = NiAB \cos\theta$

16. **(b)** The force on the two arms parallel to the field is zero.

$\therefore$ Force on remaining arms $= -F$

17. **(c)** The current sensitivily of a galvanometer is defined as the deflection produced in the galvanometer per unit current flowing through it.

18. **(b)** $\theta = \dfrac{NiAB}{C} \Rightarrow \theta \propto N$ [Number of turns]

19. **(a)** The galvanometer cannot as such be used as an ammeter to measure the value of the current in a given circuit. This is for two reasons (i) Galvanometer is a very sensitive device, it gives a full-scale deflection for a current of the order of μA. (ii) For measuring currents, the galvanometer has to be connected in series and as it has a large resistance, this will change the value of the current in the circuit.

20. **(c)** [Hint $\Rightarrow S \times (I - I_g) = R_g \times I_g$]

21. **(a)** We know

$$\frac{I}{I_S} = 1 + \frac{G}{S} \quad \frac{750}{100} = 1 + \frac{13}{S} \quad S \Rightarrow 2\Omega$$

22. **(d)**

23. **(d)** As we know that the uniqueness of helical path is determined by its pitch

$$\text{P(Pitch)} = \frac{2\pi mv\cos\theta}{Bq}$$

Where θ is angle of velocity of charge particle with x-axis For the given pitch d correspond to charge particle, we have

$$\frac{q}{m} = \frac{2\pi v\cos\theta}{BP} = \text{constant}$$

If motion is not helical, $(\theta = 0)$
As charged particles traverse identical helical paths in a completely opposite direction in a same magnetic field **B**, LHS for two particles should be same and of opposite sign.

$$\therefore \quad \left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0$$

24. **(a)** By Biot-Savart law

$$dB = \frac{Idl \sin\theta}{r^2} = \left(\frac{I \times dl}{r}\right)$$

In Biot-Savat's law, magnetic field $\mathbf{B} \| idl \times \mathbf{r}$ and *idl* due to flow of electron is in opposite direction of v and by direction of cross product of two vectors

$B \perp V$

So, the magnetic field is $\perp$ to the direction of flow of charge.

25. **(a)** As the direction of magnetic moment of circular loop of radius R placed in the x-y plane is along z-direction and given by $M = I(\pi r^2)$, when half of the loop with $x > 0$ is now bent so that it now lies in the y-z plane, the magnitudes of magnetic field moment of each semicircular loop of radius R lie in the x-y plane and the y-z plane is $M' = I(\pi r^2)/4$ and the direction of magnetic field moments are along z-directlon and x-direction respectively.
Then resultant is :

$$M_{net} = \sqrt{M'^2 + M'^2} = \sqrt{2}\, M' = \sqrt{2}\, I(\pi r^2)/4$$

So, $M_{net} < M$ or M diminishes.
Hence, the magnitude of magnetic moment is now diminishes.

26. **(d)** Magnetic Lorentz force :

$F = qVB \sin\theta$

Magnetic Lorentz force electron is projected with uniform velocity along the axis of a current carrying long solenoid $F = -qvB \sin 180° = 0 (\theta = 0°)$ as magnetic field and velocity are parallel and electric field is zero (E = 0) due to this magnetic field (B) perpendicular to the direction of motion (V). So it will not affect the velocity of moving charge particle. So the electron will continue to move with uniform velocity along the axis of the solenoid

27. **(b)** Here, $R_g = 100\,\Omega$; $I_g = 10^{-5}$ A; I = 1A; S = ?

$$S = \frac{I_g R_g}{\mathbf{I - I}_g} = \frac{10^{-5} \times 100}{1 - 10^{-5}} = 10^{-3}\,\Omega \text{ in parallel}$$

28. **(c)** An electric charge in uniform motion produces both electric and magnetic fields.

29. **(d)**

30. **(d)** $r = \dfrac{mv}{qB} \Rightarrow r \propto \dfrac{v}{B}$

31. **(c)** Equating magnetic force to centripetal force,

$$\frac{mv^2}{r} = qvB \sin 90°$$

Time to complete one revolution, $T = \dfrac{2\pi r}{v} = \dfrac{2\pi m}{qB}$

32. **(c)**

33. **(b)** If $v \perp B$, then path is circular and if v has a component along B, then path will be helical.

34. **(c)** In a velocity selector, where F_e and F_B are electric and magetic field, we get

Case I $\quad F_e = F_B \Rightarrow v = \dfrac{E}{B}$

Case II $\quad F_e > F_B \Rightarrow v < \dfrac{E}{B}$

Case III $\quad F_e < F_B \Rightarrow v > E / B$

35. **(d)** If charge is not moving then the magnetic force is zero.

Since $\vec{F}_m = q(\vec{v} \times \vec{B})$

As $\vec{v} = 0$, for stationary charge

$\therefore \quad \vec{F}_m = 0$

36. **(a)**

37. **(d)** Power $= \dfrac{\text{work done}}{\text{time}}$

As no work is done by magnetic force on the charged particle because magnetic force is perpendicular to velocity, hence power delivered is zero.

38. **(c)**

39. **(b)** Here, $\vec{E}$ and $\vec{B}$ are perpendicular to each other and the velocity $\vec{v}$ does not change; therefore

$$qE = qvB \Rightarrow v = \frac{E}{B}$$

If velocity $\vec{v}$ is $\perp^r$ to both $\vec{E}$ and $\vec{B}$,

$$\text{Also,} \left|\frac{\vec{E} \times \vec{B}}{B^2}\right| = \frac{E\,B \sin\theta}{B^2} = \frac{E\,B \sin 90°}{B^2} = \frac{E}{B} = |\vec{v}| = v$$

40. **(a)** r = mv/Bq is same for both.

41. **(c)** As electron move with constant velocity without deflection. Hence, force due to magnetic field is equal and opposite to force due to electric field.

$$qvB = qE \Rightarrow v = \frac{E}{B} = \frac{20}{0.5} = 40 \text{ m/s}$$

42. **(a)** The force acting on a charged particle in magnetic field is given by $\vec{F} = q(\vec{v} \times \vec{B})$ or $F = qvB \sin\theta$,
When angle between v and B is 180°, $F = 0$

43. **(c)** $r = \dfrac{\sqrt{2mK}}{qB}$ *i.e.* $r \propto \dfrac{\sqrt{m}}{q}$

Here kinetic energy *K* and *B* are same.

$$\therefore \quad \frac{r_p}{r_\alpha} = \frac{\sqrt{m_p}}{\sqrt{m_a}} \cdot \frac{q_\alpha}{q_p} = \frac{\sqrt{m_p}}{\sqrt{4m_p}} \cdot \frac{2q_p}{q_p} = 1$$

44. **(b)** In a perpendicular magnetic field, the path of a charged particle is a circle, and the magnetic field does not cause any change in energy.

45. **(a)**

46. **(a)** $F = ma = qvB \Rightarrow a = \dfrac{qvB}{m}$

$= \dfrac{1.6\times10^{-19}\times2\times3.4\times10^{7}}{1.67\times10^{-27}} = 6.5\times10^{15}\ \text{m/sec}^2$

47. **(b)** Magnetic field is given by $B = \dfrac{\mu_0 i}{2\pi r}$ i.e., $B \propto \dfrac{1}{r}$ which implies that field has cylindrical symmetry.

48. **(a)** 49. **(d)** 50. **(c)**

51. **(d)** There is no current inside the pipe. Therefore $\oint \vec{B}.\vec{d\ell} = \mu_o I$

$I = 0 \quad \therefore B = 0$

52. **(c)** 53. **(b)** 54. **(a)**

55. **(d)** $B = \mu_0 nI = 4\pi\times10^{-7}\times10\times5 = 2\pi\times10^{-5}$ T.

56. **(b)** Magnetic field at a point on one end of a solenoid

$B = \dfrac{1}{2}\mu_0 ni$

57. **(a)** $\dfrac{B_2}{B_1} = \dfrac{\mu_0 n_2 i_2}{\mu_0 n_1 i_1} \Rightarrow \dfrac{B_2}{6.28\times10^{-2}} = \dfrac{100\times\dfrac{i}{3}}{200\times i}$

$\Rightarrow B_2 = \dfrac{6.28\times10^{-2}}{6} = 1.05\times10^{-2}\ \text{Wb/m}^2$

58. **(d)** $B = \dfrac{\mu_0}{4\pi}.\dfrac{2\pi n i_1}{r_1} - \dfrac{\mu_0}{4\pi}.\dfrac{2\pi n i_2}{r_2} = \dfrac{\mu_0}{2}\left[\dfrac{n i_1}{r_1} - \dfrac{n i_2}{r_2}\right]$

59. **(b)** Let ℓ be length of wire.

Ist case : $\ell = 2\pi r \Rightarrow r = \dfrac{\ell}{2\pi}$

$B = \dfrac{\mu_0 In}{2r} = \dfrac{\mu_0 I\times2\pi}{2\ell} = \dfrac{\mu_0\pi I}{\ell}\ [\because n = 1]\ldots(1)$

2nd Case : $\ell = 2(2\pi r') \Rightarrow r' = \dfrac{\ell}{4\pi}$

$B' = \dfrac{\mu_0 In}{2\dfrac{\ell}{4\pi}} = \dfrac{2\mu_0 I\pi}{\dfrac{\ell}{2}} = 4\left(\dfrac{\mu_0\pi I}{\ell}\right) = 4B$

60. **(b)** We know that magnetic field at the centre of circular coil,

$B = \dfrac{\mu_0 In}{2r} = \dfrac{4\pi\times10^{-7}\times2\times50}{2\times0.5} = 1.25\times10^{-4}T$

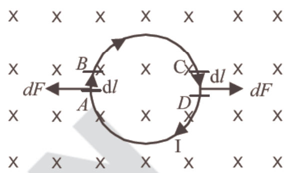
61. **(a)** A current carrying coil has magnetic dipole moment. Hence a torque $\vec{p}_m\times\vec{B}$ acts on it in magnetic field.

62. **(a)**

63. **(d)** $\tau = MB\sin\theta \Rightarrow \tau_{max} = NIAB$, $(\theta = 90°)$

64. **(c)** The magnetic field is perpendicular to the plane of the paper. Let us consider two diametrically opposite elements. By Fleming's left hand rule, on element *AB* the direction of force will be leftwards and the magnitude will be

$dF = I(d\ell)B\sin90° = I(d\ell)B$



On element *CD*, the direction of force will be towards right on the plane of the paper and the magnitude will be $dF = I(d\ell)B$.

These two forces will cancel out.

65. **(a)** Force between two long conductor carrying current,

$F = \dfrac{\mu_0}{4\pi}\dfrac{2I_1I_2}{d}\times\ell\ ;\ F' = -\dfrac{\mu_0}{4\pi}\dfrac{2(2I_1)I_2}{3d}\ell$

$\therefore \dfrac{F'}{F} = \dfrac{-2}{3}$

66. **(a)** $F = Bil\sin\theta \Rightarrow 7.5 = 2\times5\times1.5\sin\theta \Rightarrow \theta = 30°$

67. **(b)** $F = Bi\ell = 2\times1.2\times0.5 = 1.2$ N

68. **(a)** $F' = \dfrac{\mu_0 i_1 i_2}{2\pi r} = \dfrac{4\pi\times10^{-7}\times30\times30}{2\times\pi\times5\times10^{-2}} = 3.6\times10^{-3}$ N/m.

69. **(a)** $\dfrac{F}{\ell} = \dfrac{\mu_0 i^2}{2\pi d} = 9.8\times4\times10^{-6}$

$\Rightarrow i = \sqrt{\dfrac{4\times10^{-6}\times9.8\times0.12}{2\times10^{-7}}} = 4.85$ A

70. **(b)** $F = iB\,l\sin\theta$. This is maximum when $\sin\theta = 1$ or $\theta = \pi/2$.

71. **(b)** $F = I\ell B\sin\theta = 3\times0.40\times(500\times10^{-4})\times\sin30° = 3\times10^{-2}$ N.

72. **(d)** At these points, the resultant field = 0

73. **(a)** $F = \dfrac{\mu_0}{4\pi}\times\dfrac{2i_1i_2}{r}$

$= 50\times10^{-7}$ N/m. Here F is force per unit length.

74. **(b)** Current carrying conductors will attract each other, while electron beams will repel each other.

75. **(b)** Magnetic field at a point on one end of a solenoid

$B = \dfrac{1}{2}\mu_0 ni$

76. **(b)**

77. **(b)** The magnetic field from the centre of wire of radius *R* is given by

$B = \left(\dfrac{\mu_0 I}{2R^2}\right)r\ (r < R) \Rightarrow B \propto r$

and $B = \dfrac{\mu_0 I}{2\pi r}\ (r > R) \Rightarrow B \propto \dfrac{1}{r}$

From the above descriptions, we can say that the graph (b) is a correct representation.

78. **(a)** $B = \frac{\mu_0 I}{2r} \times \frac{\theta}{2\pi} = \frac{\mu_0 I\theta}{4\pi r}$

79. **(c)** Since n is an even number, we can assume the wires in pairs such that the two wires forming a pair is placed diametrically opposite to each other on the surface of cylinder. The fields produced on the axis by them are equal and opposite and can get cancelled with each other.

80. **(b)**

81. **(c)** As Lorentz force is given by

$$\vec{F} = q\left(\vec{E} + \vec{V} \times \vec{B}\right) = q\vec{E} + q\left(\vec{V} \times \vec{B}\right)$$

$$\vec{F} = \vec{F}_E + \vec{F}_B$$

82. **(a)** Lorentz force, $\vec{F} = q\,\{\vec{E} + (\vec{v} \times \vec{B})\}$

$$\vec{v} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 2 & 0 \\ 5 & 3 & 4 \end{vmatrix} = 8\hat{i} - 4\hat{j} - 7\hat{k}$$

$$\vec{F} = 1\,(2\hat{i} - 3\hat{j} + 8\hat{i} - 4\hat{j} - 7\hat{k}) = (10\hat{i} - 7\hat{j} - 7\hat{k})$$

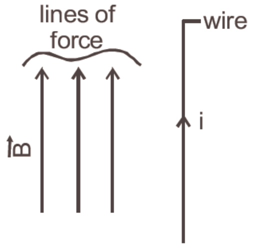
83. **(c)**

84. **(c)** $E = vB = 2 \times 10^3 \times 1.5 = 3 \times 10^3$ V/m.

85. **(b)** $\tau = m\beta\sin\theta = 0.75 \times 0.20 = 0.15$ Nm

86. **(a)** **87.** **(c)**

88. **(b)**

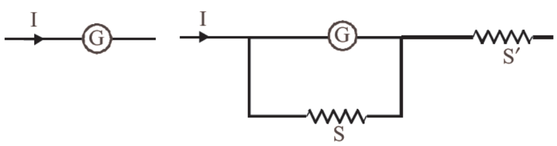


$F_m = I(\vec{\ell} \times \vec{B}) = 0$ because the directions of current $\vec{\ell}$ and magnetic field $\vec{B}$ are parallel.

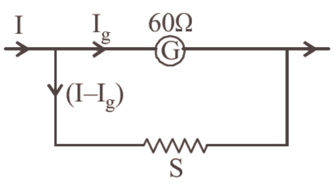
89. **(d)**

90. **(c)** To keep the main current in the circuit unchanged, the resistance of the galvanometer should be equal to the net resistance.

$$\therefore G = \left(\frac{GS}{G+S}\right) + S' \Rightarrow G - \frac{GS}{G+S} = S' \qquad \therefore S' = \frac{G^2}{G+S}.$$



91. **(c)** $G = 60\Omega$, $I_g = 1.0$A, $I = 5$A.



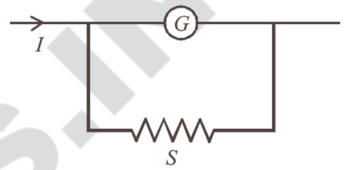
Let S be the shunt resistance connected in parallel to galvanometer

$I_g G = (I - I_g) S$,

$$S = \frac{I_g G}{I - I_g} = \frac{1}{5-1} \times 60 = 15\Omega$$

Thus by putting 15 Ω in parallel, the galvanometer can be converted into an ammeter.

92. **(a)** Galvanometer is converted into ammeter, by connected a shunt, in parallel with it.



$$\frac{GS}{G+S} = \frac{V_G}{I} = \frac{25 \times 10^{-3}}{25}$$

$$\frac{GS}{G+S} = 0.001\Omega$$

Here $S << G$ so $S = 0.001\ \Omega$

93. **(a)** $i_g = i\frac{SG}{S+G}$

or $100 \times 10^{-6} = i\left(\frac{0.1 \times 100}{100 + 0.1}\right)$ or $i = 100.1 \times 10^{-3}$ A.

94. **(c)** $I_g = 10 \times 10^{-3}/5 = 2 \times 10^{-3}$ A;

$$R = \frac{V}{I_g} - R_g = \frac{1}{2 \times 10^{-3}} - 5 = 495\Omega.$$

(Sol. 95-99):

We know that $r = \frac{mV}{qB}$

$\therefore \quad V > \frac{qBl}{m}$

95. **(a)** If $r > l$ then particle enter the III region $\frac{mV}{qB} > l$

96. **(c)** If $V = \frac{qBl}{m}$ then particle will cover semi circular path in this condition the path length of the particle in region II is maximum.

97. **(d)** Time spent in region II, $T = \frac{\pi m}{qB}$

It does not depends upon the velocity.

98. **(d)**

99. **(d)** $F = q(\vec{V} \times \vec{B})$ if $V \parallel B$, then $\vec{F} = 0$

100. **(d)** Ampere's circuital law can be derived from Biot-Savart law

101. **(c)** The magnetic field of two equal halfs of the loop is equal and opposite and so $\vec{B} = 0$.

102. **(a)** **103.** **(b)**

104. **(a)** A moving charge experiences a force in magnetic fields. It is because of interaction of two magnetic fields, one which is produced due to the motion of charge and other in which charge is moving.

105. **(c)** Due to electric field, the force is $\vec{F} = q\vec{E}$ in the direction of $\vec{E}$. Since $\vec{E}$ is parallel to $\vec{B}$, the particle velocity $\vec{v}$ (acquired due to force $\vec{F}$) is parallel to $\vec{B}$. Hence $\vec{B}$ will not exert any force since $\vec{v} \times \vec{B} = 0$ and the motion of the particle is not affected by $\vec{B}$.

106. **(c)**

107. **(c)** Since the magnetic force is always perpendicular to the velocity of the charged particle so, work done is always zero.

108. **(d)**

109. **(d)** The magnetic force acts on moving electrons, and so net force on the conductor is non-zero.

110. **(b)** If $\vec{F} \perp \vec{V}$ at all instants then motion will be circular

111. **(c)**

112. **(a)** (A) $\rightarrow$ (4) ; (B) $\rightarrow$ (3) ; (C) $\rightarrow$ (1) ; (D) $\rightarrow$ (2)

113. $(\vec{F}_E + \vec{F}_B)$ ($\vec{F} = \vec{F}_E + \vec{F}_B$ acting on)

As Lorentz force is given by

$$\vec{F} = q(\vec{E} + \vec{V} \times \vec{B}) = q\vec{E} + q(\vec{V} \times \vec{B})$$

$$\vec{F} = \vec{F}_E + \vec{F}_B$$

114. $(11q\hat{j})$ Lorentz force acting on the particle

$$\vec{F} = q\left[\vec{E} + \vec{v} \times \vec{B}\right]$$

$$= q\left[3\hat{i} + \hat{j} + 2\hat{k} + \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 4 & 1 \\ 1 & 1 & -3 \end{vmatrix}\right]$$

$$= q\left[3\hat{i} + \hat{j} + 2\hat{k} + \hat{i}(-12-1) - \hat{j}(-9-1) + k(3-4)\right]$$

$$F_y = 11q\hat{j}$$

115. $(\vec{m} \times \vec{B})$

116. (0.24) $F = IlB$

Here, $\theta = 90°$, $I = 10\ A$

$l = 8$ cm $= 8 \times 10^{-2}\ m$, $B = 0.3\ T$

$\therefore$ $F = 10 \times 8 \times 10^{-2} \times 0.3 \times \sin 90° = 0.24\ N$

117. (3.33×10^{-4}) $B = \frac{\mu_0 I}{2\pi r} \Rightarrow B \propto \frac{1}{r}$

As the distance is increased to three times, the magnetic induction reduces to one third. Hence, $B = \frac{1}{3} \times 10^{-3}$ tesla

$= 3.33 \times 10^{-4}$ tesla

118. (False) The magnitude of magnetic force on charged particle undergoing uniform circular motion in uniform magnetic field is $F = qvB$

$\therefore$ If v is doubled keeping q and B constant, the force F just doubles. Hence statement-1 is false.

119. (False)

120. (True) The magnitude of magnetic field is different at different points.

121. (True) As mangetic field and velocity are in same direction.

122. (True)

123. (True)

5 Magnetism and Matter

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. On cutting a solenoid in half, the field lines remain ...A..., emerging from one face of the solenoid and entering into the other face. Here, A refers to
(a) irregular (b) discontinuous
(c) continuous (d) alternate

2. An iron rod of length L and magnetic moment M is bent in the form of a semicircle. Now its magnetic moment will be
(a) M (b) $2M/\pi$ (c) M/π (d) M/π

3. Which of the following statement(s) is/are true/false about magnetism?
I. The Earth behaves as a magnet with the magnetic field pointing approximately from the geographic South to the North.
II. When a bar magnet is freely suspended, it points in the North–South direction. The tip which points to the geographic North is called the North –pole and the tip which points to georaphic South is called the South–pole of magnet.
III. There is a repulsive force when North–poles (or South–poles) of two magnets are brought close together. Conversely, there is an attractive force between the North–pole of one magnet and the South–pole of other.
IV. We can isolate the North or South–pole of a magnet.
(a) T, T, F, F (b) T, T, F, T
(c) F, F, T, T (d) T, T, T, F

4. The horizontal component of the earth's magnetic field is 3.6×10^{-5} tesla where the dip angle is 60°. The magnitude of the earth's magnetic field is
(a) 2.8×10^{-4} tesla (b) 2.1×10^{-4} tesla
(c) 7.2×10^{-5} tesla (d) 3.6×10^{-5} tesla

5. At a certain place, horizontal component is $\sqrt{3}$ times the vertical component. The angle of dip at this place is
(a) 0 (b) $\pi/3$ (c) $\pi/6$ (d) $\pi/8$

6. Let V and H be the vertical and horizontal components of earth's magnetic field at any point on earth. Near the north pole
(a) V >> H (b) V << H (c) V = H (d) V = H = 0

7. If μ_0 is absolute permeability of vacuum and μ_r is relative magnetic permeability of another medium, then permeability μ of the medium is
(a) $\mu_0\mu_r$ (b) μ_0/μ_r (c) μ_r/μ_0 (d) $1/\mu_0\mu_r$

8. A toroid of n turns, mean radius R and cross-sectional radius a carries current I. It is placed on a horizontal table taken as xy-plane. Its magnetic moment m
(a) is non-zero and points in the z-direction by symmetry
(b) points along the axis of the toroid ($m = m\phi$)
(c) is zero, otherwise there would be a field falling as $\frac{1}{r^3}$ at large distances outside the toroid
(d) is pointing radially outwards

9. 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° with the axis of the earth. At Mumbai, declination is nearly zero. Then,
(a) the declination varies between 11.3° W to 11.3° E
(b) the least declination is 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

10. A bar magnet is cut into two equal halves by a plane parallel to the magnetic axis. Of the following physical quantities the one which remains unchanged is
(a) pole strength
(b) magnetic moment
(c) intensity of magnetisation
(d) None of these

11. One can define ...*A*... of a place as the vertical plane which passes through the imaginary line joining the magnetic North and the South–poles.
Here, A refers to
(a) geographic meridian (b) magnetic meridian
(c) magnetic declination (d) magnetic inclination

12. The magnetic compass is not useful for navigation near the magnetic poles, since
(a) R = 0 (b) V = 0 (c) H = 0 (d) $\theta = 0^\circ$

13. The magnetism of magnet is due to
(a) spin motion of electron
(b) earth
(c) pressure of big magnet inside the earth
(d) cosmic rays

14. The primary origin (s) of magnetism lies in
(a) atomic currents (b) polar nature of molecules
(c) extrinsic spin of electron (d) None of these

15. Which of these is correct in regard to a magnet?
(a) Geometric length = 0.8 times the magnetic length
(b) Magnetic length = 0.8 times the geometric length
(c) Magnetic length = Geometric length
(d) Geometric length = 10/9 of magnetic length

16. Magnetic dipole moment is a vector quantity directed from
(a) south pole to north pole (b) north pole to south pole
(c) east to west (d) west to east

17. A bar magnet of magnetic moment M and length L is cut into two equal parts each of length L/2. The magnetic moment of each part will be
(a) M (b) M/4 (c) $\sqrt{2}$ M (d) M/2

18. When a current in a circular loop is equivalently replaced by a magnetic dipole
(a) the pole strength m of each pole is fixed
(b) the distance d between the poles is fixed
(c) the product md is fixed
(d) None of these

19. The magnetic moment of atomic neon is equal to
(a) zero (b) $\frac{1}{2}\mu_B$ (c) μ_B (d) $\frac{3}{2}\mu_B$

20. Current i is flowing in a coil of area A and number of turns N, then magnetic moment of the coil, M is
(a) NiA (b) $\frac{Ni}{A}$ (c) $\frac{Ni}{\sqrt{A}}$ (d) N^2Ai

21. Magnetic field intensity is defined as
(a) Magnetic moment per unit volume
(b) Magnetic induction force acting on a unit magnetic pole
(c) Number of lines of force crossing per unit area
(d) Number of lines of force crossing per unit volume

22. The magnetic moment of a bar magnet is thus ...*A*... to the magnetic moment of an equivalent solenoid that produces the same magnetic field. Here, *A* refers to
(a) unequal (b) different (c) equal (d) same

23. The magnetic lines of force inside a bar magnet
(a) are from north-pole to south-pole of the magnet
(b) do not exist
(c) depend upon the area of cross-section of the bar magnet
(d) are from south-pole to north-pole of the Magnet

24. The strength of the earth's magnetic field is
(a) constant everywhere
(b) zero everywhere
(c) having very high value
(d) vary from place to place on the earths surface

25. The correct relation is
(a) $B = \frac{B_V}{B_H}$ (b) $B = B_V \times B_H$
(c) $|B| = \sqrt{B_H^2 + B_V^2}$ (d) $B = B_H + B_V$

26. The line on the earth surface joining the point where the field is horizontal, is called
(a) magnetic equator (b) magnetic line
(c) magnetic axis (d) magnetic inertia

27. Horizontal component of earth's field at a height of 1 m from the surface of earth is H. Its value at a height of 10 m from surface of earth is
(a) H/10 (b) H/9 (c) H/100 (d) H

28. At the magnetic north pole of the earth, the value of the horizontal component of earth's magnetic field and angle of dip are respectively
(a) zero, maximum (b) maximum, minimum
(c) maximum, maximum (d) minimum, minimum

29. Which of the following is responsible for the earth's magnetic field?
(a) Convective currents in earth's core.
(b) Diversive current in earth's core.
(c) Rotational motion of earth.
(d) Translational motion of earth.

30. Demagnetisation of magnets can be done by
(a) rough handling
(b) heating
(c) magnetising in the opposite direction
(d) All the above

31. A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It will
(a) stay in north-south direction only
(b) stay in east-west direction only
(c) become rigid showing no movement
(d) stay in any position

32. The time period of oscillation of a freely suspended bar magnet with usual notations is given by
(a) $T = 2\pi\sqrt{\frac{I}{MB_H}}$ (b) $T = 2\pi\sqrt{\frac{MB_H}{I}}$
(c) $T = \sqrt{\frac{I}{MB_H}}$ (d) $T = 2\pi\sqrt{\frac{B_H}{MI}}$

33. To measure the magnetic moment of a bar magnet, one may use
(a) a deflection glavanometer if the earth's horizontal field is known
(b) an oscillation magnetometer if the earth's horizontal field is known
(c) both deflection and oscillation magnetometer if the earth's horizontal field is not known.
(d) all of the above

34. For protecting a sensitive equipment from the external electric arc, it should be
(a) wrapped with insulation around it when a current is passing through it
(b) placed inside an iron core
(c) surrounded with fine copper sheet
(d) placed inside an aluminium can

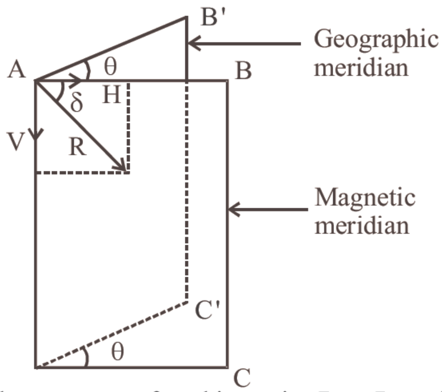
35. The magnetic needle has magnetic moment 8.7×10^{-2} Am^2 and moment of inertia 11.5×10^{-6} kgm^2. It performs 10 complete oscillations in 6.70 s, what is the magnitude of the magnetic field?
(a) 0.012 T (b) 0.120 T (c) 1.200 T (d) 2.10 T

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage

Magnetic elements of earth at a place are the quantities which can completely describe in magnitude and direction, the magnetic field of the earth. There are three elements of the magnetic field of the earth.



Horizontal component of total intensity, $B_H = R\cos\delta$;
Vertical component of total intensity,
$B_V = R\sin\delta \Rightarrow B_H^2 + B_V^2 = R^2$

$\therefore \quad R = \sqrt{B_H^2 + B_V^2}$ and $\tan\delta = \dfrac{B_V}{B_H}$

36. The strength of the earth's magnetic field is
(a) constant everywhere
(b) zero everywhere
(c) having very high value
(d) vary from place to place on the earth's surface

37. The lines of force due to earth's horizontal magnetic field are
(a) parallel and straight (b) concentric circles
(c) elliptical (d) curved lines

38. The earth's magnetic field always has a vertical component except at the
(a) magnetic equator (b) magnetic poles
(c) geographic north pole (d) latitude 45º

39. At magnetic poles, the angle of dip is
(a) 45º (b) 30º (c) zero (d) 90º

40. At the magnetic north pole of the earth, the value of the horizontal component of earth's magnetic field and angle of dip are respectively
(a) zero, maximum (b) maximum, minimum
(c) maximum, maximum (d) minimum, minimum

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

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

41. **Assertion :** Magnetic moment of an atom is due to both the orbital motion and spin motion of every electron.
Reason : A charged particle produces magnetic field.

42. **Assertion :** The poles of magnet can not be separated by breaking into two pieces.
Reason : The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.

43. **Assertion :** Soft iron is used as transformer core.
Reason : Soft iron has narrow hysteresis loop.

44. **Assertion :** The sensitivity of a moving coil galvanometer is increased by placing a suitable magnetic material as a core inside the coil.
Reason : Soft iron has high magnetic permeability and cannot be easily magnetized or demagnetized.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

45. Match the column-I and column II.

Column I	Column II
(A) Horizontal component	(1) $B_E \sin\phi$
(B) Vertical component	(2) $\dfrac{B_V}{B_H}$
(C) $\tan\phi$	(3) $B_E \cos\phi$
(D) Tangent law	(4) $B = B_H \tan\theta$

(a) $A \to (3); B \to (2); C \to (1); D \to (4)$
(b) $A \to (3); B \to (1); C \to (2); D \to (4)$
(c) $A \to (2); B \to (3); C \to (1); D \to (4)$
(d) $A \to (1); B \to (3); C \to (2); D \to (4)$

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

46. If horizontal and vertical components of earth's magnetic field are equal, then angle of dip is_______.

47. At a certain place, the angle of dip is 30º and the horizontal component of earth's magnetic field is 0.50 oerested. The earth's total magnetic field (in oerested) is______.

48. The period of oscillation of a magnet in a vibration magnetometer is 2 sec. The period of oscillation of a magnet whose magnetic moment is four times that of the first magnet is_______.

49. When 2 ampere current is passed through a tangent galvanometer, it gives a deflection of 30º. For 60º deflection, the current must be ________.

50. The magnetic field and angle of dip at a place on the earth are 0.3G and 30° respectively. The value of vertical component of the earth's magnetic field at the place is__________. **[CBSE 2020]**

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

51. The area of hysteresis loop for steel is large as compared to soft iron.

52. Steel dissipate greater energy than soft iron.

53. If a compass needle be kept at magnetic north pole of the earth, the compass needle may stay in any direction

54. Dip needle will stay vertical at the north pole of earth.

ANSWER KEY & SOLUTIONS

1. **(c)** The field lines remain continuous, emerging from one face of the solenoid and entering into the other face.

2. **(b)** On bending a rod it's pole strength remain unchanged where as its magnetic moment changes new magnetic moment $M'm(2R)=\left(\frac{2L}{\pi}\right)=\frac{2M}{\pi}$.

3. **(d)** (i) The Earth behaves as a magnet with the magnetic field pointing appoximately from the geographic South to the North.

   (ii) When a bar magnet is freely suspended, it points in the North-South direction. The tip which points to the geographic North is called the North pole and the tip which points to the geographic South is called the South-pole of the magnet.

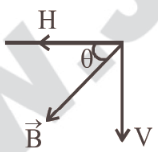
   (iii) There is a repulsive force when North poles (or South-poles) of two magnets are brought close together. Conversely there is an attractive force between the North-pole of one magnet and the South-pole of the other.

   (iv) We cannot isolate the North or South-pole of a magnet. If a bar magnet is broken into two halves, we get two similar bar magnets with somewhat weaker properties. Unlike electric charges, isolated magnetic North and South poles known as magnetic monopoles do not exist.

4. **(c)** Horizontal component of earth's field, H = B cos θ, since, θ = 60°

   $3.6\times10^{-5}=B\times\frac{1}{2}$

   $\Rightarrow B=7.2\times10^{-5}$ Tesla



5. **(c)** $\tan\delta=\frac{V}{H}=\frac{V}{\sqrt{3}V}=\frac{1}{\sqrt{3}}$

   $\therefore\ \delta=30^{o}=\pi/6$ radian

6. **(a)**

7. **(a)** Relative magnetic permeability

   $\mu_r=\frac{\mu}{\mu_\circ}\Rightarrow\mu=\mu_o\times\mu_r$

8. **(c)** Toroid is a hollow circular ring on which a large number of turns of a wire are closely wound. Thus, in this case magnetic field is only confined inside the body of toroid.

   So no magnetic field outside the toroid and magnetic field only inside the toroid.

   In case of toroid, the magnetic field is in the form of concentric magnetic lines of force and there is no magnetic field outside the body of toroid. This is because the loop encloses no current. Thus, the magnetic moment of toroid is zero.

   In other case, if we take r as a large distance outside the toroid, then $m\propto\frac{1}{r^3}$. Which is not possible.

9. **(a)** Magnetic declination is an angle between angle of magnetic meridian and the geographic meridian.

   As the earth's magnetism, the magnetic field lines of the earth resemble that of a hypothetical magnetic dipole located at the centre of the earth.

   The axis of the dipole does not coincide with the axis of rotation of the earth but is presently tilted by 11.3° (approx) with respect to geographical of axis earth. This results into two situations as given in the figure.

   So, the declination varies between 11.3° W to 11.3° E.

10. **(c)**

11. **(b)** Magnetic meridian of a place is defined as the vertical plane which passes through the imaginary line joining the magnetic North and South-poles. This pane would intersect the surface of the Earth in a longitude like circle.

12. **(c)**

13. **(a)** Spin motion of electron

14. **(a)**

15. **(b)** Magnetic length of a magnet is roughly 0.8 times the geometric length.

16. **(a)**

17. **(d)** As magnetic moment = pole strength x length and length is halved without affecting pole strength, therefore, magnetic moment becomes half.

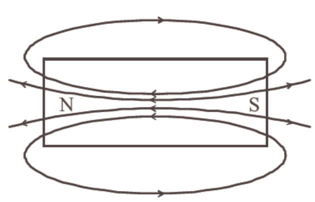
18. **(c)**

19. **(a)** Magnetic moment is cancelled and $\mu_{net}=0$.

20. **(a)** 21. **(b)**

22. **(c)** The magnetic moment of a bar magnet is thus equal to the magnetic moment of an equivalent solenoid that produces the same magnetic field.

23. **(d)** As shown in the figure, the magnetic lines of force are directed from south to north inside a bar magnet.



24. **(d)** The strength of the earth's magnetic field is not constant. It varies from one place to other place on the surface of earth. Its value being of the order of 10^{-5} T.

25. **(c)** **26.** **(a)**

27. **(d)** The value of H is fairly uniform.

28. **(a)**

29. **(a)** The earth's core is hot and molten. Hence, convective current in earth's core is responsible for it's magnetic field.

30. **(d)** **31.** **(d)** **32.** **(a)** **33.** **(d)**

34. **(b)** The iron core produces a magnetic screening for the equipment as lines of magnetic force can not enter iron enclosure.

35. **(a)** Magnetic moment, $M = 8.7 \times 10^{-2}$ Am^2 moment of inertia, $I = 11.5 \times 10^{-6}$ kg m^2 Time period of oscillation is

$$T = \frac{6.70}{10} = 0.6755$$

$$\text{As, } T = 2\pi\sqrt{\frac{I}{MB}};\ B = \frac{4\pi^2 I^2}{MT^2}$$

$$\therefore \quad B = \frac{4 \times (3.14)^2 \times 11.5 \times 10^{-6}}{8.7 \times 10^{-2} \times (0.67)^2} = 0.012\text{T}$$

36. **(d)** The strength of the earths magnetic field is not constant. It varies from one place to other place on the surface of earth. Its value being of the order of 10^{-5} T.

37. **(b)** **38.** **(a)** **39.** **(d)** **40.** **(a)**

41. **(c)** In an atom, electrons revolve around the nuclear and such the circular orbits of electrons may be considered as the small current loops. In addition to orbital motion, an electron has got spin motion also. So the total magnetic moment of electron is the vector sum of its magnetic charge moments due to orbital and spin motion. Particles at rest do not produce magnetic field.

42. **(b)** When a magnet is cut into pieces, each piece becomes new magnet. $M' = \frac{m\ell}{2} = \frac{M}{2}$.

43. **(a)**

44. **(c)** Sensitivity of galvanometer, $s = \frac{\theta}{i} \simeq \frac{\tan\theta}{i} = \frac{\mu_0 N}{2RB_H}$.

If a magnetic material is placed inside coil of galvanometer, then

$$s' = \frac{\mu_r \mu_0 N}{2RB_H}.$$

45. **(b)** $B_H = B_E \cos\phi$

$B_V = B_E \sin\phi$

$\tan\phi = \frac{B_v}{B_H}$ and $B = B_H \tan\theta$

where, θ = magnetic declination

ϕ = Angle of inclination or dip angle

46. (45°) $\tan\theta = \frac{B_V}{B_H} = 1, B_V = B_H$

$$\theta = \tan^{-1}(1) = 45°$$

47. $\left(1/\sqrt{3}\right)$ $B = \frac{H}{\cos\theta} = \frac{0.50}{\cos 30°} = \frac{0.50 \times 2}{\sqrt{3}} = 1/\sqrt{3}$

48. (1s) $T = 2\pi\sqrt{\left(\frac{I}{MB_H}\right)}$

$$T' = 2\pi\sqrt{\left(\frac{I}{4MB_H}\right)} = \frac{1}{2}\left[2\pi\sqrt{\frac{I}{(MB_H)}}\right]$$

$$= \frac{1}{2} \times 2 = 1 \text{ second.}$$

49. (6A) As $\frac{i_2}{i_1} = \frac{\tan\theta_2}{\tan\theta_1}$

50. (0.15G) Vertical component of magnetic field

$$B_V = B\sin\delta = 0.3\sin 30° = 0.3 \times \frac{1}{2} = 0.15\text{G}$$

51. (True)

52. (True)

53. (True) We know that at magnetic poles the horizontal component of earth's field is zero, only vertical component exists. So compass needle may stay in any direction.

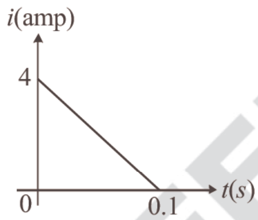
54. (True) The dip needle rotates in a vertical plane and the angle of dip at poles is 90°. Hence, the dip needle will stand vertical at the north pole of earth.

6 Electromagnetic Induction

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. In a coil of resistance 10 Ω, the induced current developed by changing magnetic flux through it, is shown in figure as a function of time. The magnitude of change in flux through the coil in weber is



(a) 8 (b) 2 (c) 6 (d) 4

2. Whenever the magnetic flux linked with a coil changes, an induced e.m.f. is produced in the circuit. The e.m.f. lasts

I. for a short time
II. for a long time
III. so long as the change in flux takes place

The true/false statement(s) is/are

(a) T, T, F (b) F, T, T
(c) T, F, T (d) F, F, T

3. Consider coil and magnet

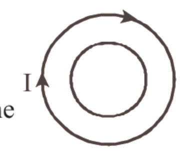
Current is induced in coil when

I. coil and magnet both are at rest.
II. coil is at rest and magnet moves along x.
III. magnet is at rest and coil moves along x.

Then true/false statements are

(a) T, F, F (b) T, T, F
(c) F, F, T (d) F, T, T

4. Two different wire loops are concentric and lie in the same plane. The current in the outer loop (I) is clockwise and increases with time. The induced current i in the inner loop______.



(a) is clockwise
(b) is zero
(c) is counter clockwise
(d) has a direction that depends on the ratio of the loop radii.

5. According to Faraday's law of electromagnetic induction

I. The induced emf is not in the direction opposing the change in magnetic flux.
II. The relative motion between the coil and magnet produces change in magnetic flux.
III. Only the magnet should be moved towards coil.

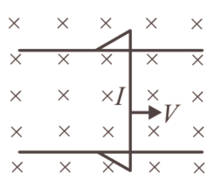
The true/false statement(s) are

(a) T,T,F (b) F,T,F
(c) F,F,T (d) F,T,T

6. A cylindrical bar magnet is kept along the axis a circular coil. If the magnet is rotated about its axis, then ________ in the coil.

(a) a current will be induced
(b) no current will be induced
(c) only an e.m.f. will induced
(d) an e.m.f and a current both will be induced

7. The figure shows a wire sliding on two parallel conducting rails placed at a separation I. A magnetic field B exists in a direction perpendicular to the plane of the rails. The force required to keep the wire moving at a constant velocity v will be



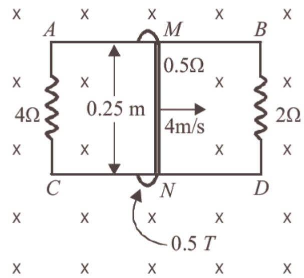
(a) evB

(b) $\frac{\mu_0 Bv}{4\pi I}$

(c) BIv

(d) zero

8. A sliding wire of length 0.25 m and having a resistance of 0.5 Ω moves along conducting guiding rails AB and CD with a uniform speed of 4 m/s. A magnetic field of 0.5 T exists normal to the plane of $ABCD$ directed into the page. The guides are short -circuited with resistances of 4 and 2 Ω as shown. The current through the sliding wire is :



(a) 0.27 A (b) 0.37 A
(c) 1.0 A (d) 0.72 A

9. A straight conductor of length 2m moves at a speed of 20 m/s. When the conductor makes an angle of 30° with the direction of magnetic field of induction of 0.1 wbm^2 then induced emf

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

10. A wire of length 1m is perpendicular to x-y plane. It is moved with velocity $\vec{v} = (3\hat{i} + 3\hat{j} + 2\hat{k})$ m/s through a region of uniform induction $\vec{B} = (\hat{i} + 2\hat{j})$ T. The potential difference between the ends of the wire is

(a) 1V (b) 1.5V (c) 2.5V (d) 3V

11. A circular wire of radius r rotates about its own axis with angular speed ω in a magnetic field B perpendicular to its plane, then the induced e.m.f. is

(a) $\frac{1}{2}B r\omega^2$ (b) $Br\omega^2$ (c) $2Br\omega^2$ (d) zero

12. If the rate of change of current of 2A/s induces an emf of 10 mV in a solenoid, the self-inductance of the solenoid is

(a) 5×10^{-3} Henry (b) 8×10^{-3} Henry
(c) 25×10^{-6} Henry (d) 55×10^{-12} Henry

13. If N is the number of turns in a coil, the value of self inductance varies as

(a) N^0 (b) N (c) N^2 (d) N^{-2}

14. Two coils of self inductances 2 mH and 8 mH are placed so close together that the effective flux in one coil is completely linked with the other. The mutual inductance between these coils is

(a) 6mH (b) 4mH
(c) 16mH (d) 10mH

15. Two solenoids of same cross-sectional area have their lengths and number of turns in ratio of 1 : 2 both. The ratio of self-inductance of two solenoids is

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

16. A small square loop of wire of side ℓ is placed inside a large square loop of side L (L >> ℓ). The loop are coplanar and their centres coincide. The mutual inductance of the system is proportional is

(a) $\frac{\ell}{L}$ (b) $\frac{\ell^2}{L}$ (c) $\frac{L}{\ell}$ (d) $\frac{L^2}{\ell}$ s

17. A square of side L metres lies in the xy-plane in a region, where the magnetic field is given by $B = B_0(2\hat{i} + 3\hat{j} + 4\hat{k})$ 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

18. 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 $B = B_0(\hat{i} + \hat{k})$ T is present in the region. The flux passing through the loop ABCDEFA (in that order) is

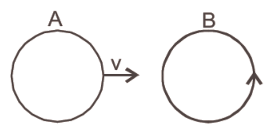
(a) B_0L^2 Wb (b) $2B_0L^2$Wb
(c) $\sqrt{2}B_0L^2$ Wb (d) $4B_0L^2$Wb

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

(a) a direct current flows in the ammeter A
(b) no current flows through the ammeter A
(c) an alternating sinusoidal current 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.

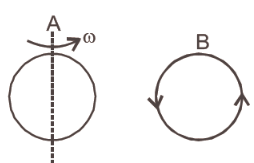
20. There are two coils A and B as shown in figure a current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counter clockwise. B is kept stationary when A moves. We can infer that

(a) there is a constant current in the clockwise direction in A
(b) there is a varying current in A
(c) there is no current in A
(d) there is a constant current in the counter clockwise direction in A



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

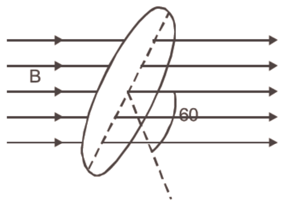
(a) constant current clockwise
(b) varying current clockwise
(c) varying current counter clockwise
(d) constant current counter clockwise



22. 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

23. Fig shown below represents an area $A = 0.5\ m^2$ situated in a uniform magnetic field $B = 2.0\ weber/m^2$ and making an angle of 60º with respect to magnetic field.



The value of the magnetic flux through the area would be equal to

(a) 2.0 weber (b) $\sqrt{3}$ weber
(c) $\sqrt{3}/2$ weber (d) 0.5 weber

24. A conductor of length 0.4 m is moving with a speed of 7 m/s perpendicular to a magnetic field of intensity 0.9 Wb/m^2. The induced e.m.f. across the conductor is

(a) 1.26 V (b) 2.52 V
(c) 5.04 V (d) 25.2 V

25. A coil is wound on a frame of rectangular cross-section. If all the linear dimensions of the frame are increased by a factor 2 and the number of turns per unit length of the coil remains the same, self-inductance of the coil increases by a factor of

(a) 4 (b) 8
(c) 12 (d) 16

26. In an AC generator, a coil with N turns, all of the same area A and total resistance R, rotates with frequency ω in a magnetic field B. The maximum value of emf generated in the coil is

(a) N.A.B.R.ω (b) N.A.B.
(c) N.A.B.R. (d) N.A.B.ω

27. The total charge induced in a conducting loop when it is moved in a magnetic field depends on

(a) the rate of change of magnetic flux
(b) initial magnetic flux only
(c) the total change in magnetic flux
(d) final magnetic flux only

28. According to Faraday's law of electromagnetic induction

(a) the direction of induced force is such that it opposes the cause producing it
(b) the magnitude of induced e.m.f. produced in a coil is directly proportional to the rate of change of magnetic flux
(c) the direction of induced e.m.f. is such that it opposes the cause producing it
(d) None of these

29. Lenz's law gives

(a) the magnitude of the induced e.m.f.
(b) the direction of the induced current
(c) both the magnitude and direction of the induced current
(d) the magnitude of the induced current

30. Induced emf in the coil depends upon

(a) conductivity of coil
(b) amount of flux
(c) rate of change of linked flux
(d) resistance of coil

31. An inductor may store energy in

(a) its electric field
(b) its coils
(c) its magnetic field
(d) both in electric and magnetic fields

32. A varying magnetic flux linking a coil is given by $\phi = xt^2$. If at a time t = 3s, the emf induced is 9V, then value of x is

(a) 0.66 Wb/s^2 (b) 1.5 Wb/s^2
(c) – 0.66 Wb/s^2 (d) –1.5 Wb/s^2

33. The magnetic flux (in weber) linked with a coil of resistance 10 Ω is varying with respect to time t as $\phi = 4t^2 + 2t + 1$. Then the current in the coil at time t = 1 second is

(a) 0.5 A (b) 2 A (c) 1.5 A (d) 1 A

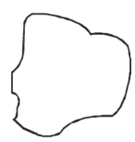
34. A rectangular coil of 100 turns and size 0.1 m × 0.05 m is placed perpendicular to a magnetic field of 0.1 T. The induced e.m.f. when the field drops to 0.05 T in 0.05s is

(a) 0.5 V (b) 1.0 V (c) 1.5 V (d) 2.0 V

35. A magnetic field of 2×10^{-2} T acts at right angles to a coil of area 100 cm^2, with 50 turns. The average e.m.f. induced in the coil is 0.1 V, when it is removed from the field in t sec. The value of t is

(a) 10 s (b) 0.1 s (c) 0.01 s (d) 1 s

36. As a result of change in the magnetic flux linked to the closed loop shown in the fig, an e.m.f. V volt is induced in the loop. The work done (joule) in taking a charge Q coulomb once along the loop is

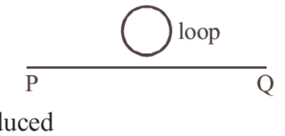


(a) QV (b) 2QV (c) QV/2 (d) Zero

37. A current i = 2 sin (πt/3) amp is flowing in an inductor of 2 henry. The amount of work done in increasing the current from 1.0 amp to 2.0 amp is

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

38. An electron moves along the line PQ which lies in the same plane as a circular loop of conducting wire as shown in figure. What will be the direction of the induced current in the loop?



