CLASS-XII (CBSE)

# Physics

## Workbook Cum Question Bank with Answers

SCHEDULED CASTES & SCHEDULED TRIBES
RESEARCH & TRAINING INSTITUTE (SCSTRTI)
ST & SC DEVELOPMENT DEPARTMENT
BHUBANESWAR

# PHYSICS

## Workbook Cum Question Bank with Answers

## CLASS-XII (CBSE)

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# CONTENT

# CHAPTER ONE

## (ELECTRIC CHARGES AND FIELDS – (I))

### Section –A

### Multiple Choice Questions (MCQ)

1. **Four charges equal to $-Q$ are placed at the four corners of a square and a charge $q$ is at it centre. If the system is in eq uilibrium, he value of $q$ is:**

   **(a)** $-\frac{Q}{4}$

   **(b)** $\frac{Q}{4}\left(1+2\sqrt{2}\right)$

   **(c)** $-\frac{Q}{2}\left(1+2\sqrt{2}\right)$

   **(d)** $\frac{Q}{2}\left(1+2\sqrt{2}\right)$

2. **Two spherical conductors A and B of radii 1 mm and 2mm are separated by a distance of 5cm and are uniformly charged. If the spheres are connected by a conducting wire then in equilibrium condition, the ratio of the magnitude of the electric fields at the surface of spheres A and B is**

   **(a)** 1 : 4

   **(b)** 4 : 1

   **(c)** 1 : 2

   **(d)** 2 : 1

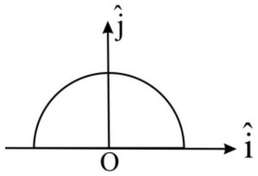
3. **A thin semi-circular ring of radius r has a positive charge $q$ distributed uniformly over it. The net field $\vec{E}$ . At the centre $O$.**

   **(a)** $\frac{q}{4\pi^2\varepsilon_0 r^2}\,\hat{j}$

   **(b)**$-\frac{q}{4\pi^2\varepsilon_0 r^2}\,\hat{j}$

   **(c)** $-\frac{q}{2\pi^2\varepsilon_0 r^2}\,\hat{j}$

   **(d)** $\frac{q}{2\pi^2\varepsilon_0 r^2}\,\hat{j}$




4. **Which one of the following is the unit of electric field?**

   **(a)** Coulomb
   **(b)** Newton
   **(c)** Volt
   **(d)** N/C

5. **Three charges + 3q, + q and Q are placed on a st. line with equal separation. In order to make it the net force on q to be zero, the value of Q will be :**

   **(a)** +3q
   **(b)** +2q
   **(c)** -3q
   **(d)** -4q

6. **If an electric dipole is kept in a uniform electric field then resultant electric force on it is :**
   **(a)** always zero
   **(b)** never zero
   **(c)** depend upon capacity of dipole
   **(d)** **N**one of the above

7. **The number of electrons taken out from a body to produce 1 coulomb of charge will be :**
   **(a)** $6.25 \times 10^{18}$
   **(b)** $625 \times 10^{18}$
   **(c)** $6.023 \times 10^{23}$
   **(d)** None of the above

8. **The work done in rotating an electric dipole in an electric field from most stable equilibrium position to another position at which angle between dipole moment and magnetic field is $\theta$:**
   **(a)** $W = pE(1 - \cos\theta)$
   **(b)** $W = pE \tan\theta$
   **(c)** $W = pE \sec\theta$
   **(d)** None of the above

9. **If sphere of bad conductor is given charge then it is distributed on:**
   **(a)** surface
   **(b)** inside the surface
   **(c)** only inside the surface
   **(d)** None of the above

10. **Electric field in a cavity of metal:**
    **(a)** depends upon the surroundings
    **(b)** depends upon the size of cavity
    **(c)** is always zero
    **(d)** is not necessarily zero

11. **The dielectric constant of a metal is:**
    **(a)** 0 **(b)** 1
    **(c)** ∞ **(d)** $-1$

12. **1 coulomb is equal to:**
    **(a)** $3 \times 10^9\ e.s.u.$
    **(b)** $13 \times 10^9\ e.s.u$
    **(c)** $3 \times 10^{10} e.s.u.$
    **(d)** $13 \times 10^{10}\ e.s.u$

13. **Each of the two point charges are doubled and their distance is halved. Force of interaction becomes p times, where p is :**
    **(a)** 1 **(b)** 4
    **(c)** 1/16 **(d)** 16

14. **$\varepsilon_0$ is the permittivity of free space. The SI units of $\varepsilon_0$ will be :**
    **(a)** $N^{-1}m^{-2}C^{-2}$
    **(b)** $Nm^{-2}C^2$
    **(c)** $N^{-1}m^{-2}C^2$
    **(d)** $Nm^{-2}C^2$

15. **When placed in a uniform field making angle ϴ with magnetic field, dipole experiences:**
    **(a)** a net force
    **(b)** a torque
    **(c)** both a net force and torque
    **(d)** neither a net force nor a torque

**16. The SI units of electric dipole moment are:**

**(a)** C **(b)** $Cm^{-1}$

**(c)** Cm **(d)** $Nm^{-1}$

**17. An electric dipole of moment p is placed parallel to the uniform electric field. The amount of work done in rotating the dipole by 90° is-**

**(a)** 2pE **(b)** pE

**(c)** pE/2 **(d)** Zero

**18. In non-uniform electric field, electric dipole experiences:**

**(a)** torque only

**(b)** torque as well as net force

**(c)** force only

**(d)** None of these

**19. An electron is sent in an electric field of magnitude $9.1 \times 10^6 NC^{-1}$. The acceleration produced in it is**

**(a)** $1.6\, ms^{-2}$

**(b)** $1.6 \times 10^{18} ms^{-2}$

**(c)** $3.2 \times 10^{18} ms^{-2}$

**(d)** $0.8 \times 10^{18}$ $ms^{-2}$

**20. When a dipole of moment $\vec{p}$ is placed in uniform electric field $\vec{E}$, then the torque acting on the dipole is:**

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

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

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

**(a)** 4L **(b)** 8L

**(c)** L/4 **(d)** 2L

**22. The graph drawn between V are r for a non-conducting charged solid sphere of radius R for r < R will be:**

**(a)** straight line

**(b)** parabola

**(c)** hyperbola

**(d)** None of these

**23. Quantization of charge implies:**

**(a)** Charge does not exist

**(b)** Charge exists on particles

**(c)** There is a minimum permissible magnitude of charge

**(d)** Charge can't be created

**24. Which statement is true for Gauss law-**

**(a)** All the charges whether inside or outside the gaussian surface contribute to the electric flux.

**(b)** Electric flux depends upon the geometry of the gaussian surface.

**(c)** Gauss theorem cannot be applied to uniform electric field.

**(d)** The electric field over the gaussian surface remains continuous and uniform at every point

25. **The minimum amount of charge observed so far is:**

**(a)** 1 C
**(b)** $4.8 \times 1^{-13}$ C
**(c)** $1.6 \times 10^{-19}$ C
**(d)** $1.6 \times 10^{19}$ C

26. **The ratio of electric force between two electrons to the gravitational force between them is of the order:**

**(a)** $10^{42}$ **(b)** $10^{39}$
**(c)** $10^{36}$ **(d)** 1

27. **Two charges $q_1$ and $q_2$ are placed in vacuum at a distance d and the force acting between them is F. If a medium of dielectric constant 4 is introduced around them, the force now will be__________.**

**(a)** F/4 **(b)** F/16
**(c)** F/2 **(d)** 8F

28. **When $10^{14}$ electrons are removed from a neutral metal sphere, the charge on the sphere becomes_______.**

**(a)** 16 μC **(b)** 64 μC
**(c)** 8 μC **(d)** None of these

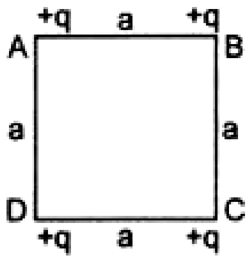
29. **Two similar spheres having $+Q$ and $-Q$ charges are kept at a certain distance. $F$ force acts between the two. If at the middle of two spheres, another similar sphere having $+Q$ charge is kept, then it experiences a force in magnitude and direction as**

**(a)** zero having no direction.
**(b)** $8F$ towards $+Q$ charge.
**(c)** $8F$ towards $-Q$ charge.
**(d)** $4F$ towards $+Q$ charge.

30. **A charge Q is divided into two parts of q and Q – q. If the coulomb repulsion between them when they are separated is to be maximum, the ratio of Q/q should be**

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

31. **Four equal charges q are placed at the four comers A, B, C, D of a square of length a. The magnitude of the force on the charge at B will be**




**(a)** $\frac{3q^2}{4\pi\varepsilon_0 a^2}$

**(b)** $\frac{4q^2}{4\pi\varepsilon_0 a^2}$

**(c)** $\frac{(1+2\sqrt{2})q^2}{2\times 4\pi\varepsilon_0 a^2}$

**(d)** $\frac{\left(\frac{2+1}{\sqrt{2}}\right)q^2}{4\pi\varepsilon_0 a^2}$

32. **Two charges of equal magnitudes kept at a distance 'r' exert a force F on each other. If the charges are halved and distance between them**

is doubled, then the new force acting on each charge is

**(a)** $\frac{F}{8}$ **(b)** $\frac{F}{4}$

**(c)** $4F$ **(d)** $\frac{F}{16}$

**33. The electric field inside a spherical shell of uniform surface charge density is**

**(a)** zero.

**(b)** constant, less than zero.

**(c)** directly proportional to the distance from the centre.

**(d)** none of the these

**34. Total electric flux coming out of a unit positive charge kept in air is**

**(a)** $\varepsilon_0$ **(b)** $\varepsilon_0^{-1}$

**(c)** $(4\pi\varepsilon_0)^{-1}$ **(d)** $4\pi\varepsilon_0$

**35. The electric field intensity due to an infinite cylinder of radius R and having charge q per unit length at a distance r(r > R) from its axis is**

**(a)** directly proportional to $r^2$.

**(b)** directly proportional to r3.

**(c)** inversely proportional to r.

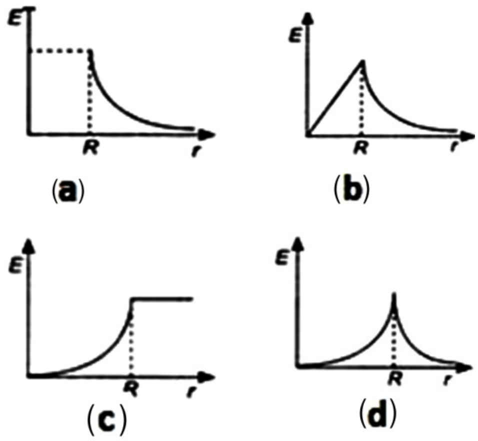
**(d)** inversely proportional to $r^2$.

**36. A point charge q is placed at a distance a/2 directly above the centre of a square of side a. The electric flux through the square is**

**(a)** $q/\varepsilon_0$ **(b)** $q/\pi\varepsilon_0$

**(c)** $q/4\varepsilon_0$ **(d)** $q/6\varepsilon_0$

**37. Which of the following graphs show the variation of electric field E due to a hollow spherical conductor of radius R as a function of distance from the centre of the sphere?**




**38. The magnitude of electric field intensity E is such that, an electron placed in it would experience an electrical force equal to its weight is given by**

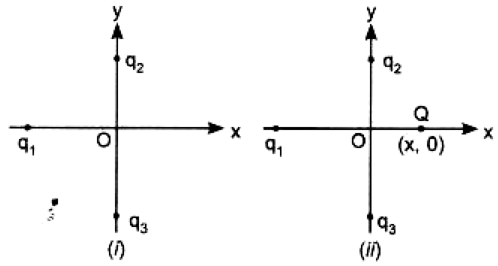
**(a)** mge

**(b)** mg/e

**(c)** e/mg

**(d)** $e^2g/m^2$

**39. In Fig. (i) 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) in figure (ii), the force on $q_1$ is**




**(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)** None of these

**40. Which of the following statement is correct? The electric field at a point is**

**(a)** always continuous.

**(b)** continuous if there is a charge at that point.

**(c)** discontinuous only if there is a negative charge at that point.

**(d)** discontinuous if there is a charge at that point.

**41. 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.

**42. Gauss's law will be invalid if**

**(a)** there is magnetic monopoles.

**(b)** the inverse square law is not exactly true.

**(c)** the velocity of light is not a universal constant.

**(d)** none of these.

**43. The force per unit charge is known as**

**(a)** electric flux

**(b)** electric field

**(c)** electric potential

**(d)** electric current

**44. Electric field lines provide information about**

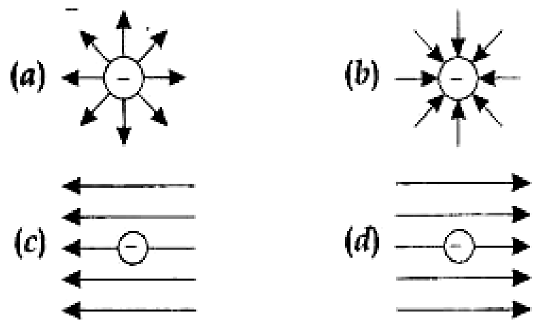
**(a)** field strength

**(b)** direction

**(c)** nature of charge

**(d)** all of these

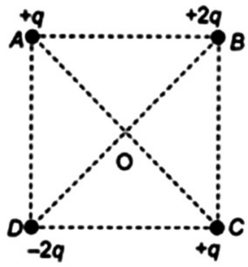
**45. Which of the following figures represent the electric field lines due to a single negative charge ?**



**46.** **The Unit of electric dipole moment is**

**(a)** newton **(b)** coulomb
**(c)** farad **(d)** debye

**47.** **Four charges are arranged at the comers of a square ABCD, as shown. The force on the charge kept at the centre O is**




**(a)** zero
**(b)** along the diagonal AC
**(c)** along the diagonal BD
**(d)** perpendicular to side AB

**48.** **In comparison With the electrostatic force between two electrons, the electrostatic force between two protons is:**

**(a)** greater **(b)** smaller
**(c)** zero **(d)** same

**49.** **When two charged spheres are connected with a wire, the electric charge on them is shared:**

**(a)** inversely as their capacity
**(b)** equally
**(c)** in proportional to their capacity
**(d)** None of these

**50.** **An electric dipole of moment p is placed in the position of stable equilibrium in a uniform electric field $\vec{E}$ . The couple required to rotate it through an angle $\theta$ from the initial position is:**

**(a)** $-PE\ cos\ \theta$ **(b)** $PE\ tan\ \theta$
**(c)** $PE\ cos\ \theta$ **(d)** $PE\ sin\ \theta.$

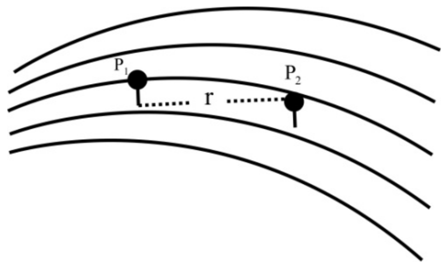
**51.** **Two point charges each of $20\ \mu C$ are placed 50 cm apart in air. What is the electric field intensity at the midpoint on the line joining the centre of two point charges?**

**(a)** $5\ \times\ 10^6\ NC^{-1}$
**(b)** $18 \times 10^6\ NC^{-1}$
**(c)** Zero
**(d)** None of these

**52.** **Two charges 10 pC and 5 pC are placed 20 cm apart. The ratio of Coulomb's force experienced by them is:**

**(a)** 2 : 5 **(b)** 1 : 1 **(c)** $\sqrt{3}\ =\ \sqrt{7}$ **(d)** None of these

**53.** **The figure here shows electric field lines. The electric field strength at $P_1$ is $E_1$ and that at $P_2$ is $E_2$ If distance between $P_1$, $P_2$ is r, then which of the following statement is true?**




**(a)** $E_1 > E_2$ **(b)** $E_1 < E_2$
**(c)** $E_2 = rE_1$ **(d)** $E_2 = E_1/r^2$

54. **The surface charge density on the copper sphere is $\sigma$. The electric field strength on the surface of Sphere of radius r is:**

(a) $\sigma/2$ (b) $\sigma$

(c) $\sigma/2\varepsilon_0$ (d) $\sigma/\varepsilon_0$

55. **An electron and a proton are placed in the same uniform electric field. What will be the ratio of the acceleration of electron to that of proton?**

(a) 1 (b) zero

(c) *mp/me* (d) *me/mp*

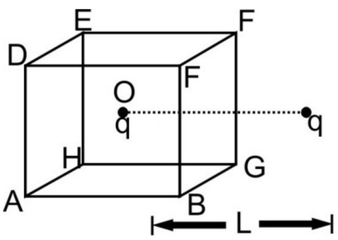
56. **A charged particle q is placed at the centre O of cube of length L (ABCDEFGH). Another same charge q is placed at a distance L from O. Then the electric flux through BCFG is –**

(a) $\frac{q}{4\pi\varepsilon_0 L}$

(b) $Zero$

(c) $\frac{q}{2\pi\varepsilon_0 L}$

(d) $\frac{q}{3\pi\varepsilon_0 L}$




57. **A charge q is placed at the centre of the line joining two equal charges Q such that the system is in equilibrium then the value of q is :**

(a) $Q / 2$

(b) $-Q/2$

(c) $Q / 4$

(d) $-Q/4$

58. **If the electric flux entering and leaving an enclosed surface respectively is $\emptyset_1$ and $\emptyset_2$, the electric charge inside the surface will be**

(a) $(\emptyset_2 - \emptyset_1)\varepsilon_0$

(b) $(\emptyset_2 + \emptyset_1)/\varepsilon_0$

(c) $(\emptyset_1 - \emptyset_2)/\varepsilon_0$

(d) $(\emptyset_2 + \emptyset_1)/\varepsilon_0$

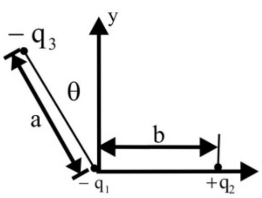
59. **Three charges $-q_1$, $+q_2$ and $-q_3$ are placed as shown in the figure. The x-component of the force on $-q_1$ is proportional to:**

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

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## Section –B

## Assertion Reason Type Question

**Read the assertion and reason carefully to mark the correct option out of the opt ions given below:**

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

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

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

**(d)** If the assertion and reason both are false

**60. Assertion:** The Coulomb force is the dominating force in the universe.

**Reason:** The Coulomb force is weaker than the gravitational force.

**61. Assertion:** When charges are shared between any two bodies, no charge is really lost but someloss of energy does occur.

**Reason:** Some energy disappears in the form of heat, sparking etc.

**62. Assertion:** The surface charge densities of two spherical conductors of different radii are equal. Then the electric field intensities near their surface are also equal.

**Reason:** Surface charge density is equal to charge per unit area.

**63. 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 the square of distance from the charge or an electric dipole.

**64. Assertion:** In a cavity within a conductor without enclosing any charge, the electric field is zero.

**Reason:** Charges in a conductor reside only at its surface.

**65. Assertion:** An electrostatic field line never form closed loop.

**Reason:** Electrostatic field is a conservative field..

**66. Assertion:** A charge q is placed at a height $\frac{b}{2}$ above the centre of a square of side b. The flux associated with the square is independent of value of b.

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

**67. Assertion:** Electrons in an atom are held due to coulomb forces.

**Reason:** The atom is stable only because centripetal force due to coulomb's law is balanced by centrifugal force.

**68. Assertion:** For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.

**Reason:** The net work done by a conservative force on an object independent of path followed and electrostatic force is a conservative force.

**69. Assertion:** Units of electric dipole moment are C-m and units of torque are N-m.

**Reason:** Electric dipole moment and torque are given by p = q (2a) and $\tau = force \times distance$ respectively.

**70. Assertion:** When a neutral body acquires +ve charge, its mass decreases.

**Reason:** A body acquires +ve charge when it loses electrons.

**71. Assertion:** A positive point charge initially at rest in a uniform electric field starts moving along electric lines of forces.

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

**72. Assertion:** Charge is quantized because only integral number of electrons can be transferred.

**Reason:** There is no possibility of transfer of some fraction of electron.

**73. 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 independent of its mass.

**74. Assertion:** Electric lines of force never cross each other.

**Reason:** They are imaginary lines, so as per the supposition they cannot cross each other.

**75. Assertion:** If conducting medium is placed between two charges, then electrostatic force becomes zero.

**Reason:** Relative permittivity of a conductor is infinite.

**76. Assertion:** Three q charges lie on a circle to form an equilateral triangle. The electric field will be zero at the centre.

**Reason:** The symmetry of forces will give zero resultant.

**77. Assertion:** The property which differentiates the two kinds of charges is called polarity of charge.

**Reason:** Du Fay was the first to show two kinds of charges. Franklin named them as positive and negative charges.

**78. Assertion:** Electric field intensity at any point distant r from the centre of a short electric dipole, lying on axial line is twice the electric field intensity at a point distant r on equatorial line of dipole.

**Reason:** The direction of electric field intensity is parallel to the direction of dipole moment in both the cases.

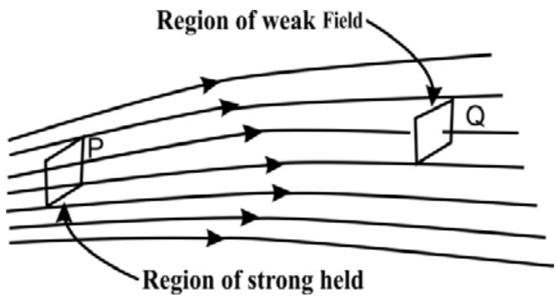
**79. Assertion:** If a point charge is rotated in a circle around another charge at the centre of the circle, the work done by electric field is zero.

**Reason:** Work done is equal to dot product of force and displacement.

***

## SECTION-C
## (Case Study Questions)

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




**80. Electric lines of force about a positive point charge are**

**(a)** radially outwards

**(b)** circular clockwise

**(c)** radially inwards

**(d)** parallel straight lines

**81. Which of the following is false for electric lines of force?**

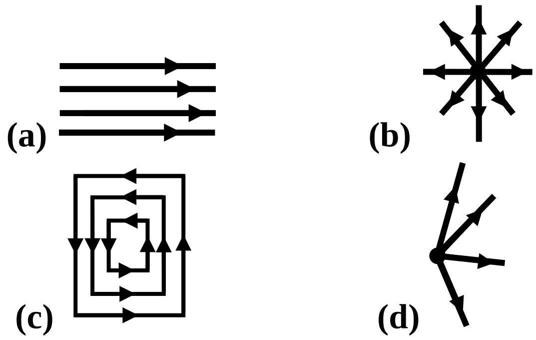
**(a)** They always start from positive charge or from infinity and terminate on negative charges or at infinity.

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

**(c)** They always form closed loops.

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

**82. Which one of the following patterns of electric line of force is not possible in field due to stationary charges?**




**83. Electric field lines are curved,**

**(a)** in the field of a single positive or negative charge

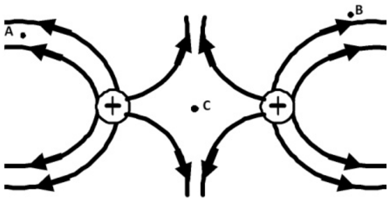
**(b)** in the field of two equal and opposite charges.

**(c)** in the field of two like charges.

**(d)** both (b) and (c)

**84. The figure below shows the electric field lines due to two positive charges.**

**The magnitudes EA, EB and EC of the electric fields at point A, B and C respectively are related as**




**(a)** $E_A > E_B > E_C$

**(b)** $E_B > E_A > E_C$

**(c)** $E_A = E_B > E_C$

**(d)** $E_A > E_B = E_C$

**B. Smallest charge that can exist in nature is the charge of an electron. During friction it is only the transfer of electron which makes the body charged. Hence net charge on anybody is an integral multiple of charge of an electron (1.6 x $10^{-19}$ C) i.e., $q = \pm ne$**

**where $r = 1, 2, 3, 4 \ldots$. Hence nobody can have a charge represented as $1.8e, 2.7e, 3e/5$, etc. Recently, it has been discovered that elementary particles such as protons or neutrons are elemental units called quarks.**

**85. Which of the following properties is not satisfied by an electric charge?**

**(a)** Total charge conservation.

**(b)** Quantization of charge.

**(c)** Two types of charge.

**(d)** Circular line of force.

**86. Which one of the following charges is possible?**

**(a)** 5.8 x $10^{-18}$C

**(b)** 3.2 x $10^{-18}$C

**(c)** 4.5 x $10^{-19}$C

**(d)** 8.6 x $10^{-19}$C

**87. If a charge on a body is 1 nC, then how many electrons are present on the body?**

**(a)** 6.25 x $10^{27}$ **(b)** 1.6 x $10^{19}$

**(c)** 6.25 X $10^{28}$ **(d)** 6.25 X $10^{9}$

**88. If a body gives out $10^9$ electrons every second, how much time is required to get a total charge of 1C from it?**

**(a)** 190.19 years **(b)** 150.12 years

**(c)** 198.19 years **(d)** 188.21 years

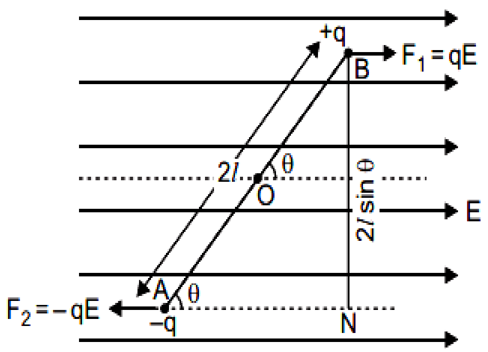
**89. A polythene piece rubbed with wool is found to have a negative charge of $3.2 \times 10^{-7} C$. Calculate the number of electrons transferred.**

**(a)** $2 \times 10^{12}$ **(b)** $3 \times 10^{12}$

**(c)** $2 \times 10^{14}$ **(d)** $3 \times 10^{14}$

**C. When electric dipole is placed in uniform electric field, its two**

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




**90.** The dipole moment of a dipole in a uniform external field $\vec{E}$ is $\vec{p}$. Then the torque $\tau$ acting on the dipole is

(a) $\tau = p \times E$

(b) $\tau = \vec{p}, \vec{E}$

(c) $\tau = 2(p + \bar{E})$

(d) $\tau = p + E$

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

(a) $0.2 \times 10^{-3}\ Nm$

(b) $1 \times 10^{-3}\ Nm$

(c) $2 \times 10^{-3}\ Nm$

(d) $4 \times 10^{-3}\ Nm$

**92.** Torque on a dipole in uniform electric field is minimum when $\theta$ is equal to

(a) $0^\circ$ (b) $90^\circ$

(c) $180^\circ$ (d) both (a) and (b)

**93.** When an electric dipole is held at an angle in a uniform electric field, the net force F and torque $\tau$ on the dipole are

(a) $F = 0, \tau = 0$

(b) $F \neq 0, \tau \neq 0$

(c) $F = 0, \tau \neq 0$

(d) $F \neq 0, \tau = 0$

**94.** An electric dipole of moment p is placed in an electric field of intensity E. The dipole acquires a position such that the axis of the dipole makes an angle with the direction of the field. Assuming that potential energy of the dipole to be zero when $Q = 90^\circ$, the

**torque and the potential energy of the dipole will respectively be**

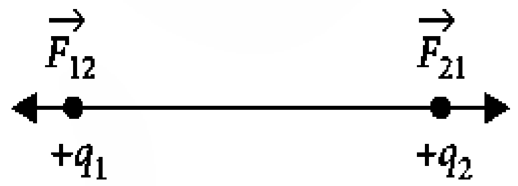
**(a)** $pEsin\theta, - pEcos\theta$

**(b)** $pEsin\theta, -2pEcos\theta$

**(c)** $pEsin\theta, 2pEcos\theta$

**(d)** $pEcos\theta, - pEsin\theta$

**D. Coulomb's law states that the electrostatic force of attraction or repulsion acting between two stationary point charges is given by** $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$




**Where F denotes the force between two charges $q_1$ and $q_2$ separated by a distance r in free space, $\varepsilon_0$ is a constant known as permittivity of free space. Free space is vacuum and may be taken to be air practically. If free space is replaced by a medium, then $\varepsilon_0$ is replaced by $(\varepsilon_0 k)$ or $(\varepsilon_0 \varepsilon_r)$ where k is known as dielectric constant or relative permittivity.**

**95. In coulomb's law, $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$, then on which of the following factors does the proportionality constant k depends?**

**(a)**Electrostatic force acting between the two charges

**(b)**Nature of the medium between the two charges

**(c)**Magnitude of the two charges

**(d)**Distance between the two charges.

**96. Dimensional formula for the permittivity constant $\epsilon_0$ of free space is**

**(a)** $[M L^{-3} T^4 A^2]$

**(b)** $[M^{-1} L^3 T^2 A^2]$

**(c)** $[M^{-1} L^{-3} T^4 A^2]$

**(d)** $[M L^{-3} T^4 A^{-2}]$

**97. The force of repulsion between two charges of 1 C each, kept 1m apart in vaccum is**

**(a)** $\frac{1}{9\times10^9} N$

**(b)**$9 \times 10^9 N$

**(c)**$9 \times 10^7 N$

**(d)**$\frac{1}{9\times10^{12}} N$

**98. Two identical charges repel each other with a force equal to 10g wt when they are 0.6m apart in air.**

**The value of each charge is : (Take $g = 10\ m/s^2$)**

**(a)** $2mC$

**(b)** $2 \times 10^{-7} mC$

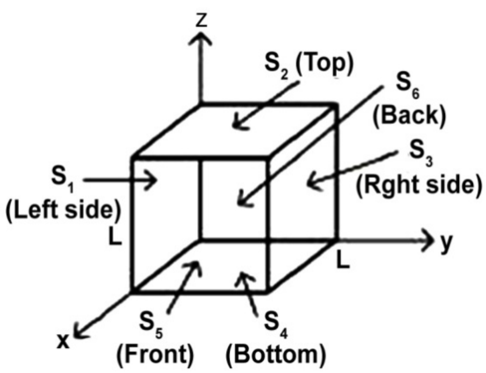
**(c)** $2\ nC$

**(d)** $2\mu C$

**99. Coulomb's Law of electrostatics most closely resembles with**

**(a)** Law of conservation of energy
**(b)** Newton's Law of gravitation
**(c)** Newton's second law of motion
**(d)** Law of conservation of charge

**E. Net electric flux through a cube is the sum of fluxes through its six faces. Consider a cube as shown in figure having sides of length $L = 10.0cm$. The electric field is uniform, has a magnitude $E = 4.00 \times 10^3\ N\ C^{-1}$ and is parallel to $XY$ plane at an angle of $37^\circ$ : measured from the $+x$ axis towards the $+y$ axis.**




**100. Electric flux passing through surface S6 is**

**(a)** $-24\ N\ m^2\ C^{-1}$

**(b)** $24\ N\ m^2\ C^{-1}$

**(c)** $32\ N\ m^2\ C^{-1}$

**(d)** $-32\ N\ m^2\ C^{-1}$

**101. Electric flux passing through surface S1 is**

**(a)** $-24\ N\ m^2\ C^{-1}$

**(b)** $24\ N\ m^2\ C^{-1}$

**(c)** $32\ N\ m^2\ C^{-1}$

**(d)** $-32\ N\ m^2\ C^{-1}$

**102. The surfaces that have zero flux are**

**(a)** $S_1$ and $S_3$ **(b)** $S_5$ and $S_6$

**(c)** $S_2$ and S4 **(d)** $S_1$ and $S_2$

**103. The dimensional formula of surface integral $\oint \vec{E}.\vec{ds}$ and electric field is**

**(a)** $[M\ L^2 T^{-2} A^{-1}]$

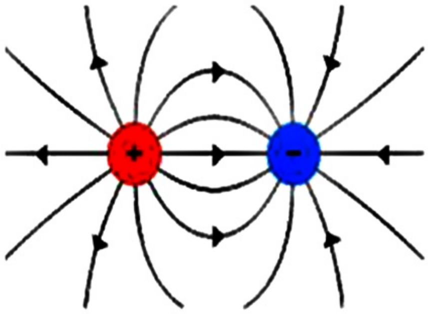
**(b)** $[M\ L^3 T^{-3} A^{-1}]$

**(c)** $[M^{-1}\ L^3 T^{-3} A]$

**(d)** $[M\ L^{-3} T^{-3} A^{-1}]$

**F. Electric charge is the physical property of matter that causes it to experience a force when placed in an electromagnetic field. There are two types of charges positive and negative charges. Also, like charges**

**repel each other whereas unlike charges attract each other.**



**104. Charge on a body which carries 200 excess electrons is :**

**(a)** $-3.2 \times 10^{-18} C$
**(b)** $3.2 \times 10^{18} C$
**(c)** $-3.2 \times 10^{-17} C$
**(d)** $3.2 \times 10^{-17} C$

**105. Charge on a body which carries 10 excess electrons is :**

**(a)** $-1.6 \times 10^{-18} C$
**(b)** $1.6 \times 10^{18} C$
**(c)** $2.6 \times 10^{-18} C$
**(d)** $1.6 \times 10^{-21} C$

**106. Mass of electron is :**

**(a)** $9.1 \times 10^{-31} kg$
**(b)** $9.1 \times 10^{-31} g$
**(c)** $1.6 \times 10^{-19} kg$
**(d)** $1.6 \times 10^{-19} g$

**107. A body is positively charged, it implies that:**

**(a)** there is only a 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 equally positive and negative charge in the body but the positive charge lies in the outer regions
**(d)** the negative charge is displaced from its position

**108. 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 the inner shell.
**(d)** none of the above

***

# ANSWER KEY

## Section –A

## Multiple Choice Questions (MCQ)

**1. b. Zero**

Both the charges are identical and placed symmetrically about ABCD. The flux crossing ABCD due to each charge is $\frac{1}{6}.\frac{q}{\epsilon_0}$ but in opposite directions. Therefore the resultant is zero

**2. d. $-Q/4$**

The distance between both equal charges $Q$ and $Q$ be $2x$

The distance between $Q$ and $q$ be $X$

For charge $Q$ to be in equilibrium

$F_{QQ} = F_{Q_Q}$

$QQ\ /4\pi\epsilon(2x)^2 = qQ/4\pi\epsilon(x)^2$

$q = \ -Q/4$

**3. a. $(\emptyset_2 - \emptyset_1)\varepsilon_0$**

We know that, electric flux $\varphi 1$ (or electric field lines) entering in a closed surface is $-$ve and electric flux $\varphi 2$ (or electric field lines) leaving a closed surface is $+$ve.

Hence, net electric flux through the closed surface,

$$\varphi = \varphi 2 - \varphi 1$$

Now, according to Gauss' theorem, the net electric flux $\varphi$ passing through a closed surface is equal to the $1/\varepsilon 0$ times of the total charge q, enclosed by surface i.e.

$\varphi = q/\varepsilon 0 \qquad \varphi 2 - \varphi 1 = q/\varepsilon 0$

$$q = \varepsilon 0(\varphi 2 - \varphi 1)$$

**4. b. $\frac{q_2}{b^2} + \frac{q_3}{a^2}\sin\theta$**

Force on $-q_1$ due to $q_2$ is

$F_{12} = [(kq_1q_2)/b^2]$ along x axis.

Force on $-q_1$ due to $-q_3$ is $F13 = [(kq_1q_3)/a^2]$ at angle $\theta$ in negative y axis.

$\therefore X$ component of force on $-q_1$ is

$F_x = F_{12} + F_{13}\sin\theta$

i.e. $Fx = kq1[(q_2/b^2) + (q_3/a^2)\sin\theta]$

i.e. $Fx = (q_2/b^2) + (q_3/a^2)\sin\ \theta$

**5. b. $\frac{Q}{4}\left(1 + 2\sqrt{2}\right)$**

Use Columb's law and Equilibrium

**6. d. 2:1**

$$\frac{Q_1}{Q_2} = \frac{r_1}{r_2}$$

**7.** **c.** $-\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$

The electric field at the centre $O$ due to the charge element is

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2} = \frac{\lambda r d\theta}{4\pi\varepsilon_0 r^2}$$

Resolve $dE$ into two rectangular components

By symmetry. $\int dE\cos\theta = 0$

The net electric field at $O$ is

$$\vec{E} = \int_0^x dE\sin\theta\ (-1)$$

$$= \int_0^x \frac{\lambda r d\theta}{4\pi\varepsilon_0 r^2}\sin\theta\,(-1)$$

$$= -\int_0^x \frac{\mathrm{dr}\sin\theta\mathrm{d}\theta}{4\pi^2\varepsilon_q r^2}\ \hat{j}$$

$$\left(\therefore \lambda = \frac{q}{xr}\right)$$

$$= -\int_0^x \frac{\mathrm{dr}\sin\theta\mathrm{d}\theta}{4\pi^2\varepsilon_q r^2}\ \hat{j}$$

$$= -\frac{q}{4\pi^2\varepsilon_q r^2}\ [-\cos\theta]_0^x\hat{j}$$

$$= -\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$$

**8.** **d. N/C**

$$E = \frac{F}{q}$$

**9.** **a.** $+3q$

**10.** **a. always zero**

**11.** **a.** $6.25\times 10^{18}$

$$q = \pm ne$$

**12.** **a. W=ME** $(1-\cos\theta)$

**13.** **d. None**

**14.** **d. is not necessarily zero**

**15.** **c.** $\infty$

**16.** **a.** $3\times 10^9$ **e.s.u**

**17.** **d. 16** **Use** $F = K\frac{q_1q_2}{r^2}$

**18.** **c.** $N^{-1}m^{-2}C^2$

**19.** **b. a torque**

**20.** **c. Cm** $\vec{p} = q\vec{d}$

**21.** **b. pE**

**22.** **b. torque as well as net force**

**23.** **b.** $1.6\times 10^{18}\ ms^{-2}$

$$a = q_e E\backslash m_e$$

**24.** **b.** $\vec{\tau} = \vec{P}\times\vec{E}$

**25.** **d. 2L**

**26.** **d. None of these**

**27.** **c. There is a minimum permissible magnitude of charge**

**28.** **d. The electric field over the gaussian surface remains continuous and uniform at every point**

**29. c.** $\mathbf{1.6\times10^{-19}C}$

**30. a.** $\mathbf{10^{42}}$

**31. a.** $\mathbf{\frac{F}{4}}$

**Explanation :** $F/4$. I the presence of medium, force becomes $1/K$ times

**32. a.** $\mathbf{16\mu C}$

Explanation :

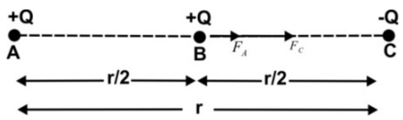
$16\mu C, Q = ne = 10^{14}\times1.6\times10^{-19}$ or $0 = 1.6\times10^{-5}\ C = 16\mu C$ as electrons are removed, so charge will be positive.

**33. c. 8F towards $-Q$charge.**

Explanation :

initially, force between A and C

$$F = \frac{\lambda Q^2}{r^2}$$




When a similar spheres B having change +Q is kept at the mild-point of line joining A and C then net force on B is

$$F_{AC} = F_A + F_C = \frac{\lambda Q^2}{\left(\frac{r}{2}\right)^2} + \frac{\lambda Q^2}{\left(\frac{r}{2}\right)^2} = \frac{8\,\lambda Q^2}{r^2} = 8F$$

The direction is shown in figure.

**34. a. 2:1**

Let separation between two parts be r, than $F = k.q(Q-q)/r^2$, for F to be maximum $dF/dq = 0$ then $Q/q = 2:1$

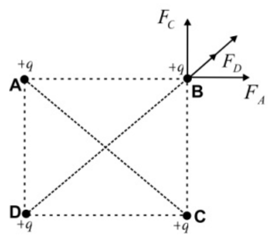
**35. c.** $\mathbf{\frac{(1+2\sqrt{2})q^2}{2\times4\pi\varepsilon_0 a^2}}$

$$F_{AC} + F_D = \sqrt{F_4^2 + F_C^2}\ since$$

$F_A = F_C = \frac{Aq^2}{a^2}$ and

$$F_a = \frac{\sqrt{2}kq^2}{a^2} + \frac{\lambda q^2}{2a^2} - \frac{\lambda q^2}{a^2}\left(\sqrt{2}+\frac{1}{2}\right)$$

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




**36. d. F/16**

F=k.Q[2]r[2]. If Q is halved, r is doubled then F=1/16 times

**37. a. Zero**

All changes reside on the outer surface of the shell so according to Gauss's law, electric field inside the shell is zero.

**38. b. $\varepsilon_0^{-1}$**

Total flux coming out from the unit charge is

$$\phi = \vec{E}.\vec{d}s = \frac{q}{\varepsilon_0} = \varepsilon_0^{-1} \quad (\because q = 1)$$

**39. c. inversely proportional to r.**

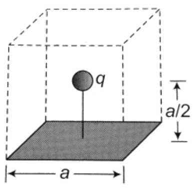
$$\oint \vec{E}.\vec{d}s = \oint ds = \frac{2\pi r}{c}$$

According to Gauss's law (E is constant)

$$E.2\pi rl = \frac{ql}{\varepsilon_0} or\ E = \frac{q}{2\pi\varepsilon_0 r^2}$$

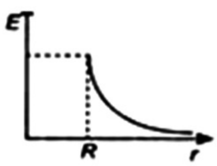
$$i.e. E \propto \frac{1}{r}$$

**40. d. $\frac{q}{6\varepsilon_0}$**




An imaginary cube can be made by considering charge q at the centre and given square is one of its face. So flux through the given square (i.e. one face)

**41. a.**




Electric field due to a hollow spherical conductor is governed by equations E=0, for r<R…. (i)

and $E = Q/4\pi\varepsilon_0 r^2$ for $r \geq R$…. (ii)

i.e. inside the conductor, electric field will be zero and outside the conductor it will vary according to $E\alpha\ 1/r^2$.

**42.** **b. mg/e** According to the question, eE=mg or E=mg/e

**43. a. shall increase along the positive x-axis**

**44. d. discontinuous if there is a charge at that point.**

The electric field due to any charge will be continuous, if there is no other charge in the medium. It will be discontinuous if there is a charge at the point under consideration.

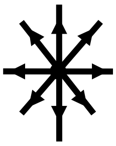
**45. a. directed perpendicular to the plane and away from the plane.**

The electric field lines are away from positive charge and perpendicular to the surface. Hence the field at a point P on the other side of the plane is directed perpendicular to the plane and away from the plane.

**46. b. the inverse square law is not exactly true**

**47. b. electric field**

**48. d. all of these**

**49. b.** 

**50. d. debye**

**51. c. along the diagonal BD**

Place a unit positive charge at O. Resultant force due to the charges placed at A and C is zero and resultant charge due to B and D is towards D along the diagonal BD.

**52. d. same**

**53. b. equally**

**54. d. PE** $\sin\theta$

**55. c. Zero**

**56. b. 1:1**

**57. a.** $E_1 > E_2$

**58. d.** $\frac{\sigma}{\varepsilon_0}$

According to Gauss's theorem

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

$$\therefore = \frac{q/4\pi R^2}{\in_0} \because q/4\pi R^2$$

$$= \sigma| \; or \; E = \sigma/\varepsilon_0$$

**59. c.** $mp/me = \frac{\alpha_t}{\alpha_p} = \frac{F/m_e}{F/m_p} = \frac{m_p}{m_e}$

***

## SECTION B-
## (Assertion Reasoning)

**60. d.** Gravitational force is the dominating force in nature and also the weakest force in nature

**61. b.** Charges always conserved but energy is lost in the term of heat

**62. b.**

**63. d.** The rate of decrease of electric field is different in the two cases

**64. a.** Electrostatics shielding

**65. b.**

**66. a.** Electric flux $= q/\varepsilon_0$

**67. c.**

**68. a.** Electrostatic field is conservative in nature

**69. a.**

**70. a.** A body can be charged by the transfer of electrons only

**71. c.** If the field lines are curved, then the charge particles does not exactly follow the curved path

**72. a.**

**73. b.** Electric force=charge × electric filed

**74. c.**

**75. a.** Coulomb force is inversely proportional to the relative permittivity

**76. a.** Superposition principle of electric forces

**77. b.**

**78. c.**

**79. a.** Force by electric field will be perpendicular to the displacement

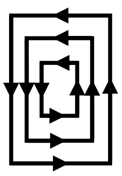
***

## SECTION –C
## (Case Study Question)

**80. a.** radially outwards

**81. c.** They always form closed loops

**82. c.**



**83. d.** both (b) and (c)

**84. a.** $E_A > E_B > E_c$

**85. d.** Circular line of force.

**86. b.** $3.2 \times 10^{-18} C$
Use law of quantization

**87. d.** $6.25 \times 10^9$
Use law of quantization $q = ne$

**88. c.** 198.19 years

$n = 10^9/sec$

$q = ne$

$= 10^9 \times 1.6 \times 10^{-19}$

$q = 1.6 \times 10^{-10} C$

$Q = qt$

$t = \frac{Q}{q}$

$= \frac{IC}{1.6 \times 10^{-10}}$

$= 0.625 \times 10^{10} Sec.$

$= \frac{.625 \times 10^{10}}{365 \times 24 \times 60 \times 60}$

$= 198.19\ yrs.$

**89. a.** $2 \times 10^{12}$

n can be calculated using the relation, $q = ne$

**90. a.** $\tau = p \times E$

**91. c.** $2 \times 10^{-3}$ Nm

Use $\tau_{max} = \vec{p}\vec{E}$

**92. d.** Both (a) and (c)

**93. c.** $F = O, \tau \neq 0$

**94. a.** $pE \sin\theta, -pE\cos\theta$

**95. b.** Nature of the medium between the two charges

**96. c.** $[m^{-1}L^{-3}T^4A^2]$

Use $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$,

**97. b.** $9 \times 10^9$ N

Use Coulomb's Law

**98. d.** $2\mu C$

Use $F = kg^2/r^2$,

**99. b.** Newton's Law of gravitation

**100. d.** $-32\ N\, m^2C^{-1}$

Here, the electric field is given by $\vec{E} = E\cos 37\,\hat{\imath} + E\sin 37\,\hat{\jmath}$

Electric flux through back surface $S_2$ is $\phi = \vec{E}.\hat{n}S_6$

Here $\hat{n} = -\hat{\imath}$, normal outward to the back surface $S_1 = L^2$

Thus,

$\phi =$
$(E\cos 37\,\hat{\imath} + E\sin 37\,\hat{\jmath}).(-L^2\hat{\imath})$
$= -EL^2\cos 37$
$= -(4\times 10^3)(0.1)^2\cos 37$
$= -31.94 \sim -32Nm^2C^{-1}$

**101. a.** $-24\ N\, m^2C^{-1}$

Here, the electric field is given by $\vec{E} = E\cos 37\,\hat{\imath} + E\sin 37\,\hat{\jmath}$

Electric flux through back surface $S_1$ is $\phi = \vec{E}.\hat{n}S_1$

Here $\hat{n} = -\hat{\jmath}$, normal outward to the back surface $S_1 = L^2$

Thus ,

$\phi = (E\cos 37\,\hat{\imath} + E\sin 37\,\hat{\jmath}).(-L^2\hat{\jmath})$
$= -EL^2\cos 37$
$= -(4\times 10^3)(0.1)^2\cos 37$
$= -24Nm^2C^{-1}$

**102. d.** Zero

Use $\phi = \vec{E}.\vec{S}$

And superposition

**103. b.** $[M\,L^3T^{-3}A^{-1}]$

**104. c.** $-3.2 \times 10^{-17}C$

Use q=ne

**105. a.** $-1.6 \times 10^{-18}C$

$q = ne = 10(-1.6 \times 10^{-19})C$

$= -1.6 \times 10^{-18}C.$

**106. a.** $9.1 \times 10^{-31}kg$

**107. b.** there is positive as well as negative charges in the body but the positive charge is more than negative charge

**108. a.** valence electrons only

***

# ( ELECTRIC CHARGES AND FIELDS- (II) )

1. **Three charges $Q, (+q)$ and $(+q)$ are placed at the vertices of an equilateral triangle of side $l$ as shown in the figure. If the net electrostatic energy of the system is zero, then $Q$ is equal to**

   **(a)** $\left(-\frac{q}{2}\right)$ **(b)** $(-q)$

   **(c)** $(+q)$ **(d)** Zero

2. **Electric field between two parallel planes oppositely charged is :-**

   **(a)** $\sigma/\varepsilon_0$ **(b)** $\sigma/2\varepsilon_0$

   **(c) zero** **(d)**$2\sigma/\varepsilon_0$

3. **In the given figure distance of Point P where the electric field is zero is :**

   **(a)**$20\ cm$

   **(b)**$10\ cm$

   **(c)** $33c\ m$

   **(d) none of the above**

4. **Which of the following results, in free space is /are expressed in units of coulomb.**

   **(a)** $\oint \bar{E}.\bar{d}i$

   **(b)** $\oiint \bar{E}.\bar{d}s$

   **(c)**$\oint \bar{B}.\bar{d}i$

   **(d)** $\oiint \bar{D}.\bar{d}s$

5. **Two point charges $\phi_1$ and $\phi_2$ are 3m apart. Their combined charge is 20$\mu$C. If one repels the other with a force of 0.075N what are the two charges. (in $\mu C$)**

   **(a)** 15,5

   **(b)** 10,5

   **(c)**10,3

   **(d)** 5,20

6. **If the individual forces acting on a given charge due to the presence of five charges are represented by the sides of a closed Pentagon, what will be the resultant force on the test charge ?**

   **(a)** $F_1 + F_2 + F_3 + F_4 + F_5$

   **(b)** Zero

7. **Two positive point charges of $10\mu C$ and $5\mu C$ are 10 cm apart. The work done in bringing them to a distance of 5cm closer is**

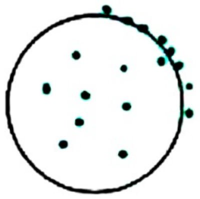
   **(a)** 2.5 ev

   **(b)** 4.5J

   **(c)** 5ev

   **(d)** 9.5 J

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



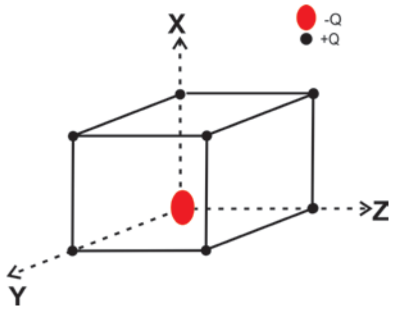
**(a)** Point beyond 2 metres

**(b)** Point beyond 10 metres

**(c)** Interior point

**(d)** outer point

9.




**A cube of side a has point charges $+Q$ located at each of its vartices except for the origin where the charge in $-Q$. As shown above the electric field at the cneter is :**

**(a)** $\frac{-Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

**(b)** $\frac{Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

**(c)** $\frac{-2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

**(d)** $\frac{2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

10. **The S.I. Unit of Electric Flux is**

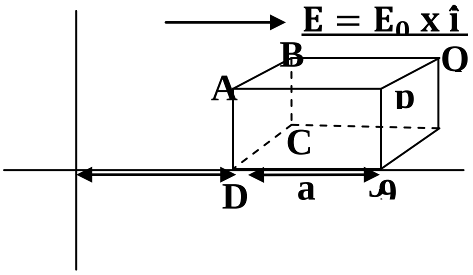
**(a)** Weber

**(b)** Newton per coulomb

**(c)** Volt × metre

**(d)** Joule per coulomb

11. **Find the flux of $\vec{E}$ through the cube of side 'a'**




**(a)** $2E_0a^3$ **(b)** $E_0a^3$

**(c)** $\frac{E_0a^3}{2}$ **(d)** None of these

12. **A cylinder of radius r and length $l$ is placed in an uniform electric field in such a way that the axis of the cylinder is parallel to the field. The flux of the field through the cylindrical surface is**

**(a)** $\frac{2rl}{\varepsilon_0}$ **(b)** $\frac{1}{\varepsilon_0}$

**(c)** $\frac{2\pi rl}{\varepsilon_0}$ **(d)** Zero

13. **The inward and outward electric flux for a closed surface in units of $N-m^2/C$ are respectively $8\times10^3$ and $4\times10^3$. Then the total charge inside the surface is [where $\varepsilon_0$ = permittivity constant]**

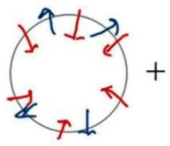
**(a)** $4\times10^3C$

**(b)** $-4\times10^3\ C$

**(c)** $\frac{(-4\times10^3)}{\varepsilon}C$

**(d)** $-4\times10^3\varepsilon_0C$

14. The electric flux for Gaussian surface $A$ that enclose the charged particles in free space is (given $q_1 = -14\ nC, q_2 = 78.84\ nC, q_3 = -56nC$




(a) $10^3 Nm^2C^{-1}$

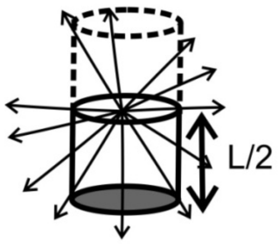
(b) $10^3 CN^{-1}m^{-2}$

(c) $6.32 \times 10^3 Nm^2C^{-1}$

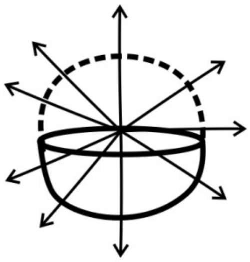
(d) $6.32 \times 10^3 CN^{-1}m^{-2}$

15. Find the flux from a, 1) semi cylinder 2) Hemisphere 3) plate at distance a/2 from charge q

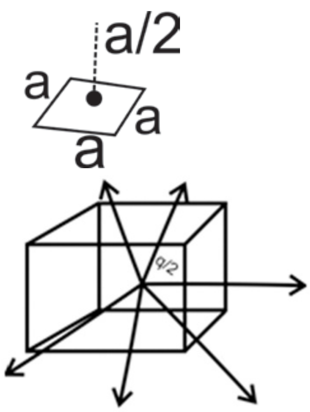
Q1)




Q2)



Q3)

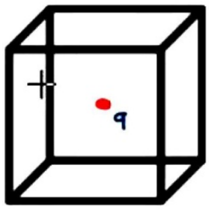



16. Find the flux through one face of the cube

a) $\frac{q}{4\varepsilon_0}$  b) $\frac{q}{2\varepsilon_0}$

c) $\frac{q}{3\varepsilon_0}$  d) $\frac{q}{6\varepsilon_0}$

17. A charge $q$ is placed at the centre of a cube. Then the flux pasing through one face of cube will be




(a) $\frac{q}{\varepsilon_0}$

(b) $\frac{q}{2\varepsilon_0}$

(c) $\frac{q}{4\varepsilon_0}$

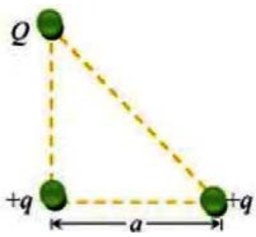
(d) $\frac{q}{6\varepsilon_0}$

18. According to Gauss' Theorem, electric field of an infinitely long straigt wire is proportional to

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

(c) $\frac{1}{r^3}$  (d) $\frac{1}{r}$

19. Three changes $Q, +q$ and +q are placed at the vartices of a right – angled isosceles triangle as shown. The net electrostatic energy of the configuration is zero if $Q$ is equal to




(a) $\frac{-q}{1+\sqrt{2}}$

(b) $\frac{-2q}{2+\sqrt{2}}$

(c) $-2q$

(d) $+q$

**20.** **An electron is moving towards $x$-axis. An electric field is along $y-$ direction then path of electron is**

**(a)** Circular **(b)** Elliptical

**(c)** Parabola **(d)** None of these

**21.** **The electric potential $V$ at any point $O(x, y, z$ all in metres) in space is given by $V = 4x^2\ volt$. The electric field at the point $(1m, 0, 2m)$ in $volt/metre$ is**

**(a)** 8 along negative $X -$ axis

**(b)** 8 along positive $X -$ axis

**(c)** 16 along negative $X -$ axis

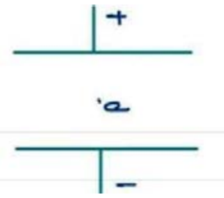
**(d)** 16 along positive $Z -$axis

**22.** **An Alpha particle is accelerated through a potential difference of $10^6\ volt$. Its kinetic energy will be**

**(a)** 1 $MeV$ **(b)** 2$MeV$

**(c)** 4 $MeV$ **(d)** 8 $MeV$

**23.** **An electron enters betwee two horizontal plates separated by 2mm and having a potential difference of 1000$V$. The force on electron is**




**(a)** $8 \times 10^{-12} N$

**(b)** $8 \times 10^{-14} N$

**(c)** $8 \times 10^{9}\ N$

**(d)** $8 \times 10^{14} N$

**24.** **The electric potential $V$ is given as a function of distance $x$ (metre) $V = (5x^2 + 10x - 9) volt$. Value of electric field at $x = 1$ is**

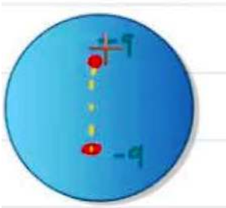
**(a)** $-20V/m$

**(b)** $6V/m$

**(c)** $11V/m$

**(d)** $-23\ V/m$

**25.** **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

**26.** **Eight dipoles of charges of magnitude $e$ are placed inside a**

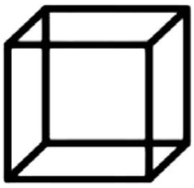
**cube. The total electric flux coming out of the cube will be**

**(a)** $\frac{8e}{\varepsilon_0}$

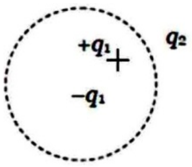
**(b)** $\frac{16e}{\varepsilon_0}$

**(c)** $e/\varepsilon_0$

**(d)** Zero



**27. A charge q is located at the centre of a cube. The electric flux through any face is**




**(a)** $\frac{4\pi q}{6(4\pi\varepsilon_0)}$  **(b)** $\frac{\pi q}{6(4\pi\varepsilon_0)}$

**(c)** $\frac{q}{6(4\pi\varepsilon_0)}$  **(d)** $\frac{2\pi q}{6(4\pi\varepsilon_0)}$

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

**(a)** $q_2$

**(b)** only the positve charges

**(c)** all the charges

**(d)** $+q_1$ and $-q_1$

***

## SHORT ANSWER TYPE

**1.** Two small identical electrical dipole AB and CD, each of dipole moment $'P'$ are kept at angle of $120°$ as shown in the figure. What is t he resultant dipole moment of this combination ? if this system is subjected to electric field $\overrightarrow{(E)}$ directed along $+x$ direction, what will be the magnitude and direction of the torque acting on this?