(a) Anticlockwise
(b) Clockwise
(c) Alternating
(d) No current will be induced

39. A coil of circular cross-section having 1000 turns and 4 cm^2 face area is placed with its axis parallel to a magnetic field which decreases by 10^{-2} Wb m^{-2} in 0.01 s. The e.m.f. induced in the coil is:
(a) 400mV (b) 200mV (c) 4mV (d) 0.4mV

40. A rectangular coil of 20 turns and area of cross-section 25 sq. cm has a resistance of 100Ω. If a magnetic field which is perpendicular to the plane of coil changes at a rate of 1000 tesla per second, the current in the coil is
(a) 1 A (b) 50 A (c) 0.5 A (d) 5 A

41. A coil of effective area 4 m^2 is placed at right angles to the magnetic induction B. The e.m.f. of 0.32 V is induced in the coil. When the field is reduced to 20% of its initial value in 0.5 sec. Find B.
(a) 0.14 Wb/m^2 (b) 0.05 Wb/m^2
(c) 0.4 Wb/m^2 (d) 0.14 Wb/m^2

42. Two identical circular loops of metal wire are lying on a table without touching each other. Loop–A carries a curent which increases with time. In response, the loop–B
(a) Remains stationary
(b) is attracted by the loop-A
(c) is repelled by the loop-A
(d) rotates about its CM, with CM fixed

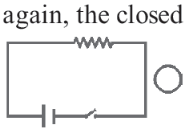
43. The magnetic flux through a circuit of resistance R changes by an amount $\Delta\phi$ in a time Δt. Then the total quantity of electric charge Q that passes any point in the circuit during the time Δt is represented by
(a) $R \cdot \frac{\Delta\varphi}{\Delta t}$ (b) $\frac{1}{R} \cdot \frac{\Delta\varphi}{\Delta t}$ (c) $\frac{\Delta\varphi}{R}$ (d) $\frac{\Delta\varphi}{\Delta t}$

44. A metal ring is held horizontally and bar magnet is dropped through the ring with its length along the axis of the ring. The acceleration of the falling magnet
(a) is equal to g
(b) is less than g
(c) is more than g
(d) depends on the diameter of ring and length of magnet

45. Two identical coaxial coils P and Q carrying equal amount of current in the same direction are brought nearer. The current in
(a) P increases while in Q decreases
(b) Q increases while in P decreases
(c) both P and Q increases
(d) both P and Q decreases

46. A solenoid has 2000 turns wound over a length of 0.3 m. Its cross-sectional area is 1.2×10^{-3} m^2. Around its central section a coil of 300 turns is wound. If an initial current of 2 A flowing in the solenoid is reversed in 0.25 s, the emf induced in the coil will be
(a) 2.4×10^{-4} V (b) 2.4×10^{-2} V
(c) 4.8×10^{-4} V (d) 4.8×10^{-2} V

47. Consider the situation shown in figure. If the switch is closed and after some time it is opened again, the closed loop will show



(a) a clockwise current
(b) an anticlockwise current
(c) an anticlockwise current and then clockwise
(d) a clockwise current and then an anticlock wise current.

48. A circular disc of radius 0.2 meter is placed in a uniform magnetic field of induction $\frac{1}{\pi}\left(Wb/m^2\right)$ in such a way that its axis makes an angle of 60° with $\vec{B}$. The magnetic flux linked with the disc is:
(a) 0.02 Wb (b) 0.06 Wb
(c) 0.08 Wb (d) 0.01 Wb

49. A 100 turns coil of area of cross section 200 cm^2 having 2 Ω resistance is held perpendicular to a magnetic field of 0.1 T. If it is removed from the magnetic field in one second, the induced charge produced in it is
(a) 0.2 C (b) 2 C (c) 0.1 C (d) 1 C

50. If N is the number of turns in a coil, the value of self inductance varies as
(a) N^0 (b) N (c) N^2 (d) N^{-2}

51. If the number of turns per unit length of a coil of solenoid is doubled, the self-inductance of the solenoid will
(a) remain unchanged (b) be halved
(c) be doubled (d) become four times

52. The self inductance of a long solenoid cannot be increased by
(a) increasing its area of cross section
(b) increasing its length
(c) changing the medium with greater permeability
(d) increasing the current through it

53. A 100 millihenry coil carries a current of 1A. Energy stored in its magnetic field is
(a) 0.5 J (b) 1 A (c) 0.05 J (d) 0.1 J

54. The self induced emf is 0.4 henry in the coil when current in it changes at the rate of 500 A/s, is
(a) 8×10^{-4} V (b) 8×10^{-3} V
(c) 200 V (d) 500 V

55. Find the self inductance of a coil in which an e.m.f. of 10 V is induced when the current in the circuit changes uniformly from 1 A to 0.5 A in 0.2 sec.
(a) 4 H (b) 2 H (c) 3 H (d) 5 H

56. In an inductor of self-inductance $L = 2$ mH, current changes with time according to relation $i = t^2 e^{-t}$. At what time emf is zero?
(a) 4s (b) 3s (c) 2s (d) 1s

57. The current in self inductance L = 40 mH is to be increased uniformly from 1 amp to 11 amp in 4 milliseconds. The e.m.f. induced in the inductor during the process is
(a) 100 volt (b) 0.4 volt
(c) 4.0 volt (d) 440 volt

58. In an induction coil the current increases from 0 to 6 amp in 0.3 sec by which induced emf of 30 volt is produced in it then the value of coefficient of self inductance of coil will be
(a) 3 henry (b) 2 henry
(c) 1 henry (d) 1.5 henry

59. When the current in a coil changes from 8 amp to 2 amp in 3×10^{-2} seconds, the emf induced in the coil is 2 volt. The self inductance of the coil is
(a) 10mH (b) 20mH (c) 5mH (d) 1mH

60. When the current changes from +2 A to -2A in 0.05 second, an e.m.f. of 8 V is induced in a coil. The coefficient of self -induction of the coil is
(a) 0.2 H (b) 0.4 H (c) 0.8 H (d) 0.1 H

61. Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon
(a) the rates at which currents are changing in the two coils
(b) relative position and orientation of the two coils
(c) the materials of the wires of the coils
(d) the currents in the two coils

62. Induction furnace is based on the heating effect of
(a) electric field (b) eddy current
(c) magnetic field (d) gravitational field

63. If rotational velocity of a dynamo armature is doubled, then induced e.m.f. will become
(a) half (b) two times
(c) four times (d) unchanged

64. The back e.m.f. in a d.c. motor is maximum, when
(a) the motor has picked up max speed
(b) the motor has just started moving
(c) the speed of motor is still on the increase
(d) the motor has just been switched off

65. Eddy currents are produced when
(a) a metal is kept in varying magnetic field
(b) a metal is kept in steady magnetic field
(c) a circular coil is placed in a magnetic field
(d) through a circular coil, current is passed

66. If a coil made of conducting wires is roated between poles pieces of the permanent magnet. The motion will generate a current and this device is called
(a) electric motor (b) electric generator
(c) electromagnet (d) All of the above.

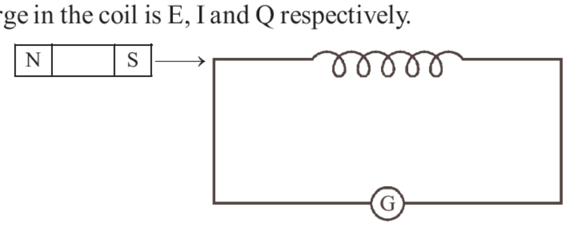
67. The armature of a dc motor has 20W resistance. It draws a current of 1.5 A when run by a 220 V dc supply. The value of the back emf induced in it is
(a) 150 V (b) 170 V (c) 180 V (d) 190 V

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

A magnet is moved with a fast speed towards a coil at rest. Due to this induced electromotive force, induced current and induced charge in the coil is E, I and Q respectively.



68. If the speed of the magnet is doubled, then
(a) E decreases
(b) E increases
(c) E remains same
(d) Either decreases or remains same

69. If the speed of the magnet is doubled, then
(a) I increases (b) I decreases
(c) I remains same (d) None of these

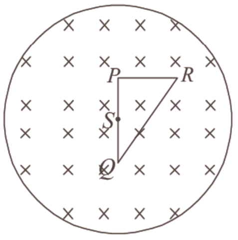
70. If the speed of the magnet is doubled, then
(a) Q increases (b) Q decreases
(c) Q remains same
(d) Either increases or decreases

71. If the speed of the magnet is halved, then
(a) E decreases (b) I decreases
(c) Q decreases (d) both (a) and (b)

72. If the speed of the magnet is halved, then
(a) E increases (b) I increases
(c) Q remains same (d) None of these

Case/Passage-II

Consider a region of cylindrical magnetic field, changing with time at the rate x. A triangular conducting loop PQR is placed in the field such that mid point of side PQ coincides with axis of the magnetic field region. $PQ = 2l$, PR = $2l$.



73. The emf induced in the side PQ of the loop is
(a) 0 (b) xl^2 (c) $\frac{xl^2}{2}$ (d) $2xl^2$

74. The emf induced in the side QR of the loop is
(a) 0 (b) xl^2 (c) $\frac{xl^2}{4}$ (d) $4xl^2$

75. The emf induced in the side PR of the loop is
(a) xl^2 (b) $\frac{xl^2}{2}$ (c) $\frac{3}{2}xl^2$ (d) zero

76. Induced emf in the coil depends upon
(a) conductivity of coil
(b) amount of flux
(c) rate of change of linked flux
(d) resistance of coil

77. Whenever the magnetic flux linked with a coil changes, an induced e.m.f.is produced in the circuit. The e.m.f. lasts
(a) for a short time
(b) for a long time
(c) for ever
(d) so long as the change in flux takes place

Case/Passage-III

Self inductance of a long solenoid: Self-inductance of a long, air-cored solenoid of lenght l, having n turns per unit length of cross-sectional area A is given by $L = \mu_0 n^2 \ell A$

When a magnetic material of relative permeability μ_r is inserted into the solenoid as a core, then the self-inductance becomes

$$L = \mu_0 \mu_r n^2 \ell A$$

78. When current in a coil changes from 5 A to 2 A in 0.1 s, average voltage of 50 V is produced. The self-inductance of the coil is :
(a) 6 H (b) 0.67 H (c) 3 H (d) 1.67 H

79. The self inductance associated with a coil is independent of
(a) current (b) time
(c) induced voltage (d) resistance of coil

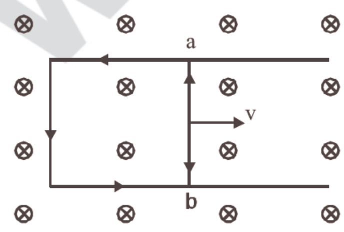
80. When the current in a coil changes from 2 amp. to 4 amp. in 0.05 sec., an e.m.f. of 8 volt is induced in the coil. The coefficient of self inductance of the coil is
(a) 0.1 henry (b) 0.2 henry
(c) 0.4 henry (d) 0.8 henry

81. The coefficient of self inductance of a solenoid is 0.18 mH. If a core of soft iron of relative permeability 900 is inserted, then the coefficient of self inductance will become nearly.
(a) 5.4 mH (b) 162 mH
(c) 0.006 mH (d) 0.0002 mH

82. The inductance of a closed-packed coil of 400 turns is 8 mH. A current of 5 mA is passed through it. The magnetic flux through each turn of the coil is
(a) $\frac{1}{4\pi}\mu_0$ Wb (b) $\frac{1}{2\pi}\mu_0$ Wb
(c) $\frac{1}{3\pi}\mu_0$ Wb (d) $0.4\,\mu_0$ Wb

Case/Passage-IV

Suppose the moving rod ab slides along a stationary U-shaped conductor, forming a complete circuit. Under the action of this field a counterclockwise current is established around this complete circuit.



The moving rod becomes a source of electromotive force. Within it, charge moves from lower to higher potential and in the remainder of the circuit, charge moves from higher to lower potential. We call this a motional electromagnetic force denoted by e, we can write,

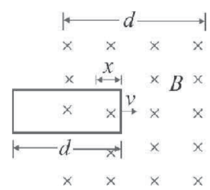
Electromotive force. $e = Bv\ell$

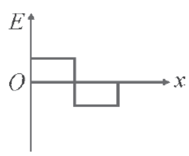
If R is the resistance of the circuit, then current in the circuit $i = \frac{e}{R} = \frac{Bv\ell}{R}$

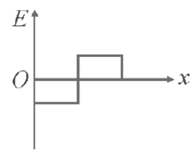
83. A 10-meter wire is kept in east-west direction. It is falling down with a speed of 5.0 meter/second, perpendicular to the horizontal component of earth's magnetic field of 0.30 $\times 10^{-4}$ weber/meter^2. The momentary potential difference induced between the ends of the wire will be
(a) 0.0015 V (b) 0.015 V
(c) 0.15 V (d) 1.5 V

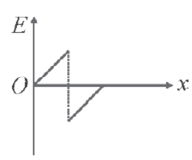
84. A conductor AB of length l moves in x – y plane with velocity $\vec{v} = v_0(\hat{i} - \hat{j})$. A magnetic field $\vec{B} = B_0(\hat{i} + \hat{j})$ exists in the region. The induced emf is
(a) zero (b) $B_0 l v_0$
(c) $B_0 l v_0$ (d) $\sqrt{2} B_0 l v_0$

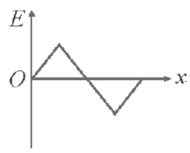
85. A rectangular loop is being pulled at a constant speed v, through a region of certain thickness d, in which a uniform magnetic field B is set up.
The graph between position x of the right hand edge of the loop and the induced emf E will be



(a)


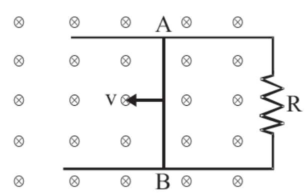
(b)


(c)


(d)


86. A six pole generator with fixed field excitation develops an e.m.f. of 100 V when operating at 1500 r.p.m. At what speed must it rotate to develop 120V?
(a) 1200 r.p.m (b) 1800 r.p.m
(c) 1500 r.p.m (d) 400 r.p.m

87. Consider the situation shown. The wire AB is sliding on fixed rails with a constant velocity. If the wire AB is replaced by semi-circular wire, the magnitude of induced e.m.f. will



(a) increase
(b) decrease
(c) remain the same
(d) increase or decrease depending on whether the semi-circle buldges towards the resistance or away from it.

Assertion & Reason

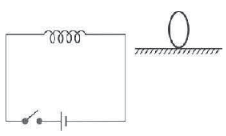
DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

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

88. **Assertion :** Only a change in magnetic flux will maintain an induced current in the coil.

Reason : The presence of constant magnetic field through a coil maintain an induced current in the coil of the circuit.

89. **Assertion :** Figure shows a horizontal solenoid connected to a battery and a switch. A copper ring is placed on a smooth surface, the axis of the ring being horizontal.



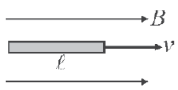
As the switch is closed, the ring will move away from the solenoid.

Reason : Induced current in the ring, $i = -\frac{d\phi}{dt}$.

90. **Assertion :** The induced charge that flows in the circuit does not depends on the time rate change of flux.

Reason : $i = \frac{dq}{dt} = -\frac{1}{R}\left(\frac{d\phi}{dt}\right) \Rightarrow dq = -\frac{d\phi}{R}$

91. **Assertion :** Figure shows a metallic conductor moving in magnetic field. The induced emf across its ends is zero.



Reason : The induced emf across the ends of a conductor is given by $e = Bv\ell\sin\theta$.

92. **Assertion :** When number of turns in a coil is doubled, coefficient of self-inductance of the coil becomes 2 times.

Reason : This is because $L \propto 1/N$.

93. **Assertion :** An induced emf appears in any coil in which the current is constant.

Reason : Self induction phenomenon does not obey Faraday's law of induction.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

94. Match the column-I and column-II

	Column I		Column II
(A)	AC generator	(1)	Eddy current
(B)	Dead beat galvanometer	(2)	Slip rings
		(3)	Split ring
(C)	Solenoid	(4)	Insulated copper wire wound in the form of a cylindrical coil

(a) (A) → (2) ; (B) → (2) ; (C) → (1)
(b) (A) → (4) ; (B) → (1) ; (C) → (3)
(c) (A) → (2) ; (B) → (1) ; (C) → (4)
(d) (A) → (2) ; (B) → (3) ; (C) → (4)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

95. A conductor of length 0.4 m is moving with a speed of 7 m/s perpendicular to a magnetic field of intensity 0.9 Wb/m^2. The induced e.m.f. across the conductor is ______ V.

96. A varying current in a coil changes from 10A to zero in 0.5 sec. If the average e.m.f induced in the coil is 220V, the self-inductance of the coil is ______ H.

97. The mutual inductance of a pair of coils is 0.75 H. If current in the primary coil changes from 0.5 A to zero in 0.01 s, find average induced e.m.f. in secondary coil ______ V.

98. A coil of N = 100 tuns carries a current I = 5A and creates a magnetic flux $\phi = 10^{-5}$ Tm^2 per turn. The value of its inductance L will be ______ mH.

99. A generator has an e.m.f. of 440 Volt and internal resistance of 4000 hm. Its terminals are connected to a load of 4000 ohm. The voltage across the load is ____________ volt.

100. The number of turns of a solenoid are doubled without changing its length and area of cross-section. The self-inductance of the solenoid will become ________ times. **[CBSE 2020]**

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

101. Emf will always induce whenever there is change in magnetic flux associated with a circuit.

102. Current will never induces whenever there is change in magnetic flux.

103. An emf can be induced by moving a conductor in a magnetic field.

104. An emf can be induced by changing the magnetic field.

ANSWER KEY & SOLUTIONS

1. **(b)** The charge through the coil = area of current-time ($i - t$) graph

$$q = \frac{1}{2} \times 0.1 \times 4 = 0.2\,C$$

$$q = \frac{\Delta\phi}{R} \quad [\because \text{Change in flux } (\Delta\phi) = q \times R]$$

$$q = 0.2 = \frac{\Delta\phi}{10}$$

$\Delta\phi = 2$ weber

2. **(d)** The induced e.m.f. is given by rate of change of magnetic flux linked with the circuit.

$$e = -\frac{d\phi}{dt}$$

For N turns $e = -N\frac{d\phi}{dt}$

Negative sign indicates that induced emf (e) opposes the change of flux.

3. **(d)** Relative motion between the magnet and the coil that is responsible for induction in the coil.

4. **(c)** As I increases, ϕ increases

$\therefore$ I_i is such that it opposes the increases in ϕ.

Hence, ϕ decreases (By Right Hand Rule). The induced current will be counter clockwise.

5. **(b)** The relative motion between the coil and the magnet produces change in the magnetic flux in the coil and the induced emf is always in such a direction that it opposes the change in the flux.

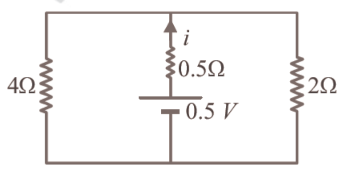
6. **(b)** Because there is no change in flux linked with coil.

7. **(d)** No change in flux, hence no force required.

8. **(a)** The induced emf across the sliding wire

$e = Bv\ell = 0.5 \times 4 \times 0.25 = 0.5\,V$

The effective circuit is shown in figure.



The equivalent resistance of the circuit

$$r = \frac{4 \times 2}{4+2} + 0.5 = 1.83\,\Omega$$

Now, $i = \frac{V}{R} = \frac{0.5}{1.83} = 0.27A$

9. **(d)** $|e| = BlV \sin\theta$

10. **(d)** $e = [Bv\ell]$

$$|e| = \begin{vmatrix} 3 & 3 & 2 \\ 1 & 2 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

(as length of conductor is $0\hat{i} + 0\hat{j} + 1\hat{k}$)

$\therefore\ |e| = 3V$

11. **(d)** The e.m.f. is induced when there is change of flux. As in this case there is no change of flux, hence no e.m.f. will be induced in the wire.

12. **(a)** $L = \frac{\varepsilon}{dI/dt} = \frac{10 \times 10^{-3}}{2} = 5 \times 10^{-3}$ Henry

13. **(b)** $L = \frac{N\phi}{i}$

14. **(b)** Mutual Inductance of two coils

$M = \sqrt{L_1 L_2} = \sqrt{2mH \times 8mH} = 4mH$

15. **(b)** Given $\frac{\ell_1}{\ell_2} = \frac{1}{2}$ and $\frac{N_1}{N_2} = \frac{1}{2}$ From

$$L = \frac{\mu_0 N^2 A}{\ell} \alpha \frac{N^2}{\ell}$$

we get, $\frac{L_1}{L_2} = \left(\frac{N_1}{N_2}\right)^2 \Big/ \left(\frac{\ell_1}{\ell_2}\right) = \frac{(1/2)^2}{1/2} = \frac{1}{2}$

16. **(b)**

17. **(c)** As we know that, the magnetic flux linked with uniform surface of area A in uniform magnetic field is

$\phi =$ B.A

The direction of A is perpendicular to the plane of square and square line in x-y plane in a region.

$A = L^2 k$

As given that, $B = B_0\left(2\hat{i} + 3\hat{j} + 4\hat{k}\right)$

So, $\phi = B.A = B_0\left(2\hat{i} + 3\hat{j} + 4\hat{k}\right).L^2\hat{k} = 4B_0L^2\,Wb$

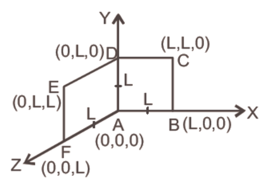
18. **(b)** The loop can be considered in two planes, Plane of ABCDA lies x-y plane whose area vector

$A_1 = |A|\,\hat{k}$, $A_1 = L^2\,\hat{k}$

whereas plane of ADEFA lies in y-z plane whose area vector

$A_2 = |A|\,\hat{i}$, $A_2 = L^2\,\hat{i}$.

Then the magnetic flux linked with uniform surface of area A in uniform magnetic field is

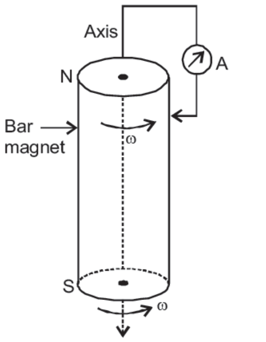


$\phi = B.A$

$A = A_1 + A_2 = (L^2\hat{k} + L^2\hat{i})$ and $B = B_0(\hat{i} + \hat{k})$

Now, $\phi = B.A = B_0(\hat{i}+\hat{k})\cdot(L^2\hat{k}+L^2\hat{i}) = 2 B_0 L^2$ Wb

19. **(b)** Induced current flow only when circuit is complete and there is a variation about circuit this problem is associated with the phenomenon of electromagnetic induction.



If there is a symmetry in magnetic field of cylindrical bar magnet is rotated about its axis, no change in flux linked with the circuit takes place, consequently no emf induces and hence, no current flows in the ammeter (A).

20. **(d)** When the coil A stops moving the current in B b ecome ze ro, it possible only if the current in A is constant. If the current in A would be variable, there must be an induced emf (current) in B even if the A stops moving. So there is a constant current in same direction or counter clockwise direction in A as in B by lenz's law.

21. **(a)** By Lenz's law, at (t = 0) the current in B is counter-clockwise and the coil A is considered above to it. The counterclockwise flow of the current in B is equivalent to north pole of magnet and magnetic field lines are emanating upward to coil A.

When coil A start rotating at t = 0, the current in A is constant along clockwise direction by Lenz's rule. As flux changes across coil A by rotating it near the N-pole formed by flowing current in B, in anticlockwise.

22. **(b)** The self-inductance of a long solenoid of cross-sectional area A and length l, having n turns per unit length, filled the inside of the solenoid with a material of relative permeability is given by

$L = \mu_r \mu_0 n^2 A l$

$\therefore \quad n = N/l$

$$L = \mu_r\mu_0\left[\frac{N^2.A}{l.l}\right].l$$

$$L = \mu_r\mu_0 [N^2A/l] \qquad \left(L \propto A, L \propto \frac{1}{l}\right)$$

As μ_r and N are constant here so, to increase L for a coil, area A must be increased and l must be decreased.

23. **(d)** $\varphi = BA\cos\theta = 2.0 \times 0.5 \times \cos 60^\circ$

$$= \frac{2.0 \times 0.5}{2} = 0.5 \text{ weber.}$$

24. **(b)** Length of conductor (l) = 0.4 m; Speed (v) = 7 m/s and magnetic field (B) = 0.9 Wb/ m^2. Induced e.m.f. $(\varepsilon) = Blv\cos\theta = 0.9 \times 0.4 \times 7 \times \cos 0^\circ = 2.52$ V.

25. **(b)**

26. **(d)** $e = -\frac{d\phi}{dt} = -\frac{d(N\vec{B}.\vec{A})}{dt}$

$$= -N\frac{d}{dt}(BA\cos\omega t) = NBA\omega\sin\omega t \Rightarrow e_{max} = NBA\omega$$

27. **(c)** $q = \int i dt = \frac{1}{R}\int e dt = \frac{1}{R}\int\left(\frac{-d\phi}{dt}\right)dt = \frac{1}{R}\int d\phi$

(taking only magnitude of e)

Hence, total charge induced in the conducting loop depends upon the total change in magnetic flux.

28. **(b)** Induced of e.m.f., $e = -\frac{d\phi}{dt}$

29. **(b)** **30.** **(c)** **31.** **(c)**

32. **(d)** $e = -\frac{d\phi}{dt} = -2x \quad t = 9$

$\therefore -2x \times 3 = 9 \quad \therefore x = -1.5$ Wb/s^2 [At t = 3]

33. **(d)** Given : $\phi = 4t^2 + 2t + 1$ wb

$$\therefore \frac{d\phi}{dt} = \frac{d}{dt}(4t^2 + 2t + 1) = 8t + 2 = |\varepsilon|$$

$$I = \frac{|\varepsilon|}{R} = \frac{8t+2}{10\Omega} = \frac{8t+2}{10} A = 1A \text{ At } t = 1 \text{ s}$$

34. **(a)** $e = \frac{d\phi}{dt} = \frac{d}{dt}(NBA) = NA\frac{dB}{dt} = 0.5$ V

35. **(b)** $e = \frac{-(\phi_2 - \phi_1)}{t} = \frac{-(0 - NBA)}{t} = \frac{NBA}{t}$

$$t = \frac{NBA}{e} = \frac{50 \times 2 \times 10^{-2} \times 10^{-2}}{0.1} = 0.1 \text{ s}$$

36. **(a)** $\xi = \frac{W}{Q} \Rightarrow V = \frac{W}{Q} \Rightarrow W = QV$

37. **(c)** **38.** **(a)**

39. **(a)** **Given:** No. of turns $N = 1000$

Face area, $A = 4$ cm$^2 = 4 \times 10^{-4}$ m^2

Change in magnetic field,

$\Delta B = 10^{-2}$ wbm^{-2}

Time taken, $t = 0.01$s $= 10^{-2}$ sec

Emf induced in the coil e = ?

Applying formula,

Induced emf, $e = \frac{-d\phi}{dt} = N\left(\frac{\Delta B}{\Delta t}\right)A\cos\theta = 400$ mV

40. **(c)** $$i = \frac{e}{R} = \frac{\frac{nAdB}{dt}}{R} = \frac{20 \times (25 \times 10^{-4}) \times 1000}{100} = 0.5A$$

41. **(b)** Given : A = 4 m^2, e = 0.32 V, dt = 0.5sec.

B_1 is the initial magnetic induction and when it is reduced to 20% $B_2 = 0.2 B_1$

$$e = \frac{d\phi}{dt} = \frac{A(B_1 - B_2)}{\Delta t} \text{ or } 0.32 = \frac{4(B_1 - 0.2B_1)}{0.5}$$

Magnetic induction $B_1 = \frac{0.16}{3.2} = 0.05$ Wb/m^2

42. (c) If the current increases with time in loop A, then magnetic flux in B will increase. According to Lenz's law, loop -B is repelled by loop -A because current in loop B will be antiparallel to that in A.

43. (c) $\frac{\Delta\phi}{\Delta t} = \varepsilon = iR \Rightarrow \Delta\phi = (i\Delta t)R = QR \quad \Rightarrow Q = \frac{\Delta\phi}{R}$

44. (b) Induced e.m.f. in the ring opposes the motion of the magnet.

45. (d) When the coils P and Q are brought nearer, the magnetic flux linked with each coil will increase and the induced current will induces in the direction opposite to original current according to Lenz, law and hence current in both P and Q decreases.

46. (b) $n = \frac{N}{\ell} = \frac{2000}{0.3} = \frac{20000}{3}$; $\xi = \frac{d}{dt}(NBA) = NA\frac{dB}{dt}$

Since $B = \mu_0 nI \Rightarrow \xi = (\mu NAn)\frac{dt}{dt} \Rightarrow \xi = 0.024\,V$

47. (d) According to Lenz's law, when switch is closed, the flux in the loop increases out of plane of paper, so induced current will be clockwise.

48. (a) Here, $B = \frac{1}{\pi}$ (Wb/m^2)

$\theta = 60°$

Area normal to the plane of the disc

$= \pi r^2 \cos 60° = \frac{\pi r^2}{2}$

Flux = B × normal area

$= \frac{0.2 \times 0.2}{2} = 0.02\,Wb$

49. (c) $A = 200\,cm^2 = 200 \times 10^{-4}\,m^2$; $N = 100$; $R = 2\Omega$

Initial magnetic flux linked with the coil is

$\phi_i = BA\cos\theta = 0.1 \times 200 \times 10^{-4} \times \cos 0^o = 2 \times 10^{-3}\,Wb$

Final magnetic flux linked with the coil is $\phi_f = 0$

$$\varepsilon = -\frac{N\Delta\phi}{\Delta t} = \frac{-N(\phi_f - \phi_i)}{\Delta t} = \frac{-100(0 - 2\times10^{-3})}{1} = 0.2V$$

Induced current $I = \frac{\varepsilon}{R} = \frac{0.2V}{2\Omega} = 0.1A$

Induced charge $q = It = 0.1 \times 1 = 0.1\,C$

50. (c) Self inductance, $L = \mu_r\mu_0 N^2 Al$

51. (d) Self inductance of a solenoid $= \frac{\mu n^2 A}{\ell}$

So, self induction $\propto n^2$

So, inductance becomes 4 times when n is doubled.

52. (d) The self inductance of a long solenoid is given by

$L = \mu_r\mu_0 n^2 Al$

Self inductance of a long solenoid is independent of the current flowing through it.

53. (c) $E = \frac{1}{2}Li^2 = \frac{1}{2} \times (100 \times 10^{-3}) \times 1^2 = 0.05\,J$

54. (c) According to faraday law of electro magnetic induction,

$$e = \left|L\frac{dI}{dt}\right| = 0.4 \times \frac{500}{1} = 200 \text{ volts.}$$

55. (a) Given : $e = 10\,V$ and $\frac{dI}{dt} = \frac{1-0.5}{0.2} = \frac{0.5}{0.2} = 2.5\,A/s$

Self inductance of coil $L = \frac{e}{dI/dt} = \frac{10}{2.5} = 4\,H$

56. (c) $L = 2mH$, $i = t^2e^{-t}$

$E = -L\frac{di}{dt} = -L[-t^2e^{-t} + 2te^{-t}]$

when $E = 0$,

$-e^{-t}t^2 + 2te^{-t} = 0$ or, $2t\,e^{-t} = e^{-t}t^2 \Rightarrow t = 2$ sec.

57. (a) $e = L\frac{di}{dt}$

Given that $L = 40 \times 10^{-3}\,H$,

$di = 11\,A - 1\,A = 10\,A$

and $dt = 4 \times 10^{-3}\,s$

$\therefore \quad e = 40 \times 10^{-3} \times \left(\frac{10}{4\times10^{-3}}\right) = 100V$

58. (d) $\Delta I = 6A$, $\Delta t = 0.3s$, $E = 30\,V$

$E = L\frac{dI}{dt} \quad \therefore L = \frac{30 \times 0.3}{6} = 1.5\,H.$

59. (a) According to Faraday's law of electro-magnetic inductions,

$e = \left|L\frac{dI}{dt}\right| \Rightarrow 2 = L\frac{(8-2)}{3\times10^{-2}} \Rightarrow L = 10\,mH$

60. (d) $e = -\frac{\Delta\phi}{\Delta t} = \frac{-\Delta(LI)}{\Delta t} = -L\frac{\Delta I}{\Delta t} \quad \therefore |e| = L\frac{\Delta I}{\Delta t}$

$\Rightarrow 8 = L \times \frac{4}{0.05} \quad \Rightarrow L = \frac{8 \times 0.05}{4} = 0.1H$

61. (b) Mutual inductance depends on the relative position and orientation of the two coils.

62. (b) Induction furnace is based on the heating effect of eddy current. The furnace is used to prepare alloys by melting the constituent metals. It produces very high temperature.

63. (b) $e \propto \omega$

64. (a) The back e.m.f. in a motor is induced e.m.f., which is maximum, when speed of rotation of the coil is maximum.

65. (a) **66. (b)** **67. (d)**

68. (b) E increases if the speed of the magnet increases.

69. (a) I increases if the speed of the magnet.

70. (c) Q remains same if the speed of the magnet is doubled.

71. (d) If the speed of the magnet is halved, then E and I decreases.

72. (c) Q does not depend upon the speed of the magnet.

73. (a) $e = \frac{d}{2}\ell\left(\frac{dB}{dt}\right)$

For PQ, $\quad d = 0, e_{PQ} = 0$

For QR, $\quad d = \ell,\ ePR = \frac{\ell}{2} \times 2\ell \quad x = x\,\ell^2$

In close loop, $e_{QP} + e_{PR} + e_{RQ} = 0$

or $0 + e_{PR} + e_{RQ} = 0$

$\therefore\ e_{RQ} = -e_{PR}$

$= e_{RP}$

$= xl^2$

74. **(b)** **75.** **(a)**

76. **(c)** Induced emf in the coil depends upon rate of change of linked flux.

77. **(d)** The emf lasts so long as the change in flux takes place.

78. **(d)** According to Faraday's law of electromagnetic induction,

Induced emf, $e = \frac{Ldi}{dt}$

$50 = L\left(\frac{5-2}{0.1\text{sec}}\right)$

$\Rightarrow\ L = \frac{50 \times 0.1}{3} = \frac{5}{3} = 1.67\ \text{H}$

79. **(d)**

80. **(b)** $\varepsilon = M\frac{di}{dt}$ or $8 = M\left[\frac{(4-2)}{0.05}\right]$

$\therefore\ M = \frac{8 \times 0.05}{2} = 0.2$ henry

81. **(b)** $L = \mu_0 nI$

$\therefore\ \frac{L_2}{L_1} = \frac{\mu}{\mu_0}$ ----($\because$ n and I are same)

$\therefore\ L_2 = \mu_r L_1 = 900 \times 0.18 = 162$ mH

82. **(a)** $N\phi = LI$

$\therefore\ \phi = \frac{LI}{N} = \frac{8 \times 10^{-3} \times 5 \times 10^{-3}}{400}$

$= 10^{-7} = \frac{\mu_0}{4\pi}$ Wb

83. **(a)** If a wire, l meter in length, moves perpendicular to a magnetic field of B weber/meter^2 with a velocity of v meter/second, then the e.m.f. induced in the wire is given by $V = B v\ell$ volt.
Here, $B = 0.30 \times 10^{-4}$ weber/meter^2,
v = 5.0 meter/second and ℓ = 10 meter.
$\therefore$ $B = 0.30 \times 10^{-4} \times 5.0 \times 10 = 0.0015$ volt.

84. **(a)** $\vec{\ell}, \vec{v}$, and $\vec{B}$ are coplanar.

85. **(b)** Till front side of the loop moves into the field the emf induced $e = Bvl$ across it. When rear side comes in the field, the emf is induced across it.

86. **(b)** The e.m.f. induced is directly proportional to rate at which flux is intercepted which in turn varies directly as the speed of rotation of the generator.

87. **(c)** E.m.f. will remain same because change in area per unit time will be same in both cases.

88. **(c)**

89. **(c)** When switch is closed , the magnetic flux through the ring will increase and so ring will move away form the solenoid so as to compensate this flux. This is according to Lenz's law.

90. **(a)** $\frac{dq}{dt} = -\frac{1}{R}\frac{d\phi}{dt} \Rightarrow dq = -\frac{d\phi}{R} \Rightarrow q = \frac{(\phi_1 - \phi_2)}{R}$

which is indipendent of time.

91. **(a)** In the given case, there is no component of velocity in perpendicular to the magnetic field and so $e = Bv\ell \sin 0°$.

92. **(c)** Number of flux linkages with the coil is proportional to the current i, N f μ i

or $N\phi = Li$ [N is the number of turns in coils]
[N ϕ is total flux linkage]

Hence, $L = \frac{N\phi}{i}$ = co-efficient of self-inductance.

93. **(d)**

94. **(c)** (A) → (2); (B) → (1); (C) → (4)
Slip ring is a part of an AC generator.
In a dead beat galvanometer, eddy current helps in electromagnetic damping.
A solenoid is formed of long coil of circular loops of insulated copper wire

95. (2.52) Length of conductor (l) = 0.4 m; Speed (v) = 7 m/s and magnetic field (B) = 0.9 Wb/ m^2. Induced e.m.f. (V) = $Blv \sin\theta = 0.9 \times 0.4 \times 7 \times \sin 90° = 2.52$ V.

96. (11) Initial current (I_1) = 10 A; Final current (I_2) = 0; Time (t) = 0.5 sec and induced e.m.f. (ε) = 220 V.
Induced e.m.f. (ε)

$= -L\frac{dI}{dt} = -L\frac{(I_2 - I_1)}{t} = -L\frac{(0-10)}{0.5} = 20L$

or, $L = \frac{220}{20} = 11\text{H}$

97. (37.5) Given : M = 0.75 H and $\frac{dI}{dt} = \frac{0.5-0}{0.01} = 50$ A/s

$\therefore$ Average induced e.m.f. in secondary coil

$e = M\frac{dI}{dt} = 0.75 \times 50 = 37.5$ V

98. (0.20) $N\phi = Li \Rightarrow L = \frac{N\phi}{i} = \frac{100 \times 10^{-5}}{5} = 0.20$ mH

99. (400) Total resistance of the circuit = 4000 + 400 = 4400 W

Current flowing $i = \frac{V}{R} = \frac{440}{4400} = 0.1$ amp.

Voltage across load = R i = 4000 × 0.1 = 400 volt.

100. (Four) Self-inductance of a long solenoid

$L = \frac{M_0 N^2 A}{\ell}$ or $L \propto N^2$ and N = 2 hence L becomes four times.

101. (True) Emf will always induces whenever, there is change in magnetic flux.

102. (False)

103. (True)

104. (True)

7 Alternating Current

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. The average value of alternating current for one complete cycle is
(a) zero (b) 1
(c) $\sqrt{2}$ (d) None of these

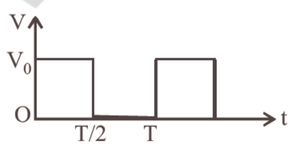
2. The ratio of mean value over half cycle to r.m.s. value of A.C. is
(a) $2:\pi$ (b) $2\sqrt{2}:\pi$ (c) $\sqrt{2}:\pi$ (d) $\sqrt{2}:1$

3. The instantaneous voltage through a device of impedance $20\,\Omega$ is $e = 80 \sin 100\pi t$. The effective value of the current is
(a) 3 A (b) 2.828 A
(c) 1.732 A (d) 4 A

4. If instantaneous current is given by $i = 4\cos(\omega t + \phi)$ ampere, then the r.m.s value of current is,
(a) 4 amperes (b) $4\sqrt{2}$ amperes
(c) $2\sqrt{2}$ amperes (d) zero amperes

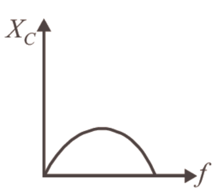
5. The average value of alternating current for one complete cycle is
(a) zero (b) 1
(c) $\sqrt{2}$ (d) None of these

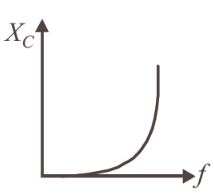
6. The r.m.s. value of potential difference V shown in the figure is

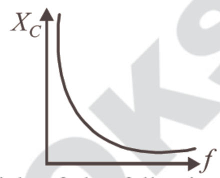


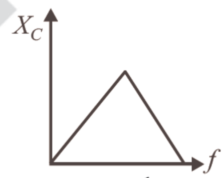
(a) V_0 (b) $V_0/\sqrt{2}$ (c) $V_0/2$ (d) $V_0/\sqrt{3}$

7. Which of the following graphs represents the correct variation of capacitive reactance X_C with frequency f ?

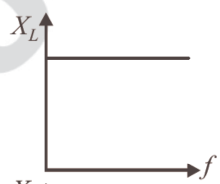
(a)


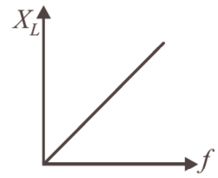
(b)


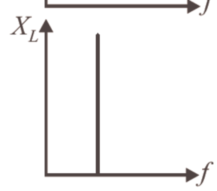
(c)


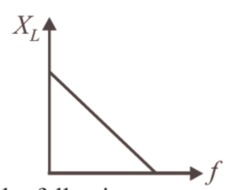
(d)


8. Which of the following graphs represents the correct variation of inductive reactance X_L with frequency f ?

(a)


(b)


(c)


(d)


9. In a series LCR circuit which of the following statements is/are true/false?
I. At resonance impedance becomes minimum and current becomes maximum.
II. At resonance current is in phase with applied voltage
III. Resonant frequency depends upon the resistance of the circuit.
(a) T,F,F (b) F,T,F (c) T,F,T (d) T,T,F

10. If the frequency of an A.C. is made 4 times of its initial value, the inductive reactance will
(a) be 4 times (b) be 2 times
(c) be half (d) remain the same

11. In an ac circuit an alternating voltage $e = 200\sqrt{2}\sin 100\,t$ volts is connected to a capacitor of capacity 1 μF. The r.m.s. value of the current in the circuit is
(a) 10 mA (b) 100 mA (c) 200 mA (d) 20 mA

12. Consider the following statements and then select the true/false statements.
I. Most of the electrical device we use require AC voltage.
II. Most of the electrical energy sold by power companies is transmitted and distributed as alternating current.
III. AC voltage can be easily and efficiently converted from one to the other by means of transformers.
(a) T,F,F (b) T,F,T (c) T,T,F (d) T,T,T

13. The primary winding of a transformer has 100 turns and its secondary winding has 200 turns. The primary is connected to an A.C. supply of 120 V and the current flowing in it is 10 A. The voltage and the current in the secondary are
(a) 240 V, 5 A (b) 240 V, 10 A
(c) 60 V, 20 A (d) 120 V, 20 A

14. A charged 30 μF capacitor is connected to a 27 mH inductor. The angular frequency of free oscillations of the circuit is
(a) 1.1×10^3 rad s^{-1} (b) 2.1×10^3 rad s^{-1}
(c) 3.1×10^3 rad s^{-1} (d) 4.1×10^3 rad s^{-1}

15. If the rms current in a 50 Hz AC circuit is 5 A, the value of the current 1/300 s after its value becomes zero is
(a) $5\sqrt{2}$A (b) $5\sqrt{3/2}$ A (c) 5/6 A (d) $5/\sqrt{2}$A

16. An alternating current generator has an internal reactance 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

17. 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

18. To reduce the resonant frequency in an L-C-R series circuit with a generator
(a) the generator frequency should be reduced
(b) another capacitor should be added in parallel to the first
(c) the iron core of the inductor should be removed
(d) dielectric in the capacitor should be removed

19. Which of the following combinations should be selected for better tuning of an L-C-R circuit used for communication?
(a) R = 20 Ω, L = 1.5 H, C = 35 μF
(b) R = 25 Ω, L = 2.5 H, C = 45 μF
(c) R = 15 Ω, L = 3.5 H, C = 30 μF
(d) R = 25 Ω, L = 1.5 H, C = 45 μF

20. Determine the rms value of the emf given by E(in volt) = 8 sin (ωt) + 6sin (2ωt)
(a) $5\sqrt{2}$V (b) $7\sqrt{2}$V (c) 10 V (d) $10\sqrt{2}$V

21. Eddy currents in the core of transformer can't be developed by
(a) increasing the number of turns in secondary coil
(b) taking laminated transformer
(c) making step down transformer
(d) using a weak a.c. at high potential

22. A.C. power is transmitted from a power house at a high voltage as
(a) the rate of transmission is faster at high voltages
(b) it is more economical due to less power loss
(c) power cannot be transmitted at low voltages
(d) a precaution against theft of transmission lines

23. Alternating current cannot be measured by dc ammeter because
(a) average value of complete cycle is zero
(b) ac cannot pass through dc ammeter
(c) ac is virtual
(d) ac changes its direction

24. The r.m.s. value of current, I_{rms} is related to the peak current, I_0 by the relation
(a) $I_{rms} = \sqrt{2}\, I_0$ (b) $I_{rms} = \pi I_0$
(c) $I_{rms} = \frac{1}{\pi} I_0$ (d) $I_{rms} = \frac{1}{\sqrt{2}} I_0$

25. The instantaneous voltage through a device of impedance 20 Ω is e = 80 sin 100 πt. The effective value of the current is
(a) 3 A (b) 2.828 A
(c) 1.732 A (d) 4 A

26. A lamp consumes only 50% of peak power in an a.c. circuit. What is the phase difference between the applied voltage and the circuit current?
(a) $\frac{\pi}{6}$ (b) $\frac{\pi}{3}$ (c) $\frac{\pi}{4}$ (d) $\frac{\pi}{2}$

27. When an ac voltage of 220 V is applied to the capacitor *C*, then
(a) the maximum voltage between plates is 220 V.
(b) the current is in phase with the applied voltage.
(c) the charge on the plate is not in phase with the applied voltage.
(d) power delivered to the capacitor per cycle is zero.

28. The voltage of an ac source varies with time according to the equation $V = 100 \sin 100\pi t \cos 100\pi t$ where t is in seconds and V is in volt. Then
(a) the peak voltage of the source is 100 volt
(b) the peak voltage of the source is 50 volt
(c) the peak voltage of the source is $100/\sqrt{2}$ volt
(d) the frequency of the source is 50 Hz

29. The voltage of an ac supply varies with time (t) as V = 120 sin 100 πt cos 100 πt. The maximum voltage and frequency respectively are
(a) 120 volt, 100 Hz (b) $\frac{120}{\sqrt{2}}$ volt, 100 Hz
(c) 60 volt, 200 Hz (d) 60 volt, 100 Hz

30. Determine the rms value of the emf given by E (in volt) = 8 sin (ω t) + 6sin (2 ω t)
(a) $5\sqrt{2}$V (b) $7\sqrt{2}$V (c) 10 V (d) $10\sqrt{2}$V

31. In an A.C. circuit with voltage V and current I the power dissipated is
(a) $\frac{1}{\sqrt{2}}$VI
(b) $\frac{1}{2}$VI
(c) VI
(d) dependent on the phase between V and I

32. The current I passed in any instrument in alternating current circuit is $I = 2 \sin \omega t$ amp and potential difference applied is given by $V = 5 \cos \omega t$ volt then power loss in instrument is
(a) 2.5 watt (b) 5 watt (c) 10 watt (d) zero

33. A resistance of 20 ohm is connected to a source of an alternating potential $V = 200 \cos(100 \pi t)$. The time taken by the current to change from its peak value to rms value, is
(a) 2.5×10^{-3} s (b) 25×10^{-3} s
(c) 0.25 s (d) 0.20 s

34. An alternating e.m.f. of angular frequency ω is applied across an inductance. The instantaneous power developed in the circuit has an angular frequency
(a) $\frac{\omega}{4}$ (b) $\frac{\omega}{2}$ (c) ω (d) 2ω

35. A sinusoidal AC current flows through a resistor of resistance R. If the peak current is I_p, then power dissipated is
(a) $I_p^2 R \cos \theta$ (b) $\frac{1}{2} I_p^2 R$
(c) $\frac{4}{3} I_p^2 R$ (d) $\frac{1}{\pi^2} I_p^2 R$

36. A direct current of 5A is superimposed on an alternating current $I = 10 \sin \omega t$ flowing through a wire. The effective value of the resulting current will be:
(a) 15/2 amp (b) $5\sqrt{3}$ amp
(c) $5\sqrt{5}$ amp (d) 15 amp

37. In an LCR circuit
(a) the impedance is equal to reactance
(b) the ratio between effective voltage to effective current is called reactance
(c) at resonance the resistance is equal to the resistance
(d) at resonance the net reactance is zero

38. The power factor in a circuit connected to an A.C.
(a) unity when the circuit contians an ideal inductance only
(b) unity when the circuit contians an ideal resistance only
(c) zero when the circuit contains an ideal resistance only
(d) unity when the circuit contains an ideal capacitance only

39. The time constant of C–R circuit is
(a) 1/CR (b) C/R (c) CR (d) R/C

40. In LCR circuit if resistance increases, quality factor
(a) increases finitely (b) decreases finitely
(c) remains constant (d) None of these

41. An inductor, a resistor and a capacitor are joined in series with an AC source. As the frequency of the source is slightly increased from a very low value, the reactance of the
(a) inductor increases (b) resistor increases
(c) capacitor increases (d) circuit increases

42. With increase in frequency of an A.C. supply, the impedance of an L-C-R series circuit
(a) remains constant
(b) increases
(c) decreases
(d) decreases at first, becomes minimum and then increases.

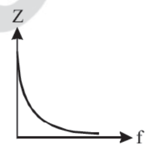
43. In an L.C.R. series a.c. circuit, the current
(a) is always in phase with the voltage
(b) always lags the generator voltage
(c) always leads the generator voltage
(d) None of these

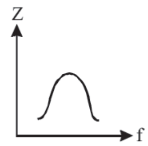
44. A bulb and a capacitor are connected in series to a source of alternating current. If its frequency is increased, while keeping the voltage of the source constant, then bulb will
(a) give more intense light
(b) give less intense light
(c) give light of same intensity before
(d) stop radiating light

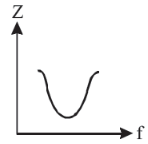
45. An LCR series circuit, connected to a source E, is at resonance. Then the voltage across
(a) R is zero (b) R equals applied voltage
(c) C is zero (d) L equals applied voltage

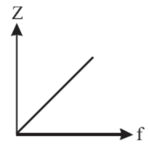
46. A capacitor in an ideal LC circuit is fully charged by a DC source, then it is disconnected from DC source, the current in the circuit
(a) becomes zero instantaneously
(b) grows , monotonically
(c) decays monotonically
(d) oscillate infinitely

47. Which one of the following curves represents the variation of impedance (Z) with frequency f in series LCR circuit?

(a)


(b)


(c)


(d)


48. An A.C. source is connected to a resistive circuit. Which of the following is true?
(a) Current leads ahead of voltage in phase
(b) Current lags behind voltage in phase
(c) Current and voltage are in same phase
(d) Any of the above may be true depending upon the value of resistance.

49. A resistance 'R' draws power 'P' when connected to an AC source. If an inductance is now placed in series with the resistance, such that the impedance of the circuit becomes 'Z', the power drawn will be
(a) $P\sqrt{\frac{R}{Z}}$ (b) $P\left(\frac{R}{Z}\right)$ (c) P (d) $P\left(\frac{R}{Z}\right)^2$

50. With increase in frequency of an A.C. supply, the inductive reactance
(a) decreases
(b) increases directly with frequency
(c) increases as square of frequency
(d) decreases inversely with frequency

51. The transformer voltage induced in the secondary coil of a transformer is mainly due to
(a) a varying electric field
(b) a varying magnetic field
(c) the vibrations of the primary coil
(d) the iron core of the transformer

52. A transformer is employed to
(a) convert A.C. into D.C.
(b) convert D.C. into A.C.
(c) obtain a suitable A.C. voltage
(d) obtain a suitable D.C. voltage

53. The loss of energy in the form of heat in the iron core of a transformer is
(a) iron loss (b) copper loss
(c) mechanical loss (d) None of these

54. Quantity that remains unchanged in a transformer is
(a) voltage (b) current
(c) frequency (d) None of these

55. The transformation ratio in the step-up transformer is
(a) one
(b) greater than one
(c) less than one
(d) the ratio greater or less than one depends on the other factor

56. A transistor-oscillator using a resonant circuit with an inductor L (of negligible resistance) and a capacitor C in series produce oscillations of frequency f. If L is doubled and C is changed to 4C, the frequency will be
(a) 8f (b) $f/2\sqrt{2}$ (c) f/2 (d) f/4

57. A transformer has an efficiency of 80%. It works at 4 kW and 100 V. If secondary voltage is 240 V, the current in primary coil is
(a) 0.4 A (b) 4 A (c) 10 A (d) 40 A

58. In an oscillating LC circuit the maximum charge on the capacitor is Q. The charge on the capacitor when the energy is stored equally between the electric and magnetic field is
(a) $\frac{Q}{2}$ (b) $\frac{Q}{\sqrt{3}}$ (c) $\frac{Q}{\sqrt{2}}$ (d) Q

59. In a transformer, number of turns in the primary coil are 140 and that in the secondary coil are 280. If current in primary coil is 4 A, then that in the secondary coil is
(a) 4 A (b) 2 A (c) 6 A (d) 10 A.

60. A fully charged capacitor C with initial charge q_0 is connected to a coil of self inductance L at $t = 0$. The time at which the energy is stored equally between the electric and the magnetic fields is:
(a) $\frac{\pi}{4}\sqrt{LC}$ (b) $2\pi\sqrt{LC}$ (c) $\sqrt{LC}$ (d) $\pi\sqrt{LC}$

61. The primary winding of a transformer has 100 turns and its secondary winding has 200 turns. The primary is connected to an A.C. supply of 120 V and the current flowing in it is 10 A. The voltage and the current in the secondary are
(a) 240 V, 5 A (b) 240 V, 10 A
(c) 60 V, 20 A (d) 120 V, 20 A

62. An AC generator of 220 V having internal resistance r = 10Ω and external resistance R = 100Ω. What is the power developed in the external circuit?
(a) 484 W (b) 400 W (c) 441 W (d) 369 W

63. A transformer is used to light a 100 W and 110 V lamp from a 220 V mains. If the main current is 0.5 amp, the efficiency of the transformer is approximately
(a) 50% (b) 90% (c) 10% (d) 30%.

64. A treansformer is used to light a 140 watt, 24 volt lamp form 240 V AC mains. The current in the main cable is 0.4 4 amp. The efficiency of the transformer is:
(a) 48% (b) 63.8% (c) 83.3% (d) 90%

65. A transformer reduces 220 V to 11 V. The primary draws 5 A of current and secondary 90 A. The efficiency of the transformer is
(a) 20% (b) 40% (c) 70% (d) 90%

66. The current flowing in a step down transformer 220 V to 22 V having impedance 220 Ω, is
(a) 0.1 mA (b) 1 mA (c) 0.1 A (d) 1 A

Case/Passage Based Questions

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

Case/Passage-I

Mean value of alternating current is defined as that value of steady current which would sent same amount of charge through a circuit in the time of half cycle ($\pi/2$) as is sent by the a.c. through the same circuit in the same time.

$$I_{mean} = \frac{2I_0}{\pi}, E_{mean} = \frac{2E_0}{\pi}$$

Here, *I_0 and E_0 are Peak current and voltage.*
R.M.S value of alternating current is the steady current which when passed through a given resistor for a certain time, shall produce the same heat as the given A.C. shall do when passed for the same time.

$$I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707I_0, E_{rms} = \frac{E_0}{\sqrt{2}} = 0.707E_0$$

67. The alternating current of equivalent value of $\frac{I_0}{\sqrt{2}}$ is
(a) peak current (b) r.m.s. current
(c) D.C. current (d) all of these

68. The r.m.s value of an a.c. of 50 Hz is 10 amp. The time taken by the alternating current in reaching from zero to maximum value and the peak value of current will be
(a) 2×10^{-2} sec and 14.14 amp
(b) 1×10^{-2} sec and 7.07 amp
(c) 5×10^{-3} sec and 7.07 amp
(d) 5×10^{-3} sec and 14.14 amp

69. The instantaneous voltage through a device of impedance 20 Ω is $e = 80 \sin 100\pi t$. The effective value of the current is
(a) 3 A (b) 2.828 A (c) 1.732 A (d) 4 A

70. The voltage of an ac supply varies with time (t) as V = 120 sin 100 πt cos 100 πt. The maximum voltage and frequency respectively are
(a) 120 volt, 100 Hz (b) $\frac{120}{\sqrt{2}}$ volt, 100 Hz
(c) 60 volt, 200 Hz (d) 60 volt, 100 Hz

71. The equation of alternating current is :
$I = 50\sqrt{2} \sin 400\pi t$ amp. Then the frequency and root mean square of current are respectively
(a) 200 Hz, 50 amp (b) 400π Hz, $50\sqrt{2}$ amp
(c) 200 Hz, $50\sqrt{2}$ amp (d) 50 Hz, 200 amp

Case/Passage-II

In a series LCR circuit with an ideal ac source of peak voltage $E_0 = 50V$, frequency $v = \frac{50}{\pi}$ Hz and $R = 300\Omega$. The average electric field energy stored in the capacitor and average magnetic energy stored in the coil are 25 mJ and 5 mJ respectively. The value of RMS current in the circuit is 0.1 A. Then find :

72. Capacitance (C) of the capacitor is
(a) 10μF (b) 15μF
(c) 20μF (d) None of these

73. Inductance (L) of inductor is
(a) 0.25 henry (b) 0.5 henry
(c) 1 henry (d) 2 henry

74. The sum of rms potential difference across each of the three elements is
(a) 50 volt (b) $50\sqrt{2}$ volt
(c) $\frac{50}{\sqrt{2}}$ volt (d) None of these

75. In a LCR circuit at resonance which of these will effect the current in circuit
(a) R only (b) L and R only
(c) R and C only (d) all L, C and R

76. In a series combination of R, L and C to an A.C. source at resonance, if R = 20 ohm, then impedance Z of the combination is
(a) 20 ohm (b) Zero (c) 1 ohm (d) 400 ohm

Case/Passage-III

A thermal power plant produces electric power of 600 kW at 4000 V, which is to be transported to a place 20 km away from the power plant for consumers' usage. It can be transported either directly with a cable of large current carrying capacity or by using a combination of step-up and step-down transformers at the two ends. The drawback of the direct transmission is the large energy dissipation. In the method using transformers, the dissipation is much smaller. In this method , a step-up transformer is used at the plant side so that the current is reduced to a smaller value. At the consumers' end, a step-down transformer is used to supply power to the consumers at the specified lower voltage. It is reasonable to assume that the power cable is purely resistive and the transformers are ideal with power factor unity. All the currents and voltages mentioned are rms values.

77. In the method using the transformers, assume that the ratio of the number of turns in the primary to that in the secondary in the step-up transformer is 1 : 10. If the power to the consumers has to be supplied at 200 V, the ratio of the number of turns in the primary to that in the secondary in the step-down transformer is
(a) 200 : 1 (b) 150 : 1 (c) 100 : 1 (d) 50 : 1

78. If the direct transmission method with a cable of resistance $0.4\ \Omega\ km^{-1}$ is used, the power dissipation| (in %) during transmission is
(a) 20 (b) 30 (c) 40 (d) 50

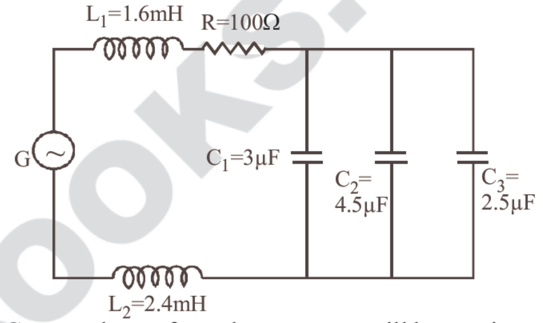
79. Transformers are used
(a) in DC circuit only
(b) in AC circuits only
(c) in both DC and AC circuits
(d) neither in DC nor in AC circuits

80. A transformer is employed to
(a) convert A.C. into D.C.
(b) convert D.C. into A.C.
(c) obtain a suitable A.C. voltage
(d) obtain a suitable D.C. voltage

81. The transformer voltage induced in the secondary coil of a transformer is mainly due to
(a) a varying electric field
(b) a varying magnetic field
(c) the vibrations of the primary coil
(d) the iron core of the transformer

Case/Passage-IV

An ac generator G with an adjustable frequency of oscillation is used in the circuit, as shown.



82. Current drawn from the ac source will be maximum if its angular frequency is
(a) 10^5 rad/s (b) 10^4 rad/s
(c) 5000 rad/s (d) 500 rad/s

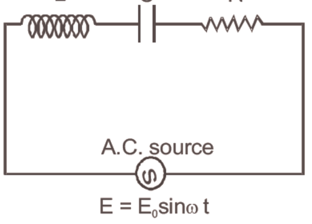
83. To increase resonant frequency of the circuit, some of the changes in the circuit are carried out. Which change(s) would certainly result in the increase in resonant frequency
(a) R is increased
(b) L_1 is increased and C_1 is decreased
(c) L_2 is decreased and C_2 is increased
(d) C_3 is decreased in the circuit

84. If the ac source G is of 100V rating at resonant frequency of the circuit, then average power supplied by the source is
(a) 50W (b) 100W (c) 500W (d) 1000W

85. A generator at a utility company produces 100 A of current at 4000 V. The voltage is stepped up to 2,40,000V by a transformer before it is sent on a high voltage transmission line. The current in transmission line is
(a) 3.67 A (b) 2.67 A (c) 1.67 A (d) 2.40 A

Case/Passage-V

A circuit containing a series combination of a resistance R, a coil of inductance L and a capacitor of capacitance C, connected with a source of alternating e.m.f. of peak value of E_0, as shown in fig.



Let in series LCR circuit applied alternating emf is $E = E_0 \sin \omega t$. As L,C and R are joined in series, therefore, current at any instant through the three elements has the same amplitude and phase. However voltage across each element bears a different phase relationship with the current.

86. If an LCR series circuit is connected to an ac source, then at resonance the voltage across
(a) R is zero
(b) R equals the applied voltage
(c) C is zero
(d) L equals the applied voltage

87. At resonant frequency the current amplitude in series *LCR* circuit is
(a) maximum (b) minimum
(c) zero (d) infinity

88. Resonance frequency of LCR series a.c. circuit is f_0. Now the capacitance is made 4 times, then the new resonance frequency will become
(a) $f_0/4$ (b) $2f_0$
(c) f_0 (d) $f_0/2$

89. If resistance of 100Ω, and inductance of 0.5 henry and capacitance of 10×10^6 farad are connected in series through 50 Hz A.C. supply, then impedance is
(a) 1.8765 Ω (b) 18.76 Ω
(c) 187.6 Ω (d) 101.3 Ω

90. In an L-C-R series circuit connected to an AC source, $V = V_0 \sin\left(100\pi t + \frac{\pi}{6}\right)$. Given $V_R = 40V$, $V_L = 40V$ and $V_C = 10V$. Resistance $R = 4\Omega$.
Peak value of current in the circuit is
(a) $10\sqrt{2}A$ (b) $15\sqrt{2}A$
(c) $20\sqrt{2}A$ (d) $25\sqrt{2}A$

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*
(a) If both **Assertion** and **Reason** are **correct** and the Reason is the **correct explanation** of the Assertion.
(b) If both **Assertion** and **Reason** are correct but Reason is **not the correct explanation** of the Assertion.
(c) If the **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If the **Assertion** is **incorrect** but the **Reason** is **correct**.

91. **Assertion :** 200V AC is more dangerous than 200V D.C.
Reason : For 200V AC, the corresponding peak value is $200\sqrt{2}$. But for 200V DC, peak value is 200V only.

92. **Assertion :** The alternating current lags behind the emf by a phase angle of $\frac{\pi}{2}$, when AC flows through an inductor.
Reason : The inductive reactance increases as the frequency of AC source increases.

93. **Assertion :** The inductive reactance limits amplitude of the current in a purely inductive circuit.
Reason: The inductive reactance is independent of the frequency of the current.

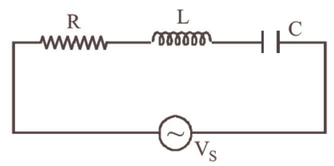
94. **Assertion :** A capacitor is connected to a direct current source. Its reactance is infinite.
Reason : Reactance of a capacitor is given by $X_c = \frac{1}{\omega C}$.

95. **Assertion :** In series LCR resonance circuit, the impedance is equal to the ohmic resistance.
Reason: At resonance, the inductive reactance exceeds the capacitive reactance.

96. **Assertion :** Choke coil is preferred over a resistor to control the current in an AC circuit.
Reason : Power factor of an ideal choked AC circuit is zero.

97. **Assertion :** The electrostatic energy stored in capacitor plus magnetic energy stored in inductor will always be zero in a series LCR circuit driven by ac voltage source under condition of resonance.
Reason : The voltage of ac source appears partially across the resistor in a series LCR circuit driven by ac voltage source under condition of resonance.

98. **Assertion :** In a series R, L, C circuit if V_R, V_L, and V_C denote rms voltage across R, L and C respectively and V_S is the rms voltage across the source, then
$V_S = V_R + V_L + V_C$.



Reason : In AC circuits, Kirchhoff voltage law is not valid at every instant of time.

99. **Assertion :** Transformer can transfer power from primary to secondary coil.
Reason : In an ideal transformer *VI* = varries.

100. **Assertion :** A laminated core is used in transformers to increase eddy currents.
Reason : The efficiency of a transformer increases with increase in eddy currents.

101. **Assertion :** In the purely resistive element of a series LCR, AC circuit the maximum value of rms current increases with increase in the angular frequency of the applied emf.
Reason : $\varepsilon_{max} = \frac{I_{max}}{z}$, $z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$,
where I_{max} is the peak current in a cycle.

102. **Assertion :** A capacitor blocks direct current in the steady state.
Reason : The capacitive reactance of the capacitor is inversely proportional to frequency f of the source of emf.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

103. Match Columns I and II.

Column I	Column II
(A) RL circuit	(1) Leading quantity - current
(B) RC circuit	(2) Leading quantity - voltage
(C) Inductive circuit	(3) Phase difference between voltage and current 0°
(D) Resistive circuit	(4) Phase difference between voltage and current 90°

(a) $(A) \rightarrow (2)$; $(B) \rightarrow (3)$; $(C) \rightarrow (1)$; $(D) \rightarrow (4)$
(b) $(A) \rightarrow (2)$; $(B) \rightarrow (2)$; $(C) \rightarrow (4)$; $(D) \rightarrow (3)$
(c) $(A) \rightarrow (4)$; $(B) \rightarrow (3)$; $(C) \rightarrow (2)$; $(D) \rightarrow (1)$
(d) $(A) \rightarrow (2)$; $(B) \rightarrow (1)$; $(C) \rightarrow (4)$; $(D) \rightarrow (3)$

104. In a series LCR circuit at resonance. Match columns I and II.

Column I	Column II
(A) Net Impedance is Z_{min} means	(1) Circuit behaves as a resistive circuit
(B) $V_L = V_C \Rightarrow V$ means	(2) Whole voltage appears across the resistance
(C) Power consumption $P = V_{rms} i_{rms}$	(3) 0°
(D) Phase difference	(4) $\frac{1}{2}V_0 i_0$

(a) $(A) \rightarrow (2); (B) \rightarrow (1); (C) \rightarrow (3); (D) \rightarrow (4)$
(b) $(A) \rightarrow (1); (B) \rightarrow (2); (C) \rightarrow (4); (D) \rightarrow (3)$
(c) $(A) \rightarrow (1); (B) \rightarrow (3); (C) \rightarrow (2); (D) \rightarrow (4)$
(d) $(A) \rightarrow (2); (B) \rightarrow (3); (C) \rightarrow (4); (D) \rightarrow (1)$

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

105. Laminated iron sheets are used to minimize ________ currents in the core of a transformer. **[CBSE 2020]**

106. A step up transformer operates on a 230 V line and supplies a current of 2 ampere. The ratio of primary and secondary winding is 1:25 . The current in primary is __________.

107. The ____________ is the loss of energy in the form of heat in the iron core of a transformer.

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

109. The output of a step-down transformer is measured to be 24 V when connected to a 12 W light bulb. The value of the peak current is _______.

110. In series combination of R, L and C with an A.C. source at resonance, if R = 20 ohm, then impedence Z of the combination is _______ Ω.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

111. 200V AC is more dangerous than 200V D.C.

112. For 200V AC, the corresponding peak value is $200\sqrt{2}$. But for 200V DC, peak value is 200V only.

113. The electrostatic energy stored in capacitor plus magnetic energy stored in inductor will always be zero in a series LCR circuit driven by ac voltage source under condition of resonance.

114. The complete voltage of ac source appears across the resistor in a series LCR circuit driven by ac voltage source under condition of resonance.

ANSWER KEY & SOLUTIONS

1. **(a)**

2. **(b)** We know that, $I_{rms} = I_0/\sqrt{2}$ and $I_m = 2I_0/\pi$

$\therefore \frac{I_m}{I_{rms}} = \frac{2\sqrt{2}}{\pi}$

3. **(b)** Given equation, $e = 80 \sin 100\pi t$ …(i)
Standard equation of instantaneous voltage is given by
$e = e_m \sin\omega t$ …(ii)
Compare (i) and (ii), we get $e_m = 80$ V
where e_m is the voltage amplitude.

Current amplitude, $I_m = \frac{e_m}{Z}$ where Z = impendence
$= 80/20 = 4$ A

$I_{r.m.s} = \frac{4}{\sqrt{2}} = \frac{4\sqrt{2}}{2} = 2\sqrt{2} = 2.828$ A

4. **(c)** $i_{rms} = \frac{i_0}{\sqrt{2}} = \frac{4}{\sqrt{2}} = 2\sqrt{2}$ ampere

5. **(a)**

6. **(b)** $V_{rms} = \sqrt{\frac{(T/2)V_0^2 + 0}{T}} = \frac{V_0}{\sqrt{2}}$.

7. **(c)** Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

$\Rightarrow X_L \propto \frac{1}{f}$

With increases in frequency, X_C decreases.
Hence, option (c) represents the hyperbolic graph which is correct.

8. **(b)** Inductive reactance,
$X_L = \omega L = 2\pi f L$
$\Rightarrow X_L \propto f$
Hence, inductive reactance increases linearly with frequency.

9. **(d)** Resonant frequency does not depend upon the resistance of the circuit.

10. **(a)**

11. **(d)** $V_{rms} = \frac{200\sqrt{2}}{\sqrt{2}} = 200\text{V}$

$I_{rms} = \frac{V_{rms}}{X_C} = \frac{200}{\frac{1}{100\times10^{-6}}} = 2\times10^{-2} = 20\text{mA}$

12. **(d)** Most of the electrical devices we use require AC voltage. This is mainly because most of the electrical energy sold by power companies is transmitted and distributed as alternating current. The main reason for preferring use of AC voltage over DC voltage is that AC voltage can be easily and efficiently converted from one voltage to the other by means of transformers.

13. **(a)** $\frac{E_s}{E_p} = \frac{n_s}{n_p}$ or $E_s = E_p \times \left(\frac{n_s}{n_p}\right)$

$\therefore E_s = 120 \times \left(\frac{200}{100}\right) = 240\text{ V}$

$\frac{I_p}{I_s} = \frac{n_s}{n_p}$ or $I_s = I_p\left(\frac{n_p}{n_s}\right)$ $\therefore I_s = 10\left(\frac{100}{200}\right) = 5$ amp

14. **(a)** Here, $C = 30\ \mu F = 30 \times 10^{-6}$ F,
$L = 27$ mH $= 27 \times 10^{-3}$ H

$\therefore \omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{27\times10^{-3}\times30\times10^{-6}}} = \frac{1}{\sqrt{81\times10^{-8}}}$

$= \frac{10^4}{9} = 1.1 \times 10^3$ rad s^{-1}

15. **(b)** As given that, $v = 50$ Hz, $I_{rms} = 5$A

$t = \frac{1}{300}$s

As we know that $I_{rms} = \frac{I_0}{\sqrt{2}}$

I_0 = Peak value $= \sqrt{2}.I_{rms} = \sqrt{2}\times 5$
$I_0 = 5\sqrt{2}$A

at, $t = \frac{1}{300}$sec, $I = I_0 \sin\omega t = 5\sqrt{2}\sin 2\pi vt$

$= 5\sqrt{2}\sin 2\pi \times 50 \times \frac{1}{300}$

$I = 5\sqrt{2}\sin\frac{\pi}{3} = 5\sqrt{2}\times\frac{\sqrt{3}}{2} = 5\sqrt{3/2}$ Amp $\left(\because \sin\frac{\pi}{3} = \frac{\sqrt{3}}{2}\right)$

$I = \left(5\sqrt{\frac{3}{2}}\right)$ A

16. **(c)** To deliver maximum power from the generator to the load, total internal reactance must be equal to conjugate of total external reactance.
So, $X_{int} = X_{ext}$
$X_g = (X_L) = -X_L$
Hence, $X_L = -X_g$ (Reactance in external circuit)

17. **(c)** As we know that,
The voltmeter in AC reads rms values of voltage

$I_{rms} = \sqrt{2}I_0$ and $V_{rms} = \sqrt{2}v_0$

The voltmeter in AC circuit connected to AC mains reads mean value ($\langle v^2\rangle$) and is calibrated in such a way that it gives rms value of $\langle v^2\rangle$, which is multiplied by form factor $\sqrt{2}$ to give rms value V_{rms}.

18. (b) As we know that,
The resonant frequency in an L-C-R series circuit is

$$\nu_0 = \frac{1}{2\pi\sqrt{LC}}$$

So, to reduce ν_0 either increase L or increase C.
To increase capacitance, another capacitor must be connect in parallel with the first capacitor.

19. (c)

20. (a) $E = 8\sin\omega t + 6\sin 2\omega t$

$$\Rightarrow E_{peak} = \sqrt{8^2 + 6^2} = 10 \text{ V}$$

$$E_{rms} = \frac{10}{\sqrt{2}} = 5\sqrt{2} \text{ V}$$

21. (b) **22. (b)**

23. (a) Average value of complete cycle of ac is zero.

24. (d)

25. (b) Given equation, $e = 80\sin 100\pi t$ ...(i)
Standard equation of instantaneous voltage is given by $e = e_m \sin\omega t$ ...(ii)
Compare (i) and (ii), we get $e_m = 80$ V
where e_m is the voltage amplitude.

Current amplitude $I_m = \frac{e_m}{Z} = 80/20 = 4$ A.

$$I_{r.m.s} = \frac{4}{\sqrt{2}} = \frac{4\sqrt{2}}{2} = 2\sqrt{2} = 2.828 \text{ A.}$$

26. (b) $P = \frac{1}{2}V_0 i_0 \cos\phi \Rightarrow P = P_{peak}.\cos\phi$

$$\Rightarrow \frac{1}{2}(P_{peak}) = P_{peak}\cos\phi \Rightarrow \cos\phi = \frac{1}{2} \Rightarrow \phi = \frac{\pi}{3}$$

27. (d) When an ac voltage of 220 V is applied to a capacitor *C*, the charge on the plates is in phase with the applied voltage.
As the circuit is pure capacitive so, the current developed leads the applied voltage by a phase angle of 90° Hence, power delivered to the capacitor per cycle is $P = V_{rms} I_{rms} \cos 90° = 0$.

28. (b) $V = 50 \times 2\sin 100\pi\cos 100\pi t = 50\sin 200\pi t$
$\Rightarrow V_0 = 50$ *Volts* and $\nu = 100$ *Hz*

29. (d) $V = 120\sin 100\pi t\cos 100\pi t \Rightarrow V = 60\sin 200\pi t$
$V_{max} = 60V$ and $v = 100Hz$

30. (a) $E = 8\sin\omega t + 6\sin 2\omega t$

$$\Rightarrow E_{peak} = \sqrt{8^2 + 6^2} = 10 \text{ V}$$

$$E_{rms} = \frac{10}{\sqrt{2}} = 5\sqrt{2} \text{ V}$$

31. (d) Power dissipated = E_{rms}. I_{rms} = $(E_{rms})(I_{rms})\cos\theta$
Hence, power dissipated depends upon phase difference.

32. (d) $I = 2\sin\omega t$

$$V = 5\cos\omega t = 5\sin\left(\frac{\pi}{2} - \omega t\right)$$

Since, there is a phase difference of $\frac{\pi}{2}$ between the current and voltage
$\therefore$ Average power over a complete cycle is zero.

33. (a) The current and potential difference are in phase with the resistance. So, the time taken would be same as time for voltage to change from (t = 0) that is peak value to rms value.

Time taken by voltage to achieve its rms value of $\frac{200}{\sqrt{2}}$.

$$\frac{200}{\sqrt{2}} = 200\cos(100\pi t)$$

$$\Rightarrow \quad \cos(100\pi t) = \frac{1}{\sqrt{2}} = \cos\left(\frac{\pi}{4}\right)$$

$$t = \frac{1}{400} \text{ second} = 2.5 \times 10^{-3} \text{ sec.}$$

34. (d) The instantaneous values of emf and current in inductive circuit are given by $E = E_0 \sin\omega t$ and $i = i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$ respectively.

$$\therefore \quad P_{inst} = E.i = E_0 \sin\omega t \times i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$$

$$= -E_0 i_0 \sin\omega t\cos\omega t \quad = -\frac{1}{2}E_0 i_0 \sin 2\omega t$$

Hence, angular frequency of instantaneous power is 2ω

35. (b) **36. (b)**

37. (d) At resonance, $X_C = X_L$
Reactance of circuit becomes zero and impedance become minimum and maximum current flows through the circuit.

38. (b) $\cos\phi = \frac{R}{Z}$, where Z is the impedance &

$Z = \sqrt{R^2 + (X_L - X_C)^2}$, if there is only resistance then
$Z = R \Rightarrow \cos\phi = 1$

39. (c) The time constant for resonance circuit, = CR
Growth of charge in a circuit containing capacitance and resistance is given by the formula, $q = q_0(1 - e^{-t/CR})$
CR is known as time constant in this formula.

40. (b)

41. (a) The reactance of inductor, $X_L = \omega L$

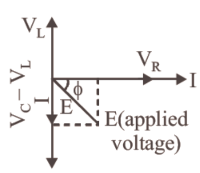
The reactance of capacitor, $X_C = \frac{1}{\omega C}$

where $\omega = 2\pi n$ & n is the frequency of A.C source.

42. (d)

43. (d) $\tan\phi = \frac{V_C - V_L}{V_R}$ (if $V_C > V_L$)

$$= \frac{V_L - V_C}{R} \text{ (if } V_L > V_C)$$



where ϕ is angle between current & applied voltage.

44. **(a)** **45.** **(b)**

46. **(a)** In ideal condition of LC circuit $R = 0$ and LC oscillation continue indefinitely. Energy being shunted back and forth between electric field of capacitor and magnetic field of inductor. As capacitor is fully charged current in L is zero and $\frac{1}{2}\frac{q_0^2}{C}$ energy is stored in electric field. Then capacitor begins to discharge through L causing a current to flow and build up a magnetic field, around L. Therefore, energy stored.

Now in $L = \frac{1}{2}LI_0^2$ when C is fully discharged, V across the plate reduces to zero.

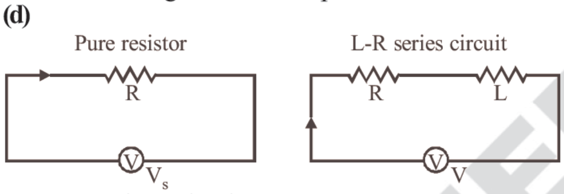
$\therefore$ Electric field energy is transferred to magnetic field and vice-versa.

47. **(c)** Impedance at resonant frequency is minimum in series LCR circuit.

So, $Z = \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$

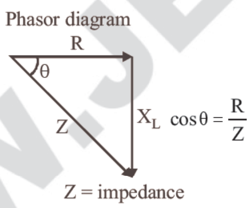
48. **(c)** When resistance is connected to A.C source, then current & voltage are in same phase.

49. **(d)**



For pure resistor circuit, power

$P = \frac{V^2}{R} \Rightarrow V^2 = PR$



For L-R series circuit, power

$P^1 = \frac{V^2}{Z}\cos\theta = \frac{V^2}{Z}.\frac{R}{Z} = \frac{PR}{Z^2}.R = P\left(\frac{R}{Z}\right)^2$

50. **(b)** $X_L = \omega L \Rightarrow X_L \propto \omega$

51. **(b)** **52.** **(c)**

53. **(a)** Iron loss is the energy loss in the form of heat due to the formation of eddy currents in the iron core of the transformer.

54. **(c)** A transformer does not change the frequency of ac.

55. **(b)**

56. **(b)** We know that frequency of electrical oscillation in L.C. circuit is

$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$; Now, $L = 2L$ & $C = 4C$

$f' = \frac{1}{2\pi}\sqrt{\frac{1}{2L.4C}} = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} \times \frac{1}{2\sqrt{2}} \Rightarrow f' = \frac{1}{2\sqrt{2}} \times f$

57. **(d)** As $E_p \mathbf{I}_p = P_i$ $\therefore$ $\mathbf{I}_p = \frac{P_i}{E_p} = \frac{4000}{100} = 40$ A.

58. **(c)** When the capacitor is completely charged, the total energy in the L.C circuit is with the capacitor and that energy is $E = \frac{1}{2}\frac{Q^2}{C}$

When half energy is with the capacitor in the form of electric field between the plates of the capacitor we get $\frac{E}{2} = \frac{1}{2}\frac{Q'^2}{C}$ where Q' is the charge on one plate of the capacitor

$\therefore \frac{1}{2} \times \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{Q'^2}{C} \Rightarrow Q' = \frac{Q}{\sqrt{2}}$

59. **(b)** $N_p = 140, N_s = 280, I_p = 4A, I_s = ?$

For a transformer $\frac{I_s}{I_p} = \frac{N_p}{N_s}$

$\Rightarrow \frac{I_s}{4} = \frac{140}{280} \Rightarrow I_s = 2\,A$

60. **(a)** Energy stored in magnetic field $= \frac{1}{2}$ Li^2

Energy stored in electric field $= \frac{1}{2}\frac{q^2}{C}$

$\therefore \frac{1}{2}Li^2 = \frac{1}{2}\frac{q^2}{C}$

Also $q = q_0 \cos\omega t$ and $\omega = \frac{1}{\sqrt{LC}}$

On solving $t = \frac{\pi}{4}\sqrt{LC}$

61. **(a)** $\frac{E_s}{E_p} = \frac{n_s}{n_p}$ or $E_s = E_p \times \left(\frac{n_s}{n_p}\right)$

$\therefore$ $E_s = 120 \times \left(\frac{200}{100}\right) = 240$ V

$\frac{\mathbf{I}_p}{\mathbf{I}_s} = \frac{n_s}{n_p}$ or $\mathbf{I}_s = \mathbf{I}_p\left(\frac{n_p}{n_s}\right)$ $\therefore$ $\mathbf{I}_s = 10\left(\frac{100}{200}\right) = 5$ amp

62. **(b)** $V = 200V;\ r = 10\Omega$

$R' = 10 + 100\Omega = 110\Omega$

$I = \frac{V}{R'} = \frac{220}{100} = 2A$

$P = I^2R = 4 \times 100 = 400\ W$

63. **(b)** Efficiency of the transformer

$\eta = \frac{P_{output}}{P_{input}} \times 100 = \frac{100}{220 \times 0.5} \times 100 = 90.9\%$

64. **(c)**

65. **(d)** $\eta = \frac{E_S I_S}{E_p I_p} = \frac{11 \times 90}{220 \times 5} = 0.9 \times 100\% = 90\%$

66. (c) In a step down transformed voltage is 22 V. By ohm's law, $I = \frac{22V}{220\,ohm} = 0.1\,Amp$

67. (b) $\frac{I_0}{\sqrt{2}}$ = RMS current

68. (d)

69. (b) Given equation, $e = 80 \sin 100\pi t$ …(i)
Standard equation of instantaneous voltage is given by
$e = e_m \sin\omega t$ …(ii)
Compare (i) and (ii), we get $e_m = 80$ V
where e_m is the voltage amplitude.

Current amplitude $I_m = \frac{e_m}{Z}$ where Z = impendence
$= 80/20 = 4$ A.

$I_{r.m.s} = \frac{4}{\sqrt{2}} = \frac{4\sqrt{2}}{2} = 2\sqrt{2} = 2.828$ A.

70. (d) $V = 120\sin 100\pi t \cos 100\pi t \Rightarrow V = 60 \sin 200\pi t$
$V_{max} = 60V$ and $\nu = 100$Hz

71. (a) $2\pi nt = 400\pi t$ $\therefore$ n = 200
$I_0 = 50\sqrt{2}$ amp.
r.m.s. current = $I_0/\sqrt{2} = 50$ amp.

72. (c) Av. electric field energy $= \left(\frac{1}{2}CV_{rms}^2\right) = 25 \times 10^{-3}$ J

$\therefore$ $\frac{1}{2}C \times (I_{rms} X_C)$

$\therefore$ $\frac{1}{2} \times C.I^2_{rms} \times \frac{1}{4\pi^2 v^2 c^2} = 25 \times 10^{-3}$ J

$\therefore$ C = 20μF

73. (c) Av. magnetic energy $\left(\frac{1}{2}LI_{rms}^2\right)$

$\therefore$ $L = \frac{2 \times 5 \times 10^{-3}}{(.10)^2} \Rightarrow L = 1$ henry

74. (d) The sum for rms voltage across C, rms voltage across R and rms voltage across L is not equal to rms voltage across ideal ac source.

75. (a) At resonance, $\omega L = \frac{1}{\omega C}$
Hence the impedance of the circuit would be just equal to R (minimum). In other words, the LCR-series circuit will behave as a purely resistive circuit. Due to this the current is maximum. This condition is known as resonance

$\therefore$ Z = R, Current $= \frac{V}{R}$

76. (a) At resonance inpedence Z = R

77. (a) Step up transformer

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow \frac{10}{1} = \frac{V_s}{4000}$$

$\therefore$ $V_s = 40{,}000$ V
Step down transformer

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{40{,}000}{200} = \frac{200}{1}$$

78. (b) Power P = V × I

$\Rightarrow$ $I = \frac{P}{V} = \frac{600 \times 1000}{4000} = 150$ A
Total resistance = 0.4 × 20 = 8 Ω
$\therefore$ Power dissipated as heat $= I^2R = (150)^2 \times 8$
= 180,000W = 180 kW

$\therefore$ % loss $= \frac{180}{600} \times 100 = 30\%$

79. (b) Transformers are used in AC circuits only

80. (c) A transformer is employed to obtain a suitable AC voltage.

81. (b) Voltage induced in the secondary coil of a transformer is mainly due to a varying magnetic field.

82. (c)

83. (d)

84. (b) Current drawn is maximum at resonant angular frequency.
$L_{eq} = 4$mH, $C_{eq} = 10\mu$F

$\omega = \frac{1}{\sqrt{LC}} = 5000$ rad / s

C_{eq} decreases thereby increasing resonant frequency.

At resonance $i_{rms} = \frac{100}{100} = 1$A

Power supplied $= V_{rms} i_{rms} \cos\phi$ ($\phi = 0$ at resonance)
P = 100 W

85. (c) For a transformer,

$$V_p I_p = V_s I_s \Rightarrow I_s = \frac{V_p I_p}{V_s} = \frac{4000 \times 100}{240000}\text{A} = 1.67\text{ A}$$

86. (b) In series RLC circuit,
Voltage, $V = \sqrt{V_R^2 + (V_L - V_C)^2}$
And, at resonance, $V_L = V_C$
Hence, $V = V_R$

87. (a)

88. (d) In LCR series circuit, resonance frequency f_0 is given by

$L\omega = \frac{1}{C\omega} \Rightarrow \omega^2 = \frac{1}{LC}$ $\therefore$ $\omega = \sqrt{\frac{1}{LC}} = 2\pi f_0$

$\therefore$ $f_0 = \frac{1}{2\pi\sqrt{LC}}$ or $f_0 \alpha \frac{1}{\sqrt{C}}$

When the capacitance of the circuit is made 4 times, its resonant frequency become f_0'

$\therefore$ $\frac{f_0'}{f_0} = \frac{\sqrt{C}}{\sqrt{4C}}$ or $f_0' = \frac{f_0}{2}$

89. **(c)** $Z=\sqrt{R^2+\left(\omega L-\frac{1}{\omega C}\right)^2}$

Here R = 100 W, L = 0.5 henry, C = 10 × 10^6 farad
$\omega = 2\,p\,\pi = 100\,\pi$.

90. **(a)**

91. **(a)** DC is a constant current but AC varies sinusoidally.

92. **(b)** In case of inductive circuit emf leads current by $\pi/2$ rad

93. **(c)** The inductive reactance limits the amplitude of current in a purely inductive circuit in the same way as the resistance limits the current in a purely resistive circuit.

i.e. $I_0=\frac{\varepsilon_0}{X_L}$

94. **(a)** As $X_C=\frac{1}{\omega C}$, so for $\omega=0$, $X_C\to\infty$.

95. **(c)** In series resonance circuit, inductive reactance is equal to capacitive reactance.

i.e. $\omega L=\frac{1}{\omega C}$

$\therefore\; Z=\sqrt{R^2+\left(\omega L=\frac{1}{\omega C}\right)^2}=R$

96. **(a)**

97. **(d)** In resonance condition when energy across capacitor is maximum, energy stored in inductor is zero, vice versa is also true.

98. **(d)** Assertion is false because the given relation is true if all voltages are instantaneous.

99. **(c)** Transformer cannot produce power, but it transfer from primary to secondary.

100. **(d)** Large eddy currents are produced in non-laminated iron core of the transformer by the induced emf, as the resistance of bulk iron core is very small. By using thin iron sheets as core the resistance is increased. Laminating the core substantially reduces the eddy currents. Eddy current heats up the core of the transformer. More the eddy currents greater is the loss of energy and the efficiency goes down.

101. **(c)** **102.** **(a)**

103. **(d)** (A)→(2); (B)→(1); (C)→(4); (D)→(3)

104. **(b)** (A)→(1); (B)→(2); (C)→(4); (D)→(3)

105. (Eddy currents)

106. (50 A) $\frac{n_p}{n_s}=\frac{E_p}{E_s}=\frac{1}{25}$

$\therefore\; E_s=25\,E_p$

But $E_S I_S=E_p I_p \Rightarrow I_p=\frac{E_S\times I_S}{E_p}\Rightarrow I_p=50\text{A}$

107. (Iron loss) Iron loss is the energy loss in the form of heat due to the formation of eddy currents in the iron core of the transformer.

108. (14.4 W) As given that,

$X_L=1\Omega, R=2\Omega, E_{rms}=6\text{V}, P_{av}=?$

The average power dissipated in the L, R, series circuit with AC source

Then $P_{av}=E_{rms}I_{rms}\cos\phi$ ... (i)

$I_{rms}=\frac{I_0}{\sqrt{2}}=\frac{E_{rms}}{Z}$

$Z=\sqrt{R^2+X_L^2}=\sqrt{4+1}=\sqrt{5}$

$I_{rms}=\frac{6}{\sqrt{5}}\text{A}$

$\cos\phi=\frac{R}{Z}=\frac{2}{\sqrt{5}}$

By putting the value of I_{rms}, E_{rms}, $\cos\phi$ in equation (i), then,

$P_{av}=6\times\frac{6}{\sqrt{5}}\times\frac{2}{\sqrt{5}}=\frac{72}{\sqrt{5}\sqrt{5}}$

$=\frac{72}{5}=14.4$ watt

109. $\left(\frac{1}{\sqrt{2}}\text{A}\right)$ As given that,

Secondary voltage (V_S) is :

$V_S=$ 24 Volt

Power associated with secondary is :

$P_S=$ 12 Watt

As we know that $P_S=V_S I_S$

$I_S=\frac{P_S}{V_S}=\frac{12}{24}=\frac{1}{2}\text{A}=0.5$ Amp

Peak value of the current in the secondary

$I_0=I_s\sqrt{2}=0.5\sqrt{2}$

$=\frac{5}{10}\sqrt{2}\left[I_0=\frac{1}{\sqrt{2}}\text{Amp}\right]$

110. (20 Ω)

111. (True)

112. (True) DC is a constant current but AC varies sinusoidally.

113. (False) In resonance condition when energy across capacitor is maximum, energy stored in inductor is zero, vice versa is also true.

114. (False)

8 Electromagnetic Waves

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. A plane electromagnetic wave is incident on a material surface. If the wave delivers momentum p and energy E, then

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

2. A new system of unit is evolved in which the values of μ_0 and $\in_0$ are 2 and 8 respectively. Then the speed of light in this system will be

(a) 0.25 (b) 0.5 (c) 0.75 (d) 1

3. The velocity of all radio waves in free space is 3×10^8 m/s. The frequency of a radio wave of wavelength 150 m is

(a) 20 kHz (b) 2 kHz
(c) 2 MHz (d) 1 MHz

4. If a source is transmitting electromagnetic wave of frequency 8.2×10^6 Hz, then wavelength of the electromagnetic waves transmitted from the source will be

(a) 36.6 m (b) 40.5 m (c) 42.3 m (d) 50.9 m

5. In an electromagnetic wave, the direction of the magnetic induction $\vec{B}$ is

(a) parallel to the electric field $\vec{E}$
(b) perpendicular to the electric field $\vec{E}$
(c) antiparallel to the Poynting vector $\vec{S}$
(d) random

6. A plane electromagnetic wave travels in free space along x-axis. At a particular point in space, the electric field along y-axis is 9.3V m^{-1}. The magnetic induction (B) along z-axis is

(a) 3.1×10^{-8} T (b) 3×10^{-5} T
(c) 3×10^{-6} T (d) 9.3×10^{-6} T

7. In an apparatus, the electric field was found to oscillate with an amplitude of 18 V/m. The magnitude of the oscillating magnetic field will be

(a) 4×10^{-6} T (b) 6×10^{-8} T
(c) 9×10^{-9} T (d) 11×10^{-11} T

8. An electromagnetic wave of frequency $f = 3$ MHz passes from vacuum into a dielectric medium with permittivity $\varepsilon = 4$. Then

(a) wavelength and frequency both become half.
(b) wavelength is doubled and frequency remains unchanged.
(c) wavelength and frequncy both remain unchanged.
(d) wavelength is halved and frequency remains unchanged.

9. The electromagnetic waves do not transport_______.

(a) energy (b) charge
(c) momentum (d) information

10. Which of the following is/are true/false for electromagnetic waves?

I. They transport energy.
II. They have momentum.
III. They travel with speed of light through vaccum.

(a) T,F,T (b) F,T,F
(c) T,T,T (d) T,T,F

11. Radio waves and visible light in vacuum have

(a) same velocity but different wavelength
(b) same frequency
(c) different velocity
(d) same wavelength

12. The waves which are electromagnetic in nature are

(a) sound waves and light waves
(b) water waves and radio waves
(c) light waves and X-rays
(d) sound waves and water waves

13. Select the true/false from the following statement(s)

I. Wavelength of microwaves is greater than that of ultraviolet rays.
II. The frequency of infrared rays is lesser than that of ultraviolet rays.
III. The frequency of microwaves is lesser than that of infrared rays.
IV. Gamma ray has largest frequency in the electromagnetic spectrum.

(a) T,T,F,F (b) F,T,T,F (c) F,F,T,T (d) T,T,T,T

14. Photons of an electromagnetic radiation has an energy 11 keV each. Then it belongs to _____region of electromagnetic spectrum.
(a) X-ray (b) Ultraviolet
(c) Infrared (d) Visible

15. One requires 11 eV of energy to dissociate a carbon monoxide molecule into carbon and oxygen atoms. The minimum frequency of the appropriate electromagnetic radiation to achieve the dissociation lies in
(a) visible region (b) infrared region
(c) ultraviolet region (d) microwave region

16. A linearly polarised electromagnetic wave given as $E = E_0\hat{i}\cos(kz - \omega t)$ 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) $E_r = E_0\hat{i}(kz - \omega t)$

(b) $E_r = E_0\hat{i}\cos(kz + \omega t)$

(c) $E_r = -E_0\hat{i}\cos(kz + \omega t)$

(d) $E_r = E_0\hat{i}\sin(kz - \omega t)$

17. 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 min is
(a) 36×10^{-5} kg-m/s (b) 36×10^{-4} kg-m/s
(c) 108×10^{4} kg-m/s (d) 1.08×10^{7} kg-m/s

18. 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) $\sqrt{2}E$

19. If E and B represent electric and magnetic field vectors of the electromagnetic wave, the direction of propagation of electromagnetic wave is along
(a) E (b) B (c) $B \times E$ (d) $E \times B$

20. The ratio of contributions made by the electric field and magnetic field components to the intensity of an EM wave is
(a) c : 1 (b) c^2 : 1 (c) 1 : 1 (d) $\sqrt{c}$: 1

21. An EM wave radiates outwards from a dipole antenna, with E_0 as the amplitude of its electric field vector. The electric field E_0 which transports significant energy from the source falls off as

(a) $\frac{1}{r^3}$ (b) $\frac{1}{r^2}$

(c) $\frac{1}{r}$ (d) remains constant

22. An electromagnetic wave travels in vacuum along z-direction $E = (E_1\hat{i} + E_2\hat{j})\cos(kz - \omega t)$. Choose the correct options from the following

(a) The associated magnetic field is given as
$$B = \frac{1}{c}(E_1\hat{i} - E_2\hat{j})\cos(kz - \omega t)$$
(b) The associated magnetic field is given as
$$B = \frac{1}{c}(E_1\hat{i} - E_2\hat{j})\cos(kz - \omega t)$$
(c) The given electromagnetic field is circularly polarised
(d) The given electromagnetic wave is plane polarised

23. An electromagnetic wave going through vacuum is described by $E = E_0\sin(kx - \omega t)$; $B = B_0\sin(kx - \omega t)$. Which of the following equations is true?
(a) $E_0k = B_0\omega$ (b) $E_0\omega = B_0k$
(c) $E_0B_0 = \omega k$ (d) None of these

24. The ozone layer in the atmosphere absorbs
(a) only the radiowaves
(b) only the visible light
(c) only the γ-rays
(d) X-rays and ultraviolet rays

25. The electric and magnetic field of an electro-magnetic wave are
(a) in opposite phase and perpendicular to each other
(b) in opposite phase and parallel to each other
(c) in phase and perpendicular to each other
(d) in phase and parallel to each other.

26. When electromagnetic waves enter the ionised layer, then the relative permittivity i.e. dielectric constant of the layer.
(a) does not change
(b) appears to increase
(c) appears to decrease
(d) sometimes appears to increase and sometimes to decrease

27. The electromagnetic waves travel with a velocity
(a) equal to velocity of sound
(b) equal to velocity of light
(c) less than velocity of light
(d) None of these

28. The speed of electromagnetic wave in vacuum depends upon the source of radiation. It
(a) increases as we move from γ-rays to radio waves
(b) decreases as we move from γ-rays to radio waves
(c) is same for all of them
(d) None of these

29. The wavelength of the matter waves is independent of
(a) charge (b) momentum
(c) velocity (d) mass

30. An electromagnetic wave is propagating along Y-axis. Then
(a) oscillating electric field is along X-axis and oscillating magnetic field is along Y-axis
(b) oscillating electric field is along Z-axis and oscillating magnetic field is along X-axis
(c) both oscillating electric and magnetic fields are along Y-axis, but phase difference between them is 90°
(d) both oscillating electric and magnetic fields are mutually perpendicular in arbitrary direction

31. When an electromagnetic wave with poynting vector is $\vec{s}$ is incident an a perfectly absorbing surface, then radiation pressure on surface is
(a) $P = \frac{\vec{S}}{C}$ (b) $P = \frac{\vec{S}}{SC}$ (c) $\frac{2\vec{S}}{3C}$ (d) $\vec{S}C$

32. An electromagnetic wave passes through space and its equation is given by $E = E_0 \sin(\omega t - kx)$ where E is electric field. Energy density of electromagnetic wave in space is
(a) $\frac{1}{2}\varepsilon_0 E_0^2$ (b) $\frac{1}{4}\varepsilon_0 E_0^2$ (c) $\varepsilon_0 E_0^2$ (d) $2\varepsilon_0 E_0^2$

33. A plane electromagnetic wave is incident on a plane surface of area A, normally and is perfectly reflected. If energy E strikes the surface in time t then force exerted on the surface is (c = speed of light)
(a) $\frac{2E}{Atc}$ (b) $\frac{E}{2c}$ (c) $\frac{2E}{ct}$ (d) zero

34. Which of the following type of radiations are radiated by an oscillating electric charge?
(a) Electric (b) Magnetic
(c) Thermoelectric (d) Electromagnetic

35. The wave impendance of free space is
(a) zero (b) 376.6 Ω
(c) 33.66 Ω (d) 3.76 Ω

36. The pressure exerted by an electromagnetic wave of intensity I (watts/m^2) on a nonreflecting surface is [c is the velocity of light]
(a) Ic (b) Ic^2 (c) I/c (d) I/c^2

37. Intensity of electromagnetic wave will be
(a) $I = c\mu_0 B_0^2 / 2$ (b) $I = c\varepsilon_0 B_0^2 / 2$
(c) $I = B_0^2 / c\mu_0$ (d) $I = E_0^2 / 2c\varepsilon_0$

38. The electric field of an electromagnetic wave travelling through vaccum is given by the equation $E = E_0 \sin(kx - \omega t)$. The quantity that is independent of wavelength is
(a) $k\omega$ (b) $\frac{k}{\omega}$ (c) $k^2\omega$ (d) ω

39. Electromagnetic radiation of highest frequency is
(a) infrared radiations (b) visible radiation
(c) radio waves (d) γ-rays

40. Which of the following electromagnetic waves has minimum frequency ?
(a) Microwaves (b) Audible waves
(c) Ultrasonic wave (d) Radiowaves

41. Which of the following shows green house effect ?
(a) Ultraviolet rays (b) Infrared rays
(c) X-rays (d) None of these

42. Which of the following waves have the maximum wavelength
(a) X-rays (b) I.R. rays
(c) UV rays (d) Radio waves

43. Which rays are not the portion of electromagnetic spectrum ?
(a) X-rays (b) Microwaves
(c) α-rays (d) Radio waves

44. Which radiation in sunlight, causes heating effect ?
(a) Ultraviolet (b) Infrared
(c) Visible light (d) All of these

45. Microwave oven acts on the principle of :
(a) giving rotational energy to water molecules
(b) giving translational energy to water molecules
(c) giving vibrational energy to water molecules
(d) transferring electrons from lower to higher energy levels in water molecule

46. If v_s, v_x and v_m are the speed of soft gamma rays, X-rays and microwaves respectively in vacuum, then
(a) $v_s > v_x > v_m$ (b) $v_s < v_x < v_m$
(c) $v_s > v_x < v_m$ (d) $v_s = v_x = v_m$

47 We consider the radiation emitted by the human body. Which of the following statements is true?
(a) the radiation emitted lies in the ultraviolet region and hence is not visible.
(b) the radiation emitted is in the infra-red region.
(c) the radiation is emitted only during the day.
(d) the radiation is emitted during the summers and absorbed during the winters.