**2.** Derive an expression for the potential energy of an electric dipole of dipole moment $\vec{P}$ in an electric field $\vec{E}$.

**3. (A)** State Gauss's Law.

**(B)** A thin straight infinitely long conducting wire of linear charge density $'\lambda'$ is enclosed by a cylindrical surface of radius and length axis coinciding with the length of the wire. Obtain the expression for the electric field, indicating its direction, at a point on the surface of the cylinder.

***

# LONG ANSWER TYPE

1. A solid sphere of radius R carries a positive charge. The volume charge density is given as where r is the distance of observation point form centre and $\rho_0$ is a constant,
   Let $\varepsilon$ be the permittivity of the ball. Then find :

   (A) The electric field inside the sphere at a distance ‘r’ from center.

   (B) The electric field intensity $(E_m)$.

2. A small conducting sphere of radius ‘r’ carrying a charge +q is surrounded by a large concentric conducting shell of radius R on which a charge +Q is placed. Using Guess's Law derive the expressions for the electric field at a point 'x'

   (A) between the sphere and the shell $(r < x < R)$.

   (B) outside the spherical shell.

***

## ANSWER KEY

## SECTION-B (MCQ)

**1. a.** $\left(-\frac{q}{2}\right)$

$U = 0$

$U = \frac{1}{4\pi\varepsilon_0} \frac{\varphi q}{l} + \frac{1}{4\pi\varepsilon_0} \frac{\varphi q}{l} + \frac{1}{4\pi\varepsilon_0} \frac{\varphi q}{l}$

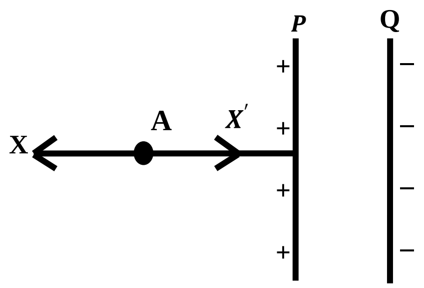
$0 = \frac{q}{4\pi\,\varepsilon_0 l}\,[\varphi + \varphi + q]$

$2\varphi + q = 0$

$2\varphi = -q$

$\varphi = -q/2$

**2. c. zero**




$E_1$ due to $P$ at A.

$= \sigma/2\varepsilon_0$ towards $AX$………. (1)

Similarly $E_2$ at Point A due to conduct or Q

$= \sigma/2\varepsilon_0$ towards $Ax'$…………. (2)

$\sigma = Surface\ change\ denisity.$

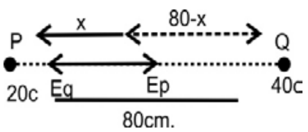
From (1) & (2)

Net intensity at A is

$$E_1 - E_2 = \frac{\sigma}{2\varepsilon_0} = 0$$

**3. c. 33Cm**

$E_p = E_Q$




$$\frac{1}{4\pi\varepsilon_0}\frac{20}{x^2} = \frac{1}{4\pi\varepsilon_0}\frac{40}{(80-x)^2}$$

$$\frac{1}{x^2} = \frac{2}{(80-x)^2}$$

$$\frac{1}{x} = \frac{\sqrt{2}}{80-x} \Rightarrow 80 - x = \sqrt{2}x$$

Or $80 = (1+\sqrt{2})x$

$$= \frac{80}{1+1.414} = \frac{80}{2.414} = 33$$

**4. d.** $\oiint \overline{\boldsymbol{D}}.\overline{\boldsymbol{ds}}$

If $\rho$ is the valume charge density

$$Q = \int_v \rho\, dv$$

From Gauss's law $\int_s \vec{E}.\overrightarrow{ds} = \frac{1}{\varepsilon_0}\int \rho\, dv$

$$\int_3 \varepsilon_0 \vec{E}\,.\vec{d}s = \int \rho\, dv$$

$$= \int_3 \vec{D}\,.\vec{d}s = Q\,.$$

**Note : -** $\boldsymbol{\nabla.E = \frac{\rho}{\varepsilon_0}}$

**= differential form of Gauss law**

**5. a. 15,5**

$Q_1 + Q_2 = 20\mu c$

$\therefore Q_2 = 20 - Q_1$

$0.075N$

$$= (9 \times 10^9\ Nm^2c^{-2})$$

$$\times \frac{Q_1Q_2}{(3m)^2}$$

Or $75 \times 10^{-12}\ c^2 = Q_1Q_2$

Or $Q_1(20 - Q_1) = 75\ \mu c^2$

$Q_1^2 - \ 20Q_1 + 75 = 0$

$Q_1^2 - 15Q_1 - \ 5Q_1 + 75 = 0$

$Q_1 = 15\mu c\ 5\mu c$

**6. b. zero**

Using principle of superposition

$F_1$ = force on the test charge due to 1st charge alone

$F_2$ = due to 2nd charge alone .

Resultant force = $F_1 + F_2 + F_3 + F_4 + F_5$

As these individual forces are represented by the sides of a closed pantagon.

But vectors form a clused geomatrical figure then the resultant of these vectors is zero.

**7. b. 4.5J**

Energy = $u_{Final} - U_{intial}$

$$u_i = \frac{1}{4\pi\varepsilon_0}\ \frac{10 \times 10^{-6} \times 5 \times 10^{-6}}{10 \times 10^{-2}m.}$$

$$u_f = \frac{1}{4\pi\varepsilon_0}\ \frac{10 \times 10^{-6} \times 5 \times 10^{-6}}{5 \times 10^{-2}m.}$$

$\therefore = u_f - u_i$

$$= \frac{1}{4\pi\varepsilon_0} \times \frac{10 \times 5 \times 10^{-12}}{10^{-2}} \left[\frac{1}{5} - \frac{1}{10}\right]$$

$$= 9 \times 10^9 \times 10 \times 5 \times 10^{-10} \times \left[\frac{1}{10}\right]$$

$= 4.5$ J

**8. c. Interior point**

**9. c. $\frac{-2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}\ (\hat{x} + \hat{y} + \hat{z})$**

Replace the charge $-Q$ at origin by two charges Q and −2Q. The new s ystem of charges is electrostatically equivalent to previous system. Fied due to eight similar charges Q will be zero. The net electric field at centre will be due to charge -2Q.

$$\bar{E} = \frac{-2Q}{4\pi\varepsilon_0\ \left(\sqrt{3}\,\frac{a}{2}\right)^2}\ \hat{e}_r$$

$\hat{e}_r$ = unit vector towards origin

$$= \frac{\hat{2} + \hat{\jmath} + \hat{u}}{\sqrt{3}}$$

$$\vec{E} = \frac{-2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}\ (\hat{2} + \hat{\jmath} + \hat{u})$$

**10. c. $\boldsymbol{Volt \times metre}$**

$$\phi = \frac{Nm^2}{C}$$

$$= \frac{Nmm}{C}$$

$$= \frac{Jm}{C}$$

$= \ Volt \times metre$

**11. b. $E_0a^3$**

$= \underset{\text{the location of ABDC}}{\overset{E}{\downarrow}} \quad (A)$

$= -E_0(a)(a^2)$

$= \underline{-E_0a^3}$

$\underset{PQRS}{\phi} = ?$

$E = \varepsilon_0 x\,\hat{i}$

$x = 2a$

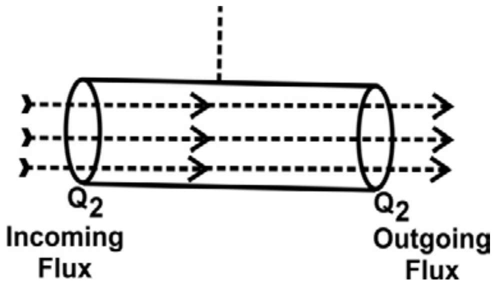
$\underset{PQRS}{\phi} = E_{at\ location} \times Area$

$= E_0\, 2a\ \ a^2$

$\phi_{PQRS} - \phi_{ABCD} = 2E_0a^3 - E_0a^3$

$= E_0a^3$

**12. d. Zero**




$\phi_1 = -E_0\, A\cos \grave{0}$

$\phi_2 = E_0 A\cos \grave{0}$

$\phi_1 + \phi_2 = 0$

$\phi_{Total} = \phi_1 + \phi_2 + \phi_3$

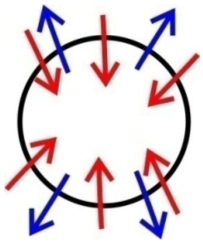
$= \phi_3$

$= E_0\, A\cos 90° = 0\ Area = 2\pi rl$

$\left[\overset{Sufae\ is\ curviliner}{of\ area\ 2\pi rl\ and\ area\ vector\ is\ perpendicular\ to\ S'}\right]$

Whenever a closed surface is placed in a uniform field, total flux is zero . (incoming flux equals outgoing flux) Provided that there is no charge inside the surface.

**13. d. $-4 \times 10^3 \varepsilon_0 C$**



$\phi = \frac{\Phi}{\epsilon}$

$\phi = \epsilon_0\phi$

$\phi = \epsilon_0\,[-8 \times 10^3 + 4 \times 10^3]$

**14. a. $10^3 Nm^2C^{-1}$**

Total Fl ux $= \frac{\varphi}{\varepsilon_0}$

$= \frac{-14 \times 10^{-9} + 78.85 \times 10^{-9} - 56 \times 10^{-9}}{\varepsilon_0}$

$= \frac{8.85 \times 10^{-9}}{8.85 \times 10^{-12}}$

$\phi = 10^3\ Nm^2/C$

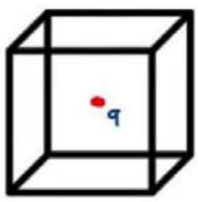
**15. a.** $\emptyset_{Semi\ cylinder} = \frac{q}{2\varepsilon_0}$

$\emptyset_{Hemi\ Sphare} = \frac{q}{2\varepsilon_0}$

$\boldsymbol{\phi\ Plate\ at\ distance\ \frac{a}{2} = \frac{q}{6\varepsilon_0}}$

**16. d.** $\frac{q}{6\varepsilon_0}$

**17. d.** $\frac{q}{6\varepsilon_0}$

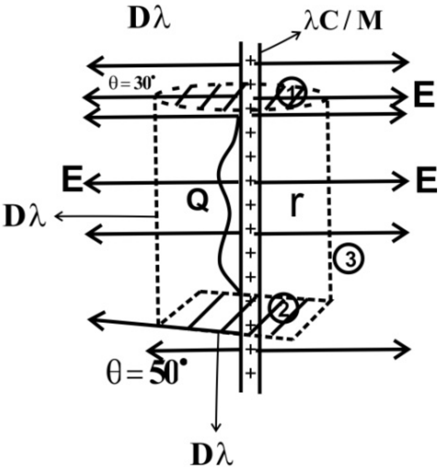



$Total\ Flux = \frac{\frac{1}{\varepsilon_0}q}{6}$

$= \frac{q}{6\varepsilon_0}$

**18. d.** $\frac{1}{r}$

$$\lambda = \frac{Q_{inside}}{\ell}$$




$$\phi_{cylinder} = \phi_1 + \phi_2 + \phi_3$$

$$\int EdA\cos 90° + \int EdA\cos 90° + \int EdA\cos 0°$$

$$\frac{Q_{inside}}{\varepsilon_0} = \int E\,dA = E\int dA$$

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

$$E = \frac{\lambda}{2\pi\varepsilon_0 r} \qquad E \propto \frac{1}{r}$$

**19. b.** $\frac{-2q}{2+\sqrt{2}}$

**20. c. Parabola**

**21. a. 8 along negative $X$ −axis**

$E.V$

$$\bar{E} = -\left[\frac{8v}{8z}i + \frac{8v}{8y}j + \frac{8v}{8z}k\right]$$

$$= -[8xi + oj + ok]$$

$$\bar{E} = -8xi$$

$$\bar{E}_{1,0,2} = -8i$$

**22. b. $2MeV$**

$$\text{K.E} = q.V$$

$$= 2e \times 10^6 \text{ J}$$

$$= \frac{2e \times 10^6}{e}eV$$

$$= 2 \times 10^6\ eV$$

$$= 2MeV$$

**23. b. $8 \times 10^{-14}N$**

$$d = 2 \times 10^{-3}m \quad E = \frac{V}{d}$$

$$V = 1000r$$

$$\bar{F} = e\bar{E}$$

$$= e\frac{V}{d} = 1.6 \times 10^{-19} \times \frac{1000}{2 \times 10^3}$$

$$= 0.8 \times 10^{-13}$$

$$= 8 \times 10^{-14}\ N$$

**24. a. $-20V/m$**

$$E_x = -\frac{dv}{dx}$$

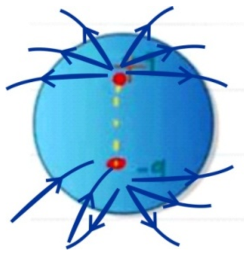
$$= -\frac{d}{dx}\,[5x^2 + 10x - 9]$$

$$= -[10x + 10 - 0]$$

$$E_x = -10x - 10$$

$$At\ x = 1\ \ E_x = -20V/m$$

**25. c. Electric fluxentering into sphere and leaving the sphere are same.**



$$Flux = \frac{1}{\varepsilon_0}q = zeor$$

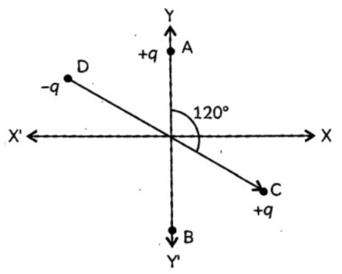
**26. d. Zero**

**27. a.** $\frac{4\pi q}{6(4\pi\varepsilon_0)}$

**28. c. all the charges**

## SHORT ANSWER

**1. Ans.**




As shown in the figure, let two identical electric dipoles AB and CD are kept at an angle $\theta = 120°$, where their dipoles moments have magnitude

$$|\overrightarrow{P_A}| = |\overrightarrow{P_C}| = P$$

The resultant dipole moment of the combination

$$|\overrightarrow{P_R}| = 2pcos\frac{\theta}{2} = 2pcos\frac{120°}{2}$$

$$= 2P\cos 60°$$

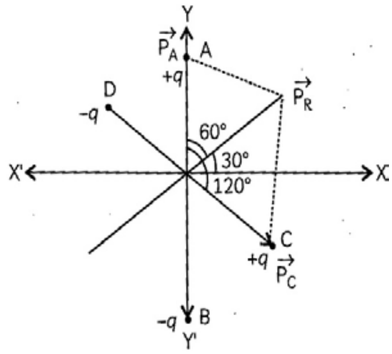
$$= 2P \times \frac{1}{2} = P$$

And the resultant dipole moment subtends on angle $\frac{\theta}{2} = 60°$ from either of two dipole $\overrightarrow{P_A}$ and $\overrightarrow{P_B}$. Therefore $\overrightarrow{P_R}$ subtends an angle $30°$ .

If the system is subjected to electric field $\vec{E}$ directed along $+x$ direction, the torque acting on the system is

$$\vec{Z} = \overrightarrow{P_R} \times \vec{E}$$

Thus, the magnitude of torque is $|T| - pE\sin 30° = \frac{1}{2}pE$ and the torque is directed into the plane of paper i.e, the torque tends to align the system along the direction of electric field $\vec{E}$.

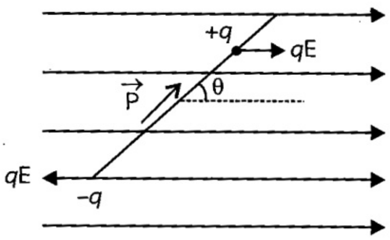



**2.Ans.**

Let us suppose that the electric dipole is brought from infinity in the region of an uniform electric field such that its dipole. moment $\vec{P}$ always remains perpendicular to electric field. The electric forces on charges. +q and -q are qE and −qE along the field direction and opposite to field direction respectively. As charges +q and -q traverse equal distance under equal and opposite forces; therefore, net work done in bringing the dipole in the region of electric field perpendicular to field direction

will be zero, i.e., $W_1 = 0$

Now the dipole is rotated and brought to orientation making on angle $\theta$ with the field direction (i.e., $\theta_1 = 90°$ and $\theta_2 = 0°$), therefore work done .




$$W_2 = pE(\cos\theta_1 - \cos\theta_2)$$
$$= pE\ (\cos 90° - \cos\theta)$$
$$= -pE\cos\theta$$

∴ Total work done in brining the electric dipole form infinity, i.e. Electric potential energy of electric dipole.

$$U = W_1 + W_2 = 0 - pE\cos\theta$$
$$= -pE\cos\theta$$

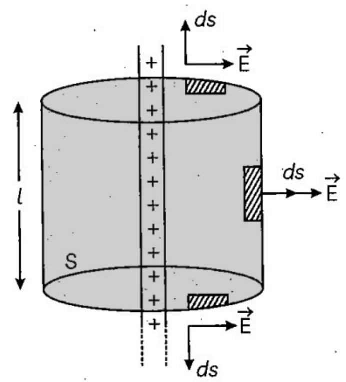
In vector from $U = \vec{P}.\vec{E}$

**3.Ans.**

**(A)** According to Gauss's law, total flux over a closed surface S in vaccum is $\frac{1}{\varepsilon_0}$ times the total charge enclosed by the closed surface S .

$$\phi = \int_S \vec{E}\ \overrightarrow{dS} = \frac{q}{\varepsilon_0}\ \text{(enclosed)}$$

**(B)** Electric field intensity due to line charge or infinite long uniformly charged wire at point P at distance $r$ from it is obtained as: Assume a cylindrical Gaussian surface $s$ with charged wire on its axis and point $P$ on its surface, then through surface $S$ is




$$\phi = \int_s Eds$$

$$= \underset{\substack{Uuper\ Plane \\ surface}}{\int E.ds\cos 90°} + \underset{\substack{Curve \\ surface}}{\int E.ds\cos 0°} + \underset{\substack{Lower\ plane \\ surface}}{\int E.ds\cos 90°}$$

Or $\phi = 0 + EA + 0$ or $\phi = E.2\pi rl$

But by Gauss's theorem $\phi = \frac{q}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$

Where q is the charge on Length $I$ of wire enclosed by cylindrical surface $S$, and $I$ is uniform linear charge density of wire'

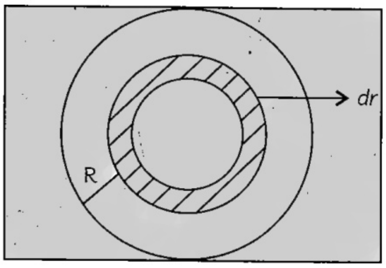
$$E \times 2\pi rl = \frac{\lambda l}{\varepsilon_0}\ \text{or}\ E = \frac{\lambda}{2\pi r\,\varepsilon_0 r}$$

Directed normal to the surface of charged wire.

# LONG ANSWER

**1. Ans.**

**(A)** Take a solid sphere of radius 'R' with solid sphere is made up of a large number of spherical shells and let us consider one such spherical shell having radius $r$ and thickness $dr$ in figure.




Volume of this spherical shell $= 4\pi r^2 dr$ and $dq = \rho\, dV = \rho. 4\pi r^2\, dr$

$$= 4\pi r^2 dr \rho_0 = \left(1 - \frac{e}{R}\right) = 4\pi\rho_0$$

$$= \left(1 - \frac{r}{R}\right) r^2 dr$$

Hence total charge in the sphere of radius $r$ is given as

$$q = \int dq = 4\pi\rho_0 \int_0^r \left(1 - \frac{r}{R}\right) r^2 dr$$

$$E = 4\pi\rho_0 \left(\frac{r}{3} - \frac{r^2}{4R}\right)$$

For any charged sphere, charge can be assumed to be concentrated at the centre of the sphere. So, the expression for electric field can be written as

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

$$= \frac{1}{4\pi\varepsilon}. 4\pi r\rho_0 \left(\frac{r^3}{3} - \frac{r^4}{4R}\right)\frac{1}{r^2}$$

$$E = \frac{\rho_0}{E}\left(\frac{r}{3} - \frac{r^2}{4R}\right)$$

**(B)** For E to be maximum $\frac{dE}{dr} = 0$

i.e. $\frac{\rho_0}{E}\left(\frac{r}{3} - \frac{2r}{4R}\right) - 0$

Or $r_m = \frac{2R}{3}$

$$\therefore E = \frac{\rho_0}{E}\left(\frac{r_m}{3} - \frac{r_m^2}{4R}\right)$$

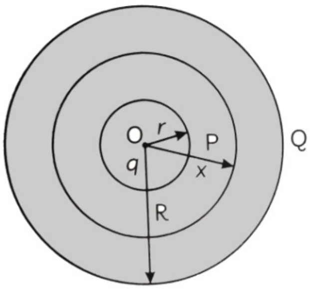
$$= \frac{\rho_0}{E}\left(\frac{2r}{9} - \frac{4R^2}{9(4R)}\right)$$

$$= \frac{\rho_0}{E}\left(\frac{2R}{9} + \frac{R}{9}\right)$$

$$\therefore E_m = \frac{\rho_0}{E}\frac{R}{9}$$

**2. Ans.**

Consider a sphere of radius r with centre 0 surrounded by a large concentric conducting shell of radius R.




To calculate the electric field intensity at any point P, where OP = x, imagine a Gaussian surface with centre 0 and radius x, as shown in the fig. The total electric flux through the Gaussian surface is given by

$$\emptyset = \oint E.ds = E\oint ds$$

New $\oint ds = 4\pi r^2$

∴ $\emptyset = \mathrm{E} \times 4\pi r^2$….. (i)

Since the charge enclosed by the Gaussian surface is q, according to Gauss's theorem,

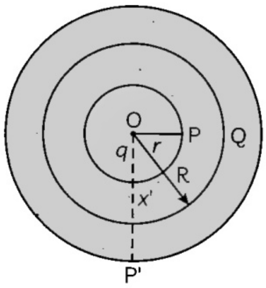
$\emptyset = \frac{q}{\varepsilon_0}$ ……(ii)

from (i) & (ii) we get

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

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

To calculate the electric field intensity at any Point P', where Point P', lies outside the spherical shell imagine a Gaussian surface with centre 0 and radius x', as shown in fig.




According to Gauss's theorem'

$$E'(4\pi r^2) = \frac{q+Q}{\varepsilon_0}$$

$$\Rightarrow E' = \frac{q+Q}{4\pi\varepsilon_0\, x^2}$$

# CHAPTER TWO

# (ELECTROSTATIC POTENTIAL AND CAPACITANCE)

## Section –A

## Multiple Choice Questions (MCQ)

1. **Two charges $+10C$ and $-10C$ are placed 10Cm apart .Potential at the centre of the line joining the two charges.**

   **(a)** $2V$ **(b)**Zero

   **(c)**$-2V$ **(d)** none of the above

2. **An electron of mass m and charge e is accelerated through a P.D of V volts in vacuum. Its final values**

   **(a)** $\frac{eV}{m}$ **(b)**$\frac{eV}{2m}$

   **(c)**$\sqrt{\frac{ev}{m}}$ **(d)**$\frac{\sqrt{2eV}}{m}$

3. **The possible unit of Electric field intensity is**

   **(a)** Newton / meter

   **(b)**Newton- Coulomb

   **(c)**$Jc^{-1}m^{-1}$ **(d)**$J\ c\ m^{-1}$

4. **A parallel plate capacitor with air between the plates has capacitance of $2\mu F$. If the capacitor is immersedin a liquid of dielectric constant 5. Its capacitance will be .**

   **(a)** $05\mu F$ **(b)**$10\mu F$

   **(c)**$5\mu F$ **(d)**$2\mu F$

5. **The electric potential at a point at a distance of 2m from a point of charge of 0.1μC is 450V. The electric field at the point will be**

   **(a)**225N/c

   **(b)**2.25N/C

   **(c)**22.5N/c

   **(d)**None of the above

6. **These are 10 units of charge at the centre of a circle of radius of 1m. The work done in moving 1 unit of charge once around the circle is .**

   **(a)** 10units

   **(b)** 100 units

   **(c)** 150units

   **(d)** Zero

7. **Two concentric spheres of radii R and r have similar charges with equal surface densities. What is the electric potential at their common centre.**

   **(a)** $\frac{\sigma}{\epsilon_0}$ **(b)**$\frac{\sigma}{\epsilon_0}(R+r)$

   **(c)**$\frac{R\sigma}{\epsilon_0}$ **(d)**$\frac{\sigma}{\epsilon_0}(R-r)$

8. **A particle A has a charge +q and particle B has a charge of +4q each of them have same mass m. When the particle are allowed to fall from rest through same P.D., ratio of their speeds $\frac{vA}{vB}$ is**

**(a)** 1:4

**(b)** 1:2

**(c)**2:1

**(d)**4:1

9. **The electric potential V is given as function of x . $V(x) = 5x^2 + 10x - 4$ . The value of electric field at . $x = 1m$ is**

**(a)** $-20V/m$

**( b)** $-23V/m$

**(c)** $11\ V/m$

**(d)** $6V/m$

10. **The electric field exist in space around a point charge +Q. A +ve charge +q is carried from A to B and A to C .,where B, C lie on the circle with +Q at the centre . Work done is:**

**(a)** greater along path AC than AB

**(b)** greater along path AB then AC

**(c)** same in both the case

**(d)** zero in both the case.

11. **The distance between the plates of a parallel plate capacitor of capacitance c is doubled and area of each plate is reduced to half. It's new capacitance will be:**

**(a)** $2c$ **(b)** $\frac{c}{2}$

**(c)** $\frac{c}{4}$ **(d)** 4c

12. **The radius of sphere having capacitance of $0.1\mu F$ is**

**(a)** 9Km **(b)** 0.9 km

**(c)** 8km **(d)** 0.8km

13. **A capacitor of capacitance $20\mu F$ is charged to a P.D of 500 volts . The energy stored in the capacitor is**

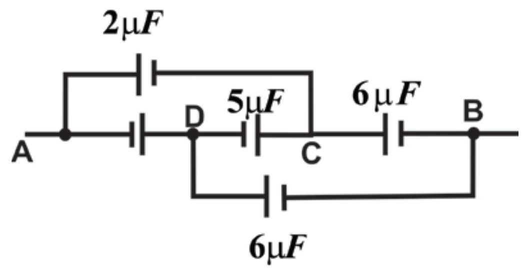
**(a)** 25joules

**(b)** 500 joules

**(c)** 2.5 joules

**(d)** 0.25 joules

14. **The equivalent capacitance between A and B is**




**(a)**$3\mu F$ **(b)**$4\mu F$

**(c)**$5\mu F$ **(d)**$6\mu F$

**15. The radius of soap bubble whose potential is16V is doubled. The new potential of the bubble is**

**(a)** 2V **(b)** 4V

**(c)** 8V **(d)** 16V

**16. The capacitance of capacitor does not depend upon**

**(a)** charge

**(b)** voltage

**(c)** nature of material

**(d)** all of these

**17. The effective capacitance between two points A and B**

**(a)**$2\mu F$ **(b)**$4\mu F$

**(c)**$3\mu F$ **(d)**$0.4\mu F$

**18. The minimum number of capacitors of $2\mu F$ each required to obtain a capacitance of $5\mu F$ is**

**(a)** 6 **(b)** 4

**(c)** 3 **(d)**5

**19. A $10\mu F$ capacitor is charged to a P.D of 50 Volts and is connected to another uncharged capacitor in parallel. Now common potential difference becomes 20V. The capacitance of the second capacitor is .**

**(a)**$15\mu F$ **(b)**$30\mu F$

**(c)**$20\mu F$ **(d)**$10\mu F$

**20. The electric charge Q is uniformly distributed around a semicircle of radius 'r'. Calculate the electric potential at the centre of a semi circle.**

**(a)**$\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$

**(b)**$\frac{1}{4\pi\varepsilon_0}\frac{Q}{2r}$

**(c)**$\frac{1}{4\pi\varepsilon_0}\frac{Q}{3r}$

**(d)**$\frac{1}{4\pi\varepsilon_0}\frac{Q}{4r}$

**21. Five capacitors of $10\mu F$capacitance each are connected to a d.c potential of 100 volt as shown in the figure. The equivalent capacitance between two points A and B is .**

**(a)**$40\mu F$ **(b)**$20\mu F$

**(c)**$10\mu F$ **(d)**$30\mu F$

**22. If a dielectric slab of $4 \times 10^{-5}$ m thick in introduced between the plates of parallel plate capacitor, the distance between the plates is to be increased by $3.5 \times 10^{-5} m$ to resume the capacity to the original value . Then dielectric constant of the material slab is**

**(a)** 6 **(b)** 8

**(c)** 12 **(d)** 20

**23. A parallel plate capacitor has the space between its plates filled by two dielectrics of thickness d/2 with dielectric constants $K_1$ and $K_2$. If d is the distance of separation between the plates, the capacitance of the capacitor is.**

**(a)** $\frac{2\epsilon_0 d}{A}\left(\frac{K_1+K_2}{K_1-K_2}\right)$

**(b)** $\frac{2\epsilon_0 A}{d}\left(\frac{K_1K_2}{K_1+K_2}\right)$

**(c)** $\frac{2\epsilon_0 d}{A}\left(\frac{K_1-K_2}{K_1+K_2}\right)$

**(d)** $\frac{2\epsilon_0 A}{d}(K_1-K_2)$

**24. Assertion (A) :Conductors having equal positive charge and volume, must also have same potential**

**Reason(R): Potential depends only on charge and volume of conductor.**

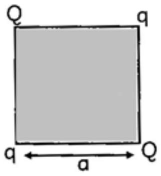
**25. Assertion(A) : Surface of symmetrical conductor can be treated as equipotential surface**

**Reason (R): Charge can easily flow in conductor**

***

# SHORT ANSWER TYPE

1. **Four point charge Q, q, eQ and q are placed at the corners of a square of side a as shown in figure.**




**Find the**

**(A) resultant electric force on a charge Q and .**

**(B) potential energy of this system**

2. **(A) How is the electric field due to a charged parallel plate capacitor affected when a dielectric slab is inserted between the plates fully occupying the intervening regions?**

**(B) A slab of material of electric constant K has the same area as the plates of a parallel plate capacitor but has thickness $\frac{1}{2}d$, where d is the separation between the plates. Find the expression for the capacitance when the slab is inserted between the plates.**

3. **In the circuit shown in Fig. initially $K_1$ is closed and $K_2$ is open. What are the charges on each capacitors. Then $K_1$ was opened and $K_2$ was closed (order is important), What will be the charge on each capacitor now? $[C = 1\mu F]$**

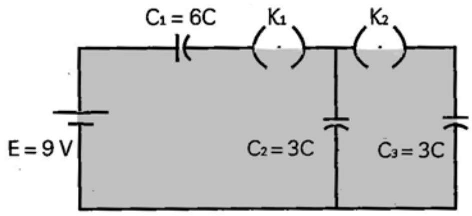



Fig. 2.12

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## LONG ANSWER TYPE

1. **Two point charge q and -q are located at points (0,0, -a) and (0,0, a) respectively.**
   **(A) Find the electrostatic potential at (0,0, z) and (x, y, 0).**

   **(B) How much work is done in moving a small test charge from the point (5, 0, 0) to (-7,0,0) along the X - axis?**

   **(C) How would your answer change if the path of the test charge between the same points is not along the X - axis but along any other random path?**

   **Justify your answer in each case.**

2. **Derive an expression for the energy stored in a parallel plate capacitor. On charging a parallel plate capacitor to a potential V, the spacing between the plates is halved and a dielectric medium of $\varepsilon_r = 10$ is introduced between the plates, is halved source. Explain, using suitable expression, how the**
   **(A) capacitance,**

   **(B) electric field,**

***

# ANSWER KEY

## Section –A

## Multiple Choice Questions (MCQ)

**1. b. zero**

Potential at P due to +10C charge

$$V_1 = \frac{1}{4\pi\varepsilon_0}\frac{10}{r}$$

Potential at P due to -10C charge

$$V_1 = \frac{-1}{4\pi\varepsilon_0}\frac{10}{r}$$

∴ total potential

$$V_1 + V_2 = \frac{1}{4\pi\varepsilon_0}\frac{10}{r}[1-1] = 0$$

**2. d.** $\sqrt{\frac{2eV}{m}}$

$$\frac{1}{2}mv^2 = eV$$

$$\Rightarrow v^2 = \frac{2eV}{m}\; v = \frac{\sqrt{2eV}}{m}$$

**3. c.**

$$\frac{F}{q} = \frac{Newton}{Coulomb} = \frac{Newton\, m}{coulum\, m} = \frac{j}{c\, m}$$

$$= Jc^{-1}m^{-1}$$

**4. b. $10\mu F$**

$$c = \varepsilon c_0$$

$$5 \times 2 = 10\mu F$$

**5. c. 225 N/c**

$$V = \frac{W}{q} = \frac{Fd}{q} = Ed$$

$$E = \frac{V}{d} = \frac{450}{2} = 225\frac{N}{c}$$

**6. d. Zero**

When the charge is at the centre of circle, potential on the surface $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$. is equipotential .

$$dW = Q\, dV = q \times 0 = 0$$

**7. b.** $\frac{\sigma}{\varepsilon_0}(R + r)$

Let Q, q are charges on two spheres

$\sigma = \frac{Q}{4\pi R^2} = \frac{q}{4\pi r^2} =$ surface density

Potential $V_1 = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

$$V_2 = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

Total potential

$$V = V_1 + V_2 = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} + \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{qr}{r^2} + \frac{1}{4\pi\varepsilon_0}\frac{QR}{R^2}$$

$$= \frac{1}{\varepsilon_0}\frac{q}{4\pi r^2} + \frac{1}{\varepsilon_0}\frac{QR}{4\pi R^2}\sigma = \frac{q}{4\pi r^2}$$

$$= \frac{\sigma}{\varepsilon_0}(R + r)$$

**8. b.** 1:2

$$\frac{1}{2}mv^2 = qV \Rightarrow \vartheta = \frac{\sqrt{2qV}}{m}$$

$$\vartheta_A = \frac{\sqrt{2qV}}{m} \vartheta_B = \frac{\sqrt{8qV}}{m}$$

$$\frac{\vartheta_A}{\vartheta_B} = \frac{\sqrt{2}}{\sqrt{8}} = \frac{1}{2}$$

$$\vartheta_A : \vartheta_B = 1:2$$

**9. a. $-20\frac{V}{m}$**

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

$$= -[10x + 10]\ at\ x = 1$$

$$= -20V/m$$

**10. c. same in both the case**

**11. c. $\frac{C}{4}$**

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

$$C_1 = \frac{\frac{\varepsilon_0 A}{2}}{2d} = \frac{\varepsilon_0 A}{4d} = \frac{C}{4}$$

**12. b. 0.9 km**

$$C = 4\pi\varepsilon_0 r \Rightarrow r = \frac{C}{4\pi\varepsilon_0}$$

$$= 9 \times 10^9 \times 0.1\mu F$$

$$= 9 \times 10^9 \times \frac{1}{10} \times 10^{-6}\ m$$

$$= 9 \times 10^2 m = 0.9 \times 10^3 m$$

$$= 0.9km$$

**13. c. 2.5 joules**

$$\frac{1}{2}cV^2 = \frac{1}{2} \times 20\mu F \times 500 \times 500$$

$$= \frac{1}{2} \times 20 \times 10^{-6}F \times 500 \times 500$$

$$= 25 \times 10^{-1} joules$$

$$= 2.5\ joules$$

**14. a. $3\mu F$**

$2\mu F\ and\ 6\mu F$ are in series

$$\frac{1}{C_1} = \frac{1}{2} + \frac{1}{6} = \frac{3+1}{6} = \frac{4}{6} = \frac{2}{3}$$

$$C_1 = \frac{3}{2}\mu F$$

Similarly $2\mu F$ and $6\mu F$along ADB is in series

$$\frac{1}{C_1} = \frac{1}{2} + \frac{1}{6} = \frac{3+1}{6} = \frac{4}{6} = \frac{2}{3}$$

$$C_1 = \frac{3}{2}\mu F$$

$C_1 and\ C_2$ are in parallel $C = C_1 +$
$C = \frac{3}{2} + \frac{3}{2} = 3\mu F$

**15. c. 8V**

$$C_1 = 4\pi\varepsilon_0 r_1 C_1$$

$$= \frac{Q}{V_1} \Rightarrow Q = C_1V_1 = C_2V_2$$

$$C_2 = 4\pi\varepsilon_0 r_2$$

$$r_2 = 2r_1$$

$$V_1 = 16\ V\ \frac{C_1}{C_2} = \frac{V_2}{V_1}$$

$$\Rightarrow \frac{4\pi\varepsilon_0 r_1}{4\pi\varepsilon_0 r_2} = \frac{r_1}{2r_1} = \frac{v_2}{16}$$

$$v_2 = 8V$$

**16. c. nature of material**

**17. d. $0.4\mu F$**

$1\mu F$ and $1\mu F$ are parallel
$C_1 = 1 + 1 = 2\mu F$
The $1\mu F$ and $2\mu F$ and $1\mu F$ are in series

$$\frac{1}{C} = \frac{1}{1} + \frac{1}{2} + \frac{1}{1} = \frac{2+1+2}{2} = \frac{5}{2}$$

$$c = \frac{2}{5} = 0.4\ \mu F$$

**18. b. 4**

$2 + 2 = 4\mu F$

$\frac{1}{C} = \frac{1}{2} + \frac{1}{2} = 1$

$C = 1\mu F$

**19. a. $\boldsymbol{15\mu F}$**

$Q = Q_1 + Q_2 = C_1V_1 + C_2V_2$
$Q = C_1V_1$
$= 10 \times 10^{-6} \times 50 = 500\mu C$
$500 = V(10 + C)$
$500 = 20\ (10 + C)$
$C = 15\mu F$

**20. a. $\boldsymbol{\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}}$**

**21. c. $\boldsymbol{10\mu F}$**

$\frac{C_1}{C_2} = \frac{10}{10} = \frac{C_3}{C_4} = 1$

$C_1C_2$ are in series

$\frac{1}{C_6} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{10} + \frac{1}{10}$

$\Rightarrow C_6 = 5\mu F$

$C_3C_4$ are in series

$\frac{1}{C_7} = \frac{1}{C_3} + \frac{1}{C_4} \Rightarrow C_7 = 5\mu F$

$C_7\ and\ C_6$ are in parallel so equivalent capacitance $= C_6 + C_7 = 10\mu F$

**22. b. 8**

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

$C' = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{k}\right)}$

To keep the capacity same thickness changed by

$x = t\left(1 - \frac{1}{k}\right)$
$= 3.5 \times 10^{-5}$
$= 4 \times 10^{-5}\left(1 - \frac{1}{k}\right)$
$= \frac{35}{40} = 1 - \frac{1}{K}$
$K = 8$

**23. b. $\boldsymbol{\frac{2\,\epsilon_0\,A}{d}\left(\frac{K_1K_2}{K_1+K_2}\right)}$**

$C_1 = \frac{\varepsilon_0 K_1 A}{\frac{d}{2}} = \frac{2\varepsilon_0 K_1 A}{d}$

$C_2 = \frac{\varepsilon_0 K_2 A}{\frac{d}{2}} = \frac{2\varepsilon_0 K_2 A}{d}$ $C_1\ and\ C_2$ are in series

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

$\therefore C = \frac{2\varepsilon_0 A}{d}\left(\frac{K_1K_2}{K_1 + K_2}\right)$

**24. (d) A is false and R is false**

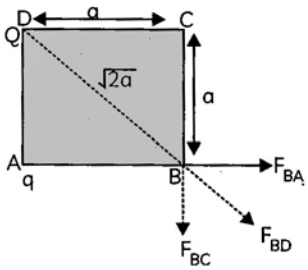
**Explanation:** Electric potential of a charged conductor depends not only on the amount of charge and volume but also on the shape of the conductor. Hence if their shapes are different, they may have different electric potential.

**25. (b) Both A and R are true but R is NOT the correct explanation of A .**

## SHORT ANSWER

**1. Ans.**

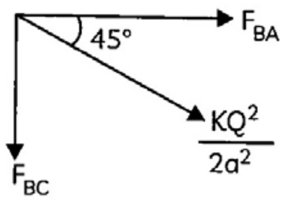
**(A)** Force acting on charge Q placed at point B, is due to charges placed at point A, C and D. Here, magnitude offorce on charge at point B due to charge at point A is $F_{BA} = \frac{KQ_q}{a^2}$




Similarly, magnitude of force on charge at point B due to charge at point C is $F_{BC} = \frac{KQq}{a^2}$

Also, the magnitude of force on charge at point B due to charge at point D is

$$F_{BD} = \frac{KQ^2}{(\sqrt{2}a)^2} = \frac{KQ^2}{2a}$$




Let F is resultant of $F_{BA}$ and $F_{BC}$

$$\therefore \quad F = \sqrt{2}\frac{KQq}{a^2} \left[As F_{BA} = F_{BC} = \frac{KQq}{a^2}\right]$$

∴ The resultant electric forece.

$$F_{net} = F + \frac{KQ^2}{2a^2}$$

$$= \sqrt{2}\frac{KQq}{a^2} + \frac{KQ^2}{2a^2}$$

$$= \frac{KQ}{a^2}\left(\sqrt{2q} + \frac{Q}{2}\right)N$$

**(B)** The potential energy of the system is given by

$$U = U_{AB} + U_{BC} + U_{CD} + U_{DA} + U_{AC} + U_{BD}$$

$$= \frac{KQq}{a} + \frac{KQq}{a} + \frac{KQq}{a} + \frac{KQq}{a} + \frac{Kq^2}{\sqrt{2a}} + \frac{Kq^2}{\sqrt{2a}}$$

$$= \left[4\left(\frac{KQq}{a}\right) + \frac{Kq^2}{\sqrt{2a}} + \frac{Kq^2}{\sqrt{2a}}\right]$$

**2. Ans.**

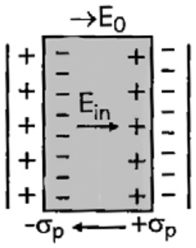
**(A)** In a dielectric under the effect of an external field, a net dipole moment is induced in the dielectric. Due to molecular dipole moments, a net charge appears on the surface of the dielectric.

These induced charges (of densities $-\sigma_p$ and $+\sigma_p$) produce a field opposing the external field. Induced field is lesser in magnitude than the external field.

So, field inside the dielectric gets reduced. $E = |E_o| - |E_{in}|$

Where, E = resultant electric field in the dielectric,

$E_0 =$ external .electric field between two plates and $E_{in}$ = electric field inside the dielectric.




**(B)** The thickness of dielectric slab is $\frac{d}{2}$ i.e.,

$$t = \frac{d}{2}$$

The capacitance of a capacitor due to dielectric slab is

$$C = \frac{\varepsilon_0 A}{d - t + \frac{t}{k}}$$

$$= \frac{\varepsilon_0 A}{d - \frac{d}{2} + \frac{d}{2k}} = \frac{2\varepsilon_0 A}{d\left(1 + \frac{1}{K}\right)}$$

**3. Ans.**

When initially $K_1$ is closed and $K_2$is open then capacitor $C_1$ and $C_2$ are connected n series with battery and have equal charge on capacitors $C_1$ and $C_2$ are

$$Q_1 = Q_2 = q = \left(\frac{C_1 C_2}{C_1 + C_2}\right) E$$

$$= \left(\frac{6C \times 3C}{6C + 3C}\right) \times = 18\mu C$$

$$Q_1 = Q_2 = 18\,\mu C \; and \; Q_3 = 0$$

Now, when $K_1$ is opened and $K_2$ is closed, the battery and capacitor C, are disconnected from the circuit. The charge is capacitor C, will remain constant equal to $Q_1 = Q_2 = 18\mu C.$

The charged capacitor $C_2$ now connects in parallel with uncharged capacitor $C_3$, consider common potential of parallel combination at V

Then $C_2 V' + C_3 V' = Q_2$

$$\Rightarrow V' = \frac{Q_2}{C_2 + C_3} = \frac{18}{3C + 3C} = 3V$$

Hence $Q_2' = 3CV' = 9\,\mu C$

$Q_3' = 3CV' = 9\,\mu C$

$Q_1' = 18\,\mu C$

# LONG ANSWER

**1.Ans.**

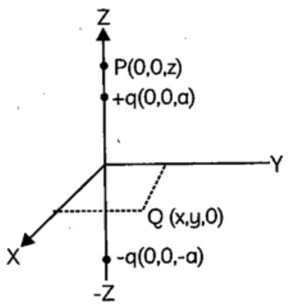
**(A)** Let p(0, 0, z) and Q (x, y, 0) are two points on which electric potential are to be calculated.:

Then electrostatic potential at 'P'

$$V_p = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(z-a)} - \frac{q}{(z+a)}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q \times 2a}{Z^2 - a^2}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{P}{(Z^2 - a^2)} \quad (\because P = q \times 2a)$$




Then, electrostatic potential at Q

$$V_Q = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{\sqrt{x^2 + y^2 + a^2}} - \frac{q}{\sqrt{x^2 + y^2 + a^2}}\right]$$

$= 0$

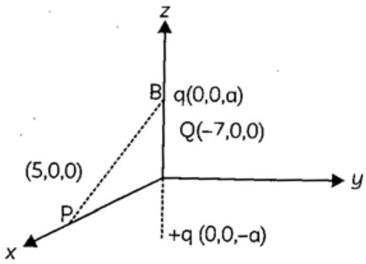
**(B)** Every point on x- axis is on equatorial line of electric dipole (system of two unlike charges)

Potential on it is 0.

No work is done on moving a test charge,

$W = 9\Delta V = q \times 0 = 0$

Work done in moving a charge on equipotential surface is 0.




**(c)** Potential energy of a single charge potential energy of a single charge q at a point with position vector in an external field is $qV\ (r)$

Where $V(r)$ is the potential at that point due to external electric field E.

Potential Energy of a system of two charges.

$$U = q_1 V(r_1) + q_2 V(r_2) + \left(\frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}\right)$$

Where

$q_1 q_2$ = tow point charges at position vector $r_1$ and $r_2$, respectively

$V(r_1)$ =potential at $r_1$ due to the external field.

$V(r_2)$ = potential at $r_2$ due to the external field.

**2. Ans.**

Let at a particular instant charge on the plate of capacitor be q and its potential difference be $\frac{q}{C}$ . If an additional charge $dq$ is given to the capacitor plate, work done for it is given by

$$dW = \left(\frac{q}{C}\right).dq$$

Therefore, whole process of charging from 0 to Q requires a work

$$W = \int_0^Q \frac{qdq}{C} = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q = \frac{Q^2}{2C}$$

This work, done is stored as the electrostatic potential energy of the charged capacitor. Hence, potential energy of charged capacitor. Hence , potential energy of charged capacitor

$$U = \frac{Q^2}{2C}$$

But Q = CV, where V be the potential difference between the plates of capacitor, hence

$$U = \frac{Q^2}{2C} = \frac{1}{2}QV = \frac{1}{2}CV^2$$

Let initial capacitance of a capacitor be $C = \frac{\varepsilon_0 A}{d}$

**A.** When spacing between the plates is halved $\left(i.e., d' = \frac{d}{2}\right)$ and a dielectric medium of $\varepsilon_r = 10$ is introduced between the plates, new capacitance of the capacitor will be

$$C' = \frac{\varepsilon_0 \varepsilon_r A}{d'} = \frac{\varepsilon_0 \times 10 \times A}{\left(\frac{d}{2}\right)}$$

$$= 20\frac{\varepsilon_0 A}{d} = 20C$$

**B.** Initial electric field $E = \frac{V}{d}$

As battery remains connected, hence $V' = V$ but $d' = \frac{d}{2}$

∴ New electric filed $E' = \frac{V'}{d'} = \frac{v}{\frac{d}{2}} = \frac{2V}{d} = 2E$

***

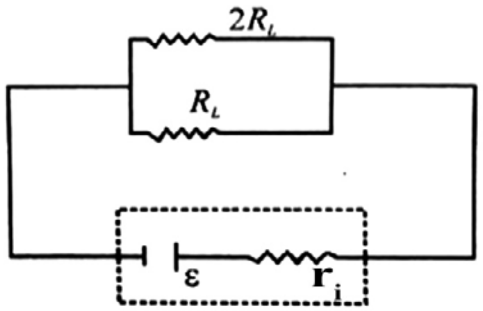
# CHAPTER THREE

## (CURRENT ELECTRICITY-(I))

### Section –A

### Multiple Choice Questions (MCQ)

**1. A battery with a constant $emf\ \varepsilon$ and internal resistance $r$, provides power to an external circuit with load resistance made up by combining resistance $R_L$ and $2R_L$ in parallel. For what value of $R_L$ will power delivered to the load be maximum ?**




**(a)** $R_L = \frac{r_i}{4}$ **(b)** $R_L = \frac{r_i}{2}$

**(c)** $R_L = \frac{2}{3} r_i$ **(d)** $R_L = \frac{3}{2} r_i$

**2. The condition for the validity of Ohm's law is that the**

**(a)** Temperature should remain constant

**(b)** Current should be proportional to voltage

**(c)** Resistance must be wire wound type

**(d)** All of the above

**3. Ohm's Law is not applicable to**

**(a)** Semiconductors

**(b)** D.C. Circuits

**(c)** Small resistors

**(d)** High currents

**4. If a wire is stretched to double its length. Find the new resistance if original resistance of the wire was R.**

**(a)** 1% **(b)** 3%

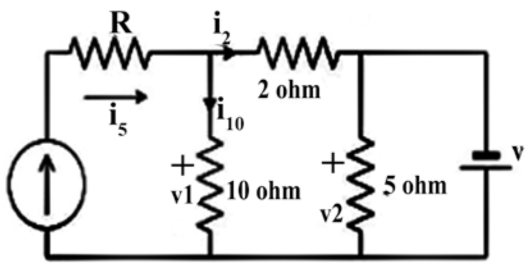
**(c)** 4% **(d)** 2%

**5. A potential difference of 100 V is applied across a conductor of length 50cm. Calculate the drift velocity of electrons if the electron mobility is $9 \times 10^{-5} m^2 V^{-1} s^{-1}$.**

**(a)** $0.0001\ ms^{-1}$ **(b)** $1.8000\ ms^{-1}$

**(c)** $0.018\ ms^{-1}$ **(d)** $0.180\ ms^{-1}$

**6. Determine Vin the circuit.**




**Given $V_{in}$ =20V, $i_6$=6A**

**(a)** $10V$ **(b)** $12V$

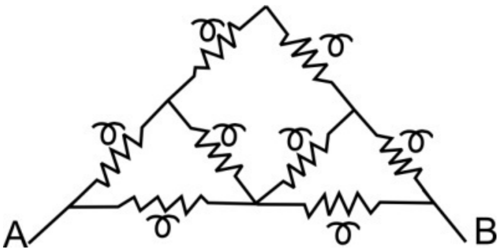
**(c)** $14V$ **(d)** $16V$

7. **Resistance of a heating element at a temperature $(27°C)$ is $200\,\Omega$. At what temperature resistance will be $218\,\Omega$ if $\propto = 1.8 \times 10^{-4} C^{-1}$**

**(a)** $460°C$ **(b)** $480°C$

**(c)** $572°C$ **(d)** $560°C$

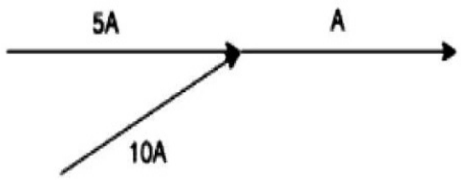
8. **Determine the equivalent resistance across AB in the circuit below .**




**(a)** 8/5r **(b)** 3/5r

**(c)** 6/5r **(d)** 2r

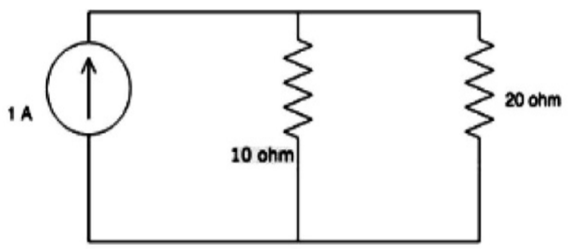
9. **Calculate the Current A.**




**(a)** 5A **(b)** 10A

**(c)** 15A **(d)** 20A

10. **Calculate the current across the 20 ohm resistor.**




**(a)** 20A **(b)** 1A

**(c)** 0.67A **(d)** 0.33A

11. **KCL deals with the conservation of?**

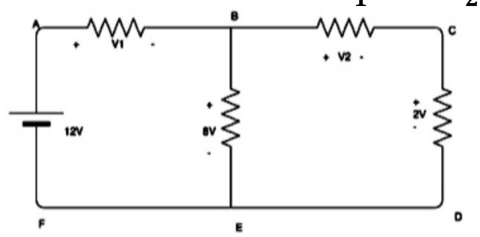
**(a)** Momentum

**(b)** Mass

**(c)** Potential Energy

**(d)** Charge

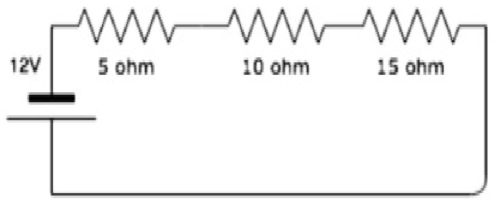
12. **Calculate the value of $V_1$ and $V_2$**




**(a)** 4V.6V **(b)** 5V.6V

**(c)** 6V.7V **(d)** 7V.8V

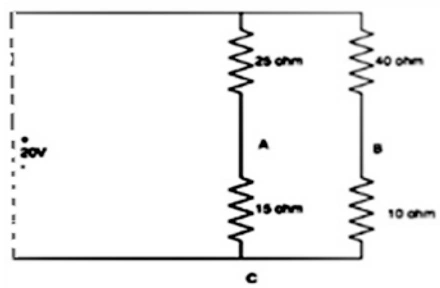
13. **Calculate the voltage across the 10 ohm resistor.**




**(a)** 12V **(b)** 4V

**(c)** 10V **(d)** 0V

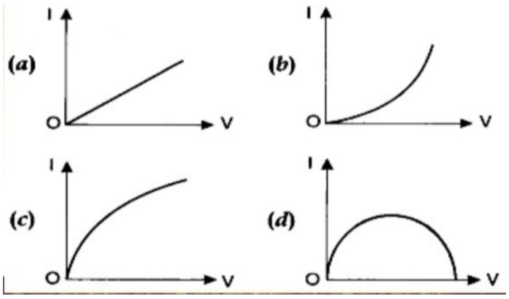
14. **Determine $V_{AB}$ (Voltage across A and B)**



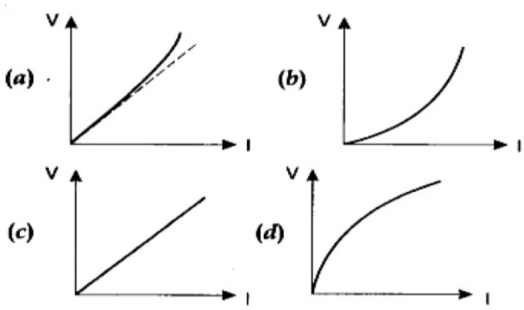

**(a)** 3.5V **(b)** 12V

**(c)** 9.5V **(d)** 6.5V

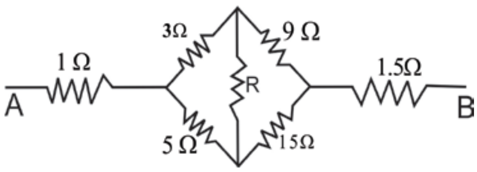
**15. Which of the following I-V graph represents ohmic conductors ?**




**16. Which of the following is correct for V-I graph of a good conductor?**



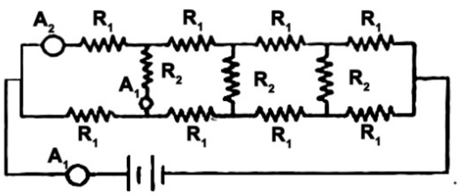

**17. What is the equivalent resistance of the given figure.**




**(a)** 5Ω **(b)** 10Ω

**(c)** 15Ω **(d)** 20Ω

**18. In the given circuit $R_1 = 20\mu R_2 = 8\mu$ and $E = 15\,V$. Then the effective resistance of the circuit is .**




**(a)** 20Ω **(b)** 30Ω

**(c)** 40Ω **(d)** 50Ω

**19. In a Wheatstone bridge if the battery and galvanometer are interchanged then the deflection in galvanometer will.**

**(a)** Change in previous direction

**(b)** not change

**(c)** change in opposite direction

**(d)** none of these

**20. When a metal conductor connected to left gap of a meter bridge is heated, the balancing point.**

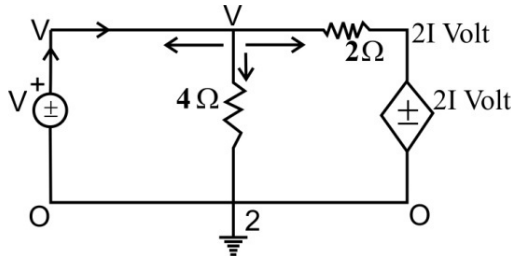
**(a)** shifts towards right

**(b)** shifts towards left

**(c)** remains unchanged

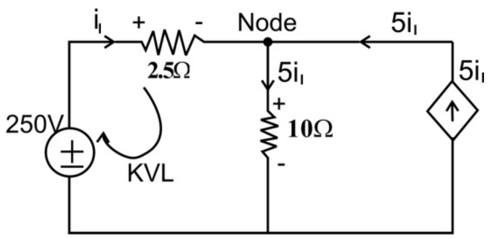
**(d)** remains at zero

**21. Determine load in the following circuit.**




**(a)** 4/3 **(b) 8**/3 **(c)** 4 **(d)** 2

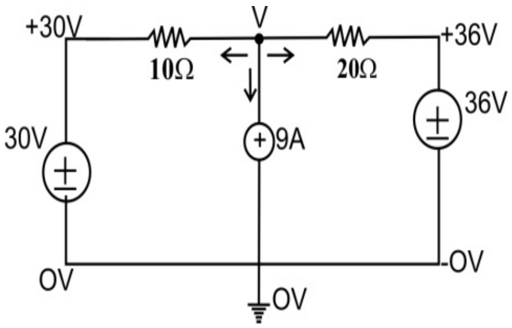
**22. Determine $i_1$ in the circuit .**




**(a)** 4 A **(b)** 2A

**(c)** 4.76A **(d)** 10 A

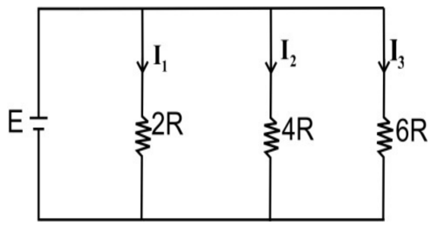
**23. Determine the value of node voltage in the given circuit.**




**(a)** 4V **(b)** 30V

**(c)** 36V **(d)** 92V

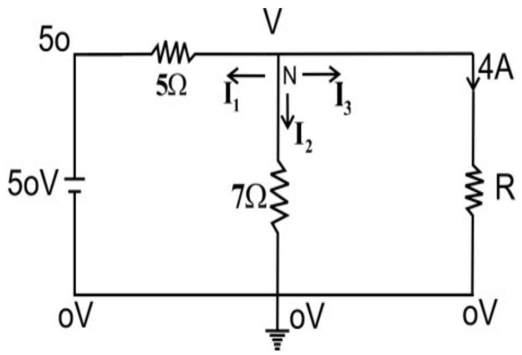
**24. Determine $I_1 : I_2 : I_3$ from the circuit**




**(a)** 3:2:6 **(b)** 2:4:6

**(c)** 6:3:2 **(d)** 6:2:4

**25. Determine the value of R?**



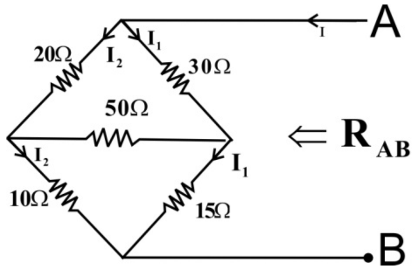

**(a)** 3.5Ω

**(b)** 2.5 Ω

**(c)** 4.5Ω

**(d)** 1.5Ω

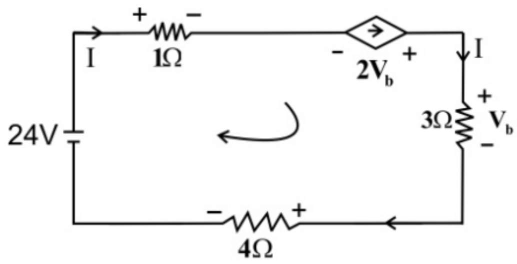
**26. Find the value of Resistance between A and B.**




**(a)** 15Ω **(b)** 45 Ω

**(c)** 30Ω **(d)** 68Ω

**27. Determine I in the circuit**




**(a)** 10A **(b)** 12A

**(c)** 14A **(d)** 16 A

**28. Which instrument is used as the null detector in Wheatstone bridge**

**(a)** Voltmeter

**(b)** Ammeter

**(c)** Galvanometer

**(d)** Multimeter

**29. The equation of balanced Wheatstone bridge is PR=QS.**

**a)** True

**b)** False

**30. For question number (A-B) tow statement are given one labeled**

**assertion (A) and the other labeled Reason(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.**

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

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

**(c) A is true but R is false**

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

(A) **Assertion(A):** A real call has always some internal resistance.