48. In which one of the following regions of the electromagnetic spectrum will the vibrational motion of molecules give rise to absorption ?
(a) Ultraviolet (b) Microwaves
(c) Infrared (d) Radio waves

49. The range of wavelength of the visible light is
(a) 10 Å to 100 Å (b) 4,000 Å to 8,000 Å
(c) 8,000 Å to 10,000Å (d) 10,000 Å to 15,000 Å

50. If microwaves, X rays, infrared, gamma rays, ultra-violet, radio waves and visible parts of the electromagnetic spectrum are denoted by M, X, I, G, U, R and V then which of the following is the arrangement in ascending order of wavelength ?
(a) R, M, I, V, U, X and G
(b) M, R, V, X, U, G and I
(c) G, X, U, V, I, M and R
(d) I, M, R, U, V, X and G

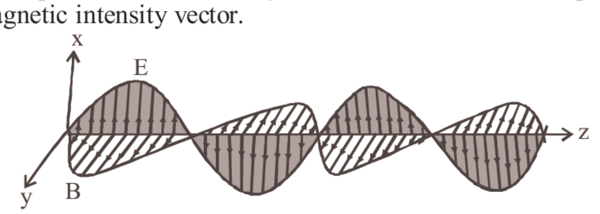
51. Which of the following is the infrared ray wavelength?
(a) 10^{-4} cm (b) 10^{-5} cm
(c) 10^{-6} cm (d) 10^{-7} cm

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

Electromagnetic waves are constituted by varying or oscillating electric and magnetic fields. The electric and magnetic fields are perpendicular to each other and are also perpendicular to the direction of propagation of the wave. Hence **electromagnetic waves are transverse in nature**. E is the envelope of electric intensity vector and B is the envelope of magnetic intensity vector.



52. In an electromagnetic wave, the direction of the magnetic induction $\vec{B}$ is
(a) parallel to the electric field $\vec{E}$
(b) perpendicular to the electric field $\vec{E}$
(c) antiparallel to the Poynting vector $\vec{S}$
(d) random

53. The polarisation of electromagnetic wave is in
(a) the directions of electric and magnetic field
(b) the directions of electric field
(c) the direction of magnetic field
(d) can not be polarized

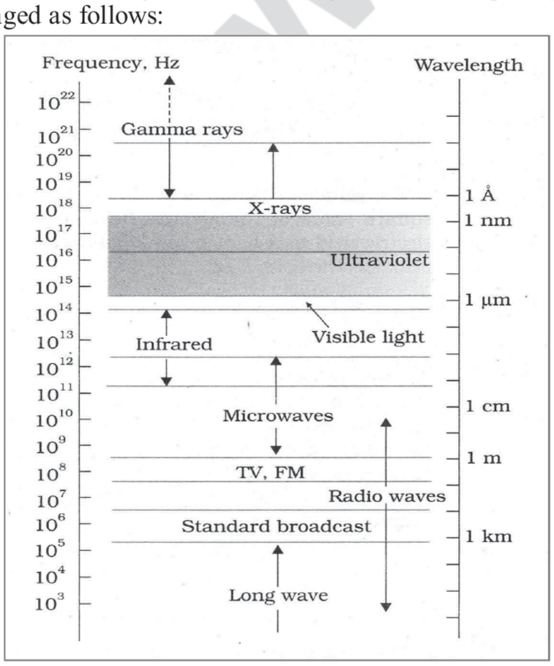
54. In an electromagnetic wave
(a) power is transmitted along the magnetic field
(b) power is transmitted along the electric field
(c) power is equally transferred along the electric and magnetic fields
(d) power is transmitted in a direction perpendicular to both the fields

55. Which of the following has/have zero average value in a plane electromagnetic wave?
(a) Both magnetic and electric field
(b) Electric field only
(c) Magnetic energy
(d) Electric energy

56. An electromagnetic wave propagating along north has its electric field vector upwards. Its magnetic field vector point towards
(a) north (b) east
(c) west (d) downwards

Case/Passage-II

The electromagnetic waves have continuous wavelength starting from short gamma rays to long radio waves. The orderly distribution of wavelength of e.m. waves is called electromagnetic spectrum. The waves according to their increasing order of wavelength or decreasing order of frequency are arranged as follows:



57 Which one of the following has the maximum energy?
(a) Radio waves (b) Infrared rays
(c) Ultraviolet rays (d) Micro waves

58. The velocity of all radio waves in free space is 3×10^8 m/s. The frequency of a radio wave of wavelength 150m is
(a) 20 kHz (b) 2 kHz (c) 2 MHz (d) 1 MHz

59. Ozone layer above earth's atmosphere will not
(a) prevent infrared radiations from sun reaching earth.
(b) prevent infra red radiations originated from earth from escaping earth's atmosphere.
(c) prevent ultraviolet rays from sun.
(d) reflect back radio waves.

60. If $\lambda = 10\,\text{Å}$ then it corresponds to
(a) infrared (b) microwaves
(c) ultraviolet (d) X-rays

61. The electromagnetic radiation used in food processing sterilizing agent is
(a) microwaves (b) UV rays
(c) gamma rays (d) radio waves

Case/Passage-III

The electric and magnetic field of a sinusoidal plane electromagnetic wave propagating in the positive x-direction can also be written as

$$E = E_m \sin(kx - \omega t); B = B_m \sin(kx - \omega t)$$

where **ω is the angular frequency of the wave** and **k is wave number** which are given by $\omega = 2\pi f$ and $k = \dfrac{2\pi}{\lambda}$

62. For plane electromagnetic waves propagating in the z-direction, which one of the following combination gives the correct possible direction for $\vec{E}$ and $\vec{B}$ field respectively?
(a) $(2\hat{i} + 3\hat{j})$ and $(\hat{i} + 2\hat{j})$
(b) $(-2\hat{i} - 3\hat{j})$ and $(3\hat{i} - 2\hat{j})$
(c) $(3\hat{i} + 4\hat{j})$ and $(4\hat{i} - 3\hat{j})$
(d) $(\hat{i} + 2\hat{j})$ and $(2\hat{i} - \hat{j})$

63. A plane electromagnetic wave propagating in the X-direction has wavelength of 6.0 mm. The electric field is in the Y-direction and its maximum magnitude is 33 Vm^{-1}. The equation for the electric field as a function of x and t is
(a) $11\sin\pi\left(t - \dfrac{x}{c}\right)$ (b) $33\sin\left[\pi \times 10^{11}\left(t - \dfrac{x}{c}\right)\right]$
(c) $33\sin\pi\left(t - \dfrac{x}{c}\right)$ (d) $11\sin\left[\pi \times 10^{11}\left(t - \dfrac{x}{c}\right)\right]$

64. The magnetic field in the plane electromagnetic field is given by: $B_y = 2 \times 10^{-7} \sin(0.5 \times 10^3 z + 1.5 \times 10^{11} t)$ T
The expression for the electric field may be given by
(a) $E_y = 2 \times 10^{-7} \sin(0.5 \times 10^3 z + 1.5 \times 10^{11} t)$ V/m
(b) $E_x = 2 \times 10^{-7} \sin(0.5 \times 10^3 z + 1.5 \times 10^{11} t)$ V/m
(c) $E_y = 60 \sin(0.5 \times 10^3 z + 1.5 \times 10^{11} t)$ V/m
(d) $E_x = 60 \sin(0.5 \times 10^3 z + 1.5 \times 10^{11} t)$ V/m

65. Suppose that the electric field amplitude of an em wave is $E_o = 120$ N/C and that its frequency is $\upsilon = 50$ Hz, then

(a) $B_o = 200$ T
(b) $\omega = r \times 10^8$ rad/s
(c) $k = \left(\frac{\pi}{4}\right)$ rad/m
(d) $\lambda = 92$m

66. The amplitude of the electric field if the intensity of a plane electromagnetic wave is given as 2.0 Wm^{-2} is

(a) 38.8 NC^{-1}
(b) 48.3 NC^{-1}
(c) 50.2 NC^{-1}
(d) 68.8 NC^{-1}

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

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

67. **Assertion :** Electromagnetic waves do not require medium for their propagation.

Reason : They can't travel in vacuum

68. **Assertion :** Electromagnetic waves exert radiation pressure.

Reason : Electromagnetic waves have momentum.

69. **Assertion :** The basic difference between various types of electromagnetic waves lies in their wavelength or frequencies.

Reason : Electromagnetic waves travel through vacuum with the same speed.

70. **Assertion :** Infrared radiation plays an important role in maintaining the average temperature of earth.

Reason : Infrared radiations are sometimes referred to as heat waves.

71. **Assertion :** Ultraviolet radiations of higher frequency waves are dangerous to human being.

Reason : Ultraviolet radiation are absorbed by the ozone layer in atmosphere

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

72. Match the following according to their uses from Column I and Column II.

	Column I		Column II
(A)	Ultraviolet rays	(1)	in satellite signals
(B)	Infrared rays	(2)	night vison and security cameras
(C)	Microwave	(3)	television and cellular phones
(D)	Radio wave	(4)	detecting forged bank notes

(a) (A) → (4) ; (B) → (2) ; (C) → (1) ; (D) → (3)
(b) (A) → (2) ; (B) → (2) ; (C) → (4) ; (D) → (3)
(c) (A) → (4) ; (B) → (3) ; (C) → (2) ; (D) → (1)
(d) (A) → (2) ; (B) → (1) ; (C) → (4) ; (D) → (3)

73. Various electromagnetic waves are given in column I and various frequency ranges in column II. Match the two columns.

	Column I		Column II
(A)	Radio waves	(1)	3×10^{16}Hz – 3×10^{19} Hz
(B)	γ–rays	(2)	300 MHz – 300 GHz
(C)	Microwaves	(3)	$> 10^{19}$ Hz
(D)	X-rays	(4)	300 GHz – 3KHz

(a) (A) → (2) ; (B) → (5) ; (C) → (3) ; (D) → (4)
(b) (A) → (2) ; (B) → (2) ; (C) → (4) ; (D) → (3)
(c) (A) → (4) ; (B) → (3) ; (C) → (2) ; (D) → (1)
(d) (A) → (2) ; (B) → (1) ; (C) → (4) ; (D) → (3)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

74. The average electric field of electromagnetic waves in certain region of free space is 9×10^{-4} NC^{-1}. Then the average magnetic field in the same region is of the order of__________ T.

75. All components of the electromagnetic spectrum in vacuum have the same_________.

76. The wavelength of X-ray is of the order of__________.

77. In radar and satellite communication E.M. waves used of frequency range_________to_________ .

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

78. The velocity of electromagnetic waves depends on electric and magnetic properties of the medium.

79. Velocity of electromagnetic waves in free space is constant.

80. The basic difference between various types of electromagnetic waves lies in their wavelength or frequencies.

81. Electromagnetic waves travel through vacuum with different speed.

ANSWER KEY & SOLUTIONS

1. **(b)** An electromagnetic wave has both energy and momentum.

2. **(a)** The speed of light $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \frac{1}{\sqrt{2 \times 8}} = \frac{1}{4} = 0.25$

3. **(c)** Velocity of electromagnetic waves in free space and wavelength are,

$v = 3 \times 10^8$ m/s and $\lambda = 150$ m

The frequency of radio waves is given by

$$f = \frac{v}{\lambda} = \frac{3 \times 10^8}{150} = 2 \times 10^6 \text{ Hz} = 2 \text{ MHz}$$

4. **(a)** Here, $\lambda = \frac{c}{f} = \frac{3 \times 10^8}{8.2 \times 10^6} = 36.6 \text{ m}$

5. **(b)** In an electromagnetic wave the directions of magnetic induction is perpendicular to electric field.

6. **(a)** Velocity of light

$$c = \frac{E}{B} \Rightarrow B = \frac{E}{c} = \frac{9.3}{3 \times 10^8} = 3.1 \times 10^{-8} \text{ T}$$

7. **(b)** Here, $E_0 = 18$ V/m; $B_0 = ?$

$$B_0 = \frac{E_0}{c} = \frac{18}{3 \times 10^8} = 6 \times 10^{-8} \text{ T}$$

8. **(d)** The frequency of electromagnetic wave remains unchanged but the wavelength of electromagnetic wave changes when it passes from one medium to another.

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

$$\therefore \quad c \propto \frac{1}{\sqrt{\varepsilon_0}} \text{ and } v \propto \frac{1}{\sqrt{\varepsilon}}$$

$$\therefore \quad \frac{c}{v} = \sqrt{\frac{\varepsilon}{\varepsilon_0}} = \sqrt{\frac{4}{1}} = 2$$

$$\frac{c}{v} = \frac{f\lambda}{f\lambda'} = \frac{\lambda}{\lambda'} = 2 \text{ or } \lambda' = \frac{\lambda}{2}$$

9. **(b)** The electromagnetic waves do not transport charge.

10. **(c)** The energy in EM waves is divided equally between the electric and magnetic fields.
EM waves also carry momentum. If a portion of EM wave of energy u propagating with speed C_1 then linear

$$\text{momentum} = \frac{\text{Energy (a)}}{\text{speed (c)}}$$

In free space, its speed

$$C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \frac{E_0}{B_0} = 3 \times 10^8 \text{ m/sec}$$

11. **(a)** In vacuum velocity of all EM waves are same but their wavelengths are different.

12. **(c)** Light waves and X-rays are electromagnetic waves.

13. **(d)** $\lambda_{micro} > \lambda_{infrared} > \lambda_{ultraviolet} > \lambda_{gamma}$

14. **(a)** $E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{11 \times 1000 \times 1.6 \times 10^{-19}} = 12.4$ Å

15. **(c)** As we know that,

$E = h\nu$

As given that $h = 6.62 \times 10^{-34}$ J-s

$E = 11 \text{ eV} = 11 \times 1.6 \times 10^{-19}$

$\nu = ?$

$11 \text{ eV} = h\nu$

$$\text{So, } \nu = \frac{11 \times 1.6 \times 10^{-19}}{h} \text{J} = \frac{11 \times 1.6 \times 10^{-19}}{6.62 \times 10^{-34}} \text{J}$$

$= 2.65 \times 10^{15}$ Hz

So, that frequency radiation belongs to ultraviolet region.

16. **(b)** The type of wave doesn't change when a wave is reflected from denser medium but only its phase changes by 180°. As E is along positive x-axis so reflected ray will be along negative x-axis and its component will also be opposite to earlier in (–z) direction and phase will change.

For the reflected wave $\hat{z} = -\hat{z}, \hat{i} = -\hat{i}$ and additional phase of π in the incident wave.
As given that the incident electromagnetic wave is,

$E = E_0 \hat{i} \cos(kz - \omega t)$

So, the reflected electromagnetic wave is

$$E_r = E_0(-\hat{i})\cos(k(-z) - \omega t + \pi)$$

$$= -E_0 \hat{i} \cos(-(kz + \omega t) + \pi)$$

$$= -E_0 \hat{i} \cos(\pi - (kz + \omega t))$$

$$= E_0 \hat{i} \cos(kz + \omega t)$$

17. **(b)** As we know that
the momentum of incident light

$$= \frac{U(\text{total energy})}{c}$$

As given that the energy flux $\phi = 20 \text{W/cm}^2$
Surface are $A = 30 \text{ cm}^2$
Time for total momentum delivered
$t = 30$ min $= 30 \times 60$ sec
So, total energy falling in time t sec is
$U = \phi A t = 20 \times 30 \times (30 \times 60)$ J
Momentum of the incident light

$$= \frac{U}{c} \qquad (\because c = 3 \times 10^8)$$

Momentum of incident light $= \dfrac{20\times30\times(30\times60)}{3\times10^8}$

$= 36\times10^{-4}$ kg-ms^{-1}

As no reflection from the surface and for comidete absorption.

Momentum of the reflected light = 0

Hence, momentum delivered to the surface

= Charge in momentum. $= (p_f - f_i)$

$= 36\times10^{-4} - 0 = \quad 36\times10^{-4}$ kg-ms^{-1}

18. **(c)** As we know that the electric field intensity on a surface due to incident radiation is,

$$I_{av} \propto E_0{}^2$$

$$\frac{P_{av}}{A} \propto E_0{}^2 \quad \text{(A is constant)}$$

Here, $P_{av} \propto E_0{}^2$

So, $E_0 \propto \sqrt{P_{av}}$

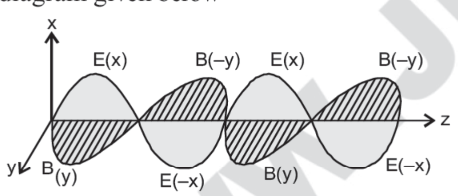
$$\therefore \quad \frac{(E_0)_1}{(E_0)_2} = \sqrt{\frac{(P_{av})_1}{(P_{av})_2}}$$

$$\frac{(E_0)_1}{(E_0)_2} = \sqrt{\frac{100}{50}} = \left[\frac{\sqrt{2}}{1}\right]$$

$$(E_0)_2 = (E_0)_1\sqrt{2}$$

19. **(d)** The direction of propagation of electromagnetic wave is perpendicular to both electric field E and magnetic field B, i.e., in the direction of E × B by right thumb rule.

The diagram given below



So, electromagnetic wave is along the z-direction which is give the cross product of E and B direction is perpendicular to E and B from $\vec{E}$ to $\vec{B}$. i.e., (E × B) in z-direction.

20. **(c)** Intensity in terms of electric field

$$U_{av} = \frac{1}{2}\varepsilon_0 E_0^2$$

Intensity in terms of magnetic field

$$U_{av} = \frac{1}{2}\frac{B_0^2}{\mu_0}$$

We also know that the relationship between E and B is $E_0 = cB_0$

So the average energy by electric field is

$$(U_{av}) = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{1}{2}\varepsilon_0 E_0 (cB_0)^2$$

$$= \frac{1}{2}\varepsilon_0 \times c^2 B^2 \qquad \left(\because c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}\right)$$

$$\therefore \quad (U_{av})_{\text{Electric field}} = \frac{1}{2}\varepsilon_0 \times \frac{1}{\mu_0\varepsilon_0} B_0^2$$

$$= \frac{1}{2}\frac{B_0^2}{\mu_0} = (U_{av})_{\text{Magnetic field}}$$

So, the energy in electromagnetic wave is divided equally between electric field vector and magnetic field vector.

Then, the ratio of contributions by the electric field and magnetic field components to the intensity of an electromagnetic wave is

$$\text{Ratio} = \frac{(U_{av})_{\text{electric field}}}{(U_{av})_{\text{Magnetic field}}} = 1 : 1$$

21. **(c)** As we know that, the electric field is inversly proportional to r, so $\left(E_0 \propto \frac{1}{r}\right)$

From a diode antenna, an electromagnetic waves are radiated outwards from dipole antenna with the amplitude of electric field vector (E_0) which transports significant energy from the source falls off intensity inversely as the distance (r) from the antenna, i.e.,

radiated energy $\left(E_0 \propto \frac{1}{r}\right)$

22. **(d)** In electromagnetic wave, the electric field vector is

$$E = (E_1\hat{i} + E_2\hat{j})\cos(kz - \omega t)$$

and the associated magnetic field vector,

$$B = \frac{E}{c} = \frac{E_1\hat{i} + E_2\hat{j}}{c}\cos(kz - \omega t)$$

So, E and B are perpendicular to each other and the propagation of electromagnetic wave is perpendicular to E as well as B, so the electromagnetic wave plane polarised.

23. **(a)** $\dfrac{E_0}{B_0} = c \cdot$ also $k = \dfrac{2\pi}{\lambda}$ and $\omega = 2\pi v$

These relation gives $E_0 k = B_0\omega$

24. **(d)**

25. **(c)** **26.** **(c)**

27. **(b)** Velocity of EM waves

$$= \frac{1}{\sqrt{\mu_0 \in_0}} = 3\times10^8 \text{ m/s} = \text{velocity of light}$$

28. **(c)** Speed of EM waves in vacuum $= \dfrac{1}{\sqrt{\mu_0 \in_0}}$ = constant

29. **(a)** **30.** **(b)** **31.** **(a)**

32. **(a)** Energy density (EM waves)

$$= \varepsilon_0 E_{rms}^2 = \varepsilon_0\left(\frac{E_0}{\sqrt{2}}\right)^2 = \frac{1}{2}\varepsilon_0 E_0^2$$

33. **(c)** Incident momentum, $p = \dfrac{E}{c}$

For perfectly reflecting surface with normal incidence

$$\Delta p = 2p = \frac{2E}{c}; \quad F = \frac{\Delta p}{\Delta t} = \frac{2E}{ct}; \quad P = \frac{F}{A} = \frac{2E}{ctA}$$

34. **(d)**

35. **(b)** Wave impedance = Z = $\sqrt{\frac{\mu_0}{\varepsilon_0}} = 376.6\ \Omega$

36. **(c)** **37.** **(b)**

38. **(b)** Here, $k = \frac{2\pi}{\lambda}$, $\omega = 2\pi\upsilon$

$\therefore \quad \frac{k}{\omega} = \frac{2\pi/\lambda}{2\pi\upsilon} = \frac{1}{\pi\upsilon} = \frac{1}{c} \qquad (\because c = \upsilon\lambda)$

where c is the speed of electromagnetic wave in vacuum. It is a constant whose value is $3 \times 10^6\ m\ s^{-1}$

39. **(c)** $\nu_{\gamma-\text{rays}} > \nu_{\text{visible radiation}} > \nu_{\text{infrared}} > \nu_{\text{Radio waves}}$

40. **(d)**

41. **(b)** Infrared radiations reflected by low lying clouds and keeps the earth warm.

42. **(d)** $\lambda_{\text{Radiowave}} > \lambda_{\text{IR rays}} > \lambda_{\text{UV rays}} > \lambda_{\text{x-rays}}$

43. **(c)**

44. **(b)** Infrared causes heating effect.

45. **(c)** Microwave oven acts on the principle of giving vibrational energy to water molecules.

46. **(d)**

47. **(b)** Depends on the magnitude of frequency

48. **(b)** Molecular spectra due to vibrational motion lie in the microwave region of EM-spectrum. Due to Kirchhoff's law in spectroscopy the same will be absorbed.

49. **(b)** Wavelength of visible spectrum is 3900Å – 7800 Å.

50. **(c)** Gamma rays < X-rays < Ultra violet < Visible rays < Infrared rays < Microwaves < Radio waves.

51. **(a)** The wavelength of infrared region is 8×10^{-5} cm to 3×10^{-3} cm. So maximum wavelength of infrared region = 8×10^{-5} cm $\approx 10^{-4}$ cm.

52. **(b)** In an electromagnetic wave the directions of magnetic induction is perpendicular to electric field.

53. **(b)** **54.** **(d)**

55. **(a)** Both magnetic and electric fields have zero average value in a plane e.m. wave.

56. **(b)** **57.** **(c)**

58. **(c)** Here : Velocity of electromagnetic waves in free space and wavelength

$v = 3 \times 10^8$ m/s and $\lambda = 150\ m$

The frequency of radio waves is given by

$$= \frac{v}{\lambda} = \frac{3 \times 10^8}{150} = 2 \times 10^6\ \text{Hz} = 2\ \text{MHz}.$$

59. **(d)** Ozone layer will absorb ultraviolet rays; reflect the infrared radiation and does not reflect back radiowaves.

60. **(d)** **61.** **(b)**

62. **(b)** As we know, $\vec{E} \cdot \vec{B} = 0 \qquad \because [\vec{E} \perp \vec{B}]$

and $\vec{E} \times \vec{B}$ should be along Z direction

As $(-2\hat{i} - 3\hat{j}) \times (3\hat{i} - 2\hat{j}) = 5\hat{k}$

Hence option (b) is the correct answer.

63. **(b)** $\omega = 2\pi v = \frac{2\pi c}{\lambda} = \frac{2\pi \times 3 \times 10^8}{6 \times 10^{-3}}$

$= \pi \times 10^{11}$ rad/sec

The equation for the electric field, along y-axis in the electromagnetic wave is

$$Ey = E_0 \sin \omega\left(t - \frac{x}{c}\right) = 33 \sin\left[\pi \times 10^{11}\left(t - \frac{x}{c}\right)\right]$$

64. **(d)** By = $2 \times 10^{-7} \sin(0.5 \times 10^3 z + 1.5 \times 10^{11} t)$ T

The electric vector is perpendicular to B as well as direction of propagation of electromagnetic wave. Therefore Ex has to be taken.

Further, $E_0 = B_0 \times c$

$= 2 \times 10^{-7} \times 3 \times 10^8$ V/m

$E_0 = 2 \times 10^{-7} \times 3 \times 10^8 = 60$ V/m

$\therefore$ The corresponding value of the electric field is

$Ex = 60 \sin(0.5 \times 10^3 z + 1.5 \times 10^{11} t)$ V/m

65. **(b)**

66. **(a)** Intersity of a plane electromagnetic wave

$= \frac{1}{2}\varepsilon_0 E_0^2 c$

$E = \sqrt{\frac{2I}{\varepsilon_0 c}} = 38.8\ \text{NC}^{-1}$

67. **(c)**

68. **(a)** Electromagnetic waves have linear momentum as well as energy. This concludes that they can exert radiation pressure by falling beam of electromagnetic radiation on an object.

69. **(a)** The basic difference between various types of electromagnetic waves lies in their wavelengths or frequencies since all of them travel through vacuum with the same speed. Consequently, the waves differ considerably in their mode of interaction with matter.

70. **(b)** Infrared radiation help to maintain the earth warmth through the greenhouse effect. Incoming visible light which passes relatively easily through the atmosphere is absorbed by the earth's surface and re-radiated as infrared radiation. The radiation is trapped by greenhouse gases such as carbon dioxide and water vapour and they heat up and heat their surrondings.

71. **(b)** The wavelength of these wave ranges between 4000 Å to 100 Å that is smaller wavelength and higher frequency. They are absorbed by atmosphere and convert oxygen into ozone. They cause skin diseases and they are harmful to eye and cause permanent blindness.

72. **(a)** (A) → (4) ; (B) → (2) ; (C) → (1) ; (D) → (3)

73. **(c)** (A) → (4) ; (B) → (3) ; (C) → (2) ; (D) → (1)

74. (3×10^{-12}) For electromagnetic waves we know that,

$\frac{E}{B} = c \quad \therefore \quad \frac{9 \times 10^{-4}}{B} = 3 \times 10^8\ \text{ms}^{-1}$

$\Rightarrow \quad B = 3 \times 10^{-12}$ T.

75. (Velocity) All components of electromagnetic spectrum travel in vacuum with velocity 3×10^8 m/s.

76. (1 Angstrom)

77. [(3×10^3 MHz) to 30×10^3 MHz)

78. (True) **79.** (True) **80.** (True) **81.** (False)

9 Ray Optics and Optical Instruments

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. A ray of light passes from vacuum into a medium of refractive index μ, the angle of incidence is found to be twice the angle of refraction. Then the angle of incidence is

(a) $2\cos^{-1}\left(\frac{\mu}{2}\right)$ (b) $\sin^{-1}(\mu)$

(c) $\sin^{-1}\left(\frac{\mu}{2}\right)$ (d) $\cos^{-1}\left(\frac{\mu}{2}\right)$

2. A rectangular tank of depth 8 meter is full of water ($\mu = 4/3$), the bottom is seen at the depth

(a) 6m (b) 8/3 m (c) 8 cm (d) 10 cm

3. When light is refracted from denser to rarer medium, then

(a) its wavelength, frequency both increase

(b) its wavelength increases, frequency remains unchanged

(c) its wavelength decreases, frequency remains unchanged

(d) its wavelength, frequency both decrease

4. Which of the following is/are true/false relations?

I. $n_{21} = \frac{1}{n_{12}}$ II. $n_{32} = n_{31} \times n_{12}$

III. $n_{21} = \frac{n_{1a}}{n_{2a}}$ IV. $n_{21} = \frac{n_{2a}}{n_{1a}}$

(a) T,T,F,T (b) T,F,T,T

(c) F,T,T,T (d) T,T,T,T

5. According to the total internal reflection which of the following statements is/are true/false?

I. Looming is an optical illusion in cold countries.

II. Mirage is an optical illusion in deserts.

III. Brilliance of diamond is due to repeated internal reflections.

(a) T,T,T (b) T,T,F

(c) T,F,T (d) None of these

6. Two thin lenses are in contact and the focal length of the combination is 80 cm. If the focal length of one lens is 20 cm, then the power of the other lens will be

(a) 1.66 D (b) 4.00 D (c) –100 D (d) –3.75 D

7. A lens made of glass whose index of refraction is 1.60 has a focal length of + 20 cm in air. Its focal length in water, whose refractive index is 1.33, will be

(a) three times longer than in air

(b) two times longer than in air

(c) same as in air

(d) None of these

8. A bi-convex lens made of glass (refractive index 1.5) is put in a liquid of refractive index 1.7. Its focal length will

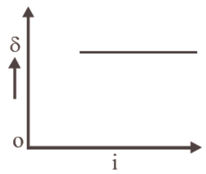
(a) decrease and change sign

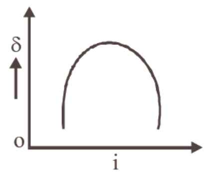
(b) increase and change sign

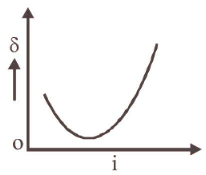
(c) decrease and remain of the same sign

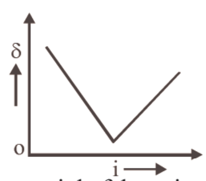
(d) increase and remain of the same sign

9. The graph between angle of deviation (δ) and angle of incidence (i) for a triangular prism is represented by

(a)


(b)


(c)


(d)


10. Find the refractive index of the material of the prism, if the angle of minimum deviation from the prism is 37° and angle of prism is 53° [take sin 26.5° = 1/2.234]

(a) 1.58 (b) 1.99 (c) 2.88 (d) 3.1

11. The angle of prism is 60° and angle of deviation is 30°. In the position of minimum deviation, the values of angle of incidence and angle of emergence are:

(a) $i = 45°; e = 50°$ (b) $i = 30°; e = 45°$

(c) $i = 45°; e = 45°$ (d) $i = 30°; e = 30°$

12. The focal length of the objective of a telescope is 60 cm. To obtain a magnification of 20, the focal length of the eye piece should be

(a) 2 cm (b) 3 cm (c) 4 cm (d) 5 cm

13. The focal length of the objective and the eyepiece of a telescope are 50 cm and 5 cm respectively. If the telescope is focussed for distinct vision on a scale distant 2 m from its objective, then its magnifying power will be:

(a) – 4 (b) – 8 (c) + 8 (d) – 2

14. In a compound microscope, the focal length of objective lens is 1.2 cm and focal length of eye piece is 3.0 cm. When object is kept at 1.25 cm in front of objective, final image is formed at infinity. Magnifying power of the compound microscope should be:

(a) 200 (b) 100 (c) 400 (d) 150

15. Larger aperture of objective lens in an astronomical telescope

(a) increases the resolving power of telescope.
(b) decreases the brightness of the image.
(c) increases the size of the image.
(d) decreases the length of the telescope.

16. 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

(a) 1.47 (b) 1.62 (c) 1.33 (d) 1.51

17. A ray of light incident at an angle θ on a refracting face of a prism emerges from the other face normally. If the angle of the prism is $5°$ and the prism is made of a material of refractive index 1.5, the angle of incidence is

(a) $7.5°$ (b) $5°$ (c) $15°$ (d) $2.5°$

18. An object approaches a convergent lens from the left of the lens with a uniform speed 5 m/s and stops at the focus. The image

(a) moves away from the lens with an uniform speed 5 m/s
(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

19. 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?

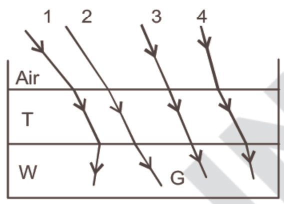
(a) The beam of red light would undergo total internal reflection
(b) The beam of red light would bend towards normal while it gets refracted through the second medium
(c) The beam of blue light would undergo total internal reflection
(d) The beam of green light would bend away from the normal as it gets refracted through the second medium

20. 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

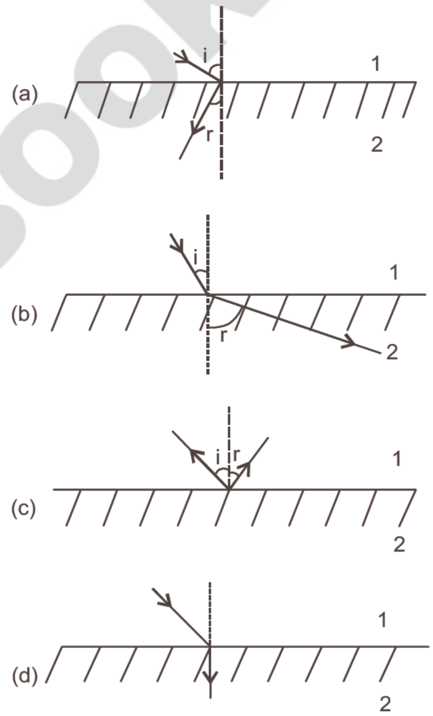
(a) act as a convex lens only for the objects that lie on its curved side
(b) act as a concave lens for the objects that lie on its curved side
(c) act as a convex lens irrespective of the side on which the object lies
(d) act as a concave lens irrespective of side on which the object lies

21. 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



22. There are certain material developed in laboratories which have a negative refractive index figure. A ray incident from air (Medium 1) into such a medium (Medium 2) shall follow a path given by



23. A planoconvex lens of focal length 16 cm, is to be made of glass of refractive index 1.5. The radius of curvature of the curved surface should be

(a) 8 cm (b) 12 cm
(c) 16 cm (d) 24 cm

24. Dispersive power of a prism to depends on:

(a) angle of prism (b) material of prism
(c) incident angle (d) refraction angle

25. Total internal reflection can take place only if

(a) light goes from optically rarer medium (smaller refractive index) to optically denser medium
(b) light goes from optically denser medium to rarer medium
(c) the refractive indices of the two media are close to different
(d) the refractive indices of the two media are widely different

26. 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 **[CBSE 2020]**
(a) 1.47 (b) 1.62 (c) 1.33 (d) 1.51

27. For a glass prism, the angle of minimum deviation will be smallest for the light of **[CBSE 2020]**
(a) red colour. (b) blue colour.
(c) yellow colour. (d) green colour.

28. Material A has critical angle i_A, and material B has critical angle i_B ($i_B > i_A$). Then which of the following is true?
(a) Light can be totally internally reflected when it passes from B to A
(b) Light can be partially reflected when it passes from A to B
(c) Critical angle for total internal reflection is $i_B - i_A$
(d) Critical angle between A and B is $\sin^{-1}\left(\frac{\sin i_A}{\sin i_B}\right)$

29. Critical angle of light passing from glass to water is minimum for
(a) red colour (b) green colour
(c) yellow colour (d) violet colour

30. A ray of light travelling inside a rectangular glass block of refractive index $\sqrt{2}$ is incident on the glass-air surface at an angle of incidence of 45º. The refractive index of air is one. Under these conditions the ray will
(a) emerge into the air without any deviation
(b) be reflected back into the glass
(c) be absorbed
(d) emerge into the air with an angle of refraction equal to 90º

31. The refractive index of a piece of transparent quartz is greatest for
(a) violet light (b) green light
(c) yellow light (d) red light

32. If $_i\mu_j$ represents refractive index when a light ray goes from medium i to medium j, then the product $_2\mu_1 \times {}_3\mu_2 \times {}_4\mu_3$ is equal to
(a) $_3\mu_1$ (b) $_3\mu_2$ (c) $\frac{1}{_1\mu_4}$ (d) $_4\mu_2$

33. Dielectric constant of mica is 6. What is the velocity of light in this medium approximately?
(a) 1.2×10^7 m/s (b) 5.0×10^7 m/s
(c) 1.2×10^8 m/s (d) 3.0×10^8 m/s

34. A vessel is half filled with a liquid of refractive index μ. The other half of the vessel is filled with an immiscible liquid of refrative index 1.5 μ. The apparent depth of the vessel is 50% of the actual depth. Then μ is
(a) 1.4 (b) 1.5 (c) 1.6 (d) 1.67

35. When light falls on a given plate at angle of incidence of 60º, the reflected and refracted rays are found to be normal to each other. The refractive index of the matertial of the plate is then
(a) 0.866 (b) 1.5 (c) 1.732 (d) 2

36. A real image is formed by a convex lens. If we put a concave lens in contact with it, the combination again forms a real image. The new image
(a) is closer to the lens system
(b) is farther form the lens system
(c) is at the original position.
(d) may be anywhere depending on the focal length of the concave lens

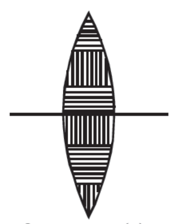
37. A parallel beam of light is incident on a converging lens parallel to its principal axis. As one moves away from the lens on the other side on its principal axis, the intensity of light
(a) remains constant
(b) continuously increases
(c) continuously decreases
(d) first increases then decreases

38. Which of the following is not the case with the image formed by a concave lens?
(a) It may be erect or inverted
(b) It may be magnified or diminished
(c) It may be real or virtual
(d) Real image may be between the pole and focus or beyond focus

39. The equi-convex lens, shown in the figure, has a focal length f. What will be the focal length of each half if the lens is cut along AB ?

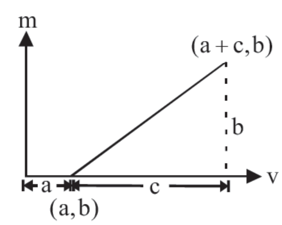
(a) $\frac{f}{2}$ (b) f
(c) $\frac{3f}{2}$ (d) 2f

40. The layered lens as shown is made of two types of transparent materials-one indicated by horizontal lines and the other by vertical lines. The number of images formed of an object will be



(a) 1 (b) 2 (c) 3 (d) 6

41. The graph shows the variation of magnification m produced by a convex lens with the image distance v. The focal length of the lens is



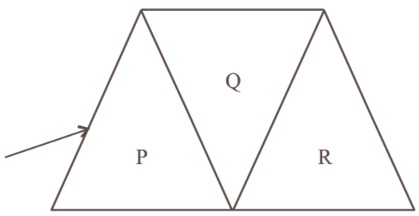
(a) $\frac{b}{c}$ (b) $\frac{c}{b}$ (c) b (d) $\frac{ab}{c}$

42. A convex lens of glass (μ = 1.5) has a focal length of 8 cm when placed in air. What is the focal length of lens when it is immersed in water $\left(\mu = \frac{4}{3}\right)$?
(a) 4 cm (b) 8 cm (c) 16 cm (d) 32 cm

43. When the incidence angle is equal to the angle of emergence of light from the prism, the refracted ray inside the prism
(a) becomes parallel to the right face of prism
(b) becomes perpendicular to the base of prism
(c) becomes parallel to the base of prism
(d) becomes perpendicular to the left face of prism

44. By properly combining two prisms made of different materials, it is not possible to have
(a) dispersion without average deviation
(b) deviation without dispersion
(c) both dispersion and average deviation
(d) neither dispersion nor average deviation

45. A ray of light suffers minimum deviation in equilateral prism P. Additional prisms Q and R of identical shape and of same material as that of P are now combined as shown in figure. The ray will now suffer



(a) greater deviation
(b) no deviation
(c) same deviation as before
(d) total internal reflection

46. The sunlight reaches us as white light and not as its components because
(a) air medium is dispersive
(b) air medium is non-dispersive
(c) air medium scatter the sunlight
(d) air medium absorbs the sunlight

47. Chromatic aberration in a lens is caused by
(a) reflection (b) interference
(c) diffraction (d) dispersion

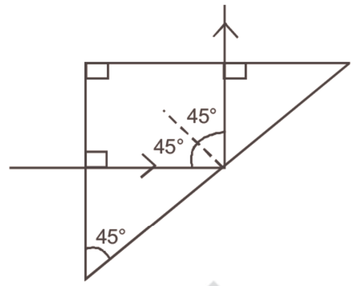
48. Spherical aberration in a lens is
(a) is minimum when most of the deviation is at first surface
(b) is minimum when most of the deviation is at the second surface
(c) is minimum when the total deviation is equally distributed over the two surfaces
(d) does not depend on the above considerations

49. When a glass prism of refracting angle 60° is immersed in a liquid, its angle of minimum deviation is 30°. The critical angle of glass with respect to the liquid medium is
(a) 42° (b) 45° (c) 50° (d) 52°

50. When sunlight is scattered by atmospheric atoms and molecules, the amount of scattering of light of wavelength 440 nm is A. The amount of scattering for the light of wavelength 660 nm is approximately

(a) $\frac{4}{9}A$ (b) 2.25A (c) 1.5A (d) $\frac{A}{5}$

51. A light ray is incident perpendicularly to one face of a 90° prism and is totally internally reflected at the glass-air interface. If the angle of reflection is 45°, we conclude that the refractive index n



(a) $n > \frac{1}{\sqrt{2}}$
(b) $n > \sqrt{2}$
(c) $n < \frac{1}{\sqrt{2}}$
(d) $n < \sqrt{2}$

52. A ray incident at 15° on one refracting surface of a prism of angle 60° suffers a deviation of 55°. What is the angle of emergence ?
(a) 95° (b) 45° (c) 30° (d) 100°

53. A normal eye is not able to see objects closer than 25 cm because
(a) the focal length of the eye is 25 cm
(b) the distance of the retina from the eye-lens is 25 cm
(c) the eye is not able to decrease the distance between the eye-lens and the retina beyond a limit
(d) the eye is not able to decrease the focal length beyond a limit

54. A telescope has an objective of focal length 100 cm and an eyepiece of focal length 5 cm. What is the magnifying power of the telescope when the final image is formed at the least distance of distinct vision ?
(a) 20 (b) 24 (c) 28 (d) 32

55. The focal lengths of objective and eye lens of an astronomical telelscope are respectively 2 meter and 5 cm. Final image is formed at (i) least distance of distinct vision (ii) infinity Magnifying power in two cases will be
(a) – 48, – 40 (b) – 40, – 48
(c) – 40, + 48 (d) – 48, + 40

56. A person can see clearly only upto a distance of 30 cm. He wants to read a book placed at a distance of 50 cm from his eyes. What is the power of the lens of his spectacles ?
(a) –1.0 D (b) –1.33 D (c) –1.67 D (d) –2.0 D

57. A compound microscope has an eye piece of focal length 10 cm and an objective of focal length 4 cm. Calculate the magnification, if an object is kept at a distance of 5 cm from the objective so that final image is formed at the least distance vision (20 cm) :
(a) 12 (b) 11 (c) 10 (d) 13

58. The focal lengths of the objective and the eyepiece of the telescope are 225 cm and 5 cm respectively. The magnifying power of the telescope will be
(a) 49 (b) 45 (c) 35 (d) 60

59. A telescope consists of two thin lenses of focal lengths, 0.3 m and 3 cm respectively. It is focused on moon which subtends an angle of 0.5° at the objective. Then the angle subtended at the eye by the final image will be
(a) 5° (b) 0.25° (c) 0.5° (d) 0.35°

60. A double concave thin lens made out of glass (μ = 1.5) have radii of curvature 500cm. This lens is used to rectify the defect in vision of a person. The far point of the person will be at
(a) 5m (b) 2.5m (c) 1.25m (d) 1m

61. Magnifying power of an objective of a compound microscope is 8. If the magnifying power of microscope is 32 then magnifying power of eye piece is
(a) 7 (b) 5 (c) 4 (d) 3

62. An astronomical telescope has a magnifying power 10, the focal length of the eyepiece is 20 cm. The focal length of the objective is

(a) $\frac{1}{200}$ cm (b) $\frac{1}{2}$ cm (c) 200 cm (d) 2 cm

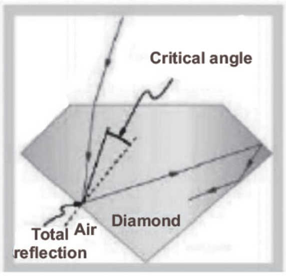
63. When a ray of light enters a glass slab from air
(a) its wavelength increases
(b) neither wavelength nor frequency changes
(c) its wavelength decreases
(d) its frequency increases

64. Absolute refractive index of glass and water is $\frac{3}{2}$ and $\frac{4}{3}$. The ratio of velocity of light in glass and water is
(a) 8 : 9 (b) 3 : 4 (c) 8 : 7 (d) 4 : 3

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I



The total internal reflection of the light is used in polishing diamonds to create a sparking brilliance. By polishing the diamond with specific cuts, it is adjusted the most of the light rays approaching the surface are incident with an angle of incidence more than critical angle. Hence, they suffer multiple reflections and ultimately come out of diamond from the top. This gives the diamond a sparking brilliance.

[CBSE Sample 2021]

65. Light cannot easily escape a diamond without multiple internal reflections. This is because:
(a) Its critical angle with reference to air is too large
(b) Its critical angle with reference to air is too small
(c) The diamond is transparent
(d) Rays always enter at angle greater than critical angle.

66. The critical angle for a diamond is 24.4 . Then its refractive index is
(a) 2.42 (b) 0.413 (c) 1 (d) 1.413

67. The basic reason for the extraordinary sparkle of suitably cut diamond is that
(a) It has low refractive index
(b) It has high transparency
(c) It has high refractive index
(d) It is very hard

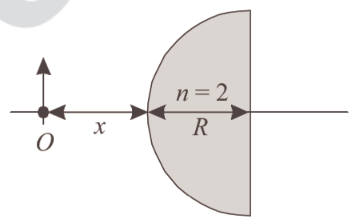
68. A diamond is immersed in a liquid with a refractive index greater than water. Then the critical angle for total internal reflection will
(a) will depend on the nature of the liquid
(b) decrease
(c) remains the same
(d) increase

69. The following diagram shows same diamond cut in two different shapes.

The brilliance of diamond in the second diamond will be:
(a) less than the first
(b) greater than first
(c) same as first
(d) will depend on the intensity of light

Case/Passage-II

Consider a transparent hemisphere ($n = 2$) in front of which a small object is placed in air ($n = 1$) as shown in Fig.



70. For which value of x, of the following, will the final image of the object at O be virtual?
(a) $2R$ (b) $3R$ (c) $R/2$ (d) $1.5R$

71. What is the nature of final image of the object when $x = 2R$?
(a) Erect and magnified (b) Inverted and magnified
(c) Erect and same size (d) Inverted and same size

72. Consider a ray starting from O which strikes the spherical surface at grazing incidance ($i = 90°$). Taking $x = R$, what will be the angle (from normal) at which the ray may emerge from the plane surface
(a) 90° (b) 0° (c) 30° (d) 60°

73. Which one of the following is correct? For a spherical surface

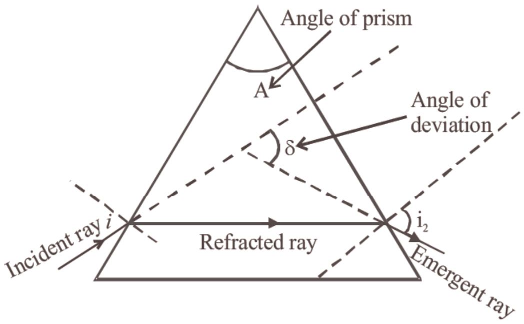
(a) $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$ (b) $\frac{\mu_2}{v} + \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

(c) $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 + \mu_1}{R}$ (d) $\frac{\mu_2}{v} + \frac{\mu_1}{u} = \frac{\mu_2 + \mu_1}{R}$

74. A spherical convex surface separates object and image spaces of refractive indices 1.0 and 4/3. If radius of curvature of the surface is 10 cm, find its focal length.
(a) 3.5 D (b) 2.5 D (c) 25 D (d) 1.5 D

Case/Passage-III

Consider a triangular glass prism. It has two triangular bases and three rectangular lateral surfaces. These surfaces are inclined to each other. The angle between its two lateral faces is called the angle of the prism A.



In figure you can see the incident ray, the refracted ray inside the prism and the emergent ray. You may note that a ray of light is entering from air to glass at the first surface. The light ray on refraction has bent towards the normal. At the second surface, the light ray has entered from glass to air. Hence it has bent away from the normal.

The peculiar shape of the prism makes the emergent ray bend at an angle to the direction of the incident ray. This angle is called **the angle of deviation.**

75. The angular dispersion produced by a prism
(a) increases if the average refractive index increases
(b) increases if the average refractive index decreases
(c) remains constant whether the average refractive index increases or decreases
(d) has no relation with average refractive index.

76. The refracting angle of a prism is 'A', and refractive index of the material of the prism is cot(A/2). The angle of minimum deviation is :
(a) $180° - 2A$ (b) $90° - A$
(c) $180° + 2A$ (d) $180° - 3A$

77. Yellow light is refracted through a prism producing minimum deviation. If i_1 and i_2 denote the angle of incidence and emergence for this prism, then
(a) $i_1 = i_2$ (b) $i_1 > i_2$
(c) $i_1 < i_2$ (d) $i_1 + i_2 = 90°$

78. By properly combining two prisms made of different materials, it is not possible to have
(a) dispersion without average deviation
(b) deviation without dispersion
(c) both dispersion and average deviation
(d) neither dispersion nor average deviation

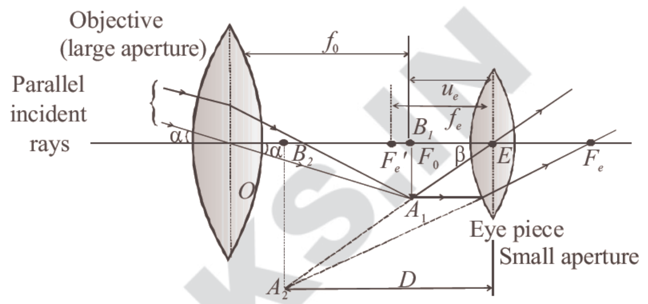
79. When the incidence angle is equal to the angle of emergence of light from the prism the refracted ray inside the prism
(a) becomes parallel to the right face of prism
(b) becomes perpendicular to the base of prism
(c) becomes parallel to the base of prism
(d) becomes perpendicular to the left face of prism

Case/Passage-IV

A refracting type astronomical telescope, used to see the distant objects at large distances, consists of objective, i.e., a converging lens, or lens combination of larger focal length f_0 and larger aperture, and an eyepiece, i.e., also a converging lens, or lens combination, but of smaller focal length f_e and smaller aperture, placed coaxially.

Magnifying power (*M*), also called angular magnification of a telescope is defined as *the ratio of the visual angle subtended by the final image at the eye and the visual angle subtended by the object when the object lies in the actual position.* (In contrast to the definition of magnifying power of a microscope, the object is not placed at the near point in case of telescope)

$$M = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha} \quad (\because \alpha, \beta \text{ are small})$$



80. A student look at distant tree of height 15m with a telescope of magnifying powre 25. To the student, the tree appears.
(a) 20 times taller (b) 15 times taller
(c) 15 times nearer (d) 25 times nearer

81. A telescope has an objective lens of focal length 150 cm and an eyepiece of focal length 5 cm. If a 50 m tall tower at a distance of 1 km is observed through this telescope in normal setting, the angle formed by the image of the tower is θ, then θ is close to :
(a) 6.1 rad (b) 3.2 rad (c) 1.5 rad (d) 0.2 rad

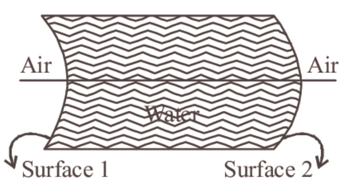
82. The focal lengths of objective and eye lens of an astronomical telelscope are respectively 2 meter and 5 cm. Final image is formed at (i) least distance of distinct vision (ii) infinity Magnifying power in two cases will be
(a) $-48, -40$ (b) $-40, -48$
(c) $-40, +48$ (d) $-48, +40$

83. The magnifying power of a telescope is 9. When it is adjusted for parallel rays, the distance between the objective and the eye piece is found to be 20 cm. The focal length of lenses are
(a) 18 cm, 2 cm (b) 11 cm, 9 cm
(c) 10 cm, 10 cm (d) 15 cm, 5 cm

84. The focal lengths of objective lens and eye lens of a Galilean telescope are respectively 30 cm and 3.0 cm. telescope produces virtual, erect image of an object situated far away from it at least distance of distinct vision from the eye lens. In this condition, the magnifying power of the Galilean telescope should be:
(a) +11.2 (b) – 11.2 (c) – 8.8 (d) +8.8

Case/Passage-V

All objects referred to the subsequent problems lie on the principle axis.