**Reason(R):** When call is in open circuit then $I$ is equal to zero and $V = E$.

**(B) Assertion (A):** We often use a combination of cells.

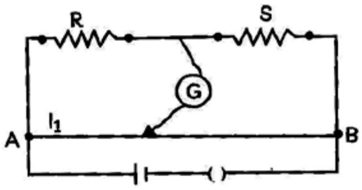
**Reason (R):** To get the higher current in the circuit as a single cell provides a feeble current.

***

## SHORT ANSWER TYPE

**1. (A) Write the principle of working of a meter bridge.**

**(B) In a meter bridge, the balance point is found at a distance $l_1$ with resistances R and S as shown in the figure.**

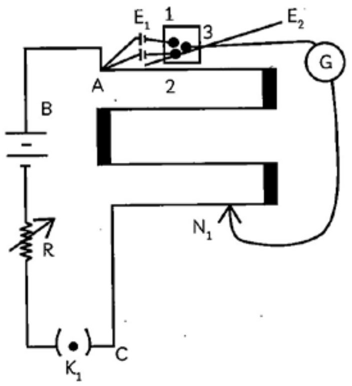



**An unknown resistance X is now connected in parallel to the resistance S and the balance point is found at a distance $l_2$. Obtain a formula for X in terms of $l_1$,$l_2$ and S.**

***

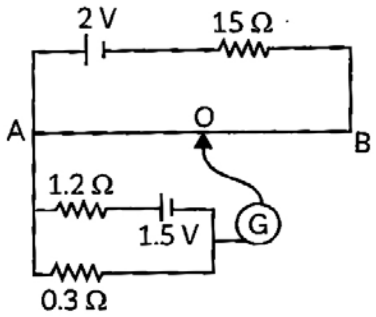
# LONG ANSWER TYPE

1. **In an experiment with a potentiometer, $V_B = 10$ V. R is adjusted to be $50\Omega$ . A student wanting to measure voltage $E_1$ of a battery (approx. 8 V) finds no null point possible. He then diminishes R to $10\Omega$ and is able to locate the null point on the last (4th) segment of the potentiometer. Find the resistance of the potentiometer wire and potential drop per unit length across the wire in the second case.**




2. **(A) State the principle of working of a potentiometer.**

   **(B) In the following potentiometer circuit AB is a uniform wire of length 1 m and resistance 10 Ω. Calculate the potential gradient along the wire and balance length $AO(= l)$.**

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# ANSWER KEY

## Section –A
## Multiple Choice Questions (MCQ)

1. **d. $R_L = \frac{3}{2} r_i$**

   Resultant Load. $R = \frac{2R_L \times R_L}{3R_L} = \frac{2R_L}{3}$

   Power transfer will be maximum

   If $r_i = \frac{2R_L}{3}$

   $$R_L = \frac{3}{2} r_i$$

2. **a.Temperature should remain constant**

3. **a. Semiconductors**

4. **d. 2%**

   $$R' = \frac{\rho l}{A}$$

   $\frac{\Delta R}{R} = \frac{\Delta \rho}{\rho} + \frac{\Delta l}{l} - \frac{\Delta A}{A}$ and $\frac{\Delta l}{l} = \frac{\Delta A}{A}$

   $$\frac{\Delta R}{R} = 0 + 1 + 1 = 2$$

   Hence, percentage increase in the Resistance = 2%

   : Above method is applicable when % change is very small.

5. **c. $0.018 ms^{-1}$**

   Clarification :

   Drift Velocity = Mobility × Electric field.

   It can be rearranged as,

   Drift velocity =

   (frac {(mobility, times, Potential, difference)}{length})

   Drift velocity=

   (frac {(9×10^{-5} times 100)}{0.5})=

   $0.018 mx^{-1}$

6. **b. 12V**

   The current through the 10 ohm resister = $v_1/10$=2A. Applying KCL at node 1:$i_5=i_{10}+i_2$,

   $i_2$=6-2=4A.

   Thus the drop in the 2 ohm resistor =4×2=8V

   $v_1$=20V; hence $v_2$=20-v across 2 ohm resistor =20-8=12V

   $v_2$= V since they are connected in parallel .

7. **c. $527°C$**

   at $t = 27°C$, $R_o = 200\Omega$

   at t = $t°C$, $R_f = 218\Omega$

   $$R_f = R_o(1 + \propto \Delta T)$$

   $$R_f = R_o\left(1 + \propto (t - 27)\right)$$

   $$\frac{R_f - R_o}{R_o \propto} = t - 27$$

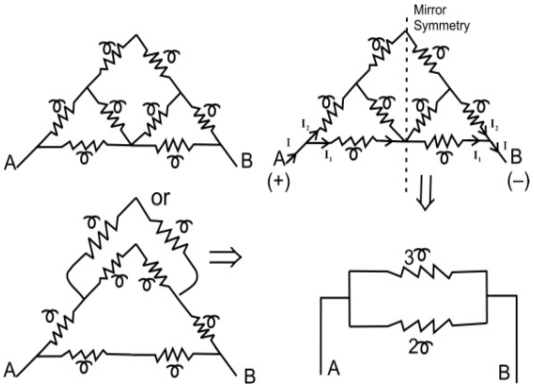
   $$t - 27 = \frac{R_f - R_o}{R_o \propto}$$

   $$t = 27 + \frac{R_f - R_o}{R_o \propto}$$

   $$= 27 + \frac{218 - 200}{200 \times 1.8 \times 10^{-4}}$$

$$= 27 + \frac{18 \times 10^4}{1.8 \times 200}$$
$$= 527°C$$

**8. c. 6/5 r**




$$r + 2r||2r = 3r$$
$$3r||2r$$
$$r_{eq} = \frac{3r \times 2r}{3r + 2r}$$
$$= 6/5r$$

**9. c. 15A**

KCI states that the total current leaving the junction is equal to the current entering it. In this case, the current entering the junction is 5A+10A=15A

**10. d. 0.33A**

Assume lower terminal of 20 ohm at 0V and upper terminal at V vold and applying KCL, we get V/10+V/20=1. V=20/3V so current through 20 ohm = V/20= (20/3)/20=1/3=0. 33V.

**11. d. Charge**

KCL states that the amount of charge entering a junction is equal to the amount of charge leaving it, hence it is the conservation of charge.

**12. a. 4V. 6V**

Using KVL. 12-$V_1$-8=0
$V_1$=4V

8-$V_2$-2=0.

$V_2$=6V

**13. b. 4V**

Using voltage divider rute. V=10* 12/30=4V

**14. a.3.5V**

For branch A:

$V_{AC}$=15×20/(25+15)=7.5V

For branch B:

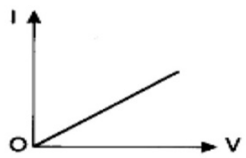
$V_{BC}$=10×20/(10+40)=4V

Applying KVL to loop ABC:

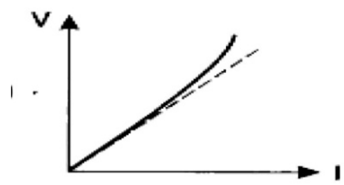
$V_{AB}$+$V_{BC}$+$V_{CA}$=0

$V_{AB}$=3.5V

**15.** –a




**16. a.**



**17. b. 10Ω**

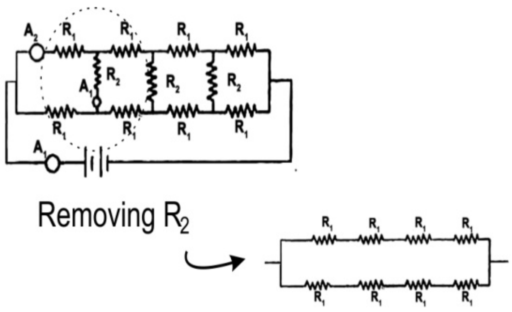
$R_{effective}$ across bridge

$$\frac{(9+3)\times(5+5)}{12+20} = \frac{240}{32}$$

$$R_{AB} = 1\Omega + \frac{240}{32} + 1.5\Omega$$

$$\frac{32+240+48}{32} = \frac{320}{32} = 10\Omega$$

**18. c. 40Ω**




Circuit elements arrange this way

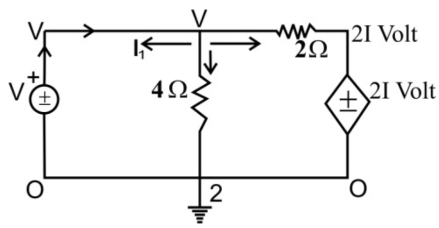
$\therefore 4R_1 \parallel 4R_1$

$$R_{eq} = \frac{4R_1 \times 4R_1}{8R_1} = 2R_1 = 40\Omega$$

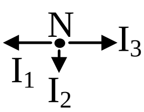
**19. b. not change-**

**20. a. shifts towards right-**

**21. b. 8/3**




Note: (Curent defendant voltage source)




Applying KCL

$I_1 + I_2 + I_3 = 0$

$I_1 + I_2 + I_3 = 0$

$$\Rightarrow -I + \frac{V-O}{4} + \frac{V-2I}{2} = 0$$

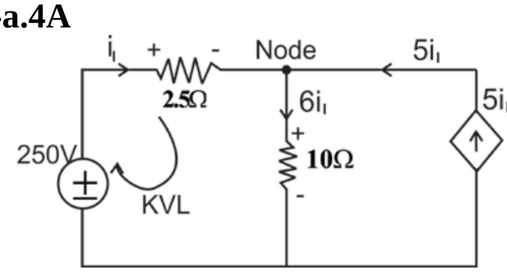
$$\frac{-4I + V + 2V - 4I}{4} = 0$$

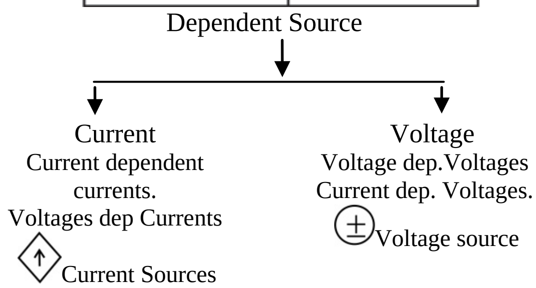
$-8I + 3V = 0$

$3V = 8I$

$\frac{V}{I} = \frac{8}{3}$ = impedence

**22.-a.4A**




In our circuit

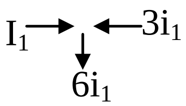
5i → Current dependtdent current source

If 5i given → Voltage dep. current s.

But we have

5i → Current dependtdent current source

Use KVL




at Node, $6i_1$ entering

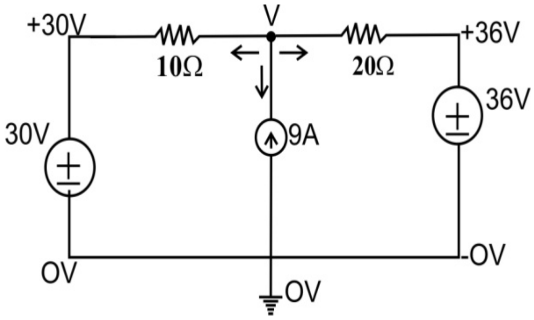
$= 6 i_1$ moving out

$$+250 - (i_1 \times 2.5\Omega) - (6i_1 \times 10) = 0$$

$250 - 2.5i_1 - 60i_1 = 0$

$62.5\, i_1 = 250 \Rightarrow i_1 = 4\, Amp$

**23. -d.92V**



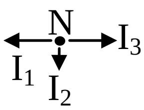

Nodal V = ?

3 Sources given

Voltage s $(30V)$ and $36V$

And one current sources 9A

Apply KCL at Node N




$I_1 + I_2 + I_3 = 0$

Note voltage is always higher than the other value (e.g. 30V)

$\therefore I_1 = \dfrac{V-30}{10\Omega}$

$I_1 + I_2 + I_3 = 0$

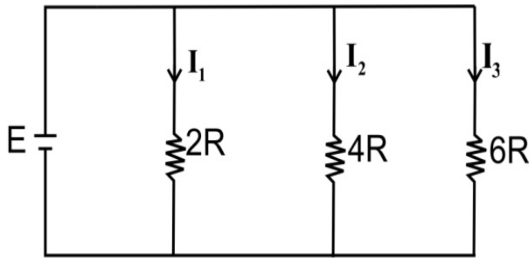
$\Rightarrow \dfrac{V-30}{10} + (-9) + \dfrac{V-36}{20} = 0$

$= \dfrac{2V - 60 - 180 + V - 36}{20} = 0$

$\Rightarrow 3V - 276 = 0$

$V = 92V$

**24. c. 6:3:2**




$E$ is same in all branches :

(II Circuit)

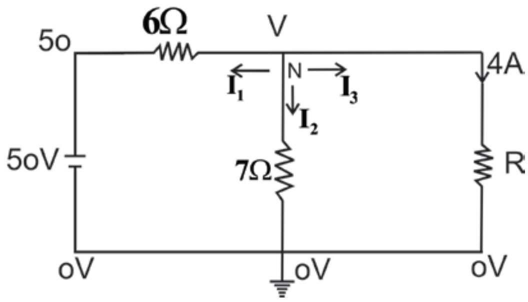
$I_1 : I_2 : I_3$

$\Rightarrow \dfrac{E}{2R} : \dfrac{E}{4R} : \dfrac{E}{6R}$

$\Rightarrow \dfrac{1}{2} : \dfrac{1}{4} : \dfrac{1}{6}$

$\Rightarrow 6 : 3 : 2$

**25. a. 3. 5Ω**




Applying KCL

$I_1 + I_2 + I_3$

$\dfrac{V-50}{6} + \dfrac{V-0}{7} + 4 = 0$

$(\because V > 50V)$

$\dfrac{7(V-50) + 6V + 42 \times 4}{42} = 0$

Or $\quad 13V - 350 + 168 = 0$

$13V = 182$

$V = 14V$

$R = \dfrac{V}{I} = \dfrac{14V}{4A} 3.5\Omega$

**26. a. 18 Ω**

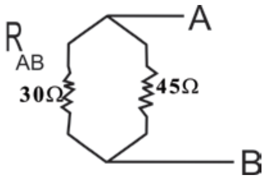
When bridge is balanced current across $30\Omega = 0$

$30\Omega \times 10 = 20\Omega \times 15$

$300\Omega = 300\Omega$ (Balanced)

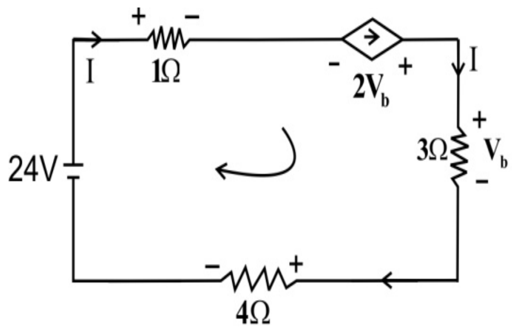
∴ Remove the $50\Omega$ Branch

$R_{AB} = \frac{45\Omega \times 30\Omega}{75\Omega}$




$= 18\Omega$

**27. b. 12A**




We can solve using KVL

$+24 - (I \times (1\Omega)) + 2V_b - V_b - 4 \times I = 0$….(1)

Note

I intering $3\Omega$

∴ $(3\Omega) \times I = V_b = 3I$

$Substitute\ V_b = 3I$ in ….. (1)

24-I+2(3I)-3I-4I=0

24-8I+6I=0

2I=24

I=12A

**28. -C. Galvanometer**

A galvanometer is used as the null detector in a Wheatstone bridge. The null point means the situation in which no current flows through the circuit. Galvanometer is used for measuring the current and also to determine the voltage between any two points of the circuit. Galvanometer is used due to its sensitivity and therefore, even small currents can be measured.

**29. -b. False**

A Wheatstone bridge is an electrical divice u sed to measure unknown resistance by placing it in one of the branches and balancing the two legs of the bridge. If R is the unknown resistance. S is varied until the galvanometer shows null deflection, whereas P and Q are fixed. This is the balanced conditions. So the equation is $(frac\,\{P\} - \{Q\} = frac\,\{R\} - S \rightarrow PS = QR.$ Also, in the balanced condition, no current passes through the galvanometer.

**30.** **(A).** Both A and R are ture and R is the currect explanation of A

**(B)** Both A and R are ture and R is NOT the currect explanation of A

# SHORT ANSWER

**1. Ans.**

**(A)** Meter bridge works on the principle of balanced Wheatstone bridge i.e., when the bridge is balanced,

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

where $R_1, R_2, R_3$ and $R_4$ are resistances connected in four arms of Whetstone's bridge.

**(B)** In first case,

$$\frac{R}{S} = \frac{l_1}{100-l_1} \quad \text{....(i)}$$

In second case

$$\frac{\frac{R}{XS}}{(X+S)} = \frac{l_2}{100-l_2}$$

.....(ii)

Dividing (ii) by (i)

$$\frac{X+S}{X} = \frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right)$$

$$1 + \frac{S}{X} = \frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right)$$

$$X = \frac{S}{\frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right) - 1}$$

$$X = \frac{l_1(100-l_1)}{100(l_2-l_1)}S$$

***

# LONG ANSWER

**1. Ans.**

Equivalent resistance of potentiometer is $R'$ and variable resistor $R = 50\Omega$

$$R_{eq} = 50\Omega + R'$$

Equivalent voltage applied across potentiometer = $10\,V$

Current, $I = \frac{V}{50\Omega + R'} = \frac{10}{50\Omega + R'}$

Potential difference across the wire of potentiometer

$$V = IR'$$

$$V' = \frac{10R'}{50 + R'}$$

Null point is obtained when

$$V' < 8$$

$$\frac{10 \times R'}{50 \times R} < 8 \Rightarrow 10R' < 400 + 8R'$$

$2R' < 400$ or $R' < 200\ \Omega$

For $10\ \Omega$ resistor, null point is obtained when

$$\frac{10 \times R'}{10 + R'} > 40$$

$$2R' > 80$$

$$R' > 40$$

The null point is obtained on 4th segment or at $\frac{3}{4}$ of total length.

$$\frac{10 \times \frac{3}{4} R'}{10 + R'} < 8$$

$$\Rightarrow 7.5R' < 80 + 8R' \Rightarrow R' > 160$$

$$\Rightarrow 160 < R' < 200$$

Potential drop across 400 cm wire $> 8\ V$ It means potential gradient

$$K \times 400\ cm > 8V \Rightarrow K > 2\ V/m$$

$$K > \frac{8}{400}\ volt/cm$$

$$K > \frac{8}{4}\ volt/m$$

Similarly potential drop across 300 cm wire $< 8V$

$$K \times 300\ cm < 8V \Rightarrow K < 2\frac{2}{3}\ V/m$$

Thus, $2\frac{2}{3}\frac{V}{m} > K > 2\ V/m$

**2. Ans.**

**(A) Principle of potentiometer:** The basic principle of potentiometer is that when a constant current flows through a wire of uniform cross-section area then the potential drop across any length of the wire is directly proportional to that length. A potentiometer is a device used to measure an unknown emf or potential difference and internal resistance of a cell accurately.

**(B)** Total resistance of the primary circuit $= 15 + 10 = 25\ \Omega$

$$emf\ =\ 2\ V$$

∴ Current in the wire $AB$

$$I = \frac{2}{25} = 0.08A$$

P.D. across the wire AB= Current × Resistance of wire $AB$

$$= 0.08 \times 10 =\ 0.8V$$

Potential gradient $= \frac{P.D.}{Length} = \frac{0.8}{100}$

$= 0.008\ V\ cm^{-1}$

Resistance of secondary circuit

$$= 1.2 + 0.3 = 1.5\ \Omega$$

$$emf = 1.5\ V$$

Current in the secondary circuit

$$= \frac{1.5}{1.5} = 1.0 A$$

The same is the current in $0.3\ \Omega$ resistor. P.D. between points A and O, P.D. across $0.3\ \Omega$ resistor in the zero-deflection condition.

$= Current \times resistance$

$= 1.0 \times 0.3 = 0.3\ V$

$$Length\ AO = \frac{\text{Potential difference}}{\text{Potential gradient}}$$

$$= \frac{0.3V}{0.008\ Vcm^{-1}}$$

$= 37.5\ cm$

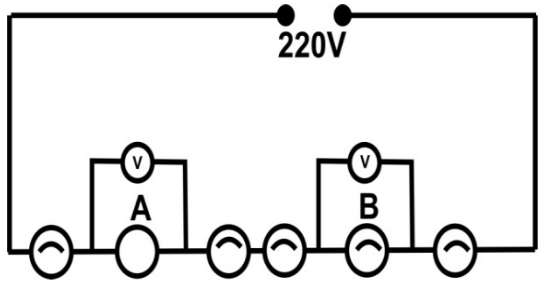
***

# (CURRENT ELECTRICITY-II)

## Section –B

## Multiple Choice Questions (MCQ)

**1.**




**Mains circuit contains six similar bulbs connected in series. One of the bulbs has a broken filament . ideal voltmeters are connected as shown. What are the voltmeter readings ?**

| | **A reading** | **Breading** |
|---|---|---|
| **a)** | 220V | 0V |
| **b)** | 0V | 0V |
| **c)** | 0V | 220V |
| **c)** | 36.7V | 36.7V |

**2. Telephone campanies make use of the wheatstone bridge for _________**

**a)**Measuring the telephone resistance

**b)** computing the line strength.

**c)** maintaing a dialtone.

**d)**locating the cable faults

**3. Wheat stone bridge is used to measure the dc resistance of various types of wires for:-**

**a)**determining their effective resistance

**b)** computing the power dissipation

**c)** quality control of the wire

**d)** maintainng a source of constant e.m.f

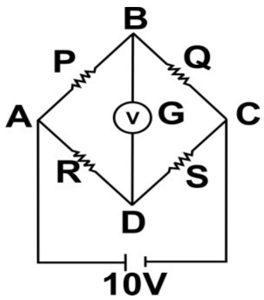
**4. The value of resistances P, Q, R and S of a wheat stone bridge are 20,15,30 and 25 ohms respectively. Calculate the current passing through the battery of neglizible int. resistance.**

**(a)** 0.36 A

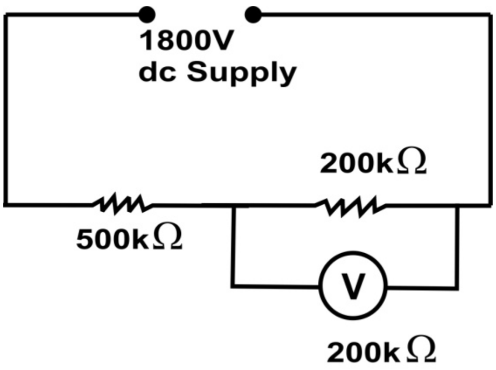
**(b)** 22.22 A

**(c)** 0.25A

**(d)** 0.45A




**5. A constant voltage dc source is connected as shown in the circuit across a resistance of 500KΩ and 200KΩ. What is the reading of the voltmeter resistance (200KΩ) when connected across the second resistor as shown ?**




**(a)** 100V **(b)** 200V

**(c)** 300V **(d)** 400V

**6. If the balance point is obtained at the 35th cm in a meter bridge, the resistance in the left gap and right gap are in the ratio of**

**(a)**7:13 **(b)** 13:7

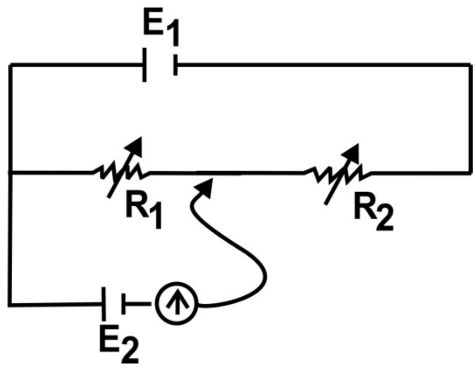
**(c)** 9:11 **(d)** 11:9

**7. A circuit whose resistance is R is connected to n similar cells. If the current in the circuit is same, whether the cells are connected in series or in parallel, then the internal resistance r of each cell is given by : -**

**(a)**r =R/n **(b)** r=R

**(c)** r =nR **(d)** r = 1/R

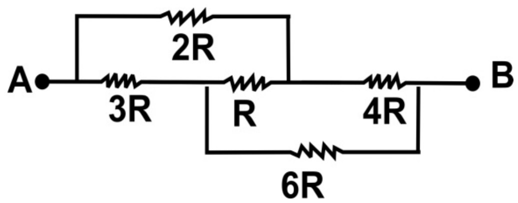
**8. Two cells of emfs $E_1$ and $E_2$ and negligible internal resistances are connected with two variable resisters as shown in the circuit. When the galvanometer shows no deflection the value of the resistances are$R_1$ and $R_2$. What is the value of $E_1/E_2$ ?**




**(a)**$\frac{R_1+R_2}{R_1}$ **(b)**$\frac{R_1+R_2}{R_2}$

**(c)** $\frac{R_1}{R_1+R_2}$ **(d)** $\frac{R_2}{R_1+R_2}$

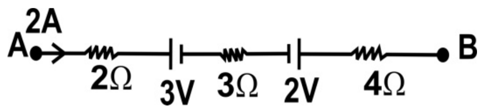
**9. What is the equivalent resistance between A and B ?**




**(a)**$\frac{9R}{5}$ **(b)**$\frac{14R}{5}$

**(c)** $\frac{16R}{5}$ **(d)** $\frac{18R}{5}$

**10. What is the potential difference between A and B ?**

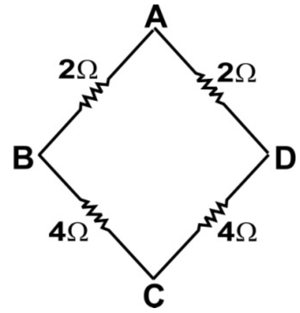



**(a)** 18V **(b)** 19V

**(c)** 20V **(d)** 9V

**11. Four resistances are connected as shown in the circuit. Between which two points does the**

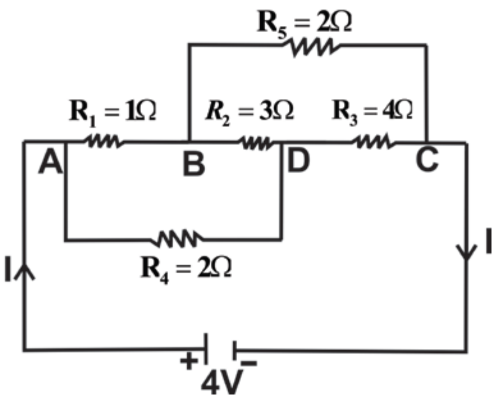
maximum resistance of the combination occur ?




**(a)** A and B **(b)** B and C

**(c)** C and D **(d)** D and A

**12. Deterimen I in the circuit.**




**(a)** 1A **(b)** 3A

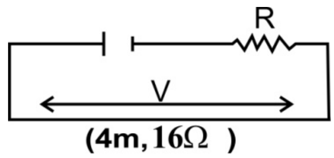
**(c)** 2A **(d)** 4A

**13. A potentiometer circuit has been set up for finding internal resistance of a given cell. Battery supplied is of e.m.f 2.0 V and negligible resistance. Potentiometer wire is 4 m long- when the resistance R connected across the given cell has values of (i) infinity (ii) 9.5Ω , the balancing lengths in the potentiometer wire are found to be 3m and 2.85m respectively. The value of internal resistance of the cell is .**

**(a)** 0.25Ω **(b)** 0.95Ω

**(c)**0.50Ω **(d)**0.75Ω

**14. A potentiometer wire has length 4m and resistance 16Ω. The resistance that must be connected in series with the wire and an accumulator of e.m.f. 2V so as to get a potential gradient 1mv per cm is:**




**(a)** 64 Ω **(b)** 42Ω

**(c)** 30Ω **(d)** 40Ω

**15. A potentiometer wire is 1000cm long and a constant potential difference is maintained across it. Two cells are connected in series to support one another and then in opposite direction. Balance points are obtained at 500cm and 200cm from the positive end of the wire in two cases. Ratio of e.m.f s are**

**(a)** 3:4 **(b)** 7:3

**(c)** 5:1 **(d)** 5:4

**16. A potentiometer wire is 100cm long and constant potential difference is**

maintained across it. Two cells are connected in series to support one another and then in opposite direction. Balance points are obtained at 50cm and 10cm from the positive and of the wire in two cases. Ratio of e.m.fs are

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

**(c)** 5:1 **(d)** 5:4

**17.** **A potentiometer is an accurate and versatile device to make electrical measurements of e.m.f because the method involves : -**

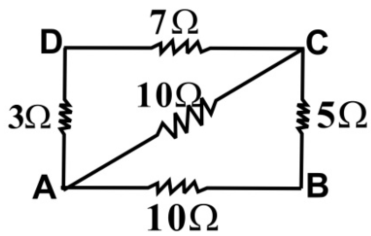
**(a)**Potential gradients

**(b)**Condition of no current flow through the galvanometer

**(c)** Combination of cells, galvanometer and resistances.

**(d)** Cells.

**18.** **For the circuit shown below, the equivalent resistance between A and B is**




**(a)** 10Ω **(b)** $\frac{10}{3}\Omega$

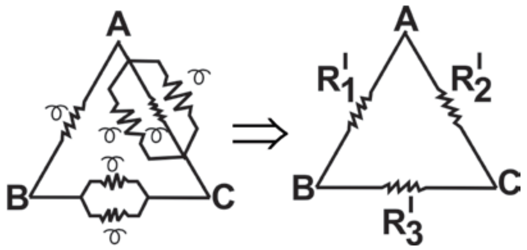
**(c)** 5Ω **(d)** 2Ω

**19.** **If the voltage across a bulb rated 220V-100w drops by 3% of its rated value, then the percentage of the rated value by which the power would decrease.**

**(a)** 10% **(b)** 6%

**(c)** 3.5% **(d)** 7.5%

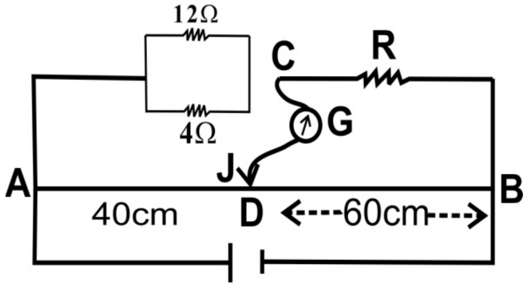
**20.** **Six resistances each of value $r = 5\Omega$ are connected between A,B and C are shown in the figure . IF $R_1 R_2$ and $R_3$ are not resistance between A and B, B and C and A and c, respectively; then $R_1 : R_2 : R_3$ will be equal to .**




**(a)** 6:3:2 **(b)** 1:2:3

**(c)** 5:4:3 **(d)** 4:3:2

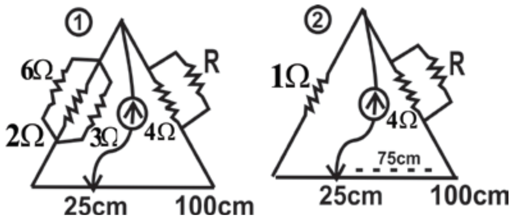
**21.** **Null point at 40 cm in the given circuit. Determine R**




**(a)** 1Ω **(b)** 5Ω

**(c)** 4.5Ω **(d)** 3.5Ω

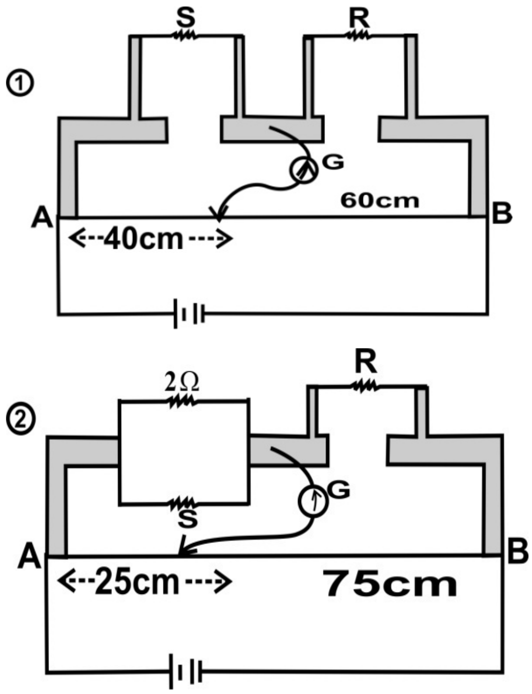
**22.** **Null point is at 25cm. Find R in the circuit below.**




**(a)** $10\Omega$ **(b)** $12\Omega$

**(c)** $20\Omega$ **(d)** $11\Omega$

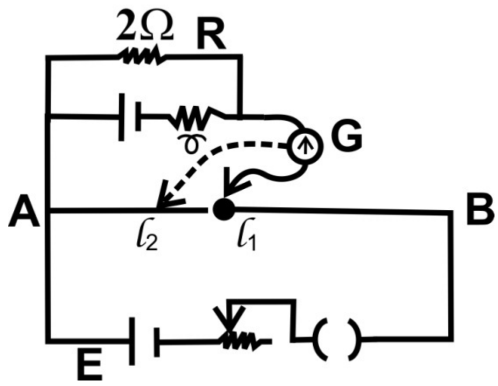
**23.** **Null point is observed at 40cm if a 2Ω resister is added in Parallel to S. the null point shifts to 25cm. Find R and S.**




**(a)** $3\Omega, 2\Omega$ **(b)** $3\Omega, .75\Omega$

**(c)** $3\Omega\,, 1\Omega$ **(d)** $2\Omega\,, 0.5\Omega$

**24.** **In potentiometer experiment, the balancing with a cell is at length of 240 cm on shunting the cell with a resistance of 2 ohm, the balancing length becomes 120cm the internal resistance of the cell is : -**




**(a)** 1 ohm **(b)** 0.5 ohm

**(c)** 4 ohm **(d)** 2 ohm

**25.** **A galvanometer whose coil resistance is 10Ω gives full scale deflection for 5mA. How can you convert it into an ammeter of range $O-5A$**

**(a)** $0.01\Omega$ **(b)** $0.03\Omega$

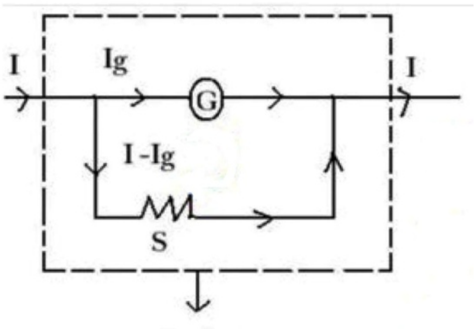
**(c)** $0.02\Omega$ **(d)** $0.06\Omega$

**26.** **A galvanometer whose coil resistance is 1Ω has 50 dimsions which measures I $\mu A$|division. How can you convert it into an ammeter of Range O-10A**

**(a)** $5\times10^{-6}\Omega$ **(b)** $3\times10^{-6}\Omega$

**(c)** $7\times10^{-6}\Omega$ **(d)** $9\times10^{-6}\Omega$

27. **How can you apply KVL in Shunt's Circuit ?**




28. **Resistance of 100 cm long potentiomenter wire is 10Ω.It is connected to a bettery of 2 volt and resistance R is in series. A source of 10mV gives null point at 40cm length, then external resistance R is**

**(a)** 490 Ω **(b)** 790 Ω

**(c)** 590 Ω **(d)** 990 Ω

29. **A potentiometer has uniform potential gradient. Two cells in series (i) to support each other and (ii) to oppose each other are balanced over 6m and 2m respectively on the potentiometer wire. The emf of the cells are in the ratio of**

**(a)** 1:2 **(b)** 1:1

**(c)**3:1 **(d)** 2:1

30. **A voltmeter has a resistance of G ohm and range V volt. Then the value of the resistance used in series to convert it into a voltmeter of range nv volt is:-**

**(a)nG** **(b)(n-1)G**

**(c)G/n** **(d)G/n-1**

31. **For question number (A-C) tow statement are given one labeled assertion (A) and the other labeled Reason(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.**

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

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

**(c) A is true but R is false**

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

**(A).Assertion (A):** in the wheatstone bridge the arm BD and AC are called conjugate arms of the bridge.

**Reason (R):** When the bridge is balanced, then on interchanging the positions of he galvonometer and the battery there is no effect on the balance of the bridge.

**(B) Assertion (A):** A potentiometer wire is usually mode of an alloy such as nichrome.

**Reason(R):** Alloy has high resistivity and low temeperture coefficient of resistance.

**(C) Assertion (A) :** The current should not be passed through potentiometer wire for long time.

**Reson (R):** A laclanche cell should be used in the main cirucit of the petentimeter.

***

## ANSWER KEY

**SECTION-B (MCQ)**

**1. a. A reading 220V B reading 0V**

Since no current flows through the circuit all the voltage drops across the bulb that has a broken filaments i.e. reading of voltmeter $A = 220V$ and the reading of voltmeter $B = 0V$

**2. d. Locating the cable faults**

Cable faults in telephones can be located by telephone companies by making us of a wheat stone bridge. Telephone resistance are determined by using a suitable technology. Dial tone is maintained through optical fibers technology.

**3. c. quality control of the wire**

Wheat stone bridge is used to measure the dc resistance of various types of wires for controlling the quality of wires. Voltage source maintains a constant e.m.f in the bridge circuit.

**4. d. 0.45A**

When a wheat stone bridge is balanced

:– there is no current passing through the galvanometer . So P and R in series and Q and S in series.

$$(P+R) \quad || \quad Q+S$$

$$\therefore R_{eff} = (20+30) \quad || \quad (10+25)$$

$$50\Omega \quad || \quad 40\Omega$$

$$\therefore R_{iq} = \frac{50 \times 40}{90} = 22.22\Omega$$

$$\therefore i = \frac{V}{R_{eq}} = \frac{10}{22.22} = 0.45A$$

**5. c. 300V**

Effective resistance across

Voltmeter $= \frac{200 \times 200}{400} = 100K\Omega$

Total resistances across do supply is

$= (500 + 100) = 600K\Omega$

$= 600 \times 10^3\Omega$

Current drawn from the supply is

$$\frac{1800}{600 \times 1000} = \frac{3}{1000} A$$

Potential difference across voltmeter is

$$i\,R = \frac{3}{1000} \times 100 \times 1000 = 300V$$

**6. a. 7:13**

When bridge is balanced

$$\frac{p}{Q} = \frac{35}{100-35} = \frac{35}{65} = \frac{7}{13}$$

$$\therefore 7:13$$

**7. c. r = R**

**(i)** In series combination : -

Net e.m.f in series – nE

Net int. resistance = nr

$\therefore I_s = \dfrac{nE}{nr + R}$

**(ii)** in parallel combination

Net e.m.f = E, net int. resistance

= r/n

$\therefore i_p = \frac{E}{\frac{r}{n}+R}$ given $i_s = i_p$

$\frac{nE}{nr+R} = \frac{E}{\frac{r}{n}+R}$

Or $nr + R = r + nR$

Or $R(1-n) = r(1-n)$

$R = r$

**8. a.** $\boldsymbol{\frac{R_1+R_2}{R_1}}$

Potential difference across $R_1 = V_1$

$$V_1 = \left[\frac{E_1}{R_1 + R_2}\right].R_1$$

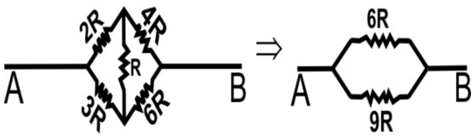
We have $V_1 = E_2$

$$E_2 = \left[\frac{E_1}{R_1 + R_2}\right].R_1$$

$$\frac{E_2}{E_1} = \frac{R_1}{R_1 + R_2}$$

Or $\frac{E_1}{E_2} = \frac{R_1+R_2}{R_1}$

**9. d.** $\boldsymbol{\frac{18R}{5}}$

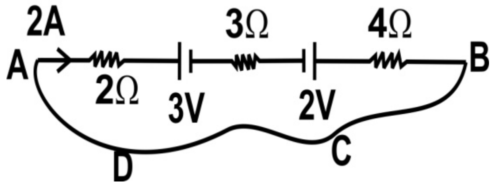



This is a balanced wheat stone bridge

$$R_{AB} = \frac{(6R \times 9R)}{6R + 9R} = \frac{18R}{5}$$

**10. b. 19V**

Consider the loop ABCDA .




From Kirchhoff law

$2(2+3+4) + V_B + V_A = 2 - 3$

$18 + V_B - V_A = -1$

Or $V_A - V_B = 18 + 1 = 19V$

**11. b. B and C**

**c. C and D**

$$R_{eff\,AB} = \frac{10 \times 2}{10 + 2} = \frac{20}{12} = \frac{5}{3}\Omega$$

$$R_{eff\,BC} = \frac{8 \times 4}{8 + 4} = \frac{32}{12} = \frac{8}{3}\Omega$$

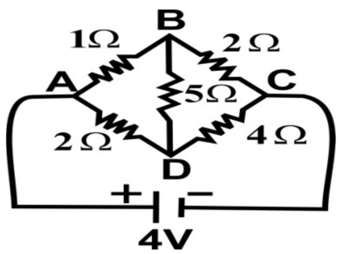
$$R_{eff\,CD} = \frac{8 \times 4}{8 + 4} = \frac{32}{12} = \frac{8}{3}\Omega$$

$$R_{eff\,AD} = \frac{10 \times 2}{10 + 2} = \frac{20}{12} = \frac{5}{3}\Omega$$

Max R across C.D, B.C

**12. c. 2A**

Take points A B C D .

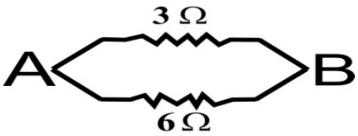



$i_{BD} = 0$

$\left(\therefore \frac{1}{2} = \frac{p}{q} = \frac{R}{S} = \frac{2}{4}\right)$bridge is balanced

Remove 5Ω

$\therefore (1\,\Omega + 2\Omega) \,||\, (2\Omega + 4\Omega)$

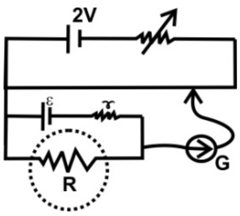



$$\frac{1}{R_{eq}} = \frac{1}{3} + \frac{1}{6} = \frac{3}{6} = \frac{1}{2}$$

$R_{eq} = 2\Omega$

$$\therefore i = \frac{V}{R_{eq}} = \frac{4V}{2\Omega} = (2\,Amp)$$

**13. c. 0.50Ω**




To Find r

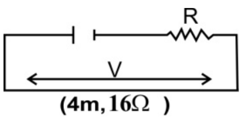
$r = ?$

$$r = R\left(\frac{l_1}{l_2} - 1\right)$$

$$r = 9.5\left(\frac{3}{2.85} - 1\right)$$

$$= 9.5 \times \frac{0.15}{2.85} = 0.50\Omega$$

**14. a. 64Ω**




$\phi = $ 1mv / cm

pot. gradient

$= 10^{-3} V / 10^{-2} m$

$=$ $10^{-1}$ v/m

Find R to make $\phi = 10^{-1}$ v/m

Sol :- $\phi = \frac{pot.drop\ V}{l} = \frac{I \times 16\,\Omega}{4\text{m}}$

$= 4I$

$= \frac{1}{10}$v/m

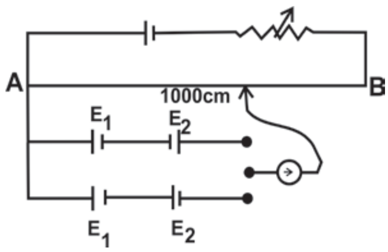
Or $I = \frac{1}{40} = \frac{Total\ e.m.f.}{total\ \ resistance}$

$$= \frac{2}{16 + R} = \frac{1}{40}$$

$80 = 16 + R$

$R = 64\Omega$

**15. b. 7:3**




$E_1 + E_2 = \phi \times 500$

$E_1 - E_2 = \phi \times 200$

(same polarity balancing)

$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{5}{2}$$

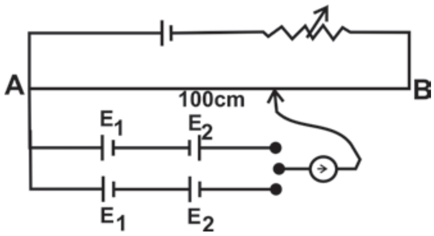
$$\frac{E_1}{E_2} = x = ?$$

$$\frac{\frac{E_1}{E_2} + 1}{\frac{E_1}{E_2} - 1} = \frac{x+1}{x-1} = \frac{5}{2}$$

$2x + 2 = 5x - 5$

$x = \frac{7}{3}$

**16. b. 3:2**



$$E_1 + E_2 = \phi \times 50$$

$$E_1 - E_2 = \phi \times 10$$

$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{50}{10} = 5$$

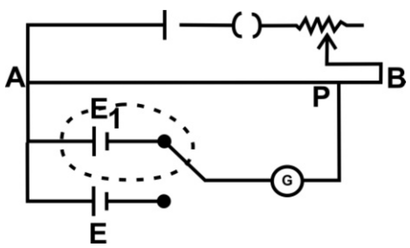
$$\frac{\frac{E_1}{E_2} + 1}{\frac{E_1}{E_2} - 1} = 5 = \frac{x+1}{x-1}$$

$$5x - 5 = x + 1$$

$$4x = 6$$

$$x = \frac{6}{4} = \frac{3}{2}$$

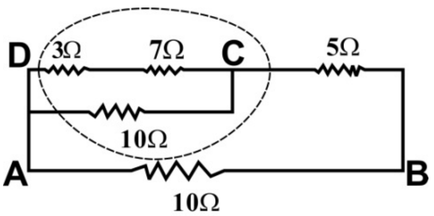
**17. b.**




$i_g = 0$

condition of no current flow through the galvanometer

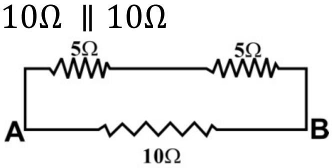
**18. c. 5Ω**




$$R_{\parallel} = (3\Omega + 7\Omega = 10\Omega) \parallel 10\Omega$$

$$R_{\parallel} = \left(\frac{10 \times 10}{20}\right) \parallel 10\Omega$$

$$10\Omega \parallel 10\Omega$$




$$\frac{1}{10} + \frac{1}{10} = \frac{1}{R_{AB}} \Rightarrow R_{AB} = \frac{10}{2} = 5\Omega$$

**19. b. 6%**

$$P = V^2 \backslash R$$

$$\frac{\Delta p}{p} = 2\frac{\Delta V}{V} + \frac{\Delta R}{R} \to 0$$

$$= 2\frac{\Delta V}{V}$$

$$\therefore \frac{\Delta p}{p} \times 100\,\% = 2\frac{\Delta V}{V} \times 100\%$$

$$= 2 \times 3\% = 6\%$$

**20. c. 5:4:3**

$$R_1 = (R_2' \; series \; R_3') \parallel \; R_1'$$

$$R_2 = (R_3' \; series \; R_1') \parallel \; R_2'$$

$$R_3 = (R_1' \; series \; R_2') \parallel \; R_3'$$

$$R_3 = \left(r + \frac{r}{2}\right) \parallel R_3' \Rightarrow \left(\frac{3r}{2} \parallel \frac{r}{3}\right)$$

$$\frac{1}{R_3} = \frac{2}{3r} + \frac{3}{r} = \frac{2+9}{3r} = \frac{11}{3r}$$

$$R_3 = \frac{3r}{11}$$

$$R_1 = \frac{5r}{11}, R_2 = \frac{4r}{11}, R_3 = \frac{3r}{11} \Rightarrow R_1 : R_2 : R_3$$

$$= 5:4:3$$

**21. c. 4. 5Ω**

$$\frac{P}{Q} = \frac{R}{S}$$

$$P = 12 \parallel 4\Omega \frac{12 \times 4}{12 + 4} = 3\Omega$$

$$Q = R$$

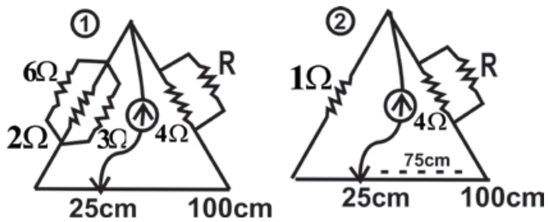
$R = 40\,\rho \qquad S = 60\,\rho$ , $\rho$= resistivity

$$\therefore \frac{3}{R} = \frac{40\rho}{60\rho}$$

Or $\frac{3}{40} = \frac{R}{60}$

$$R = \frac{18}{4} = 4.5\Omega$$

**22. a. 10Ω**




$6\Omega, 2\Omega, 3\Omega$
$(II) Connected$

$$\frac{1}{R_{eff}} = \frac{1}{6} + \frac{1}{2} + \frac{1}{3}$$

$$\frac{1}{R_{eff}} = \frac{2+6+4}{12}$$

$$R_{eff} = 1\Omega$$

$R \parallel 4\Omega$

$$\therefore R^1 = \frac{R \times 4}{R+4}\Omega$$

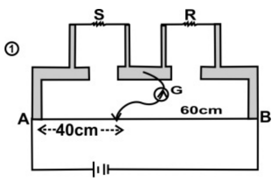
Balancing condition of Bridge

$$\frac{1}{25} = \frac{\frac{4R}{R+4}}{75}$$

Or $3 = \frac{4R}{R+4}$
3R+12= 4R
R=12Ω

**23. a. 3Ω, 2Ω**

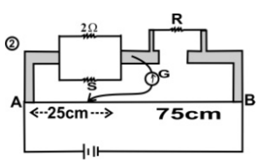
From Circuit – 1




$$\frac{3}{40} = \frac{R}{60}$$

$$R = \frac{6}{4}S$$

$R = \frac{3}{2}S$ ...(1)




$2\Omega \parallel S$

$$S_{eff} = \frac{2S}{2+S}$$

$$\frac{\frac{2S}{2+S}}{25} = \frac{R}{75}$$

$$3\left(\frac{2S}{2+S}\right) = R$$

$6S = 2S + RS$ ….. (2)

Putting (1) in (2) we get

$$6S = 2 \times \frac{3}{2}S + S \times \frac{3}{2}S$$

$$12S = 6S + 3S^2$$

$$3S^2 - 6S = 0$$

$3S(S-2) = 0 \Rightarrow S = 0$ Or 2Ω

$$\therefore R = \frac{3}{2} \times 2 = 3\Omega$$

$$S = 2\Omega$$

**24. d. 2 ohm**

$$r = \left(\frac{l_1 - l_2}{l_2}\right)R$$

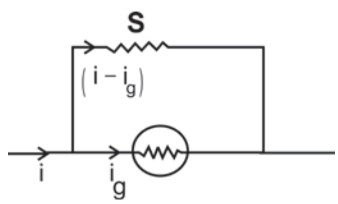
$$= \frac{240-120}{120} \times 2\Omega$$

$$= 2\Omega$$

Note: Potentiometer is and ideal volt meter

**25. a. 0.01Ω**

$G = 10\Omega$




$$i_g = 5mA$$

$i = 5A$
$ig \times G = (i - ig) \times S$

$5mA \times 10 = (5. - 5mA) \times S$

$5 \times 10^{-3} \times 10 = (5 - 5 \times 10^{-3}) \times S$

$5 \times 10^{-2} = 5 \times S$

$S = 10^{-2}\Omega$

$S = 0.01\Omega$

By connecting a shunt of 0.01Ω in parallel with coil of galvanometer.

**26. a. $5 \times 10^{-6}\Omega$**

$1\mu A \rightarrow 1$ Division

50μA

→ 50 division (Ful Scale dellection)

$10 - 50 \times 10^{-6} \approx 10$

$G = 1\Omega$

$i_g = 50\mu A$

$i = 10A$

$i_g \times G = (i - i_g) \times S$

$50\mu A \times 1 = (10 - 50\mu A) \times S$

$5 \times 10^{-6}(10 - 50 \times 10^{-6}) \times S$

$5 \times 10^{-6} = 10 \times S$

$S = 5 \times 10^{-6}\Omega$

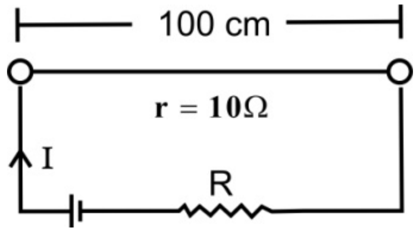
**27. By appling KVL :-**

$Ig\,G - (I - Ig)S = 0$

$Ig\,G = (I - Ig)S$

$\left[S = \frac{IgG}{(I - Ig)}\right]$

**28. b. 790Ω**




$\epsilon = 2V$

$I = \frac{\varepsilon}{R + r}$

$10mV = \frac{E\,r}{(R + r)L} \times l$

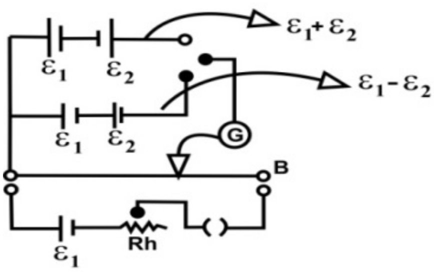
$R + r = \frac{Erl}{L \times 10 \times 10^{-3}}$

$= \frac{2 \times 10\Omega \times 40\,cm}{100cm \times 10^{-2}}$

$R + r = 800$

$R = 800 - 10 = 790\Omega$

**29. d. 2:1**




$xl \rightarrow \varepsilon_1 + \varepsilon_2 = x \times 6$

$\varepsilon_1 - \varepsilon_2 = x \times 2$

$\frac{\varepsilon_1 + \varepsilon_2}{\varepsilon_1 - \varepsilon_2} = 3$

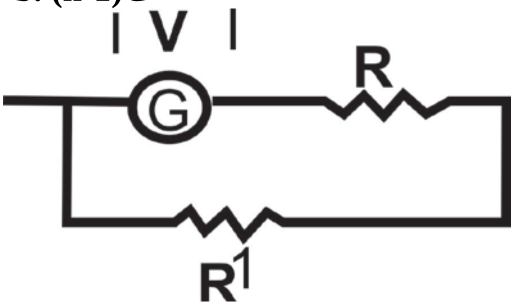
$\varepsilon_1 + \varepsilon_2 = 3\varepsilon_1 - 3\varepsilon_2$

$4\varepsilon_2 = 2\varepsilon_1$

$\frac{\varepsilon_1}{\varepsilon_2} = \frac{4}{2}$

$\therefore 2:1$

**30. b. (n-1)G**




$I_g = \frac{V}{G}$

Potential across R is  R Ig = RV/G

$$V + R\frac{V}{G} = nV$$

$$1 + \frac{R}{G} = n \Rightarrow R = (n-1)G$$

**31. (A)** Both A and R are ture and R is the correct explanation of A .

**(B)** Both A and R are ture and R is the correct explanation of A .

**(C)** A is true but R is flase

**Explanation:** The current should not be passed through potentiometer wire for long time as it will heat of the potentiometer wire and will change the ristance. Potential drop per unit length of the wire will also change.