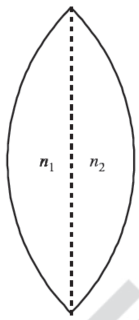
85. If light is incident on surface 1 from left, the image formed after the first refraction is definitely
(a) real for a real object
(b) virtual for a real object
(c) real for a virtual object
(d) virtual for a virtual object

86. In above question if the object is real, then the final image formed after two refractions
(a) may be real (b) may be virtual
(c) must be virtual (d) Both (a) and (b)

87. If light is incident on surface 2 from right then which of the following is true for image formed after a single refraction
(a) real object will result in a real image
(b) virtual object will result in a virtual image
(c) real object will result in a virtual image
(d) virtual object will result in a real image

Case/Passage-VI

A thin convex lens is made of two materials with refractive indices n_1 and n_2, as shown in figure. The radius of curvature of the left and right spherical surface are equal. f is the focal length of the lens when $n_1 = n_2 = n$. The focal length is $f + \Delta f$ when $n_1 = n$ and $n_2 = n + \Delta n$. Assuming $\Delta n << (n - 1)$ and $1 < n < 2$.



(i) If $\frac{\Delta n}{n} < 0$ then $\frac{\Delta f}{f} > 0$

(ii) The relation between $\frac{\Delta f}{f}$ and $\frac{\Delta n}{n}$ remains unchanged if both the convex surfaces are replaced by concave surface of the same radius of curvature.

(iii) For $n = 1.5$, $\Delta n = 10^{-3}$ and $f = 20$ cm, the value of $|\Delta f|$ will be 0.02 cm (round off to 2nd decimal place).

(iv) $\left|\frac{\Delta f}{f}\right| < \left|\frac{\Delta n}{n}\right|$

88. If $\frac{\Delta n}{n} < 0$ then
(a) $\frac{\Delta f}{f} > 0$ (b) $\frac{\Delta f}{f} < 0$
(c) $\frac{\Delta f}{f} = 0$ (d) Cannot find

89. If both the convex surfaces are replaced by concave surface of the same radius of curvature then
(a) the relation between $\frac{\Delta f}{f}$ and $\frac{\Delta n}{n}$ will be change
(b) the relation between $\frac{\Delta f}{f}$ and $\frac{\Delta n}{n}$ remains unchanged
(c) there is no relation between $\frac{\Delta f}{f}$ and $\frac{\Delta n}{n}$
(d) None of these

90. Which of the following is correct?
(a) $\left|\frac{\Delta f}{f}\right| = \left|\frac{\Delta n}{n}\right|$ (b) $\left|\frac{\Delta f}{f}\right| < \left|\frac{\Delta n}{n}\right|$
(c) $\left|\frac{\Delta f}{f}\right| > \left|\frac{\Delta n}{n}\right|$ (d) $\frac{\Delta f}{f} = \left|\frac{n}{\Delta n}\right|$

91. For $n = 1.5$, $\Delta n = 10^{-3}$ and $f = 20$ cm, the value of $|\Delta f|$ is
(a) 2 cm (b) 0.2 cm
(c) 0.02 cm (d) 0.002 cm

92. Which of the following is correct?
(a) $\frac{\Delta f}{f} = \frac{-\Delta n}{2(n-1)}$ (b) $\frac{\Delta f}{f} = \frac{\Delta n}{2(n-1)}$
(c) $\frac{\Delta f}{f} = \frac{2(n-1)}{\Delta n}$ (d) None of these

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*
(a) If both **Assertion** and **Reason** are **correct** and the Reason is the **correct explanation** of the Assertion.
(b) If both **Assertion** and **Reason** are correct but Reason is **not the correct explanation** of the Assertion.
(c) If the **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If the **Assertion** is **incorrect** but the **Reason** is **correct**.

93. **Assertion :** The air bubble shines in water.
Reason : Air bubble in water shines due to refraction of light.

94. **Assertion :** Diamond glitters brilliantly.
Reason : Diamond does not absorb sunlight.

95. **Assertion:** Critical angle is minimum for violet colour.
Reason : Because critical angle $\theta_c = \sin^{-1}\left(\frac{1}{\mu}\right)$ and $\mu \propto \frac{1}{\lambda}$.

96. **Assertion :** A ray passing through optical centre proceeds undeviated through the lens.
Reason : For lens Snell's law is not valid.

97. **Assertion :** If objective and eye lens of a microscope are interchanged then it can work as telescope.
Reason : The objective of telescope has large focal length.

98. **Assertion :** If the rays are diverging after emerging from a lens; the lens must be concave.
Reason : The convex lens can give diverging rays.

99. **Assertion :** When a convex lens ($\mu_g = 3/2$) of focal length f is dipped in water, its focal length becomes $\frac{4}{3}f$.
Reason : The focal length of convex lens in water becomes $3f$.

100. **Assertion :** Dispersion of light occurs because velocity of light in a material depends upon its colour.

Reason : The dispersive power depends only upon the material of the prism, not upon the refracting angle of the prism.

101. **Assertion :** There exists two angles of incidence for the same magnitude of deviation (except minimum deviation) by a prism kept in air.

Reason : In a prism kept in air, a ray is incident on first surface and emerges out of second surface. Now if another ray is incident on second surface (of prism) along the previous emergent ray, then this ray emerges out of first surface along the previous incident ray. This particle is called principle of reversibility of light.

102. **Assertion :** A ray passing through optical centre proceeds undeviated through the lens.

Reason : For lens Snell's law is not valid.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

103. Match the Column-I and Column-II

Column I	Column II
(A) Bi-convex lens	(1) $f = -\frac{R}{2(\mu-1)}$
(B) Plano-convex lens	(2) $f = \frac{R}{2(\mu-1)}$
(C) Bi-concave lens	(3) $f = -\frac{R}{(\mu-1)}$
(D) Plano-concave lens	(4) $f = \frac{R}{(\mu-1)}$

(a) (A) $\to$ (2); (B) $\to$ (3); (C) $\to$ (4); (D) $\to$ (5)
(b) (A) $\to$ (5); (B) $\to$ (4); (C) $\to$ (3); (D) $\to$ (1)
(c) (A) $\to$ (2); (B) $\to$ (4); (C) $\to$ (1); (D) $\to$ (3)
(d) (A) $\to$ (1); (B) $\to$ (5); (C) $\to$ (2); (D) $\to$ (4)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

104. A plano-convex lens is made of material of refractive index 1.6. The radius of curvature of the curved surface is 60 cm. The focal length of the lens is _________ cm.

105. A double convex lens of focal length 6 cm is made of glass of refractive index 1.5. The radius of curvature of one surface is double that of other surface. The value of small radius of curvature is _________ .

(a) 6 cm (b) 4.5 cm (c) 9 cm (d) 4 cm

106. A convex lens is immersed in a liquid of refractive index greater than that of glass. It will behave as a _________ lens.

107. A ray of light passes through an equilateral prism such that the angle of incidence is equal to the angle of emergence and the latter is equal to 3/4th of the angle of prism. Then_____ is angle of deviation.

108. The image formed by an objective of a compound microscope is ____________ and _____________.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

109. If a glass prism is dipped in water, its dispersive power increases.

110. To increase the angular magnification of a simple microscope, one should increase the power of the lens.

111. For a glass prism, the angle of minimum deviation will be smallest for the light of red colour.

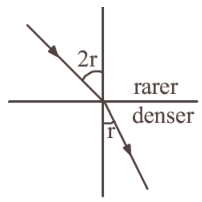
112. A short pulse of white light is incident from air to a glass slab at normal incidence. After travelling through the slab, the first colour to emerge is violet.

ANSWER KEY & SOLUTIONS

1. **(a)** $\mu = \dfrac{\sin i}{\sin r} \quad \because i = 2r$

$\Rightarrow \mu = \dfrac{\sin 2r}{\sin r} = \dfrac{2\sin r . \cos r}{\sin r}$

$r = \cos^{-1}\left(\dfrac{\mu}{2}\right) \quad \therefore \quad i = 2\cos^{-1}\left(\dfrac{\mu}{2}\right)$



2. **(a)** $\mu = \dfrac{h}{h'} \Rightarrow h' = \dfrac{8}{4/3} = 6m$

3. **(b)** According to Snell's law

$\dfrac{\sin i}{\sin r} = \dfrac{v_1}{v_2} = \dfrac{\mu_2}{\mu_1}$

From fig. we see that

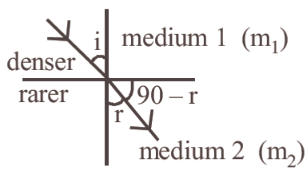
$r > i \Rightarrow v_2 > v_1$

from Snell's Law

So $v_2 = n\lambda_2 > v_1 = n\lambda_1$

$\Rightarrow \lambda_2 > \lambda_1$

(Frequency of wave does not change on refraction)



4. **(a)** When light travels from medium (1) to medium (2) then refractive index of medium (2) with respect to medium (1) is called it's relative refractive index,

$${}_1n_2 = \frac{n_2}{n_1} \text{ or } n_{12} = \frac{n_2}{n_1}$$

5. **(a)**

6. **(d)** $P_2 = P - P_1 = \dfrac{100}{80} - \dfrac{100}{20} = -3.75 \text{ D}$

7. **(a)** ${}_a n_\ell = 1.6, {}_a n_w = 1.33$

f = 20 cm

We have,

$\dfrac{1}{f} = ({}_a n_\ell - 1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$

$\dfrac{1}{20} = (1.6 - 1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right) \quad ..... (1)$

Also, $\dfrac{1}{f'} = ({}_w n_\ell - 1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$

$= \left(\dfrac{{}_a n_\ell}{{}_a n_w} - 1\right)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$

$\dfrac{1}{f'} = \left(\dfrac{1.6}{1.33} - 1\right)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right) \quad ..... (2)$

Dividing equation (1) by (2)

$\Rightarrow \dfrac{f'}{20} = \dfrac{0.6}{(1.2 - 1)} \quad f' = \dfrac{0.6 \times 20}{0.2} = 60 \text{ cm.}$

Hence it's focal length is three times longer than in air.

8. **(b)**

9. **(c)** For the prism as the angle of incidence (i) increases, the angle of deviation (δ) first decreases goes to minimum value and then increases.

10. **(a)** $\mu = \dfrac{\sin\left(\dfrac{A + \delta_m}{2}\right)}{\sin(A/2)} = \dfrac{\sin 45°}{\sin 26.5°} = 1.58$

11. **(c)** In the position of minimum deviation

$i = e = \dfrac{A + \delta m}{2} = \dfrac{60 + 30}{2} = 45°$

12. **(b)** In normal adjustment,

$M = \dfrac{f_0}{f_e} = 20, \; f_e = \dfrac{f_0}{20} = \dfrac{60}{20} = 3 \text{ cm}$

13. **(d)**

14. **(a)** **Given :** $f_0 = 1.2$ cm; $f_e = 3.0$ cm

$u_0 = 1.25$ cm; $M_\infty = ?$

From $\dfrac{1}{f_0} = \dfrac{1}{v_0} - \dfrac{1}{u_0} \Rightarrow \dfrac{1}{1.2} = \dfrac{1}{v_0} - \dfrac{1}{(-1.25)}$

$\Rightarrow \dfrac{1}{v_0} = \dfrac{1}{1.2} - \dfrac{1}{1.25} \Rightarrow v_0 = 30 \text{ cm}$

Magnification at infinity,

$M_\infty = -\dfrac{v_0}{u_0} \times \dfrac{D}{f_e} = \dfrac{30}{1.25} \times \dfrac{25}{3}$

($\because D = 25$cm least distance of distinct vision)

= 200

Hence the magnifying power of the compound microscope is 200

15. **(a)** **16.** **(a)**

17. **(a)** As we know that the deviation

$\delta = (\mu - 1)A \quad ..... (i)$

By geometry, the angle of refraction by first surface is 5° and given μ = 1.5

So, $\delta = (1.5 - 1) \times 5° = 2.5°$

also, $\delta = \theta - r, \quad ..... (ii)$

By putting the value of δ and r in equation (ii)

$2.5° = \theta - 5°$

So, $\theta = 5 + 2.5 = 7.5°$

18. **(c)** According to the question, when object is at different position, and if an object approaches towards a convergent lens from the left of the lens with a uniform speed of 5 m/s, the image move away from the lens to infinity with a non-uniform acceleration.

19. **(c)** Among all given sources of light, the bule light have smallest wavelength. According to Cauchy relationship, smaller the wavelength higher the refractive index and consequently smaller the critical angle as $\mu = \dfrac{1}{\sin c}$.

Hence, corresponding to blue colour, the critical angle is least which facilitates total internal reflection for the beam of blue light and the beam of green light would also undergo total internal reflection.

20. **(c)** Using lens maker's formula for plano-convex lens, so focal length is

$$\frac{1}{f} = (\mu_2 - \mu_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

If object on curved suface

so, $R_2 = \infty$ then, $f = \frac{R_1}{(\mu_2 - \mu_1)}$

Lens placed in air, $\mu_1 = 1$.

(As given that, R = 20cm, $\mu_2 = 1.5$, on substituting the values in)

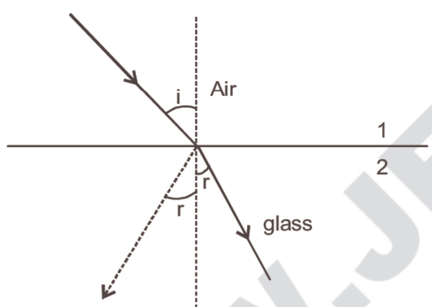
$$f = \frac{R_1}{\mu - 1} = \frac{20}{1.5 - 1} = 40 \text{ cm}$$

So, f is converging nature, as f > 0. Hence, lens will always act as a convex lens irrespective of the side on which the object lies.

21. **(b)** As we know, when the ray goes from rarer medium air to optically denser turpentine, then it bends towards the normal i.e., i > r whereas when it goes from optically denser medium turpentine to rarer medium water, then it bends away from normal i.e., i < r.

So, the path of ray 2 is correct.

22. **(a)** When the negative refractive index materials are those in which incident ray from air (Medium 1) to them refract or bend differently to that of positive refractive index medium.



23. **(a)** $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$$\frac{1}{16} = (1.5 - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right) \Rightarrow \frac{1}{16} = 0.5 \times \frac{1}{R} \Rightarrow R = 8 \text{ cm}$$

24. **(b)** Dispersive power $w = \frac{\delta_v - \delta_R}{\delta_y} = \frac{(n_v - n_R)A}{(n_y - 1)A}$

$$= \frac{n_v - n_R}{n_y - 1}$$

So, it depends only on the material of the prism

25. **(b)** **26.** **(a)**

27. **(a)** Angle of minimum deviation δ.

$\delta = (\mu - 1)A$

Now $\lambda_{red} > \lambda_{violet}$

$\therefore \mu_{red} < \mu_{violet}$

So δ_{red} is smallest.

28. **(d)** $i_B > i_A$ or $\sin^{-1}\left(\frac{1}{\mu_B}\right) > \sin^{-1}\left(\frac{1}{\mu_A}\right)$ or $\mu_A > \mu_B$

Hence medium A is denser and B is rarer.

Total internal Reflection : When the object is placed in a optically denser medium. and if the incident angle is greater than the critical angle then the ray of light gets reflected back to the originating medium.

For critical angle (α) from medium A to B, ${}_B\mu_A$

$${}_B\mu_A = \frac{1}{\sin\alpha} \text{ or } \sin\alpha = \frac{1}{{}_B\mu_A} = \frac{\mu_B}{\mu_A}$$

$$\Rightarrow \sin\alpha = \frac{1}{\sin i_B} \times \frac{\sin i_A}{1} \Rightarrow \alpha = \sin^{-1}\left[\frac{\sin i_A}{\sin i_B}\right]$$

29. **(d)**

30. **(d)** $\sin C = \frac{1}{\mu} = \frac{1}{\sqrt{2}}$

$$\therefore C = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45^\circ$$

Now $\frac{\sin C}{\sin r} = \frac{1}{\mu}$ or $\frac{\sin 45^\circ}{\sin r} = \frac{1}{\sqrt{2}}$

$\sin r = 1$ or $r = 90^\circ$

31. **(a)** In terms of wavelength, $\mu \propto \frac{1}{\lambda}$.

So shorter the wavelength, greater is the refractive index. λ is minimum for violet so μ is maximum.

32. **(c)** ${}_2\mu_1 \times {}_3\mu_2 \times {}_4\mu_3 = \frac{\mu_1}{\mu_2} \times \frac{\mu_2}{\mu_3} \times \frac{\mu_3}{\mu_4} = \frac{\mu_1}{\mu_4} = \frac{1}{{}_1\mu_4}$.

33. **(a)** Velocity in medium, $= \frac{c}{\sqrt{\mu_r \in_r}} \simeq \frac{3 \times 10^8}{\sqrt{\in_r}}$

($\because \mu_r < 1$ for mica)

$$= \frac{3 \times 10^8}{\sqrt{6}} \simeq 1.2 \times 10^7 \text{ m/s}.$$

34. **(d)** Let d be the depth of two liquids.

Then apparant depth

$$\frac{(d/2)}{\mu} + \frac{(d/2)}{1.5\mu} = \frac{d}{2} \text{ or } \frac{1}{\mu} + \frac{2}{3\mu} = 1$$

Solving we get $\mu = 1.671$

35. **(c)** Here i = 60°. As the angle between reflected and refracted ray is 90°, then i + r = 90 or r = 30°

$$\text{Now } \mu = \frac{\sin i}{\sin r} = \frac{\sin 60}{\sin 30} = \frac{\sqrt{3}/2}{1/2} = \sqrt{3} = 1.732$$

The angle for which $i + r = 90^\circ$, called Brewster' Angle.

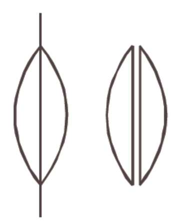
36. **(b)** When we bring in contact a concave lens the effective focal length of the combination decreases.

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} = \frac{1}{u} + \frac{1}{f}$$

according to above relation as f reduces, v increases.

37. **(a)** **38.** **(d)**

39. **(d)** $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$



This is combination of two lenses of equal focal lengths

$$\therefore \frac{1}{f} = \frac{1}{f'} + \frac{1}{f'} = \frac{2}{f'} \Rightarrow f' = 2f.$$

40. **(b)** Due to difference in refractive indices images obtained will be two. Two media will form images at two different points due to difference in focal lengths.

41. **(b)** $m = \frac{v}{u}$ and $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Multiply the equation by v

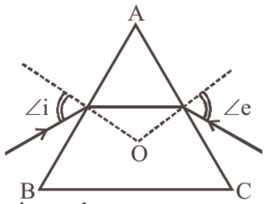
$1 - \frac{v}{u} = \frac{v}{f} \Rightarrow \frac{v}{u} = 1 - \frac{v}{f} \Rightarrow \therefore m = 1 - \frac{v}{f}$

Slope $= -\frac{1}{f} = \frac{b}{c} \Rightarrow f = \frac{c}{b}$

42. **(d)** $\frac{f_a}{f_\omega} = \frac{\left(\frac{\mu_g}{\mu_\omega} - 1\right)}{(\mu_g - 1)} = \frac{\left(\frac{1.5}{\left(\frac{4}{3}\right)} - 1\right)}{1.5 - 1} = \frac{\frac{1}{8}}{\frac{1}{2}} = \frac{1}{4}$

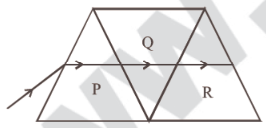
$f_\omega = 4f_a = 4 \times 8 = 32$ cm

43. **(c)** At the minimum deviation, f = D_m angle of incidence $\angle i$ = angle of emergence $\angle e$ and inside the prism refracted ray parallel to the base of the prism



44. **(d)** We can combine two prisms in such a way
(i) deviation is zero but dispersion not
(ii) dispersion is zero but deviation is not.
But in any situation both deviation & dispersion can not be zero simultaneously.

45. **(c)** When the ray suffers minimum deviation, it becomes parallel to the base of prism P. As prisms Q and R are of same material and have identical shape, therefore, the ray continues to be parallel to base of Q and R. Hence final deviation of the ray remains the same as before.



46. **(b)** Air medium is non-dispersive in nature.

47. **(d)**

48. **(c)** To minimise spherical aberration in a lens, the total deviation should be equally distributed over the two surfaces.

49. **(b)** We have,

$$_\ell\mu_g = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}} = \frac{\sin\left(\frac{60° + 30°}{2}\right)}{\sin\left(\frac{60°}{2}\right)}$$

$$= \frac{\sin 45°}{\sin 30°} = \frac{1}{\sqrt{2}} \times 2 = \sqrt{2}$$

Now, $\sin C = \frac{1}{_\ell\mu_g} = \frac{1}{\sqrt{2}} \therefore C = 45°.$

50. **(d)** Amount of scattering of light $I_s \propto \frac{1}{\lambda^4}$

As given $\lambda_1 = 440$ nm, $I_s = A$

For $\lambda_2 = 660$ nm, let $I_s = A'$

then $\frac{A'}{A} = \left(\frac{440}{660}\right)^4 A' = \left(\frac{2}{3}\right)^4 A \simeq \frac{A}{5}.$

51. **(b)** The incident angle is 45°.
Incident angle > critical angle, $i > i_c$

$\therefore \sin i > \sin i_c$ *or* $\sin 45 > \sin i_c$

$\sin i_c = \frac{1}{n}$

$\therefore \sin 45° > \frac{1}{n}$ *or* $\frac{1}{\sqrt{2}} > \frac{1}{n} \Rightarrow n > \sqrt{2}$

52. **(d)** Here, $i_1 = 15°, A = 60°, \delta = 55°, i_2 = e = ?$
As $i_1 + i_2 = A + \delta$
$i_2 = A + \delta - i_1 = 60° + 55° - 15° = 100°.$

53. **(d)** Because, the focal length of eye lens cannot decrease beyond a certain limit.

54. **(b)** $f_0 = 100$ cm, $f_e = 5$ cm
When final image is formed at least distance of distinct vision (d), then

$M = \frac{f_0}{f_e}\left(1 + \frac{f_e}{d}\right) = \frac{100}{5}\left(1 + \frac{5}{25}\right) \quad [\because D = 25\text{ cm}]$

$M = 20 \times \frac{6}{5} = 24$

55. **(a)** (i) $M = -\frac{f_0}{f_e}\left(1 + \frac{f_e}{d}\right) = -\frac{200}{5}\left(1 + \frac{5}{25}\right) = -48$

(since least distance d = 25cm)

(ii) $M = -\frac{f_0}{f_e} = -\frac{200}{5} = -40$

56. **(b)** u = –50 cm = –0.5 m, v = –30 cm = –0.3 m

$P = \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{-1}{0.3} + \frac{1}{0.5} = \frac{-0.2}{0.15} = -1.33$ D.

57. **(a)** $m = \frac{v_0}{|u_0|}\left(1 + \frac{d}{f_e}\right) = \frac{20}{5}\left(1 + \frac{20}{10}\right) = 12$

58. **(b)** Magnifying power of telescope is

$M = \frac{f_0}{f_e} = \frac{225}{5} \Rightarrow M = 45$ cm.

59. **(a)** Magnification $= \frac{f_0}{f_e} = \Rightarrow \frac{30\text{ cm}}{3\text{cm}} = \frac{\beta}{0.5°} \Rightarrow \beta = 5°$

60. **(a)** Lens is concave. So defect is myopia.
So | focal length of lens | = far point

$f = \frac{-R}{2(\mu - 1)} \Rightarrow |f| = \frac{R}{2(\mu - 1)} \Rightarrow |f| = 500$ cm = 5m.

61. **(c)** Let magnifying power of eye and objective is m_e and m_0. therefore, $m = m_0 \times m_e \Rightarrow 32 = 8 \times m_e$
$\Rightarrow m_e = 4$

62. **(c)** The magnifying power of telescope in normal adjustment is given by, $M = \frac{f_0}{f_e}$

$\Rightarrow 10 = \frac{f_0}{20} \Rightarrow f_0 = 200$ cm.

63. **(c)** When a ray of light travels in glass, the velocity of light as well as wavelength decreases while frequency remains constant, according to Snell's law

$$\mu = \frac{\text{wavelength in air}}{\text{wavelength in glass}}$$

$[\because\ v = n\lambda,\ v\downarrow \lambda\downarrow \text{ as } n = \text{constant}]$

64. **(a)** $\left.\begin{matrix}\mu_g = \dfrac{c}{v_g} \Rightarrow \dfrac{3}{2} = \dfrac{c}{v_g} \\ \mu_\omega = \dfrac{c}{v_\omega} \Rightarrow \dfrac{4}{3} = \dfrac{c}{v_\omega}\end{matrix}\right\}$

Dividing, $\dfrac{v_\omega}{v_g} = 9:8$

or $v_g : v_\omega = 8:9$

65. **(b)** Its critical angle with reference to air is too small.

66. **(a)** 2.42

67. **(c)** high refractive index

68. **(d)** increase

69. **(a)** less than first

70. **(c)** $\dfrac{\mu_2}{v} - \dfrac{\mu_1}{u} = \dfrac{\mu_2 - \mu_1}{R}$

Taking refraction first at curved surface,

$$\frac{2}{v_1} + \frac{1}{x} = \frac{1}{R} \Rightarrow v_1 = \frac{2Rx}{x-R}$$

For plane surface,

$$v' = v_1 - R \Rightarrow v' = \frac{xR + R^2}{x - R}$$

$$\Rightarrow \frac{1}{v} - \frac{2(x-R)}{R(x+R)} = 0$$

$$\frac{1}{v} = \frac{2(x-R)}{R(x+R)}$$

For virtual image,

$$\frac{1}{v} < 0 \Rightarrow \frac{2(x-R)}{R(x+R)} < 0$$

$x < R$

71. **(d)** For $x = 2R$

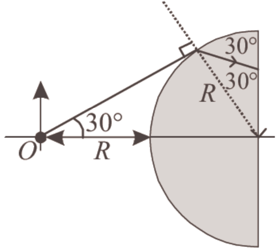
$$v_1 = \frac{4R^2}{R} = 4R \Rightarrow u = -2R$$

$$m_1 = \frac{\mu_1}{\mu_2}, \frac{v}{u} = \frac{1}{2}, \frac{4R}{(-2R)} = -1$$

$m_2 = 1 \Rightarrow m_1 m_2 = -1$

Image is real, inverted, and of same size.

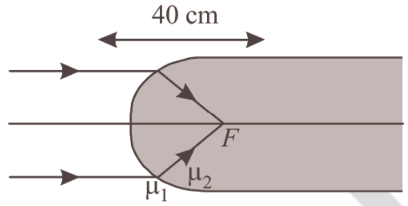
72. **(a)**



73. **(a)** For spherical surface

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

74. **(b)**



$$\frac{\mu_1}{v} - \frac{\mu_2}{u} = \frac{\mu_2 - \mu_1}{R}$$

With proper values and signs, we have

$$\frac{4/3}{f} - \frac{1.0}{\infty} = \frac{4/2 - 1.0}{+10}$$

or $f = 40\,\text{cm} = 0.4\,\text{m}$

Since the rays are converging, its power should be positive Hence,

$$P(\text{in dioptre}) = \frac{+1}{f(\text{meter})} = \frac{1}{0.4}$$

or $P = 2.5$ D

75. **(a)** The angular dispersion θ *i.e.*, the angle between the extreme rays of light, $\theta = (\delta_V - \delta_R)$ where $\delta_V = (\mu_V - 1)A$, $\delta_R = (\mu_V - 1)A$ & A is angle of prism.

So if refractive index increases, then δ increases & hence θ increases.

76. **(a)**

77. **(a)** In the position of minimum deviation, $i_1 = i_2$.

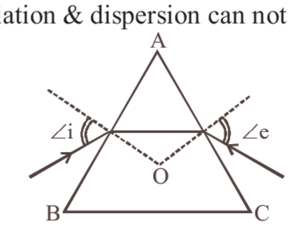
78. **(d)** We can combine two prisms in such a way

(i) deviation is zero but dispersion not

(ii) dispersion is zero but deviation is not.

But in any situation both deviation & dispersion can not be zero simultaneously.

79. **(c)** At the minimum deviation, f = D_m angle of incidence ∠i = angle of emergence ∠e and inside the prism refracted ray parallel to the base of the prism



80. **(d)**

81. **(c)** Magnifying power of telescope,

$$MP = \frac{\beta \text{ (angle subtended by image at eye piece)}}{\alpha \text{ (angle subtended by object on objective)}}$$

Also, $MP = \dfrac{f_o}{f_e} = \dfrac{150}{5} = 30$

$$\alpha = \frac{50}{1000} = \frac{1}{20}\text{rad}$$

$$\therefore\ \beta = \theta = MP \times \alpha = 30 \times \frac{1}{20} = \frac{3}{2} = 1.5\,\text{rad}$$

82. **(a)** (i) $M = -\dfrac{f_0}{f_e}\left(1 + \dfrac{f_e}{d}\right) = -\dfrac{200}{5}\left(1 + \dfrac{5}{25}\right) = -48$

(since least distance d = 25cm)

(ii) $M = -\dfrac{f_0}{f_e} = -\dfrac{200}{5} = -40$

83. (a) $\frac{f_0}{f_e} = 9$, $\quad \therefore f_0 = 9f_e$

Also $f_0 + f_e = 20$ ($\because$ final image is at infinity)
$9f_e + f_e = 20$, $f_e = 2$ cm, $\quad \therefore f_0 = 18$ cm

84. (d) Given, Focal length of objective, $f_0 = 30$ cm
focal length of eye lens, $f_e = 3.0$ cm
Magnifying power, M = ?
Magnifying power of the Galilean telescope,

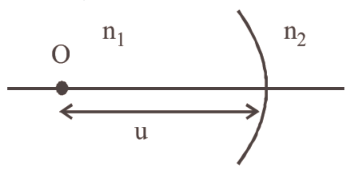
$$M_D = \frac{f_0}{f_e}\left(1 - \frac{f_e}{D}\right) = \frac{30}{3}\left(1 - \frac{3}{25}\right) \quad [\because D = 25 \text{ cm}]$$

$$= 10 \times \frac{22}{25} = 8.8$$

85. (b) **86. (d)**

87. (d) $\frac{\mu_2}{v} = \frac{\mu_1}{u} + \left(\frac{\mu_2 - \mu_1}{R}\right)$

$(\mu_2 - \mu_1)$ is +ve and R is –ve, if u is –ve, v will always be –ve.
i.e., for real object image is always virtual.
Consider object on left side of spherical surface seperating two media. If real object is in rarer media i.e., $n_1 < n_2$



Then, $\frac{n_2}{v} = \frac{n_2 - n_1}{(-u)} + \frac{n_1}{(-R)} = -ve$

Hence image shall be virtual for a real object lying on concave side with rarer media. .... (1)
If real object is in denser media i.e., $n_1 > n_2$

$$\frac{n_2}{v} = \frac{-(n_1 - n_2)}{(-u)} + \frac{n_1}{(-R)} = \frac{n_1 - n_2}{u} - \frac{n_1}{R}$$

$\therefore$ Image is real if $\frac{n_1 - n_2}{u} > \frac{n_1}{R}$

or $\quad u < \frac{(n_1 - n_2)R}{n_1}$ .... (2)

and image is virtual if $u > \left(\frac{n_1 - n_2}{n_1}\right)R$ .... (3)

From statements 1, 2 and 3 we can easily conclude the answers.

88. (a) From (i), if $\frac{\Delta n}{n} < 0$, then $\frac{\Delta f}{f} > 0$.

89. (b) The relation between $\frac{\Delta f}{f}$ and $\frac{\Delta n}{n}$ remains unchanged, if convex surface are replaced by concave surface of the same radius of curvature.

90. (c) Also, $\left|\frac{\Delta f}{f}\right| > \left|\frac{\Delta n}{n}\right|$

91. (c) For $n = 1.5$, $\Delta n = 10^{-3}$ and $f = 20$ cm then

$$\frac{\Delta f}{20} = -\frac{10^{-3}}{2(1.5 - 1)} \Rightarrow \Delta f = -0.02 \text{ cm}$$
or $\quad |\Delta f| = 0.02$ cm

92. (a)

93. (c) Shining of air bubble in water is on account of TIR.

94. (b) Diamond glitters brilliantly because light enters in diamond suffers total internal reflection. All the light entering in it comes out of diamond after number of reflections and no light is absorbed by it.

95. (b)

96. (c) Snell's law is valid for lens too.

97. (d)

98. (b) When object is placed between F and optical center of convex lens then the emerging rays is diverging.

99. (d) $f_w = f\frac{{}_a\mu_g - 1}{\left(\frac{{}_a\mu_g}{{}_a\mu_w} - 1\right)} = f\frac{\left(\frac{3}{2} - 1\right)}{\left(\frac{3/2}{4/3} - 1\right)} = 4f$

100. (d) **101. (b)** **102. (c)**

103. (c) (A) → (2); (B) → (4); (C) → (1); (D) → (3)
for bi-convex lens, $R_1 = R$ and $R_2 = -R$
for plano-convex lens, $R_1 = \infty$ and $R_2 = -R$
for bi-concave lens, $R_1 = -R$ and $R_2 = +R$
for plano-concave, $R_1 = \infty$ and $R_2 = R$

104. (100) $R_1 = 60$ cm, $R_2 = \infty$, $\mu = 1.6$

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = (1.6 - 1)\left(\frac{1}{60}\right) \Rightarrow f = 100 \text{ cm}$$

105. (4.5 cm) If $R_1 = R$, $R_2 = -2R$, $f = 6$ cm

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{6} = (1.5 - 1)\left(\frac{1}{R} + \frac{1}{2R}\right) = \frac{0.5 \times 3}{2R}$$

R = 4.5 cm

106. (divergent) $\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

As $\frac{\mu_2}{\mu_1} < 1$

$\therefore$ f is negative. It acts as divergent lens.

107. (30°) $i_1 = i_2 = \frac{3}{4}A$ [A = angle of Prism]

As $A + \delta = i_1 + i_2$

$$\therefore \delta = i_1 + i_2 - A = \frac{3}{4}A + \frac{3}{4}A - A = \frac{A}{2} = \frac{60^\circ}{2} = 30^\circ$$

108. (real, enlarged) The image formed by objective lens of compound microscope is real and enlarged, while final image formed by compound microscope is inverted, virtual, enlarged and at a distance D to infinite or from an eye, on same side of eye piece.

109. (False) Dispersive power of a prism $\omega = \dfrac{\mu_V - \mu_R}{\mu_y - 1} = \dfrac{d\mu}{\mu - 1}$,

where $\mu = \mu_y = \dfrac{\mu_V + \mu_R}{2}$

110. (True) One should increase the power of lens i.e., decrease the focal length of a lens.

111. (True) Angle of minimum deviation δ.

$\delta = (\mu - 1)A$

Now $\lambda_{red} > \lambda_{violet}$

$\therefore \quad \mu_{red} < \mu_{violet}$

So δ_{red} is smallest.

112. (False) As we know that when light ray goes from one medium to other medium, the frequency of light remains unchanged.

And, $c = \nu\lambda$

So, $c \propto \lambda$ the light of red colour is of highest wavelength and therefore of highest speed. Thus, after travelling through the slab, the red colour emerge first.

10 Wave Optics

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. Wavefront is the locus of all points, where the particles of the medium vibrate with the same ________ .
(a) phase (b) amplitude
(c) frequency (d) period

2. Shape of wavefront in case of
I. light diverging from a point source is spherical.
II. light emerging out of a convex lens when a point source is placed at its focus is plane.
III. the portion of the wavefront of light from a distant star intercepted by the Earth is plane.
Which of the above statements are true/false?
(a) T, T, F (b) F, T, T
(c) T, F, T (d) T, T, T

3. Huygens concept of secondary wave
(a) allows us to find the focal length of a thick lens
(b) is a geometrical method to find a wavefront
(c) is used to determine the velocity of light
(d) is used to explain polarisation

4. Who gave the idea of secondary wavelets for the propagation of a wave.
(a) Newton (b) Huygen
(c) Maxwell (d) Fresnel

5. Huygens wave theory allows us to know
(a) The wavelength of the wave
(b) The velocity of the wave
(c) The amplitude of the wave
(d) The propagation of wavefronts

6. The fringe width in a Young's double slit experiment can be increased if we decrease
(a) width of slits
(b) separation of slits
(c) wavelength of light used
(d) distance between slits and screen

7. Two coherent monochromatic light beams of intensities I and 4I are superposed. The maximum and minimum possible intensities in the resulting beam are
(a) 5I and I (b) 5 I and 3I
(c) 9 I and I (d) 9 I and 3I

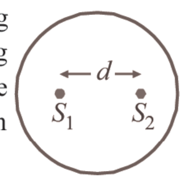
8. Distance between screen and source is decreased by 25%. Then the percentage change in fringe width is.
(a) 20% (b) 31% (c) 75% (d) 25%

9. In Young's double slit experiment, angular width of fringes is 0.20° for sodium light of wavelength 5890 Å. If complete system is dipped in water, then angular width of fringes becomes.
(a) 0.11° (b) 0.15° (c) 0.22° (d) 0.30°

10. The path difference between two interfering waves at a point on screen is 171.5 times the wavelength. If the path difference is 0.01029 cm. Find the wavelength.
(a) 6000×10^{-10} cm (b) 6000 Å
(c) 6000×10^{-8} mm (d) None of these

11. The colour of bright fringe nearest to central achromatic fringe in the interference pattern with white light will be
(a) violet (b) red (c) green (d) yellow

12. Two coherent sources separated by distance d are radiating in phase having wavelength λ. A detector moves in a big circle around the two sources in the plane of the two sources. The angular position of $n = 4$ interference maxima is given as



(a) $\sin^{-1}\frac{n\lambda}{d}$ (b) $\cos^{-1}\frac{4\lambda}{d}$
(c) $\tan^{-1}\frac{d}{4\lambda}$ (d) $\cos^{-1}\frac{\lambda}{4d}$

13. True/false statements are
Diffraction is a characteristic which is exhibited by
I. Matter waves II. Water waves
III. Sound waves IV. Light waves
(a) T, T, F, F (b) T, T, T, F
(c) F, F, T, T (d) T, T, T, T

14. If the width of the slit in single slit diffraction experiment is doubled, then the central maximum of diffraction pattern becomes
(a) broader and brighter
(b) sharper and brighter
(c) sharper and fainter
(d) broader adn fainter.

15. The condition for observing Fraunhoffer diffraction from a single slit is that the light wavefront incident on the slit should be
(a) spherical (b) cylindrical
(c) plane (d) elliptical

16. The phenomenon of diffraction can be treated as interference phenomenon if the number of coherent sources is
(a) one (b) two
(c) zero (d) infinity

17. Consider sunlight incident on a slit of width 10^4 Å. 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

18. 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 bv the top surface of the glass and the bottom surface is

(a) $\frac{2\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+\pi$

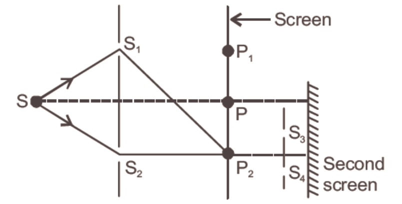
(b) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}$

(c) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+\frac{\pi}{2}$

(d) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+2\pi$

19. 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

20. Figure shows a standard two slit arrangement witn slits S_1, S_2, P_1, P_2 are the two minima points on either side of P (figure).



At P_2 on the screen, there is a hole and behind P_2 is a second 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

21. The phenomena which is not explained by Huygen's construction of wavefront is
(a) reflection (b) diffraction
(c) refraction (d) origin of spectra

22. In Young's double slit experiment, one slit is covered with red filter and another slit is covered by green filter, then interference pattern will be
(a) red (b) green
(c) yellow (d) invisible

23. Larger aperture of objective lens in an astronomical telescope
(a) increases the resolving power of telescope.
(b) decreases the brightness of the image.
(c) increases the size of the image.
(d) decreases the length of the telescope.

24. The condition for obtaining secondary maxima in the diffraction pattern due to single slit is
(a) $a\sin\theta = n\lambda$ (b) $a\sin\theta = (2n-1)\frac{\lambda}{2}$
(c) $a\sin\theta = (2n-1)\lambda$ (d) $a\sin\theta = \frac{n\lambda}{2}$

25. According to Huygens, medium through which light waves travel is
(a) vacuum only (b) luminiferous ether
(c) liquid only (d) solid only

26. Wave normal is a direction which is
(a) normal at every point on the wavefront.
(b) tangential to every point on the wavefront.
(c) directed at every point of the wavefront.
(d) independent of wavefront.

27. According to Huygen's construction which of the following wavefront does not exists?
(a) forward wavefront (b) backward wavefront
(c) cylindrical wavefront (d) can not be predicted

28. Light waves travel in vacuum along the y-axis. Which of the following may represent the wave-front?
(a) x = constant (b) y = constant
(c) z = constant (d) x + y + z = constant

29. According to Huygen's construction, tangential envelope which touches all the secondary spheres is the position of
(a) original wavefront (b) secondary wavefront
(c) geometrical wavefront (d) extended wavefront

30. The phase difference between incident wave and reflected wave is 180° when light ray
(a) enters into glass from air
(b) enters into air from glass
(c) enters into glass from diamond
(d) enters into water from glass

31. In interference pattern, the energy is:
(a) created at the maximum
(b) destroyed at the minimum
(c) conserved but redisturbed
(d) None of the above

32. Interference was observed in interference chamber where air was present, now the chamber is evacuated, and if the same light is used, a careful observer will see
(a) no interference
(b) interference with brighter bands
(c) interference with dark bands
(d) interference fringe with larger width

33. In which of the following is the interference due to the division of wave front ?
(a) Young's double slit experiment
(b) Fresnel's biprism experiment
(c) Lloyd's mirror experiment
(d) Demonstration colours of thin film

34. Two identical light sources S_1 and S_2 emit light of same wavelength λ. These light rays will exhibit interference if
(a) their phase difference remain constant
(b) their phases are distributed randomly
(c) their light intensities remain constant
(d) their light intensities change randomly

35. Which one of the following statements is correct ?
(a) Monochromatic light is never coherent.
(b) Monochromatic light is always coherent.
(c) Two independent monochromatic sources are coherent.
(d) Coherent light is always monochromatic.

36. Coherence is a measure of
(a) capability of producing interference by wave
(b) waves being diffracted
(c) waves being reflected
(d) waves being refracted

37. Which of the following, cannot produce two coherent sources?
(a) Lloyd's mirror (b) Fresnel biprism
(c) Young's double slit (d) Prism

38. If in an interference pattern, I_{max} represents the intensity maximum value and I_{min} represents the intensity minimum value, then the fringe visibility is defined as:
(a) $V = \frac{I_{max}}{I_{min}}$ (b) $V = \frac{I_{max} + I_{min}}{I_{max} - I_{min}}$
(c) $V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$ (d) $V = \frac{\sqrt{I_{max}} - \sqrt{I_{min}}}{\sqrt{I_{max}} + \sqrt{I_{min}}}$

39. The contrast in the fringes in an interference pattern depends on
(a) fringe width
(b) wavelength
(c) intensity ratio of the sources
(d) distance between the slits

40. Ratio of intensities of two waves are given by 4 : 1. Then the ratio of the amplitudes of the two waves is
(a) 2 : 1 (b) 1 : 2 (c) 4 : 1 (d) 1 : 4

41. The ratio of intensities of two waves is 9 : 1. They are producing interference. The ratio of maximum and minimum intensities will be
(a) 10 : 8 (b) 9 : 1 (c) 4 : 1 (d) 2 : 1

42. A beam of electron is used in an YDSE experiment. The slit width is d. If the velocity of electron is increased, then
(a) no interference is observed
(b) fringe width increases
(c) fringe width decreases
(d) fringe width remains same

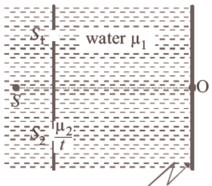
43. The maximum number of possible interference maxima for slit- separation equal to twice the wavelength in Young′s double-slit experiment is
(a) infinite (b) five (c) three (d) zero

44. If yellow light emitted by sodium lamp in Young's double slit experiment is replaced by a monochromatic blue light of the same intensity
(a) fringe width will decrease
(b) finge width will increase
(c) fringe width will remain unchanged
(d) fringes will become less intense

45. The Young's double slit experiment is performed with blue and with green light of wavelengths 4360Å and 5460Å respectively. If x is the distance of 4th maxima from the central one, then
(a) x (blue) = x (green) (b) x (blue) > x (green)
(c) x (blue) < x (green) (d) $\frac{x(\text{blue})}{x(\text{green})} = \frac{5460}{4360}$

46. In double slit experiment, the angular width of the fringes is 0.20° for the sodium light $(\lambda = 5890\text{Å})$. In order to increase the angular width of the fringes by 10%, the necessary change in wavelength is
(a) zero (b) increased by 6479 Å
(c) decreased by 589 Å (d) increased by 589 Å

47. A YDSE is conducted in water (μ_1) as shown in figure. A glass plate of thickness t and refractive index μ_2 is placed in the path of S_2. The optical path difference at O is



(a) $(\mu_2 - 1)t$
(b) $(\mu_1 - 1)t$
(c) $\left(\frac{\mu_2}{\mu_1} - 1\right)t$
(d) $(\mu_2 - \mu_1)t$

48. In a Young's double-slit experiment the fringe width is 0.2 mm. If the wavelength of light used is increased by 10% and the separation between the slits is also increased by 10%, then the fringe width will be

(a) 0.20 mm (b) 0.401 mm
(c) 0.242 mm (d) 0.165 mm

49. In a Young's double slit experiment, the intensity at a point where the path difference $\frac{\lambda}{6}$ (λ is wavelength of the light) is I. If I_0 denotes the maximum intensity, then $\frac{I}{I_0}$ is

(a) $\frac{1}{2}$ (b) $\frac{\sqrt{3}}{2}$ (c) $\frac{1}{\sqrt{2}}$ (d) $\frac{3}{4}$

50. In an experiment the two slits are 0.5 mm apart and the fringes are observed to 100 cm from the plane of the slits. The distance of the 11th bright fringe from the Ist bright fringe is 9.72 mm. Calculate the wavelength used.

(a) 4.85×10^{-5} cm (b) 4.85×10^{-5} m
(c) 4.86×10^{-7} m (d) 4.86×10^{-5} cm

51. S is the size of the slit, d is the separation between the slits and D is the distance where Young's double slit interference pattern is being observed. If λ be the wavelength of light, then for sharp fringes, the essential condition is:

(a) $\frac{S}{D} < \frac{\lambda}{d}$ (b) $\frac{S}{D} > \frac{\lambda}{d}$ (c) $S\lambda < dD$ (d) $SD > \lambda d$

52. The first maxima is closest of _______ colour

(a) violet (b) red
(c) blue (d) green

53. In a two-slit experiment, with monochromatic light, fringes are obtained on a screen placed at some distance from the slits. If the screen is moved by 5×10^{-2} m towards the slits, the change in fringe width is 10^{-3} m. Then the wavelength of light used is (given that distance between the slits is 0.03 mm)

(a) 4500 Å (b) 5000 Å (c) 5500 Å (d) 6000 Å.

54. In a double slit experiment, the screen is placed at a distance of 1.25 m from the slits. When the apparatus is immersed in water ($\mu_w = 4/3$), the angular width of a fringe is found to be 0.2°. When the experiment is performed in air with same set up, the angular width of the fringe is

(a) 0.4° (b) 0.27° (c) 0.35° (d) 0.15°

55. At two points P and Q on screen in Young's double slit experiment, waves from slits S_1 and S_2 have a path difference of 0 and $\frac{\lambda}{4}$, respectively. The ratio of intensities at P and Q will be :

(a) 2 : 1 (b) $\sqrt{2}$: 1 (c) 4 : 1 (d) 3 : 2

56. In Young's expt., the distance between two slits is $\frac{d}{3}$ and the distance between the screen and the slits is 3 D. The number of fringes in $\frac{1}{3}$m on the screen, formed by monochromatic light of wavelength 3λ, will be

(a) $\frac{d}{9D\lambda}$ (b) $\frac{d}{27D\lambda}$ (c) $\frac{d}{81D\lambda}$ (d) $\frac{d}{D\lambda}$

57. The diffraction effects in a microscopic specimen become important when the separation between two points is

(a) much greater than the wavelength of light used
(b) much less than the wavelength of light used
(c) comparable to the wavelength of light used
(d) independent of the wavelength of light used

58. Conditions of diffraction is

(a) $\frac{a}{\lambda} = 1$ (b) $\frac{a}{\lambda} >> 1$
(c) $\frac{a}{\lambda} << 1$ (d) None of these

59. A diffraction pattern is being formed at the screen. Firstly yellow light was used for it. If yellow light is replaced by the X-rays, then the central maxima

(a) becomes wider (b) becomes narrower
(c) no change (d) None of these

60. Angular width (β) of central maxima of a diffraction pattern of a single slit does not depend upon

(a) distance between slit and source
(b) wavelength of the light used
(c) width of slit
(d) frequency of light used

61. If we observe the single slit Fraunhofer diffraction with wavelength λ and slit width b, the width of the central maxima is 2θ. On decreasing the slit width for the same λ

(a) θ increases
(b) θ remains unchanged
(c) θ decreases
(d) θ increases or decreases depending on the intensity of light

62. In a single slit diffraction experiment, the width of the slit is made double its original width. Then the central maxima of the diffraction pattern will become

(a) narrower and fainter (b) narrower and brighter
(c) broader and fainter (d) broader and brighter

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

Huygen proposed the wave theory of light. According to his theory

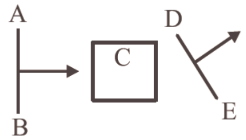
(i) Each point of the wavefront is the source of a secondary disturbance and secondary wavelets emanating from these points spread out in all directions with the speed of the wave.

(ii) The new position of the wavefront at a later time is a common tangent drawn to all these spheres.

63. A plane wave passes through a convex lens. The geometrical shape of the wavefront that emerges is

(a) plane (b) diverging spherical
(c) converging spherical (d) None of these

64. A wavefront AB passing through a system C emerges as DE. The system C could be



(a) a slit
(b) a biprism
(c) a prism
(d) a glass slab

65. Newton's corpuscular theory could not explain the phenomenon for
(a) reflection (b) refraction
(c) diffraction (d) rectilinear propagation

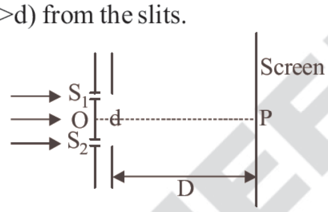
66. Wave normal is a direction which is
(a) normal at every point on the wavefront.
(b) tangential to every point on the wavefront.
(c) directed at every point of the wavefront.
(d) independent of wavefront.