***

# CHAPTER FOUR

# (MOVING CHARGES AND MAGNETISM & MAGNETISM….. MATTER)

## SECTION -A

**1. The direction of magnetic lines of force due to a straight conductor carrying current is given by**

**(a)** Ampere's rule

**(b)** Fleming's left hand rule.

**(c)** Fleming's right hand rule

**(d)** Right hand thumb rule.

**2. The dimension of magnetic induction is**

**(a)** $[ML^0T^{-2}A^{-1}]$ **(b)** $[MLT^{-2}A]$

**(c)** $[ML^2T^{-1}A^{-1}]$ **(d)** $[M^2L\,T^{-1}A]$

**3. Which of the following motion cannot be deflected by the magnetic field ?**

**(a)** Electron

**(b)** Proton

**(c)** Positron

**(d)** Neutron

**4.** $\left(\frac{Weber}{ampere\,.metre}\right)$ **is the unit of**

**(a)** Magnetic flux

**(b)** Magnetic induction

**(c)** Magnetic permeability

**(d)** Magnetic moment

**5. The SI Unit of magnetic flux is**

**(a)** Gauss **(b)** Weber

**(c)** Tesla **(d)** Maxwell

**6. The relation between Weber and Maxwell is**

**(a)** 1 Maxwell= $10^8$ Weber

**(b)** 1 Weber = $10^8$ Maxwell

**(c)** 1 Maxwell = $10^4$ Weber

**(d)** 1 Weber = $10^4$ Maxwell

**7. Biot Savarts law**

**If 'r' is the radius of a circular coil, then magnetic induction ($\vec{B}$) at the centre of the coil.**

**(a)** $\vec{B} \propto \frac{1}{r}$ **(b)** $\vec{B} \propto r$

**(c)** $\vec{B} \propto \frac{1}{r^2}$ **(d)** $\vec{B} \propto r^2$

**8. The magnitude of the magnetic field induction at a point due to a current element is given by**

**(a)** Coulomb's law

**(b)** Biot Savart's law

**(c)** Gauss's law

**(d)** Lenz's law

**9. Which of the following relations represents Biot Savart's law ?**

**(a)** $\overrightarrow{dB} = \frac{\mu_0}{4\pi} \quad I\frac{(\overrightarrow{dl}\times\vec{r})}{r^2}$

**(b)**$\overrightarrow{dB} = \frac{\mu_0}{4\pi} \quad I\frac{(\overrightarrow{dl}\times\hat{r})}{r^3}$

**(c)** $\overrightarrow{dB} = \frac{\mu_0}{4\pi} \ I \ \frac{(\overrightarrow{dl}\times\vec{r})}{r^3}$

**(d)** $\overrightarrow{dB} = \frac{\mu_0}{4\pi} \quad I\frac{(\overrightarrow{dl}\times\hat{r})}{r^4}$

**10. Magnetic induction of the centre of a circular coil carrying current is**

**(a)** $\frac{\mu_0 NI}{2\pi}$ **(b)**$\frac{\mu_0 NI}{2r}$

**(c)** $\frac{\mu_0 NI}{4\pi}$ **(d)** $\frac{\mu_0 NI}{4r}$

**11. A circular coil A has radius 'a' and the current flowing through it is 'I'. Another circular coil has radius '2a' and if '2I' is the current flowing through it, then the magnetic fields at the centre of the circular coils are in the ratio of :**

**(a)** 1:1 **(b)** 2:1

**(c)** 3:1 **(d)** 4:1

**12. The magnetic flux density at a point distance of 18 meter from a long straight wire carrying a current of 36 A is .**

**(a)** $4 \times 10^{-7}T$ **(b)**$2 \times 10^{-7}T$

**(c)** $8 \times 10^{-7}T$ **(d)** $4 \times 10^{-8}T$

**13. Amperes Law**

**Amperes circuital law when applied to infinitely long straight conductor gives value of magnetic field.**

**(a)** $B = \frac{\mu_0 I}{2\pi r}$ **(b)**$B = \frac{\mu_0 I}{2r}$

**(c)** $B = \frac{\mu_0 I}{2r^2}$ **(d)** $B = \frac{\mu_0 I}{r}$

**14. Ampere's circuital law relates**

**(a)** magnetic field to magnetic flux

**(b)** magnetic field to electric current

**(c)** electric current to heating effect

**(d)** magnetic field to magnetic flux density

**15. Which of the following represent mathematical form of Ampere's circuital law ?**

**(a)** $\oint B\ dl = \frac{I}{\mu_0}$ **(b)**$\oint B\ dl = \frac{\mu_0}{I}$

**(c)**$\oint B.dl = \mu_0 I$ **(d)** $\oint B.dl = \mu_0 I^2$

**16. Magnetic field intensity at any point near a long straight conductor is**

**(a)** $2\frac{\mu_0 I}{\pi r}$ **(b)**$\frac{2\pi}{\mu_0 r}$

**(c)**$\frac{\mu_0 I}{2\pi r}$ **(d)** $\frac{\mu_0 I}{4\pi r}$

**17. The magnetic field at a distance 'r' from a long straight wire carrying current I is 0.4 tesla. The magnetic field at a distance 4r is**

**(a)** 0.1 tesla **(b)** 0.2 tesla

**(c)** 0.4 tesla **(d)** 0.8 tesla

**18. The strength of the magnetic field at a point distance 'r' near a long straight current carrying wire is B . The field at a distance $\frac{r}{2}$ will be.**

**(a)** $\frac{B}{2}$ **(b)** $\frac{B}{4}$

**(c)** $2B$ **(d)** $4B$

**19. A length of wire carries a steady current. It is bent, first to form a circular plane coil of one turn. The same length is, now bent more sharply to give a double loop of smaller radius. Ratio of the magnetic induction at the centre in 1st case $B_1$, to 2nd case $B_2$ is :**

**(a)** $\frac{B_1}{B_2} = 4$ **(b)** $\frac{B_2}{B_1} = 4$

**(c)** $\frac{B_1}{B_2} = 1$ **(d)** $\frac{B_1}{B_2} = 8$

**20. The flux density in air at a point 0.06m from a long straight wire carrying a current of 9 A is**

**(a)** $9 \times 10^{-5}T$ **(b)** $3 \times 10^{-5}T$

**(c)** $3 \times 10^{-4}T$ **(d)** $3 \times 10^{5}T$

**21. A solenoid of length 1m has 5 layers of 1400 turns each. If the current through the solenoid is 2A, then flux density at the centre is**

**(a)** 0.088T **(b)** 0.176T

**(c)** 1.76T **(d)** 0.0176T

**22. Force between two parallel conductors:**
**Two parallel conductors carrying current in same direction are placed at a distance (r) apart, the nature of force between them is**

**(a)** attractive **(b)** repulsive

**(c)** 1st attract then repel **(d)** no affect.

**23. Two free parallel wires carrying currents in the opposite direction**

**(a)** attract each other

**(b)** repel each other

**(c)** don't affect each other

**(d)** get rotated to be perpendicular to each other

**24. When two conductors carrying currents in the same direction are placed parallel, then**

**(a)** the conductors move away

**(b)** the conductors come closer

**(c)** no change is observed

**(d)** none of the above.

**25. Two thin long parallel wires are separated by a distance (r) and carrying current I ampere each. The magnitude of the force per unit length exerted by one wire due to the other is :**

**(a)** $\frac{\mu_0 I^2}{r^2}$ **(b)** $\frac{\mu_0 I^2}{2\pi r}$

**(c)** $\frac{\mu_0 I}{2\pi r}$ **(d)** $\frac{\mu_0 I}{4\pi r^2}$

**26. Force an a moving charge and current carrying conductor.**

**Force acting on a moving charge in a uniform magnetic field is**

**(a)** $q\left(\vec{v} \times \vec{B}\right)$

**(b)** $q\left(\vec{B} \times \vec{v}\right)$

**(c)** $q\,\vec{B}$

**(d)** $q\vec{v}$

**27. Radius of the path of an electron projected in to a magnetic fields perpendicular to the direction of the field is**

**(a)** $\frac{qv}{mB}$ **(b)** $\frac{qB}{mV}$

**(c)** $\frac{mq}{vB}$ **(d)** $\frac{mv}{qB}$

**28. Force acting on a current carrying conductor in the presence of magnetic field is**

**(a)** $I\left(\vec{\iota} \times \vec{B}\right)$ **(b)** $I\left(\vec{B} \times \vec{l}\right)$

**(c)** $I\left(\vec{l}.\vec{B}\right)$ **(d)** $\vec{l}\left(I.\vec{B}\right)$

**29. An electron of mass 'm' charge 'e' enters into a uniform magnetic field region of induction B and is found to describe a circle of radius 'r'. The magnetic field induction B is given by**

**(a)** $\frac{mev}{r}$ **(b)** $\frac{mvr}{e}$

**(c)** $\frac{mv}{er}$ **(d)** $\frac{ev}{mr}$

**30. An electron of mass $9.1 \times 10^{-31}kg$ and charge $1.6 \times 10^{-19}$ moving with velocity $v = 10$ m/s enters into a magnetic field region and is found to describe a circle of radius 9.1cm. The magnetic field induction in tesla is.**

**(a)** $6.25 \times 10^{-11}T$

**(b)** $6.25 \times 10^{-12}T$

**(c)** $6.25 \times 10^{-10}T$

**(d)** $6.25 \times 10^{-8}T$

**31. Time period of revolution of a charged particle is**

**(a)** $T = \frac{2\pi m}{qB}$ **(b)** $\frac{qB}{2\pi m.}$

**(c)** $\frac{q}{2\pi mB}$ **(d)** $\frac{B}{2\pi mq}$

**32. Frequency of revolution of charged particle is**

**(a)** $\frac{qB}{2\pi}$ **(b)** $\frac{qBm}{2\pi}$

**(c)** $\frac{qB}{2\pi m}$ **(d)** $\frac{qm}{2\pi B}$

**33. An electron moves with a uniform velocity 'V' and enters a region of uniform magnetic field B. If 'V' and 'B' are parallel to each other, the electron will.**

**(a)** move in circular path

**(b)** continue to move in same direction

**(c)** not move

**(d)** move at right angles to the direction of B

**34. An electron moves with a uniform velocity $\vec{v}$ and enters a region of uniform magnetic field $\vec{B}$. if $\vec{v}$ and $\vec{B}$ are orthogonal to each other then electron will.**

**(a)** Continue to move in same direction

**(b)** move parallel to $\vec{v}$

**(c)** move in a circular path

**(d)** not move

**35. How much force a $\beta-$ particle experiences when projected along a magnetic field of 1-6T**

**(a)** 1.6 N **(b)** 0.8 N

**(c)** 3.2 N **(d)** 0N

**36. Moving coil galvanometer**

**The direct ion of deflection of coil in a moving coil galvanometer can be obtained by applying**

**(a)** Flemings left hand rule

**(b)** Flemings right hand rule

**(c)** Amperes rule

**(d)** right hand thumb rule

**37. A galvanometer can be converted in to an ammeter by connecting .**

**(a)** a small resistance in parallel

**(b)** a high resistance in parallel

**(c)** a small resistance in series

**(d)** a high resistance in series

**38. A galvanometer can be converted in to and voltmeter by connecting.**

**(a)** a high resistance in series

**(b)** a low resistance in series

**(c)** a high resistance in parallel

**(d)** a low resistance in parallel

**39. If an ammeter is to be used in place of a voltmeter, then we must connect with the ammeter a**

**(a)** low resistance in parallel

**(b)** high resistance in parallel

**(c)** low resistance in series

**(d)** high resistance in series

**40. A circular coil of wire consisting of 100 turns, each of radius $\frac{22}{7}$ cm carries a current of 0.4A . The magnitude of the magnetic field at the centre of the coil is .**

**(a)** $4 \times 10^{-4}T$

**(b)**$8 \times 10^{-4}T$

**(c)**$4 \times 10^{-3}T$

**(d)**$8 \times 10^{-3}T$

**41. A long straight wire carries a current of 25 A . The magnitude of the field B at a point 20 cm from the wire is**

**(a)** $2.5 \times 10^{-4}T$

**(b)**$2.5 \times 10^{-6}T$

**(c)**$2.5 \times 10^{-3}T$

**(d)**$2.5 \times 10^{-5}T$

**42. The magnitude of magnetic force per unit length on a wire carrying current of 4A and making an angle of $30°$ with the direction of a uniform magnetic field of 0.15T is**

**(a)** $0.6\ Nm^{-4}$

**(b)**$0.8\ Nm^{-1}$

**(c)**$0.3\ Nm^{-1}$

**(d)**$0.5\ Nm^{-1}$

**43. A 2 cm wire carrying a current of 5A is placed inside a solenoid perpendicular to its axis. The magnetic field inside the solenoid is given to be 0.2T. The magnitude of force on the wire is**

**(a)** $0.002\ T$

**(b)**$0.2T$

**(c)**$0.4T$

**(d)**$0.02T$

**44. Two long and parallel straight wires A and B carrying currents of 10 A and 4A in the same direction are separated by a distance of 4 cm. The force on a 10cm section of wire A is**

**(a)** $4 \times 10^{-5} N$

**(b)**$2 \times 10^{-5} N$

**(c)**$10^{-5} N$

**(d)**$2 \times 10^{-4} N$

**45. A strong magnetic field is applied to a stationary electron, then**

**(a)** electron moves in the direction of field

**(b)** electron starts spinning

**(c)** electron moves in the opposite direction of field

**(d)** electron remains stationary

**46. What is the resistance of an ideal ammeter**

**(a)** 0 **(b)**$\infty$

**(c)**$2R$ **(d)**$G$

**47. What is the resistance of an ideal voltmeter.**

**(a)** 0 **(b)**$\infty$

**(c)**$2R$ **(d)**$G$

**48. Sensitivity of moving coil galvanometer can increase.**

**(a)** by increasing number of turns of coil

**(b)** by increasing magnetic field

**(c)** by increasing area of the coil

**(d)** all of the above

**49. In the moving coil galvanometer, the deflection $\theta$ of the coil is related to the electric current by the relation.**

**(a)** $i \propto \sqrt{\theta}$ **(b)**$i \propto \theta$

**(c)**$i \propto \theta^2$ **(d)**$i \propto \frac{1}{\theta}$

**50. Assertion(A):** The poles of magnet cannot be separated by breaking into two pieces.

**Reason (R):** The magnetic moment will be reduced to half when a magnet is broken into two pieces.

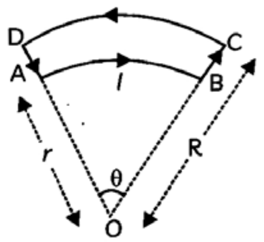
**51. Assertion(A):** Basic difference between an electric lines and magnetic lines of force is that former is discontinuous and the latter is continuous or endless.

**Reason(R):** No electric lines of force exist inside a charged body but magnetic lines do exist inside a magnet.

***

## SHORT ANSWER TYPE

**1.** Obtain the expression for magnetic field at O for a given loop of wire carrying current in the direction shown in the figure. The loop contains two circular segments of a metallic wire of radii r and R, subtending angle $\theta$ at the centre O.




**2.** (A) State the underlying principle of a moving coil galvanometer.

(B) Give two reasons to explain why a galvanometer cannot as such be used to measure the value of the current in a given circuit

(C) Define the terms:

(i) voltage sensitivity and

(ii) current sensitivity of a galvanometer.

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

4. A bar magnet of magnetic moment m and moment of inertia I (about centre, perpendicular to length) is cut into two equal pieces, perpendicular to length. Let T be the period of oscillations of the original magnet about an axis through the midpoint, perpendicular to length, in a magnetic field B. What would be the time period 'T' for each piece?

***

## LONG ANSWER TYPE

1. Consider a circular current-carrying loop of radius R in the x-y plane with centre at origin. Consider the line integral $JL = \left| \int_{-L}^{L} \boldsymbol{B}.\boldsymbol{dl} \right|$ taken along z-axis.

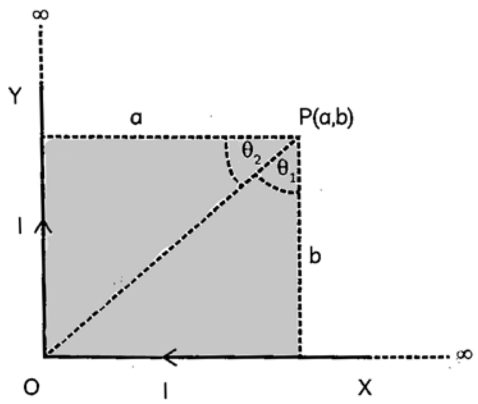
   (A) Show that $J(L)$ monotonically increases with L.

   (B) Use an appropriate Amperian loop to show that $J(\infty) = \mu_0 I$, where I is the current in the wire.

   (C) Verify directly the above result.

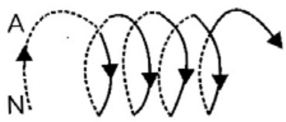
   (D) Suppose we replace the circular coil by a square coil of sides R carrying the same current I. What can you say about $J(L)$ and $J(\infty)$?

2. Two infinitely long current carrying conductors are held at right angles to each other as shown in the following figure. Find the value of magnetic field at the point $P(a, b)$.



3. **(A) State Ampere's circuital law. Use this law to obtain the expression for the magnetic field inside an air cored toroid of average radius, having $'n'$ turns per unit length and carrying a steady current $I$.**

**(B) An observer to the left of a solenoid of N turns each of cross section area A observes that a steady current $I$ in it flows in the clockwise direction. Depict the magnetic field lines due to the solenoid specifying its polarity and show that it acts as a bar magnet of magnetic momentum $M = NIA$.**




4. **Show that the current loop behaves Like a magnetic dipole and find its magnetic dipole moment:**

***

# ANSWER KEY

## SECTION-A(MCQ)

1. d
2. a
3. d
4. c
5. b
6. b
7. a
8. b
9. c
10. b
11. a
12. a
13. a
14. b
15. c
16. c
17. a
18. c
19. b
20. b
21. d
22. a
23. b
24. b
25. b
26. a
27. d
28. a
29. c
30. c
31. a
32. c
33. b
34. c
35. d
36. a
37. a
38. a
39. d
40. b
41. d
42. c
43. d
44. b
45. d
46. a
47. b
48. d
49. b
50. **(b) Both A and R are true but R is NOT correct explanation of A .**

    **Explanation:** - As we know every atom of a magnetic as a dipole, so poles cannot be separated when magnet is broken into two equal pieces, magnetic moment of each part will be half of the original magnet.

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

**Explanation :** in case of an electric field of an electric dipole the electric lines of force originate from positive charge and end at negative charge. Whereas magnetic lines are closed continuous loops extending throughout the body of the magnet .

***

## SHORT ANSWER

**1. Ans.**

Magnetic field due to segment AB in downward direction

$$B_{AB} = \frac{\theta}{360°}\left[\frac{\mu_0 I}{2r}\right]$$

$$= \frac{\theta}{2\pi}\left[\frac{\mu_0 I}{2r}\right] \text{(inwards)}$$

Magnetic field due to segment CD in upward direction

$$B_{CD} = \frac{\theta}{360°}\left[\frac{\mu_0 I}{2r}\right]$$

$$= \frac{\theta}{2\pi}\left[\frac{\mu_0 I}{2r}\right] \text{(outwards)}$$

Net magnetic field

$$B_{net} = (B_{AB} - B_{CD})$$

$$= \frac{\theta}{2\pi}\left[\frac{\pi_0 I}{2}\right]\left[\frac{1}{r} - \frac{1}{R}\right]$$

**2. Ans.**

**(A) The Principle:** When a current flows through the conductor coil, a torque acts on it due to the external radial magnetic field. Counter torque due to suspension balances coil after appropriate deflection due to current in the circuit.

**(B)** A galvanometer can be used as such to measure current due to following two reasons.

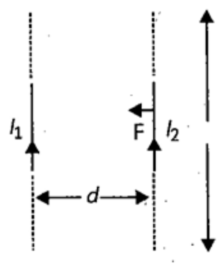
**(i)** A galvanometer has 'a finite large resistance and is connected in series in the circuit, so it will increase the resistance of circuit and hence change the value of current in the circuit.

**(ii)** A galvanometer is a very sensitive device, it gives a full scale deflection for the current of the order of micro ampere, hence if connected as such it will not measure current of the order of ampere.

**(C) (i) Voltage sensitivity:** It is defined as the deflection produced in the galvanometer when a unit voltage is applied across it.

**(ii) Current Sensitivity:** The ratio of deflection produced by the coil to the current in the coil is called the current sensitivity. It is the deflection of the meter per unit current.

**3. Ans.** Magnetic field produced on the wire (carrying current $I_2$) due to $I_1$ will be




$$B = \frac{\mu_0 I_1}{2\pi d}$$

Force acting at $l$ length is

$$F = I_2 l B$$

$$F = \frac{\mu_0 I_1 I_2 l}{2\pi d} \; towards \; I_1$$

If $l = 1m, d = 1m, I_1 = I_2 = I$ and $F = 2 \times 10^{-7}$ N

$$\Rightarrow \quad I = 1A$$

So, 1 ampere is defined as the current, which when maintained in two parallel infinite length conductors, held at a separation of one meter will produce a force of $2 \times 10^{-7}$N per meter on each conductor.

**4. Ans.**

A magnet is oscillating in a uniform magnetic field, the time period of oscillation is

$$T = 2\pi\sqrt{\frac{I}{mB}} \quad \ldots\ldots\ldots\ldots\text{(i)}$$

Where

m = magnetic moment of the magnet

B = uniform magnetic field

But $\quad I = \frac{ml^2}{12}$

When magnet is cut into two equal pieces, perpendicular to length, then moment of inertia of each piece of magnet about an axis perpendicular to length, passing through its centre is

$$I^2 = \frac{m\left(\frac{l}{2}\right)^2}{12 \times 2} = \frac{ml^2}{12} \times \frac{1}{8} = \frac{I}{8}$$

Magnetic dipole moment $M' = \frac{M}{2}$

Its time period of oscillation is

$$T' = 2\pi \sqrt{\frac{I'}{m'B}} = 2\,\pi \sqrt{\frac{\frac{I}{8}}{\left(\frac{M}{2}\right)B}}$$

$$= \frac{2\pi}{2} \sqrt{\frac{I}{MB}}$$

From $eq^n$ (i), We get

$$T' = \frac{T}{2}$$

***

## LONG ANSWER

1. **(A)** Magnetic field due to a circular current carrying loop of radious $R$ in the $xy$ plane with Center at origin acts along z-axis

$$(L) - \int_{-l}^{+L} \vec{B}, \vec{d} = \int_{-l}^{+L} Bdl \cos 0°$$

$$= 2BL$$

$\therefore$ $J(L)$ is monotonically increasing function of L

**(B)** The loop enclose a current I, Now using Ampere's law

$$J(\infty) = \int_{-\infty}^{+\infty} \vec{B}\, dl = \mu_0 l$$

**(C)** The magnetic field at the axis (z-axis) of circular coil is

$$B_z = \frac{\mu_0 IR^2}{2(Z^2 + R^2)^{3/2}}$$

Now integrating

$$\int_{-\infty}^{+\infty} B_z \,. dz$$

$$= \int_{-\infty}^{+\infty} \frac{\mu_0 IR^2}{2(Z^2 + R^2)^{3/2}}\, dz$$

Let $Z = R\, tan\, \theta,$ So $dz = R \sec^2 \theta \, d\theta$

$$(Z^2 + R^2)^{3/2}$$

$$= (R^2 \tan^2 \theta + R^2)^{3/2}$$

$$= R^3 \sec^3 \theta$$

Thus,

$$\int_{-\theta}^{+\theta} B_z\,.dz$$

$$= \frac{\mu_0 I}{2}\int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} \frac{R^2(R\sec^2\theta\, d\theta)}{R^3\sec^3\theta}$$

$$= \frac{\mu_0 I}{2}\int_{-\pi/2}^{+\pi/2} \cos\theta\,.d\theta = \mu_0 I$$

**(D)** We know that $(B_Z)_{square} < (B_z)_{circular}$ coil for the same current and side of the square equal to radius of the coil

$$J(\infty)\ square\ = J(\infty)\ circular\ coil$$

**2.Ans.**

Magnetic field at point P due to the conductor along $x$-axis is

$$B_1 = \frac{\mu_0 I}{4\pi b}\left[Sin\alpha + Sin\frac{\pi}{2}\right]$$

$$= \frac{\mu_0 I}{4\pi b}\left[\frac{a}{\sqrt{a^2+b^2}} + 1\right]$$

Magnetic field at point P due to the conductor along $y$-axis is

$$B_2 = \frac{\mu_0 I}{4\pi a}\left[Sin\beta + Sin\frac{\pi}{2}\right]$$

$$= \frac{\mu_0 I}{4\pi a}\left[\frac{b}{\sqrt{a^2+b^2}} + 1\right]$$

According to right hand thumb rule, both $B_1$ and $B_2$ act normally into the plane of paper. Hence, the resultant magnetic field at point P is

$$B = B_1 + B_2$$

$$= \frac{\pi_0 I}{4\pi}\left[\frac{1}{\sqrt{a^2+b^2}}\left(\frac{a}{b}+\frac{b}{a}\right) + \left(\frac{1}{a}+\frac{1}{b}\right)\right]$$

$$= \frac{\pi_0 I}{4\pi}\left[\frac{\sqrt{a^2+b^2}}{ab} + \frac{a+b}{ab}\right]$$

$$= \frac{\pi_0 I}{4\pi}\left[\frac{\sqrt{a^2+b^2}+(a+b)}{ab}\right]$$

**3. Ans.**

**(A)** Ampere's circuital Law states that "The line integral of resultant magnetic field along a closed plane curve is equal to $\mu_0$ times the total current crossing the area bounded by the closed curve provided the electric field inside the loopremains constant

Thus $\oint B.dl = \mu_0 I_{enc}$ where $\mu_0$ is permeability of free space and lenc is the net current enclosed by the loop. A toroid is a hollow circular ring on which a large number of turns of a wire are closely wound.

Consider an air-cored toroid (as shown below) with center O.

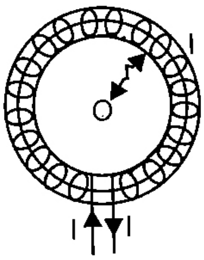
Here,

$r =$ Average radius of the toroid

$I\ =$ Current through the solenoid

$n\ =$ Number of turns per unit length

To determine the magnetic field inside the toroid, we consider three amperian loops (loop 1, loop 2 and loop 3) as shown in the figure below.




According to Ampere's circuital law, we have

$\oint B.dl\ = \mu_0 I_{enc}$ (Total current)

Total current for loop 1 is zero because no current is passing through this loop. So, for loop 1

$\oint B.dl = \mu_0$ ( Total current)

**For loop 3**

According to Ampere's circuital law, we have

$\oint B.dl = \mu_0$ ( Total current)

Total current for loop 3 is zero because net current coming out of this loop is equal to the net current going inside the loop.

**For loop 2:**

The total current flowing through the toroid is NI, where N is the total number of turns

$\oint \vec{B}.\overrightarrow{dt} = 0 =$
$\mu_0(NI)$ ..............(i)

Now, $\vec{B}$ and $\overrightarrow{dl}$ are in the same direction

$$\oint \vec{B}.\overrightarrow{dl} = B \oint dl$$

$$\Rightarrow \oint \vec{B}.\overrightarrow{dl} = B(2\pi r)$$

Comparing (i) and (ii), we get

$$B(2\pi r)\ = \mu_o Nl$$

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

Number of turns per unit length is given by

$$n = \frac{N}{2\pi r}$$

$$\therefore \quad B = \mu_0 nl$$

This is the expression for magnetic field inside air-cored toroid.

**(B)** Given that the current flows in the clockwise direction for an observer on the left side of the solenoid. This means that left face of the solenoid acts as south pole and right face acts as north pole. Inside a bar magnet the magnetic field lines are directed from south to north. Therefore, the magnetic field lines are directed from left to right in the solenoid.

Magnetic moment of single current carrying loop is given by

$$m = IA$$

where, $I =$ Current flowing through the loop, $A$ = Area of the loop

So, Magnetic moment of the whole solenoid is given by

$$M = Nm = N(IA)$$

**4. Ans.**

Current loop as a magnetic dipole: A current carrying circular loop of wire produces magnetic field at its centre of magnitude $B = \frac{\mu_0 l}{2R}$ and behaves like a small magnet fig. Looking at the upper face, the current is anticlockwise. Therefore, it has a north polarity fig. Looking at the lower face of the loop, current is clockwise. Therefore, it has a south polarity. Fig This polarity of current loop can be determined by right hand palm rule of right hand screw rule. The current carrying loop thus behaves as a system of two equal and opposite magnetic poles and hence is magnetic dipole.


The magnetic dipole moment of the loop (M) is directly proportional to strength of current $(I)$ and area enclosed by the loop (A).

$$M \propto IA$$

$M = kIA$ (in S.I. units k = 1)

M=IA

For N number of turns in the loop

$$M = NIA$$

The S.I. unit of magnetic dipole moment is ampere metre$^2$ and the plane of the loop outward.

***

# SECTION –B

## OBJECTIVE TYPE QUESTIONS (OTQ)

### MCQ

1. **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)** $\frac{2M}{\pi}$

   **(c)** $\frac{M}{\pi}$ **(d)** $M\pi$

2. **Unit of magnetic flux density (or magnetic induction) is**

   **(a)** Tesla

   **(b)** Weber/metre$^2$

   **(c)** Newton/ampere-meter

   **(d)** All of the above

3. **Magnetic intensity for an axial point due to a short bar magnet of magnetic moment $M$ is given by**

   **(a)** $\frac{\mu_0}{4\pi} \times \frac{M}{d^3}$ **(b)** $\frac{\mu_0}{4\pi} \times \frac{M}{d^2}$

   **(c)** $\frac{\mu_0}{2\pi} \times \frac{M}{d^3}$ **(d)** $\frac{\mu_0}{2\pi} \times \frac{M}{d^2}$

4. **The torque acting on a bar magnet of magnetic moment $M$ in a uniform magnetic**

   **(a)** $MB \sin\theta$ **(b)** $\frac{MB}{\sin\theta}$

   **(c)** $Mb \cos\theta$ **(d)** $\frac{MB}{\cos\theta}$

   **Where $\theta$ is the angle between the axis of the bar magnet and the direction of the magnetic field.**

5. **Which of the following is the most suitable material for making permanent magnet?**

   **(a)** Steel **(b)** Soft iron

   **(c)** Copper **(d)** Nickel

6. **A magnetic needle is kept in a non-uniform magnetic field. It experiences.**

   **(a)** A force and a torque

   **(b)** A force but not a torque

   **(c)** A torque but not a force

   **(d)** Neither a torque nor a force

***

# Assertion – Reason Questions

**Read the assertion and reason carefully to mark the correct option out of the options given below:**

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

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

**(c)** A is true but R is false

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

7. **Assertion (A) :** The poles of magnet cannot be separated by breaking into two pieces.

   **Reason (R):** The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.

8. **Assertion(A):** Basic difference between an electric line and magnetic line of force is that former is discontinuous and the later is continuous and endless.

   **Reason (R):** No electric lines of force exist inside a charged body but magnetic lines do exist inside a magnet.

***

# Very Short Answer Type Questions

9. **Compare the magnetic field of a straight solenoid and a bar magnet.**

10. **How does the (A) pole strength and (B) magnetic moment of each part of a bar magnet change if it is cut into two equal pieces transverse to its length?**

11. **What should be the orientation of a magnetic dipole in a uniform, magnetic field so that its potential energy is maximum?**

***

# Competency Based Questions

**12.** *Earth's magnetic field is a approximately a magnetic dipole, with the magnetic field S pole near the Earth's geographic north pole and the other magnetic field N pole near the Earth's geographic south pole. This makes the compass usable for navigation. The causes of the field is explained by a Theory called Dynamo Theory.*

**A magnetic dipole is placed in a uniform magnetic field. The net magnetic force on the dipole**

**(a)** Is always zero

**(b)** Depends on the orientation of the dipole

**(c)** Can never be zero

**(d)** Depends on the strength of the dipole

**13.** *A freely suspended bar magnet capable of rotation in a horizontal plane in its equilibrium state, rests in the directions of earth's magnetic field at the place if the magnet is slightly rotated from its equilibrium direction and then released, it executes angular oscillation of period T given as per relation*

$$T = 2\pi\sqrt{\frac{I}{mB_H}}$$

*Here $I$ = moment of inertia of bar magnet about its oscillation axis, $m$ = magnetic moment of bar magnet and $B_H$ = horizontal component of earth's magnetic field at the place.*

*An oscillation magnetometer is designed on this principle and is employed to compare magnetic moments of magnets and for determining earth's magnetic field at a place.*

**(A) Two bar magnets A and B of same configuration and mass have oscillation period of 2 s and 2.5 s repeetively at a given place. The ratio of magnetic moments of A and B is**

**(a)** $5:4$ **(b)** $5:2$

**(c)** $25:16$ **(d)** $16:25$

**(B) The oscillation period of a given magnetic needle is 5 s at place A and 6 s at place B. The ratio of horizontal components of earth's magnetic field at A and B is**

**(a)** $\frac{5}{6}$ **(b)** $\frac{36}{25}$

**(c)** $\frac{12}{5}$ **(d)** $\frac{6}{5}$

***

## Short Answer Type Questions

**14. A bar magnet of magnetic moment $m$ and moment of inertia $I$ (about centre, perpendicular to length) is cut into two equal pieces, perpendicular to length. Let $T$ be the period of oscillations of the original magnet about an axis through the midpoint, perpendicular to length, in a magnetic field $B$. What would be the similar period $T'$ for each piece?**

***

## Long Answer Type Questions

**15. Find an expression of magnetic field intensity due to a magnetic dipole at (A) axial position (B) equatorial position.**

***

# ANSWERS KEY

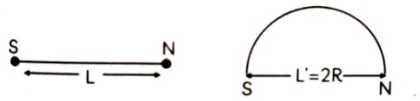
## MCQ

1. **(b)** $\frac{2M}{\pi}$

**Explanation:** On bending a rod its pole strength remains unchanged where as its magnetic moment changes.

New magnetic moment $M^{'}$

$$= m\left(\frac{2L}{\pi}\right) = \frac{2M}{\pi}$$




2. **(d)** all of the above

3. **(c)** $\frac{\mu_0}{2_\pi} \times \frac{M}{d^3}$

**Explanation:**

$$B_a = \frac{\mu_0}{4_\pi} \times \frac{2M}{d^3} = \frac{\mu_0}{2_\pi} \times \frac{M}{d^3}$$

4. **(a)** $MB \sin \theta$

5. **(a)** Steel

6. (a) A force and a torque.

***

## ASSERTION –REASON

7. **(b)** Both A and R are true but R is NOT the correct explanation of A.

**Explanation:** As we know every atom of a magnet acts as a dipole, so poles cannot be separated. When magnet is broken into two equal pieces, magnetic moment of each part will be half of the original magnet.

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

**Explanation:** In case of the electric field of an electric dipole, the electric lines of force originate from positive charge and end at negative charge. Where as isolated magnetic lines are closed continuous loops extending through out the body of the magnet

***

## VERY SHORT ANSWER

**9.** Magnetic field of straight solenoid and a bar magnet are almost identical because ends of a solenoid behave as north and south poles.

Both the fields are identical. A long straight current carrying solenoid behaves as a bar magnet having dipole moment $m = N \mid A$.

**10.** The pole strength will remain unchanged while, (B) the magnetic moment $[M = m(2l)]$ will reduce to half.

**11.** The orientation of dipole should be antiparailei to the magnetic field B.

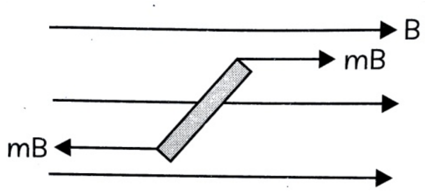
In that orientation, $U_{max'} = +rnB$

***

## CBQs

**12.** (a) is always zero

**Explanation:** Net force on dipole in uniform field will be zero.




**13.** **(A)** (C) 25:16

**Explanation :**

$$\left[Hint: \frac{m_A}{m_B} = \left(\frac{T_B}{T_A}\right)^2 = \left(\frac{2.5}{2}\right)^2 = \frac{25}{16}\right]$$

**(B)** (b) $\frac{36}{25}$

**Explanation :**

$$\left[Hint: \frac{(B_H)_A}{(B_H)_B} = \left(\frac{T_B}{T_A}\right)^2 = \left(\frac{6}{5}\right)^2 = \frac{36}{25}\right]$$

***

## SHORT ANSWER

**14.** A magnet is oscillating in a uniform magnetic field, the time period of oscillation is

$T = 2\pi\sqrt{\frac{I}{mB}}$ .....(i)

Where

$m =$ magnetic moment of the magnet

$B =$ uniform magnetic field

But $I = \frac{ml^2}{12}$

When magnet is cut into two equal pieces perpendicular to length, then moment of inertia of each piece of magnet about an axis perpendicular to length, passing through its centre is

$$I' = \frac{m\left(\frac{l}{2}\right)^2}{12 \times 2} = \frac{ml^2}{12} \times \frac{1}{8} = \frac{I}{8}$$

Magnetic dipole moment $M' = \frac{M}{2}$

Its time period of oscillation is

$$T' = 2\pi\sqrt{\frac{I'}{m'B}} = 2\pi\sqrt{\frac{\frac{I}{8}}{\left(\frac{M}{2}\right)B}}$$

$$= \frac{2\pi}{2}\sqrt{\frac{I}{MB}}$$

From equation (i) we get

$$T' = \frac{T}{2}$$

***

## LONG ANSWER

**15. (A) Magnetic point:** Let there be a point $P$ at the distance of $r$ from a magnetic dipole of dipole moment $(M = 2ml)$ where magnetic field intensity is to be determined.

The magnetic field intensity due to north pole at $P$.

$$\vec{B}_1 = \frac{\mu_0}{4\pi}\frac{m}{(r-l)^2}\,(\overrightarrow{OP})$$

And the magnetic field intensity at $P$ due to south pole.

$$\vec{B}_2 = \frac{\mu_0}{4\pi}\frac{m}{(r+l)^2}\,(\overrightarrow{OP})$$

The net magnetic field intensity at$P$.

$$\vec{B} = \vec{B}_1 + \vec{B}_2$$

$$= \frac{\mu_0 m}{4\pi}\left[\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2}\right] (\overrightarrow{OP})$$

$$= \frac{\mu_0 m}{4\pi}\left[\frac{r^2 + l^2 + 2lr - r^2 - l^2 + 2lr}{(r^2 - l^2)^2}\right] (\overrightarrow{OP})$$

$$= \frac{\mu_0 m 4rl}{4\pi(r^2 - l^2)^2} \qquad (\because 2\overline{\text{ml}} = \bar{M})$$

Or $|\vec{B}| = \frac{\mu_0 2Mr}{4\pi(r^2 - l^1)^2}$

For r >>> l, $l^2$ can be neglected

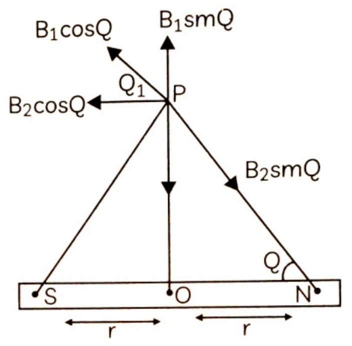
Or $\vec{B} = \frac{\mu_0 2M}{4\pi r^3}$

**(B) At equatorial point**: This magnetic field intensity due to north pole of the magnetic dipole of dipole moment $M$ =2ml at point at the distance from the dipole.

$$B_1 = \frac{\mu_0}{4\pi}\frac{m}{(r^2 + l^2)} (\overrightarrow{NP})$$

And magnetic field intensity at $P$ due to south pole.

$$\vec{B}_2 = \frac{\mu_0 m}{4\pi(r^2 + l^2)} (\overrightarrow{PS})$$




The $B_1$ and $B_2$ can be resolved into two rectangular components and due to $|B_1| = |B_2|$, the $B_1 \sin\theta$ and $B_2 \sin\theta$ being equal and opposite cancel each other fig.

The net magnetic field,

$$B = [B_1 \cos\theta + B_2 \cos\theta]\,\overrightarrow{NS}$$

$$= \frac{2\mu_0 m}{4\pi(r^2 + l^2)}\cos\theta\ (\overrightarrow{NS})$$

$$= \frac{2\mu_0 m}{4\pi(r^2 + l^2)}\frac{l}{\sqrt{r^2 + l^2}}\ (\overrightarrow{NS})$$

$$= \frac{\mu_0 m}{4\pi(r^2 + l^2)^{\frac{3}{2}}}\ (\overrightarrow{NS})$$

For $r >>> l$, $l^2$ can be neglected

$$B = \frac{\mu_0 M}{4\pi r^3}\,\overrightarrow{NS}\ or\ |B| = \frac{\mu_0 M}{4\pi r^3}$$

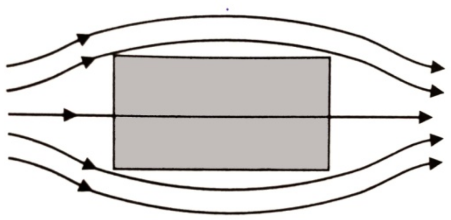
***

# SECTION -C

# Earth's Magnetism and Magnetic Properties of Materials

1. **What do you mean by Diamagnetism. Explain briefly.**

Diamagnetic materials are those that instead of getting attracted towards magnets, tend to get repelled from it. When kept in a magnetic field the diamagnets tend to repel the magnetic field lines out of itself. The figure below exhibits the property.



The main reason behind the diamagnetic property is that every electron in the orbit behaves like a small dipolar magnet. Now in those magnets where the net dipole moment because of these revolving electrons is zero tend to show this property. When placed in an external field one orbital electron slows down while the other speeds up. Due to this a net dipole moment in created which tends to repel the field. Water, copper, bismuth etc, are diamagnetic in nature.

**Caution**

Superconductors are perfect diamagnets as they repel the magnetic field lines completely. This phenomenon of perfect diamagnetism is known as Meissner effect.

2. **What do you mean by Paramagnetism. Explain briefly.**

In paramagnetic materials there already exists a net dipole moment except that due to random orientation of the atomic magnets a net magnetic moment doesn't exist. So at low temperature and high magnetic fields the materials concentrate the field lines though them giving rise to weak magnetic field inside it.

Experimentally it has been found that in an external field $B_0$ the magnetization is related as

$$M = C\frac{B_0}{T}$$

Which is equivalent to

$$x = C\frac{\mu_0}{T}$$

Which is known as the Curie Low.

**3. What do you mean by Ferromagnetism. Explain briefly.**

Just like in paramagnets, Ferro magnets also possess a net non-zero dipole moment but what differentiates them from paramagnets is that the atoms interact in such a way that they spontaneously align themselves in one direction in a macroscopic volume known as domain. These domains are not aligned in a general direction and hence they tend not to be magnetic in nature. Under the influence of external field these domains tend to align with the field and form extremely strong magnets.

Nickel, Iron, Cobalt etc. are ferromagnetic materials and have a relative permeability in excess of 1000. As temperature is increased after a point the Ferro magnets become paramagnets. This transition temperature is known as Curie temperature and the relation is given by

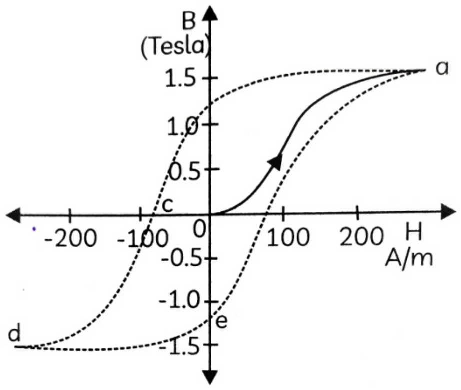
$$x = \frac{C}{T - T_C}$$

Where $T > T_C$

**4. What do you mean by Hysteresis. Explain briefly.**

Imagine a solenoid with a piece of iron rod inside. As you turn on the current and hence the magnetic field, the iron rod also gets magnetized. After a certain point $t$ time the magnetic field inside the iron get saturated. So now if you turn back the current (reverse the current) you would expect the magnetic field to also reverse back and reach zero when the external field is zero. But that never happens. As the external field is made zero the field of the rod doesn’t become zero and a certain magnetic field remains. This is known as retentivity.

To coerce the magnetized iron to get completely demagnetized a further negative current has to be passed and a reversed magnetic field will have to be applied. The external field when the internal field becomes zero is called coercivity. The entire cycle is shown below.




*Hysteresis Curve*

**5. What are permanent and electromagnets.**

Take a solenoid place a steel rod inside. Then connect the solenoid to a battery. What you will get after sometime is a permanent magnet which the steel rod has got converted to. This is because the constant magnetic field generated by the solenoid will force all domains inside the steel to get arranged in one direction which will not get demagnetized easily. Such magnets which do not require a constant source of electricity are called permanent magnets. From the speakers of the earphones to small dc motors everything has a permanent magnet inside.

The solenoid however will demagnetise the moment the electricity is switched off. Hence it can be considered as an electromagnet. Those magnetis which remain magnets as long as the source of electricity is maintained are known as electromagnets.

**6. A closely wound solenoid of 800 turns and area of cross section $\mathbf{2.5 \times 10^{-4} m^2}$ carries a current of 3.0 A. Explain the sense in which the solenoid acts like a bar magnet. What is its associated magnetic moment ?**

**Ans.** A current-carrying solenoid behave as a bar magnet because magnetic field develops along its length.

The magnetic moment associated with the given current-carrying solenoid is calculated as:

$$m = NIA$$

$$= 800 \times 2.5 \times 10^{-4} \times 3 = 0.6\, JT^{-1}$$

***

# OBJECTIVE TYPE QUESTIONS (OTQ)

## MCQ

1. **The correct relation is.**

   **(a)** $B = \frac{B_V}{B_H}$ **(b)** $B = B_V \times B_H$

   **(c)** $|B| = B_H^2 + B_V^2$ **(d)** $B = B_H + B_V$

   **[Where $\boldsymbol{B_H}$= Horizontal component of earth's magnetic field; $\boldsymbol{B_V} =$ vertical component of earths mangeitc field and $\boldsymbol{B} =$ Total intensity of earth's magnetic field.]**

2. **At a certain place, the horizontal component of earth's magnetic field is 3 times the vertical component. The angle of dip at that place is**

   **(a)** $60°$ **(b)** $45°$

   **(c)** $90°$ **(d)** $30°$

3. **The line on the earth's surface joining the points where the field is horizontal is**

   **(a)** Magnetic meridian

   **(b)** Magnetic axis

   **(c)** Magnetic line

   **(d)** Magnetic equator

4. **The magnetic susceptibility is**

   **(a)** $X = \frac{1}{H}$ **(b)** $X = \frac{B}{H}$

   **(c)** $X = \frac{M}{V}$ **(d)** $X = \frac{M}{H}$

5. **S is the surface of a lump of magnetic material.**

   **(a)** Lines of B are necessarily continuous across S.

   **(b)** Some lines of B must be discontinuous across S.

   **(c)** Lines of H are necessarily continuous across S.

   **(d)** Lines of H cannot all be continuous across S.

6. **Curie's law can be written as**

   **(a)** $X \propto (T - T_c)$ **(b)** $X \propto \frac{1}{T-T_c}$

   **(c)** $X \propto \frac{1}{T}$ **(d)** $X \propto T$

7. **The relative permeability is represented by $\boldsymbol{\mu}$, and the susceptibility is denoted by $\boldsymbol{X}$ for a magnetic substance. Then for a paramagnetic substance.**

   **(a)** $\mu_r < 1, X < 0$ **(b)** $\mu_r < 1, X > 0$

   **(c)** $\mu_r > 1, X < 0$ **(d)** $\mu_r > 1, X > 0$

***

## Assertion – Reason Questions

**Read the assertion and reason carefully to mark the correct option out of the options given below:**

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

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

**(c)** A is true but R is false

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

8. **Assertion (A) :** The earth's magnetic field does not affect the working of a moving coil galvanometer.

   **Reason (R):** Earth's magnetic field is very weak.

9. **Assertion(A):** Diamagnetic materials can exhibit magnetism.

   **Reason (R):** Diamagnetic materials have permanent magnetic dipole moment.

10. **Assertion(A):** The susceptibility of diamagnetic materials does not depend upon temperature.

    **Reason (R):** Every atom of a diamagnetic material is not a complete magnet in itself.

***

## Competency Based Question

**11.** *Electromagnetic have a wide variety of uses. A summary of the principles of operation of some of applications like communications, research, electrical industry and magnetic recording.*

**Steel is preferred for making permanent magnets whereas soft**

**iron is preferred for making electromagnets. Explain.**

**12.** *Every matter is formed of atoms. According to atomic model of magnetism, each atom is a complete magnetic dipole. Each atom, consist of a positively charged small nucleus at the centre and electrons revolve around the nucleus in definite orbits. The electrons revolve around the nucleus is identical to that of earth around the sun. The electrons revolve around the nucleus in a definite orbit and the motion is called orbital motion. The electron spins about its own axis and the motion is called spin motion. This spin motion may be clockwise or anticlockwise.*

*The magnetic moment is produced due to both orbital motion and spin motion. However, most of the magnetic moment is produced due to spin motion and very small contribution due to orbital motion.*

*The magnetic dipole moment of orbit motion is*

$$\overrightarrow{m_l} = \frac{e}{2M_e}\vec{L}$$

In addition to-orbital angular momentum $\vec{L}$ electron possess spin angular momentum $\vec{s}$ this contribute to spin magnetic moment.

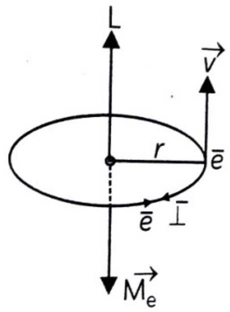
$$\overrightarrow{m_s} = \frac{-\vec{e}}{M_e}\vec{S}$$

So, total magnetic moment will be

$$\vec{m} = m_l' + m_s'$$

$$= \frac{e}{2M_e}\vec{L} + \frac{-e}{M_e}\vec{S}$$

$$= -\frac{e}{2M_e}[\vec{L} \times 2\vec{S}]$$




**(A) An atom is a current loop. It is assumed that the magnetism of atom is caused by revolving electron due to its**

**(a)** orbital motion

**(b)** spin motion

**(c)** both (a) and (b)

**(d)** None of these

**(B)** **An electron moving in a circle orbit of radius $r$ makes $n$ rotation per second. The magnetic field produced at the centre is,**

**(a)** $\frac{\mu_0 n^2 e^2}{r}$ **(b)** $\frac{\mu_0 n^2 e}{r}$

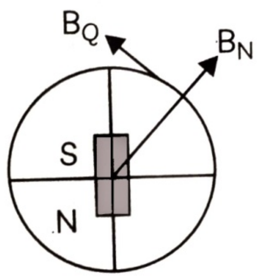
**(c)** $\frac{\mu_0 ne}{2\pi r}$ **(d)** $\frac{\mu_0 ne}{2r}$

**13.** *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 is presently tilted by approximately 11.3°with respect to the axis of rotation of the earth.*

*The pole near the geographic North Pole the earth is called the North magnetic pole and the near the geographic south pole is called South magnetic pole.*

**(A)** **At what place earth magnetic field become horizontal ?**

**(B)** **What are isogonic, isoclinic, isodynamic lines?**

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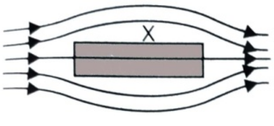
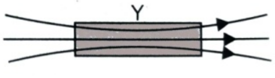
## Short Answer Type Questions

**14.** **A uniform magnetic field gets modified as shown in fig. when two specimens X and Y are placed in it.**

**(A)** **Identify the two specimen X and Y.**

**(B)** **State the reason for the behavior of the field line in X and Y.**

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## Long Answer Type Questions

**15. (A) A small compass needle of magnetic moment 'm' is free to turn about an axis perpendicular to the direction of uniform magnetic field 'B', The moment of inertia of the needle about the axis is 'I'. The needle is slightly disturbed from its stable position and then released, Prove that it executes simple harmonic motion. Hence, deduce the expression for its time period.**

**(B) A compass needle, free to turn in a vertical plane orients itself with its axis vertical at a certain place on the earth. Find out the values of (i) horizontal component of earth's magnetic field and (ii) angle of dip at the place.**

***

# ANSWERS KEY

## MCQ

1. **(C)** $|B| = B_H^2 + B_V^2$
2. **(d)** 30°
3. **(d)** *Magnetic equator*
4. **(a)** $X = \frac{1}{H}$
5. **(a)** *Lines of B are necessarily continuous across S.*

   **(d)** *Lines of H cannot all be continuous across S.*

   **Explanation:** Magnetic field lines for magnetic induction (B) form continuous lines so lines of B are necessarily continuous across S.

   Magnetic intensity H varies for inside and outside the lump so, lines of H cannot all be continuous across S.
6. **(c)** $X \propto \frac{1}{T}$
7. **(d)** $\mu_r > 1\ X > 0$

***

## ASSERTION –REASON

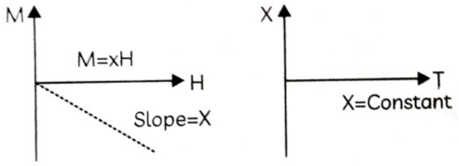
8. **(a) Both A and R are true and R is the correct explanation of A.**

   **Explanation:** In a moving coil galvanometer, the coil is suspended in a very strong uniform magnetic field created by two magnetic pole places. The earth's magnetic field is quite weak as compared to that field, therefore, it does not affect the working of magnetic field.
9. **(c) A is true but R is false**

   **Explanation:** Diamagnetic materials, when placed in magnetic field are oppositely magnetized.
10. **(c)** A is true but R is false

    **Explanation:** Diamagnetism is non-cooperative behavior of orbiting electrons when exposed to an applied magnetic field. Diamagnetic substances are composed of atoms which have no net magnetic moment (i.e. all the orbital shells are filled and there are no unpaired electrons). When exposed to field, a negative magnetization is produced and thus the susceptibility is negative.

Behaviour of diamagnetic material is that the susceptibility is temperature independent

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# CBQs

**11.** Steel is preferred for making permanent magnets on account of its high permeability and high coercivety. Soft iron is preferred for preferred for making electromagnets on account of low retentively, low coercively and low hysteresis loss.

**12.** (B) (c) *both (a) and (b)*

**Explanation :** When electron revolve around the nucleus, the magnetism is caused by both angular momentum due to spin motion and linear momentum due to orbital motion.

(D) (d) $\frac{\mu_0 ne}{2r}$

**Explanation :** B at centre $= \frac{\mu_0 I}{2r}$

Here, $I = ne$

So, $B = \frac{\mu_0 ne}{2r}$

**13.** **(A)** At equater.

**(B)** **Isogonic Line:** The line joining places of equal declination are called isogonic lines.

**Isoclinic Line:** The line joining places of equal inclination are called isoclinic lines.

**Isodynamic Line:** The line joining place of equal horizontal component of earth magnetic field.

***

## SHORT ANSWER

**14.** (A) Specimen X is diamagnetic but specimen $Y$ is paramagnetic

(B) Individual atoms of a diamagnetic material (say X) do not possess a permanent dipole moments of their own. The application of an external magnetic field induces in each atom a small dipole moment in the opposite direction. As a result

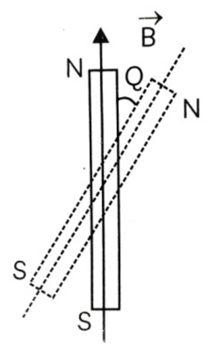
Individual atoms of the paramagnetic material posses a permanent dipole moment of their own on account of continuous random thermal motion of the atom, the net magnetization of the material is zero. In the presence of an external magnetic field, the individual atomic dipole moments tends to align in the same direction. As a result, field lines gets concentrated. As a result, field lines gets concentrated inside the material and the field inside is enhanced.

***

## LONG ANSWER

**15. (A)** Let a small magnetic needle of magnetic moment $m$ be freely suspended in a uniform magnetic field $B$ so that in equilibrium position magnet comes to rest along he direction of B.

If the magnetic needle is rotated by a small angle $\theta$ from its equilibrium and then released, a restoring torque acts on the magnet, where




Restoring torque $\tau = m \times B$

Or $\tau = -m\,B\sin\theta$

If | be the moment of inertia of magnetic needle about the axis of suspension, then

$$\tau \propto I = I\frac{d^2\theta}{dt^2}$$

Hence, in a equilibrium state, we have

$I\frac{d^2\theta}{dt^2} = -mB\sin\theta$

If $\theta$ is small then $\sin\theta \to \theta$ and we get

$I\frac{d^2\theta}{dt^2} = -mB\theta$ or $\frac{d^2\theta}{dt^2} = \frac{mB}{I}\theta$

Here angular acceleration is directly proportional to angular displacement and directed towards the equilibrium position, motion of the magnetic needle is simple harmonic motion, and

Angular frequency of SHM

$$\omega = \sqrt{\frac{mB}{I}}$$

Time period of oscillation

$\tau = \frac{2\pi}{W} = 2\pi\sqrt{\frac{I}{mB}}$

**(B) (i)** When a compass needle, free to turn in a vertical plane, orients itself with its axis vertical at a certain place on the earth, it means that magnetic field of earth is along, vertical direction at that place. Consequently, the horizontal component of earth's magnetic field is zero at that place.

**(ii)** As $\tan\delta = \frac{B_V}{B_H}$ is zero, $\tan\delta =$ and so $\delta = 90°$. Thus, angle of dip $\delta$ at given place is 90°.

***

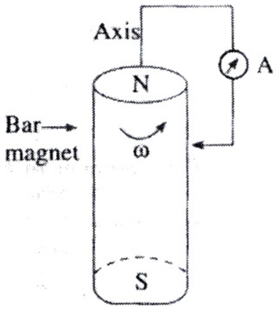
# CHAPTER FIVE

## (ELECTROMAGNETIC INDUCTION)

## Section –A

### QUESTION

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



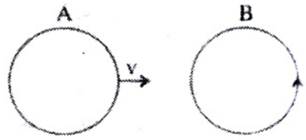

**(a)** a direct current flows in the ammeter A.

**(b)** no current flows through the ammeter A.

**(c)** an alternating sinusoidal current flows through the ammeter A with a time period $T \pi \omega$

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

**2. 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 counterclockwise. 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 counterclockwise direction in A.

**3. The inductance of coil is directly proportional to**

**(a)** its length

**(b)** the number of turns

**(c)** the resistance of the coil

**(d)** the square of the number of turns.

**4. The self inductance L of a solenoid of length I and area of cross-section A, with a fixed number of turns N increase as**

**(a)** $l$ and A increase

**(b)** $l$ decrease and A increases

**(c)** $l$ increase and A decrease

**(d)** both $l$ and A decrease

5. **The physical quantity expressed in henry is :**
   **(a)** magnetic flux
   **(b)** self- inductance
   **(c)** magnetic permeability
   **(d)** magnetic induction

6. **When current in a circuit drops from 10A to 2A in 2 Seconds, the induced e.m.f developed in the circuit is 16 volts. The self inductance of the circuit is**
   **(a)** 16 henry
   **(b)** 8 henry
   **(c)** 6 henry
   **(d)** 4 henry

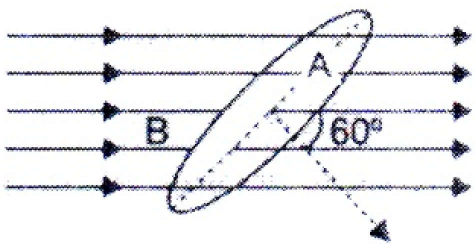
7. **The current passing through a choke of self-inductance 5 henry is decreased at the rate of 2 A/s. The induced emf developed across the coil is**
   **(a)** 10 volt
   **(b)** -10 volt
   **(c)** 25 volt
   **(d)** -2.5 volt

8. **Lenz's law is a consequence of the law of conservation of**
   **(a)** momentum **(b)** mass
   **(c)** energy **(d)** charge

9. **Whenever the flux linked with a circuit changes, there is an induced emf in the circuit. This emf in the circuit lasts.**
   **(a)** for a very short duration
   **(b)** for a long duration
   **(c)** forever
   **(d)** as long as the magnetic flux in the circuit changes.

10. **The area of a square shaped coil is $10^{-2} m^2$. Its plane is perpendicular to a magnetic field of strength $10^{-3} T$ . The magnetic flux linked with the coil is :**
   **(a)** $10\ Wb$ **(b)** $10^{-5} Wb$
   **(c)** $10^{5} Wb$ **(d)** $100\ Wb$

11. **An are $A(= 0.5 m^2)$ shown in the figure is situated in a uniform magnetic field $B = 4.0\ Wb/m^2$ and its normal makes an angle of $60°$ with the field. The magnetic flux passing through the area A would be equal to :**




   **(a)** 2.0 weber **(b)** 1.0 weber
   **(c)** $\sqrt{3}$ weber **(d)** 0.5 weber

**12. If the number of turns in a coil is doubled, then its self-inductance becomes :**

**(a)** double **(b)** half

**(c)** four times **(d)** unchanged

**13. A magnet is dropped with its north pole towards a closed circular coil placed on a table.**

**(a)**looking from above, the induced current in the coil will be anti-clockwise.

**(b)**the magnet will fall with uniform acceleration.

**(c)**as the magnet falls, its acceleration will be reduced.

**(d)**no current will be induced in the coil.

**14. A coppering is held horizontally and a magnet is dropped through the ring with its length along the axis of the ring. The acceleration of the falling magnet is :**

**(a)** equal to the due to gravity

**(b)** less then that due to gravity

**(c)** more than that due to gravity

**(d)**depends on the diameter of the ring and the length of the magnet.

**15. Lenz's law is essential for :**

**(a)** conservation of energy

**(b)** conservation of mass,

**(c)** conservation of momentum

**(d)** conservation of charge.

**16. A thin circular ring of area A is held perpendicular to a uniform magnetic field of induction B.A small cut is made in the ring and galvanometer is connected across its ends in such a way that the total resistance of the circuit is R. When the ring is suddenly squeezed to zero area, the charge flowing through the galvanometer I s:**

**(a)** $\frac{BR}{A}$ **(b)**$\frac{AB}{R}$

**(c)** $ABR$ **(d)** $\frac{B^2A}{R^2}$

**17. Inductance plays the role of :**

**(a)** inertia **(b)** friction

**(c)** source of emf **(d)** force

**18. When the current in a coil changes from 8A to $2A$ in $3 \times 10^{-2}$ second, the emf induced in the coil in 2 volt. The self-inductance of the coil, in millihenry, is :**

**(a)** 1 **(b)** 5

**(c)** 20 **(d)** 10

**19. When the current in a coil is changed from 2A to 4A in 0.05 second, the emf induced in the coil is 8V. The self inductance of coil is :**

**(a)** 0.1H **(b)** 0.2H

**(c)** 0.4H **(d)** 0.8H

**20.** **If $L$ and $R$ represent inductance and resistance respectively then the dimensions of $L/R$ will be:**

**(a)** $M°L°T^{-1}$
**(b)** $M°T^{-1}$
**(c)** $M°L°T$
**(d)** cannot be expressed in terms of M,L and T.

**21.** **Dimensions of the quantity $L/RCV$ are those of :**

**(a)** charge **(b)** $(\text{charge})^{-1}$
**(c)** current **(d)** $(\text{current})^{-1}$

**22.** **Two coils of self inductances 2 mH and 8 mH are placed to close to each other that the flux linkage is complete between the coils. The mutual inductance between these coils is :**

**(a)** 4 $mH$ **(b)** 6 $mH$
**(c)** 10 $mH$ **(d)** 16 $mH$

**23.** **A conducting circular loop is placed in a uniform magnetic field 0.04T with its plane perpendicular to the magnetic field. The radius of the loop starts shrinking at 2 mm/s . The induced emf in the loop when the radius is 2cm is :**

**(a)** $4.8\,\pi\,\mu\,V$ **(b)** $0.8\,\pi\,\mu\,V$
**(c)** $1.6\,\pi\,\mu\,V$ **(d)** $3.2\,\pi\,\mu\,V$

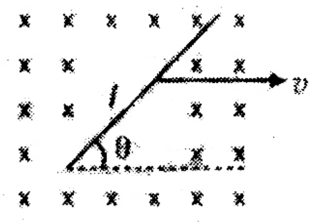
**24.** **Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon:**

**(a)** the materials of wires of the coils.
**(b)** the current in the two coils
**(c)** the rates at which currents are changing in the two coils
**(d)** relative position and orientation of the two coils.

**25.** **The current in a wire $AB$ is increasing in magnitude . The direction of induced current in the loop (if any) will be:**

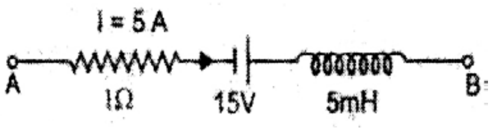

**(a)** clock wise
**(b)** anticlockwise
**(c)** arbitrary
**(d)** no current is induced.

**26.** **A circular loop of radius $R$ carrying current $I$ lies in $x-y$ plane with the centre at origin. The total magnetic flux through $xy$ plane is :**




**(a)** directly proportional to $l$
**(b)** directly proportional to $R$
**(c)** directly proportional to $R^2$
**(d)** zero

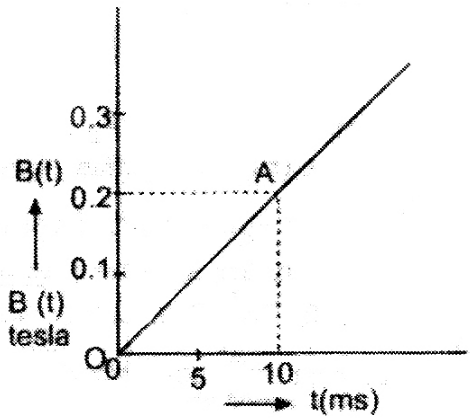
27. A rod of length $l$ is taken out of magnetic field with a velocity $v$ in a direction as shown in fig. the emf induced in the rod is :




(a) $Bvl$ (b) $Bvl \cos\theta$

(c) $Bvl\, sin\ \theta$ (d) $zero$

28. A coil of area $5.0 \times 10^{-3}\, m^2$ is placed perpendicular to a time varying magnetic field shown in figure. The value of induced emf in coil in 10 ms is :




(a) 0.1 $V$ (b) 0.1 $mV$

(c) 0.5 $V$ (d) 0.5$mV$

29. When the current changes from +2 A to −2A in 0.05s, an emf of 8 V is induced in a coil. The coefficient of self-inductance of the coil is :

(a) 0.1 $H$ (b) 0.2 $H$

(c) 0.4 $H$ (d) 0.8 $H$

30. An emf of 100 mV in induced in a coil when current in neighbouring coil becomes 10A from 0 in 0.1 second. The coefficients of mutual inductance between the two coils will be :

(a) $1mH$ (b) $10\ mH$

(c) $100\ mH$ (d) $1000mH$

31. The magnetic flux linked with a coil at any instant '*E*' is given by

$\phi = 10t^2 - 50t + 250Wb$

The induced emf at $t = 3$s is :

(a) $-190\ V$ (b) $-10\ V$

(c) $10\ V$ (d) $190\ V$

32. 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) $H^{-1/2}$

33. The wavelength of a photon needed to remove a proton from a nucleus which is bound to the nucleus with 1 MeV energy is nearly.

(a) 1.2 $nm$

(b) $1.2 \times 10^{-3} nm$

(c) $1.2 \times 10^{-6} nm$

(d) $1.2 \times 10^{1}\ nm$

**34. 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 $E_0 - \phi$ ($\phi$ is the work function).

**(d)** electrons can be emitted with any energy, with a maximum of $E_0$

**35. A charge q contains n electrons each of mass m. This charge is accelerated under a potential difference V. The speed acquired by the charge is .**

**(a)** $\sqrt{\frac{2eV}{m}}$

**(b)** $\sqrt{\frac{2qV}{m}}$

**(c)** $\sqrt{\frac{2e}{mV}}$

**(d)** $\sqrt{\frac{2q}{mnV}}$

**36. A photon with energy E is characterized by wavelength given by**

**(a)** $E/hc^2$ **(b)** $\frac{Ec^2}{h}$

**(c)** $E/hc$ **(d)** $\frac{hc}{E}$

**37. Photoelectric effect occurs when the frequency of the light incident on the photosensitive material is ________ the threshold frequency for the material. Fill the blank with one of the following.**

**(a)** Less than **(b)** Half of

**(c)** greater than **(d)** one third of

**38. The photoelectric effect is described as the emission of electrons from the surface of a metal when :**

**(a)** it is heated to a high temperature

**(b)** electrons of suitable velocity impinge on it

**(c)** light of suitable wavelength falls on it

**(d)** it is placed in a strong magnetic field.

**39. Photoelectric effect was discovered by :**

**(a)** Hertz **(b)** Einstein

**(c)** Hallwachs **(d)** Millikan

**40. Photoelectric effect supports:**

**(a)** Newton's corpuscular nature of light

**(b)** Huygen's wave theory of light

**(c)** Maxwell's electromagnetic theory of light

**(d)** Plank's quantum theory of light

**41. The phenomenon of photoelectric effect was explained by:**

**(a)** Planck

**(b)**Maxwell

**(c)** Einstein

**(d)** Bohr

**42. Work function of a metal is :**

**(a)** minimum energy required to free an electron from surface against Coulomb's forces.

**(b)** minimum energy required to free a nucleon

**(c)** minimum energy required to eject an electron from electronic orbit

**(d)**minimum energy to ionize an atom

**43. Photoelectrons emitted from a metallic surface are those which are:**

**(a)** present inside the nucleus

**(b)** are orbiting very near to nucleus

**(c)** are generated by the decay of neutrons within the nucleus

**(d)** free to move within inter atomic spacing

**44. In photoelectric effect:**

**(a)** light energy is converted into heat energy.

**(b)** light energy is converted into electric energy.

**(c)** light energy is converted into sound energy.

**(d)** electric energy is converted into light energy.

**45. Which of the following phenomenon support the quantum nature of light?**

**(a)** Interference

**(b)**Diffraction

**(c)** Polarisation

**(d)** Compton effect

**46. Compton effect is associated with:**

**(a)** visible light

**(b)** X-rays

**(c)** $\beta$- rays

**(d)** positive rays

**47. The momentum of a photon of wavelength $\lambda$ is**

**(a)** $h\lambda$ **(b)** $h/\lambda$

**(c)** $\lambda/h$ **(d)** $h/c\lambda$

**48. Einstein's photoelectric equation is :**

**(a)** $hv = hv_0 + \frac{1}{2}mv^2$

**(b)** $hv_0 = hv + \frac{1}{2}mv^2$

**(c)** $hv = \frac{1}{2}mv^2$

**(d)** $2hv = hv_0 + mv^2$

**49. The photoelectric effect is based on the law of conservation of:**

**(a)** energy

**(b)** mass

**(c)** liner momentum

**(d)** angular momentum

**50. The unit of Planck's constant $h$ is that of :**

**(a)** work

**(b)** energy

**(c)** liner momentum

**(d)** angular momentum

**51. For light of wavelength 5000 A the photon energy is nearly 2.5eV. For X-rays of wavelength 1 A, the photon energy will be close to:**

**(a)** $2.5 / 5000\ eV$

**(b)** $2.5/(5000)^2 eV$

**(c)** $2.5 \times 5000\ eV$

**(d)** $2.5 \times (5000)^2\ eV$

**52. In photoelectric effect, when photons of energy $hv$ fall on a photosensitive surface (work function $hv_0$) electrons are emitted from the metallic surface with a kinetic energy. It is possible to say that:**

**(a)** all ejected electrons have same kinetic energy equal to $hv - hv_0$

**(b)** the ejected electrons have a distribution of kinetic energy from zero to $(hv - hv_0)$

**(c)** the most energetic electrons have kinetic energy equal to $hv$

**(d)** all ejected electrons have kinetic energy $hv_0$

**53. Einstein's photoelectric equation states that:**

$$E_k = hv - W_0$$

**In this equation $E_k$ refers to :**

**(a)** kinetic energy of all ejected electrons

**(b)** mean kinetic energy of emitted electrons

**(c)** minimum kinetic energy of emitted electrons

**(d)** maximum kinetic energy of emitted electrons

**54. The rest mass of a photon of wavelength $\lambda$ is :**

**(a)** $zero$ **(b)** $\frac{h}{c\lambda}$

**(c)** $\frac{h}{\lambda}$ **(d)** $\frac{hc}{\lambda}$

**55. The dynamic mass of a photon of wavelength $\lambda$ is :**

**(a)** $zero$ **(b)** $\frac{h}{c\lambda}$

**(c)** $\frac{h}{\lambda}$ **(d)** $\frac{hc}{\lambda}$

**56. In photoelectric effect, the number of photoelectrons emitted is proportional to:**

**(a)** intensity of incident beam

**(b)** frequency of incident beam

**(c)** velocity of incident beam

**(d)** work function of photocathode

**57. The threshold frequency of potassium is $3 \times 10^{14}$ $Hz$. The work function is :**

**(a)** $1.0 \times 10^{-19}\ J$

**(b)** $2 \times 10^{-19} J$

**(c)** $4 \times 10^{-19} J$

**(d)** $0.5 \times 10^{-19} J$

**58. The threshold wavelength for photoelectric emission from a material is 5200 Å. Photoelectrons will be emitted when this material is illuminated with monochromatic radiation from a :**

**(a)** 50 watt infrared lamp

**(b)** 1000 watt infrared lamp

**(c)** 1 watt ultraviolet lamp

**(d)** 1 watt infrared lamp

**59. Sodium surface is illuminated by ultraviolet and visible radiation successively and the stopping potential determined. This stopping potential is:**

**(a)** equal in both cases.

**(b)** more with ultraviolet light

**(c)** more with visible light

**(d)** varies randomly

**60. $X$-ray are used to irradiate sodium and copper surfaces in two separate experiments and stopping potential determined. This stopping potential is :**

**(a)** equal in both cases.

**(b)** greater for sodium

**(c)** greater for copper

**(d)** infinite in both cases

**61. A photo-sensitive material would emit electrons if excited by photons beyond a threshold. To cross the threshold you would increase:**

**(a)** intensity of light

**(b)** wavelength of light

**(c)** frequency of light

**(d)** the voltage applied to light source

**62. The strength of a photoelectric current depends upon:**

**(a)** frequency of incident radiation

**(b)** intensity of incident radiation

**(c)** angle of incident radiation

**(d)** distance between anode and cathode.

**63. Photoelectrons are being obtained by irradiating zinc by a radiation of 3100 Å. In order to increase the kinetic energy of ejected photoelectrons:**

**(a)** the intensity of radiation should be increased

**(b)**the wavelength of radiation should be increased.

**(c)** the wavelength of radiation should be decreased.

**(d)** both wavelength and intensity of radiation should be increased.

**64. A photo cell is illuminated by a small bright source placed 1 m away . When the same source of light is placed 0.5m away, the electrons emitted by the photo cathode would.**

**(a)** increase by a factor of 4

**(b)** decrease by a factor of 4

**(c)** decrease by a factor of 2

**(d)** increase by a factor of 2

**65. The frequency and the intensity of a beam of light falling on the surface of photoelectric material are increased by a factor of two. This will.**

**(a)**increase the maximum kinetic energy of the photoelectrons, as well as the photoelectric current by a factor of two.

**(b)**increase the maximum kinetic energy of the photoelectrons and would increase the photoelectric current by a factor of two.

**(c)**increase the maximum kinetic energy of the photoelectrons by a factor of two and will have no effect on the magnitude of the photoelectric current produced.

**(d)**not produce any effect on the kinetic energy of the emitted electrons but will increase the photoelectric current by a factor of two.

**66. A photoelectric cell is illuminated by a point source of light 1 m away. The plate emits electrons having stopping potential *V*. Then:**

**(a)** $V$ decreases as distance increase

**(b)** $V$ increase as distance increase

**(c)** $V$ is independent of distance ($r$)

**(d)**$V$ becomes zero when distance increase or decreases

**67. In a photoelectric experiment, the stopping- potential for the incident light of wavelength 4000 Å is 2 volt. If the wavelength be changed to 3000 Å. The stopping – potential will be.**

**(a)** 2volt **(b)** less than 2 volt

**(c)** zero **(d)** more than 2 volt

**68. In a photoelectric experiment, the wavelength of the incident radiation is reduced from 6000 Å to 400 Å,**

**while the intensity of radiation remains the same, then**

**(a)**the cut-off potential will decrease

**(b)**the cut –off potential will increase

**(c)**the photoelectric current will increase

**(d)**the kinetic energy of the emitted electrons will decrease

**69. In photoelectric effect, the work-function of a metal is 3.5 eV. The emitted electrons can be stopped by applying a potential of – $\mathbf{1.2V}$:**

**(a)** the energy of the incident photons is 4.7 eV

**(b**) the energy of the incident photons is 2.3 eV

**(c)** if higher-frequency photons be used, the photoelectric current will rise

**(d)** When the energy of photons is 3.5 eV, the photoelectric current will be maximum.

**70. Photoelectric cell:**

**(a)** converts electricity into light

**(b)** converts light into electricity

**(c)** stores light

**(d)** stores electricity

**71. The work-function for a metal is 3eV. To emit a photoelectron of energy 2 eV from the surface of this metal, the wavelength of the incident light should be.**

**(a)** 6187 Å

**(b)** 4125 Å

**(c)** 12375 Å

**(d)** 2875Å

**72. Ultraviolet radiation of 6.2 eV falls on an aluminium surface (work-funct ion 4.2 eV) . The kinetic energy (in joule) of the fastest electron emitted is approximately :**

**(a)**$3 \times 10^{-21}$ **(b)** $3 \times 10^{-19}$

**(c)** $3 \times 10^{-17}$ **(d)** $3 \times 10^{-15}$

**73. The work-function of a photoelectric materials is 3.3 eV. Its threshold frequency will be.**

**(a)** $8 \times 10^{14} Hz$ **(b)** $5 \times 10^{33} Hz$

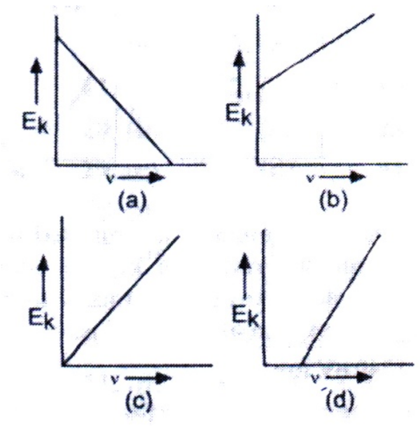
**(c)** $8 \times 10^{10} HZ$ **(d)** $4 \times 10^{11} Hz$

**74. The work-function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectrons emission from the substance is approximately.**

**(a)** 540 nm **(b)** 400 nm

**(c)** 310 nm **(d)** 220 nm

**75. According to Einstein's photoelectric equation, the graph between the kinetic energy ($E_k$) of photoelectrons ejected and the frequency (v) of incident radiation is:**




**76. The work-function of a surface of a photosensitive material is 6.2 eV. The wavelength of incident radiation for which the stopping potential is 5V lies in.**

**(a)** ultraviolet region

**(b)** visible region

**(c)** infrared region

**(d)** X-ray region

**77. The number of photoelectrons emitted for light of frequency v (higher than the threshold frequency $v_0$) is proportional to:**

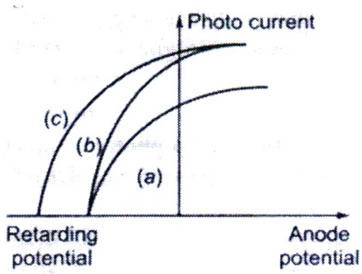
**(a)** threshold frequency $v_0$

**(b)** intensity of light

**(c)** frequency of light

**(d)** $v - v_0$

**78. The figure shows a plot of photocurrent versus anode potential for a photosensitive surface for three different radiations. Which one of t he following is correct statement.**




**(a)** curves (a) and (b) represent incident radiations of same frequency but of different intensities.

**(b)** curves (a) and (c) represent incident radiations of different frequency and of different intensities.

**(c)** curves (b) and (c) represent incident radiations of same frequency having same intensity.

**(d)** curves (a) and (b) represent incident radiations of different frequencies and different intensities.

**79. Monochromatic light of wavelength 667 nm is produced by a helium neon laser. The power emitted is 9mW. The number of photons arriving per second on the average**

at a target irradiated by this beam is :

**(a)** $3 \times 10^{16}$ **(b)** $9 \times 10^{15}$

**(c)** $3 \times 10^{19}$ **(d)** $9 \times 10^{17}$

**80. A source $S_1$ is producing $10^5$ photons/ second of wavelength 5000 $\dot{A}$. Another source $S_2$ is producing $1.02 \times 10^{15}$ photons/ second of wavelength $5100\,\dot{A}$. Then the ratio $\left(\frac{Power\ of\ S_2}{Power\ of\ S_1}\right)$ is**

**(a)** 1.02

**(b)** 1.04

**(c)** 0.98

**(d)**1.00

**81. When a monochromatic radiation of intensity 'I' falls on a metal surface, the number of photo-electrons and their maximum kinetic energy are N and T respectively. If the intensity of radiation is 21, the number of emitted electrons and their maximum kinetic energy are respectively.**

**(a)** 2 N and T

**(b)** 2 N and 2T

**(c)** N and T

**(d)**N and 2T

**82. A 0.66 mg ball is moving with a speed of 100 m/s. The associated wave length will be $(h = 6.6 \times 10^{-34})$ is**

**(a)** $6.6 \times 10^{-13} m$

**(b)** $1.0 \times 10^{-29} m$

**(c)** $1.0 \times 10^{-32} m$

**(d)** $6.6 \times 10^{-32} m$

**83. The de Broglie wavelength of an electron accelerated through a p.d. $V$ is directly proportional to $V^n$ . Then $n$ must be equal to $n =$**

**(a)** 1 **(b)** $-1$

**(c)** 0.5 **(d)** $-0.5$

**84. For a given kinetic energy which of the following has smallest de Broglie wavelength.**

**(a)** electron

**(b)** proton

**(c)** deuteron

**(d)** $\alpha$ $-$particle

**85. If an electron and a photon propagate in the form of waves having same wavelength, it implies that they have same.:**

**(a)** speed

**(b)** momentum

**(c)** energy

**(d)** all the above.

**86. A particle of mass 1 mg has the same wavelength as an electron moving with a velocity of $3 \times 10^8\ ms^{-1}$. The velocity of the particle is (mass of electron = $9.1 \times 10^{-31} kg$)**

**(a)** $2.7 \times 10^{-18} ms^{-1}$

**(b)** $9 \times 10^{-2} ms^{-1}$

**(c)** $3 \times 10^{-31} ms^{-1}$

**(d)** $2.7 \times 10^{-16} ms^{-1}$

**87. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photoelectrons from a metal versus frequency, of incident radiation gives a straight line, whose slope.**

**(a)** depends on the nature of metal

**(b)** depends on the intensity of radiation

**(c)** depends both on intensity of the radiation and the metal used

**(d)** is the same for all metals and independent of the intensity of the radiation.

**88. A photon has energy $E = 100\ eV$ which is equal to kinetic energy of proton. If $\lambda_1$ is the wavelength of proton and $\lambda_2$ the wavelength of photon, then $\frac{\lambda_1}{\lambda_2}$ is directly proportional to :**

**(a)** $E^{1/2}$

**(b)** $E^{-1/2}$

**(c)** $E$

**(d)** $E^2$

**89. When a monochromatic point-source of light is at a distance of 0.2m from a photo-electric cell, the cut-off voltage and the saturation current are respectively 0.6 volt and 18.0 mA. If the same source is placed 0.6m away from the photo-electric cell, then;**

**(a)** the stopping potential will be 0.2 volt

**(b)** the stopping potential will be 0.6 volt

**(c)** the saturation current will be 6.0 mA

**(d)** the saturation current will be 2.0 mA.

**90. The work function of a substance is 4.0eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately.**

**(a)** 540 nm

**(b)** 400 nm

**(c)** 310 nm

**(d)** 220 nm

**91. The maximum kinetic energy of photoelectrons emitted from a surface when photons of energy 6 eV fall on it is 4 eV. The stopping potential is:**

**(a)** 2V **(b)** 4V
**(c)** 6V **(d)** 10V

**92. If $E$ is energy and $p$ is momentum, then equation $E = pc$ is valid:**

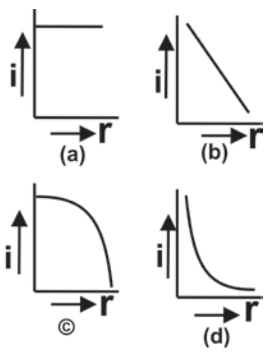
**(a)** for an electron as well as for a photon

**(b)** for an electron but not for a photon

**(c)** for a photon but not for an electron

**(d)** neither for an electron nor for a photon

**93. A photon source causes photoelectric effect from a small metal plate. Which of the following curve best represents the saturation photocurrent (i) as a function of distance (r) between the source and the metal ?**




**94. The surface of a metal is illuminated with light of wavelength 400nm. The kinetic energy of the ejected photoelectrons was found to be 1.68 eV. The work-function of the metal is :**
($hc = 1270\ eV\ nm$)

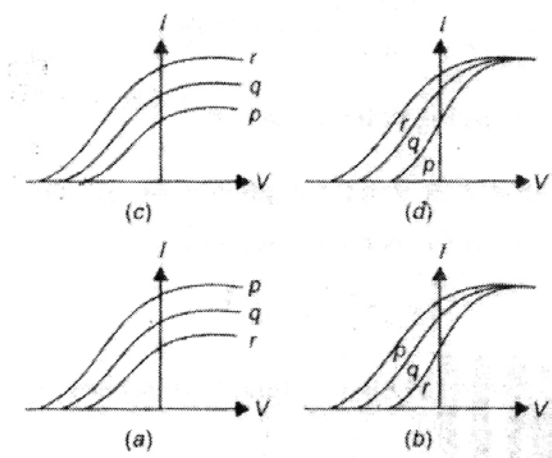
**(a)** 3.09 $eV$

**(b)** 1.41 $eV$

**(c)** 1.51 $eV$

**(d)** 1.68 $eV$

**95. Photoelectric effect experiments are performed using three different metal plates $p, q$ and $r$ having work functions $\phi_p = 2.0\ eV, \phi_q = 2.5\ eV$ and $\phi_r = 3.0 eV$ respectively . A light beam containing wavelengths of 550 nm, 450nm and 350nm with unequal intensities illuminates each of the plates. T he correct $I - V$ graph for the experiment is:**
**(Take $hc = 1240\ eV\ nm$)**

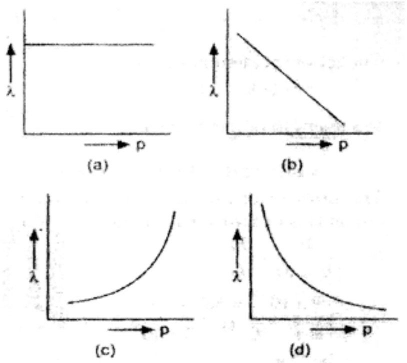


96. A particle of mass $m$ at rest decays into two masses $m_1$ and $m_2$ with non-zero velocities. The ratio of de Broglie wavelengths of the particles $\frac{\lambda_1}{\lambda_2}$ is :

(a) $\frac{m_2}{m_1}$ (b) $\frac{m_1}{m_2}$

(c) $\sqrt{\frac{m_1}{m_2}}$ (d) $1:1$

97. Which of the following graphs correctly represents the variation of de Broglie wavelength ($\lambda$) with particle momentum ($p$) ?




98. If the kinetic energy of a free electron doubles its de Broglie wavelength changes by a factor:

(a) 2

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

(c) $\sqrt{2}$

(d) $\frac{1}{\sqrt{2}}$

99. If a source of power 4 kW produces $10^{20}$ photons per second, the radiation belongs to the part of spectrum called.

(a) y-rays

(b) X-rays

(c) ultraviolet ray

(d) microwaves

***

## SHORT ANSWER TYPE

1. A rectangular coil of N-turns, area A is held in a uniform magnetic field B. If the coil is rotated at a steady angular velocity $\omega$, deduce an expression for the induced emf in the coil at any instant of time.

OR

A rectangular coil of area 'A' having number of turns N, is rotated at ‘f ’ revolutions per second in a uniform magnetic field B, the field being perpendicular to the coil. Prove that the maximum emf induced in the coil is $2\pi$fNBA.

## LONG ANSWER TYPE

1. (A) State Faradays law of electromagnetic induction.

   (B) Figure shows a rectangular conductor PQRS in which the conductor PQ is free to move in a uniform magnetic field B perpendicular to the plane of the paper. The field extends from $x = 0$ to $x = b$ and is zero for $x > b$. Assume that only the arm PQ possesses resistance r. When the arm PQ pulled outward from $x = 0$ to $x = 2b$ and then moved backward to $x = 0$ with constant speed v, obtain the expression for the flux and induced emf. Sketch the variations of these quantities with distance $0 < x < 2b$.

***

# ANSWER KEY

## SECTION-A(MCQ)

1. **a.** a direct current flows in the ammeter A.
2. **d.** there is a constant current in the counterclockwise direction in A
3. **d.** the square of the number of turns
4. **b.** $l$ decrease and A increase
5. **b.** self- inductance
6. **d.** 4 henry
7. **a.** 10 volt
8. **c.** energy
9. **d.** as long as the magnetic flux in the circuit changes.
10. **b.** $10^{-5}$ Wb
11. **b.** 1.0 weber
12. **c.** four times
13. **a.** looking from above, the induced current in the coil will be anti-clockwise
14. **b.** less than due to gravity
15. **a.** conservation of energy
16. **b.** $\frac{AB}{R}$
17. **a.** inertia
18. **d.** 10
19. **b.** 0.2H
20. **c.** $M°L°T$
21. **d.** $(\text{current})^{-1}$
22. **a.** 4 mH
23. **d.** 3.2 $\pi\mu V$
24. **d.** relative position and orientation of the two coils
25. **a.** clockwise
26. **c.** directly proportional to
27. **c.** $Bvl \sin\theta$
28. **a.** 0.1 V
29. **a.** 0.1H
30. **a.** 1 mH
31. **b.** -10 V
32. **d.** $H^{-1/2}$
33. **b.** $1.2 \times 10^{-3} nm$

**34. c.** electrons can be emitted with any energy, with a maximum of $E_0 - \phi(\phi$ is the work function).

**35. a.** $\sqrt{\frac{2eV}{m}}$

**36. d.** $\frac{hc}{E}$

**37. c.** greater than

**38. c.** light of suitable wavelength falls on it

**39. a.** Hertz

**40. d.** plancks quantum theory of light

**41.** c. Einstein

**42. a.** minimum energy required to free an electron from surface against Coulomb's forces

**43. d.** free to move within inter atomic spacing

**44. b.** light energy is converted into electric energy

**45. d.** Compton effect

**46. b.** X-rays

**47. b.** $h/\lambda$

**48. a.** $hv = hv_0 + \frac{1}{2}mv^2$

**49. a.** energy

**50. d.** angular momentum

**51. c.** $2.5 \times 5000\ eV$

**52. b.** the ejected electrons have a distribution of kinetic energy from zero to $(hv - hv_0)$

**53. d.** maximum kinetic energy of emitted electrons

**54. a.** zero

**55. b.** $h/\ c\lambda$

**56. a.** intensity of incident beam

**57. b.** $2 \times 10^{-19} J$

**58. c.** 1 watt ultraviolet lamp

**59. b.** more with ultraviolet light

**60. b.** greater for sodium

**61. c.** frequency of light

**62. b.** intensity of incident radiation

**63. c.** the wavelength of radiation should be decreased

**64. a.** increase by a factor of 4

**65. b** increase the maximum kinetic energy of the photoelectrons and would increase the photoelectric current by a factor of two

**66. c.** *V* is independent of distance *(r)*

**67. d.** more than 2 volt.

**68. b.** the cut-off potential will increase

**69. a.** the energy of the incident photons is 4.7eV

**70. b.** converts light into electricity

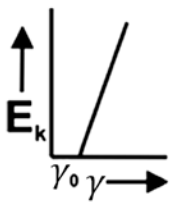
**71. d.** 2875 Å

**72. b.** $3 \times 10^{-19}$

**73. a.** $8 \times 10^{14} Hz$

**74. c.** 310 nm

**75. (b)**




**76. a.** ultraviolet region

**77. b.** intensity of light

**78. a.** curves (a) and (b) represent incident radiations of same frequency but of different intensities.

**79. a.** $3 \times 10^{16}$

**80. d.** 1.00

**81. a.** 2 N and T

**82. b.** $1.0 \times 10^{-29}$

**83. d.** $-0.5$

**84. d.** $\alpha$ - particle

**85. b.** momentum

**86. d.** $2.7 \times 10^{-16} ms^{-1}$

**87. d.** is the same for all metals and is independent of the intensity of the radiation.

**88. a.** $E^{\frac{1}{2}}$

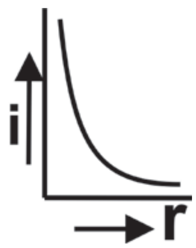
**89. b.** & d

**90. c.** 310 nm

**91. b.** 4V

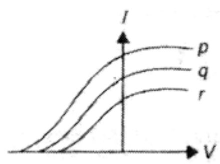
**92. c.** for a photon but not for an electron

**93. (d)**



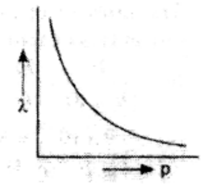

**94. b.** 1.41 eV

**95. a.**



**96. d.** 1:1

**97. (d)**




**98.** d. $\frac{1}{\sqrt{2}}$

**99.** b. X-rays

***

## SHORT ANSWER

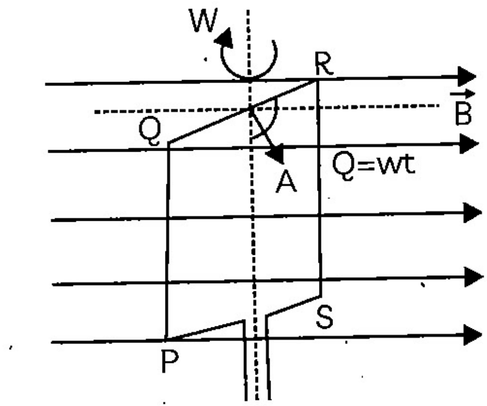
1. **Ans.**

Consider a rectangular coil PQRS of N turns, each of area A, held in a uniform magnetic field B. Let the coil be rotated at a steady angular velocity co about its own axis. Let at any instant t, normal to the area (i.e., the area vector A) subtends an angle $\theta = \omega t$ from direction of magnetic field B. Then, at the moment, the magnetic flux linked with the coil is

Where $\varepsilon_0 = NBA\omega =$ maximum value of induced emf.

If the coil be rotating at 'f' revolutions per second, then $\omega = 2\pi f$ and the maximum induced emf.

$$\varepsilon_0 = NBA\omega = 2\pi f NBA$$

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## LONG ANSWER

**1. Ans.**

**(A)** Faraday's law of induction is the basic Law of electromagnetism which helps us to predict how a magnetic field would interact with an electric circuit to produce an electromotive force (EMF). This phenomenon is known as electromagnetic induction.

**(B)** Refer to the figure given with the question let us first consider the forward motion of the arm PQ from x = 0 to x = 2b. Obviously now the magnetic flux linked with the circuit SPQR is O = BA Hence,

(i) $\phi = Blx \, for \;\; 0 \leq x \leq b$

(ii) $\phi = Blb \, for \;\; b \leq x \leq 2b$

Consequently the induced emf will be $E = -\frac{d\phi}{dt}$. Hence

As a result the induced emf will be

**(i)** $E = 0 \, for \, b \leq x \leq 2b$

**(ii)** $E = +Blv \, for \, O \leq x \leq b$

Variation of the magnetic flux and induced emf during forward and backward motion of the arm PQ is shown in the graph.

**(i)** $E = -d\frac{(Blx)}{dt}$

$= -Blv \, for \, 0 \leq x \leq b$

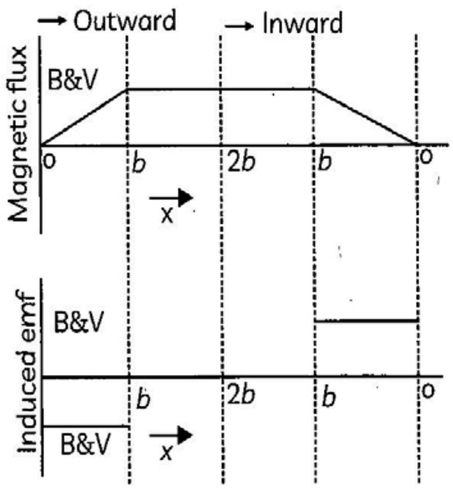
**(ii)** $E = -d\frac{(Blb)}{dt}$

$= 0 \, for \, b \leq x \leq 2b$

Again for the backward motion of the arm pe from x = 2b to x=0, the magnetic flux with the circuit SPQR is

**(i)** $\phi = Blb \, for \, b \leq x \leq 2b$

**(ii)** $\phi = Blx \, for \, 0 \leq x \leq b$ (and flux is gradually decreasing )

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# CHAPTER SIX

## (ALTERNATIVE CURRENT)

### Section –A

1. **A voltage $\boldsymbol{E = 60\,sin\,120\pi t}$ is applied across a $\boldsymbol{20\Omega}$ resistance, what will an A.C ammeter is read with new resistance ?**

   **(a)** $3A$

   **(b)** $2.12A$

   **(c)** $\frac{1}{3}A$

   **(d)** $3.12\ A$

2. **An A.C ammeter reads 10 A in an AC current . The peak value of Current is:**

   **(a)** $\frac{10}{\sqrt{2}}A$

   **(b)** $\frac{20}{\pi}A$

   **(c)** $5\pi A$

   **(d)** $10\sqrt{2}A$

3. **The effective value of alternating current is 5A. The current passes through 12Ω resister. The maximum potential difference across the resister is**

   **(a)** $60\ volts$

   **(b)** $\frac{60}{\sqrt{2}}volts$

   **(c)** $60\sqrt{2}\ volts$

   **(d)** $12\sqrt{2}\ volts$

4. **A 100Ω iron is connected to a 220 volt, 50 cycle wall plug. The r.m.s value of current is**

   **(a)** $22\ Amp$

   **(b)** $220\ Amp$

   **(c)** $2.2\ Amp$

   **(d)** $100\ Amp$

5. **A 100 Hz a.c is flowing in a 14 mH coil. The reactance of the coil is:**

   **(a)** 88Ω  **(b)** 14Ω

   **(c)** 1.4Ω  **(d)** 8.8Ω

6. **A capacitor of 1μF is connected to a source of AC having $\boldsymbol{E\,mf}$ given by equation $\boldsymbol{E = 200\sqrt{2}\,cos\,50\,t}$. The r.ms value of current through the capacitor is**

   **(a)** 1 amp  **(b)** 0.001 amp

   **(c)** 0.01A  **(d)** 10 amp

7. **In a circuit containing an inductance and resistance, the current leads the applied a.c voltages by a phase angle.**

   **(a)** 90°  **(b)** $-90°$

   **(c)** $0°C$  **(d)** 180°

**8. The average power dissipated in a pure capacitive a.c circuit is**

**(a)** $\frac{1}{2}cV^2$ **(b)** $cV^2$

**(c)** $\frac{1}{4}.cV^2$ **(d)** 280

**9. Energy needed to establish an alternating current I in a circuit of self inductance L is**

**(a)** $L\frac{dI}{dt}$

**(b)** $LI$

**(c)** $\frac{1}{2}LI^2$

**(d)** $\frac{1}{2}I\ L^2$

**10. A circuit has an inductance of $\frac{1}{\pi}H$ and a resistance of 2000 ohm. A 50 cycle a.c is applied to it. The impedance of the circuit is**

**(a)** $200\ \Omega$

**(b)** $2000\ \Omega$

**(c)** $2002.5\Omega$

**(d)** $202.5\Omega$

**11. A 100 Hz alternating current is flowing in a coil of inductance 7mH. The reactance of the coil is**

**(a)** $7\ \Omega$

**(b)** $100\ \Omega$

**(c)** $44\Omega$

**(d)** $4.4\Omega$

**12. An A.C voltage $E = 200\sqrt{2}\ sin\ 100\ t$ is connected in a circuit containing an a.c. ammeter and a capacitor of capacitance 1 $\mu F$ . The reading of the ammeter is :**

**(a)** 2A **(b)** 0.02A

**(c)** 20A **(d)** 40A

**13. If $E$ represents the peak value of voltage in an ac current the rms value of voltage will be.**

**(a)** $\frac{E}{\pi}$ **(b)** $\frac{E}{2\pi}$

**(c)** $\frac{E}{\sqrt{2}}$ **(d)** $\frac{E}{2}$

**14. An alternating current cannot be measured by D.C ammeter because**

**(a)** A.C changes direction

**(b)** A.C. cannot pass through D.C ammeter

**(c)** Average value of current for complete cycle is zero .

**(d)** D.C ammeter will be damaged.

**15. A coil has a resistance of $8\Omega$ and an inductive reactance of $6\Omega$. The impedance of Coil is**

**(a)** $10\ \Omega$

**(b)** $8\Omega$

**(c)** $6\Omega$

**(d)** $14\Omega$

16. **In A.C circuit containing inductance and capacitance in series. The current is found to be maximum when the value of inductance is 0.5 H and capacitance is $8\mu F$. The angular frequency of input A.C is**

**(a)** $500$ **(b)** $5 \times 10^4$

**(c)**$5000$ **(d)** $4000$

17. **The primary coil of transformer has 500 turns and secondary has 5000 tons. The primary is connected to AC supply 120V, 50 Hz. The secondary will have output.**

**(a)** 200V, 500Hz

**(b)** 200 V 50 Hz

**(c)** 2V, 50 Hz

**(d)** 2V 5Hz

***

## ASSERTION- REASON QUESTIONS

**(a), (b), (c) and (d) as given below**

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

1. **Assertion(A): the alternating current lags behind the emf by a phase angle of $\frac{\pi}{2}$, when ac flows through an inductor**

   **Reason (R): The inductive reactance increase as the frequency of ac source decrease.**

2. **Assertion(A): An inductance and a resistance are connected in series with an ac circuit. In this circuit the current and the potential difference across the resistance lags behind potential difference across inductance by an angle of $\frac{\pi}{2}$**

**Reason (R):** IN LR circuit voltage leads the current by phase angle which depends on the value of inductances and resistance both.

3. **Assertion(A):** When capacitive reactance is smaller than the inductive reactance is LCR circuit, em,f. leads the current.

**Reason (R):** The phase angle is the angle between the alternating e.m.f. and alternating current of the circuit.

4. **Assertion(A):** In series LCR circuit resonance can take place.

**Reason (R):** Resonance takes place if inductance and capacitive reactances are equal and opposite.

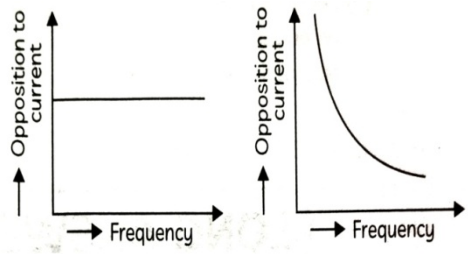
***

## SHORT ANSWER TYPE

1. **Draw phase diagram showing phase relationship between voltage and current in an a.c. circuit containing.**
   **(A) a pure inductor only, and**
   **(B) a pure capacitor only**

2. **(A) The graphs (i) and (ii) shown in the figure represent variation of apposition offered by the circuit elements, X and Y, respectively to the flow of alternating current versus the frequency of the applied emf, identify the element X and Y.**

   **(B) Write the expression for the impedance offered by the series combination of these two elements connected to an a.c, source of voltage $V= V_m \sin \omega t$. Shown on a graph the variation of the voltage and the current with $'\omega t'$ in the circuit.**



3. **Show diagrammatially two different arrangements used for winding the primary and secondary coils in a transformer. Assuming the transformer to be an ideal one, writhe expressions for the ratio of its.**

   **(A) output voltage to input voltage.**

   **(B) output current to input current in terms of the number of turns in the primary and secondary coils.**

   **Mention two reasons for energy losses in actual transformer.**

***

## LONG ANSWER TYPE

1. **A pure inductor is connected across an a.c. source. Show mathe-matically that the current in it lags behind the applied emf by a phase angle of $\frac{\pi}{2}$. What is the inductive reactance ?**

2. **A series LCR circuit is connected to an a.c. source having voltage $V = V_m \sin \omega t$. Derive the expression for the instantaneous current I and its phase relationship to the applied voltage. Obtain the condition for resonance to occur. Define 'power factor' State the conditions under which it is (A) maximum, (B) minimum.**

***

## ANSWER KEY
## SECTION-A(MCQ)

**1. b. 2.12A**

$E = E_0 \sin 120\pi t$

$I = \frac{E_0}{R} \sin 120\pi t$

$I_{rms} = \frac{I_0}{\sqrt{2}}$

$= \frac{E_0}{R\sqrt{2}}$

$= \frac{60}{20\sqrt{2}}$

$= \frac{3}{1.414} = 2.12$

**2. d. $10\sqrt{2}A$**

$I_{rms} = 10\ A \quad I_{rms} = \frac{I_0}{\sqrt{2}}$

$I_0 = I_{rms}\sqrt{2} = 10\sqrt{2}\ A$

**3. c. 60 $\sqrt{2}$ volts**

$I_{rms} = 5A \quad I_{rms} = \frac{I_0}{\sqrt{2}}$

Peak value of current $I_0 = I_{rms}\sqrt{2}$

$= 5\sqrt{2}$

Maximum P.D $= E_0 = I_0 R$

$= 5\sqrt{2} \times 12$

$= 60\sqrt{2}\ volts$

**4. c. 2.2 Amp**

$E_{rms} = 220\ volts$

$I_{rms} = \frac{E_{rms}}{R} = \frac{220}{100}\ A = 2.2\ A$

**5. d. 8.8Ω**

Given $f = 100Hz$

$L = 14\ mH$

Reactance $X_L = \omega L = 2\pi f l$

$= 2\pi \times 100 \times 14 \times 10^{-3} H$

$= 2 \times \frac{22}{7} \times 100 \times 14 \times 10^{-3}$

$= 88 \times 10^{-1} = 8.8\Omega$

**6. c. 0.01A**

$E = E_0 \cos \omega t = 200\sqrt{2} \cos 50\ t$

$E_0 = 200\sqrt{2} \qquad \omega = 50$

Capacitive reactance $X_c = \frac{1}{\omega_c}$

$= \frac{1}{50 \times 1 \times 10^{-6}} \Omega$

r.ms value voltage $= E_{rms} = \frac{E_0}{\sqrt{2}} = \frac{200\sqrt{2}}{\sqrt{2}}$

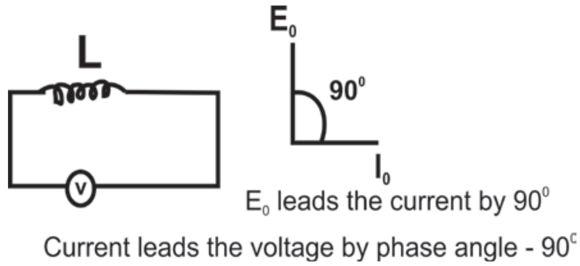
∴ r.ms value of current $= I_{rms} = \frac{E_{rms}}{X_c}$

$= 200 \times 50 \times 10^{-6}$

$= 10^4 \times 10^{-6}$

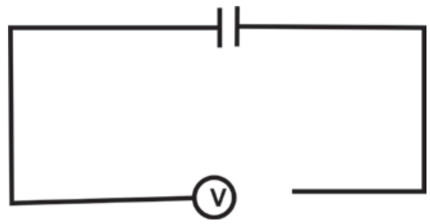
$= 0.01A$

**7. b. -90$^0$**




**8. d. 280**

In capacitive circle




$$E = E_0 \sin \omega t$$

$E = E_0 \sin \omega\gamma$

$E = \frac{Q}{C} \Rightarrow Q = CE = CE_0 \sin \omega t$

$I = \frac{dQ}{dt} = CE_0\omega \cos \omega t = I_0 \cos \omega t$

$= CE_0\omega \sin\left(\omega t + \frac{\pi}{2}\right)$

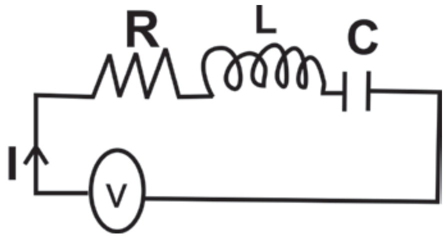
$I_0 \sin\left(\omega t + \frac{\pi}{2}\right) = \frac{E_0}{X_c} \sin\left(\omega t + \frac{\pi}{2}\right)$

Average power $P = EI$

$= E_0 \sin\ \omega t\ \ I_0 \cos \omega t$

$= \frac{E_0 I_0}{2} \int_0^T \sin 2\omega t\, dt = 0$

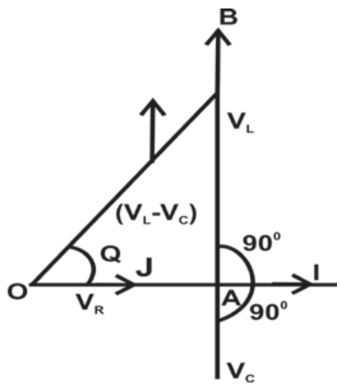
**9.** Ac circuit containing induction capacitor and require




Voltage across $R\ \ V_R = IR$

Voltage across $L\ \ V_L = I\,X_L, V_L\ lead\ \ I\ by\ 90°$

Voltage across $C = V_c = I\,X_c\ \ V_L lags\ I\ by\ 90°$




Therefore applied voltage

$$E = \sqrt{V_R^2 + \ (V_L - V_C)^2}$$

$$= \sqrt{I^2R^2 + (IX_L - IX_c)^2}$$

$$= I\sqrt{R^2 + \ (X_L - \ X_c)^2}$$

$$\therefore I = \frac{E}{\sqrt{R^2 + (X_L - X_c)^2}}$$

$Z = \sqrt{R^2 + (X_L - X_c)^2}$ = Impedance of the current

Power factor $\cos\theta = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + (X_L - X_c)^2}}$

**10. c. 2002.5Ω**

$L = \frac{I}{\pi}\text{H} \quad R = 2000\Omega \quad f = 50$

$X_L = \omega L = 2\pi f L = 2\pi \times 50 \times \frac{1}{\pi} = 100\Omega$

$Z = \sqrt{R^2 + X_L^2}$

$= \sqrt{(2000)^2 + (100)^2}$

$= \sqrt{4 \times 10^6 + 10^4}$

$= \sqrt{10^4 \times 400 + 10^4}$

$= 10^2\sqrt{(400 + 1)} = 10^2 \times \sqrt{401}$

$= 100 \times 20.02 = 2002.5\Omega$

**11. d. 4.4 Ω**

$f = 100\,Hz \quad L = 7mH$

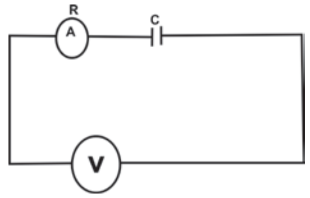
$= 7 \times 10^{-3}\,H$

$X_L = 2\pi f\,L$

$= 2 \times \frac{22}{7} \times 100 \times 7 \times 10^{-3}$

$= 44 \times 10^2 \times 10^{-3} = 4.4\Omega$

**12. b. 0.02 A**




Impedance of the circuit = $Z = X_c$

$E_0 = 200\sqrt{2} \qquad E_{rms} = \frac{E_0}{\sqrt{2}}$

$= \frac{200\sqrt{2}}{\sqrt{2}}$

$X_c = \frac{1}{\omega C} = \frac{1}{100 \times 1\mu F}$

$= \frac{1}{100 \times 10^{-6}}\Omega$

$= 10^4\Omega$

$I_{rms} = \frac{E_{rm\,s}}{X_c} = \frac{200}{10^4} = 2 \times 10^{-2}A = 0$

**13. C $\frac{E}{V2}$**

**14. c. Average value of current for complete cycle is zero**

**15. a. 10Ω**

$Z = \sqrt{R^2 + X_L^2}$

$= \sqrt{8^2 + 6^2} = \sqrt{64 + 36}$

$= \sqrt{100} = 10\Omega$

**16. a. 500**

$Z = \sqrt{(X_L - X_C)^2}$

current is maximum when $(X_L -$ *XC2=0*

$X_L = X_C$

$\Rightarrow \omega L = \frac{1}{\omega C} \Rightarrow \omega = \frac{1}{\sqrt{LC}}$

$= \frac{1}{\sqrt{0.5 \times 8 \times 10^{-6}}}$

$= 500$

**17. b. 200V 50Hz**

$\frac{20}{E_s} = \frac{E_p}{E_s} = \frac{N_p}{N_s} = \frac{500}{5000}$

$E_s = 20 \times 10 = 200$

***

## ASSERTION- REASON ANSWER

1. **(C) A is true but R is false.**

   **Explanation:** When a.c. pass through an inductor, current lags behind the emf by phase of $\frac{\pi}{2}$. Inductive reactance, $X_L = 2\pi f L$ so when frequency increase than value of inductive reactance also increases.

2. **(b) both A and R are true but R is Not the correct explanation of A.**

   As the inductance and resistance are joined in series. Hence current through both will be same but in case of resistance, both the current and potential vary simentinously hence they are in same phase. In case of inductance there is a phase difference of $\frac{\pi}{2}$.

3. **(b) both A and R are true but R is Not the correct explanation of A.**

   **Explanation :** $\tan \phi = \frac{X_L - X_C}{R}$

   $$= \frac{\omega L - \frac{1}{\omega C}}{R}$$

   Where $X_L, X_C$ are inductive reactance and capacitive reactance respectively. When $X_L > X_C$ then $tan\,\phi$ is positive. i.e., $\phi$ is positive (between 0 and $\frac{\pi}{2}$) hence emf leads the current

4. **(a) both A and R are true but R is the correct explanation of A**

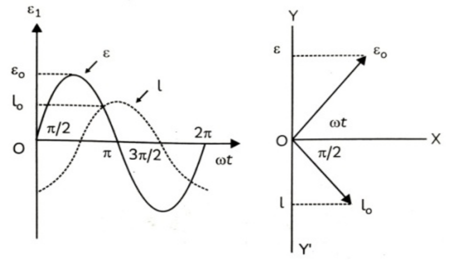
   **Explanation:** At resonant frequency. $X_L = X_C$ $Z = R$ [Minimum], Hence current in the circuit is maximum.

***

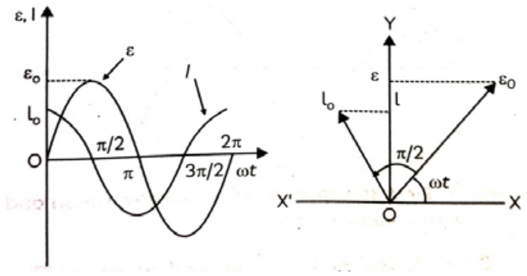
## SHORT ANSWER TYPE

1. **(A)** Phasor diagram for a pure inductive a.c. circuit has been shown in figure. Here current I lags behind the voltage V by a phase angle $\frac{\pi}{2}$

   **(B)** Phasor diagram for a pure capacitive a.c. circuit has been shown in figure. Here current I leads the voltage V by a phase angle $\frac{\pi}{2}$



Phasor diagram for pure inductive a.c. circuit.



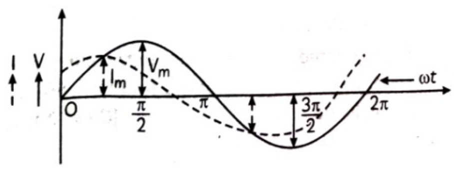

Phasor diagram for pure capacitive a.c. circuit.

**2.** **(A)** The circuit element X is a resistance R because opposition offered by it for flow of and a.c. is independent of frequency. The circuit element y is a capacitor, as the opposition offered by it for flow of an ac. decreases with increase in frequency.

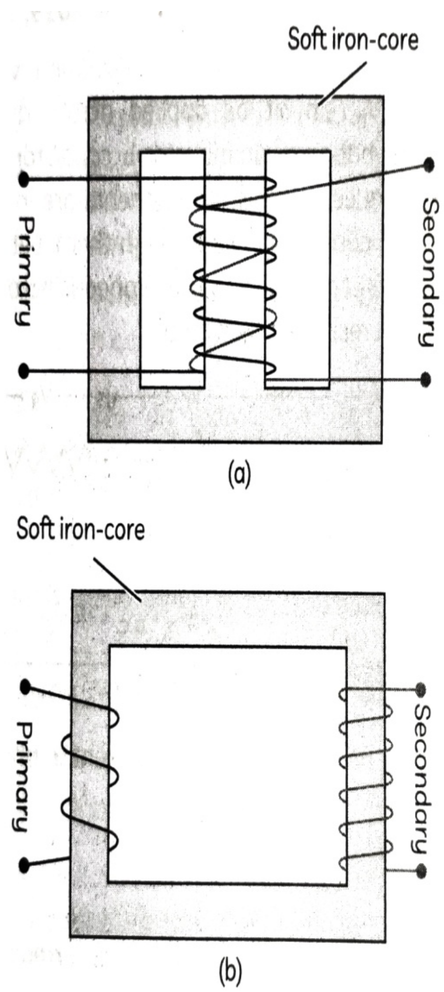
**(B)** For an RC circuit in series the impedance Z is given as

$Z = \sqrt{R^2 + X_C^2}$, where $X_c = \frac{1}{C\omega}$

Variation of V and I of the circuit with $'\omega t'$ is given in fig.




**3.** Two different arrangements used for winding of primary and secondary coils in a transformer are shown in fig (a) and (b) given below.