67. The shape of wavefront produced by linear light source is:
(a) parabolic (b) cylinderical
(c) elliptical (d) spherical

Case/Passage-II

A student is performing Young's double slit experiment. There are two slits S_1 and S_2. Separation between them is d. There is large screen at a distance D(D >>d) from the slits.

The set-up is shown in the following figure. A parallel beam of light is incident upon it. A monochromatic light of wavelength λ is used.



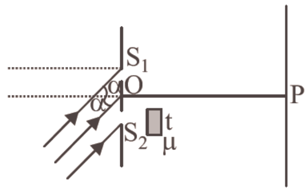
The initial phase difference between the two slits which behaves as two coherent sources of light is zero.

The intensity of light waves on the screen coming out of S_1 and S_2 are same and is I_0. In this situation, the principal maximum is formed at the point P. At the point on screen where principal maximum is formed, phase difference between two interfering waves will be zero.

68. Initially the distance of third minima from principal maxima will be
(a) $\frac{3}{2}\frac{\lambda D}{d}$ (b) $\frac{3\lambda D}{d}$ (c) $\frac{5}{4}\frac{\lambda D}{d}$ (d) $\frac{5}{2}\frac{\lambda D}{d}$

69. A glass slab of thickness t and refractive index μ is introduced before S_2, now P does not remain the point of principal maximum. Suppose principal maximum forms at a point P' on screen. Then PP' is equal to
(a) $\frac{tD(\mu-1)}{d}$ (b) $\frac{tD(\mu-1)}{2d}$
(c) $\frac{D(\mu-1)}{t}$ (d) $\frac{D(\mu-1)}{d}$

70. Use the statement given in previous question. Now parallel beam is incident at an angle α w.r.t. line OP, such that principal maximum again comes at point P. The figure is shown. The value of α is



(a) $\sin^{-1}\frac{t(\mu-1)}{d}$
(b) $\cos^{-1}\frac{t(\mu-1)}{d}$
(c) $\sin^{-1}\frac{t(\mu-1)D}{d}$
(d) $\sin^{-1}\frac{tD}{d}$

71. A slit of width a is illuminated by white light. The first minimum for red light ($\lambda = 6500$ Å) will fall at $\theta = 30^\circ$ when a will be
(a) 3250 Å (b) 6.5×10^{-4} cm
(c) 1.3 micron (d) 2.6×10^{-4} cm

72. In Young's double slit experiment, the source S and two slits A and B are lying in a horizontal plane. The slit A is above slit B. the fringes are obtained on a vertical screen K. The optical path from S to B is increased by putting a transparent material of higher refractive index. The path from S to A remains unchanged. As a result of this the fringe pattern moves somewhat
(a) upwards
(b) downwards
(c) towards left horizontally
(d) towards right horizontally

Case/Passage-III

All types of waves, be it sound waves, light waves, water waves exhibit the phenomenon of diffraction. The size of the obstacle or opening should be comparable to the wavelength of the wave for the diffraction to be pronounced. Since the wavelength of light is much smaller than the dimensions of most obstacles; the diffraction of light is not easily observed. Sound waves having larger wavelength can be easily diffracted.

73. Wave(s) exhibit diffraction is/are
(a) light (b) water
(c) sound (d) all of the above

74. The diffraction effects in a microscopic specimen become important when the separation between two points is
(a) much greater than the wavelength of light used.
(b) much less than the wavelength of light used.
(c) comparable to the wavelength of light used.
(d) independent of the wavelength of light used.

75. The phenomenon of diffraction can be treated as interference phenomenon if the number of coherent sources is
(a) one (b) two (c) zero (d) infinity

76. Which of the following statements are true about the diffraction pattern?
I. It has a central bright maxima of twice the width of other maxima.
II. The first null occurs at an angle $\lambda/2a$.
III. The intensity of maxima falls as we move away from the central maxima.
IV. The bands are of decreasing width.
(a) II and III (b) I and II
(c) I, III and IV (d) I and III

77. Yellow light is used in a single slit diffraction experiment with slit width of 0.6 mm. If yellow light is replaced by X– rays, then the observed pattern will reveal,
(a) that the central maximum is narrower
(b) more number of fringes
(c) less number of fringes
(d) no diffraction pattern

Case/Passage-IV

When two coherent sources interact with each other, there will be production of alternate bright and dark fringes on the screen. Young's double-slit experiment demonstrates the idea of making two coherent sources. For better visibility, one has to choose proper amplitude for the sources. The phenomena is good enough to satisfy the conservation of energy principle. The pattern formed in YDSE is of uniform thickness and is nicely placed on a long distance screen.

78. Law of conservation of energy is satisfied because
(a) equal loss and gain in intensity is observed
(b) all bright fringes are equally bright
(c) all dark fringes are of zero brightness
(d) the average intensity on screen is equal to the sum of intensities of the two sources

79. For better visibility of fringe pattern, which of the following is incorrect ?
(a) amplitudes of the sources are aqual
(b) the width of the slits should not be equal
(c) dark should be the darkest and bright should be the brightest
(d) the widths should be same

80. The best combination of independent sources to produce sustained pattern among the following is
$Y_1 = a\sin\omega t$ $\quad$ $Y_2 = a\cos\omega t$
$Y_3 = a\sin\left(\omega t + \frac{\pi}{4}\right)$ $\quad$ $Y_4 = 2a\sin(\omega t + \pi)$
(a) Y_1, Y_2 only
(b) Y_2, Y_3 only
(c) Y_3, Y_4 only
(d) none of these

81. In Young's interference experiment, if the slits are of unequal width, then
(a) no fringes will be formed
(b) the positions of minimum intensity will not be completely dark
(c) bright fringe as displaced from the original central position
(d) distance between two consecutive dark fringes will not be equal to the distance between two consecutive bright fringes

82. In Young's interference experiment, the central bright fringe can be identified due to the fact that it
(a) has greater intensity than other fringes which are bright
(b) is wider than the other bright fringes
(c) is narrower than the other bright fringes
(d) can be obtained by using white light instead of monochromatic light

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*
(a) If both **Assertion** and **Reason** are **correct** and the Reason is the **correct explanation** of the Assertion.
(b) If both **Assertion** and **Reason** are correct but Reason is **not the correct explanation** of the Assertion.
(c) If the **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If the **Assertion** is **incorrect** but the **Reason** is **correct**.

83. **Assertion :** According to Huygen's principle, no backward wave-front is possible.
Reason : Amplitude of secondary wavelet is proportional to $(1 + \cos\theta)$ where θ is the angle between the ray at the point of consideration and the direction of secondary wavelet.

84. **Assertion :** When a light waves travels from a rarer to a denser medium, it loses speed. The reduction in speed imply a reduction in energy carried by the light wave.
Reason : The energy of a wave is proportional to velocity of wave.

85. **Assertion :** Thin film such as soap bubble or a thin layer of oil on water show beautiful colours when illuminated by white light.
Reason : It happens due to the interference of light reflected from upper and lower face of the thin film.

86. **Assertion :** No interference pattern is detected when two coherent sources are extremely close to each other.
Reason : The fringe width is inversely proportional to the distance between the two sources.

87. **Assertion :** In Young's experiment, the fringe width for dark fringes is different from that for white fringes.
Reason : In Young's double slit experiment the fringes are performed with a source of white light, then only black and bright fringes are observed.

88. **Assertion :** In YDSE, if $I_1 = 9I_0$ and $I_2 = 4I_0$ then $\frac{I_{max}}{I_{min}} = 25$.
Reason : In YDSE $I_{max} = \frac{1}{2}(\sqrt{I_1} + \sqrt{I_2})^2$ and
$I_{min} = \frac{1}{2}(\sqrt{I_1} - \sqrt{I_2})^2$.

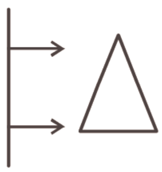
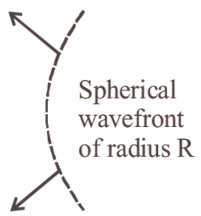
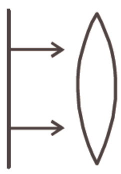
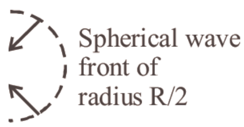
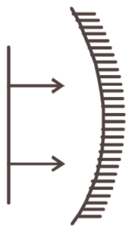
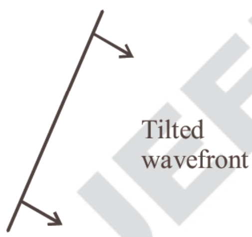
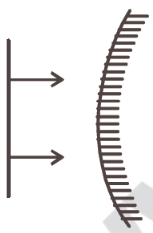
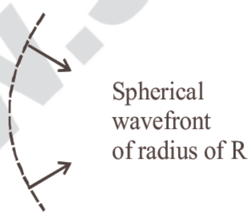
89. **Assertion :** In YDSE number of bright fringe or dark fringe can not be unlimited.
Reason : In YDSE path difference between the superposing waves can not be more than the distance between the slits.

90. **Assertion :** Coloured spectrum is seen when we look through a muslin cloth.
Reason : It is due the diffraction of white light on passing through fine slits.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

91. Match Plane wave incident on different surfaces. In column I with the emergent wavefront in Column II.

Column I		Column II	
(A)		(1)	
(B)		(2)	
(C)		(3)	
(D)		(4)	

(a) (A) $\rightarrow$ (1); (B) $\rightarrow$ (3); (C) $\rightarrow$ (2); (D) $\rightarrow$ (4)
(b) (A) $\rightarrow$ (3); (B) $\rightarrow$ (4); (C) $\rightarrow$ (2); (D) $\rightarrow$ (1)
(c) (A) $\rightarrow$ (2); (B) $\rightarrow$ (4); (C) $\rightarrow$ (3); (D) $\rightarrow$ (1)
(d) (A) $\rightarrow$ (4); (B) $\rightarrow$ (2); (C) $\rightarrow$ (1); (D) $\rightarrow$ (3)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

92. Wavelength of light of frequency 100 Hz is _______.

93. The wavefronts of a light wave travelling in vacuum are given by $x + y + z = c$. The angle made by the direction of propagation of light with the X-axis is _______.

94. The colour of bright fringe nearest to central achromatic fringe in the interference pattern with white light will be _______.

95. Sodium light $(\lambda = 6 \times 10^{-7}\,m)$ is used to produce interference pattern. The observed fringe width is 0.12 mm. The angle between two interfering wave trains, is _______ rad.

96. With a monochromatic light, the fringe-width obtained in a Young's double slit experiment is 0.133 cm. The whole set-up is immersed in water of refractive index 1.33, then the new fringe-width is _______ cm.

97. The condition for observing Fraunhoffer diffraction from a single slit is that the light wavefront incident on the slit should be _______.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

98. Diffraction takes place for all types of waves mechanical or non-mechanical, transverse or longitudinal.

99. Diffraction's effect are perceptible only if wavelength of wave is comparable to dimensions of diffracting device.

100. In YDSE, if a thin film is introduced in front of the upper slit, then the fringe pattern shifts in the downward direction.

101. In YDSE if the slit widths are unequal, the minima will be completely dark.

ANSWER KEY & SOLUTIONS

1. **(a)** Wavefront is the locus of all points, where the particles of the medium vibrate with the same phase.
2. **(d)** The shape of the wavefront in case of light diverging from a point source is spherical and shape of the wavefront in case of a light emerging out of a convex lens when a point source is placed at its focus is a parallel grid.
3. **(b)** Huygen's principle gives us a geometrical method of tracing a wavefront.
4. **(b)** The idea of secondary wavelets is given by huygen.
5. **(d)** Huygen's theory explains propagation of wavefronts.
6. **(b)** Fringe width, $\beta = \frac{\lambda D}{d} \Rightarrow \beta \propto \frac{1}{d}$

   where d = distance between slits
7. **(c)** $I_{max} = I + 4I + 2\sqrt{I \times 4I} = 9I$,

   and $I_{min} = I + 4I - 2\sqrt{I \times 4I} = I$.
8. **(d)** $\beta = \frac{D\lambda}{d}$ so $\beta \propto D$
9. **(b)** Angular fringe width, $\theta = \frac{\lambda}{d}$

   $\therefore \theta \propto \lambda$

   so, $\theta_w = \frac{\theta_{air}}{\mu_{water}} = \frac{0.20}{4/3} = 0.15°$
10. **(b)** Path difference $= 171.5\lambda = \frac{343}{2}\lambda$

    = odd multiple of half wavelength.
    It means dark fringe is observed.

    According to question, $0.01029 = \frac{343}{2}\lambda$

    $\Rightarrow \lambda = \frac{0.01029 \times 2}{343} = 6 \times 10^{-5}$ cm $\Rightarrow \lambda = 6000$ Å
11. **(a)** As $\beta = \frac{\lambda D}{d} \therefore \beta \propto \lambda$.

    As λ for violet is least, therefore, fringe nearest to central achromatic fringe will be violet.
12. **(b)** The path difference at a point P on the circle is given by, $\Delta x = d\cos\theta$ ...(i)

    for maxima at P

    $\Delta x = n\lambda$ ...(ii)

    from equations (i) and (ii)

    $n\lambda = d\cos\theta \Rightarrow \theta = \cos^{-1}\left[\frac{n\lambda}{d}\right]$

    $\theta = \cos^{-1}\left[\frac{4\lambda}{d}\right]$
13. **(d)** Diffraction is a general characteristics exhibited by all types of waves.
14. **(b)** Width of central maximum in diffraction pattern due to single slit $= \frac{2\lambda D}{d}$ where λ is the wavelength, D is the distance between screen and slit and a is the slit width. As the slit width a increases, width of central maximum becomes sharper or narrower. As same energy is distributed over a smaller area. therefore central maximum becomes brigther.
15. **(c)** Because both source & screen are effectively at infinite distance from the diffractive device.
16. **(d)** Diffraction on a single slit is equivalent to interference of light from infinite number of coherent sources contained in the slit.
17. **(a)** As given that the width of the slit $= 10^4$ Å $= 10000$ Å $= 10^4 \times 10^{-10}$ m $= 10^{-6}$ m $= 1$ μm

    Wavelength of visible sunlight varies from 4000 Å to 8000 Å. Thus the width of slit is 10000 Å comparable to that of wavelength visible light i.e., 8000 Å. So diffraction occurs with maxima at centre. Hence at the centre all colours appear i.e., mixing of colours form white patch at the centre.
18. **(a)** Let, us consider the diagram, the ray (P) is incident at an angle θ and gets reflected in the direction P' and refracted in the direction P' through O'. Due to reflection from the glass medium there is a phase change of π. The time difference between two refracted ray OP' and O'P'' is equal to the time taken by ray to travel along OO'.

    $\Delta t = \frac{OO'}{V_g} = \frac{d/\cos r}{c/n} = \frac{nd}{c\cos r}$

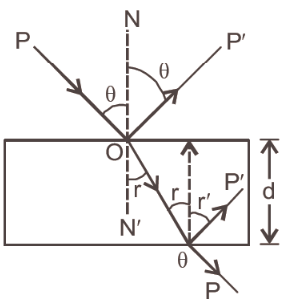
    From Snell's law, $n = \frac{\sin\theta}{\sin r}$

    $\sin r = \frac{\sin\theta}{n}$

    As we know that, $\cos r = \sqrt{1-\sin^2 r}$,
    so by putting sin r value in that relation.

    So, $\cos r = \sqrt{1-\sin^2 r}$

    $\cos r = \sqrt{1-\frac{\sin^2\theta}{n^2}}$



$\therefore \quad \Delta t = \frac{nd}{c\left(1-\frac{\sin^2\theta}{n^2}\right)^{1/2}} = \frac{nd}{c}\left(1-\frac{\sin^2\theta}{n^2}\right)^{-1/2}$

Phase difference $= \Delta\phi = \frac{2\pi}{T} \times \Delta t = \frac{2\pi d}{\frac{1}{\nu}\cdot\nu\lambda}\left(1-\frac{\sin^2\theta}{n^2}\right)^{-1/2}$

$$\Delta\phi = \frac{2\pi d}{\lambda}\left[1-\frac{\sin^2\theta}{n^2}\right]^{-1/2}$$

$\therefore$ Hence the net phase difference $= \Delta\phi + \pi$

$$= \frac{2\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{+1/2} + \pi$$

19. **(c)** For sustained interference pattern to be formed on the screen, the sources must be coherent and emits lights of same frequency and wavelength.
In a Young's double-slit experiment, when one of the holes is covered by a red filter and another by a blue filter. In this case due to filteration only red and blue lights are present which has different frequency. In this monochromatic light is used for the formation of fringes on the screen. So, in that case there shall be no interference fringes.

20. **(d)** Consider the given figure there is a hole at point P_2. By Huygen's principle, wave will propagates from the sources S_1 and S_2. Each point on the screen will acts as sources of secondary wavelets.
Wavefront starting from P_2 reaches at S_3 and S_4 which will again act as two monochromatic or coherent sources.
Hence, there will be always a regular two slit pattern on the second screen.

21. **(d)** The Huygen's construction of wavefront does not explain the phenomena of origin of spectra.

22. **(d)** Interference pattern will be invisible, because red and green are complimentary colours.

23. **(a)** **24.** **(d)** **25.** **(b)** **26.** **(a)** **27.** **(b)**

28. **(b)** If a plane wave of light travelling along the y-direciton electric field may be along any direction in x-z plane (i.e. y = c), hence wavefront represented by y = c.

29. **(b)**

30. **(a)** When light reflects from denser surface phase change of π occurs.

31. **(c)** In interference pattern, the energy is conserved but redisturbed.

32. **(d)** **33.** **(b)**

34. **(a)** For interference phase difference must be constant.

35. **(d)** Coherent light is always monochromatic.

36. **(a)** Coherence is a measure of capability of producing interference by waves.

37. **(d)** A prism cannot produce coherent sources.

38. **(c)** **39.** **(c)**

40. **(a)** $\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{4}{1} \quad \therefore \frac{a_1}{a_2} = \frac{2}{1}$

41. **(c)** $\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{9}{1}$ or $\frac{a_1}{a_2} = \frac{3}{1}$

$$\therefore \frac{I_{max}}{I_{min}} = \frac{(3+1)^2}{(3-1)^2} = \frac{16}{4} = \frac{4}{1}$$

42. **(c)** $\lambda = \frac{h}{P} = \frac{h}{mv}$, so with the increase in velocity of electron, wavelength decreases, and so fringe width decreases.

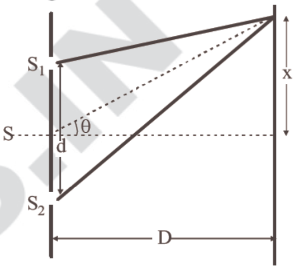
43. **(b)** $\Delta x_{max} = 2\lambda$.
So there are five maxima.
These are for $\Delta x = 0, \pm\lambda, \pm 2\lambda$.

44. **(a)** As $\beta = \frac{\lambda D}{d}$ and $\lambda_b < \lambda_y$,
$\therefore$ fringe width β will decrease

45. **(c)** Distance of nth maxima, $x = n\lambda\frac{D}{d} \propto \lambda$
As $\lambda_b < \lambda_g \therefore x_{blue} < x_{green}$

46. **(d)** Let λ be wavelength of monochromatic light incident on slit S, then angular distance between two consecutive fringes, that is the angular fringe width is

$\theta = \frac{\lambda}{d}$ where d is distance between coherent sources.



Given, $\frac{\Delta\theta}{\theta} = \frac{10}{100}$

So, from eq. (1),

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta\theta}{\theta} = \frac{10}{100} = 0.1$$

$\Rightarrow \Delta\lambda = 0.1\lambda = 0.1 \times 5890\text{Å} = 589\text{Å}$ (increases)

Note: Since, $\theta \propto \lambda$, as θ increases, λ increases.

47. **(d)** Optical path difference $\Delta x = (\mu_2 - \mu_1)t$.

48. **(a)** $\beta = \frac{D\lambda}{d}$

and $\beta' = \frac{D \times 1.1\lambda}{1.1d} = \frac{D\lambda}{d} = \beta = 0.2$ mm.

49. **(d)**

50. **(d)** Given d = 0.5 mm = 5×10^{-2} cm
D = 100 cm.
$X_n = X_{11} - X_1 = 9.72$ mm.

$$\therefore \quad X_n = \frac{n\lambda D}{d}$$

$$\Rightarrow \lambda = \frac{X_n d}{nD} = \frac{0.972 \times 5 \times 10^{-2}}{10 \times 100} = 4.86 \times 10^{-5} \text{ cm.}$$

51. **(d)** **52.** **(a)** **53.** **(d)**

54. **(b)** Here, D = 1.25m, $\mu_w = 4/3$, $\theta_w = 0.2^o$

$$\mu_w = \frac{\lambda_a}{\lambda_w} = \frac{4}{3} \qquad ...(i)$$

Angular width $\theta_a = \frac{\beta}{D} = \frac{(\lambda_a D/d)}{D} = \frac{\lambda_a}{d}$

As d remains the same

$$\therefore \frac{\theta_a}{\theta_w} = \frac{\lambda_a}{\lambda_w} \text{ or } \theta_a = \theta_w \times \frac{\lambda_a}{\lambda_w} = 0.2^o \times \frac{4}{3} = 0.27^o$$

55. **(a)**

56. **(c)** $\beta = \frac{\lambda' D'}{d'} = \frac{3\lambda 3D}{d/3} = 27\frac{\lambda D}{d}$.

No. of fringes $= \frac{1/3}{\beta} = \frac{d}{81\lambda D}$.

57. **(c)** When the wavelength of light used is comparable with the separation between two points, the image of the object will be a ϕ diffraction pattern whose size will be

$$\theta = \frac{1.22\lambda}{D}$$

where λ = wavelength of light used
D = diameter of the objective
Two objects whose images are closer than this distance, will not be resolved.

58. (a)

59. (b) In diffraction, width of central maxima $\propto \lambda$.
$\therefore$ Wavelength of X rays is less than that of yellow light, so the width decreases.

60. (a) For single slit diffraction pattern $e \sin\theta = \lambda$ Angular width, e = slit width

$$\therefore \quad \theta = \sin^{-1}\left(\frac{\lambda}{e}\right)$$

It is independent of distance between source and slit.

61. (a) We know that for maxima $b\sin\theta = (2n+1)\frac{\lambda}{2}$

or $\sin\theta = \frac{2n+1}{2}\left(\frac{\lambda}{b}\right)$

So on decreasing the slit width, 'b', keeping λ same, $\sin\theta$ and hence θ increases.

62. (b) The width of the central maximum is given by

$$\beta = \frac{2\lambda D}{d} \Rightarrow \text{If } d \to 2d, \text{ then } \beta \text{ decreases.}$$

Also, intensity $I = I_0\left[\frac{\sin\alpha}{\alpha}\right]^2$ where $\alpha = \frac{\pi d\sin\theta}{\lambda}$

$\therefore$ I increases as d increases
$\therefore$ The central maximum will become narrower and brighter.

63. (c) Converging spherical

64. (c) A slit would give divergent; a biprism would give double; a glass slab would give a parallel wavefront. Edge is downward.

65. (c) Newtons coupuscular theory is based on the assumption that light is made up of particles. It cannot explain diffraction which is based on wave nature of light.

66. (a)

67. (b) Line source produce cylindrical wavefront.

68. (a) Distance of third minima from principal maxima $= \frac{3}{2}\frac{D}{d}\lambda$

69. (b) **70. (a)**

71 (c) The position of n^{th} dark fringe in Fraunhoffer Diffraction from a single slit is $a\sin\theta = n\lambda$

$$a = \frac{n\lambda}{\sin\theta} = \frac{1\times 6.5\times 10^{-7}}{\sin 30^o}, \text{(for first min. n = 1)}$$

$$= \frac{6.5\times 10^{-7}}{1/2} = 13\times 10^{-7}\,\text{m} = 1.3\,\mu\text{m}.$$

72. (b) As optical path SB of lower slit is increased, therefore, fringe pattern shifts somewhat downwards.

73. (d)

74. (c) When the wavelength of light used is comparable with the separation between two points, the image of the object will be a ϕ diffraction pattern whose size will be

$$\theta = \frac{1.22\lambda}{D}$$

where λ = wavelength of light used
D = diameter of the objective
Two objects whose images are closer than this distance, will not be resolved.

75. (d) **76. (d)**

77. (d) For diffraction pattern to be observed, the dimension of slit should be comparable to the wave length of rays. The wavelength of X-rays (1 – 100 Å) is less than 0.6 mm.

78. (d) $I_{av} = \frac{I_{max.} + I_{min.}}{2}$

$$= \frac{(A_1 + A_2)^2 + (A_1 - A_2)^2}{2} = A_1^2 + A_2^2 = I_1 + I_2$$

$I_{av} = I_1 + I_2$
Neither loss nor gain of energy is observed, but only redistribution of energy takes place.

79 (b) If $A_1 = A = a, I_{max} = 4a^2, I_{min} = 0$. So, visibility is the best. Choice (a) is correct.
Since $I_{min} = 0$, choice (c) is also correct.
Width decides intensity and thereby the amplitude. So, choice (d) is correct making (b) wrong.

80. (d) Sources are independent. They cannot form a coherent source since ϕ cannot be constant with time.

81. (b) When slits are of unequal width, then intensity of sources S_1 and S_2 is not equal. So, position of minimum intensity will not be completely dark.

82. (d) Because white light will give a general illumination at the central maxima.

83. (b) **84. (d)**

85. (a) Both top and bottom surfaces of this oil film can reflect light. If path difference between two light rays is an integral multiple of λ, there will be constructive interference.

86. (a) $\beta = \frac{D\lambda}{d}$. When $d \to 0$, $\beta \to \infty$, and so fringes will not be seen over the screen.

87. (d) **88. (c)** **89. (a)**

90. (a) When white light is passed through a fine hole of muslin cloth in diffraction occurs resulting coloured spectrum.

91. (b) (A)$\to$ (3); (B)$\to$ (4); (C)$\to$ (2); (D) $\to$ 1

92. $(3 \times 10^6 \text{m})$ Frequency (n) = 100 Hz

$$v = n\lambda \Rightarrow \lambda = \frac{3\times 10^8}{100} \quad \lambda = 3\times 10^6\,\text{m}.$$

[where, velocity (v) = 3×10^8 m/s of light]

93. Huyghen's principle gives us a geometrical method of tracing a wavefront.

94. As $\beta = \frac{\lambda D}{d} \therefore \beta \propto \lambda$.

95. (5×10^{-3}) The fringe width is given by, $\beta = \frac{\lambda D}{d}$

The angular width of fringe is given by

$$\frac{d}{D} = \frac{\lambda}{\beta} = \frac{6\times 10^{-7}}{0.12\times 10^{-3}} = 5\times 10^{-3}\,\text{rad}.$$

96. (0.1) $\beta' = \frac{\beta}{\mu} = \frac{0.133}{1.33} = 0.1$ cm

97. (Both source & screen are effectively at infinite distance from the diffractive device)

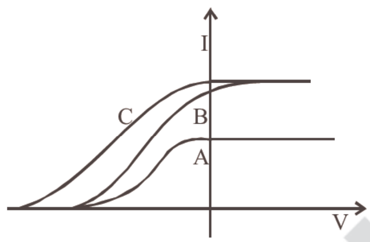
98. (True) **99.** (True) **100.** (False) **101.** (True)

11 Dual Nature of Radiation and Matter

Multiple Choice Questions (MCQs)

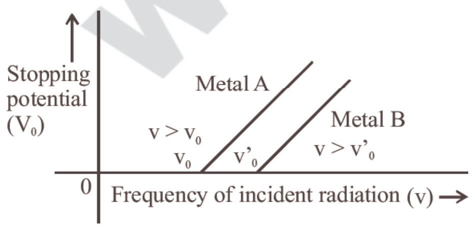
DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. In a photoelectric experiment, anode potential (V) is plotted against plate current (I)



(a) A and B will have different intensities while B and C will have different frequencies.
(b) B and C will have different intensities while A and C will have different frequencies.
(c) A and B will have different intensities while A and C will have equal frequencies.
(d) A and B will have equal intensities while B and C will have different frequencies.

2. Select true/false statements according to the graph

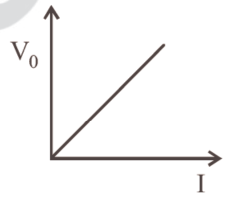


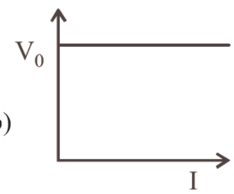
I. the stopping potential varies linearly with the frequency of incident radiation for the given metal.
II. the work function of metal *A* is greater than that for metal *B*.
III. stopping potential depends upon the angle of incident light.
IV. the stopping potential is independent of the intensity of incident radiation.

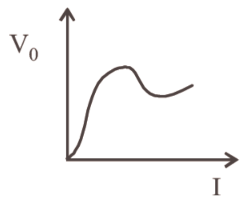
(a) T, F, T, F (b) T, F, F, T
(c) F, T, F, T (d) T, T, F, T

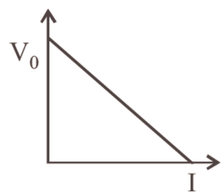
3. A strong argument for the particle nature of cathode rays is that they
(a) produce fluoroscence
(b) travel through vacuum
(c) get deflected by electric and magnetic fields
(d) cast shadow

4. The correct graph between the stopping potential (V_0) and intensity of incident light (I) is

(a) 

(b) 

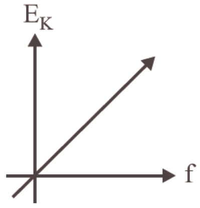
(c) 

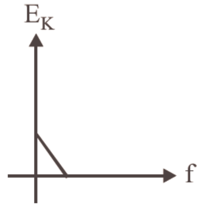
(d) 

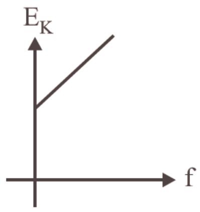
5. The work function of aluminium is 4.2 eV. If two photons, each of energy 3.5 eV strike an electron of aluminium, then emission of electrons
(a) will be possible
(b) will not be possible
(c) data is incomplete
(d) depends upon the density of the surface

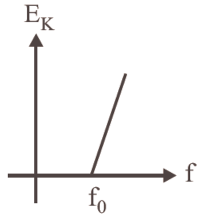
6. Which of the following is/are true/false regarding cathode rays?
I. They produce heating effect
II. They don't deflect in electric field
III. They cast shadow
IV. They produce fluorescence
(a) F, T, T, T (b) T, T, T, T
(c) F, F, F, T (d) T, F, T, T

7. Which one of the following graphs represents the variation of maximum kinetic energy (E_K) of the emitted electrons with frequency f in photoelectric effect correctly?

(a) 

(b) 

(c) 

(d) 

8. If a photon and an electron have same de-Broglie wavelength, then
(a) both have same kinetic energy
(b) proton has more K.E. than electron
(c) electron has more K.E. than proton
(d) both have same velocity

9. If E_1, E_2, E_3 are the respective kinetic energies of an electron, an alpha-particle and a proton, each having the same de-Broglie wavelength, then
(a) $E_1 > E_3 > E_2$ (b) $E_2 > E_3 > E_1$
(c) $E_1 > E_2 > E_3$ (d) $E_1 = E_2 = E_3$

10. 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
(a) 1 : 2 (b) 1 : 1
(c) 1 : 3 (d) 1 : 4

11. 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) $H^{-1/2}$

12. 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 **[CBSE 2020]**
(a) 1 : 2 (b) 1 : 1
(c) 1 : 3 (d) 1 : 4

13. 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

14. 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) $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

15. An electron is moving with an initial velocity $v = v_0 \vec{i}$ and is in a magnetic field $B = B_0 \vec{j}$. Then, it's de-Broglie wavelength
(a) remains constant
(b) increases with time
(c) decreases with me
(d) increases and decreases periodically

16. An electron (mass m) with an initial velocity $v = v_0 i$ ($v_0 > 0$) is in an electric field $E = -E_0 \hat{i}$ (E_0 = constant > 0). It's de-Broglie wavelength at time t is given by
(a) $\dfrac{\lambda_0}{\left(1+\dfrac{eE_0}{m}\dfrac{t}{v_0}\right)}$ (b) $\left(1+\dfrac{eE_0 t}{mv_0}\right)$
(c) λ_0 (d) $\lambda_0 t$

17. An electron (mass m) with an initial velocity $v = v_0\hat{i}$ is in an electric field $E = E_0\hat{j}$. If $\lambda_0 = h/mv$, it's de-Broglie wavelnegth at time t is given by
(a) λ_0 (b) $\lambda_0\sqrt{1+\dfrac{e^2E_0^2t^2}{m^2v_0^2}}$
(c) $\dfrac{\lambda_0}{\sqrt{1+\dfrac{e^2E_0^2t^2}{m^2v_0^2}}}$ (d) $\dfrac{\lambda_0}{\left(1+\dfrac{e^2E_0^2t^2}{m^2v_0^2}\right)}$

18. The photoelectrons emitted from a metal surface are such that their velocity
(a) is zero for all
(b) is same for all
(c) lies between zero and infinity
(d) lies between zero and a finite maximum

19. The work function of aluminium is 4.2 eV. If two photons, each of energy 3.5 eV strike an electron of aluminium, then emission of electrons
(a) will be possible
(b) will not be possible
(c) Data is incomplete
(d) Depends upon the density of the surface

20. In a photoelectric experiment the stopping potential for the incident light of wavelength 4000Å is 2 volt. If the wavelength be changed to 3000 Å, the stopping potential will be
(a) 2V (b) zero
(c) less than 2 V (d) more than 2 V

21. A free particle with initial kinetic energy *E*, de-Broglie wavelength λ, enters a region wherein it has a potential energy *V*, what is the new de-Broglie wavelength?
(a) $\lambda(1 + E/V)$ (b) $\lambda(1 - V/E)$
(c) $\lambda(1 + V/E)^{0.5}$ (d) $\lambda/(1 - V/E)^{0.5}$

22. Cathode rays and canal rays produced in a certain discharge tube are deflected in the same direction if
(a) a magnetic field is applied normally
(b) an electric field is applied normally
(c) an electrin field is applied tangentially
(d) a magnetic field is applied tangentially

23. A material particle with a rest mass m_0 is moving with speed of light c. The de-Broglie wavelength associated is given by
(a) $\frac{h}{m_0 c}$ (b) $\frac{m_0 c}{h}$ (c) zero (d) ∞

24. The ratio of de-Broglie wavelengths of proton and α-particle having same kinetic energy is
(a) $\sqrt{2}:1$ (b) $2\sqrt{2}:1$ (c) 2 : 1 (d) 4 : 1

25. When the speed of electrons increase, then the value of its specific charge
(a) increases
(b) decreases
(c) ramains unchanged
(d) increases upto some velocity and then begins to decrease

26. A steel ball of mass m is moving with a kinetic energy K. The de Broglie wavelength associated with the ball is
(a) $\frac{h}{2mK}$ (b) $\sqrt{\frac{h}{2mK}}$
(c) $\frac{h}{\sqrt{2mK}}$ (d) $\sqrt{\frac{h}{3mk}}$

27. If the two particles have fallen through the same height, the heavier of the two particles has ____ de Broglie wavelength.
(a) same (b) greater (c) smaller (d) None

28. The de-Broglie wavelength of neutron in thermal equilibrium at temperature T is
(a) $\frac{30.8}{\sqrt{T}}$ Å (b) $\frac{3.08}{\sqrt{T}}$ Å (c) $\frac{0.308}{\sqrt{T}}$ Å (d) $\frac{0.0308}{\sqrt{T}}$ Å

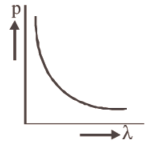
29. The wavelength λ_e of an electron and λ_p of a proton are of same energy E are related by
(a) $\lambda_p \propto \lambda_e$ (b) $\lambda_p \propto \sqrt{\lambda_e}$
(c) $\lambda_p \propto \frac{1}{\sqrt{\lambda_e}}$ (d) $\lambda_p \propto \lambda_e^2$

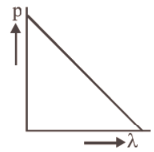
30. If the kinetic energy of a free electron doubles, it's deBroglie wavelength changes by the factor
(a) 2 (b) $\frac{1}{2}$ (c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

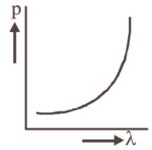
31. de-Broglie wavelength of an electron accelerated by a voltage of 50 V is close to ($|e| = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg, $h = 6.6 \times 10^{-34}$ Js) :
(a) 2.4 Å (b) 0.5 Å (c) 1.7 Å (d) 1.2 Å

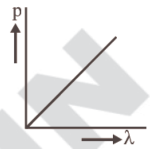
32. The de Broglie wavelength of a neutron at 927 °C is λ. What will be its wavelength at 27 °C ?
(a) $\frac{\lambda}{2}$ (b) λ (c) 2λ (d) 4λ

33. Which of the following figures represent the variation of particle momentum and the associated de-Broglie wavelength?

(a) 

(b) 

(c) 

(d) 

34. If the kinetic energy of the particle is increased to 16 times its previous value, the percentage change in the de-Broglie wavelength of the particle is :
(a) 25 (b) 75 (c) 60 (d) 50

35. The phenomenon which can be explained only by quantum nature of light is
(a) photoelectric effect (b) reflection
(c) interference (d) polarization

36. Photoelectric effect is the phenomenon in which
(a) photons come out of a metal when it is hit by a beam of electrons.
(b) photons come out of the nucleus of an atom under the action of an electric field.
(c) electrons come out of a metal with a constant velocity which depends on the frequency and intensity of incident light wave.
(d) electrons come out of a metal with different velocities not greater than a certain value which depends only on the frequency of the incident light wave and not on its intensity.

37. In which of the following, emission of electrons does not take place?
(a) Thermionic emission
(b) Photoelectric emission
(c) Secondary emission
(d) None of these

38. In the photoeletric effect, electrons are emitted
(a) at a rate that is proportional to the amplitude of the incident radiation
(b) with a maximum velocity proportional to the frequency of the incident radiation
(c) at a rate that is independent of the emitter
(d) only if the frequency of the incident radiations is above a certain threshold value

39. The wavelength of a photon is 4000 Å. Calculate its energy.
(a) 49.5×10^{-19} J (b) 495×10^{-19} J
(c) 4.95×10^{-19} kJ (d) 4.95×10^{-19} J

40. What is the kinetic energy gained by an electron due to acceleration through a potential difference of 1 V?
(a) 1 eV (b) 1 joule (c) 5 Nm (d) 10 Nm

41. The work function of photoelectric substance is 3.3eV. The value of threshold frequency will be
(a) 4×10^{11} Hz (b) 8×10^{10} Hz
(c) 5×10^{33} Hz (d) 8×10^{14} Hz

42. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of the wavelengths is nearest to
(a) 1 : 2 (b) 4 : 1 (c) 2 : 1 (d) 1 : 4

43. If the wavelength of incident light falling on a photosensitive material decreases, then
(a) photoelectric current increases
(b) stopping potential decreases
(c) stopping potential remains constant
(d) stopping potential increases

44. A photosensitive metal is not emitting photo–electrons when irradiated. It will do so when threshold is crossed. To cross the threshold we need to increase
(a) intensity (b) frequency
(c) wavelength (d) None of these

45. The number of photoelectrons emitted for light of a frequency ν (higher than the threshold frequency ν_0) is proportional to:
(a) Threshold frequency (ν_0)
(b) Intensity of light
(c) Frequency of light (ν)
(d) $\nu - \nu_0$

46. The wavelength of a 1 ke V photon is 1.24×10^{-9}m. What is the frequency of 1 MeV photon?
(a) 1.24×10^{15} (b) 2.4×10^{20}
(a) 1.24×10^{18} (b) $2 \times 4 \times 10^{23}$

47. Einstein's photoelectric equation is $E_k = h\nu - \phi$. In this equation E_k refers to
(a) kinetic energy of all the emitted electrons
(b) mean kinetic energy of emitted electrons
(c) maximum kinetic energy of emitted electrons
(d) minimum kinetic energy of emitted electrons

48. A monochromatic source of light operating at 200 W emits 4×10^{20} photons per second. Find the wavelength of light.
(a) 400 nm (b) 200 nm
(c) 4×10^{-10} Å (d) None of these

49. The photoelectric threshold of Tungsten is 2300Å. The energy of the electrons ejected from the surface by ultraviolet light of wavelength 1800Å is
(a) 0.15 eV (b) 1.5 eV
(c) 15 eV (d) 150 eV

50. Using light of wavelength 6000 Å stopping potential is obtained 2.4 volt for photoelectric cell. If light of wavelength 4000 Å is used then stopping potential would be
(a) 2.9 V (b) 1.9 V (c) 3.43 V (d) 9.4 V

51. In an electron gun, the potential difference between the filament and plate is 3000 V. What will be the velocity of electron emitting from the gun?
(a) 3×10^8 m/s (b) 3.18×10^7 m/s
(c) 3.52×10^7 m/s (d) 3.26×10^7 m/s

52. No photoelectrons are emitted from a metal if the wavelength of the light exceeds 600 nm. The work function of the metal is approximately equal to
(a) 3×10^{-16} J (b) 3×10^{-19} J
(c) 3×10^{-20} J (d) 3×10^{-22} J

53. The shortest wavelength of X-ray emitted from an X-ray tube operated at 2×10^6 volt, is of the order of
(a) 10^{-5} Å (b) 10^{-2} Å (c) 0.15 Å (d) 1 Å

54. What is the energy of k_α X-ray photon of copper (Z = 29)?
(a) 7.99 keV (b) 8.29 keV
(c) 8.25 keV (d) 7.19 keV

55. When ultraviolet radiation is incident on a surface, no photoelectrons are emitted. If a second beam causes photoelectrons to be ejected, it may consists of
(a) infra-red waves (b) X-rays
(c) visible light rays (d) radio waves

56. The maximum kinetic energy of the electrons hitting a target so as to produce X-ray of wavelength 1 Å is
(a) 1.24 keV (b) 12.4 keV
(c) 124 keV (d) None of these

57. The ratio of the energy of an X-ray photon of wavelength 1 Å to that of visible light of wavelength 5000 Å is
(a) 1 : 5000 (b) 5000 : 1
(c) $1 : 25 \times 10^6$ (d) 25×10^6

58. An X-rays tube is being operated at 20 kV, the maximum speed of electrons striking the anticathode will be
(a) 8.4 m/s (b) 8.4×10^7 m/s
(c) 4.4×10^7 m/s (d) zero

59. When the minimum wavelength of X-rays is 2Å then the applied potential difference between cathode and anticathode will be
(a) 6.2 kV (b) 2.48 kV (c) 24.8 kV (d) 62 kV

60. The maximum distance between interatomic lattice planes is 15 Å. The maximum wavelength of X-rays which are diffracted by this crystal will be
(a) 15 Å (b) 20 Å (c) 30 Å (d) 45 Å

61. An X-ray tube is operated at 15 kV. Calculate the upper limit of the speed of the electrons striking the target.
(a) 7.26×10^7 m/s (b) 7.62×10^7 m/s
(c) 7.62×10^7 cm/s (d) 7.26×10^9 m/s

62. The glancing angle in a X-ray diffraction is 30º and the wavelength of X-rays used is 20 nm. The interplanar spacing of the crystal dffracting these X-rays will be
(a) 40 nm (b) 20 nm (c) 15 nm (d) 10 nm

63. An element with atomic number Z = 11 emits k_αx-ray of wavelength λ then the atomic number of the element which emits k_αx-ray of wavelength 4 λ is:
(a) 11 (b) 44 (c) 6 (d) 5

64. The X-rays of wavelength 0.5 Å are scattered by a target. What will be the energy of incident X-rays, if these are scattered at an angle of 72º ?
(a) 12.41 keV (b) 6.2 keV
(c) 18.6 keV (d) 24.82 keV

65. An X-ray tube with Cu target is operated at 25 kV. The glancing angle for a NaCl crystal for the Cu k_α line is 15.8°. Find the wavelength of this line.
(d for NaCl = 2.82 Å, h = 6.62×10^{-27} erg-sec)
(a) 3.06 Å (b) 1.53 Å
(c) 0.75 Å (d) None of these

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

A physicist wishes to eject electrons by shining light on a metal surface. The light source emits light of wavelength of 450 nm. The table lists the only available metals and their work functions.

Metal	W_0 (eV)
Barium	2.5
Lithium	2.3
Tantalum	4.2
Tungsten	4.5

66. Which metal(s) can be used to produce electrons by the photoelectric effect from given source of light ?
(a) Barium only
(b) Barium or lithium
(c) Lithium, tantalum or tungsten
(d) Tungsten or tantalum

67. Which option correctly identifies the metal that will produce the most energetic electrons and their energies ?
(a) Lithium, 0.45 eV (b) Tungston, 1.75 eV
(c) Lithium, 2.30 eV (d) Tungston, 2.75 eV

68. Suppose photoelectric experiment is done separately with these metals with light of wavelength 450 nm. The maximum magnitude of stopping potential amongst all the metals is-
(a) 2.75 volt (b) 4.5 volt
(c) 0.45 volt (d) 0.25 volt

69. The photoelectric effect is based on the law of conservation of
(a) momentum (b) energy
(c) angular momentum (d) mass

70. The momentum of photon whose frequency f is
(a) $\frac{hf}{c}$ (b) $\frac{hc}{f}$ (c) $\frac{h}{f}$ (d) $\frac{c}{hf}$

Case/Passage-II

According to de-Broglie a wave is associated with moving material particle called matter waves or de-Broglie wave.
De Broglie proposed wavelength of a particle of momentum p as

$$\lambda = \frac{h}{p} = \frac{h}{mv}; \quad m = \text{mass of particle, } v = \text{speed}$$

λ = wavelength of matter wave or de Broglie wavelength.

71. If the momentum of electron is changed by P, then the de- Broglie wavelength associated with it changes by 0.5%. The initial momentum of electron will be
(a) 200 P (b) 400 P
(c) $\frac{P}{200}$ (d) 100 P

72. If the kinetic energy of a free electron doubles, it's de-Broglie wavelength changes by the factor
(a) 2 (b) $\frac{1}{2}$ (c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

73. If the kinetic energy of the particle is increased to 16 times its previous value, the percentage change in the de-Broglie wavelength of the particle is :
(a) 25 (b) 75 (c) 60 (d) 50

74. A proton and α-particle are accelerated through the same potential difference. The ratio of their de-Broglie wavelength will be
(a) 1 : 1 (b) 1 : 2 (c) 2 : 1 (d) $2\sqrt{2}:1$

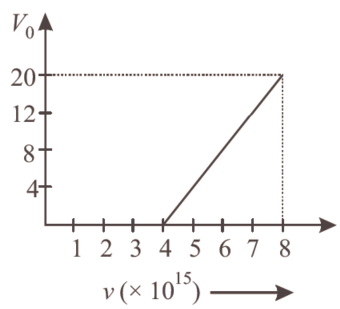
75. An α-particle and a singly ionized $_4Be^8$ atom are accelerated through the same potential difference. What is the ratio of the de-Broglie wave lengths in the two cases?
(a) 1 : 2 (b) 1 : 1 (c) 2 : 1 (d) 4 : 1

Case/Passage-III

When a high frequency electromagnetic radiation is incident on a metallic surface, electrons are emitted from the surface. Energy of emitted photoelectrons depends only on the frequency of incident electromagnetic radiation and the number of emitted electrons depends only on the intensity of incident light. Einstein's photoelectric equation [$K_{max} = hv - \phi$] correctly explains the PE, where υ = frequency of incident light and ϕ = work function.

76. Light of wavelength 3300 is incident on two metals A and B, whose work functions are 4 eV and 2 eV, respectively. Then
(a) A will emit photoelectrons but B will not
(b) B will emit photoelectrons, but A will not
(c) both A and B will not emit photoelectrons
(d) neither A nor B will emit photoelectrons

77. For photoelectric effect in a metal, the graph of the stopping potential V_0 (in volt) versus frequency υ (in hertz) of the incident radiation is shown in fig. The work function of the metal (in eV) is



(a) 12.5 (b) 14.5 (c) 16.5 (d) 18.5

78. The slope of the graph shown in fig. [here h is the Planck's constant and e is the charge of an electron] is
(a) $\frac{h}{e}$ (b) eh (c) h (d) $\frac{e}{h}$

79. The magnitude of saturation photoelectric current depends upon

(a) frequency (b) intensity
(c) work function (d) stopping potential

80. The number of photo-electrons emitted per second from a metal surface increases when
(a) the energy of incident photons increases
(b) the frequency of incident light increases
(c) the wavelength of the incident light increases
(d) the intensity of the incident light increases

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*
(a) If both **Assertion** and **Reason** are **correct** and the Reason is the **correct explanation** of the Assertion.
(b) If both **Assertion** and **Reason** are correct but Reason is **not the correct explanation** of the Assertion.
(c) If the **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If the **Assertion** is **incorrect** but the **Reason** is **correct**.

81. Assertion : In photoelectric effect on increasing the intensity of light, kinetic energy of electrons increased but photoelectric current remains unchanged.
Reason : The photoelectric current depends on frequency of light.

82. Assertion : The kinetic energy of photoelectrons emitted from metal surface does not depend on the intensity of incident photon
Reason : The ejection of electrons from metallic surface is not possible with frequency of incident photons below the threshold frequency.

83. Assertion : Though light of a single frequency (monochromatic) is incident on a metal, the energies of emitted photoelectrons are different.
Reason : The energy of electrons emitted from inside the metal surface, is lost in collision with the other atoms in the metal.

84. Assertion : The photon behaves like a particle.
Reason : If E and P are the energy and momentum of the photon, then $p = E/c$.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

85. Match the Columns I and II.

Column I	Column II
(A) Field emission	(1) Heat is supplied to the metal surface
(B) Photoelectric emission	(2) Electric field is applied to the metal surface
(C) Thermionic emission	(3) Light of suitable frequency illuminates the metal surface
(D) Secondary emission	(4) Striking fast moving electrons on the metal surface

(a) (A) → (2); (B) → (3); C → (1); (D) → (4)
(b) (A) → (1); (B) → (3); C → (2); (D) → (4)
(c) (A) → (4); (B) → (1); C → (3); (D) → (2)
(d) (A) → (4); (B) → (3); C → (2); (D) → (1)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

86. Photoelectric emmision occurs only when the incident light has more than a certain minimum ________ .

87. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then_______ is the ratio of their threshold wavelengths.

88. A steel ball of mass m is moving with a kinetic energy K. The de-Broglie wavelength associated with the ball is________.

89. The wavelength of the matter wave is independent of ________ .

90. The wavelength of a photon needed to remove a proton from a nucleus which is bound to the nuclear with 1 MeV energy is nearly__________ nm.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

91. If a proton and electron have the same de Broglie wavelength, then momentum of electron > momentum of proton

92. In a photoelectric experiment, if both the intensity and frequency of the incident light are doubled, then the saturation photoelectric current is doubled.

93. If in a photoelectric cell, the wavelength of incident light is changed from 4000Å to 3000 Å then change in stopping potential will be 0.33 V.