For an ideal transformer

$(a)$ $\frac{V_{Output}}{I_{Input}} = \frac{N_s}{N_p}$ and

$(b)$ $\frac{I_{Output}}{I_{Output}} = \frac{N_p}{N_s}$

Two possible reasons for energy loss in an actual transformer are :

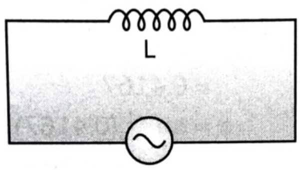
(1) Eddy currents and (2) hysteres

***

## .LONG ANSWER TYPE

1. **Ans.**

**A.C. Cicuit containing inductor only:** Consider an a.c. cirucit consisting of a non-ohmic inductor of inductance L




When an a.c. voltage is applied

$$E = E_0 \sin \omega t$$

The voltage dropses across the inductor

$$E = L\frac{dI}{dt}$$

Or $dI = \frac{E}{L} = \frac{E_0}{L}\sin \omega t \ dt$

Or $\int dI = \frac{E_0}{L}\int \sin \omega t \ dt$

Or $I = \frac{E_0}{\omega L}(-\cos \omega t)$

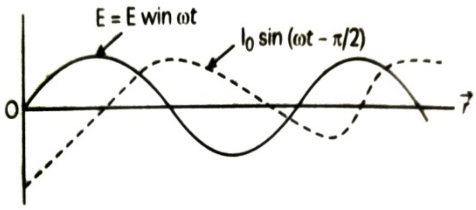
$$= \frac{E_0}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$$

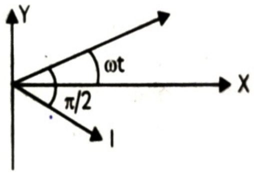
Or $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

Where, $I_0 = \frac{E_0}{\omega l}$

Or $\omega L = \frac{E_0}{I_0}$

The resistance offered by inductor is called inductive reactance $(X_L = \omega L)$. The eqaation of voltage $E = E_0 \sin \omega t$ and current $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$ show a phase difference of $\frac{\pi}{2}$ and the current lags behind the voltage by $\frac{\pi}{2}$. The variation of voltage and current and their phasor diagram is shown.

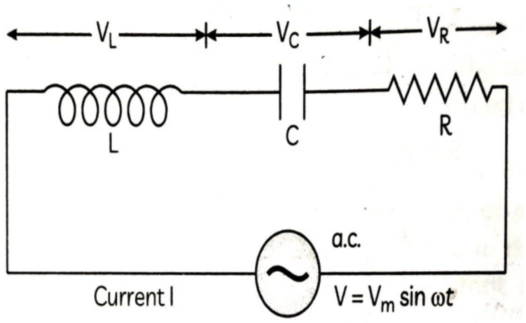



The resistane offered by inducor is called inductive reactance $(X_L = \omega t)$. The equation $E = E_0 \sin \omega t$ and current $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$ shows a phase different of $\frac{\pi}{2}$ and the current lags behind the voltage by $\frac{\pi}{2}$. The the variation of voltage and current and their phasor diagram is shown in figure.

2. Let as shown in fig an alternating voltage $V = V_m \sin \omega t$ be applied across a series combination of an inductor L, capacitor C and resistance R. As all components are in series., same currrent $I$ flows through them,

Let $V_L, V_C$ and $V_R$ represent the instantaneous voltage across L, C and R respectively, where




**(1)** $V_L = I\, X_L$ and leads the current in phase by $\frac{\pi}{2}$

**(2)** $V_C = I\, X_C$ and lags behind the current by $\frac{\pi}{2}$ and

**(3)** $V_R = I\, R$ in same phase as the current I.

The voltage are shown in phasor diagram in fig. Since $V_L$ and $V_C$ are in mutually opposite phase, they can be combined into a single phasor having magnitude $(V_L - V_C)$ and leading the current by $\frac{\pi}{2}$

Resultant of $V_R$ and $(V_L - V_C)$ gives the total voltage, which is equal to the voltage of a.c. source. Thus.

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$= \sqrt{(IR)^3 + I(X_L - X_C)^2}$$

$$= I\sqrt{R^2 + (X_L\, X_C)^2} = IZ$$

Where Z is known as the impedance of given LCR series circuit.
Hence, impedance

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)}$$

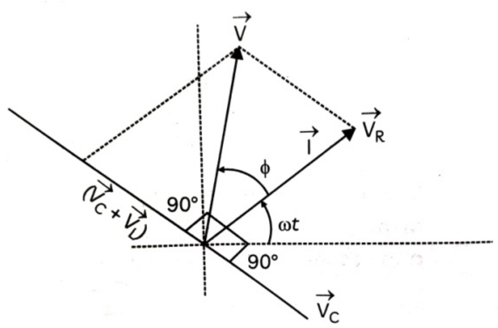
Moreover, the voltage leads the current (or current lags behind the voltage) by a phase angle $\phi$ such that.

$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$$

$$= \frac{\left(L\omega - \frac{1}{C\omega}\right)}{R}$$

Thus, current in the circuit is given by $I = \frac{X_L - X_C}{R}\sin(\omega t - \phi)$, where $Z = \sqrt{R^2 + (X_L - X_C)^2}$ and $\phi = \tan^{-1}\frac{X_L - X_C}{R}$.
The current amplitude $I_m = \frac{V_m}{Z}$

Condition for Resonance and Resonant Frequency : Impedance of the given a.c. circuit will be minimum and the current maximum if $X_L = X_C$ because then $Z = R$ and $I = \frac{V}{R}$. it is called resonance condition. For resonance to happen angular frequency of a,c, should be $\omega_0$. So That



$$X_L = (\omega L) = \omega_0 = X_C = \left(\frac{1}{\omega C}\right) = \frac{1}{\sqrt{LC}}$$

Power factor of an a.c. circuit is the cosins of the angle $(\cos\phi)$by which the current logs or leads the a.c. voltage.

Power factor.

$$\cos\phi = \frac{R}{Z}$$

$$= \frac{R}{\sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)}}$$

$$= \frac{R}{\sqrt{R^2 + X^2}}$$

(A) The power factor is maximum, having a value one, when either the circuit is purely resistive circuit or when $X_L = X_C$ so that $Z = R$

(B) The power factor is minimum, having a value zero, when **no resister R ($R = 0$)** is present in the circuit and impedance is purely reactive impedance.

***

# CHAPTER SEVEN

## (ELECTROMAGNETIC WAVES)

### Section –A

1. **Electromagnetic waves are**
   **(a)**longitudinal wave
   **(b)**transverse wave
   **(c)**may be longitudinal or transverse
   **(d)** none of these

2. **Electromagnetic waves travel with velocity of**
   **(a)** $3 \times 10^{10} m/s$
   **(b)**$3 \times 10^{6} m/s$
   **(c)**$3 \times 10^{8}$m/s
   **(d)**332m/s

3. **In an electromagnetic wave the electric and magnetic fields are**
   **(a)** parallel to each other
   **(b)** perpendicular to each other
   **(c)**inclined at acute angle
   **(d)** inclined at obtuse angle

4. **Which of the following does not support the wave nature of light ?**
   **(a)** interference
   **(b)** diffraction
   **(c)**polarization
   **(d)** photoelectric effect

5. **Reflection of radio waves takes place from**
   **(a)** stratosphere
   **(b)** troposphere
   **(c)**ionosphere
   **(d)** mesosphere

6. **The process of mixing sound wave with carriers waves is called**
   **(a)** modulation
   **(b)** demodulation
   **(c)**amplification
   **(d)** rectification

7. **Which of the following waves are used for sterilizing foods and utensils ?**
   **(a)** microwave
   **(b)** X-ray
   **(c)**$\gamma$-ray
   **(d)** ultraviolet wave.

8. **Bolometers are used to detect the following waves.**
   **(a)** microwave
   **(b)** X-ray
   **(c)**$\gamma$-ray
   **(d)** infrared ray.

9. **The frequency of electromagnetic wave used for radio transmission as compared to that of visible region is:**
   **(a)**larger
   **(b)**smaller
   **(c)**may be larger or smaller
   **(d)**same

10. **An electromagnetic wave of wavelength $5 \times 10^{-5} cm$ lies in the region.**
   **(a)**$\gamma$-ray
   **(b)** ultraviolet
   **(c)**visible
   **(d)**infra red

11. **Which wave would you prefer for transmission of radio signals ?**
   **(a)**infrared wave
   **(b)**waves longer than infrared
   **(c)**waves shorts than infra red
   **(d)**x-rays

12. **Which of the following waves are used for radio communication?**
   **(a)**long waves
   **(b)** micro waves
   **(c)** ultraviolet rays
   **(d)** standard broadcasting waves

13. **If value of electric field intensity is E and the value of magnetic field intensity is B then the value of velocity of waves is given by the relation.**
   **(a)** $V = \frac{B}{E}$ **(b)**$V = \frac{E}{B}$
   **(c)**$V = EB$ **(d)**$V = \sqrt{EB}$

14. **The wave that cause sunburn is**
   **(a)**radio wave
   **(b)** infrared
   **(c)**ultraviolet
   **(d)** visible

15. **Which ray is used in radio therapy ?**
   **(a)**infrared
   **(b)**ultraviolet
   **(c)**$\gamma$-ray
   **(d)** X-ray

16. **Which wave has high penetrating power ?**
   **(a)**infrared
   **(b)**ultraviolet
   **(c)**microwave
   **(d)** X-ray

17. **Velocity of electromagnetic wave is**
   **(a)** $\mu_0 \varepsilon_0$
   **(b)**$\frac{1}{\mu_0 \varepsilon_0}$
   **(c)**$\sqrt{\mu_0 \varepsilon_0}$
   **(d)**$\frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

**18.** **Frequency of long waves are**

**(a)** $10^5 Hz$ **(b)**$10^3 Hz$

**(c)** $50\ Hz$ **(d)**$10^{-3} Hz$

**19.** **Which of the following waves are existing in A.C. power lines ?**

**(a)** X-ray **(b)**$\gamma$rays

**(c)**long waves **(d)** infrared rays

**20.** **If frequency of an electromagnetic wave is 50 MHz, then its wavelength is**

**(a)**12m **(b)** 6m

**(c)**120m **(d)** 60m

**21.** **If electric field amplitude of an electromagnetic wave is $E_0 = 120$ N/C then its magnetic field amplitude is**

**(a)** $4 \times 10^{-6} T$

**(b)**$4 \times 10^{-7} T$

**(c)**$4 \times 10^{-8} T$

**(d)**$4 \times 10^{-9} T$

**22.** **The amplitude of the magnetic field part of a harmonic electromagnetic wave in vacuum is $B_0 = 420\ nT$. Then amplitude of the electric field part of the wave is.**

**(a)** $126\ Vm^{-1}$

**(b)**$12.6\ Vm^{-1}$

**(c)**$1260\ Vm^{-1}$

**(d)**$1.26\ Vm^{-1}$

**23.** **The electric field part of an electromagnetic wave in vacuum is**

$$E = \left[3\frac{N}{C}\cos\left\{\left(1.8\frac{rad}{m}\right)y + \pi \times 10^8 \frac{rad}{s} t\right\}\right]\hat{\imath}$$

**(a)** $18m$ **(b)**$12m$

**(c)**$9m$ **(d)**$6m$

**24.** **The order of energy in the visible radiation is**

**(a)** $10^3 eV$ **(b)**$10^0\ eV$

**(c)**$10^{-3} eV$ **(d)**$10^{-6} eV$

**25.** **If $\lambda_m T = 0.29\ cm\ K$, the characteristic temperature of the 5800 $\dot{A}$ is**

**(a)** $2500\ K$ **(b)**$5000\ K$

**(c)**$1000\ K$ **(d)**$500\ K$

**26.** **Wavelength of $10\ m$ belongs to**

**(a)**visible radiation

**(b)**infrared rays

**(c)**microwaves

**(d)**radio waves

**27.** **A wave has a wavelength of 0.003 mm and electric field associated with it has an amplitude of $30\ Vm^{-1}$. The ratio of amplitude to frequency of oscillation of the magnetic field is**

**(a)** $10^{18}$ **(b)**$10^4$

**(c)**$10^{-4}$ **(d)**$10^{-18}$

***

## SHORT ANSWER TYPE

**1. Infrared (IR) waves (Electromagnetic) are used by electrical heaters, intruders alarms, cookers for cooking food, short - range communications like remote controls, security systems and thermal imaging cameras which detect people in the dark.**

**(A) Which of the following has zero average value in a plane electromagnetic wave?**

**(a)** Electric field

**(b)** Electric energy

**(c)** Magnetic energy

**(d)** None of the above

**(B) The condition under which a microwave oven heats up a food item containing water molecules most efficiently is**

**(a)** The frequency of the microwaves must match the resonant frequency of the water molecules.

**(b)** The frequency of the microwaves has no relation with natural frequency of the water molecules.

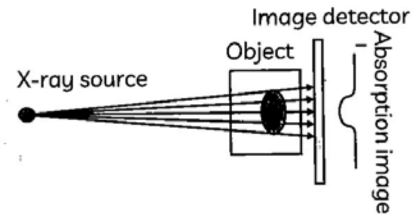
**(c)** Microwaves are heat waves, so always produce heating

**(d)** Infrared wave produce heating in a microwave oven.

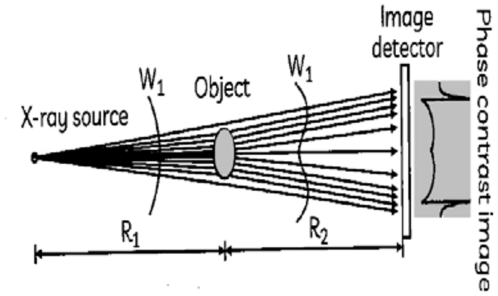
**2.** X - Ray *(Electromagnetic wave)* Absorption and Medical Imaging.

Atomic electrons can absorb *x- rays.* Hence, materials with many electrons per atom tend to be better x-ray absorbs than materials with few electrons. In this *x-ray* image the lighter areas show where *x ray*s are absorbed as they pass through the body, while the darker areas indicate regions that are relatively transparent to *x rays.* Bones contain large amounts of elements such as phosphorus and calcium, with 15 and 20 electrons per atom, respectively. In soft tissue, the predominant elements are hydrogen, carbon, and oxygen, with only 1, 6 and 8 electrons per atom, respectively. Hence *x rays* are absorbs by bone but can pass relatively easily through soft tissue.

**(a)**




**(b)**




**(A) Electromagnetic waves travelling in a medium having relative permeability $\mu_r = 1.3$ and relative permittivity $\varepsilon_r = 2.14$. The speed of electromagnetic waves in medium must be**

**(a)** $1.8 \times 10^8 \ ms^{-1}$

**(b)** $1.8 \times 10^4 \ ms^{-1}$

**(c)** $1.8 \times 10^6 \ ms^{-1}$

**(d)** $1.8 \times 10^2 \ ms^{-1}$

**(B) Which of the following has maximum penetrating power?**

**(a)** Ultraviolet radiation

**(b)** Microwaves

**(c)** $\gamma$-rays

**(d)** Radio waves

**(C) 10 cm is a wavelength corresponding to the spectrum of**

**(a)** infrared rays

**(b)** ultraviolet rays

**(c)** microwaves

**(d)** X - rays

**3. Give reason for the following :**

**(A)** Long distance radio broadcast use short wave bands.

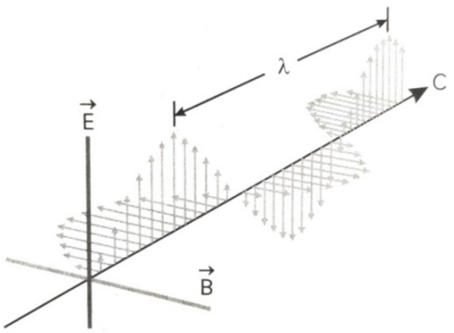
**(B)** The small layer on top of the stratosphere is crucial for human survival.

**(C)** Satellites are used for long distance TV transmission.

**4.** A parallel plate capacitor has circular plates of radius 5 cm. It is being charged so that electric field between the plates rises steadily at the rate of $10^{12}$ $Vm^{-1} s^{-1}$. What is the displacement current?

**Case based**

From Maxwell's equation, important prediction emerged in the existence of electromagnetic waves. Maxwell's equation are basic laws of electricity and magnetism. Maxwell's work unified the domain of electricity, magnetism and light. Hertz's successful experimental test of Maxwell's theory proved the existence of electromagnetic waves by using an oscillatory L-C circuit. Later on Sir. J.C. Bose succeeded in producing electromagnetic wave of much shorter wavelength with the help of self designed radiator. Electromagnetic waves are produced by accelerated charges and do not require any material for propagation. The waves travel in free space with speed of light with means that light waves are also electromagnetic waves. The energy in electromagnetic waves fields. Electromagnetic waves like other carries energy and momentum. Because it has momentum, an electromagnetic wave exerts pressure called radiant pressure.




**5. (A) Which statement represents the symmetrical counterpart of faraday's law and a consequence of the displacement current being a source of magnetic field?**

**(a) An electric field changing with time gives rise to a magnetic field.**

**(b) A magnetic field changing with time gives rise to an electric field.**

**(c) An emf changing with time gives rise to an electric field.**

**(d) Displacement current changing with time gives rise to an electric field.**

**(B) A linearly polarised electromagnetic wave given E = $E_0$ $\boldsymbol{sin\ (kz - \omega t)}$ 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)** $E_r = E_0\ \hat{\imath}\ (kz - \omega t)$

**(b)** $E_r = E_0\ \hat{\imath}\ cos\ (kz + \omega t)$

**(c)** $E_r = -E_0\ I\ cos\ (kz - \omega t)$

**(d)** $E_r = E_0 I sin(kz - \omega t)$

**(C) Radiations of intensity 0.5 Wm$^{-2}$ are striking a metal plate. The pressure on the plate is**

**(a)** $0.166 \times 10^{-8}\ Mm^{-2}$

**(b)** $0.332 \times 10^{-8}\ Nm^{-2}$

**(c)** $0.111 \times 10^{-8}\ Nm^{-2}$

**(d)** $0.083 \times 10^{-8}\ Nm^{-2}$

**(D) Total energy density of electromagnetic waves in vacuum is given by the relation**

**(a)** $\frac{1}{2}\frac{E^2}{\varepsilon_0} + \frac{B^2}{2\mu_0}$

**(b)** $\frac{E^2+B^2}{c}$

**(c)** $\frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\mu_0 B^2$

**(d)** $\frac{1}{2}\varepsilon_0 E^2 + \frac{B^2}{2\mu_0}$

**(E) A plane electromagnetic wave of frequency 25MHz travels in free space along *x-axis.* At a particular point in space and time E = 6.3 JV/m. What is B at this point?**

**(a)** $2.0 \times 10^{-8}\ kT$

**(b)** $2.1 \times 10^{-8}\ kT$

**(c)** $1.9 \times 10^{-8}\ kT$

**(d)** $2.5 \times 10^{-8} kT$

**Case based**

All known radiations from a big family of electromagnetic waves which stretch over a large range of wavelength. They are orderly distributed on the basic of different aspects and form an electromagnetic spectrum. Various regions of electromagnetic spectrum do not have sharply defined boundaries and they overlap. This classification is based roughly on how the waves are produced or detected. Radio waves are produced by accelerated motion of charge in conducting wires or oscillating circuits. They are used in radio and television communication systems. Cellular phones use Ultrahigh frequency. Microwaves are produced by special vacuum tubes. Microwave oven is the basic example of their application. Frequency of microwave is selected to match the resonant frequency of water molecules so that energy from waves is transferred efficiently to the kinetic energy of the molecules to raise the temperature of the food. Infrared waves are produced by hot bodies and molecules. They play an important role in maintaining the earth’s temperature through greenhouse effect. Visible light is the most familiar form of electromagnetic wave and can be detected by human eye. They are radiated by an excited atom. Ultraviolet light is the wave emitted by the sun. In large amount UV radiation is harmful for human skin and can be a cause of cancer, although it is used in water purifiers for killing germs. X-rays are familiar waves in medical industry. They are generated by bombarding the high energy electrons on metal target. Gamma rays has the lowest wavelength but the highest frequency, therefore they are used in nuclear reactions.

**6. (A) The speed of electromagnetic wave in vacuum depends upon the source of radiation**

**(a)** Increases as we move from gamma rays to radio waves

**(b)** Decreases as we more from gamma rays to radio waves

**(c)** Is same for all of them

**(d)** None of the above

**(B) One requires 11 eV of energy to dissociate a carbon monoxide 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

**(C) Which of the following is known as thermal radiation?**

**(a)** X-rays

**(b)** Microwaves

**(c)** Infrared waves

**(d)** Ultraviolet rays

**(D)Who among the following discovered X-rays?**

**(a)** Rontgen

**(b)** Ritter

**(c)** William Herschel

**(d)** Henry Becqurel

**(E) What is the full-form of LASIK and it falls in which spectrum?**

**(a)** Laser Associated Spectrum In Kyphosis, X-rays

**(b)** Laser assisted in situ keratomieusis, Gamma Rays

**(c)** Laser Associated Spectrum In Kyphosis, UV rays

**(d)** Laser assisted in situ keratomieusis, UV rays.

***

## OBJECTIVE TYPE QUESTIONS

1. **The conduction current is same as displacement current when source is**
   **(a)** a.c only
   **(b)** d.c only
   **(c)** both a.c and d.c
   **(d)** neither a.c nor d.c

2. **Assertion (A): Microwave are used in Radar.**

   **Reason (R): Microwave are radiowaves having very small wavelength.**

3. **Assertion(A): In an electromagnetic wave, the direction of the magnetic field induction B is parallel to the electric field E.**

   **Reason (R): Electric field vector E and magnetic field vector B , have the same frequency.**

***

## LONG ANSWER TYPE

1. **State the characteristics of electromagnetic waves and justify the transverse nature of these waves.**

2. **A long straight cable of length $l$ is placed symmetrically along *z-axis* and has radius a $(\ll l)$. The cable consists of a thin wire and a co-axial conducting tube. An alternating current I (i) $= I_0 \sin(2\pi \nu t)$ flows down the central thin wire and returns along the coaxial conducting tube. The induced electric electric field at a distance s from the wire inside the cable is $E(s,t) = \mu_0 I_0 \nu \cos(2\pi \nu t) \ln\left(\frac{s}{a}\right) k$.**

   **(A)** Calculate the displacement current density inside the cable.

   **(B)** Integrate the displacement current density across the cross-section of the cable to find the total displacement current $I_d$.

   **(C)** Compare the conduction current $I_0$ with the displacement current $I_d$

***

# ANSWER KEY

## SECTION-A(MCQ)

1. b.
2. c.
3. b.
4. d.
5. c.
6. a.
7. d.
8. d.
9. b.
10. c.
11. b.
12. b.
13. b.
14. c.
15. d.
16. d.
17. d.
18. c.
19. c.
20. b.

$$\left(\because \lambda = \frac{c}{f} = \frac{3\times10^8}{50\times10^6} = 6m\right)$$

21. b.

$$\left(\because B_0 = \frac{E_0}{c} = \frac{120}{3\times10^8} = 4\times10^{-7}T\right)$$

22. a.

$$(\because E_0 = cB_0 = 3\times10^8\times420\times10^{-9} = 126\,Vm^{-1})$$

23. d.

$$\left(\because \lambda = \frac{c}{f} = \frac{2\pi c}{\omega} = \frac{2\pi\times3\times10^8}{\pi\times10^8} = 6m\right)$$

$$E = E_0\,cos\,(k\,y + wt)$$

24. b.

$$\left(\because E = \frac{hc}{\lambda} = \frac{6.62\times10^{-34}\times3\times10^8}{6620\times10^{-8}} = 1.6\times10^{-19}\times1\right)$$

25. b.

$$\left(\because T = \frac{0.29\,cm\,K}{5800A^\circ} = \frac{0.29}{5800\times10^{-8}} = 5000K\right)$$

26. d.
27. d.

$$\left(f = \frac{C}{\lambda} = \frac{3\times10^8}{3\times10^{-3}} = 10^{11}Hz, B_0 = \frac{E_0}{c} = \frac{30}{3\times10^8} = 10^{-7}T\right)$$

***

## KEY TO SHORT ANSWER

1. **Ans..(A) (a) Electric field**

**Explanation:** Electric field has zero average value in a plane electromagnetic field

**(b) (a)** The frequency of the microwaves must match the resonant frequency of the water molecules.

**2. Ans. (A) (a) $\mathbf{1.8 \times 10^{8}\ ms^{-1}}$**

**Explanation:**

$$v = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_r \mu_0 \varepsilon_r \varepsilon_0}}$$

$$= \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \frac{1}{\sqrt{\mu_r \varepsilon_r}} = \frac{C}{\sqrt{\mu_r \varepsilon_r}}$$

**(B) (c) $\gamma$ -rays**

**Explanation:** These are e.m. wave of highest frequency range and lowest wave length range

**(C) (c) microwaves**

**3. Ans. (A)** AS radio wave from short wave bands gets reflected from ionosphere, we use them for long distance communication.

**(B)** It absorb large portion of UV radiations harmful for living organism on earth emitted by the sun.

**(C)** TV signals of the frequency 100 MHz to 200 MHz neither follow the curvature of earth nor get reflected by ionosphere. Therefore Satellites are used in long distance communication

**4. Ans.** Here $r = 5cm = 5 \times 10^{-2}m$

$$\frac{dE}{dt} = 10^{12} Vm^{-1}s^{-1}$$

$$i_d = \varepsilon_0 \left(\frac{d\varphi_E}{dt}\right) = \varepsilon_0 A \left(\frac{dE}{dt}\right)$$

$$= \varepsilon_0 \pi r^2 \frac{dE}{dt}$$

$$8.85 \times 10^{-12} \times \pi \times (5 \times 10^{-2} \times 10^{12}\ A = 0.07A$$

**5. Ans.**

**(A)** (a) An electric field changing with time gives rise to a magnetic field.

**Explanation:** The fact that an electrical field changing with time gives rise to a magnetic field, symmetrical counterpart and is a consequence of the displacement current being a source of a magnetic field.

**(B)** $(\boldsymbol{b})\ \boldsymbol{E_r = E_0 \hat{\imath}\, cos\, (kz + \omega t)}$

**Explanation**: Only the phase changes by 180°

Thus, for reflected wave:

$$\hat{Z} = -\hat{z}, \hat{\imath} = -\hat{\imath}$$

And additional phase of 180°,

So the reflected wave will be:

$$E_r = E_0\, \hat{\imath}\, cos\, (kz + \omega t)$$

**(C) (a)** $\boldsymbol{0.166 \times 10^{-8} Nm^{-2}}$

**Explanation:** Intensity of radiation is

$$l = pc$$

$$\frac{0.5}{3 \times 10^8} = 0.166 \times 10^{-8} Nm^{-2}$$

**(D) (d)** $\boldsymbol{\frac{1}{2}\ \varepsilon_0 E^2 + \frac{B^2}{2\mu_0}}$

**Explanation:** Total energy per unit volume is given by

$$u = u_e + u_m$$

$$u = \frac{1}{2}\varepsilon_0 E^2 + \frac{B^2}{2\mu_0}$$

**(E) (b)** $\boldsymbol{-2.1 \times 10^{-8}\ kT}$

**Explanation:**

$$B = \frac{E_0}{c}$$

$$= \frac{6.2}{3 \times 10^8} = 2.1 \times 10^{-8}\ kT$$

Here k denotes the direction of magnetic field.

**6. Ans.**

**(A) (c) Is same for all of them**

**Explanation:** Speed of electromagnetic wave in vacuum is given by,

$$C = \frac{1}{\mu_0 \varepsilon_0}$$

**(B) (c) Ultraviolet region**

Given E = 11 eV

$$E = hv$$

$$\nu = 2.65 \times 10^{15} Hz$$

This frequency radiation belongs to ultraviolet region.

**(C) (c) Infrared Waves**

**Explanation:** The water molecules or $CO_2, NH_3$ molecules present in different materials absorb infrared waves, increase the thermal motion and hence heat up the material and their surroundings. Hence they are called thermal radiations.

**(D) (a) Rongten**

**(E) (d) Laser Associated Spectrum In Kyphosis, UV rays**

**Explanation:** UV radiations can be focused into very narrow beam for high precision application such as LASIK eye surgery.

***

## OBJECTIVE TYPE QUESTIONS

1. **Ans**. **(c)** Both a.c and d.c
2. **Ans. (a)** Both A and R are true and R is the correct explanation of A

   **Explanation:** Microwave are frequently used in Radar because these are radio waves of much shorter wavelength and can be easily reflected back by an aeroplane.
3. **Ans. (c) A is true but R is false**

   **Explanation:** The electric field vector and magnetic field vector are perpendicular to each other.

***

## LONG ANSWER TYPE

**1. Ans.** Electromagnetic waves and their characteristics: Electromagnetic waves are generated by accelerating charge particle. These waves :

**(1)** Travel with the speed of light.

**(2)** Consist of electric and magnetic field perpendicular to each other and perpendicular to the direction of wave propagation.

**(3)** Carry energy and momentum and hence exert pressure if they encounter a surface.

**(4)** Have relative magnitudes of E and B in the empty space related by E/B = c.

**(5)** Obey the principle of superposition.

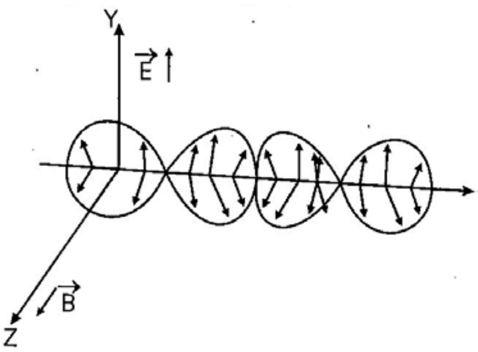
**(6)** Can penetrate the substances

**(7)** Can ionise the gases.

**(8)** Can affect the photographic plate.

**(9)** Can produce photoelectric effect.

**(10)** Can produce X - rays.




Transverse Nature of Electromagnetic Waves : The electromagnetic waves consists of electric and magnetic fields perpendicular to each other and perpendicular to the direction of propagation. The field vibrations are perpendicular to the directions, therefore, the electromagnetic waves are transverse in nature just like the light waves. The transverse nature of the waves can be proved by polarization. The phenomenon of polarization proved that electromagnetic waves are transverse in nature.

*x-axis* is the direction of wave propagation.

*y-axis* is the direction of electric field vibration

and *z-axis* is the direction of magnetic field vibration.

**2. Ans.**

**(A)** Displacement curing density can be found from the relation be

$$J_0 = E_0 \frac{dE}{dt}$$

$$= E_0\mu_0 l_0 \frac{\partial}{\partial t}\cos(2\pi v t)\,.\,In\left(\frac{s}{a}\right)\hat{k}$$

$$= \frac{1}{c^2}\ I_0 2\pi v^2(-\sin(2\pi\ vt))In\ \left(\frac{s}{a}\right)\ \hat{k}$$

$$= \left(\frac{v}{c}\right)^2 I_0\ In\ \left(\frac{a}{s}\right)\sin(2\pi v t)\,\hat{k}$$

**(B)** $\boldsymbol{I_d = \int J_0 S\ ds\ d\theta}$

$$= \frac{2\pi}{\lambda^2}E_0 2\pi\ \int_{s=0}^{\alpha} ln\left(\frac{\alpha}{S}\right).Sds\sin(2\pi v t)$$

$$= \left(\frac{2\pi}{\lambda}\right)^2 I_0\ \int_{s=0}^{\alpha}\frac{1}{2}ds^2 ln\left(\frac{\alpha}{S}\right)\sin(2\pi v t)$$

$$= \frac{\alpha^2}{4}\left(\frac{2\pi}{\lambda}\right)^2 I_0\ \int_{s=0}^{\alpha} d\ \left(\frac{S}{\alpha}\right)^2 ln\ \left(\frac{\alpha}{S}\right)^2\sin(2\pi v t)$$

$$= \frac{\alpha^2}{4}\left(\frac{2\pi}{\lambda}\right)^2 I_0\int_0^1 ln\ \ d\sin(2\pi v t)$$

$$= +\left(\frac{\alpha}{2}\right)^2\left(\frac{2\pi}{\lambda}\right)^2 I_0\sin(2\pi v t)$$

(∴ The integral hasvalue-1)

**(C) The displacement current**

$$I_d = \left(\frac{\alpha}{2}\cdot\frac{2\pi}{\lambda}\right)^2 I_0\sin 2\pi v t$$

$$= I_{0_d}\sin 2\pi v t$$

$$\frac{I_{0_d}}{I_0} = \left(\frac{a\pi}{\lambda}\right)^2$$

***

# CHAPTER EIGHT

# (RAY OPTICS)
## SECTION -A
### ASSERTION-REASON QUESTIONS

**For the following questions two statements are given one labelled assertion (A) and the other labeled Reason (R). Select the correct answer to those questions from the codes (a),(b), (c) and (d) as given below:**

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

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

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

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

**1. Assertion : A Mirror with a covered half with an opaque object will show complete image.**

**Reason : Laws of reflection are independent of the area of the mirror.**

**2. Assertion (A): frequency of a monochromatic light changes while travelling from one medium to another.**

**Reason (R) : Refractive index for a given pair of media is independent of velocity of light and frequency of light.**

**3. Assertion: By using parabolic mirrors we can reduce spherical aberration.**

**Reason: A parabolic mirror focuses all the rays in a wide parallel beam to a single point on the principal axis.**

**4. Assertion (A): A convex mirror cannot form real images.**

**Reason (R): Convex mirror converges the parallel rays that are incident on it.**

5. **Assertion:** A concave mirror is used as shaving or make-up mirror.

**Reason:** Concave mirror forms a magnified and erect image of the face when it is held closer to the face.

6. **Assertion:** During summer noon, the trees and houses on the other side of an open ground appear to be shaking.

**Reason:** Critical angle depends upon the colour of light.

7. **Assertion(A):** The formula that relates the focal length of a lens to the refractive index of the lens material and the radii of curvature of its two surface is Lens maker's formula.

**Reason (R):** It is used by manufacturers to design lenses of required focal length from a glass of given refractive index.

8. **Assertion(A):** Sun glass have curved surface but they do not have any power.

**Reason(R):** Both the surfaces of sun glass are equally curved, i.e. $R_1 = R_2$ resulting in Zero power.

9. **Assertion(A):** The total magnification of combination of lenses is a product of magnification of individual lenses.

**Reason(R):** the image formed by the first lens becomes the object for second.

10. **Assertion(A):** A convex lens of focal length 30cm can't be used as a simple microscope in normal setting.

**Reason(R):** For normal setting, the angular magnification of simple microscope is $M = \frac{D}{F}$

**11. Assertion(A):** It is possible to increase the range of the telescope by increasing the diameter of its objective.

**Reason(R):** The light gathering power of objective will increase and even faint objects will become visible.

**12. Assertion(A):** Clouds appear white.

**Reason(R):** Clouds have large particles like dust and water droplets which scotter light of all colours almost equally.

**13. Assertion(A):** The sequence of colours in the secondary rainbow reverse of that in the primary rainbow.

**Reason(R):** A secondary rainbow is formed by two internal reflections of light in water droplets while a primary rainbow is formed by just one total internal reflection.

***

## ANSWER KEY

## ASSERTION-REASON QUESTIONS

1. **Ans. (a) Both A and R are true and R is the correct explanation of A.**

   **Explanation :** Laws of reflection are true at every point of the mirror and does not depend of the area of the reflecting surface. Half cover mirror will have no effect on type of image formed. Uncovered mirror will act as the complete mirror. Intensity of the image will decrease as less number of rays will be responsible for creating the image hence quality of image will suffer.

2. **Ans. (c) A is true but r is false.**

   **Explanation:** Refraction of light for a given pair of media depends on the ratio of wavelength and velocity of light but not on frequency. Frequency remains constant during refraction of light.

3. **Ans. (a) Both A and R are true and R is the correct explanation of** A.

4. **Ans. (c) A is true but R is false.**

   **Explanation:** A convex mirror cannot form real images because it has virtual focal point Convex mirror diverges the parallel rays that are incident on it and seems to come from a point that is virtual focus.

5. **Ans. (a) Both A and R are true and R is the correct explanation of A.**

6. **Ans. (b) Both A and R are true but R is NOT the correct explanation of A.**

   **Explanation:** Open ground becomes very hot during a summer noon and it heats up the air in contact, convection currents are set up in the air. Light rays passing through this air change their path due to refraction. This gives the shaking appearance to the objects from which these light rays are coming.

7. **Ans. (a) Both A and R are true and R is the correct explanation of A .**

8. **Ans. (a) Both A and R are true and R is the correct explanation of A .**

9. **Ans. (a) Both A and R are true and R is the correct explanation of A .**

10. **Ans. (b) Both A and R are true and but R is NOT the correct explanation of A.**

11. **Ans. (a) Both A and R are true and R is the correct explanation of A .**

12. **Ans. (a) Both A and R are true and R is the correct explanation of A .**

13. **Ans. (a) Both A and R are true and R is the correct explanation of A .**

***

## MULTIPLE CHOICE QUESTIONS

1. **Ray optics is valid when characteristic dimensions:**
   **(a)** of the order of one millimeter
   **(b)** of same order as wavelength of light
   **(c)** much larger then wave length of light
   **(d)** much smaller than wavelength of light

2. **A short pulse of white light is incident from air to a glass slab at normal incidence. After travelling through the slab, the first colour to emerge is**
   **(a)** blue, **(b)** green
   **(c)** violet **(d)** red

3. **You are given four source 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$^{o}$. 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 ?**

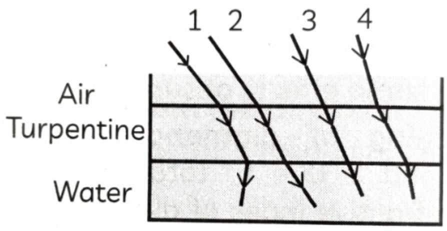
**(a)** The beam of red light would undergo total internal reflection.

**(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.

**4. 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

**5. Two mirrors are kept at 60º to each other and the body is placed at middle, the total number of images formed is**

**(a)** six

**(b)** four

**(c)** five

**(d)** three

**6. A double convex lens of refractive index $\mu_1$ is immersed in a liquid of refractive index $\mu_2$. The lens will act as transparent plane sheet when**

**(a)** $\mu_1 = \mu_2$

**(b)** $\mu_1 > \mu_2$

**(c)** $\mu_1 < \mu_2$

**(d)** $\mu_1 = 1\mu_2$

**7. Optical fibres are based on the phenomena of**

**(a)** reflection

**(b)** refraction

**(c)** dispersion

**(d)** total internal reflection

**8. When light enters from air to glass its wavelength**

**(a)** Increases

**(b)** Decreases

**(c)** Remain unchanged

**(d)** Data is insufficient.

**9. Given**

**(i) Plane Mirrors**

**(ii) Concave Mirrors**

**(iii) Convex Mirrors**

Among the above choices. Virtual images can be formed by

**(a)** (i), (ii) and (iii)

**(b)** (i) and (ii)

**(c)** (i) and (iii)

**(d)** (ii) only

**10. Between the primary and secondary rainbows, there is a dark band known as Alexandar's dark band. This is because.**

**(a)** Light scattered into this region interface destructively

**(b)** There is no light scattered into this region.

**(c)** Light is absorbed in this region.

**(d)** Angle made at the eye by the scattered rays with respect to the incident light of the sun lies between approximately 42° and 50°.

**11. The phenomena involved in the reflection of radio waves by ionosphere is similar to**

**(a)** Reflection of light by a plane mirror.

**(b)** Total internal reflection of light in air during a mirage.

**(c)** Dispersion of light by water molecules during the formation of a rainbow.

**(d)** Scattering of light by the particles of air.

**Case based (12-16)**

Two or more lenses are used in many optical devices. The idea is to place lens as per requirement on the same principal axis to magnify the image, to increase sharpness of the final image by minimizing certain defects or aberrations in it, to erect the final image and to increase the field of view. Mainly, combination is used in cameras and telescopes. When a ray of light in incident on the first lens. It creates a real image which serves as a virtual object for lens. 2. As the ray keeps on refracting from one lens to another. A new image is formed by every lens which serves as the object for the next one. The lens used in combination can be in contact with each other or can have distance between them.

**12. If two lenses are kept in contact with other of power +15 D and -5D**

**respectively, then the power of the combination is ?**

**(a)** 10 D

**(b)** 20 D

**(c)** -10 D

**(d) -**75 D

**13. What is the total focal length when two lenses of power +15D and -5D are kept in combination?**

**(a)** 10m

**(b)** 100 cm

**(c)** 10 cm

**(d)** 75 cm

**14. If the distance between the lenses in increased to 10cm. What will be the effect on the magnification of the image?**

**(a)** Doubles

**(b)** Increases by 10 units

**(c)** Decreases by 10 units

**(d)** Remains the same.

**15. An object is placed 30 cm from this combination of focal length 10m. Calculate the position of the image.**

**(a)** +15 cm

**(b)** +30 cm

**(c) -**15 cm

**(d) -**30 cm

**16. If n no. of lenses of magnification = 1 are added in the combination. The net magnification will:**

**(a)** m×n

**(b)** $\frac{m}{n}$

**(c)** m

**(d)** 0

**17. An object approaches a convergent lens from the left of the lens with a uniform speed 5m/s and stops at the focus. The image**

**(a)** Moves away from the lens with an uniform speed 5 m/s.

**(b)** Moves away from the lens with on uniform acceleration.

**(c)** Move away from the lens with a non-uniform acceleration.

**(d)** Moves towards the lens with a non-uniform acceleration.

**18. The focal length of uniconvex lens is equal to the radius of curvature of either faces. What is the refractive index of the lens material.**

**(a)** 1.5

**(b)** 1.6

**(c)** 2

**(d)** 1.42

**19. There is an air bubble inside water. At what distance from the bubble**

**should an object be placed so that real image is formed at the same distance from dubble ? Refractive index of water is 4/3.**

**(a)** R

**(b)** 2R

**(c)** 3R

**(d)** Air bubble cannot form real image.

**20. A thin lens of focal length $f$ and its aperture has diameter $d$. It forms an image of intensity $I$. Now the central part of the aperture upto diameter d/2 is blocked by an opaque paper. The focal length and image intensity would change to**

**(a)** $\frac{f}{2}, \frac{1}{2}$

**(b)** $f, \frac{1}{4}$

**(c)** $\frac{3f}{4}, \frac{1}{2}$

**(d)** $f, \frac{3I}{4}$

**21. A double convex lens of refractive index $\mu_1$ is immersed in a liquid of refractive index $\mu_2$. The lens will act as transparent plane sheet when.**

**(a)** $\mu_1 = \mu_2$

**(b)** $\mu_1 > \mu_2$

**(c)** $\mu_1 < \mu_2$

**(d)** $\mu_1 = 1\mu 2$

**22. A concave lens made of glass having refractive index 1.5, has both surface of same radius of curvature R. On immersion in a medium of refractive index 1.75, it will behave as**

**(a)** Convergent lens of focal length 3.4 R.

**(b)** Convergent lens of focal length 3R

**(c)** Divergent lens of focal length 3.5R

**(d)** Divergent lens of focal length 3R

**23. The focal length of the converging lens's measured for violet, green and red color. It is $f_V, f_G$ and $f_R$ respectively. We will get.**

**(a)** $f_V = f_G$

**(b)** $f_G = f_R$

**(c)** $f_V < f_R$

**(d)** $f_V > f_R$

**24. The radius of curvature of the curved surface of a plano-convex lens is 20cm. if the refractive index of the material of the lens be 1.5, it will**

**(a)** Act as convex lens only for the objects that lie on its curved side.

**(b)** Act as a concave lens for the objects lie on it 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.

***

## ANSWER KEY

## MCQ

1. **(c) much larger than wavelength of light**

**Explanation:** The size of obstacle must be much larger than the wavelength of light , if wavelength is comparable to the size of the object, then diffraction could happen, but it cannot be explained using ray optics.

2. **(d) red**

**Explanation:** The light of red colour is of highest wavelength and therefore of highest speed. Therefore, after travelling through the slab, the red colour emerges first.

3. **(c) the beam of blue light would undergo total internal reflection.**

**Explanation:** The critical angle $sin\ c = \frac{1}{\mu}$

Also velocity of light $v \propto \frac{1}{\mu}$

Among all given sources of light, the blue light have smallest wavelength. It means critical angle is least which facilitates total internal reflection for the beam of blue light.

4. **(b) 2**

**Explanation:** Here, light ray goes from (optically) rarer medium (air) to optically denser medium (turpentine) then it bends towards the normal. i.e., whereas when it goes from to optically denser medium water, then it bends away the normal.

5. **(c) five**

**Explanation:** Number of images $= \left[\frac{360}{60} - 1\right]$

$$= 6 - 1 = 5$$

6. **(a) $\boldsymbol{\mu_1 = \mu_2}$**

**Explanation:** When the refractive index of the liquid is same as the lens material, no light will be reflected by the lens and it will not be visible and act as a transparent plane sheet.

**7. (d) Total internal reflection.**

**Explanation:** When light is incident on one end of the fibre at a small angle. It goes inside and suffers repeated total internal reflections because the angle of incidence is greater than the critical energy of the fibre material with respect to its outer coating.

**8. (b) decreases**

**Explanation**: When a ray of light enters from air to glass its velocity decreases and its wavelength decreases.

**9. (a) (i) (ii) and (iii)**

**Explanation:** Plane mirrors and convex mirrors always form virtual image Concave mirrors form virual image when object is placed between F and P.

**10. (a) light scattered into this region interfere destructively**

**(b) angle made at the eye by the scattered rays with respect to the incident light of the sun lies between approximately 42º and 50º.**

**Explanation:** The Alexandar's dark band lies between the primary and secondary rainbows, formed due to light scattered into this region interfere destructively. The primary rainbow subtends on angle nearly 41º to 42º at observer's eye. Whereas secondary rainbows subtends on angle nearly 51º to 54º at observer's eye w.r.t incident light ray.

Hence, the scattered rays with respect to the incident light of the sun lies between approximately 42º and 50º.

**11. (b) total internal reflection of light in air during a mirage.**

**Explanation:** Radio waves are reflected by a layer of atmosphere called the lonosphere, so they can reach distant parts of the earth. The reflection of radio waves by ionosphere is due to total internal reflection. It is the same as total internal reflection of light in air during a mirage. i.e. angle of incidence is greater than critical angle.

**12. (a) +10**

**Explanation :** $P = P_1 + P_2$

**13. (c) 10 cm**

**Explanation:**

$$f = \frac{1}{P} = \frac{1}{10}m = 10cm$$

**14. (d) remains the same**

**Explanation:** magnification is a property of lens. Independent of distance between the lenses.

**15. (a) +15 cm**

**Explanation :** $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$

$$\frac{1}{10} - \frac{1}{30} = \frac{1}{15}$$

$$v = +15cm$$

**16. (c) m**

**Explanation:**

$$m = m_1 \times m_2 \times m_3 \times m_4 \ldots$$

Total magnification is the product of magnification caused by individual lenses. If the n no. of lenses with $m = 1$ are added in the combination.

$$m \times 1 = m$$

**17. (c) moves away from the lens with a non-uniform acceleration.**

**Explanation**: in this problem the object approaches a convergent lens from the left of the lens with a uniform speed of 5 m/s, hence the image will move away from the lens with a non-uniform acceleration. The image moves slower in the beginning and faster later on will move from F to 2F and when the object moves from 2F to F, the image will move from 2F to infinity. At 2F, the speed of the object and image will be equal.

**18. (a) 1.5**

**Explanation:** Lens maker formula

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Here, $R_1 = -R_2 = f = R$

$$\frac{1}{2} = (\mu - 1) \Rightarrow \mu = \frac{3}{2} = 1.5$$

**19. (d) air bubble cannot form real image**

**Explanation:** An air bubble inside water behaves like the concaves lens. So, it does not form real image.

**20. (d)** $\boldsymbol{f, \frac{3I}{4}}$

**Explanation:** Due to blocking of central part focal length does not change but intensity decreases. The amount of light crossing the lens decreases by the factors of

$$\left[\frac{\left\{\pi\left(\frac{d}{2}\right)^2\right\}}{(\pi d^2)}\right] = \frac{1}{4}$$

$\therefore \quad I' = I/4$

Hence intensity decrease by

$I - I' = 1 - \frac{1}{4} = \frac{3I}{4}$

**21. (a) $\mu_1 = \mu_2$**

**Explanation:** when the refractive index of the liquid is same as the lens material, no light will be reflected by the lens and it will not be visible and act as a transparent plane sheet.

**22. (a) convergent lens of focal length 3.5R**

**Explanation:** Here, $R_1 = R_2$

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} + \frac{1}{R}\right)$$

$$= -\left[\frac{2(\mu - 1)}{R}\right]$$

When it is dipped in the liquid

$$\mu_g = \frac{1.5}{1.75}$$

$$\therefore \frac{1}{f_1} = -\frac{2}{R}\left(\frac{1.5}{1.75} - 1\right)$$

$$= \frac{2}{7R}$$

$$\therefore f_1 = \frac{7R}{2} = 3.5R$$

**23. (c) $f_V < f_R$**

**Explanation:** $\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

Since the refractive index of violet color $(\mu_V)$ is greater than the refractive index of red colour $(\mu_R)$. Therefore focal length of violet colour is less than the focal length of red colour i.e. $f_V < f_R$

**24. (c) act as a convex lens irrespective of the side on which the object lies.**

**Explanation:**

Here, $R = 20cm, \mu = 1.5$

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$R_1 = \infty, R_2 = -R$$

$$\frac{1}{f} = \frac{R}{(\mu - 1)} = \frac{20}{1.5 - 1} = 40cm$$

As $f > 0$ means converging nature. Therefore lens act as a convex lens irrespective of the side on which the object lies.

***

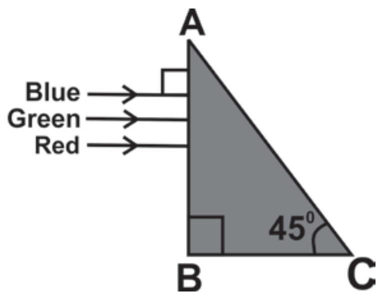
## SHORT ANSWER TYPE

1. An objects is kept in front of a concave mirror of a focal length 15cm. The image formed is three time the size of the object. Calculate the two possible distance of the object from the mirror.

2. A square wire of side 3 cm is placed 25cm away from a concave mirror of focal length 10cm. What is the area enclosed by the image of the wire ? the centre of wire is on the axis of the mirror, with two sides normal to the axis.

3. Determine the direction in which a fish under the water sees the setting sun. Refractive index of water is 1.33.

4. **(A)** A beam of light consisting of red, green and blue colours, is incident on a right angled prism, as shown in the diagram given below. The refractive index of the material of the prism for the red, green and blue wavelengths are 1.35, 1.46 and 1.57 respectively. Out of three colours which colour ray will emerge out of face AC?




**(B)** How will the situation change if these rays were incident normally on one of the faces of an equilateral prism ?

5. Obtain the mirror formula and write the expression for the linear magnification.

***

## ANSWER KEY

### SHORT QUESTION

**1.** As the mirror is a concave, so

$$f = -15cm$$

When the image formed is real

$$m = \frac{-h'}{h} = -\frac{v}{u} = -3 \; or \; v = +3u$$

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\frac{1}{u} + \frac{1}{3u} = -\frac{1}{15}$$

$$\frac{4}{3u} = -\frac{1}{15}$$

$$u = -20cm$$

When the image formed is virtual

$$m = \frac{-h'}{h} = -\frac{v}{u} = +3 \text{or } v = +3u$$

**2.** Here $u = -25cm, f = -10cm$

As $\frac{1}{u} = \frac{1}{f} - \frac{1}{v}$

$$= \frac{1}{u} - \frac{1}{3u} = -\frac{1}{25}$$

$$= -\frac{3}{50} \text{ or } v = -\frac{50}{3}$$

now , $m = \frac{v}{u} = -\frac{50}{75} = -\frac{2}{3}$

$$-\frac{2}{3} = \frac{Size\ of\ the\ image\ of\ wire\ h'}{Size\ of\ square\ wire\ h}$$

So $\frac{Size\ of\ the\ image\ of\ wire\ h'}{Size\ of\ square\ wire\ h} =$

$$-\frac{2}{3}h = -\frac{2}{3}.3 = -2cm$$

**3.** The apparent position of the sun makes an angle $i_c$ with the vertical.

From snell's law

$$\frac{\sin 90°}{\sin i_c} = 1.33$$

$$\sin i_c = \frac{1}{1.33}$$

$$i_c = \sin^{-1}(0.7518) = 48.74°$$

Angle between apparent position of the sun and the horizontal.

$$90° - 48.74° = 41.26°$$

**4.** **(A)** As light is incident normally on face AB, so no refraction occurs at face AB. Light is incident on face AC at $i = 45°$. The face AC will not transmit light for which

$$i < i_c$$

$or\ \sin i < \sin i_c$

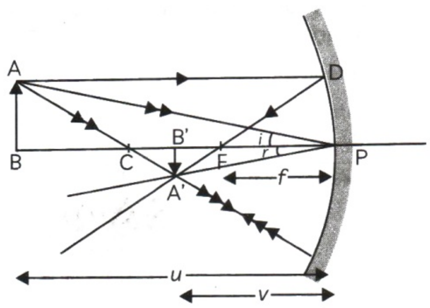
$or \sin 45° < 1/\mu$

$\Rightarrow \mu > \sqrt{2} = 1.414$

As $\mu_R < \mu$ while $\mu_G$ and $\mu_B > \mu$ so red colour will be transmitted through face AC while green and blue rays will suffer total internal reflection.

**(B)** if these rays falls normally on equilateral prism, then all the rays will suffer total internal reflection because the angle of incidence on the inside face will $60° > i_c$.

**5.** Derivation for mirror formula and magnification: Consider an object AB be placed in front of a concave mirror beyond centre of curvature C.




If $F$ is the facus, Focal length $=f$; object distance $= u$; image distance $= v$

As $\Delta$s $ABC$ and $A'B'C$ are similar,

$\frac{AB}{A'B'} = \frac{CB}{CB'}$ ....(i)

Again, as $\Delta$s $ABP$ and $A'B'P'$ are similar

$\frac{AB}{A'B'} = \frac{PB}{B'P}$.....(ii)

$\Rightarrow \quad \frac{CB}{CB'} = \frac{PB}{PB'}$......(iii)

$\therefore$ From (iii), $\frac{PB-PC}{PC-PB'} = \frac{PB}{PB'}$

$\Rightarrow \quad \frac{-u+R}{-R+V} = \frac{-u}{V}$

$[\therefore PB = u, PC = -R\ PB' = -V]$

$\Rightarrow uR + vR = 2uV$

$\Rightarrow \frac{1}{V} + \frac{1}{u} = \frac{2}{R}$

$\Rightarrow \boxed{\frac{1}{V} + \frac{1}{u} = \frac{1}{f}} \quad (\therefore R = 2f)$

Linear magnification,

m= $\frac{Image\ \ height\ (h_i)}{Object\ \ height\ (h_0)}$

From equation (ii), $\frac{A'B'}{AB} = \frac{PB'}{PB}$

Using new Cartesian sign convention $A'B' = -h_2, AB = +h_1, PB' = -v, PB = -u$

$\therefore \frac{-h_2}{h_1} = \frac{-v}{u} = \frac{v}{u}$

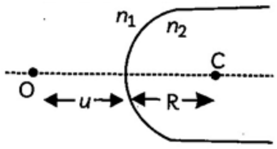
or $m = \frac{h_2}{h_1} = \frac{-v}{u}$

## LONG QUESTION TYPE

1. **(A)** Derive lens maker's formula for a biconvex len**s.**

   **(B)** A point object is placed at a distance of 12 cm on the principal axis of a convex lens of focal length 10 cm. A convex mirror is placed coaxially on the other side of the lens at a distance of 10 cm. If the final image coincides with the object, sketch the ray diagram and find the focal length of the convex mirror.

2. (A) A point object 'O' is kept in a medium of refractive index n in front of a convex spherical surface of radius of curvature R which separate the second medium of refractive index $n_2$ from the first one as shown in the figure. Draw the ray diagram showing the image formation and deduce the relationship between the object distance and the image distance in terms of $n_1, n_2$ and $R$.




   (B) When the image formed above acts as a virtual object for a concave spherical surface separating the medium $n_2$ from $n_1 (n_2 > n_1)$ draw this ray diagram and write the similar (similar to (A)) relation. Hence obtain the expression for the Lens Maker's formula.

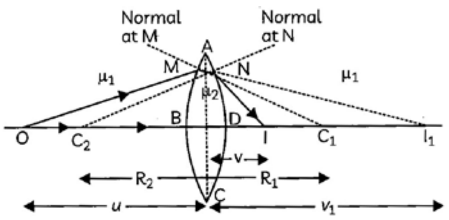
***

# ANSWER KEY

## LONG QUESTION

1. **Ans.**

**(A)** Consider a thin biconvex lens made of material of refractive index $\mu_2$. This lens is placed in a medium with a refractive index $\mu_1$ where $\mu_1 < \mu_2$. Consider the two surfaces of the lens ABC and ADC such that their poles are B and D, and their centres of curvature are $C_1$ and $C_2$ respectively. The radius of curvature of $ABC$ and $ADC$ are $R_1$ and $R_2$ respectively.




Let a point object $O$ be placed on the principal axis of the biconvex lens. The object is present in the medium of the rarer refractive index $\mu_1$. Ray $OM$ is incident on the curved surface $ABC$. It undergoes refraction along $MN$ and bends toward the normal at this surface. If the second curved surface i.e. $ADC$ been absent in the lens, $MN$ would have met the principal axis at $I_1$. Thus $I_1$ can be treated the real image formed by $ABC$ in the medium having a refractive index $\mu_2$.

The object distance $u_1$ image distance $v_1$ and the radius of curvature $R_1$ are related as

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} \quad \text{........ (1)}$$

Ray $MN$ undergoes refraction again at the curved surface $ADC$. It bends away from the normal at $N$. The ray emerging meets the principal axis at point $l$. Here the final image of $O$ is formed by the lens.

For refraction at the second surface, $I_1$ behaves as a virtual object placed in the medium of refractive index $\mu_2$.

Similarly, $I$ is the real image formed in the medium of refractive index $\mu_1$. The radius of curvature $R_2$ is related to the object distance $v_1$ and the image distance $v$ by the relation:

$\frac{\mu_1}{v} - \frac{\mu_2}{v_1} = \frac{\mu_1 - \mu_2}{R_2}$ .......(ii)

Adding} equations (i) and (ii), we get,

$$\frac{\mu_1}{v} - \frac{\mu_1}{u} = (\mu_2 - \mu_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$\Rightarrow \frac{1}{v} - \frac{1}{u} = \left[\frac{\mu_2 - \mu_1}{\mu_1}\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$.(iii)

For an object placed at infinity, $u = \infty$.

The image will be formed at the focus of the lens.

$\therefore\ v = f$

$\frac{1}{f} = \left[\frac{\mu_2 - \mu_1}{\mu_1}\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

.... (iv)

For a lens with refractive index u placed in air,

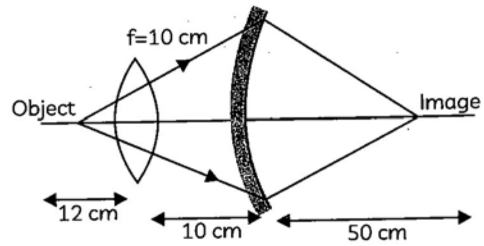
$$\mu_1 = 1\ and\ \mu_2 = \mu$$

$$\frac{1}{f} = [\mu - 1]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

Comparing equation (iii) and (iv), we get,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

(B)




The final image, formed by the combination, is coinciding with the object itself. This implies that the rays, from the object, are retracing their path, after refraction from the lens and reflection from the mirror. The (refracted) rays are, therefore, falling normally on the mirror. Thus, the image of the convex lens should form at the centre of curvature of the convex mirror.

The image distance of the convex lens using the lens formula

$$\frac{1}{v} - \frac{1}{-12} = \frac{1}{10}$$

$$\Rightarrow \quad v = 60cm$$

So, the centre of curvature of convex mirror is at a distance of 60 cm from the convex lens.

Thus, radius of curvature of the convex mirror,

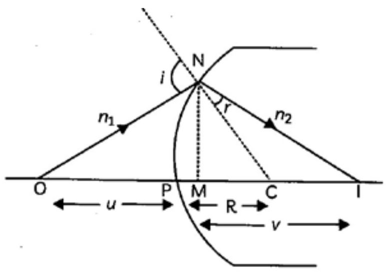
$$R = 60\,cm - 10\,cm$$
$$= 50\,cm$$

Therefore, focal length of the convex mirror,

$$R = \frac{f}{2} = \frac{50}{2} cm = 25\,cm$$

2. **Ans.**

**(A)** Let a spherical surface separate a rarer medium of refractive index $n_1$ from second medium of refractive index $n_2$. Let C be the centre of curvature and $R = MC$ be the radius of the surface.




Consider a point object $O$ lying on the principal axis of the surface. Let a ray starting from $O$ incident normally on the surface along $OM$ and pass straight. Let another ray of light incident on $NM$ along $ON$ and refract along $NI$.

From $M$, draw $MN$ perpendicular to $OI$.

The above figure shows the geometry of formation of image $I$ of an object O and the principal axis of a spherical surface with centre of curvature C and radius of curvature R.

Let us make the following assumptions:

(1) The aperture of the surface is small as compared to the other distance involved.

(2) The object consists only of a point lying on the principal axis of the spherical refracting surface

$$tan\angle NOM = \frac{MN}{OM}$$

$$\tan\angle NCM = \frac{MN}{MI}$$

$$\tan\angle NIM = \frac{MN}{MI}$$

For $\Delta NOC, i$ is the exterior angle.

∴ $i = \angle NOM + \angle NCM$

For small angles $\tan i = i$,

$i = \frac{MN}{OM} + \frac{MN}{MC}$ ……(i)

Similarly, $r = \angle NCM - \angle NIM$

$r = \frac{MN}{MC} - \frac{MN}{MI}$….(ii)

By Snell's law

$$n_1 \sin i = n_2 \sin r$$

For small angles,

$n_1 i = n_2 r$

Substituting the values of $i$ and r from (i) and (ii), we obtain

$$n_1\left(\frac{MN}{OM} + \frac{MN}{MC}\right) = n_2\left(\frac{MN}{MC} + \frac{MN}{MI}\right)$$

Or $\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$…..(iii)

Applying new Cartesian sign conventions, we get

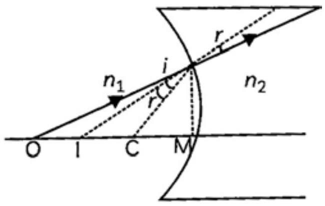
$$OM = -u, MI$$

$$= +v, MC = +R$$

Substituting these values in equation (iii), we obtain

$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$…….(iv)

**(B)**




Now the image $I$ acts as virtual object for the second surface that will form real image at $l$. As refraction takes place from denser to rarer medium

∴ $\frac{-n_2}{v} + \frac{n_1}{v'} = \frac{n_1 - n_2}{R}$ ……(v)

$$\left[\therefore k = \frac{1}{4\pi\varepsilon_0}\right]$$

Adding (iv) and (v) we get

$$\frac{n_1}{v'} - \frac{n_1}{u} - (n_2 - n_1)\left[\frac{1}{R} - \frac{1}{R'}\right]$$

$$\frac{1}{f} = (n_{21} - 1)\left[\frac{1}{R} - \frac{1}{R'}\right]$$

$$\left[\because n_{21} = \frac{n_2}{n_1}, \frac{1}{f} = \frac{1}{v'} - \frac{1}{u}\right]$$

***

## SECTION-B

A compound microscope with an objective of 1cm focal length and an eyepiece of 2cm focal length has a tube of 20cm, find the magnifying power if the final image if formed at the near point of the eye.

$$f_0 = 1cm, f_e = 2cm,$$

$$L = 20cm, D = 25cm$$

**Ans.** When the final image is formed at the near point of the eye, the magnifying power is ,

$$m = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$$

$$= \frac{21}{1}\left(1 + \frac{25}{2}\right)$$

$$20 \times 13.5 = 270$$

***

## Objective type questions

1. **A ray of light incident at an angle $\theta$ 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 mode of a material of refractive index 1.5, the angle of incidence is**

   **(a)** 7.5° **(b)** 5°
   **(c)** 15° **(d)** 2.5°

2. **When length of compound microscope increases, its magnifying power.**

   **(a)** decreases

   **(b)** increases

   **(c)** does not change

   **(d)** may increase or decreases

***

# Assertion and Reason Question

**Read the assertion and reason carefully to mark the correct option out of the options given below:**

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

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

**(c)** A is true but R is false

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

3. **Assertion (A) :** A convex lens of focal length 30cm can't be used as a simple microscope in normal setting.

   **Reason (R):** For normal setting, the angular magnification of simple microscope is $M = \frac{D}{f}$

4. **Assertion (A) :** It is possible to increase the range of the telescope by increasing the diameter of its objective.

   **Reason (R):** The light gathering power of objective will increase and even faint objects will become visible.

5. **Assertion (A) :** Clouds appear white.

   **Reason (R):** Clouds have large particles like dust and water droplets which scatter light of all colours almost equally.

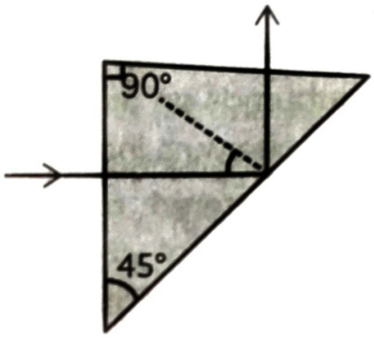
6. **Assertion (A) :** The sequence of colours in the secondary rainbow reverse of that in the primary rainbow.

   **Reason (R):** A secondary rainbow is formed by two internal reflections of light in water droplets while a primary rainbow is formed by just one total internal reflection.

***

## Very Short Answer Type Questions

**7. A ray of light incident normally on one face of a right isosceles prism is totally reflected as shown in the figure. What must be the minimum value of refractive index of glass ?**




**8. Write the relationship between angle of incidence 'i' angle of prism 'A' and angle of minimum deviations $\delta_m$ for a triangular prism.**

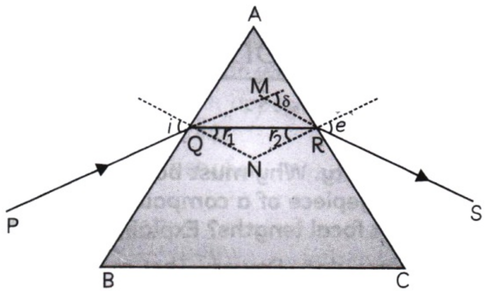
**9. How many times the total internal reflection occurs in the drop for formation of primary and secondary rainbows?**

**10. What should be the position of an object relative to a biconvex lens, so that it behaves like a magnifying lens ?**

***

## Competency Based Questions

**11.** *Figure shows the passage of light through a triangular prism ABC. The angles of incidence and refraction at the first face AB are $i$ and $r_1$, while the angle of incidence (from glass to air) at the second face AC is $r_2$ and the angle of refraction or emergence e. The angle between the emergent ray RS and the direction of the incident ray PQ is called the angle of deviation $\delta$*




*Thus, the angle of deviation depends on the angle of incidence.*

*For any given value of $\delta$, except for $i = e$, corresponds to two values $i$ and hence of e. This, in fact, is expected from the symmetry of $i$ and e in above equation, i.e., $\delta$ remains the same if $i$ and e are interchanged.*

**(A) The refractive index of the material of an equilateral prism is $\sqrt{3}$. What is the angle of minimum deviation ?**

**(a)** 450 **(b)** 600

**(c)** 370 **(d)** 300

**(B) The angle of prism is 60° and angle of deviation is 30°. In the position of minimum deviation, the angle of incidence $i$ and the angle of emergence e are**

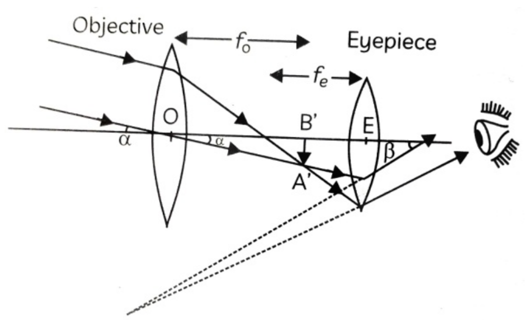
**(a)** $i = 45°, e = 50°$

**(b)** $i = 30°, e = 45°$

**(c)** $i = 45°, e = 45°$

**(d)** $i = 30°, e = 30°$

**12.** *The telescope is used to provide angular magnification of distant objects. It also has an objective and an eyepiece. But here, the objective has a large focal length and a much larger operture than the eyepiece. Light from a distance objet enters the objective and a real image is formed in the tube at its second focal point . The eyepiece magnifies this image producing a final inverted image. The magnifying power m is the ratio of the angle $\beta$ subtended at the eye by the final image to the angle $\alpha$ which the object subtends at the lens or the eye.*




*The length of the telescope tube is $f_0 + f_e$*

**(A) How will you distinguish between a compound microscope and a telescope simply by seeing it ?**

**(B) What is the position of an object relative to the objective of the compound microscope ? Where is its image formed ?**

***

## Short Answer Questions

**13. Draw the ray diagram of an astronomical telescope showing image formation in the normal adjustment position. Write the expression for its magnifying power.**

***

# ANSWERS KEY

## MCQ

**1)** **(a)** 7.5°

**Explanation:** Here, the angle of prism $A = 5°$. The ray emerges from refracting face of a prism normally.

Then, $i_2 = r_2 = 0$

As $A = r_1 + r_2 \Rightarrow r_1 = A = 5°$

But $i_1 = \mu r_1 = \frac{3}{2} \times 5 = 7.5°$

**Caution**

Students are often confused about thin prisms. In thin prisms, the distance between the refracting surfaces is negligible and the angle of prism is very small.

**2)** **(a) decreases**

**Explanation :** Length of compound microscope is the tube length L

Magnifying power of compound microscope

$$m = \frac{-L}{f_0}\left(1 + \frac{D}{f_e}\right)$$

$D$ is the least distance of distinct vision. $f_0$ and $f_e$ are the focal length of objective and eyepiece lens respectively.

From the above formula $m$ is proportional to negative of $L$ so, if length of the tube is increased, its magnification power decreases.

***

## Assertion & Reason

**3)** **(b) Both A and R are true but R is NOT the correct explanation of A.**

**Explanation:** A convex lens of focal length 30cm can't be used as a simple microscope in normal setting as for simple microscope lens of short focal length is used.

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

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

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

***

# Very Short Answer

**7)** Refractive index $\mu = \frac{1}{\sin 45°} = \sqrt{2}$

So, the minimum value of refractive index = $\sqrt{2}$

**8)** The relation between the angle of incidence $i$, angle of prism $A$, and the angle of minimum deviation $\delta_m$, for a triangular prism is given by

$$i = \frac{A + \delta_m}{2}$$

**9)** In the drop for formation of primary and secondary rainbow the number of total internal reflections are one and two respectively.

**10)** The object should be placed between the optical centre and focus of the lens at such a point that its image is formed at the least distance of distinct vision.

**11)** **(A)** (b) 600

**Explanation:** By using prism formula

$$\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\frac{A}{2}}$$

$$\Rightarrow \sqrt{3} = \frac{\sin\left(\frac{\delta_m + 60°}{2}\right)}{\sin\frac{60°}{2}}$$

$$\Rightarrow \sqrt{3} \times \sin 30° = \sin\left(\frac{\delta_m + 60°}{2}\right)$$

$$\Rightarrow \sin\left(\frac{\delta_m + 60°}{2}\right)$$

$$= \sqrt{3} \times \frac{1}{2} = \sin 60°$$

$$\Rightarrow \left(\frac{\delta_m + 60°}{2}\right) = 60°$$

$$\Rightarrow \delta_m = 60°$$

(B) (c) $i = 45°, e = 45°$

**Explanation:** in the position of minimum deviation

$$i = e = \frac{A + \delta_m}{2}$$

$$= \frac{60 + 30}{2} = 45°$$

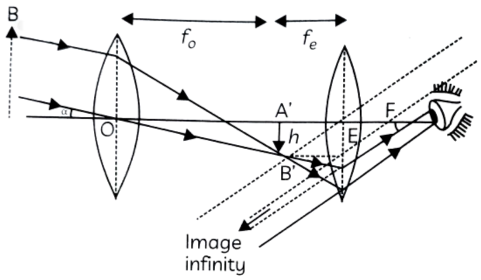
**12)** (A) The distance between the objective lens and eye lens i.e. the length of the tube is fixed, while in case of a telescope it is adjustable.

(B) When object is placed slightly larger than $f_0$ then final image is formed at infinity.

***

# Short Answer

**13) Ans**.




The magnifying power $m$ is the ratio of the angle subtended at the eye by the final image to the angle which the object subtends at the lens or the eye. Hence.

$$m = \frac{\beta}{\alpha} = \frac{h}{f_e} . \frac{f_0}{h} = \frac{f_0}{f_e}$$

***

# CHAPTER NINE

## (WAVE OPTICS)

### MULTIPLE CHOICE QUESTIONS

**1. Light propagates rectilinearly, because of its:**

**(a)** Frequency

**(b)** wavelength

**(c)** Velocity

**(d)** Wave nature

**2. Consider a ray of light incident from air onto a slab of glass (refractive index n) of width $d$, at an angle $\theta$. The phase difference between the ray reflected by the top surface of the glass and the bottom surface is**

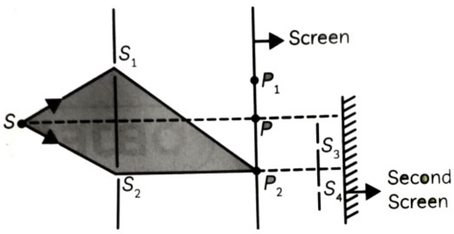
**(a)** $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}sin^2\theta\right)^{\frac{1}{2}}+\pi$

**(b)** $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}sin^2\theta\right)^{\frac{1}{2}}$

**(c)** $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}sin^2\theta\right)^{\frac{1}{2}}+\frac{\pi}{2}$

**(d)** $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}sin^2\theta\right)^{\frac{1}{2}}+2\pi$

**3. Figure shows a standard two slits arrangement with slits $S_1, S_2, P_1, P_2$ are the tow minima points on either side of P (Fig.) at $P_2$ there is a hole and behind is a second two 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.

**4. The rectilinear propagation of light in a medium is due to:**

**(a)** Its short wavelength

**(b)** Its high frequency

**(c)** Its high velocity

**(d)** The refractive index of medium

**5. Huygens concept of secondary wave**

**(a)** Allows us to find the focal length of a thick lens

**(b)** Is a geometrical method to trace a wavefront.

**(c)** Is used to determine the velocity of light

**(d)** Is used to explain polarization

**6. Two waves are said to be coherent, if they have :**

**(a)** same phase and different amplitude.

**(b)** different frequency, phase and amplitude

**(c)** some frequency but different amplitude

**(d)** same frequency, phase and amplitude

**7. The phase difference between two light waves reaching at a point is $\frac{\pi}{2}$. What is the resultant amplitude if the individual amplitude are 3 mm and 4mm ?**

**(a)** 4mm

**(b)** 3mm

**(c)** 5mm

**(d)** 8mm

**8. The frequency of a light wave in material is $2 \times 10^{14}$ HZ and wavelength is 500 nm. The refractive index of the material will be**

**(a)** 1.50

**(b)** 3

**(c)** 1.33

**(d)** 1.40

**9. The Yong's double slit experiment is performed with blue and green light of wavelength 4360Åand 5460Å respectively . If x is the distance of $4^{th}$ maximum from the central one, then:**

**(a)** x (blue) = x (green)

**(b)** x (blue > x (green)

**(c)** x(blue <x (green)

**(d)** $\frac{x(blue)}{x(green)} = \frac{5460}{4360}$

**10. 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)** **t**here 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.

**11. In Young's double slit experiment, if a thin glass plate is placed in the**

**path of one of the interfering beams, then**

**(a)** fringe width decreases

**(b)** fringe width increases

**(c)** fringe pattern is shifted

**(d)** fringe pattern is unaffected

**12. The contrast in the fringes in on interference pattern depends on**

**(a)** Fringe width

**(b)** Wavelength

**(c)** Intensity ratio of the sources

**(d)** Distance between the slits

**13. The maximum number of possible interference maxima, for a slit separation equal to twice the wavelength, in young's double –slit experiment is**

**(a)** Infinite

**(b)** Five

**(c)** Three

**(d)** Zero

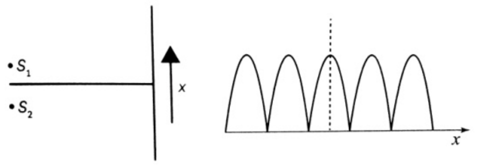
**14. Two source $S_1$ and $S_2$ of intensity $I_1$ and $I_2$ are placed in front of a screen. The pattern of intensity distribution screen in the central portion is given by figure. In this case which of the following statements are true.**

**(a)** $S_1$ and $S_2$ have the same intensities.

**(b)** $S_1$ and $S_2$ have a constants phase difference.

**(c)** $S_1$ and $S_2$ have the same phase.

**(d)** $S_1$ and $S_2$ have the same wavelength.




**(a)** **(b)**

**15. Interference occurs in which of the following waves?**

**(a)** Longitudinal

**(b)** Transverse

**(c)** Electromagnetic

**(d)** All of these

**16. Two demonstrate the phenomenon of interference, we require two source, which emit radiation of**

**(a)** Only the same frequency

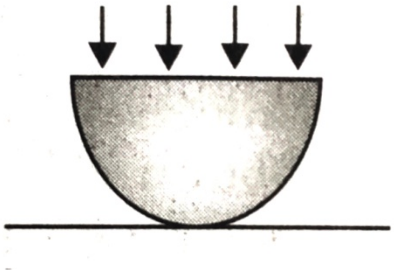
**(b)** Different wavelength

**(c)** Only constant phase difference

**(d)** The same frequency and having definite phase relationship

**17. A this slice is cut out a glass cylinder along a plane parallel to its axis. The**

**slice is placed on a flat plate as shown. The observed interference fringes from this combination shall be:**



**(a)** Straight
**(b)** Circular
**(c)** Equally spaced
**(d)** Having fringe spacing which increases as we go outwards.

**18. Case based (A) to (E)**

There are two types of waves, Longitudinal and Transverse. Both undergo reflection, refraction, interference and diffraction. Only transverse waves can be polarized. Longitudinal waves cannot be polarized as these waves are symmetrical about the direction of propagation. If we pass a long spring through two slits and generate a longitudinal wave in it by alternately compressing and releasing its free end, it is seen that the compressions and rarefactions pass through the two sits. Whatever is their relative orientation. This is because the oscillation occur along the length of the spring. i.e. along the direction of the wave propagation. Hence it cannot be polarized. A light which has vibration in all direction in a plane perpendicular to the direction of propagation is said to be unpolarised light.

**(A) Light propagates in rectilinear path because**

**(a)** Its speed is very large
**(b)** Its wavelength is very small
**(c)** It is not absorbed by the atmosphere
**(d)** Reflected from the upper surface of atmosphere

**(B) If two polaroids are being used to study and the analyser is rotated by 90°. How would the intensity change?**

**(a)** $2I_0$ **(b)** $I_0$
**(c)** 0 **(d)** $\frac{I_0}{2}$

**(C) In the propagation of light waves, the angle between the direction of vibration and plane of polarisation is**

**(a)** 0° **(b)** 45°
**(c)** 90° **(d)** 120°

**(D) The phenomenon of polarisation indicates the light is of**

**(a)** Particle nature

**(b)** Transverse nature

**(c)** Longitudinal nature

**(d)** None of the above

**(E) Which of the following cannot be polarised?**

**(a)** Ultraviolet

**(b)** Xrays

**(c)** Radiowaves

**(d)** Ultrasonic waves

**19. Sound wave do not exhibit the phenomena of**

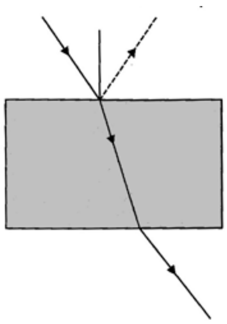
**(a)** interference

**(b)** diffraction

**(c)** polarization

**(d)** reflection

**20. Consider a light beam incident from air to a glass slab at Brewster's angle as shown in Fig. A polaroid is placed in the path of the emergent ray at point P and rotated about an axis passing through the centre and perpendicular to the plane of the polaroid.**



**(a)** For a particular orientation there shall be darkness as observed through the Polaroid.

**(b)** The intensity of light as seen through he polaroid shall be independent of the rotation.

**(c)** The intensity of light as seen through the Polaroid shall go through a minimum but not zero for two orientations of the polaroid.

**(d)** The intensity of light as seen through the polaroid shall go through a minimum for four orientations of the polaroid.

**21 While both light and sound show wave character, diffraction is much harder to observe in light. This is because:**

**(a)** light does not require a medium

**(b)** wavelength of light is far smaller

**(c)** waves of light are transverse

**(d)** speed of light is far greater

**22. Bending of light about the corner of the sharp edged obstacle is called**

**(a)** deviation **(b)** dispersion

**(c)** polarization **(d)** diffraction

**23. Consider sunlight incident on a slit of width $10^4\,A$. The image seen through the slit shall**

**(a)** be a fine sharp slit white in colour at the center.

**(b)** a bright slit white at the center diffusing to zero intensities at the edges.

**(c)** a bright slit white at the center diffusing to regions of different colours.

**(d)** only be a diffused slit white in colour.

**24. Consider sunlight incident on a pinhole of width $10^3 A$. The image of the pinhole seen on a screen shall be**

**(a)** a sharp white ring.

**(b)** different from a geometrical image.

**(c)** a diffused central spot, white in colour.

**(d)** diffused coloured region around a sharp central white spot.

**25. The first minimum due to single slit diffraction is at o $\theta = 30°$ for light of wavelength $5000\,A^{\circ}$. The width of the slit is**

**(a)** $5 \times 10^{-5}$ cm

**(b)** $10 \times 10^{-5}$cm

**(c)** $2.5 \times 10^{-5}$ cm

**(d)** $1.25 \times 10^{-5}$ cm

**26. The phenomena of polarization is exhibited by**

**(a)** Longitudinal wave

**(b)** Transverse wave

**(c)** Matter wave

**(d)** Mechanical wave

***

# ANSWER KEY

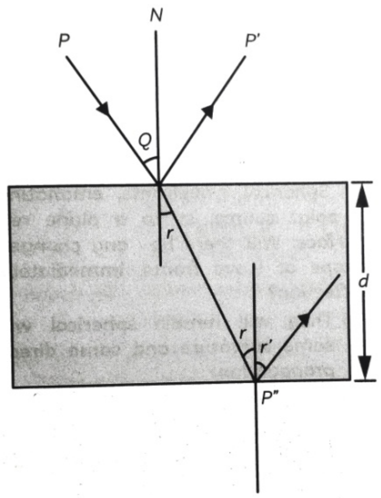
## MCQ

1. **(d) wave nature**

   **Explanation :** The rectilinear propagation of a wave explains the tendency of the wave to propagate in a straight line as it travels through a homogeneous medium. It is due to the wave nature of light.

2. **(a)** $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}sin^2\theta\right)^{\frac{1}{2}}+\pi$

   **Explanation :** Let the ray P is incident at an angle $\theta$. Due to reflection form glass, there is a phase change of $\pi$. Time taken is travel along $QP''$.




3. **(d) there would be a regular two slit pattern on the second screen.**

   **Explanation:** Here, there is a hole at point which is a maxima point. From Huggen's principle, wave will propagate from the sources $S_1$ and $S_2$. Each point on the screen will act as secondary sources of wavelets.

4. **(b) its high frequency**

   **Explanation:** Frequency of light depends on the source of a light travelling in a medium . So the rectilinear propagation of light in a medium is due to its high frequency.

5. **(b) is a geometrical method to trace a wavefront.**

   **Explanation:** Huggen's construction is a geometrical method of locating the new position and shape of a wavefront at any instant from its known position and shape at any other instant.

6. **(d) some frequency, phase and amplitude**

   **Explanation:** Two sources of light which continuously emit light waves of same frequency (or wavelength) with a zero or constant phase difference between them, are called coherent sources.

7. **(c) 5mm**

**Explanation:** Here $A_1 = 3mm$, $A_2$=4mm and $\phi = \frac{\pi}{2}$

Resultant amplitude

$$= \sqrt{A_1^2 + A_1^2 + 2A_1A_2\cos\phi}$$

$$= \sqrt{(3)^2 + (4)^2 + 2 \times 3 \times 4 \times \cos\frac{\pi}{2}}$$

$$= 5mm$$

8. **(b) 3**

**Explanation:** Here, frequency $v = 2 \times 10^{14}$ Hz, wavelength $\lambda = 500nm = 500 \times 10^{-9}$m.

Refractive index $n = \frac{c}{v} = \frac{c}{v\lambda}$ $(v = v\lambda)$

$$= \frac{3 \times 10^8}{2 \times 10^{14} \times 500 \times 10\hat{} - 9} = 3$$

9. **(c) x (blue)< x (green)**

**Explanation :** distance $x \propto \lambda$

As $\lambda_b < \lambda_g$

$\therefore \quad x(blue) < x\ (green)$

$$x = n\lambda\frac{D}{d}$$

10. **(c) there shall be no interference fringes.**

**Explanation :** Here, in Young's double – slit experiment, one of the holes is covered by a red filter and another by a blue filter. In this case, due to filtration only red and blue lights are presents. In young's double-slit experiment monochromatic light is used for the formation of fringes on the screen. Hence in this case there shall be no interference fringes.

11. **(c) fringe pattern is shifted**

**Explanation:** In Young's double slit experiment if a thin glass plate is placed in the path of one of the interfering beams then there is change of place of fringes on the screen. All the fringes including central fringe are shifted.

12. **(c) intensity ratio of the sources.**

**Explanation:** The fringe contrast is the measure of the interference quality. The fringe contrast is scaled between 0 to 1, where 0 is no fringe contrast, and 1 is perfect fringe contrast. Thus, the contrast in the maxima and minima intensity on the fringe depends on the intensity ratio of the sources.

13. **(b) Five**

**Explanation:** For possible interference maxima

$dsin\,\theta = n\lambda$......(i)

$\Rightarrow \quad 2\lambda\sin\theta = n\lambda$

$\Rightarrow\ 2\sin\theta = n$

$\sin\theta = \frac{n}{2}$

The maximum value of $\sin\theta$ is 1, so n=2 equation (i) is satisfied by 5 integers i.e. -2,-1, 0,1,2

**14. (a) $S_1$ and $S_2$ have the same intensities.**

**(b) $S_1$ and $S_2$ have a constant phase difference.**

**(d) $S_1$ and $S_2$ have the same wavelength.**

**Explanation:** The intensities of all successive minima are zero. So, the sources $S_1$ and $S_2$ are having same frequencies.

The graph of maxima and minima is symmetric. So $S_1$ and $S_2$ have a constant phase difference.

In YDSE, a monochromatic light is used. So, $S_1$ and $S_2$ have the same wavelength .

**15. (d) all of the these**

**Explanation:** interference is a characteristic of all wave motion, any sort of wave can show interference pattern.

**16. (d) the same frequency and having definite phase relationship**

Explanation: for interference of light we require the coherent sources i.e. the sources with same frequency and with a stable phase difference.

**17. (a) Straight**

**Explanation:** when a cylinder is placed on a glass plate with its curved touching the plane surface, a thin film is formed between the curved surface of the cylinder and the glass plate. The glass plate will touch the slice of the cylinder in a straight line parallel to the axis of the cylinder. The thickness of the film increases as we move away from its straight line. The loci of all points having the some thickness are straight lines. Thus straight line fringes will appear in this combination. The fringe spacing will decrease as we go outwards.

**18. Case based (A-E)**

**(A) (b) Wavelength is very small**

**Explanation:** The wavelength of the visible light is very small compared to the size of ordinary objects, diffraction of light is not easily noticeable so it seems to propagate ,n rectilinear path.

**(B) (b) 0**

**Explanation:** When $\theta$ = 90°

$$I = I_0 \cos^2 90° = 0$$

**(C) (a) 0°**

**Explanation:** Plane of vibration is perpendicular to the direction of propagation and also perpendicular to the plane of polarisation ,.e., they are parallel.

**(D) (b) transverse nature^**

**Explanation:** When an unpolarised light passes through the polarizer in the vibration of transmitted rays are parallel to the axis of polarizer, rest vibrations are absorbed in polariser. So this phenomenon verifies the, transverse nature of light

**(E) (a) ultrasonic waves**

**Explanation:** Ultrasonic waves are sound waves Due to their longitudinal nature, they cannot be polarised.

**19. Ans. (c) polarization**

**Explanation:** Sound waves are longitudinal waves they do not exhibit polarization phenomenon, which is exhibited by the transverse wave.

**20. Ans. (c)** The intensity of light as seen through the Polaroid shall go through a minimum but not zero for two orientations of the Polaroid Explanation: If a light beam is incident on a glass slab at Brewster's angle, the transmitted beam is unpolarised and reflected beam is polarised. As the emergent ray is unpolarised, hence intensity cannot be zero when passes through Polaroid.

21. **Ans. (b) wavelength of light is far smaller**

**Explanation:** In our macroscopic world, objects have size comparable to the wavelength of sound, therefore diffraction with light is difficult to observe.

**22. Ans. (d) diffraction**

**Explanation:** The phenomenon of bending of light around the corners of small obstacles or apertures and its consequent spreading into the regions of geometrical shadow is called diffraction of light.

**23. Ans. (a) be a fine sharp slit white in colour at the center.**

**Explanation:** Here, width of the slit $b = 10^4$ A$^\circ$ $= 10^4 \times 10^{-10}\ m = 10^{-6}\ m$.

Wavelength of' (visible) sunlight varies from $4000\ A^\circ$ to $8000\ A^\circ$. Hence, the width of slit is comparable to that of wavelength, hence diffraction occurs with maxima at centre. So, at the centre all colours appear, i.e., mixing of colours form white patch at the centre.

**24.Ans. (b) different from a geometrical image.**

**(d) diffused coloured region around a sharp central white spot.**

**Explanation:** Here, width of pinhole = $10^3$ Å $= 1000$ Å

The wavelength sunlight ranges from 4000 Å to 8000 Å.

Here, wavelength < width of the slit.

Hence, light is diffracted from the hole. Due to diffraction from the slit the image formed on the screen will be different from the geometrical image.

**25. Ans. (b) $10 \times 10^{-5}\ cm$**

**Explanation:**

**Here,** $\lambda = 5000\ A^\circ = 5000 \times 10^{-8}\ cm,\ \theta = 30^\circ$

Width $a = \frac{\lambda}{\sin\theta}$

$$= \frac{5000 \times 10^{-8}}{0.5} cm$$

$$= 10 \times 10^{-5} \text{cm}$$

**26. Ans. (b) transverse wave**

**Explanation:** The phenomenon of restricting the oscillations of a wave to just one direction in the transverse plane is called polarization of waves.

***

## ASSERTION-REASON QUESTIONS

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

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

**1. Assertion(A): No diffraction is produced in sound waves near a very small opening.**

**Reason (R): For diffraction to take place the aperture of opening should be of the same order as wavelength of the waves.**

**2. Assertion(A): An excessively thin film appear black in reflected light.**

**Reason (R): A soap bubble shows beautiful colours when illuminated by white light.**

**3. Assertion (A): We are able to hear a person standing behind a wall, but not see him.**

**Reason (R): Sound waves get easily diffracted round the edge of the wall while light waves do not.**

## ASSERTION-REASON ANSWER

1. **Ans. (a) Both A and R are true and R is the correct explanation of A.**

2. **Ans. (b) Both A and R. are true but R is NOT the correct explanation of A.**
**Explanation:** For an excessively thin film ($t \ll \lambda$), the factor $2\mu t$ cos $r$ is slightly small. The effective path difference between any two successive rays in reflected system is $\frac{\lambda}{2}$. This is the condition for minimum intensity and hence the film will appear dark.

3. **Ans. (b) Both A and R are true but R is NOT the correct explanation of A.**

***

## VERY SHORT ANSWER TYPE QUESTION

1. **Why is the diffraction of sound waves more evident in daily experience than that of light wave?**
2. **How does the angular separation between fringes in single-slit diffraction experiment change when the distance of separation between the slit and screen is doubled?**
3. **Distinguish between unpolarized and linearly polarized light.**
4. **A polaroid (I) is placed in front of a monochromatic source. Another Polaroid (II) is placed in front of this polaroid (I) and rotated till no light passes. A third Polaroid (III) is now placed in between (I) and (II). In this case, will light emerge from (II). Explain.**
5. **How does resolving power of a telescope change on decreasing the aperture of its objective lens? Justify your answer.**

## VERY SHORT ANSWER

1. **Ans.** The wavelength of sound waves ranges between 15 m to 15 mm. The wavelength of light waves is $7000 \times 10^{-10}\,m$ to $4000 \times 10^{-10}\,m$. For diffraction of light we need very narrow slit width. In daily life experience we observe the slit width very near to the wavelength of sound waves as compared to light waves. Thus, the diffraction of sound waves is more evident in daily life than that of light waves.

2. **Ans.** We know angular separation is given as

$$\theta = \frac{\lambda D}{dD} = \frac{\lambda}{d}$$

Since $\theta$ is independent of D i.e., the distance of separation between the screen and the slit, so when D is doubled, angular separation would remain same.

3. **Ans. Unpolarized light:** The light having vibration of electric field vector in all possible directions perpendicular

to the direction of wave propagation the light is known as unpolarized light.

**Linearly polarized light:** The light having vibrations of electric field; vector in only one direction perpendicular to the direction if propagation of light is as plane or linearly polarized light.

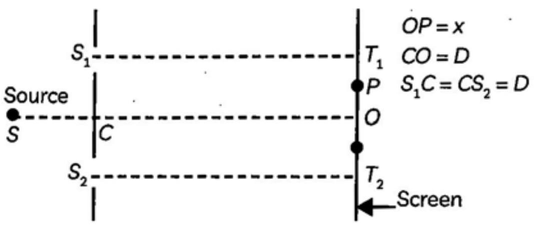
4. **Ans.** When the third polaroid (III) is placed in between (I) and (II). Only in the special case when the principal axis of (III) is parallel to (I) or (II) there' shall be no light emerging. In all other cases there shall be light emerging because the principal axis of (II) is no longer perpendicular to the principal axis of (III).

5. **Ans.** When the aperture of the objective lens is decreased, the resolving power of telescope also decreases. Resolving Power ∝ aperture distance

***

## SHORT ANSWER TYPES

**1. Consider a two slit interference arrangements (Fig.) such that the distance of the screen from the slits is half the distance between the slits. Obtain the value of D in terms of $\lambda$, such that the first minima on the screen falls at a distance D from the centre O.**




2. **Use Huygens's principle to explain the formation of diffraction pattern due to a single slit illuminated by a monochromatic source of light. When the width of the slit is made double the original width, how would this affect the size and intensity of the central diffraction band?**

**3. (A) If one of two identical slits producing interference in Young's experiment is covered with glass, so that the light**

intensity passing through it is reduced to 50%, find the ratio of the maximum and minimum intensity of the fringe in the interference pattern.

(B) What kind of fringes do you expect to observe if white light is used instead of monochromatic light?

4. (A)What happens to the interference pattern if the phase difference between the two sources varies continuously?

(B) A double slit is illuminated by light of wavelength 600 nm. The slits are 0.1 cm apart and the screen is placed 1 m away. Calculate (i) the angular position of 10th maximum in radian and (ii) separation of the adjacent minima.

5. For a single slit of width a, the first minimum of the interference pattern of a monochromatic light of wavelength $\lambda$, occurs at an angle of $\lambda/a$. At the same angle of $\lambda/a$ we get a maximum for two narrow slits separated by a distance a. Explain

6. Find an expression for intensity of transmitted light when a Polaroid sheet is rotated between two crossed Polaroids. In which position of the Polaroid sheet will the transmitted intensity be maximum?

7. Draw the intensity pattern for single slit diffraction and double slit interference. Hence, state two differences between interference and diffraction patterns.

8. When are two objects just resolved? Explain. How can the resolving power of a compound microscope be increased ? Use relevent formula to support your answer.

***

## SHORT ANSWER

**1. Ans.**

The minima will occur when $x = S_2P - S_1P$

$$= \left(\frac{2n-1}{2}\right)$$

For first minima $n = 1$, then the above equation becomes

$S_2P - S_1P = \frac{\lambda}{2}$ ……(i)

$T_2P = D + x, T_1P = D - x$

$S_1P = \sqrt{(S_1T_1)^2 + (PT_1)^2} = \sqrt{D^2 + (D-x)^2}$…………….(ii)

$S_2P = \sqrt{(S_2T_2)^2 + (PT_2)^2} = \sqrt{D^2 + (D+x)^2}$ ……………….(iii)

Substituting the values of $S_1P$ and $S_2P$ from equation (ii) and (iii) in equation (i), we get,

$\sqrt{D^2 + (D-x)^2} - \sqrt{D^2 + (D+x)^2} = \frac{\lambda}{2}$

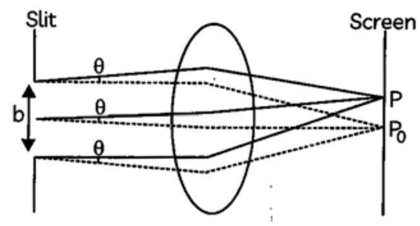
If $x = D$

$$(5D^2)^{1/2} = \frac{\lambda}{2} \Rightarrow D = \frac{\lambda}{2\sqrt{5}}$$

**2. Ans.**

Consider a parallel beam of monochromatic light is incident normally on a slit of width $b$ as shown in figure. According to Huygens's principle, every point of slit acts as a source of secondary wavelets spreading in all directions. Screen is placed at a larger distance.

Consider a particular point P on the screen that receives waves from all the secondary sources. All these waves start from different point of the slit and interfere at point P to give resultant intensity.




Point $P_0$ is a bisector plane of the slit. At $P_0$, all waves are travelling equal optical path. So all wavelets are in phase thus interfere constructively with each other and maximum intensity is observed. As we move from $P_0$, the wave arrives with different phases and intensity is changed. Intensity at point $P$ is given by

$$I = I_0 \sin^2 \alpha$$

Where $\alpha = \frac{\pi}{\lambda} b \sin\theta$

For central maxima, $\alpha = 0$ thus,

$$I = I_0$$

When the width of slit is made double the original width intensity will get four times of its original value.

Width of central maximum is given by,

$$\beta = \frac{2D\lambda}{b}$$

Where, D = Distance between screen and slit,

$\lambda$ = Wavelength of the light,

$b$ = size of slit

So with the increase in size of slit the width of central maxima decrease. Hence, double the size of the slit would result in half the width of the central maxima.

**3. Ans.**

**(A)** The resultant intensity in Young's experiment is given by

$$IR = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\phi$$

When slit is not covered, then $I_0$ is the intensity from each slit.

Maximum intensity ($I_{max}$) occurs when $(\Phi) = 0°$

Minimum intensity ($I_{min}$) occurs when $(\Phi) = 180°$

If one slit is covered with glass to reduce its intensity by 50%, then

$$I_{max} = I_0 + \frac{I_0}{2} + 2\sqrt{I_0 \times \frac{I_0}{2}} \cos 0°$$

$$= 1.5\, I_0 + 2 \times 0.707\, I_0$$

$$= 2.914\, I_0$$

$$I_{min} = I_0 + \frac{I_0}{2} + 2\sqrt{I_0 \times \frac{I_0}{2}} \cos 180°$$

$$= 1.5\, I_0 - 2 \times 0.707\, I_0$$

$$= 0.086\, I_0$$

Ratio

$$= \frac{I_{max}}{I_{min}} = \frac{2.914\, I_0}{0.086\, I_0}$$

$$= 33.884 = 34$$

**(B)** If instead of monochromatic light, white light is used, then the central fringe will be white and the fringes on either side will be coloured. Blue colour will be nearer to the central fringe and red will be farther away. The path difference at the centre on perpendicular bisector of slits will be zero for all colours and each colour produces a bright fringe thus resulting in white fringe. Further, the shortest visible wave, blue, produces a bright fringe first.

**4. Ans.**

**(A)** If the phase difference between the two sources varies continuously, the positions of . bright and dark fringes will change rapidly that cannot be detected by our eyes. So, a uniform illumination is seen on the screen i.e. interference pattern disappears.

**(B)(i)**The angular position-of $n^{th}$ maxima is given by,

$$Q_n = \frac{X_n}{(D)} = \frac{n\lambda D}{d} \times \frac{1}{D} = \frac{n\lambda}{d}$$

$$Q_{10} = \frac{10 \times 600 \times 10^{-9}}{0.1 \times 10^{-2}}$$
$$= 0.006\, rad$$

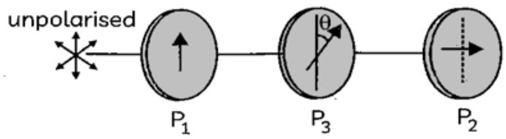
**(ii)** Fringe width $\beta = \frac{D\lambda}{d}$

$$= \frac{1 \times 600 \times 10^{-9}}{0.1 \times 10^{-2}} = 0.6mm$$

**5. Ans.**

When a single slit is used, the interference pattern is due to the diffraction phenomenon. In case of diffraction from a single slit of width a using monochromatic light of wavelength $\lambda$, the first minimum of the interference pattern occurs at an angle $\lambda$, which is given by Hence, it proves the result.

**6. Ans.**




Let us consider two crossed polarisers $P_1$ and $P_2$ with a polaroid sheet $P_3$ placed between them. Let $I_0$ be the intensity of polarised light after passing through the first polarizer $P_1$. If $\theta$ is the angle between the axes of $P_1$ and $P_3$, then the intensity of the polarized light after passing through $P_3$ will be $I = I_0 \cos^2 \theta$.

As $P_1$ and $P_2$ are crossed, the angle between the axes of $P_1$ and $P_2$ = 90°.

Angle between the axes of $P_1$ and $P_2$ $= (90° - \theta)$.

The intensity of light emerging from $P_2$ will be given by

$$I' = I\cos^2(90-\theta)$$

$$I' = [I_0\cos^2\theta]\cos^2(90° - \theta)$$

$\Rightarrow \quad I' = [I_0\cos^2\theta]\sin^2\theta$

$\Rightarrow \quad I' = \frac{I_0}{4}\ (4\cos^2\theta\, sin\, 2\,\theta)$

$\Rightarrow \quad I' = \frac{I_0}{4}\ (2\sin\theta\cos\theta)^2$

$\Rightarrow \quad I' = \frac{I_0}{4}\ (\sin 2\theta)$

The intensity of polarized light trasmitted from $P_2$ will be maximum when

$$sin\,2\,\theta = maximum = 1$$

$\Rightarrow \quad sin\,2\,\theta = \sin 90°$

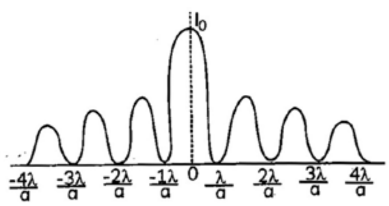
$\Rightarrow \quad 2\,\theta = 90°$

$\Rightarrow \quad \theta = 45°$

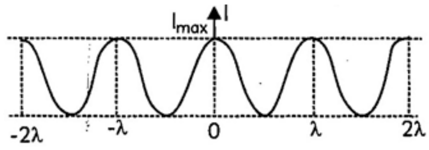
The maximum transmitted intensity of polarised light is

$$I' = \frac{I_0}{4}$$

**7. Ans.** Intensity pattern for single slit diffraction:



Intensity pattern for double slit interference.

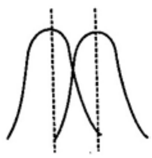


Difference between interference and diffraction patterns:

**(A)** Interference fringes are of the same width while diffraction fringes are not of the same width.

**(B)** In interference pattern all bright bands are of same intensity while in diffraction pattern all bright bands are not of same intensity.

**8. Ans.** When the maxima of diffraction pattern from one object coincide with the minima of second object then they are just resolved.



The resolving power of a compound microscope can be increased by increasing $\mu$ and by decreasing $\lambda$.

***

# COMPETENCY BASED QUESTIONS

**1. Laboratory $X-ray$ sources can be classified into two types. Sealed-tube and rotating anode. Both may be used to generate monochromatic $X-ray$ radiation and they basically differ only in the intensity of the radiation produced.**

**The $X-ray$ cannot be diffracted by means of an ordinary grating because of**

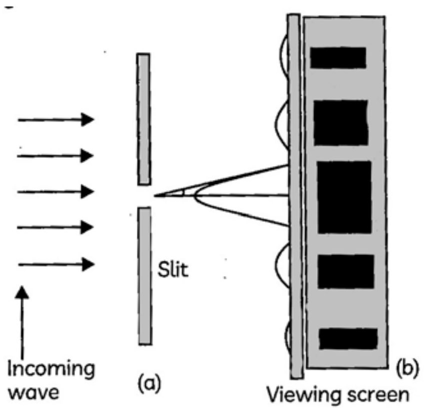
(a) high speed

(b) large wavelength

(c) short wavelength

(d) speed and wavelength both

**2. Before Young, early experimenters-including Newton - had noticed that light spreads out from narrow holes and slits. It seems to turn around corners and enter regions where we would expect a shadow. These effects, known as diffraction, can only be properly understood using wave ideas.**




**When the double slit in Young's experiment is replaced by a single narrow slit (illuminated by a monochromatic source), a broad pattern with a central bright region is seen. On both sides, there are alternate dark, and bright regions, the intensity becoming weaker away from the centre (Fig.).**

**(A) In the diffraction pattern due to single slit of width a with incident light of wavelength $\lambda$ with angle of diffraction $\theta$, the condition for the first minimum is**

**(a)** $\lambda\, sin\theta = a$

**(b)** $a\, cos\, \theta = \lambda$

**(c)** $a\, sin\, \theta = \lambda$

**(d)** $\lambda \cos\theta = a$

**(B) 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:**

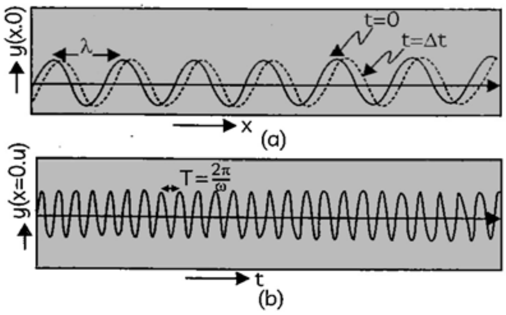
**(a)** that the central maxima is narrower

**(b)** more number of fringes

**(c)** less number of fringes

**(d)** no diffraction pattern

**3.** Consider holding a long string that is held horizontally, the other end of which is assumed to be fixed. If we move the end of the string up and down in a periodic manner, we will generate a wave propagating in the + x direction (Fiq).




Such a wave could be described by the following equation

$$y\ (x, t)\ =\ a\ sin\ (kx - \omega t)$$

where a and $\omega$ $(=\ 2\pi v)$ represent the amplitude and the angular frequency of the wave, respectively; further,

$$\lambda = \frac{2\pi}{k}$$

represents the wavelength associated with the wave.

Since the displacement is in the y direction, it is often referred to as a y-polarized wave. Since each point on the string moves on a straight line, the wave is also referred to as a linearly polarised wave. Further, the string always remains confined to the x-y plane and therefore it is also referred to as a plane polarised wave.

**(A)** If the angle between the pass axis of polariser and the analyser is 450, write the ratio of the intensities of original light and the transmitted light after passing through the analyser.

**(B)** If the polarising angle for air glass interface is 56.3°, what is the angle of refraction in glass?

***

# ANSWER KEY

## COMPETENCY BASED

**1. Ans.**

**(c) short wavelength**

**Explanation:** $X-rays$ have very short wavelengths that are shorter than the spacing between two lines in the grating. Therefore $X-ray$ cannot be diffracted by means of an ordinary grating.

**2. Ans.**

**(A) (c) a sin $\boldsymbol{\theta} = \boldsymbol{X}$**

**Explanation:** Path difference between extreme waves

$$a\, sin\theta = r\lambda$$

For the first minimum $n = 1$

$$a\, sin\, \theta = \lambda$$

**(B) (d) no diffraction pattern**

**Explanation:** Slit width $a = 0.6\, mm = 0.6 \times 10^{-3} m$

Wavelength of $X-rays = \lambda = 1\, A^{\circ} = 10^{-10}\, m$

$$\frac{a}{\lambda} = 0.6 \times 10^{7} \gg 1$$

$a$ is very Large compared to the wavelength $\lambda$ . In this case, the diffraction pattern disappears.

**3. Ans. (B) $\boldsymbol{I(\theta) = I_0 \cos^2 \theta}$**

$$\theta = 45°$$

$$I(\theta) = I_0 \cos^2 45° = \frac{I_0}{4}$$

$$\frac{I_0}{I} = 4:1$$

.-. Ratio of intensity original light and transmitted light is 4 : 1.

(C) As $i_p + r_p = 9000$

$$r_p = 90^0 - i_p$$

$$= 90° - 56.3° = 33.7°$$

***

## LONG ANSWER TYPE

**1.(A) Why cannot the phenomenon of interference be observed by illuminating two pin holes with two sodium lamps?**

**(B) Two monochromatic waves having displacements $y_1 = a\cos\omega t \; and \; y_2 = a\cos(\omega t + \Phi)$ from two coherent sources interfere to produce on interference pattern. Derive the expression for the resultant intensity and obtain the conditions for constructive and destructive interference.**

**(c) Two wavelengths of sodium light of 590 nm and 596nm are used in turn to study the diffraction taking place at a single slit of aperture $2 \times 10^{-6} m$. If the distance between the slit and the screen 1.5m, calculate the separation between the positions of the second maxima of diffraction of the second maxima of diffraction pattern obtained in the two cases.**

**2. (A) Write the distinguishing features between a diffraction pattern due to a single slit and the interference fringes produced in Young's double slit experiment.**

**(B) If a monochromatic source of light is replaced by white light, what change would you observe in the diffraction pattern?**

**(C) In a single slit diffraction experiment, the width of the slit is reduced to half its original width. How would this affect the size and intensity of the central maximum?**

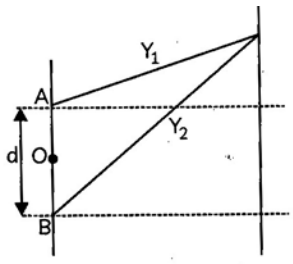
# ANSWER KEY

## LONG ANSWER

**1. Ans.**

(A) Phenomenon of interference can't be observed by illuminating two pinholes with two sodium lamps because these sources are not coherent source (it means they are not in same phase).

(B) Consider two monochromatic coherent source $A$ and $B$ with waves $y_1 = a\,cos\,\omega t$ and $y_2 = a\cos(\omega t + \Phi)$ respectively.




From principle of superposition,

$$y = y_1 + y_2$$

$$= a\sin\omega t + b\sin(\omega t + \phi)$$

$$= a\sin\omega t + b\sin\omega t\cos\phi + b\cos\omega t\sin\phi$$

$$= (a + b\cos\phi)\sin\omega t + b\sin\phi\cos\omega t$$

Let

$$a + b\cos\phi = A\cos\delta$$

$$b + \sin\phi = A\sin\delta$$

$$y = A\sin\omega t\cos\delta + A\cos\omega t\sin\delta$$

$$= A\sin(\omega t + \delta)$$

$$A = \sqrt{a^2 + a^2 + 2ab\cos\phi}$$

$$\tan\delta = \frac{b\sin\phi}{a + b\cos\phi}$$

**(1) Constructive interference**

For maxima

$$I \propto A^2$$

and for $A$ to be maximum.

$$\cos\phi = 1$$

$$\cos\phi = \cos 2n\pi\,, n = 0, 1,2, ....$$

$$\phi = 2n\pi$$

and path difference

$$\Delta x = n\lambda$$

$$A_{max} = a + b$$

$$I \to I_{max} = k(a + b)^2$$

**(2)** Destructive Interference

For I- minima

$$\cos\phi = -1$$

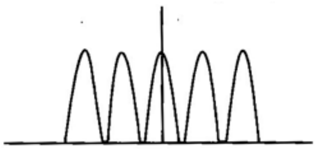
$$\Delta\phi = (2n - 1)$$

Path difference.

$$\Delta x = (2n + 1)\frac{\lambda}{2}$$

$$A_{min} = a - b$$

$$I \rightarrow I_{min} = k(a - b)^2$$



(c) $\theta = \left(n + \frac{1}{2}\right)\frac{\lambda}{2}$

$a = 2 \times 10^{-6}$ $(aperature\ of\ slit)$

$$\theta_1 = \frac{\lambda}{2a} = \frac{590 \times 10^{-9}}{4 \times 10^{-6}} = \frac{590}{4} \times 10^{-3}$$

$$= 147.5 \times 10^{-3}$$

$$\theta = \frac{\lambda'}{2a} = \frac{596 \times 10^{-9}}{4 \times 10^{-6}} = 149 \times 10^{-3}$$

$\theta_2 - \theta_1 = 1.5 \times 10^{-3}$ (angular difference)

$\lambda_1 = 596nm, \lambda_2 = 590\ nm$

$a = 2 \times 10^{-6}$

$D = 1.5m$

$$y = \frac{3\lambda D}{2a}$$

$$y_1 - y_2 = \frac{3D}{2a}(\lambda_1 - \lambda_2)$$

$$= \frac{3 \times 1.5}{2 \times 2 \times 10^6}(596 - 590) \times 10^{-9}m$$

$$= \frac{4.5}{4 \times 10^{-6}} \times 6 \times 10^{-9}m$$

$$= \frac{4.5 \times 6}{4} \times 10^{-3}m$$

$$= 6.78m$$

**2.(A) Difference between interference and diffraction of light**

| Interference | Diffraction |
|---|---|
| (1) Interference is the result of superposition of secondary waves starting from two coherent sources. | Diffraction is the result of superposition of secondary waves starting from different parts of the same wavefront. |
| (2) All bright fringes are of same intensity. | Intensity of bright fringes decreases as we move away from central bright fringe on other side. |
| (3) All fringes are of equal width. | The width of central bright fringe is twice the width of any secondary maxima. |
| (4) There is good contrast between dark and bright fringes. | Regions of dark fringes are not perfectly dark. So, there is poor contrast between .dark and bright fringes. |

(B) If monochromatic source of light is replaced by a source of white light, then ,we get the coloured fringes with uniform illumination.

(C) Fringe width

$$\beta = \frac{\lambda D}{d}$$

Here width of the slit is reduced to half, then

$$d' = \frac{d}{2}$$

Fringe width $\beta' = \frac{\lambda D}{d'}$

$$= \frac{\lambda D}{d/2} = \frac{2\lambda D}{d} = 2\beta$$

Fringe width is doubled and intensity $I = d^2$

So, new intensity $I' = \left(\frac{d}{2}\right)^2 = \frac{I}{4}$

***

## CHAPTER TEN

# DUAL NATURE OF RADIATION AND MATTER

## Multiple Choice Questions

1. **J.J Thomson's cathode-ray tube experiment demonstrated that**
   **(a)** cathode rays are streams of negatively charged ions
   **(b)** all the mass of an atom is essentially in the nucleus
   **(c)** the $\frac{e}{m}$ of electrons is much greater than the $\frac{e}{m}$ of protons
   **(d)** The $\frac{e}{m}$ ratio of the cathode-ray particles changes when a different gas is placed in the discharged tube

2. **Photons absorbed in matter are converted to heat. A source emitting n photon/ sec of frequency v is used to convert . 1kg of ice at 0ºC to water at 0ºC. Then, the time T taken for the conversion**
   **(a)** Decreases with increasing $n$, with $v$ fixed.
   **(b)** Decreases with $n$ fixed, $v$ increasing
   **(c)** Remains constant with $n$ and $v$ changing such that $nv =$ constant.
   **(d)** Increases when the product $nv$ increases.

3. **Which of the following waves can produce photoelectric effect?**
   **(a)** Ultrasound
   **(b)** Infrared
   **(c)** Radio waves
   **(d)** X-ray

4. **Photoelectric effect is an example of:**
   **(a)** Elastic collision
   **(b)** Inelastic collision
   **(c)** Two dimensional collision
   **(d)** Oblique collision

5. **Which phenomenon illustrates the particle nature of light of waves?**
   **(a)** Interference
   **(b)** Diffraction
   **(c)** Polarisation
   **(d)** Photoelectric effect.