94. When the X-ray tube is operated at 1kV, then X-rays of minimum wavelength 6.22 Å are produced. If the tube is operated at 10 kV, then the minimum wavelength of X-rays will be 0.622 Å.

ANSWER KEY & SOLUTIONS

1. **(a)** From the graph it is clear that A and B have the same stopping potential and therefore the same frequency. Also B and C have the same intensity.
2. **(b)**
3. **(c)** As cathode rays are deflected by electric and mangetic fields, it shows that cathode rays carry charged particles (i.e. electrons)
4. **(b)** Stoping potential does not depend upon intensity of incident light (I).
5. **(b)** For emission of electrons incident energy of each photon must be greater than work function (threshold energy).
6. **(d)** Cathode rays deflect in electric field.
7. **(d)** $hf - hf_0 = E_K$, according to photoelectric equation, when $f = f_0$, $E_K = 0$.
   Graph (d) represents $E_K - f$ relationship.
8. **(c)** $\lambda = \frac{h}{m_p v_p} = \frac{h}{m_e v_e}$; then $m_p v_p = m_e v_e$

   or $\frac{v_p}{v_e} = \frac{m_e}{m_p}$

   $$\frac{E_p}{E_e} = \frac{\frac{1}{2}m_p v_p^2}{\frac{1}{2}m_e v_e^2} = \frac{m_p}{m_e} \times \left(\frac{m_e}{m_p}\right)^2 = \frac{m_e}{m_p} < 1$$

   $\therefore\ E_p < E_e$
9. **(a)** According to relation, $E = \frac{1}{2}mv^2$

   $\sqrt{\frac{2E}{m}} = v$

   $\lambda = \frac{h}{\sqrt{2mE}}$

   Because $m_1 < m_3 < m_2$

   So for same λ, $E_1 > E_3 > E_2$.
10. **(c)** *K.E.* = Photon energy – Work function.

    $\therefore\ \frac{K.E_1}{K.E_2} = \frac{1-0.5}{2-0.5} = \frac{0.5}{1.5} = \frac{1}{3}$
11. **(d)** Velocity of a body freely falling from a height H is

    $v = \sqrt{2gH}$

    So, $\lambda = \frac{h}{mv} = \frac{h}{m\sqrt{2gH}} \Rightarrow = \frac{h}{m\sqrt{2g}\sqrt{H}}$

    (h, m and g are constant)

    Here, $\frac{h}{m\sqrt{2g}}$ is also constant

    So, $h \propto \frac{1}{\sqrt{H}} \Rightarrow$ or $\boxed{\lambda \propto H^{-1/2}}$
12. Option (c) is correct.

    K.E. = Photon energy – Work function.

    $\therefore\ \frac{K.E_1}{K.E_2} = \frac{1-0.5}{2-0.5} = \frac{0.5}{1.5} = \frac{1}{3}$
13. **(d)** When a beam of electrons of energy E_0 is incident on a metal surface kept in vacuum or evacuated chamber so electrons can be emitted with maximum energy E_0 (due to elastic collision) and with any energy less than E_0, when part of incident energy of electron is used in liberating the electrons from the surface of metal. So maximum energy of emitted electrons can be E_0.
14. **(b)** The relation between λ and K is given by

    $\lambda = \frac{h}{\sqrt{2mK}}$

    So, for the given value of kinetic energy K,

    $\frac{h}{\sqrt{2K}}$ is a constant.

    Thus, $\lambda \propto \frac{1}{\sqrt{m}}$

    $\therefore\ \Rightarrow \lambda_p : \lambda_n : \lambda_e : \lambda_\alpha$

    $\Rightarrow\ = \frac{1}{\sqrt{m_p}} : \frac{1}{\sqrt{m_n}} : \frac{1}{\sqrt{m_e}} : \frac{1}{\sqrt{m_\alpha}}$

    if $(m_p = m_n)$, then $\lambda_p = \lambda_n$
    if $(m_\alpha > m_p)$, then $\lambda_\alpha < \lambda_p$
    if $(m_e < m_n)$, then $\lambda_e > \lambda_n$
    Hence, $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$.
15. **(a)** As given that, $v = v_0\,\vec{i}$ and $B = B_0\,\vec{j}$

    Force on moving electron due to perpendicular magnetic field B is, $F = -e\,(v \times B)$

    $F = -e\left[v_0\hat{i} \times B_0\hat{i}\right] = -e\,v_0\,B_0\,(\hat{i} \times \hat{j})$

    $\Rightarrow\ = -ev_0B_0\hat{k} \quad (\because \hat{k} = \hat{i} \times \hat{j})$

    So, the force is perpendicular to v and B, both as the force is $\perp$ to the velocity so the magnitude of v will not change, so momentum is (= mv) will remain same or constant in magnitude. Hence,

    de-Broglie wavelength $\lambda = \frac{h}{mv}$ remains constant.

16. **(a)** de-Brogile wavelength of electron,

$$\lambda_0 = \frac{h}{mv_0} \quad ...(i)$$

Force on electron

$$\Rightarrow \quad F = -eE = (-e)(-E_0\hat{i}) = eE_0\hat{i}$$

Acceleration of electron

$$a = \frac{F}{m} = \frac{eE_0\hat{i}}{m} \quad (\because F = ma)$$

Velocity of electron after time t, is $v = (v_0 + at)$

$$v = v_0\hat{i} + \left(\frac{eE_0\hat{i}}{m}\right)t = \left(v_0 + \frac{eE_0}{m}t\right)\hat{i}$$

$$v = v_0\left(1 + \frac{eE_0}{m}t\right)\hat{i}$$

Now for new de-Broglie wavelength associated with electron at time t is

$$\lambda = \frac{h}{mv} \Rightarrow \lambda = \frac{h}{v_0 m\left[\left(1 + \frac{eE_0 t}{mv_0}\right)\hat{i}\right]} = \frac{\lambda_0}{\left[1 + \frac{eE_0}{mv_0}t\right]} \quad \left[\because \lambda_0 = \frac{h}{mv_0}\right][\hat{i} = 1]$$

$$\lambda = \frac{\lambda_0}{\left[1 + \left(\frac{eE_0}{mv_0}\right)t\right]}$$

17. **(c)** **18.** **(d)**

19. **(b)** For emission of electrons incident energy of each photon must be greater than work function (threshold energy).

20. **(d)** $eV_s = \frac{hc}{\lambda} - W_0$. If λ decreases, V_s increases

21. **(b)**

22. **(a)** In discharge tube cathode rays (a beam of negative particles) and canal rays (positive rays) move opposite to each other. They will experience a magnetic force in the same direction, if a normal magnetic field is applied.

23. **(c)** $\lambda = \frac{h}{mv}$, $v = \frac{m_0}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$, $v \to c$, $m \to \infty$

hence, $\lambda \to 0$.

24. **(c)** de-Broglie wavelength, $\lambda = \frac{h}{\sqrt{2mE_{K.E}}}$

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_p}} = \sqrt{\frac{4m_p}{m_p}} = \frac{2}{1} \, [\because E_{K.E(\alpha)} = E_{K.E(p)}]$$

25. **(b)** Here the velocity of electron increases, so as per Einstein's equation mass of the electron increases, hence the specific charge $\frac{e}{m}$ decreases.

26. **(c)** de-Broglie's relation, $\lambda = \frac{h}{p}$; $p = \sqrt{2mE}$

$$\Rightarrow \lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mK}} \quad (\because E = K)$$

27. **(c)**

28. **(a)** From formula $\lambda = \frac{h}{\sqrt{2mKT}}$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 1.67 \times 10^{-27} \times 1.38 \times 10^{-23} T}} = \frac{30.8}{\sqrt{T}} \text{Å}$$

29. **(a)**

30. **(d)** $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2.m.(K.E)}} \quad \therefore \lambda \propto \frac{1}{\sqrt{K.E}}$

If K.E is doubled, wavelength becomes $\frac{\lambda}{\sqrt{2}}$

31. **(c)** $\lambda = \frac{h}{P} = \frac{h}{mv} = \frac{h}{\sqrt{2mqV}}$

or, $\lambda = \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 50}} = 1.7$ Å

32. **(c)** de-Broglie wavelength of a material particle at temperature T is given by

$$\lambda = \frac{h}{\sqrt{2mkT}}, \Rightarrow \quad \lambda \propto \frac{1}{\sqrt{T}}$$

$$\therefore \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{T_1}{T_2}} \text{ or } \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{1200}{300}} = 2$$

$$\therefore \lambda_2 = 2\lambda_1 = 2\lambda$$

33. **(a)** According to De-broglie $p = \frac{h}{\lambda}$ or $P \propto \frac{1}{\lambda}$

$P \propto \frac{1}{\lambda}$ represents rectangular hyperbola.

34. **(b)** As we know

$$\lambda = \frac{h}{P} = \frac{h}{\sqrt{2mK}} \text{ or } \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{K_2}{K_1}} = \sqrt{\frac{16K}{K}} = \frac{4}{1}$$

Therefore the percentage change in de-Broglie wavelength $= \frac{1-4}{4} \times 100 = -75\%$

35. **(a)** Photoelectric effect can be explained only by quantum nature of light.

36. **(d)** **37.** **(d)**

38. **(d)** Photoelectrons are emitted if the frequency of incident light is greater than the threshold frequency.

39. **(d)** $E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{4000 \times 10^{-10}} = 4.95 \times 10^{-19}$ J

40. **(a)** Gain in K.E. = q V = $(1.6 \times 10^{-19} \times 1)$ J = 1 eV.

41. **(d)** W = 3.3 eV; $h\nu_0 = 3.3 \times 1.6 \times 10^{-19}$ J.

$$\nu_0 = \frac{3.3 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 8 \times 10^{14} \text{ Hz}$$

42. **(c)** We know that work function is the energy required and energy $E = h\upsilon$

$$\therefore \frac{E_{Na}}{E_{Cu}} = \frac{h\upsilon_{Na}}{h\upsilon_{Cu}} = \frac{\lambda_{Cu}}{\lambda_{Na}}$$

$$\therefore \frac{\lambda_{Na}}{\lambda_{Cu}} = \frac{E_{Cu}}{E_{Na}} = \frac{4.5}{2.3} \approx \frac{2}{1}$$

43. **(d)** Stopping potential increases if wavelength of light falling on a photosensitive material decreases.

44. **(b)**

45. **(b)** The number of photoelectrons emitted is proportional to the intensity of incident light. Saturation current $\propto$ intensity.

46. **(b)** Here, $\frac{hc}{\lambda} = 10^3$ eV and $h\nu = 10^6$ eV

Hence, $\nu = \frac{10^3 c}{\lambda}$

47. **(c)**

48. **(a)** The energy of each photon $= \frac{200}{4 \times 10^{20}} = 5 \times 10^{-19}$ J

Wavelength $= \lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{5 \times 10^{-19}}$

$\Rightarrow \lambda = 4.0 \times 10^{-7} = 400$ nm

49. **(a)**

$$E_k = \frac{hc}{c}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) (\text{in eV})$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19}}\left(\frac{10^{10}}{1800} - \frac{10^{10}}{2300}\right) = 0.15\text{eV}$$

50. **(c)** $V_0 = \frac{hc}{e\lambda} - \frac{\phi_0}{e}$,

$$2.4 = \frac{hc}{6000 \times 10^{-10} e} - \frac{\phi_0}{e} \quad ....(1)$$

$$V_0 = \frac{hc}{4000 \times 10^{-10} e} - \frac{\phi_0}{e} \quad ....(2)$$

Eq. (1) – Eq.(2), and solving it, we get

$V_0 = 2.4 + 1.03 = 3.43$ V

51. **(d)** $v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 3000}{9.1 \times 10^{-31}}} = 3.26 \times 10^7$ m/s.

52. **(b)** $W = \frac{hc}{\lambda_0} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{600 \times 10^{-9}}$ J $= 3.31 \times 10^{-19}$ J

53. **(b)** $E = eV = 2 \times 10^6 \times 1.6 \times 10^{-19}$ J

$\Rightarrow \lambda = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3.2 \times 10^{-13}} \approx 10^{-2}$ Å

54. **(a)** $E(k_\alpha) = 10.2\,(Z-1)^2$ eV

$= 10.2 \times 28^2 = 7.997$ keV $= 8$ KeV

55. **(b)** Energy of photon of *X*-rays is more than energy of photon of ultraviolet rays. Because frequency of *X* rays is more than ultraviolet rays.

56. **(b)** $\lambda_{min} = 1$ Å (given) $\because \lambda_{min} = \frac{1240}{E}$ (eV) (nm)

Thus, $E = \frac{1240(\text{eV})(\text{nm})}{0.01(\text{nm})} = 12400$ eV; $E = 12.4$ KeV

57. **(b)** $E = h\nu = h\frac{c}{\lambda} \therefore \frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1} = \frac{5000}{1}$

58. **(b)** $v_{max} = \sqrt{\frac{2eV}{m}}$

$$= \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 20 \times 10^3}{9.1 \times 10^{-31}}} = 8.4 \times 10^7 \text{ m/s}$$

59. **(a)** $V = \frac{12400}{\lambda_{min}(\text{Å})}$ Volt $\Rightarrow V = \frac{12400}{2} = 6.2$ KV

60. **(c)** $\lambda_{max.} = \frac{2d\sin\theta}{n_{min.}} = \frac{2 \times 15 \times \sin 90^\circ}{1} = 30$ Å

61. **(a)** The maximum kinetic energy of an electron accelerated through a potential difference of V volt is $\frac{1}{2}mv^2 = eV$

$\therefore$ maximum velocity $v = \sqrt{\frac{2eV}{m}}$

$$v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 15000}{9.1 \times 10^{-31}}} \Rightarrow v = 7.26 \times 10^7 \text{ m/s}$$

62. **(b)** $2\,d\sin\theta = n\lambda$ or $d = \frac{n\lambda}{2\sin\theta} = \frac{1 \times 20}{2 \times \sin 30^\circ} = 20$ nm

63. **(c)**

64. **(d)** Energy $= \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{0.5 \times 10^{-10}}$ J

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{5 \times 10^{-11} \times 1.6 \times 10^{-19}} \text{eV} = 24.82 \text{ keV}$$

65. **(b)** According to Bragg's law, $\Rightarrow 2d\sin\theta = n\lambda$,

n = 1 for first order

$\Rightarrow 2 \times 2.82 \sin 15.8 = \lambda \Rightarrow \lambda = 5.64 \times 0.2723 = 1.53$ Å

66. **(b)** $\Delta E = \frac{12400}{4.500\text{Å}} = 2.75$ eV

For photoelectric effect, $\Delta E > W_0$ (work function).

67. **(a)** $\Delta E = W_0 + E$; $(E_k) = \Delta E - W_0$

For maximum value of (E_k), W_0 should be minimum

W_0 for lithium $= 2.3$ eV

$\therefore (E_k) = 2.75 - 2.3 = 0.45$ eV

68. **(c)** The maximum magnitude of stopping potential will be for metal of least work function.
$\therefore$ required stopping potential is

$$V_s = \frac{h\nu - \phi_0}{e} = 0.45 \text{ volt.}$$

69. **(b)** Photoelectric effect is based on law of conservation of energy.

70. **(a)** Moment of photon $= p = \frac{h}{\lambda}$ $\because E = mc^2$

But, $p = mc$ $\therefore E = mc.c$ So, $E = pc$ or $E = \frac{hc}{\lambda}$

$\therefore \frac{hc}{\lambda} = pc$ or $p = \frac{h}{\lambda}$ and $\lambda = \frac{c}{f}$ $\therefore p = \frac{hf}{c}$

71. **(a)** The de-Broglie's wavelength associated with the moving electron $\lambda = \frac{h}{P}$

Now, according to problem

$$\frac{d\lambda}{\lambda} = -\frac{dp}{P}$$

$$\frac{0.5}{100} = \frac{P}{P'}$$

72. **(d)** de-Broglie wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2.m.(K.E)}}$$

$$\therefore \lambda \propto \frac{1}{\sqrt{K.E}}$$

If K.E is doubled, λ becomes $\frac{\lambda}{\sqrt{2}}$

73. **(b)** As we know

$$\lambda = \frac{h}{P} = \frac{h}{\sqrt{2mK}}$$
$$(\because P = \sqrt{2mKE})$$

or $\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{K_2}{K_1}} = \sqrt{\frac{16K}{K}} = \frac{4}{1}$

Therefore the percentage change in de-Broglie wavelength

$$= \frac{1-4}{4} \times 100 = -75\%$$

74. **(d)** $qV = \frac{1}{2}mv^2$ or $mv = \sqrt{2qVm}$;

So $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2qVm}}$ *i.e.,* $\lambda \propto \frac{1}{\sqrt{qm}}$;

so $\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{q_\alpha m_\alpha}{q_p m_p}} = \sqrt{2\times 4} = 2\sqrt{2}$

75. **(b)**

76. **(b)** Energy of incident photon

$$E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{3300\times10^{-10}} = 3.75 \text{ eV}$$

A will not emit photoelectrons because energy of incident photon is less than work function of *A*.

77. **(c)** $eV_0 = h(\nu - \nu_0)$
When $V_0 = 0$, $\nu = \nu_0$, the threshold frequency.
From the graph it follows that
$\nu_0 = 4\times10^{15}$ Hz
Therefore, work function is
$\phi = h\nu_0 = 6.6\times10^{-34}\times4\times10^{15} = 16.5$ eV

78. **(a)** $eV_0 = h\nu - h\nu_0$

$$V_0 = \frac{h}{e}\nu - \frac{h}{e}\nu_0$$

$Y = mn + e$

Slope $= \frac{h}{e}$

79. **(b)**

80. **(d)** Intensity $\propto$ no. of photons $\propto$ no. of photoelectrons.

81. **(d)** On increasing the intensity of incident light, the current in photoelectric cell will increase. The energy of the photon ($h\nu$) will however not increase with increase in intensity, and hence the kinetic energy of the emitted electrons will not increase. The photoelectric current does not depends on frequency of light.

82. **(b)** According to Einstein's equation, $KE = h\nu - h\nu_0$
KE depends upon the frequency. Photoelectrons are emitted only if incident frequency is more than threshold frequency.

83. **(a)** When a light of single frequency falls on the electrons of inner layer of metal, then this electron comes out of the metal surface after a large number of collisions.

84. **(a)**

85. **(a)** (A) $\rightarrow$ (2); (B) $\rightarrow$ (3); (C) $\rightarrow$ (1); (D) $\rightarrow$ (4)

86. (Frequency) For occurence of photoelectric effect, the incident light should have frequency more than a certain minimum which is called the threshold frequency (ν_0).

We have, $\frac{1}{2}mv^2 = h\nu - h\nu_0$

For photoelectric effect emission $\nu > \nu_0$
where ν is the frequency of the incident light.

87. (2:1) $hc/\lambda_0 = W_0$; $\frac{(\lambda_0)_1}{(\lambda_0)_2} = \frac{(W_0)_2}{(W_0)_1} = \frac{4.5}{2.3} = 2:1.$

88. $\left(\frac{h}{\sqrt{2mk}}\right)$ de-Broglie's relation, $\lambda = \frac{h}{p}$

momentum $p = \sqrt{2mE}$

$$\Rightarrow \lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mK}} \quad (\because E = K)$$

89. (Charge) The wavelength of the matter wave is independent of charge.

90. $(1.2 \times 10^{-3}$ nm) Energy of a photon is $E = \frac{hc}{\lambda}$

Where λ is the minimum wavelength of the photon required to eject the proton from nucleus.

Energy of photon must be equal to the binding energy of proton.

So, energy of a photon, $E = 1$ MeV $\Rightarrow 10^6$eV (given)

Now, $\left(E = \frac{hc}{\lambda}\right)$

So, $\lambda = \frac{hc}{E} = \left(\frac{6.63 \times 10^{-34} \times 3 \times 10^8}{10^6 \text{ eV}}\right)$

$\Rightarrow$ So, $\lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{10^6 \times 1.6 \times 10^{-19} \text{ J}}$

$= 1.24 \times 10^{-9} \times 10^{-3} = 1.24 \times 10^{-3}$ nm

91. (False) de Broglie wavelength, $\lambda = \frac{h}{p}$

As $\lambda_{proton} = \lambda_{electron}$ (Given)

$\therefore\ p_{electron} = p_{proton}$

92. (True)

93. (False) $eV_1 = h\nu_1 - h\nu_0$; $eV_2 = h\nu_2 - h\nu_0$

$$V_2 - V_1 = \frac{hc}{e}\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right) = 1.03 \text{ eV}$$

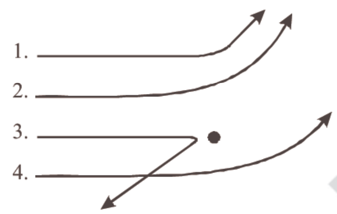
94. (True) $\frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{V_1}{V_2} \Rightarrow \lambda_{m_2} = \frac{6.22 \times 10^3}{10^4} = 0.622$ Å

12 Atoms

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. The diagram shows the path of four α-particles of the same energy being scattered by the nucleus of an atom simulateneously. Which of those is not physically possible?



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

2. Rutherford's model could explain
I. Nucleus is positively charged.
II. There is a maximum empty space in an atom.
True/false statements are
(a) T, F (b) F, T
(c) T, T (d) F, F

3. When an α-particle of mass 'm' moving with velocity 'v' bombards on a heavy nucleus of charge 'Ze', its distance of closest approach from the nucleus depends on v as :

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

4. The observations of Geiger–Marsden experiment are
I. Many of α-particles pass straight through the gold foil.
II. Some of α-particles scattered through small angles.
III. Few α-particles (1 in 1000) is deflected more than 90°.
IV. Very few particles are reflected back.
True/false statements are
(a) T, F, T, F (b) F, F, T, T
(c) T, T, F, F (d) T, T, T, T

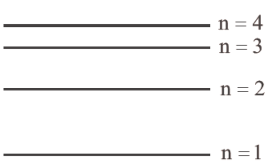
5. When hydrogen atom is in its first excited level, it's radius is
(a) four times, it ground state radius
(b) twice times, it ground state radius
(c) same times, it ground state radius
(d) half times, it ground state radius

6. Bohr's atomic model concludes that
I. Orbits are elliptical
II. The radiation of energy occurs only when an electron jumps from one permitted orbit to another
True/false statements are
(a) F, T (b) T, F
(c) F, F (d) T, T

7. The angular momentum of electron n^{th} orbit is given by
(a) nh (b) $h/2\pi n$
(c) $\frac{nh}{2\pi}$ (d) $\frac{n^2h}{2\pi}$

8. The ionization energy of hydrogen atom is 13.6 eV. Following Bohr's theory, the energy corresponding to a transition between 3rd and 4th orbit is
(a) 3.40 eV (b) 1.51 eV
(c) 0.85 eV (d) 0.66 eV

9. Four lowest energy levels of H-atom are shown in the figure. The number of possible emission lines would be



(a) 3 (b) 4
(c) 5 (d) 6

10. Which of the following series in the spectrum of hydrogen atom lies in the visible region of the electromagnetic spectrum?
(a) Paschen series (b) Balmer series
(c) Lyman series (d) Brackett series

11. Which of the following statements is ***not*** correct according to Rutherford model ? **[CBSE 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.

12. 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

13. 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 in correct 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

14. Two H atoms in the ground state collide inelastically. The maximum amount by which their combined kinetic energy is reduced, is
(a) 10.20 eV (b) 20.40 eV
(c) 13.6 eV (d) 27.2 eV

15. Rutherford's atomic model was unstable because
(a) nuclei will break down
(b) electrons do not remain in orbit
(c) orbiting electrons radiate energy
(d) electrons are repelled by the nucleus

16. In Balmer series of emission spectrum of hydrogen, first four lines with different wavelength H_α H_β $H\gamma$ and H_δ are obtained. Which line has maximum frequency out of these?
(a) H_α (b) H_β
(c) $H\gamma$ (d) H_δ

17. Electron in hydrogen atom first jumps from third excited state to second excited state and then from second excited to the first excited state. The ratio of the wavelength $\lambda_1 : \lambda_2$ emitted in the two cases is
(a) 7/5 (b) 27/20
(c) 27/5 (d) 20/7

18. According to the Bohr theory of H-atom, the speed of the electron, its energy and the radius of its orbit varies with the principal quantum number n, respectively, as
(a) $\frac{1}{n}, n^2, \frac{1}{n^2}$ (b) $n, \frac{1}{n^2}, n^2$
(c) $n, \frac{1}{n^2}, \frac{1}{n^2}$ (d) $\frac{1}{n}, \frac{1}{n^2}, n^2$

19. Electrons in the atom are held to the nucleus by
(a) electrostatic force (b) nuclear force
(c) vander waal's force (d) gravitational force

20. According to the Rutherford's atomic model, the electrons inside the atom are
(a) stationary (b) not stationary
(c) centralized (d) None of these

21. According to classical theory, the circular path of an electron in Rutherford atom is
(a) spiral (b) circular
(c) parabolic (d) straight line

22. Which of the following statements is correct in case of Thomson's atomic model ?
(a) It explains the phenomenon of thermionic emission, photoelectric emission and ionisation.
(b) It could not explain emission of line spectra by elements.
(c) It could not explain scattering of α-particles
(d) All of the above

23. Rutherford's atomic model was unstable because
(a) nuclei will break down
(b) electrons do not remain in orbit
(c) orbiting electrons radiate energy
(d) electrons are repelled by the nucleus

24. Rutherford scattering experiment was explained by making following assumptions that
(a) the colllision is inelastic
(b) the nucleus can be treated as a point particle
(c) the nucleus is light
(d) None of these

25. Which one did Rutherford consider to be supported by the results of experiments in which α-particles were scattered by gold foil?
(a) The nucleus of an atom is held together by forces which are much stronger than electrical or gravitational forces
(b) The force of repulsion between an atomic nucleus and an α-particle varies with distance according to inverse square law
(c) α-particles are nuclei of Helium atoms
(d) Atoms can exist with a series of discrete energy levels

26. In the ground state in ...*A*... electrons are in stable equilibrium while in ...*B*... electrons always experiences a net force. Here, *A* and *B* refer to
(a) Dalton's theory, Rutherford model
(b) Rutherford's model, Bohr's model
(c) Thomson's model, Rutherford's model
(d) Rutherford's model, Thomson's model

27. The significant result deduced from the Rutherford's scattering experiment is that
(a) whole of the positive charge is concentrated at the centre of atom
(b) there are neutrons inside the nucleus
(c) α-particles are helium nuclei
(d) electrons are embedded in the atom
(e) electrons are revolving around the nucleus

28. Value of Impact parameter will be zero, when scattering angle is
(a) $\pi/2$ (b) π (c) $2\pi/3$ (d) $3\pi/2$

29. The correct relation between scattering angle (θ), impact parameter (b) and distance of closest approach (D) is
(a) $\sin\theta = Db$ (b) $\tan\frac{\theta}{2} = \frac{D}{2b}$
(c) $\frac{\cos\theta}{b} = D$ (d) $\cot\frac{\theta}{2} = \frac{b}{2D}$

30. In an atom, the two electrons move round the nucleus in circular orbits of radii R and 4R. The ratio of the time taken by them to complete one revolution is
(a) 1/4 (b) 4/1 (c) 8/1 (d) 1/8

31. An α-particle of energy 5 MeV is scattered through 180º by a fixed uranium nucleus. The distance of closest approach is of the order of
(a) 10^{-12} cm (b) 10^{-10} cm
(c) 10^{-20} cm (d) 10^{-15} cm

32. According to Bohr's model of hydrogen atom
(a) the linear velocity of the electron is quantised
(b) the angular velocity of the electron is quantised
(c) the linear momentum of the electron is quantised
(d) the angular momentum of the electron is quantised

33. The spectrum obtained from a sodium vapour lamp is an example of
(a) band spectrum (b) continuous spectrum
(c) emission spectrum (d) absorption spectrum

34. The time period of an electron in n^{th} Bohr's orbit is proportional to
(a) n^3 (b) n^2 (c) n (d) 1/n

35. Current due to the orbital motion of an electron revolving in n^{th} Bohr's orbit is proportional to
(a) $1/n^3$ (b) n^3 (c) n^2 (d) n

36. The Balmer series for the H-atom can be observed
(a) if we measure the frequencies of light emitted when an excited atom falls to the ground state
(b) if we measure the frequencies of light emitted due to transitions between excited states and the first excited state
(c) in any transition in a H-atom
(d) None of these

37. The ratio of radii of the first three Bohr orbits is
(a) $1:\frac{1}{2}:\frac{1}{3}$ (b) 1 : 2 : 3
(c) 1 : 4 : 9 (d) 1 : 8 : 27

38. Which of the following statements are true regarding Bohr's model of hydrogen atom?
(a) Orbiting speed of electron decreases as it shifts to discrete orbits away from the nucleus
(b) Radii of allowed orbits of electron are inversely proportional to the principal quantum number
(c) Frequency with which electrons orbit around the nucleus in discrete orbits is inversely proportional to the cube of principal quantum number
(d) Binding force with which the electron is bound to the nucleus increases as it shifts to outer orbits

39. When an electron jumps from the fourth orbit to the second orbit, one gets the
(a) second line of Lyman series
(b) second line of Paschen series
(c) second line of Balmer series
(d) first line of Pfund series

40. As the quantum number increases, the difference of energy between consecutive energy levels
(a) remain the same
(b) increases
(c) decreases
(d) sometimes increases and sometimes decreases.

41. Line spectrum is obtained whenever the incandescent vapours at low pressure of the excited substance are in their
(a) atomic state (b) molecular state
(c) nuclear state (d) None of these

42. The angular speed of the electron in the n^{th} orbit of Bohr hydrogen atom is
(a) directly proportional to n
(b) inversely proportional to $\sqrt{n}$
(c) inversely proportional to n^2
(d) inversely proportional to n^3

43. In a hydrogen atom following the Bohr's postulates the product of linear momentum and angular momentum is proportional to $(n)^x$ where 'n' is the orbit number. Then 'x' is
(a) 0 (b) 2 (c) –2 (d) 1

44. The ratio of maximum to minimum wavelength in Balmer series is
(a) 3 : 4 (b) 1 : 4 (c) 5 : 36 (d) 5 : 9

45. Energy of an electron in an excited hydrogen atom is –3.4 eV. Its angular momentum will be
(a) 3.72×10^{-34}Js (b) 2.10×10^{-34}Js
(c) 1.51×10^{-34} Js (d) 4.20×10^{-34}Js

46. In Hydrogen spectrum, the wavelength of H_α line is 656 nm, whereas in the spectrum of a distant galaxy, H_α line wavelength is 706 nm. Estimated speed of the galaxy with respect to earth is
(a) 2×10^8 m/s (b) 2×10^7m/s
(c) 2×10^6 m/s (d) 2×10^5 m/s

47. What element has k_α line of wavelength 1.785 Å? $R = 109737\ cm^{-1}$.
(a) Platinum (b) Zinc (c) Iron (d) Cobalt

48. The wavelength of K_α-line characteristic emitted by an element is 0.32 Å. The wavelength of k_β-line emitted by the same element will be
(a) 0.27 Å (b) 0.32 Å (c) 0.39 Å (d) 0.49 Å

49. If the k_α radiation of Mo (Z = 42) has a wavelength of 0.71Å. Calculate the wavelength of the corresponding radiation of Cu (Z = 29).
(a) 1.52Å (b) 2.52Å (c) 0.52Å (d) 4.52Å

50. The ratio of the longest to shortest wavelengths in Brackett series of hydrogen spectra is
(a) 25/9 (b) 17/6 (c) 9/5 (d) 4/3

51. The kinetic energy of the electorn in an orbit of radius r in hydrogen atom is (e = electronic charge)
(a) $\frac{e^2}{r^2}$ (b) $\frac{e^2}{2r}$ (c) $\frac{e^2}{r}$ (d) $\frac{e^2}{2r^2}$

52. The largest wavelength in the ultraviolet region of the hydrogen spectrum is 122 nm. The smallest wavelength in the infrared region of the hydrogen spectrum (to the nearest integer) is
(a) 802 nm (b) 823 nm (c) 1882 nm (d) 1648 nm

53. The energy of electron in the nth orbit of hydrogen atom is expressed as $E_n = \frac{-13.6}{n^2}$ eV. The shortest wavelength of Lyman series will be
(a) 910 Å (b) 5463 Å
(c) 1315 Å (d) None of these

54. The ionisation potential of H-atom is 13.6 V. When it is excited from ground state by monochromatic radiations of 970.6 Å, the number of emission lines will be (according to Bohr's theory)
(a) 10 (b) 8 (c) 6 (d) 4

55. The ratio of areas between the electron orbits for the first excited state to the ground state for the hydrogen atom is
(a) 2 : 1 (b) 4 : 1 (c) 8 : 1 (d) 16 : 1

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

Rutherford gave the **nuclear model of the atom**. According to this model, "the entire positive charge and most of the mass of the atom is concentrated in a small volume called nucleus and electrons revolve around it."

In 1911 Geiger-Marsden performed the gold foil alpha particle scattering experiment which supported Rutherford's model.

56. Rutherford's α-particle experiment showed that the atoms have
(a) Proton (b) Nucleus
(c) Neutron (d) Electrons

57. The significant result deduced from the Rutherford's scattering experiment is that
(a) whole of the positive charge is concentrated at the centre of atom
(b) there are neutrons inside the nucleus
(c) α-particles are helium nuclei
(d) electrons are embedded in the atom

58. In Rutherford's α-particle scattering experiment, what will be correct angle for α scattering for an impact parameter b = 0?
(a) 90º (b) 270º (c) 0º (d) 180º

59. An α-particle of energy 5 MeV is scattered through 180º by a fixed uranium nucleus. The distance of closest approach is of the order of
(a) 10^{-12} cm (b) 10^{-10} cm
(c) 10^{-20} cm (d) 10^{-15} cm

60. The distance of closest approach of a certain nucleus is 7.2 fm and it has a charge of 1.28×10^{-17} C. The number of neutrons inside the nucleus of an atom is
(a) 136 (b) 142 (c) 140 (d) 132

Case/Passage-II

The spacing between lines within certain sets of the hydrogen spectrum. Each of these sets is called a spectral series.
Balmer's empirical formula for the observed wavelength,

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right); \; R = \frac{me^4}{8\varepsilon_0^2 h^3 c}$$

where R = Rydberg constant = 1.097×10^7 m^{-1}; n_f = final orbital number and n_i = initial orbital number

61. Out of the following which one is not a possible energy for a photon to be emitted by hydrogen atom according to Bohr's atomic model?
(a) 1.9 eV (b) 11.1 eV
(c) 13.6 eV (d) 0.65 eV

62. If 13.6 eV energy is required to ionize the hydrogen atom, then the energy required to remove an electron from *n* = 2 is
(a) 10.2 eV (b) 0 eV
(c) 3.4 eV (d) 6.8 eV.

63. Excitation energy of a hydrogen like ion in its excitation state is 40.8 eV. Energy needed to remove the electron from the ion in ground state is
(a) 54.4 eV (b) 13.6 eV
(c) 40.8 eV (d) 27.2 eV

64. A hydrogen atom in its ground state absorbs 10.2 eV of energy. The orbital angular momentum is increased by
(a) 1.05×10^{-34} J-s (b) 3.16×10^{-34} J-s
(c) 2.11×10^{-34} J-s (d) 4.22×10^{-34} J-s

65. If the wavelength of the first line of the Balmer series of hydrogen is 6561 Å, the wavelength of the second line of the series should be
(a) 13122 Å (b) 3280 Å
(c) 4860 Å (d) 2187 Å

Case/Passage-III

The energy levels of a hypothetical one electron atom are shown in fig.

$n = \infty$ ———————— 0 eV
$n = 5$ ———————— –0.80 eV
$n = 4$ ———————— –1.45 eV
$n = 3$ ———————— –3.08 eV
$n = 2$ ———————— –5.30 eV
$n = 1$ ———————— –15.6 eV

66. Find the ionization potential of the atom.
(a) 11.2 eV (b) 13.5 eV
(c) 15.6 eV (d) 12.6 eV

67. Find the short wavelength limit of the series terminating at $n = 2$.
(a) 3256 Å (b) 2339 Å
(c) 2509 Å (d) 3494 Å

68. Find the excitation potential for the state $n = 3$.
(a) 14.64 eV (b) 9.93 eV
(c) 12.52 eV (d) 10.04 eV

69. Find the wave number of the photon emitted for the transition $n = 3$ to $n = 1$.
(a) $2.23 \times 10^7\ m^{-1}$ (b) $1.009 \times 10^7\ m^{-1}$
(c) $3.005 \times 10^6\ m^{-1}$ (d) $0.432 \times 10^6\ m^{-1}$

70. If an electron with initial kinetic energy 6 eV is to interact with this hypothetical atom, what minimum energy will this electron carry after interaction ?
(a) 2 eV (b) 3 eV
(c) 6 eV (d) 0 eV

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

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

71. **Assertion :** Electrons in the atom are held due to coulomb forces.
Reason : The atom is stable only because the centripetal force due to Coulomb's law is balanced by the centrifugal force.

72. **Assertion :** In Lyman series, the ratio of minimum and maximum wavelength is $\frac{3}{4}$.
Reason : Lyman series constitute spectral lines corresponding to transition from higher energy to ground state of hydrogen atom.

73. **Assertion :** Between any two given energy levels, the number of absorption transitions is always less than the number of emission transitions.
Reason : Absorption transitions start from the lowest energy level only and may end at any higher energy level. But emission transitions may start from any higher energy level and end at any energy level below it.

74. **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 $n = 3, 4, 5$.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

75. Match quantities given in Column -I to those given in Column-II.

Column I	Column II
(A) Number of scattered particles proportional to	(1) $\frac{1}{v^2}$
(B) Distance of closest approach is proportional to	(2) $\frac{1}{\sin^4(\theta/2)}$
(C) Impact parameter is proportional to	(3) $\frac{n^2}{Z}$
(D) Radius of orbit is proportional to	(4) $\cot(\theta/2)$

(a) (A) → (2); (B) → (1); (C) → (4); (D) → (3)
(b) (A) → (1); (B) → (2); (C) → (3); (D) → (4)
(c) (A) → (3); (B) → (2); (C) → (1); (D) → (4)
(d) None of these

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

76. According to classical theory, the path of an electron in Rutherford atomic model is______.

77. When an electron jumps from the fourth orbit to the second orbit, one gets the_______series.

78. Excitation energy of a hydrogen like ion in its excitation state is 40.8 eV. Energy needed to remove the electron from the ion in ground state is _______ eV.

79. As one considers orbits with higher values of n in a hydrogen atom, the potential energy of the atom _______.

80. 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 _______ pm.

81. According to Bohr's atomic model, the circumference of the electron orbit is always an ________ multiple of de Broglie wavelength. **[CBSE 2020]**

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

82. Bohr had to postulate that the electrons in stationary orbits around the nucleus radiate energy.

83 According to classical electromagnetic theory, an accelerated charged particle, should continueously radiate energy.

84. The force of repulsion between atomic nucleus and α-particle varies with distance according to inverse square law.

85. Rutherford did α-particle scattering experiment.

ANSWER KEY & SOLUTIONS

1. **(d)** α-particle cannot be attracted by the nucleus.
2. **(c)**
3. **(c)** At closest distance of approach, the kinetic energy of the particle will convert completely into electrostatic potential energy.

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

Potential energy P.E. $= \frac{KQq}{r}$

$\frac{1}{2}mv^2 = \frac{KQq}{r} \Rightarrow r \propto \frac{1}{v^2}$

4. **(d)** Geiger and Marsden (students of Rutherford) studied the scattering of α-particles by gold foil on the advice of Rutherford and all those observations.
5. **(a)** $r_n = r_o.n^2$, where r_o is radius of ground-state and r_n is radius of n^{th} state. (For first excited state n = 2).
6. **(a)** Bohr postulated that an electron in an atom can more around the nucleus in certain circular stable orbits without emitting radiations.
7. **(c)** According to Bohr's second postulate.
8. **(d)** $E = E_4 - E_3$

$$= -\frac{13.6}{4^2} - \left(-\frac{13.6}{3^2}\right) = -0.85 + 1.51 = 0.66\,\text{eV}$$

9. **(d)** Number of possible emission lines $= \frac{n(n-1)}{2}$
10. **(b)** Transition from higher states to n = 2 lead to emission of radiation with wavelengths 656.3 nm and 365.0 nm. These wavelengths fall in the visible region and constitute the Balmer series.
11. **(d)**
12. **(a)** The simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons. So the nuclear the electrons not being subject to a central force.
13. **(a)** Accroding Bohr's second postulate states that the electron evolves around the nucleus only in those orbits for which the angular momentum is some integral multiple of $\frac{h}{2\pi}$ where h is the Planck's constant ($= 6.6 \times 10^{-34}$ J-s). So, the magnitude of angular momentum is kept equal to some integral multiple of $\frac{h}{2\pi}$, where, h is Planck's constant and thus, the Bohr model does not gives correct value of angular momentum.
14. **(a)** We know that,

Electron on the lowest state of the atom, called the ground state have the lowest energy and the electron revolving in the orbit of smallest radius, the Bohr radius, r. The energy of this state (n = 1), E_1 is – 13.6 eV.

Total energy of two H – atoms in the ground state collide in elastically = 2 × (–13.6 eV) = –27.2 eV.

The maximum amount by which their combined kinetic energy is reduced when any one H–atom goes into first excited state after the inelastic collision. So that the total energy of the two H – atoms after the inelastic collision

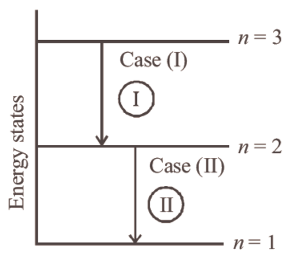
$$= \left(\frac{13.6}{2^2}\right) + (13.6) = 17.0\text{eV} \left[\because \text{for excited state } (n = 2)\right].$$

So, maximum loss of their combined kinetic energy.

Due to inelastic collision

$= 27.2 - 17.0 = 10.2$ eV

15. **(b)**
16. **(d)** Since out of the given four lines H_δ line has smallest wavelength. Hence the frequency of this line will be maximum.
17. **(c)**



The wave number $(\bar{v})$ of the radiation $= \frac{1}{\lambda}$

$$= R_\infty\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Now for case (I) $n_1 = 3, n_2 = 2$

$$\frac{1}{\lambda_1} = R_\infty\left[\frac{1}{9} \frac{-1}{4}\right], R_\infty = \text{ Rydberg constant}$$

$$\frac{1}{\lambda_1} = R_\infty\left[\frac{4-9}{36}\right] = \frac{-5R_\infty}{36} \Rightarrow \lambda_1 = \frac{-36}{5R_\infty}$$

$$\frac{1}{\lambda_2} = R_\infty\left[\frac{1}{4} - \frac{1}{1}\right] = \frac{-3R_\infty}{4}$$

$$\lambda_2 = \frac{-4}{3R_\infty} \Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{-36}{5R_\infty} \times \frac{3R_\infty}{-4}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{27}{5}$$

18. **(d)**

19. **(a)** In an atom, electrons held to the nucleus by electrostatic force.

20. **(b)** **21.** **(a)** **22.** **(c)** **23.** **(b)** **24.** **(b)**

25. **(b)**

26. **(c)** In Thomson's modle, electrons are in stable equilibrium i.e., no force or no net force, while, in Rutherford's model, there is always a centripetal force acting on electron towards nucleus.

27. **(a)** The significant result deduced from the Rutherford's scattering is that whole of the positive charge is concentrated at the centre of atom i.e. nucleus.

28. **(b)** **29.** **(b)**

30. **(d)** $\frac{R_1}{R_2}=\frac{n_1^2}{n_2^2}=\frac{1}{4} \quad \therefore \frac{n_1}{n_2}=\frac{1}{2}$

$$\frac{T_1}{T_2}=\left(\frac{n_1}{n_2}\right)^3=\left(\frac{1}{2}\right)^3=\frac{1}{8}$$

31. **(a)** Distance of closest approach $r_0=\frac{Ze(2e)}{4\pi\varepsilon_0\left(\frac{1}{2}mv^2\right)}$

Energy, $E=5\times10^6\times1.6\times10^{-19}$ J

$$\therefore r_0=\frac{9\times10^9\times(92\times1.6\times10^{-19})(2\times1.6\times10^{-19})}{5\times10^6\times1.6\times10^{-19}}$$

$$\Rightarrow r=5.2\times10^{-14}m=5.3\times10^{-12}\text{ cm.}$$

32. **(d)** According to Bohr's model, $mvr=\frac{nh}{2\pi}$ where n is an integer.

33. **(c)** A spectrum is observed, when light coming directly from a source is examined with a spectroscope. Therefore spectrum obtained from a sodium vapour lamp is emission spectrum.

34. **(a)** **35.** **(a)** **36.** **(b)** **37.** **(c)**

38. **(a)** Orbital speed varies inversely as the radius $v\propto\frac{1}{n}$

39. **(c)** When the electron drops from any orbit to second orbit, then wavelength of line obtained belongs to Balmer series.

40. **(c)** **41.** **(a)** **42.** **(d)** **43.** **(a)**

44. **(d)** $\frac{1}{\lambda}=RZ^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$

For Balmer series n = 2

$$\frac{1}{\lambda_{max}}=RZ^2\left(\frac{1}{2^2}-\frac{1}{\infty^2}\right) \text{ and}$$

$$\frac{1}{\lambda_{min}}=RZ^2\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$$

$$\text{or } \frac{1/\lambda_{min}}{1/\lambda_{max}}=\frac{(1/2^2-1/3^2)}{(1/2^2)} \Rightarrow \frac{\lambda_{max}}{\lambda_{min}}=\frac{5}{9}$$

45. **(b)** $E=-3.4$ eV and $r=\frac{kze^2}{2E}$

angular momentum = mvr

$$\Rightarrow \frac{1}{2}mv^2=E=3.4\times(10^{-19}\times1.6)$$

$$\Rightarrow m^2v^2=(9.1\times10^{-31})2\times3.4\times1.6\times10^{-19}$$

$$=99.008\times10^{-50}$$

$$mv=9.95028\times10^{-25}$$

$$\therefore L=(9.95028\times10^{-25})\left(\frac{9\times10^9\times1\times(1.6\times10^{-19})^2}{2\times(3.4)}\right)$$

$$=2.10\times10^{-34}\text{ Js.}$$

46. **(b)** $\frac{1}{\lambda'}=\frac{1}{\lambda}\sqrt{\frac{c-v}{c+v}}$

Here, $\lambda'=706$ nm, $\lambda=656$ nm

$$\therefore \frac{c-v}{c+v}=\left(\frac{\lambda}{\lambda'}\right)^2=\left(\frac{656}{706}\right)^2=0.86 \Rightarrow \frac{v}{c}=\frac{0.14}{1.86}$$

$$\Rightarrow v=0.075\times3\times10^8=2.25\times10^7\text{m/s}$$

47. **(d)** For k_α line $\frac{1}{\lambda_{k_\alpha}}=R(Z-1)^2\left[\frac{1}{1^2}-\frac{1}{2^2}\right]$

$$(Z-1)^2=\frac{4}{3}\frac{1}{\lambda_{k_\alpha}}\frac{1}{R}=\frac{4}{3}\times\frac{1}{1.785\times10^{-8}}\times\frac{1}{109737}$$

$$\Rightarrow (Z-1)^2=680.6 \Rightarrow Z-1=26 \Rightarrow Z=27$$

Thus, the element is cobalt.

48. **(a)** $\frac{1}{\lambda_\alpha}=R(Z-b)^2\left[\frac{1}{1^2}-\frac{1}{2^2}\right]$

$$\Rightarrow \frac{1}{\lambda_\beta}=R(Z-b)^2\left[\frac{1}{1^2}-\frac{1}{3^2}\right]$$

$$\therefore \frac{\lambda_\beta}{\lambda_\alpha}=\frac{\left(1-\frac{1}{4}\right)}{\left(1-\frac{1}{9}\right)} \Rightarrow \lambda_\beta=\frac{27}{32}\times0.32 \Rightarrow \lambda_\beta=0.27\text{ Å}$$

49. **(a)** $\frac{(Z_{MO}-1)^2}{(Z_{Cu}-1)^2}=\frac{\lambda_{Cu}}{\lambda_{MO}}$ or $\left(\frac{41}{28}\right)^2=\frac{\lambda_{Cu}}{0.71}$

$$\therefore \lambda_{Cu}=0.71\times\left(\frac{41}{28}\right)^2=1.52\text{Å}$$

50. **(a)** For Brackett series

$$\frac{1}{\lambda_{max}}=R\left[\frac{1}{4^2}-\frac{1}{5^2}\right]=\frac{9}{25\times16}R$$

$$\text{and } \frac{1}{\lambda_{min}}=R\left[\frac{1}{4^2}-\frac{1}{\infty^2}\right]=\frac{R}{16} \Rightarrow \frac{\lambda_{max}}{\lambda_{min}}=\frac{25}{9}$$

51. **(b)** Potential energy of electron in n^{th} orbit of radius r in H-atom $U=-\frac{e^2}{r}$ (in CGS)

$$\because \text{ K.E.}=\frac{1}{2}|\text{P.E.}| \Rightarrow K=\frac{e^2}{2r}$$

52. (b) The smallest frequency and largest wavelength in ultraviolet region will be for transition of electron from orbit 2 to orbit 1.

$$\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\Rightarrow \frac{1}{122 \times 10^{-9} m} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = R\left[1 - \frac{1}{4}\right] = \frac{3R}{4}$$

$$\Rightarrow R = \frac{4}{3 \times 122 \times 10^{-9}} m^{-1}$$

The highest frequency and smallest wavelength for infrared region will be for transition of electron from ∞ to 3rd orbit.

$$\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow \frac{1}{\lambda} = \frac{4}{3 \times 122 \times 10^{-9}}\left(\frac{1}{3^2} - \frac{1}{\infty}\right)$$

$$\therefore \quad \lambda = \frac{3 \times 122 \times 9 \times 10^{-9}}{4} = 823.5\text{nm}$$

53. (a) $\frac{1}{\lambda_{min}} = R\left[\frac{1}{(1)^2} - \frac{1}{\infty}\right] \Rightarrow \lambda_{min} = \frac{1}{R} \approx 910\text{Å}.$

54. (c) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$$\Rightarrow \frac{1}{970.6 \times 10^{-10}} = 1.097 \times 10^7\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right] \Rightarrow n_2 = 4$$

$\therefore$ Number of emission line $N = \frac{n(n-1)}{2} = \frac{4 \times 3}{2} = 6$

55. (d) $r \propto n^2 \Rightarrow \pi r^2 \propto n^4$

56. (b)

57. (a) The significant result deduced from the Rutherford's scattering is that whole of the positive charge is concentrated at the centre of atom i.e. nucleus.

58. (d) When b = 0, scattering angle, $\theta = 180°$

59. (a) Distance of closest approach $r_0 = \frac{Ze(2e)}{4\pi\varepsilon_0\left(\frac{1}{2}mv^2\right)}$

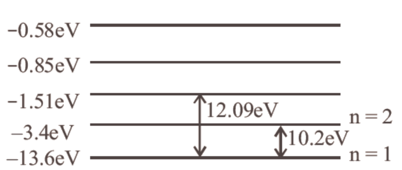
Energy, $E = 5 \times 10^6 \times 1.6 \times 10^{-19}$ J

$$\therefore r_0 = \frac{9 \times 10^9 \times (92 \times 1.6 \times 10^{-19})(2 \times 1.6 \times 10^{-19})}{5 \times 10^6 \times 1.6 \times 10^{-19}}$$

$$\Rightarrow r = 5.2 \times 10^{-14} m = 5.3 \times 10^{-12} \text{ cm.}$$

60. (a)

61. (b) Obviously, difference of 11.1eV is not possible.



62. (c) $E_n = -\frac{13.6}{n^2} \Rightarrow E_2 = -\frac{13.6}{2^2} = -3.4$ eV.

63. (a) Excitation energy $\Delta E = E_2 - E_1 = 13.6 Z^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$$\Rightarrow 40.8 = 13.6 \times \frac{3}{4} \times Z^2 \Rightarrow Z = 2.$$

Now required energy to remove the electron from ground state $= \frac{+13.6Z^2}{(1)^2} = 13.6(Z)^2 = 54.4$ eV.

64. (a) Electron after absorbing 10.2 eV energy goes to its first excited state (n = 2) from ground state (n = 1).

$\therefore$ Increase in momentum $= \frac{h}{2\pi}$

$$= \frac{6.6 \times 10^{-34}}{6.28} = 1.05 \times 10^{-34} \text{ J-s.}$$

65. (c) For Balmer series, $n_1 = 2$, $n_2 = 3$ for 1st line and $n_2 = 4$ for second line.

$$\frac{\lambda_1}{\lambda_2} = \frac{\left(\frac{1}{2^2} - \frac{1}{4^2}\right)}{\left(\frac{1}{2^2} - \frac{1}{3^2}\right)} = \frac{3/16}{5/36} = \frac{3}{16} \times \frac{36}{5} = \frac{27}{20}$$

$$\lambda_2 = \frac{20}{27}\lambda_1 = \frac{20}{27} \times 6561 = 4860 \text{ Å}$$

66. (c) Given that $E_1 = -15.6$ eV, $E_\infty = 0$ eV.

Ionization energy of the atom :

$$E_\infty - E_1 = 0 - (-15.6 \text{ eV}) = 15.6 \text{ eV}$$

So, ionization potential = 15.6 V

67. (b) For short wavelength limit of the series terminating at $n = 2$, a transition must take place from $n = \infty$ state to $n = 2$ state. For this, $\Delta E = 5.30$ eV

$$\lambda = \frac{12400}{\Delta E(eV)}\text{Å} = \frac{12400}{5.30}\text{Å} = 2339\text{Å}$$

68. (c) The excitation energy for the $n = 3$ state is

$$\Delta E = E_3 - E_1 = 15.6 - 3.08 = 12.52 \text{ eV}$$

Excitation potential = 12.52 V

69. (b) $\lambda = \frac{12400}{E_3^z - E_1^z} = \frac{12400}{12.52}\text{Å} = 990\text{Å}$

Wave number

$$= \frac{1}{\lambda} = \frac{1}{990 \times 10^{-10} m} = 1.009 \times 10^7 \text{ m}^{-1}$$

70. (c) Because excitation energy for the second shell is more than 6 eV, hence electron having initial kinetic energy of 6 eV will not interact with the atom. Because it cannot transfer its energy to the electron in the atom.

71. (c) According to postulates of Bohr's atom model the electron revolves around the nucleus in fixed orbit of definite radii. As long as the electron is in a certain orbit it does not radiate any energy.

72. **(b)** For Lyman series,

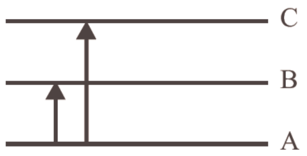
$\lambda_{max} = 4/3R$

$\lambda_{min} = 1/R$

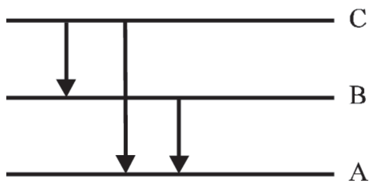
so $\frac{\lambda_{min}}{\lambda_{max}} = \frac{1}{R} \times \frac{3R}{4}$

$\frac{\lambda_{min}}{\lambda_{max}} = \frac{3}{4}$

73. **(a)** Absorption transition



Two possibilities in absorption transition.



Three possibilities in emission transition.

Therefore, absorption transition < emission.

74. **(a)** The wavelength in Balmer series is given by,

$$\Rightarrow \frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right], n = 3, 4, 5, ...$$

$$\Rightarrow \frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$$\Rightarrow \frac{1}{\lambda_{max}} = \frac{36}{5R} = \frac{36}{5 \times 1.097 \times 10^7} = 6563\text{Å}$$

$$\text{and } \frac{1}{\lambda_{min}} = R\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right]$$

$$\Rightarrow \lambda_{min} = \frac{4}{R} = \frac{4}{1.097 \times 10^7} = 3646\text{Å}$$

The wavelenth 6563Å and 3646Å lie in visible region. Therefore, Balmer series lies in visible region.

75. **(a)** Number of scattered particle, $N \propto \frac{1}{\sin^4(\theta/2)}$

Distance of closest approach,

$$r_0 = \frac{Ze^2}{mv^2 \pi \varepsilon_0} \Rightarrow r_0 \propto \frac{1}{v^2}$$

Impact parameter, $b \propto \cot(\theta/2)$

Radius of orbit, $r_n = \frac{n^2 h^2 \varepsilon_0}{\pi m Z e^2} \Rightarrow r_n \propto \frac{n^2}{Z}$

76. (Spiral) According to classical theory, the path on an electron in Rutherford atomic model is spiral.

77. (Balmer) Jump to second orbit leads to Balmer series. When an electron Jumps from 4th orbit to 2nd orbit shall give rise to second line of Balmer series.

78. (54.4) Excitation energy $\Delta E = E_2 - E_1 = 13.6 Z^2 \left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$$\Rightarrow 40.8 = 13.6 \times \frac{3}{4} \times Z^2 \Rightarrow Z = 2.$$

Now required energy to remove the electron from ground state $= \frac{+13.6Z^2}{(1)^2} = 13.6(Z)^2 = 54.4$ eV.

79. (Increases) The potentical energy of the atom increases in higher values of n.

80. (18) According to Bohr's model of atom rading of an atom in ground stateme is $r = \frac{r_0}{z}$ where r_0 is Bohr's radius and z is a atomic number. Given $r_0 = 53$ pm

The atomic number of lithium is 3, therefore, the radius of Li^{++} ion in its ground state, on the basis of Bohr's model, will be about $\frac{1}{3}$ times to that of Bohr radius.

So, the radius of lithim ion is $= \frac{r_0}{z} = \frac{53}{3} \approx 18$ pm.

81. (Integral multiple)

82. (False) Bohr's postulated that electrons in stationary orbits around the nucleus do not radiate.

83. (True)

84. (True)

85. (True)

13 Nuclei

Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. The set which represents the isotope, isobar and isotone respectively is

(a) $({}_1H^2, {}_1H^3), ({}_{79}Au^{197}, {}_{80}Hg^{198})$ and $({}_2He^3, {}_1H^2)$

(b) $({}_2He^3, {}_1H^1), ({}_{79}Au^{197}, {}_{80}Hg^{198})$ and $({}_1H^1, {}_1H^3)$

(c) $({}_2He^3, {}_1H^3), ({}_1H^2, {}_1H^3)$ and $({}_{79}Au^{197}, {}_{80}Hg^{198})$

(d) $({}_1H^2, {}_1H^3), ({}_2He^3, {}_1H^3)$ and $({}_{79}Au^{197}, {}_{80}Hg^{198})$

2. Which of the following statements are true/false for isotope?

I. Same number of protons but different number of neutrons.

II. Same number of neutrons but different number of protons.

II. Same number of protons and neutrons.

(a) F, F, F (b) F, T, F
(c) T, T, T (d) T, F, F

3. If the radius of a nucleus of mass number 3 is R, then the radius of a nucleus of mass number 81 is

(a) 3 R (b) 9 R
(c) $(27)^{1/2}$ R (d) 27 R

4. Which of the following statements are true/false?

I. Atoms of isotopes have same electronic structure.

II. Atoms of isotopes occupies same place in periodic table.

III. Atoms of isotopes have same number of protons.

IV. Atoms of isotopes have same number of neutrons.

(a) T, T, F, F (b) T, T, T, F
(c) T, T, T, T (d) F, T, F, T

5. Consider the following statements and select true/false.

I. The relative abundance of different isotopes differs from element to element.

II. Atomic species of the same element differing in mass but same number of protons are called isotopes.

III. Hydrogen has two isotopes.

(a) T, F, F (b) F, T, F
(c) T, T, F (d) T, T, T

6. 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

7. If radius of the ${}^{27}_{13}Al$ nucleus is estimated to be 3.6 fermi then the radius of ${}^{125}_{52}Te$ nucleus be nearly

(a) 8 fermi (b) 6 fermi
(c) 5 fermi (d) 4 fermi

8. The constituents of atomic nuclei are believed to be

(a) neutrons and protons

(b) protons only

(c) electrons and protons

(d) electrons, protons and neutrons.

9. The mass number of a nucleus is

(a) always less than its atomic number

(b) always more than its atomic number

(c) always equal to its atomic number

(d) sometimes more than and sometimes equal to its atomic number

10. The volume of a nucleus is directly proportional to
(a) A (b) A^3 (c) $\sqrt{A}$ (d) $A^{1/3}$

11. Outside a nucleus
(a) neutron is stable
(b) proton and neutron both are stable
(c) neutron is unstable
(d) neither neutron nor proton is stable

12. A nucleus represented by the symbol ${}_Z^A X$ has
(a) A protons and (Z-A) neutrons
(b) Z neutrons and (A-Z) protons
(c) Z protons and (A-Z) neutrons
(d) Z protons and A neutrons

13. Which of the following statement is incorrect?
(a) Atoms of isotopes have same electronic structure.
(b) Atoms of isotopes occupies same place in periodic table.
(c) Atoms of isotopes have same number of protons.
(d) Atoms of isotopes have same number of neutrons.

14. If the distance between nuclei is 2×10^{-13} cm, the density of nuclear material is
(a) 3.21×10^{-12} kg/m^3 (b) 1.6×10^{-3} kg/m^3
(c) 2×10^9 kg/m^3 (d) 1×10^{17} kg/m^3

15. Which of the following statement is incorrect ?
(a) Nuclear density is a constant for all matter.
(b) Nuclear density is around 3.3×10^{17} kg/m^3.
(c) Nuclear density is very large compared to ordinary matter.
(d) Mass of ordinary matter is mainly due to nucleus.

16. If radius of the ${}_{12}^{27}Al$ nucleus is taken to be R_{Al}, then the radius of ${}_{53}^{125}X$ nucleus is nearly:
(a) $\frac{5}{3}R_{Al}$ (b) $\frac{3}{5}R_{Al}$
(c) $\left(\frac{13}{53}\right)^{1/3} R_{Al}$ (d) $\left(\frac{53}{13}\right)^{1/3} R_{Al}$

17. Which of the following statements is true for nuclear forces?
(a) they obey the inverse square law of distance
(b) they obey the inverse third power law of distance
(c) they are short range forces
(d) they are equal in strength to electromagnetic forces.

18. If in nuclear fusion process the masses of the fusing nuclei be m_1 and m_2 and the mass of the resultant nucleus be m_3, then
(a) $m_3 > (m_1 + m_2)$ (b) $m_3 = m_1 + m_2$
(c) $m_3 = |m_1 - m_2|$ (d) $m_3 < (m_1 + m_2)$

19. Heavy water is used in nuclear reactors
(a) to absorb neutrons to sustain controlled reaction
(b) to absorb neutrons to stop the chain reaction
(c) to reduce hazardous radiation from nuclear reaction
(d) to slow down the neutrons to thermal energies

20. Which of the following nuclear reactions is not possible?
(a) ${}_6^{12}C + {}_6^{12}C \longrightarrow {}_{10}^{20}Ne + {}_2^4He$
(b) ${}_4^9Be + {}_1^1H \longrightarrow {}_3^6Li + {}_2^4He$
(c) ${}_5^{11}Be + {}_1^1H \longrightarrow {}_4^9Be + {}_2^4He$
(d) ${}_3^7Li + {}_2^4He \longrightarrow {}_1^1H + {}_4^{10}B$

21. In any fission process, the ratio
$\frac{\text{mass of fission products}}{\text{mass of parent nucleus}}$ is
(a) equal to 1
(b) greater than 1
(c) less than 1
(d) depends on the mass of the parent nucleus

22. From the following equations, pick out the possible nuclear reactions.
(a) ${}_6C^{13} + {}_1H^1 \rightarrow {}_6C^{14} + 4.3$ MeV
(b) ${}_6C^{12} + {}_1H^1 \rightarrow {}_7N^{13} + 2$ MeV
(c) ${}_7N^{14} + {}_1H^1 \rightarrow {}_8O^{16} + 7.3$ MeV
(d) ${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{54}X^{140} + {}_{38}Si^{94} + {}_{20}n^1 + \gamma + 200$ MeV

23. A nuclei having same number of neutron but different number of protons / atomic number are called
(a) isobars (b) isomers (c) isotones (d) isotopes

24. The nuclei of which one of the following pairs of nuclei are isotones?
(a) ${}_{34}Se^{74}$, ${}_{31}Ga^{71}$ (b) ${}_{38}Sr^{84}$, ${}_{38}Sr^{86}$
(c) ${}_{42}Mo^{92}$, ${}_{40}Zr^{92}$ (d) ${}_{20}Ca^{40}$, ${}_{16}S^{32}$

25. For effective nuclear forces, the distance should be
(a) 10^{-10} m (b) 10^{-13} m
(c) 10^{-15} m (d) 10^{-20} m

26. The ratio of the mass densities of nuclei of 40_{Ca} and 16_O is
(a) 5 (b) 2 (c) 0.1 (d) 1

27. Nucleus of an atom whose atomic mass is 24 consists of
(a) 11 electrons, 11 protons and 13 neutrons
(b) 11 electrons, 13 protons and 11 neutrons
(c) 11 protons and 13 neutrons
(d) 11 protons and 13 electrons

28. A nucleus splits into two nuclear parts which have their velocity ratio equal to 2 : 1. What will be the ratio of their nuclear radius?

(a) $2^{1/3} : 1$ (b) $1 : 2^{1/3}$

(c) $3^{1/2} : 1$ (d) $1 : 3^{1/2}$

29. Atomic weight of boron is 10.81 and it has two isotopes $_5B^{10}$ and $_5B^{11}$. Then ratio of $_5B^{10} : {_5B^{11}}$ in nature would be

(a) 19 : 81 (b) 10 : 11

(c) 15 : 16 (d) 81 : 19

30. The nuclear radius of $_8O^{16}$ is 3×10^{-15} m. If an atomic mass unit is 1.67×10^{-27} kg, then the nuclear density is approximately

(a) 2.35×10^{17} g cm^{-3} (b) 2.35×10^{17} kg m^{-3}

(c) 2.35×10^{17} gm^{-3} (d) 2.35×10^{17} kg mm^{-3}

31. Nuclear forces are

(a) spin dependent and have no non-central part

(b) spin dependent and have a non-central part

(c) spin independent and have no non-central part

(d) spin independent and have a non-central part

32. Two nucleons are at a separation of 1 fermi. The net force between them is F_1 if both are neutrons, F_2 if both are protons and F_3 if one is proton and the other is a neutron. Then

(a) $F_1 > F_2 > F_3$ (b) $F_1 = F_3 > F_2$

(c) $F_2 > F_1 > F_3$ (d) $F_1 = F_2 > F_3$

33. A moderator is used in nuclear reactors in order to

(a) slow down the speed of the nuetrons

(b) acceleerate the neutrons

(c) increase the number of neutrons

(d) decrease the number of neutrons

34. Fusion reactions take place at high temperature because

(a) atoms are ionised at high temperature

(b) molecules break up at high temperature

(c) nuclei break up at high temperature

(d) kinetic enrgy is high enough to overcome repulsion between nuclei

35. For a nuclear fusion process, suitable nuclei are

(a) any nuclei

(b) heavy nuclei

(c) lighter nuclei

(d) nuclei lying in the middle of periodic table

36. Fusion reaction occurs at temperatures of the order of

(a) 10^3 K (b) 10^7 K (c) 10 K (d) 10^4 K

37. Control rods used in nuclear reactors are made of

(a) stainless steel (b) graphite

(c) cadmium (d) plutonium

38. Which of the following statements is true?

(a) $_{78}Pt^{192}$ has 78 neutrons

(b) $_{84}Po^{214} \rightarrow {_{82}Pb^{210}} + \beta^-$

(c) $_{92}U^{238} \rightarrow {_{90}Th^{234}} + {_2He^4}$

(d) $_{90}Th^{234} \rightarrow {_{91}Pa^{234}} + {_2He^4}$

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

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

(b) If both **Assertion** and **Reason** are correct but Reason is **not the correct explanation** of the Assertion.

(c) If the **Assertion** is **correct** but **Reason** is **incorrect**.

(d) If the **Assertion** is **incorrect** but the **Reason** is **correct**.

39. **Assertion :** Density of all the nuclei is same.

Reason : Radius of nucleus is directly proportional to the cube root of mass number.

40. **Assertion :** Nuclear forces are independent of charges.

Reason : Nuclear force is not a central force.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

41. Match the column-I and column-II.

	Column – I		Column – II
(A)	Nuclear fusion	(1)	$E = mc^2$
(B)	Nuclear fission	(2)	Generally possible for nuclei with low atomic number
(C)	β-decay	(3)	Generally possible for nuclei with higher atomic number
(D)	Mass-energy equivalence	(4)	Essentially proceeds by weak reaction nuclear forces

(a) (A) → (2); (B) → (3); (C) → (4); (D) → (1)

(b) (A) → (4); (B) → (1); (C) → (2); (D) → (4)

(c) (A) → (1); (B) → (3); (C) → (2); (D) → (4)

(d) (A) → (3); (B) → (4); (C) → (2); (D) → (1)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

42. The nuclei $_6C^{13}$ and $_7N^{14}$ can be described as________.

43. Order of magnitude of density of uranium nucleus is ($m_p = 1.67 \times 10^{-27}$ kg)__________ kg/m^3.

44. The ratio of volumes of nuclei (assumed to be in spherical shape) with respective mass numbers 8 and 64 is________.

45. If u denotes 1 atomic mass unit. One atom of an element has mass exactly equal to Au, where A is mass number of element and is equal to _________.

46. If the radius of a nucleus ^{256}X is 8 fermi, then the radius of 4 He nucleus will be_________ fermi.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

47. The nuclear density is independent of mass number.

48. Strong nuclear force is the strongest force in nature.

49. Nuclear force is charge dependent.

50. Radius of nucleus (R) is related to mass number (A) as $R = R_0A^{1/2}$ where R_0 is a constant.

ANSWER KEY & SOLUTIONS

1. **(d)** ${}_1H^2$ and ${}_1H^3$ are isotopes
   ${}_2He^3$ and ${}_1H^3$ are isobars
   ${}_{79}Au^{197}$ and ${}_{80}Hg^{198}$ are isotones.
2. **(d)** For is isotsope Z is same and A is different. Therefore the number of neutrons A-Z will also be different.
3. **(a)**
4. **(b)** The nuclei having equal number of neutrons called isotones.
5. **(c)** Hydrogen has three isotopes.
6. **(b)** The moderator used have light nuclei (like proton). When protons undergo perfectly elastic collision with the neutron emitted their velocities are exchanged, i.e., neutrons come to rest and protons move with the velocity of neutrons. To slowdown the speed of neutrons substance should be made up of proton for perfectly elastic i.e., we need light nuclei not heavy nuclei because heavy nuclei will not serve the purpose because elastic collisions of neutrons with heavy nuclei will not slow them down or speed but only direction will change.
7. **(b)** $R = R_0(A)^{1/3}$

$$\therefore \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5}$$

$$R_2 = \frac{5}{3} \times 3.6 = 6 \text{ fermi}$$

8. **(a)** Nucleus contains only neutrons and protons.
9. **(d)** In hydrogen, atomic number and mass number are equal.
10. **(a)** Radius of nucleus $R = R_0A^{1/3}$ where A is the mass number of nucleus.

$$\therefore \text{Volume of nucleus} = \frac{4}{3}\pi R^3 = \left(\frac{4}{3}\pi R_0^3\right)A$$

   $\therefore$ Volume is proportional to A.
11. **(c)** Out side the nucleus, neutron is unstable (life ≈ 932 s).
12. **(c)** ${}_Z^AX$ has Z protons and $(A - Z)$ neutrons
13. **(d)**
14. **(d)** Density of nuclear material = mass/volume

$$= \frac{10^{-27}}{\frac{4}{3}\pi r^3} = \frac{3 \times 10^{-27}}{4\pi(2 \times 10^{-15})^3} = 10^{17} \text{ kg/m}^3$$

15. **(b)** As $R \propto A^{1/3}$ and volume of nucleus is proportional to R^3 is proportional to A. Thus, the density of nucleus is a constant, independent of A, for all nuclei. Different nuclei are likes drop of liquid of constant density. The density of nuclear matter is approximately 2.3×10^{17} kg m^{-3}.
   This density is very large compared to ordinary matter, say water which is 10^{23} kg m^{-3}. This is understandable, as we have already seen that most of the atom is empty. Ordinary matter consisting of atoms has a large amount of empty space.
16. **(a)** As we know, $R = R_0 (A)^{1/3}$
   where A = mass number
   $R_{AI} = R_0 (27)^{1/3} = 3R_0$

$$R_X = R_0 (125)^{1/3} = 5R_0 = \frac{5}{3} R_{AI}$$

17. **(c)** Nuclear forces are short range attractive forces which balance the repulsive forces between the protons inside the nucleus.
18. **(d)** $m_3 < (m_1 + m_2)$ $(\because m_1 + m_2 = m_3 + E]$
   as $E = [m_1 + m_2 - m_3] C^2$
19. **(d)** Heavy water is used in nuclear reactors to slow down the neutrons to thermal energies to initiate the nuclear reaction.
20. **(c)** In this reaction mass is not conserved.
21. **(c)** Binding energy per nucleon for fission products is higher relative to Binding energy per nucleon for parent nucleus, i.e., more masses are lost and are obtained as kinetic energy of fission products. So, the given ratio < 1.
22. **(b)** **23. (c)**
24. **(a)** Isotones means equal number of neutrons *i.e.*, $(A–Z)$ $= 74 - 34 = 71 - 31 = 40$.
25. **(c)**
26. **(d)** Nuclear density is independent of atomic number.
27. **(c)** Nucleus does not contain electron.
28. **(b)** As momentum is conserved, therefore,

$$\frac{m_1}{m_2} = \frac{A_1}{A_2} = \frac{v_2}{v_1} = \frac{1}{2}$$

$$\therefore \quad \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{2}\right)^{1/3} = 1 : 2^{1/3}$$

29. **(a)** Let the percentage of B^{10} atoms be x, then average atomic weight

$$= \frac{10x + 11(100 - x)}{100} = 10.81 \Rightarrow x = 19$$

$\therefore \frac{N_{B^{10}}}{N_{B^{11}}} = \frac{19}{81}$

30. **(b)** For nucleus of $_8O^{16}$

Mass = (16) (1.67×10^{-27}) kg

$$\text{Volume} = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi(3\times10^{-15})^3\,m^3 = 36\pi \times 10^{-45}\,m^3$$

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{16\times1.67\times10^{-27}\text{kg}}{36\pi\times10^{-45}m^3}$$

$$= 2.35 \times 10^{17}\ \text{kgm}^{-3}$$

31. **(b)**

32. **(b)** In case of Proton-Proton Electrostatic repulsive force is also present which reduces the net force.

33. **(c)** Moderator slows down neutrons.

34. **(d)** Extremely high temps needed for fusion make K.E. large enough to overcome repulsion between nuclei.

35. **(c)** **36.** **(b)**

37. **(c)** Control rods are made of cadmium.

38. **(c)**

39. **(a)** Density, $\rho = \frac{M}{V} = \frac{A}{\frac{4}{3}\pi r^3}$

$$= \frac{A}{\frac{4}{3}\pi(r_0A^{1/3})^3} = \frac{1}{\left(\frac{4}{3}\pi r_0^3\right)} = \text{constant}$$

40. **(b)**

41. **(a)** (A) $\rightarrow$ (2); (B) $\rightarrow$ (3); (C) $\rightarrow$ (4); (D) $\rightarrow$ (1)

42. (Isotones) As $_6C^{13}$ and $_7N^{14}$ have same no. of neutrons (13 – 6 = 7 for C and 14 – 7 = 7 for N), so they are isotones.

43. (10^{17}) The order of magnitude of mass and volume of uranium nucleus will be

$m \simeq A\,(1.67 \times 10^{-27}$ kg) (A is atomic number)

$$V = \frac{4}{3}\pi r^3 \simeq \frac{4}{3}\pi[(1.25\times10^{-15}\,m)A^{1/3}]^3$$

$$\simeq (8.2 \times 10^{-45} m^3)A$$

$$\text{Hence, } \rho = \frac{m}{V} = \frac{A(1.67\times10^{-27}\,kg)}{(8.2\times10^{-45}\,m^3)A}$$

$$\simeq 2.0 \times 10^{17}\ kg/m^3.$$

44. (0.125) As we know $R = R_0 A^{1/3}$

$\therefore R \propto A^{1/3}$

As, $V \propto R^3$ or $V \propto A$

$$\therefore \frac{V_1}{V_2} = \frac{8}{64} = \frac{1}{8} = 0.125$$

45. (1) A = 1

46. (2) $R = R_0(A)^{1/3}$

$$\therefore \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{256}{4}\right)^{1/3} = 4$$

$$R_2 = \frac{R_1}{4} = \frac{8}{4} = 2\ \text{fermi}$$

47. (True) The order of nuclear density is 10^{17}.

48. (True)

49. (False)

50. (False) Radius $R = R_0A^{1/3}$

14 Semiconductor Electronics : Materials, Devices and Simple Circuits

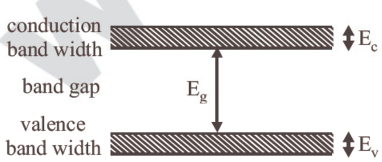
Multiple Choice Questions (MCQs)

DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. The electrical conductivity of pure germanium can be increased by
(a) increasing the temperature
(b) doping acceptor impurities
(c) doping donor impurities
(d) All of the above

2. Which of the following statements is/are true/false ?
I. Pure Si doped with trivalent impurities gives a p-type semiconductor.
II. Majority carriers in a *n*-type semiconductor are holes.
III. Minority carriers in a *p*-type semiconductor are electrons.
IV. The resistance of intrinsic semiconductor decreases with increase of temperature.
(a) T, F, F, F (b) T, F, T, T
(c) T, F, F, T (d) F, T, F, F

3. If the lattice constant of this semiconductor is decreased, then which of the following is correct?



(a) All E_c, E_g, E_v increase
(b) E_c and E_v increase, but E_g decreases
(c) E_c and E_v decrease, but E_g increases
(d) All E_c, E_g, E_v decrease

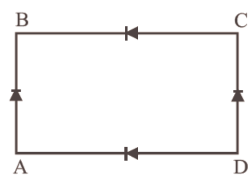
4. On doping germanium with donor atoms of density 10^{17} cm^{-3} its conductivity in mho/cm will be
[Given : $\mu_e = 3800$ cm^2/V–s and $n_i = 2.5 \times 10^{13}$ cm^{-13}]
(a) 30.4 (b) 60.8
(c) 91.2 (d) 121.6

5. These are used for doping
I. A trivalent impurity. II. A tetravalent impurity.
III. A pentavalent impurity. IV. A monovalent impurity.
Select the true/false statements from above
(a) T, T, F, F (b) F, T, F, T
(c) F, T, T, F (d) T, F, T, F

6. If the forward bias on *p-n* junction is increased from zero to 0.045 V, then no current flows in the circuit. The contact potential of junction i.e. V_B is
(a) zero (b) 0.045 V
(c) more than 0.045 V (d) less than 0.045 V

7. Rectifier converts
(a) ac into dc (b) dc into ac
(c) both (a) and (b) (d) None of the above

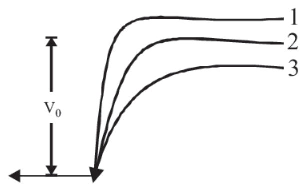
8. In fig., the input is across the terminals A and C and the output is across B and D. Then the output is



(a) zero (b) same as the input
(c) half wave rectified (d) full wave rectified

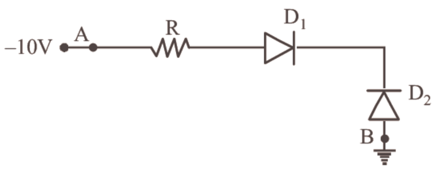
9. The conductivity of a semiconductor increases with increase in temperature because
(a) number density of free current carries increases
(b) relaxation time increases
(c) both number density of carries and relaxation time increase
(d) number density of carries increases, relaxation time decreases but effect of decrease in relaxation time is much less than increase in number density

10. In figure given below V_0 is the potential barrier across a p–n junction, when no battary is connected across the junction

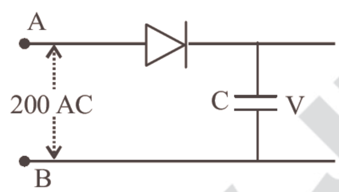


(a) 1 and 3 both correspond to forward bias of junction
(b) 3 corresponds to forward bias of junction and 1 corresponds to reverse bias of junctions
(c) 1 corresponds to forward bias and 3 corresponds to reverse bias of junction
(d) 3 and 1 both correspond to reverse bias of junction

11. In figure given below, 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



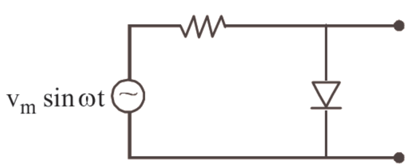
12. A 220 V AC supply is connected between points A and B (figure). What will be the potential difference V across the capacitor?



(a) 220 V (b) 110 V
(c) 0 V (d) $220\sqrt{2}$ V

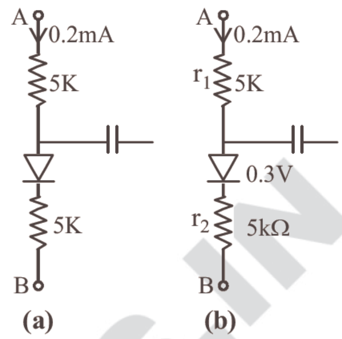
13. Hole in semiconductor is
(a) an anti – particle of electron
(b) a vacancy created when an electron leaves a covalent bond
(c) absence of free electrons
(d) an artificially created particle

14. The output of the given circuit in figure given below,



(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

15. In the circuit shown in figure given below, if the diode forward voltage drop is 0.3 V, the voltage difference between A and B is



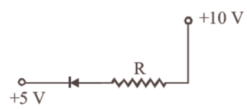
(a) 1.3 V (b) 2.3 V
(c) 0 (d) 0.5 V

16. Electric conduction in a semiconductor takes place due to
(a) electrons only
(b) holes only
(c) both electrons and holes
(d) neither electrons nor holes

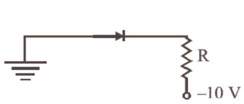
17. The depletion layer in the p-n junction region is caused by
(a) drift of holes only
(b) diffusion of charge carriers
(c) migration of impurity atoms
(d) drift of electrons only

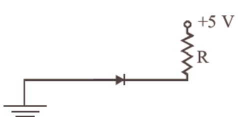
18. The forbidden energy gap for germanium crystal at 0 K is
(a) 0.071 eV (b) 0.71 eV
(c) 2.57 eV (d) 6.57 eV

19. Of the diodes shown in the following diagrams, which one is reverse biased?

(a)


(b)


(c)


(d)


20. In a semiconductor
(a) there are no free electrons at 0 K
(b) there are no free electrons at any temperature
(c) the number of free electrons increases with pressure
(d) the number of free electrons is more than that in a conductor

21. Let n_h and n_e be the number of holes and conduction electrons in an extrinsic semiconductor. Then
(a) $n_h > n_e$ (b) $n_h = n_e$
(c) $n_h < n_e$ (d) $n_h \neq n_e$

22. In semiconductors, at room temperature
(a) the conduction band is completely empty
(b) the valence band is partially empty and the conduction band is partially filled
(c) the valence band is completely filled and the conduction band is partially filled
(d) the valence band is completely filled

23. The mobility of free electrons is greater than that of free holes because
(a) they are light
(b) they carry negative charge
(c) they mutually colllide less
(d) they require low energy to continue their motion

24. In a p-type semiconductor, the acceptor valence band is
(a) close to the valence band of the host crystal
(b) close to conduction band of the host crystal
(c) below the conduction band of the host crystal
(d) above the conduction band of the host crystal

25. A piece of copper and another of germanium are cooled from room temperature to 77K, the resistance of
(a) copper increases and germanium decreases
(b) each of them decreases
(c) each of them increases
(d) copper decreases and germanium increases

26. Select the incorrect statement from the following.
(a) In conductors, the valence and conduction bands may overlap.
(b) Substances with energy gap of the order of 10 eV are insulators.
(c) The resistivity of a semiconductor increases with increase in temperature.
(d) The conductivity of a semiconductor increases with increase in temperature.

27. Which of the following statements is incorrect?
(a) Pure Si doped with trivalent impurities gives a p-type semiconductor
(b) Majority carriers in a n-type semiconductor are holes
(c) Minority carriers in a p-type semiconductor are electrons
(d) The resistance of intrinsic semiconductor decreases with increase of temperature

28. In a n-type semiconductor, which of the following statements is correct?
(a) Electrons are minority carriers and pentavalent atoms are dopants.
(b) Holes are minority carriers and pentavalent atoms are dopants.
(c) Holes are majority carriers and trivalent atoms are dopants.
(d) Electrons are majority carriers and trivalent atoms are dopants.

29. When n-type semiconductor is heated
(a) number of electrons increases while that of holes decreases
(b) number of holes increases while that of electrons decreases
(c) number of electrons and holes remain same
(d) number of electrons and holes increases equally.

30. The difference in the variation of resistance with temeperature in a metal and a semiconductor arises essentially due to the difference in the
(a) crystal sturcture
(b) variation of the number of charge carriers with temperature
(c) type of bonding
(d) variation of scattering mechanism with temperature

31. Choose the only false statement from the following.
(a) In conductors, the valence and conduction bands may overlap.
(b) Substances with energy gap of the order of 10 eV are insulators.
(c) The resistivity of a semiconductor increases with increase in temperature.
(d) The conductivity of a semiconductor increases with increase in temperature.

32. In a semiconductor diode, the barrier potential offers opposition to
(a) holes in P-region only
(b) free electrons in N-region only
(c) majority carriers in both regions
(d) majority as well as minority carriers in both regions

33. If the ratio of the concentration of electrons to that of holes in a semiconductor is 7/5 and the ratio of currents is 7/4, then what is the ratio of their drift velocities?
(a) 5/8 (b) 4/5
(c) 5/4 (d) 4/7

34. The electrical conductivity of pure germanium can be increased by
(a) increasing the temperature
(b) doping acceptor impurities
(c) doping donor impurities
(d) All of the above

35. The resistivity of a semiconductor at room temperature is in between
(a) 10^{-2} to $10^{-5}\ \Omega$ cm (b) 10^{-3} to $10^{6}\ \Omega$ cm
(c) 10^{6} to $10^{8}\ \Omega$ cm (d) 10^{10} to $10^{12}\ \Omega$ cm

36. The relation between number of free electrons (n) in a semiconductor and temperature (T) is given by
(a) $n \propto T$ (b) $n \propto T^2$
(c) $n \propto \sqrt{T}$ (d) $n \propto T^{3/2}$

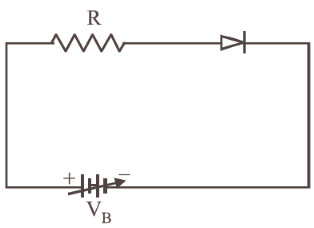
Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

P-N Junction Diode and its Characteristics

A Si diode (p-n junction) is connected to a resistor and a biasing battery of variable voltage V_B. Assume that the diode requires a minimum current of 1 mA to be above the knee point 0.7 V of its V-I characteristic curve. Also assume that the voltage V across the diode is independent of current above the knee (cut-off) point



37 If $V_B = 5V$, then the maximum value of R so that the voltage V is above the knee point voltage, should be

(a) 0.7 kΩ (b) 4.3 kΩ
(c) 5 kΩ (d) 5.7 kΩ

38. If V_B = 5V, then the value of R in order to establish a current of 5 mA in the circuit, will be

(a) 140 Ω (b) 215 Ω
(c) 430 Ω (d) 860 Ω

39. If V_B = 6V and 5mA current flows through the circuit, then the power dissipated in R will be

(a) 32.6 mW (b) 26.4 mW
(c) 3.26 mW (d) 2.6 mW

40. A semiconductor device is connected in a series circuit with a battery and a resistance. A current is found to pass through the circuit. If the polarity of the battery is reversed, the current drops to almost zero. The device may be a/an

(a) intrinsic semiconductor
(b) p-type semiconductor
(c) n-type semiconductor
(d) p-n junction diode

41 The drift current in a p-n junction is

(a) from the n-side to the p-side
(b) from the p-side to the n-side
(c) from the n-side to the p-side if the junction is forward-biased and in the opposite direction if it is reverse biased
(d) from the p-side to the n-side if the junction is forward-biased and in the opposite direction if it is reverse-biased

Case/Passage-II

Rectifier is a device which converts ac to dc.
Junction diode allows current to pass through only if it is forward biased, hence a pulsating voltage will appear across the load only during positive half cycles when diode is F.B. Here, reverse breakdown voltage of diode must be higher than peak a.c. voltage at the secondary of the transformer to prevent breakdown of diode.

42. The average value of output direct current in a half wave rectifier is

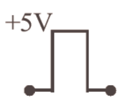
(a) I_0/π (b) $I_0/2$ (c) $\pi I_0/2$ (d) $2I_0/\pi$

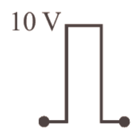
43. The average value of output direct current in a full wave rectifier is

(a) I_0/π (b) $I_0/2$ (c) $\pi I_0/2$ (d) $2I_0/\pi$

44. If in a p-n junction diode, a square input signal of 10 V is applied as shown

Then the output signal across R_L will be

(a) 

(b) 

(c) 

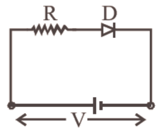
(d) 

45. In the half wave rectifier circuit operating from 50 Hz mains frequency, the fundamental frequency in the ripple would be

(a) 25 Hz (b) 50 Hz (c) 70.7 Hz (d) 100 Hz

46. A d.c. battery of V volt is connected to a series combination of a resistor R and an ideal diode D as shown in the figure below. The potential difference across R will be

(a) 2V when diode is forward biased
(b) zero when diode is forward biased
(c) V when diode is reverse biased
(d) V when diode is forward biased



Case/Passage-III

The electric conductivity of an intrinsic semiconductor increases when the electromagnetic waves of wavelength equal or shorter than 2475 nm is incident on it. The charge carrier concentration of this semiconductor at room temperature is $1.6 \times 10^{16}\ m^{-3}$ and the mobilities of electrons and holes at the same temperature are $0.4\ m^2\ V^{-1}\ S^{-1}$ and $0.2\ m^2\ V^{-1} S^{-1}$ respectively.

47. The forbidden energy gap of the semiconductor is

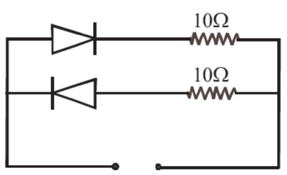
(a) 0.2 eV (b) 0.5 eV (c) 1.0 eV (d) 1.5 eV

48. Conductivity of the semiconductor is
(a) $1.54 \times 10^{-2}\ Sm^{-1}$ (b) $1.54 \times 10^{-3}\ Sm^{-1}$
(c) $1.54 \times 10^{-4}\ Sm^{-1}$ (d) $1.54 \times 10^{-5}\ Sm^{-1}$

49. If a battery of 5V is connected across a plate of the semiconductor of area $2 \times 10^{-4}\ m^2$ and thickness 1.2×10^{-3} m, then the current flowing through the plate is
(a) 0.32 mA (b) 0.64 mA
(c) 1.28 mA (d) 2.56 mA

50. When the forward bias voltage of a diode is changed from 0.6 V to 0.7 V, the current changes from 5 mA to 15 mA. Then its forward bias resistance is
(a) 0.01 Ω (b) 0.1 Ω
(c) 10 Ω (d) 100 Ω

51. A 2-V battery is connected across the points A and B as shown in the figure given below. Assuming that the resistance of each diode is zero in forward bias, and infinity in reverse bias, the current supplied by the battery when its positive terminal is connected to A, is



(a) 0.2 A (b) 0.4 A (c) 0.3A (d) 0.1 A

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*
(a) If both **Assertion** and **Reason** are **correct** and the Reason is the **correct explanation** of the Assertion.
(b) If both **Assertion** and **Reason** are correct but Reason is **not the correct explanation** of the Assertion.
(c) If the **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If the **Assertion** is **incorrect** but the **Reason** is **correct**.

52. **Assertion :** In semiconductors, thermal collisions are responsible for taking a valence electron to the conduction band.
Reason : The number of conduction electrons go on increasing with time as thermal collisions continuously take place.

53. **Assertion :** In an energy band, the highest energy level occupied by electron at 0K is called fermi level and its energy is called fermi-energy.
Reason : The band seperating the valence band and conduction band is callled forbidden energy gap.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

54. Match the column I and Column II

Column I	Column II (Range of resistivity, ρ)
(A) Metals	(1) $10^{11} - 10^{19}\ \Omega$ m
(B) Semiconductors	(2) $10^{-5} - 10^{6}\ \Omega$ m
(C) Insulators	(3) $10^{-2} - 10^{-8}\ \Omega$ m

(a) (A) → (3); (B) → (2); (C) → (1)
(b) (A) → (1); (B) → (2); (C) → (3)
(c) (A) → (1); (B) → (2); (C) → (3)
(d) (A) → (1); (B) → (2); (C) → (3)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

55. In N-type semiconductor, _________ are majority and _____ are minority charge carriers.

56. In ________ semiconductor, the fermi level lies in the energy gap, very close to conduction band.

57. A p-n photodiode is made of a material with a band gap of 2.0eV. The minimum frequency of the radiation that can be absorbed by the material is nearly _______.

58. In general maximum rectification efficiency for a half wave recifier is _______.

59. Temperature coefficient of resistance of semiconductor is _______.

60. At absolute zero, Si acts as _______.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

61. A p-n junction with forward bias can be used as a photodiode to measure light intensity.

62. In a reverse bias condition the current is small but is more sensitive to changes in incident light intensity.

63. Silicon is preferred over germanium for making semiconductor devices.

64. Electron has higher mobility than hole in a semiconductor.

ANSWER KEY & SOLUTIONS

1. **(d)** Electrical conductivity of pure germanium can be increased by increasing acceptor or donor impurities. Also by increasing temperature.
2. **(b)** Majority carriers in an *n*-type semiconductor are electrons.
3. **(c)** A crystal structure is composed of a unit cell, a set of atoms arranged in a particular way; which is periodically repeated in three dimensions on a lattice. The spacing between unit cells in various directions is called its lattice parameters or constants. Increasing these lattice constants will increase or widen the band-gap (E_g), which means more energy would be required by electrons to reach the conduction band from the valence band. Automatically E_c and E_v decreases.
4. **(b)** Conductivity $\sigma = n_i e \mu_e$
$= 10^{17} \times (1.6 \times 10^{-19}) \times 3800$
$= 60.8$ mho/cm
5. **(d)** The process of addition of impurity is called doping. The impurities are pentavalent and trivalent.
6. **(c)** When no current flows at the junction plane, then contact potential of junction plane is equal to the forward voltage applied = 0.045 V
7. **(a)** Rectifier is a device which converts ac into dc.
8. **(d)** It is the circuit of full wave rectifier.
9. **(c)**
10. **(b)** The depletion layer in the p-n junction region is caused by diffusion of charge carriers.
11. **(b)** 12. **(d)**
13. **(b)** Atom of semiconductor are bounded by covalent bonds between the atoms of same or different type. The concept of hole describes the lack of an electron at a position where one could exist in an atom or atomic lattice. If an electron is excited into a higher state, it leaves a hole in its old state. So, hole can be defined as a vacancy created when an electron leaves a covalent bond.
14. **(c)** When the diode will be in forward biased during positive half cycle of input AC voltage, the resistance of p–n junction is low. The current in the circuit is maximum. So, a maximum potential difference will appear across resistance connected in series of circuit. So, potential across PN junction will be zero. When the diode will be in reverse biase during negative half cycle of AC voltage, the resistance of p–n juntion becomes high which will be more than resistance in series. So, there will be voltage across p–n junction with negative cycle in output.
15. **(b)** Let the potential difference between A and B is V, Given here $r_1 = 5$ kΩ and $r_2 = 5$ kΩ are resistance in series connection.
So,
$V_{AB} - 0.3 = [(r_1 + r_2)\ 10^3] \times (0.2 \times 10^{-3})]$
$[\because V = ir]$
$(V_{AB} - 0.3) = 10 \times 10^3 \times 0.2 \times 10^{-3} = 2$
So, $V_{AB} = 2 + 0.3 = 2.3$ V
16. **(d)** In semiconductor the density of change carriers (electron hole) are very small, so its resistance is high when the conductivity of a semiconductor increases with increase in temperature, because the number density of current carries increases then the speed of free electron increase and relaxation time decreases but effect of decrease in relaxation is much less than increase in number density.
17. **(b)** When p–n junction is forward biased then the depleton layer is compresses or decrease so it opposes the potential junction resulting decrease in potential barrier junction when p–n junction is reverese biased, it supports the potential barrier junction, resulting increase in potential across the junction.
18. **(b)** 19. **(d)**
20. **(a)** In a semiconductor, no free electrons at 0k.
21. **(d)** In extrinsic semi conductor the number of holes are not equal to number of electrons i.e., $n_h \neq n_e$
In p - type $n_h > n_e$
In n - type $n_e > n_h$
22. **(c)** 23. **(a)**
24. **(a)** The acceptor valence band is close to the valence band of host crystal
25. **(d)** Copper is a conductor, so its resistance decreases on decreasing temperature as thermal agitation decreases,; whereas germanium is semiconductor therefore on decreasing temperature resistance increases
26. **(c)**
27. **(b)** Majority carriers in an n-type semiconductor are electrons.
28. **(b)** In a n-type semiconductor holes are minority carriers and pentavalent atoms are dopants.
29. **(d)** Due to heating, when a free electron is produced then simultaneously a hole is also produced.
30. **(b)** When the temperature increases, certain bounded electrons become free which tend to promote conductivity. Simultaneously, number of collisions between electrons and positive kernels increases
31. **(c)** 32. **(c)**
33. **(c)** $\frac{I_e}{I_h} = \frac{n_e e A v_e}{n_h e A v_h} \Rightarrow \frac{7}{4} = \frac{7}{5} \times \frac{v_e}{v_h} \Rightarrow \frac{v_e}{v_h} = \frac{5}{4}$

34. **(d)**

35. **(b)** Resistivity of a semiconductor at room temp. is in between $10^{-5}\ \Omega m$ to $10^{4}\ \Omega m$ i.e. 10^{-3} to $10^{6}\ \Omega cm$

36. **(d)** For semiconductor, $n = AT^{3/2} e^{-\frac{E_g}{2KT}}$;

so $n \propto T^{3/2}$

37. **(b)** $V_B = I(R_D + R)$ $(1 \times 4 = 4 \text{ marks})$

$\Rightarrow 5 = 1 \times 10^{-3}\left(\frac{0.7}{10^{-3}} + R\right)$

$\Rightarrow R = 4.3\ k\Omega$

38. **(d)** $V_B = I(R_D + R)$

$\Rightarrow 5 = 5 \times 10^{-3}\left(\frac{0.7}{5mA} + R\right)$

$\Rightarrow 1\ k\Omega = 180\Omega + R$

$\Rightarrow R = 860\Omega$

39. **(b)** Power $= VI = (6 - 0.7) \times 5 \times 10^{-3}\ W = 26.4\ mW$

40. **(d)** 41. **(a)**

42. **(a)** The average value of output direct current in a half wave rectifier is = (average value of current over a cycle) $2 = (2\ I_0/\pi)/2 = I_0/\pi$

43. **(d)** The average value of output direct current in a full wave rectifier = average value of current over a cycle $= 2\ I_0/\pi$

44. **(a)** The current will flow through R_L when the diode is forward biased.

45. **(b)** In half wave rectifier, we get the output only in one half cycle of input a.c. therefore, the frequency of the ripple of the output is same as that of input a.c. *i.e.*, 50 Hz.

46. **(c)**

47. **(b)** Forbidden energy gap $= \frac{12400\ (eV - Å)}{\lambda\ (Å)}$

$= \frac{12400}{24750} eV = 0.5\ eV$

48. **(b)** $\sigma = ne(\mu_e + \mu_h) = 1.6 \times 10^{16} \times 1.6 \times 10^{-19}(0.4 + 0.2)$
$= 1.54 \times 10^{-3}\ Sm^{-1}$

49. **(c)** $\rho = \frac{1}{\sigma} = \frac{1}{1.54 \times 10^{-3}}$

$I = \frac{V}{R} = \frac{V}{\frac{\rho L}{A}} = \frac{5}{\frac{1}{1.54 \times 10^{-3}}} \times \frac{2 \times 10^{-4}}{1.2 \times 10^{-3}} = 1.28\ mA$

50. **(c)** Forward bias resistance $= \frac{\Delta V}{\Delta I}$

$= \frac{(0.7 - 0.6)V}{(15 - 5)mA} = \frac{0.1}{10 \times 10^{-3}} = 10\Omega.$

51. **(a)** As one of the diodes (the lower one) will be in reverse bias, no current will pass through it, so the effective resistance of the circuit $= 10\ \Omega$.

$\therefore$ Current in the circuit $= \frac{2\ V}{10\ \Omega} = 0.2\ A$

52. **(c)** Sometimes, thermal collisions do not provide sufficient energy to the electron to jump. Also, energy is last in the form of heat because of the collision of the carriers with other charge carriers and atoms. Because of all these losses only few electrons are left with sufficient energy to jump from VB to CB. So the population of electron in the CB does not keep on increasing with time.

53. **(b)**

54. **(a)** (A) $\rightarrow$ (3); (B) $\rightarrow$ (2); (C) $\rightarrow$ (1)

55. (Electrons, holes)

56. (*n*-type semiconductor)

57. $(5 \times 10^{14}$ Hz)

58. (40.6%) $\eta = \frac{0.406}{1 - \frac{R_f}{R_L}}$

$\%\ \eta_{max} = 40.6\%$ $\left(\text{if } \frac{R_f}{R_L} \ll 1\right)$

59. (Negative) The temperature coefficient of resistance of a semiconductor is negative. It means that resistance decrease with increase of temperature.

60. (Insulator) Semiconductors are insulators at low temperature

61. (False) When photo-diode is used in reverse barrier are proportional to the amount of light incident on the diode.

62. (True) A current is generated in a depletion region due to the absorbed light. This amount of current is proportional to the light inensity.

63. (True) The energy gap for germanium is less than the energy gap of Si. The structure of Germanium crystals will be distroyed at higher temperature.

64. (True)