6. **The work function of metalic surface is 5 eV. The threshold frequency is approximately.**
   **(a)** $1.6 \times 10^{7}\ Hz$
   **(b)** $8.68 \times 10^{15}\ Hz$
   **(c)** $9.68 \times 10^{17}\ Hz$
   **(d)** $1.2 \times 10^{15}\ Hz$

**7. Which of the following properties of light cannot be explained using wave theory?**

**(a)** Light waves can be polarized

**(b)** Light obeys laws of reflection and refraction

**(c)** Light waves show interference

**(d)** Light shows photoelectric effect.

**8. If $K_1$ and $K_2$ are maximum kinetic energies of photoelectrons emitted when lights of wavelength $\lambda_1$ and $\lambda_2$ respectively incident on a metallic surface and $\lambda_1 = 3\lambda_2$, then**

**(a)** $K_1 > \left(\frac{K_2}{3}\right)$

**(b)** $K_1 < \left(\frac{K_2}{3}\right)$

**(c)** $K_1 = 2K_2$

**(d)** $K_2 = 2K_1$

**9. Alkali metal are preferred more than the other metals for photoelectric emission, because work function of alkali metal is**

**(a)** Just equal to metals

**(b)** Less than zero

**(c)** Greater than metals

**(d)** Less than other metals

**10. At the threshold frequency, the velocity of the electrons is**

**(a)** Zero

**(b)** Maximum

**(c)** Minimum

**(d)** Infinite

***

## ANSWER KEY

### MCQ

1. **(c) the $\frac{e}{m}$ of electrons is much greater than the $\frac{e}{m}$ of protons.**

   **Explanation:** J.J. Thomson was the first to determine experimentally the speed and the specific charge [charge to mass ratio $\left(\frac{e}{m}\right)$of the cathode ray particles.]

2. **(a) decreases with increasing $n$, with $v$ fixed.**

   **(b)decreases with n fixed, v increasing**

   **(c) remains constant with n and v changing such that nv=constant.**

   **Explanation:** Energy used to convert ice into water = mass× latent heat

   Energy of photon used $= nT \times E$

   $= nT \times h\mu$

   $\Rightarrow mL = nT\ h\mu$

   $\Rightarrow T = \frac{mL}{nh\mu}$

   $\therefore T \propto \frac{1}{\mu}$, when n remains constant

   So, time taken for conversion decreases with increasing v, with n kept constant.

   $\therefore T \propto \frac{1}{n}$, when n remains constant

   So, time taken for conversion decreases with increasing n, with v kept constant

   $\Rightarrow T \propto \frac{1}{nv}$

   So, time taken for conversion decreases with increase in product of nv. With nv kept constant.

3. **(d) X-rays**

   **Explanation:** Electromagnetic radiation, being of high frequency such as X-rays can produce photoelectric effect.

4. **(b) inelastic collision**

   **Explanation:** Above the threshold frequency the maximum kinetic energy of the electrons increases linearly with the frequency v of the incident radiation. The increase in intensity increases only the number of incident photons and not their energy.

5. **(d) Photoelectric effect**

   **Explanation:** interference, Diffraction and Polarisation will explain wave nature of light and photoelectric effect explains quantum theory of light and according to quantum theory light behaves like wave as well as particle.

6. **(d) $\mathbf{1.2 \times 10^{15} Hz}$**

**Explanation:** $W = h\nu_0$

$\Rightarrow \quad \nu_0 = \frac{W}{h}$

$$= \frac{5 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}}$$

$= 1.2 \times 10^{15} Hz$

7. **(d) Light shows photoelectric effect**

**Explanation :** in phenomena like interference diffraction and polarization, light behaves as a wave while in photoelectric effect, it behaves as a particle. According to Max Planck, light travels in the form of small packets of energy called photons.

8. **(b) $\boldsymbol{K_1 < \left(\frac{K_2}{3}\right)}$**

**Explanation:** $K_1 = \frac{hc}{\lambda_1} - \phi_0$...(i)

$$K_2 = \frac{hc}{\lambda_2} - \phi_0$$

$$\frac{hc}{\lambda_1} = (K_2 + \phi_0) \ldots\ldots\text{(ii)}$$

$$K_1 - K_2 = hc \left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right]$$

$$= hc \left[\frac{1}{3\lambda_2} - \frac{1}{\lambda_2}\right]$$

$$= \frac{2hc}{3\lambda_2}$$

From equation (ii)

$$K_1 - K_2 = -\frac{2}{3}(K_2 + \phi_0)$$

$\Rightarrow \quad K_1 = \frac{K_2}{3} - \frac{2}{3}\phi_0$

So, $\quad K_1 < \left(\frac{K_2}{3}\right)$

9. **(d) less than other matels**

**Explanation:** Different substance emit photoelectrons only when exposed to radiations of different frequencies. Alkali metals are highly photosensitive. They emit electrons even with visible light. Other metals like Zn.Cd. Mg etc. respond only to ultraviolet light.

10. **(a) Zero**

**Explanation:** Here $\nu = \nu_{th}$

So the kinetic energy of the electron becomes

$$K.E. = h\nu - h\nu_{th}$$

$$= h\nu - h\nu = 0$$

If the kinetic energy of the electrons is zero. The velocity of the electron is also zero.

***

## SHORT WITH ANSWER

**1. Consider a 20 W bulb emitting light of wavelength 5000Å and shining on a metal surface kept at a distance 2 m. Assume that the metal surface has work function of 2 eV and that each atom on the metal surface can be treated as a circular disk of radius 1.5Å.**

**(A)** Estimate no. of photons emitted by the bulb per second. [Assume no other losses]

**(B)** Will there be photoelectric emission?

**(C)** How much time would be required by the atomic disc to receive energy equal to work function (2 eV)?

**(D)** How many photons would atomic disk receive within time duration calculated in (C) above?

**(E)** Can you explain how photoelectric effect was observed instantaneously?

[Hint Time calculated in part (C) is from classical consideration and you may further take the target of surface area say 1cm2 and estimate what would happen?]

**Ans.**

Here, $P = 20W, \lambda = 5000\text{Å} = 5000 \times 10^{-10} m$

$$d = 2m, \phi_0 = 2eV, r = 1.5A$$
$$= 1.5 \times 10^{-10} m$$

**(A)** Number of photon emitted by bulb per second

$$n' = \frac{dN}{dt} = \frac{p}{\frac{hc}{\lambda}} = \frac{p\lambda}{hc}$$

$$= \frac{20 \times (5000 \times 10^{-10})}{(6.62 \times 10^{-34}) \times (3 \times 10^{8})}$$

$= 5 \times 10^{19}$ per second

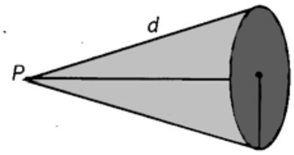
**(B)** Energy of the incident photon

$$= \frac{hc}{\lambda} = \frac{(6.61 \times 10^{-13})(3 \times 10^{8})}{5000 \times 10^{10} \times 1.6 \times 10^{-19}}$$
$$= 2.48\ eV$$

This is greater than 20 V (work function) So, the photoelectric emission take place

**(C)** Let $\Delta t$ be the time spent is getting the energy.

If $P$ is the power of source received by atomic disc




$$\frac{P}{4\pi d^2} \times \pi r^2 \Delta t = \phi_0$$

$$\Delta t = \frac{4\phi_0 d^2}{r^2 P}$$

$$= \frac{4 \times (2 \times 1.6 \times 10^{-19}) \times 2^2}{20 \times (1.5 \times 10^{-10})^2} = 28.4\ s$$

**(D)** Number of photons received by atomic disc in time $\Delta t$ is$N = \frac{n' \times \pi r^2}{4\pi d^2} \times \Delta t$

$$= \frac{n' r^2 \Delta t}{4d^2}$$

$$= \frac{(5 \times 10^{19}) \times (1.5 \times 10^{-10})^2 \times 28.4}{4 \times (2)^2} = 2$$

Hence, time of emission is 11.04 s. So, photoelectric emission is not instantaneous.

**(E)** In photoelectric emission collision between incident photon and free electron lasts for very less time. So, photoelectric emission is instantaneous.

**2. Two particles A and B of de-Broglie wavelengths $\lambda_1$ and $\lambda_2$ combine -to form a particle C. The process conserves momentum. Find the de Broglie wavelength of the particle C. (The motion is one dimensional).**

**Ans.**

According to law of conservation of momentum

$|P_c| = |P_A| + |P_B| = \frac{h}{\lambda_A} + \frac{h}{\lambda_B} = \frac{h}{\lambda_C}$ if

$P_A . P_B > 0$ or $P_A, P_B < 0$

Or, $\lambda_C = \lambda_A \lambda_B / (\lambda_A + \lambda_B)$

If $P_A > 0, P_B < 0$ or $P_A < 0, P_B > 0$

$$P_C = h \frac{\lambda_B - \lambda_A}{|\lambda_A \lambda_B|} = \frac{h}{\lambda_c}$$

$$= \lambda_c = \frac{\lambda_A \lambda_B}{|\lambda_A + \lambda_B|}$$

**3. Why is wave theory of electromagnetic radiation not able to explain photo electric effect? How does photon picture resolve this problem?**

**Ans.**

Wave theory cannot explain the following laws of photoelectric effect.

**(1)** The instantaneous emission of photo electrons.

**(2)** Existence of threshold frequency for metal surface.

**(3)** K.E. of emitted electrons is independent of intensity of light and depends on frequency.

The concept of photon explained that energy is not only emitted and absorbed in discrete energy quanta, but also it propagates through space in definite quanta with the speed of light. It can explain all the above photoelectric effect, which wave theory cannot explain.

**4. A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has**

**(A) greater value of de-Broglie wavelength associated with it, and**

**(B) less momentum ?**

**Give reasons to justify your Answer.**

**Ans.**

(A) de-Broglie wavelength, $\lambda \propto \frac{1}{mass}$ (for same accelerating potential) Mass of a proton is less as compared to a deuteron. So, proton will have greater value of de-Broglie wavelength associated with it.

(B) Momentum, p $\propto$ mass (for same accelerating potential) Mass of deuteron is more as compared to a proton. So, it will have a greater value of momentum.

**5. Write briefly the underlying principle used in Davisson-Germer experiment to verify wave nature of electrons experimentally. What is the de-Broglie wavelength of an electron with kinetic energy 120 eV?**

**Ans.**

A fine beam of accelerated electrons obtained , from the electron gun is made to fall normally on the surface of nickel crystal, by this incident electrons get scattered in different directions by atom of the crystal.

$$K.E. = 120eV$$

$$\lambda = \frac{h}{\sqrt{2mK.E}}$$

$$= \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 120 \times 1.6 \times 10^{-19}}}$$

$$= \frac{6.62 \times 10^{-9}}{59.1}$$

$$= 1.1 \times 10^{-10} m = 1.1.\mathring{A}$$

**6. An electron and a proton are accelerated through the same potential. Which one of the two has a greater value of (A) de-Broglie wavelength associated with it and (B) less momentum? Justify your answer. Ans. (A) de-Broglie wavelength,**

**<u>Ans.</u>**

**(A)** de- Broglie wavelength.

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

For same V,

$$\lambda \propto \frac{1}{\sqrt{mq}}$$

$$\therefore \quad \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p \times e}{m_e \times e}} = \sqrt{\frac{m_p}{m_e}}$$

As $m_p > m_e$ so $\lambda_e > \lambda_p$, i.e. electron has a greater de-Broglie wavelength.

(B) Momentum

$$P = \sqrt{2meV}$$

Or $P \propto \sqrt{m}$

As. $m_e < m_p$ $P_e < P_p$

i.e. electron has less momentum

**7. The speed of electrons in an electron microscope is 10s m/s. If protons with the same speed are used instead of electrons, what additional advantage such a proton microscope has over an electron microscope? Ans. de-Broglie wavelength,**

**<u>Ans.</u>**

de- Broglie wavelength.

$$\lambda = \frac{h}{mv}$$

As the mass of a proton is 1836 times that of an electron, so for the same speed, the wavelength of the proton beam will be $\frac{1}{1836}$ times that of an electron beam. But, resolving power of a microscope $\propto \frac{1}{Wavelengt\ h}$

Hence the resolving power of proton microscope will be 1836 times that of an electron microscope.

***

## LONG ANSWER TYPE QUESTION AND ANSWER

1. **A particle A with a mass $m_A$ is moving with a velocity v and hits a particle B (mass $m_B$) at rest (one dimensional motion). Find the change in the de Broglie wavelength of the particle A. Treat the collision as elastic.**

**Ans.** Here, the collision is elastic so, the momentum and kinetic energy is conserved.

By the law of conservation of momentum

$$m_A v + m_B \times 0 = m_A v_1 + m_B v_2$$

$$\Rightarrow m_A(v - v_1) = m_B v_2 \ldots\ldots(i)$$

By the law of conservation of kinetic energy

$$\frac{1}{2}m_A v^2 = \frac{1}{2}m_A v_1^2 + \frac{1}{2}m_B v_2^2$$

$$\Rightarrow m_A(v^2 - v_1^2) = m_B v_2^2$$

$$\Rightarrow m_A(v - v_1)(v + v_1) = m_B v_2^2 \ldots.(ii)$$

Dividing equation (2) by (1)

$$v + v_1 = v_2 \Rightarrow v = v_2 - v_1$$

$$v_1 = \left(\frac{m_A - m_B}{m_A + m_B}\right) \text{ and } v_2 = \left(\frac{2mA}{m_A + m_B}\right)$$

$$\therefore \lambda_{initial} = \frac{h}{m_A V}$$

$$\lambda_{final} = \frac{h}{m_A v_1} = \frac{h(m_A + m_B)}{m_A(m_A - m_B)}$$

$$\Delta\lambda = \lambda_{final} - \lambda_{initial}$$

$$= \frac{h}{m_A v}\left[\frac{m_A + m_B}{m_A - m_B} - 1\right]$$

# CHAPTER ELEVEN

# ATOM & NUCLEI- I

According to electromagnetic theory, the energy of an accelerating electron continuously decreases and spiral inwards eventually falling into the nucleus.

Niels Bohr made certain modifications in Rutherford's model and gave three postulates.

An electron in an atom could revolve in certain stable orbits without the emission of radiant energy.

Electrons revolves around the nucleus only in those orbits for which the angular momentum is some integral of multiple$\frac{h}{2\pi}$. Thus angular momentum (L) of the orbiting electron is quantised, that is $L = \frac{nh}{2\pi}$.

An electron might make a transition from one of the specified non-radiating orbit to another of lower energy. When it does so, a photon is emitted having the energy equal to the energy difference between the initial and final state. The frequency of emitted photon is then given by

$$hv = E_i - E_f$$

Assertion (A): A simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons.

Reason (R): Electrons experience fore due to neighbouring electrons in different shells.

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

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

(c) A is true but R is false.

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

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

**Explanation:** The simple Bohr model cannot be directly applied because when we derive the formula for radius or energy, etc., we make the assumption that centripetal forces is provided only by electrostatic force of attraction by the nucleus. In multi-electron atoms, there will be repulsion due to other electrons.

The angular momentum L is given by

L=mvr

From Bohr's second postulate

$$Ln = mv_n r_n = \frac{nh}{2\pi}$$

The allowed orbits are numbered 1, 2, 3.....According to the values of n, this is called the principal quantum number of the orbit.

Relation between $v_n$ and $r_n$ is-

$$v_n = \frac{e}{\sqrt{4\pi\varepsilon_0 m r_n}}$$

Combining it with equation of linear momentum, we get

$$v_n = \frac{1}{n}\frac{e^2}{4\pi\varepsilon_0}\frac{(\frac{1}{h})}{2\pi}$$

And

$$r_n = \frac{h^2\varepsilon_0}{\pi m e^2}$$

The total energy of the electron in the stationary states of hydrogen atom can be obtained by-

$$E_n = \frac{e^2}{8\pi\varepsilon_0}\frac{m}{n^2}\left(\frac{2\pi}{h}\right)^2\frac{e^2}{4\pi\varepsilon_0}$$

Or

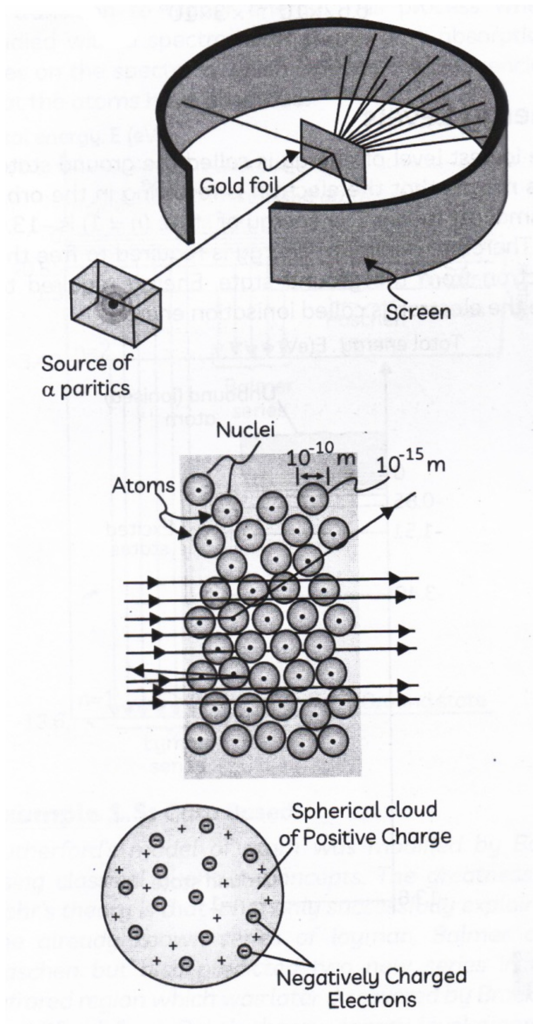
$$E_n = \frac{me^4}{8n^2\varepsilon_0^2 h^2}$$

Substituting the values, we get

$$E_n = \frac{2.18 \times 10^{-18}}{n^2}$$

**Case Based:**

Due to many reasons, Rutherford model of atom had many limitations. Rutherford model failed to explain the stability of an atom. As the electron's energy decreases gradually, it collapses into the nucleus. Hence the charge of the atom will disrupt making the atom unstable. In Rutherford model, an electron can revolve in orbit of all possible radii hence it should emit a continuous spectrum but atoms like hydrogen always emit a discrete line of spectrum. From the developing ideas of quantum hypothesis. Bohr made modification to Rutherford's model by studying the Rutherford's model for months he presented three postulates by combining classical early quantum concepts. Bohr gave the conditions of angular momentum and energy associated with different orbits. By following his postulates, we were Me to find total energy on an electron, the radius of the orbit, velocity of an electron revolving around the nucleus.




**(A) In Bohr Model, what is the atomic radius of 3rd orbit?**

**(a)** $\frac{r_0}{9}$

**(b)** $r_0$

**(c)** $9r_0$

**(d)** $3r_0$

**(B) The ratio between the Bohr radii is**

**(a) 1:2:3**

**(b) 2:4:6**

**(c) .1:4:9**

**(d) 1:3:5**

**(C) As per bohr model, the radius of stationary orbit are related to principal quantum number n as**

**(a) Inversely proportional to square of *n***

**(b) Inversely proportional to *n***

**(c) Directly proportional to *n***

**(d) Directly proportional to *n* square**

**(D) If the orbital radius of electron in the hydrogen is $4.7 \times 10^{-11}$m. Kinetic energy of electron atom is**

**(a) 15.3 eV**

**(b) −15.3eV**

**(c) 13.6 eV**

**(d) −13.6eV**

**(E) What is tfie angular momentum of an electron in the third orbit of an atom?**

**(a)** $\mathbf{3.15 \times 10^{-34}\, Js}$

**(b)** $\mathbf{3.15 \times 10^{-35} Js}$

**(c)** $\mathbf{3 \times 10^{-34}\, Js}$

**(d)** $\mathbf{1.15 \times 10^{-28}\, Js}$

**<u>Ans.</u>**

**(A) (c)** $\mathbf{9r_0}$

**Explanation:**

$$r_n = r_n n^2$$

$$r_3 = r_0 9$$

**(B) (c) 1:4:9**

**Explanation:**

$$r_n = r_n n^2$$

Taking $n = 1,2,3$ we get

$$r_1 : r_2 : r_3 = 1 : 4 : 9$$

**(C)(d) Directly proportional to n square**

**Explanation:**

Centripetal force = electrostatic force

$$\frac{mv^2}{r} = \frac{e^2}{4\pi\varepsilon_0 r^2}$$

Since

$$mv_n r_n = \frac{nh}{2\pi}$$

We get:

$$mr = \frac{n^2h^2}{4\pi^2}\frac{4\pi\varepsilon_0}{e^2}$$

the radius of stationary orbit is directly proportional to n square.

**(D) (a)** $\mathbf{15.3\, eV}$

**Explanation:**

$$K = \frac{e^2}{8\pi\varepsilon_0 r}$$

$$K = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{2 \times 4.7 \times 10^{-11}} \times \frac{1}{(1.6 \times 10^{-19})}$$

$$= 15.3\ eV$$

**(E) (a)** $\mathbf{3.15 \times 10^{-34}}$ **Js**

**Explanation:**

$n = 3.\, h = 6.6 \times 10^{-34}$ Js

Angular momentum.

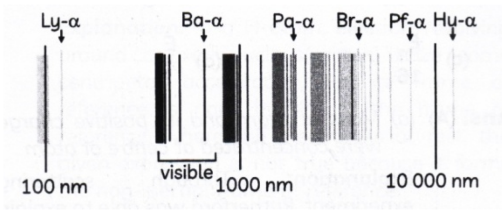
$$L = \frac{nh}{2\pi}$$

$$= L = \frac{3 \times 6.6 \times 10^{-34}}{2 \times 3.14}$$

$$= 3.15 \times 10^{-34} \text{Js}$$

**Case Based:**

Rutherford's model of atom was modified by Bohr using classical quantum concepts. The greatness of Bohr's theory is that it not only successfully explained the already known series of layman, Balmer and Paschen but also predicted two new series in the infrared region which was later discovered by Brackett and Pfund. From Bohr's theory, energy level diagram was established in which different energies of different stationary states of an atom are represented by parallel horizontal lines, drawn according to some suitable energy scale. An electron can have definite values of energy while revolving in different orbits. This is called energy quantisation. Atoms may acquire sufficient energy to raise the electron in higher energy level. It is known as excitation energy and the accelerating potential which excites the electron to higher energy level is known as excitation potential. In various lines, when photons are emitted, it means electrons jump from higher energy to lower energy state. Those spectral lines are called emission lines. But when an atom absorbs a photon, it has energy equal to the energy needed by the electron in a lower state to make the transition to higher state. This is called absorption.




**(A)For scattering $\alpha$ particles, Rutherford suggested that**

**(a) Mass of atom and its positive charge were concentrated at centre of atom**

**(b) Only mass of atom is concentrated at centre of the atom**

**(c) Only positive charge of atom is concentrated at centre of atom**

**(d) Mass of atom is uniformly distributed throughout it's volume**

**(B) In Pfund series, the ratio of maximum to minimum wavelength of emitted spectral lines is**

**(a)** $\frac{\lambda_{max}}{\lambda_{min}} = \frac{4}{3}$

**(b)** $\frac{\lambda_{max}}{\lambda_{min}} = \frac{9}{5}$

**(c)** $\frac{\lambda_{max}}{\lambda_{min}} = \frac{2}{3}$

**(d)** $\frac{\lambda_{max}}{\lambda_{min}} = \frac{36}{11}$

**(C) A set of atoms in excited state decays**

**(a) In general to any of the state with lower energy**

**(b) Into a lower state only when excited by an external field**

**(c) All together simultaneously into a lower state**

**(d) To emit photons only when they collide**

**(D) Which of the following spectral series in hydrogen atom gives line of 4860Å**

**(a) Lyman**

**(b) Balmer**

**(c) Paschen**

**(d) Brackett**

**(E)The ground state energy of the hydrogen atom is $E_0$. The Kinetic energy of the electron in 3rd exited level is**

**(a)** $-\frac{E_0}{16}$ **(b)** $-\frac{E_0}{9}$

**(c)** $\frac{E_0}{16}$ **(d)** $\frac{E_0}{9}$

**Ans.**

**(A) (a) Mass of atom and its positive charge were concentrated at centre of atom**

**Explanation:** Through scattering experiment, Rutherford was able to explain the most of the alpha particles passed through the atom suggesting most of the space is empty and most deflection (180°) was observed when alpha particles retaliated from the nucleus due to like charge.

**(B) (d)** $\frac{\lambda_{max}}{\lambda_{min}} = \frac{36}{11}$

**Explanation:** In P- fund series

$$\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{n^2}\right), n = 6,7 \ldots$$

Maximum wavelength is given by

$$\frac{1}{\lambda_{max}} = \left(\frac{1}{5^2} - \frac{1}{6^2}\right)$$

In transition 5 to 6

Minimum Wavelength is given by

$$\frac{1}{\lambda} = \left(\frac{1}{5^2} - \frac{1}{\infty}\right)$$

In transition 5 to ∞

So, ratio is $\frac{36}{11}$

**(C) (a) In general to any of the state with Lower energy**

**Explanation:** A set of atoms in excited state decays to any state with lower energy because they are more stable than the excited state.

**(D) (b) Balmer**

**Explanation:** Spectral line wavelength 4860Å lies in visible region of spectrum which is Balmer series of spectrum.

**(E) (a) $\frac{E_0}{16}$**

**Explanation:** For third excited level,

$$E = \frac{E_0}{n^2}$$

For third excited level, $n = 4$

Kinetic Energy = $-E_0 = -\frac{E_0}{16}$

**1. Write two important limitations of Rutherford nuclear model of the atom.**

**Ans.**

Two important limitations of Rutherford nuclear model of the atom:

(A) It is not in accordance with the Maxwell's theory and could not explain the stability of an atom.

(B) It did not say anything about the arrangement of electrons in an atom.

**2. Show that the radius of the orbit in hydrogen atom varies as $n^2$. Where n is the principal quantum number of the atom.**

**Ans.**

According to the Bohr's theory of hydrogen atom, the angular momentum of a revolving electron is given by

$$mvr = \frac{nh}{2\pi}$$

Here, m = Mass of the electron

v = Velocity of the electron

r = Radius of the orbit

h = Planck's constant

n = Principal quantum number of the atom

If an electron of mass m and velocity v is moving in a circular orbit of radius r, then the centripetal force required is given by

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

Also, if the charge on the nucleus is Ze, then the force of electrostatic attraction between the nucleus and the electron will provide the necessary centripetal force.

$$F = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{r^2} = \frac{KZe^2}{r^2}$$

Where $K = \frac{1}{4\pi\varepsilon_0}$

$\therefore \quad \frac{mv^2}{r} = \frac{KZe^2}{r^2}$

$$v = \frac{nh}{2\pi mr}$$

Putting this value in (ii), we get

$$\frac{m}{r}\frac{n^2h^2}{4\pi^2m^2r^2} = \frac{KZe^2}{r^2}$$

$\Rightarrow \quad r = \frac{n^2h^2}{4\pi^2mKZ\,e^2}$

$\Rightarrow \quad r \propto n^2$

**3. Using Rutherford model of the atom, derive the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron?**

**Ans.**

In a hydrogen atom, an electron having charge $-e$ revolves around the nucleus having charge $+e$ in a circular orbit of radius $r$.

Let,

$F_c$ = Centripetal force required by the electron to move in circular orbit of radius $r$.

$F_e$ = Electrostatic force of attraction between revolving electron and nucleus.

The electrostatic force of attraction ($F_e$.) provides the necessary centripetal force.

$$F_c = F_e$$

$\frac{mv^2}{r} = \frac{(e)(e)}{4\pi\varepsilon_0 r^2}$.....(i)

K.E. of electron in the orbit,

$$K.E. = \frac{1}{2}mv^2$$

From equation (i),

$$K.E. = \frac{e^2}{8\pi\varepsilon_0 r}$$

Potential energy of electron in hydrogen atom

$$P.E. = \frac{(e)(-e)}{4\pi\varepsilon_0 r} = \frac{-e^2}{4\pi\varepsilon_0 r}$$

∴ Total energy of electron in hydrogen atom

$$E = E.K. + P.E. = \frac{e^2}{8\pi\varepsilon_0 r} - \frac{e^2}{4\pi\varepsilon_0 r}$$

$$E.K. = -\frac{e^2}{8\pi\varepsilon_0 r}$$

Here, negative sign indicates that the revolving electron is bound to the positive nucleus.

4. **Positronium is just like a H-atom with the proton replaced by the positively charged anti-particle of the electron (called the positron which is as massive as the electron). What would be the ground state energy of positronium?**

**Ans.** Total energy of the electron in the stationary states of the hydrogen atom is

$$E_n = -\left\{\frac{\mu}{2h^2}\left(\frac{e^2}{4\pi\varepsilon_0}\right)^2\right\}\frac{1}{n^2}$$

$\mu$ is the reduced mass of electron and proton. For hydrogen atom

$$\mu = \frac{m_e m_p}{m_e + m_p} = m_e m_p = m_e (m_p \gg me)$$

$m_e$ and $m_p$ are the masses of electron and proton which are the same.

For positronium: $\mu = \frac{m_e m_p}{m_e + m_p} = \frac{me^2}{2m_e} = \frac{me}{2}$

$$E_n = -\left\{\frac{m_e}{2h^2}\left(\frac{e^2}{4\pi\varepsilon_0}\right)\right\}\frac{1}{n^2}$$

$$-\frac{13.6eV}{2}\frac{1}{n^2}$$

$$= \frac{-6.8eV}{n^2}$$

The energy is half of the hydrogen level.

The lowest energy level of positronium (n = 1) is -6.8 eV. The next highest level (n = 2) is -1.7 eV, the negative s.ign implies a bound state.

***

## SHORT QUESTION WITH ANSWER (2 MARKS)

**1. Why do stable nuclei never have more protons than neutrons?**

**Ans.** Protons are positively charged and repel one another electrically. This repulsion becomes sogreat in nuclei with more than 10 protons or so, that an excess of neutrons which produce only attractive forces, is required for stability.

**2. Write three characteristic properties of nuclear force.**

**Ans.** (1) Nuclear forces are short range forces;

(2) Nuclear forces are primarily attractive and extremely strong;

(3) Nuclear forces are charge independent.

**3. If the nucleons of the nucleus are separated from each other, the total mass of the nucleons is larger than the mass of the nucleus. Where does this mass difference come from?**

**Ans.** When the nucleons of the nucleus are largely separated, a certain amount of energy is to be given to the nucleus, which is called binding energy (B.E.).

B. E. = (No. of nucleons * mass of the nucleon) **-** (Mass of the nucleus)

When the nucleons are separated, the increase in the total mass from the B.E., which is given to the nucleus to break the constituent nucleons as energy is related to the mass as $E = \Delta mc^2$

**4. Define ionization energy. How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron but having the same charge?**

**Ans.** Ionization energy is the amount of energy required to knock out the valence electron from an isolated, gaseous atom in its ground state to form a cation. Ionization energy is also depend on the orbit from which electron is to be removed.

When the electron in hydrogen atom is replaced by the particle of mass 200 times that of the electron but having the same charge then the atomic radius decreases. Smaller the radii of the atom, more is the atomic energy. With the decrease in size, ionization energy increases due to valence electron are tightly held and more energy is required to remove it.

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## SHORT QUESTION WITH ANSWER

**5. Are the nucleons fundamental particles, or do they consist of still smaller parts? One way to find out is to probe a nucleon just as Rutherford probed an atom. What should be the kinetic energy of an electron for it to be able to probe a nucleon? Assume the diameter of a nucleon to be approximately $10^{-15}$ m.**

**Ans.** Nucleons are known to be composite particles, made of three quarks bound together by the strong interaction. The interaction between two or more nucleons is called nuclear force, which is also ultimately caused by the strong interaction. For resolving two objects separated by distance $d$, the wavelength $\lambda$ of the proving signal must be less than $d$. Therefore, to detect separate parts inside a nucleon, the electron must have a wavelength less than $10^{-15}$ m.

$\lambda = \frac{h}{p}$ and $K \approx pc$

$$\Rightarrow \quad K \approx pc = \frac{hc}{\lambda}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{1.6 \times 10^{-18} \times 10^{-15}}$$

$$\approx 10^{9}\ eV = 1\ GeV$$

**6. (A) State two distinguishing features of nuclear force.**

**(B) Draw a plot showing the variation of potential energy of a pair of nucleons as a function of their separation. Mark the regions on the graph where the force is**

**(i) attractive, and**

**(ii) repulsive.**

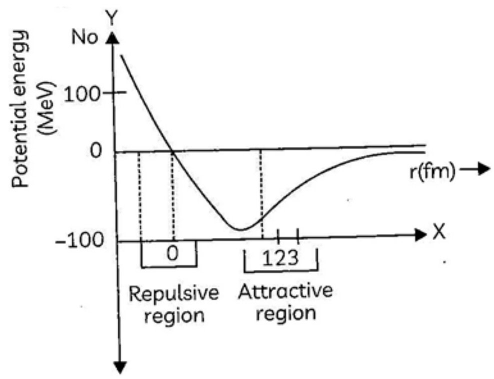
**Ans.** (A) Distinguish features of nuclear force are:

(1) Nuclear forces are very strong binding forces (attractive force.)

(2) It is independent of the charges protons and neutrons (charge independent.)

(3) It depends on the spins of the nucleons.

(B) Plot showing variation of potential energy of a pair of nucleons as a function of separation mark attractive and repulsive region.




X-axis shows separation between pair of nucleons and Y-axis shows variation of potential energy w.r.t. separation (($in \times 10^{-15} m$)

**7. Write any three conclusions obtained from binding energy curve.**

**Ans.** (1) The force is attractive and sufficiently strong to produce a binding energy of a few MeV per nucleon.

(2) The constancy if the binding energy in the range 30 < A < 170 is a consequence of the fact that nuclear force is short ranged, if any other nucleon is at a distance more than the range of the nuclear force from the particular nucleon it will have no influence on the binding energy of the nucleon.

(3) A very heavy nucleus A = 240 has lower binding energy compared to that of nucleus with A = 120. Thus, if a nucleus A = 240 breaks into two A = 120 nuclei, nucleons get more tightly bound. Energy would be released in this process.

***

## LONG QUESTION WITH ANSWER

**1. State the postulates of Bohr's theory. Derive an expression for energy of an electron in the nth Orbit of hydrogen atom orbiting in a circular path.**

**Ans.**

Bohr applied Planck's quantum theory to the Rutherford model of atom, and suggested a new model on the basis of following postulates.

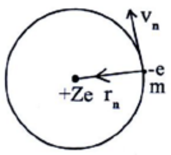
Postulates of Bohr's theory

**(i)** The electrons revolve around the nucleus in circular orbits. The necessary centripetal force is provided by electrostatic force of attraction between the electrons and nucleus.

$\frac{mv^2}{r_n} = \frac{1}{4\pi\varepsilon_0}\frac{ze^2}{r_n^2}$..... .(1)

Where

$m$ = mass of electron.




$v$ = velocity of electron in nth orbit.

$r_n$ = radius of nth orbit

$z$ = atomic number of the element.

**(ii)** The electron revolves round the nucleus in certain specified circular orbits called stationary orbit for which the angular momentum of the electron is equal to integral multiple of $\frac{h}{2\pi}$.

$mvr_n = \frac{nh}{2\pi}$..............(2)

**(iii)** The electrons neither emit nor absorb energy, while revolving round the nucleus in certain stationary orbits. The electrons can emit or absorb energy only when they jump from one orbit to another according to

$E_i - E_f = hv$.........(3)

Where

$E_i$ = energy of the electron in the initial orbit.

$E_f$ = energy of the electron in the final orbit.

$h$ = Planck's constant

$v$ = frequency of radiation

From equation (1) we get

$v^2 = \frac{1}{4\pi\varepsilon_0}\frac{ze^2}{mr_n}$................. .(4)

From equation (2) $v = \frac{nh}{2\pi m r_n}$

Or

$v^2 = \frac{n^2h^2}{4\pi^2 r_n^2 m^2}$..........(5)

From equation (4) & (5) we get

$$\frac{Ze^2}{4\pi\varepsilon_0 r_n m} = \frac{n^2h^2}{4\pi^2 r_n m}$$

$r_n = \frac{n^2h^2\varepsilon_0}{\pi m\ Ze^2}$....................(6)

For hydrogen atom $(Z = 1) r_n = \frac{n^2h^2\varepsilon_0}{\pi m e^2} r_n \propto n^2$

**Total energy of an electron in nth orbit.**
The total energy of the electron in the nth orbit is the sum of kinetic energy and potential energy

$E_n = E_k + E_p$

Where $E_n$- total energy of the electron in the nth orbit.

$E_k$- kinetic energy of the electron in the nth orbit.

$E_p$- potential energy of the electron in the nth orbit.

$$K.E = \frac{1}{2}mv^2$$

$= \frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}$............(7)

V= electric potential at a distance $r_n$ from the nucleus

$$= \frac{1}{4\pi\varepsilon_0}\frac{Ze}{r_n}$$

PE= work done = $V(-e) = \frac{-1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}$............ (8)

$E_n = E_k + E_p$

$$= \frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n} + \frac{-1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}$$

$= \frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}$................ (9)

Putting the value of $r_n$ from equation (6)

$E_n$= Total energy of the electron in the nth orbit.

$= -\frac{1}{2}\frac{Ze^2}{4\pi\varepsilon_0^2 n^2h^2}\frac{\pi\ mZe^2}{} = \frac{-Z^2e^4m}{8\varepsilon_0^2n^2h^2}$........(10)

$$E_n \propto -\frac{1}{n^2}$$

$\propto Z^2$

For hydrogen atom, $Z = 1$

$E_n = \frac{-me^4}{8\varepsilon_0^2h^2} \cdot \frac{1}{n^2}$............ (11)

$$E_n \propto -\frac{1}{n^2}$$

Total energy of electron is inversely proportional to square of the order of the orbit. So higher the orbit greater is the energy. Total energy negative means the electron is bound to the atom.

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# RADIOACTIVITY

**1. The half –life of $\underset{92}{238}\cup$ undergoing $\alpha$- decay is $4 \times 10^9$ years. What is the activity of 1g sample of $\underset{92}{238}\cup$.**

**Ans.**

$T_{\frac{1}{2}} = 4.5 \times 10^9 y$

$= 4.5 \times 10^9 \times 3.16 \times 10^7$ s/y

$= 1.42 \times 10^{17} s$

1g of $92^{\cup 238}$ contains

$$N = \frac{1}{238 \times 10^{-3}}\ kmol \times 6.025 \times 10^{26}\ \frac{atom}{kmol}$$

$= 25.3 \times 10^{20}\ aoms$

The rate of decay R is

$$R = \lambda N$$

$$= \frac{0.693}{\lambda} N$$

$$= \frac{0.693 \times 25.3 \times 10^{20}}{1.42 \times 10^{17}} s^{-1}$$

$= 1.23 \times 10^4\ Bq$

**Important**

$\Delta N$ is the number of nuclei that decay and hence is always positive. $dN$ is the change in $N$. Which may have either sign.

**2. How many $\alpha -$ and $\beta -$ particles will be emitted when $_{90}Th^{232}$ changes to $_{82}Pb^{208}$ ?**

**Ans.** $_{90}Th^{232} \rightarrow {}_{82}Pb^{208}$

Decrease in mass number

$$= 232 - 208 = 24$$

No. of a-particles emitted $= \frac{24}{4} = 6$

Expected decrease in atomic number due to emission of $\alpha -$ particles is $6 \times 2 = 12$

Expected atomic number of the nucleus formed

$$= 90 - 12 = 78$$

But the atomic number of the nucleus formed $= 82$

Increase in atomic number $= 82 - 78 = 4$

Number of $\beta^- -$ particles emitted = 4

Thus 6 alpha particles and 4 beta particles are emitted in the process.

**3. <u>Case based:</u>**

Neutrons are produced for fission of nuclear fuel like U-235 which is found more abundantly in nature. These neutrons are slowed down otherwise they will escape from the reactor without interacting with the nucleus of the fuel. Process of slowing down the reactor is done via moderators. Apsara reactor at Bhabha Atomic research centre uses water as moderator. The use of moderator is used to keep the ratio of number of fission produces by a given generation of neutrons to the number of fission of the preceeding generation. This ratio is also called multiplication factor. It is to be kept on the value of unity. Exceeding the value of unity will ease an explosion the world once witnessed in Chernobyl. The rate of reaction is altered by control rods made of cadmium or boron and help in absorbing neutrons to eliminate the leak of radiation. For avoiding leak of radiation, the reactor is shielded.

**(A) What is the value of multiplication factor for critical operation?**

**(a)** $\boldsymbol{K = 0}$

**(b)** $\boldsymbol{K = l}$

**(c)** $\boldsymbol{K} > 1$

**(d)** $\boldsymbol{K} < 0$

**(B) Which of the following is not a moderator used in Nuclear reactor?**

**(a) $H_20$**

**(b) $D_20$**

**(c) Boron**

**(d) Graphite**

**(C) Control rods in a nuclear reactor are used to**

**(a) Increase /Decrease the rate of reaction**

**(b) Absorb the harmful radiation**

**(c) Control the rate of neutron production**

**(d) All of the above**

**(D) The coolant used in the reactor must have**

**(a) Low specific heat**

**(b) Low boiling point**

**(c) Low pressure**

**(d) High specific heat**

**(E) Which among the following cannot be used as reactor fuel?**

**(a) U-235**

**(b) Th-232**

**(c) Pu-329**

**(d) U-238**

**Ans. (A) (b)K=l**

**Explanation**: If K = 1, the chain reaction in nuclear reactor is critical and neutron population will remain constant keeping the reactor stable.

**(B) (c) boron**

**Explanation:** Boron will absorb the neutrons instead of slowing the neutrons down due to which self-sustaining chain reaction will not be achieved.

**(C) (d) All of the above**

**Explanation:** Control rods are made of neutron absorbing material such as boron which help to control the rate of chain reaction by keeping the neutron population constant and absorbs leak of neutrons to prevent radiation leak.

**(D) (d) high specific heat**

**Explanation:** Radioactive reaction produces high amount of heat for which coolant with high specific heat is required to absorb maximum amount of heat without raising its own temperature.

**(E) (d) U-238**

**Explanation:** Neutrons fired at U-238 would need much higher energy for fission to take place. U-238 has an even mass and odd nuclei are more fissile because the extra neutron adds energy because of which U-238 will not undergo fission in nuclear reactor.

***

## MULTIPLE CHOICE QUESTIONS WITH ANSWER

**1. In $\beta -$ decay, a**

**(a) neutron converts into a proton emitting antineutrino.**

**(b) neutron converts into a proton emitting neutrino.**

**(c) proton converts into a proton emitting antineutrino.**

**(d) proton converts into a proton emitting neutrino.**

**Ans. (a) neutron converts into a proton emitting antineutrino.**

**Explanation:** $\beta -$decay is represented as

$$
{}_{0}^{1}n\ (neutron) \rightarrow {}_{1}^{1}p\ (proton) + {}_{-1}^{0}e\ (electron) + \bar{V}_e\ (antineutrino)
$$

**2. Suppose we consider a large number of containers each containing initially 10000 atoms of a radioactive material with a half life of 1 year. After 1 year,**

**(a) all the containers will have 5000 atoms of the material**

**(b) all the containers will contain the same number of atoms of the material but that number will only be approximately 5000.**

**(c) the containers will in general have different numbers of the atoms of the material but their average will be close to 5000.**

**(d) none of the containers can have more than 5000 atoms**.

**Ans. (c) the containers will in general have different numbers of the atoms of the material but their average will be close to 5000.**

**Explanation:** Here, in half-life (t= 1 yr) of the material on the average half the number of atoms will decay. Therefore, the containers will in general have different number of atoms of the material, but their average will be close to 5000.

**Related Theory**

Radioactivity is a process due to which a radioactive material spontaneously decays. Time interval in which the mass of a radioactive substance or the number of its atom reduces to half of its initial value is called the half life of the substance.

**3. The same radioactive nucleus may emit**

**(a) either a or $\beta$ or $\gamma$ at a time**

**(b) all the three $\alpha, \beta$ and $\gamma$ one after another**

**(c) all the three $\alpha, \beta$ and $\gamma$ simultaneously**

**(d) only $\alpha$ and $\beta$ simultaneously**

**Ans. (a) either $\alpha$ or $\beta$ or $\lambda$ at a time**

**Explanation:** No radioactive substance emit both $\alpha$ and $\beta$ particles simultaneously. Some substance emits $\alpha$-particles and some other emits $\beta$-particles. $\gamma$-rays are emitted along with both a and $\beta$-particles.

So, radioactive nucleus emits one alpha, beta or gamma at a time.

**Related Theory**

Radioactivity is a nuclear phenomenon in which an unstable nucleus undergoes a decay and is referred as radioactive decay.

**4. Fusion reaction takes place at high temperature because**

**(a) atoms get ionised at high temperature**

**(b) kinetic energy is high enough to overcome the coulombic repulsion between nuclei**

**(c) molecules break up at high temperature**

**(d) nuclei break up at high temperature**

**Ans. (b) Kinetic energy is high enough to overcome the coulombic repulsion between nuclei.**

**Explanation:** For nuclear fusion in a bulk material, the temperature of the material has to be raised $10^6$ K, so that the colliding nuclei have enough kinetic energy due to their thermal motion and they can penetrate the thermal barrier.

The process in which two lighter nuclei combine to form a single heavier nucleus is called nuclear fusion.

**5. Penetrating power is minimum for**

**(a) $\alpha$-rays** **(b) $\beta$-rays**

**(c) $\gamma$-rays** **(d) X-rays**

**Ans. (a) $\alpha$-rays**

**Explanation:** Alpha particles are the biggest, beta particles are very much smaller and gamma rays have no mass. The bigger the particle, the more likely it is to have a collision with the atoms of the material. The collision will stop the particle going through the material. So, Penetrating power is minimum for $\alpha$-rays

**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.**

**Ans. (b) elastic collision of neutrons with heavy nuclei will not slow them down.**

**Explanation:** 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. Heavy nuclei will not serve the purpose because elastic collisions of neutrons with heavy nuclei will not slow them down.

**Related Theory**

A moderator is a material used in a nuclear reactor to slow down the neutrons produced from fission.

**7. Fusion processes, like combining two deuterons to form a He nucleus are impossible at ordinary temperatures and pressure. The reasons for this can be traced to the fact:**

**(a) nuclear forces have short range.**

**(b) nuclei are positively charged.**

(c) the original nuclei must be completely ionized before fusion can take place.

(d) the original nuclei must first break up before combining with each other.

**Ans.(a) nuclear forces have short range.**

**(b) nuclei are positively charged.**

**Explanation:** In fusion, the high temperature gives the hydrogen atoms enough energy to overcome the electrical repulsion between the protons. High pressure squeezes the hydrogen atoms together. They must be within $1 \times 10^{-15}$ metres of each other to fuse and the nuclear forces are short range.

**Related Theory**

In nuclear fusion, two or more than two lighter nuclei combine to form a single heavy nucleus. The mass of a single nucleus so formed is less than the sum of the masses of parent nuclei.

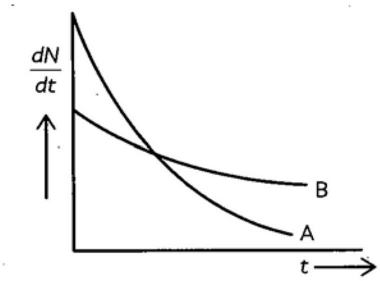
**8. The variation of decay rate of two radioactive samples A and B with time is shown in fig. Which of the following statements are true?**

**(a) Decay constant of A is greater than that of B, hence A always decays faster than B.**

**(b) Decay constant of B is greater than that of A but its decay rate is always smaller than that of A.**

**(c) Decay constant of A is greater than that of B but it does not always decay faster than B.**

**(d) Decay constant of B is smaller than that of A but still its decay rate becomes equal to that of A at a later instant.**




**Ans. (c) Decay constant of A is greater than that of B but it does not always decay faster than B.**

**(d)** Decay constant of B is smaller than that of A but still its decay rate becomes equal to that of A at a later instant **Explanation:** The slope of curve A is greater than the curve B, it means the rate of decay is faster for A than that of B. According to Rutherford radioactive decay $-\left(\frac{dN}{dt}\right)\alpha\lambda$ where $\lambda$ is decay constant.

Hence, at point of intersection of both curves, rate of decay for both A and B is the same.

***

## ASSERTION-REASON QUESTIONS WITH ANSWER

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

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

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

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

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

**9. Assertion (A): It is experimentally difficult to detect neutrinos in nuclear $\beta$-decay.**

**Reason(R): Neutrinos are uncharged particles with almost zero mass and also they interact weakly with matter.**

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

**10. Assertion (A): Light nuclei usually undergo nuclear fusion.**

**Reason (R): That time only nuclear fusion is known.**

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

**Explanation :** Light nuclei usually undergo nuclear fusion because their binding energy per nucleon in the nucleus is less so they combine together to release energy on the cost of some mass and get more stable by fusion.

**11. Assertion (A): Control rods made of cadmium.**

**Reason (R): Cd absorbs neutrons and by pushing or pulling Cd rods in and out the rate of nuclear reaction can be increased or decreased.**

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

**12. Assertion (A): Solar energy is mainly caused due to fusion of protons.**

**Reason (R): It is the result of fusion of protons during synthesis of heavier elements in which enormous amount of heat is liberated.**

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

***

## LONG QUESTION WITH ANSWER

**1. (A) Explain the processes of nuclear fission and nuclear fusion by using the plot of binding energy per nucleon (BE/A) versus the mass number A.**

**(B) A radioactive isotope has a half - life of 10 years. How long will it take for the acitvity to reduce to 3.125%?**

**Ans.** (A) Nuclear fission: Binding energy per nucleon is smaller for heavier nuclei than the middle ones, it means heavier nuclei are less stable. When the heavier nucleus splits into the lighter nuclei, the binding energy per nucleon changes from about 7.6 MeV to 8.4 MeV. Greater binding energy of the product nuclei results in the liberation of energy.

Nuclear fusion: Binding energy per nucleon is small for lighter nuclei and they are less stable. So when two light nuclei fuse to form a heavier nucleus, the higher binding energy per nucleon of the latter results in the release of energy.

(B) Here, A =3.125% of $A_0$

$$= \frac{3.125}{100} \times A_0 = \frac{A_0}{32}$$

$$\frac{A}{A_0} = \frac{N}{N_0} = \left(\frac{1}{2}\right)^5$$

So, the activity will reduce to 3.125% after 5 half lives. Hence, required time = 5 × 10 = 50 years.

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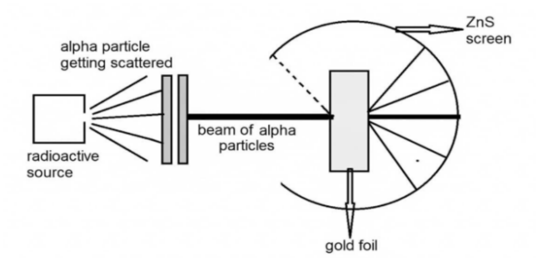
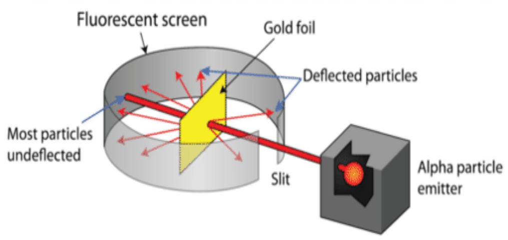
# ATOMS & NUCLEI-II

**1. Describe briefly the $\alpha -$ particle scattering experiment. Explain Rutherford's observations and model of atom. State its limitations.**

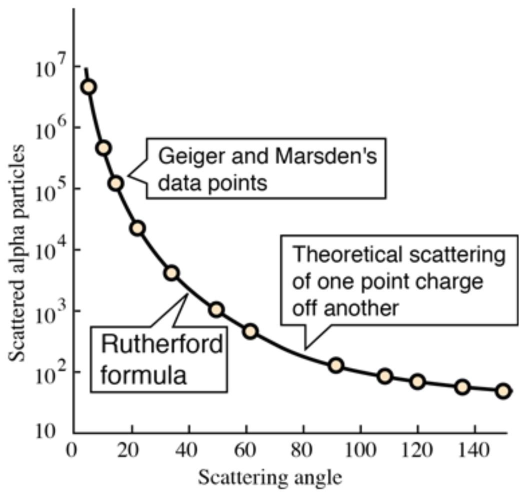
**$\alpha$- Particle scattering experiment:**




Geiger and Marsden in 1911 performed experiment on $\alpha$- particle scattering on suggestion of Rutherford from a thin foil and got insight into the structure of atom. A radioactive source of $\alpha$ – particle is enclosed in a thick block of lead, provided with a narrow opening. The $\alpha$ particles from the source are collimated to a narrow beam through a narrow slit. The beam is allowed to fall on a thin gold foil of thickness$2.1 \times 10^{-7}$m.

The $\alpha$- particles scattered in different directions are observed with the help of a detector which consist of a zinc sulphide screen and a microscope. Whenever an $\alpha$-particle strikes the screen it produces a flash, which is viewed through the microscope. The number of $\alpha$-particles scattered at different angles can be counted. The whole apparatus is enclosed in an evacuated chamber.




Observation: - A graph is plotted between scattering angle $\theta$ and $N(\theta)$ the number of $\alpha$- particles scattered at an angle $\theta$ for a large number of $\alpha -$ particles. The following are the observations from the experiment.

1 - Most of the $\alpha -$ particles either pass straight through the Gold foil or suffer small deflections.

2 - A few $\alpha -$ particles get deflected through an angle 90° or more.

3 - Very few $\alpha -$ particles get rebounded from the gold foil suffering a deflection nearly 180°.

***Conclusion of significance:***

1- As most of the $\alpha -$particles pass straight through the foil leads to the conclusion that most of the space within the atom is empty.

2- $\alpha -$particles are heavy charged particles having high initial speed. They could be deflected through large angles only by strong electric force. So Rutherford suggested that all the +ve charge and almost the entire mass of the atom is concentrated in a small region called nucleus.

***Rutherford model of atom :*** On the basis of $\alpha$- particle scattering experiment Rutherford suggested a model of atom according to which

1- Every atom consists of a small central core called nucleus which contains all the +ve charge and almost all the mass of the atom.

2- The electrons occupy space outside the nucleus. As the atom consists of equal amount of +ve and –ve charge it is electrically neutral.

3- Electrons revolve around the nucleus in circular orbit.

4- The size of the nucleus ($\sim 10^{-15} m$) is very small as compared to size of the atom ($\sim 10^{-10}$m).

Limitations of Rutherford Model:

1- Rutherford could not explain the stability of the electrons around the nucleus. According to Maxwell’s classical electromagnetic theory an accelerated charged particle will continuously emit energy in the form of electro magnetic waves. The electrons revolving around the nucleus experience centripetal acceleration and continuously loose energy. Due to continuous loss of energy the electrons follow a spiral path and finally fall to the nucleus. So the atomic structure would collapse. But in actual particle atom is stable.

2- According to Rutherford’s model the electrons revolve around the nucleus in any orbit and radiate energy of all frequencies. So it will give continuous spectra. But experiments show that an atom emit line spectra and each line corresponds to a particular frequency. So Rutherford's model fails to explain line spectra.

**2. What is Radio Activity ? Explain radio active decay laws. Establish the relation between half life and decay constant.**

The Phenomenon of spontaneous disintegration of nuclei of heavier elements with emission of certain radiation is called natural radioactivity.

**Laws of radioactive decay :**

**(1)** The radioactive decay is spontaneous

**(2)** It is not influenced by external conditions like temperature and pressure.

**(3)** Law of conservation of charge holds good in radioactivity

**(4)** In radioactive decay $\alpha -$ particle or $\beta -$ particle or $\gamma -$ rays are emitted. (Two particles are not emitted simultaneously). An atom does not emit more than one $\alpha -$ particle or $\beta -$particle at a time.

**(5)** Emission of $\alpha -$particle results in a decrease of atomic number by 2 and atomic mass by 4.

$z^{X^A} \rightarrow_{z-2} Y^{A-4} +_2^{He^4}\ (\alpha - particle)$

$$\begin{matrix} Parent & Daughter \\ nucleus & necleus \end{matrix}$$

$$88^{Ra^{224}} \xrightarrow{\alpha} 86^{Rn^{220}} + 2^{He^4} + energy$$

**(6)** Emission of $\beta -$ particle results in an increase in atomic number by one but atomic mass remains same.

$$z^{X^A} \rightarrow z+1^{Y^A} + -1^{e^0}\ (\beta - particle)$$

$$6^{C^{14}} \rightarrow 7^{N^{14}} + -1^{e^0} + energy$$

**(7)** Neither atomic number nor atomic mass number changes with the emission of $\gamma$ rays.

$$z^{X^A} \rightarrow z^{X^A} + hv\ (\gamma\ rays)$$

**(8)** Each of the product nuclei is a new element having different physical and chemical properties.

**(9)** Statistical law of radioactivity : The rate of disintegration of radioactive substances at any instant of time is directly proportional to the number of atoms present in the sample at the instant of time. This is called decay law.

Let $N_0$ - number of radioactive atoms present in a given sample initially $(t = 0)$ N- number of radioactive atoms present after a time t.

Let dN- be the number of atoms disintegrate further in a short interval of time dt.

Rate of disintegration = $= -\frac{dN}{dt}$

According to decay law $-\frac{dN}{dt} \propto N$

Where $\lambda =$ const. of proportionality called decay constant.

The $-ve$ sign indicates $N$ decreases with time.

$$\frac{dN}{N} = -\lambda dt$$

Integrating both sides $\int \frac{dN}{N} =$

$\int -\lambda\, dt + C$

$\log_e N = \lambda t + C$

Initially at $t = 0, N = N_0$

$\log_e N_0 = C$

So $\log_0 N = -\lambda t + \log_0 N_0$

$$\log_e \frac{N}{N_0} = -\lambda t$$

$$N = N_0 e^{-\lambda t}$$

If $t = \frac{1}{\lambda}$ then

$$N = N_0 e^{-1} = \frac{N_0}{e} = 0.37 N_0$$

So radioactive decay constant is defined as the reciprocal of time in which the number of atoms of radioactive sample reduces to $\frac{N_0}{e}$

**Half Life (T) :** The time during which t he number of atoms of the radioactive substance reduces to half of its original value is called Half life.

At $t = T, N = \frac{N_0}{2}$

$$N = N_0 e^{-\lambda T} \Rightarrow \frac{N_0}{2} = N_0 e^{-\lambda T} \Rightarrow \frac{1}{2} = e^{-\lambda T}$$

$$\Rightarrow e^{\lambda T} = 2, \quad \Rightarrow \lambda T = \log_0 2$$

$$T = \frac{\log_2 2}{X} = \frac{2.303 \log_{10} 2}{\lambda} = \frac{0.693}{\lambda}$$

$$T \propto \frac{1}{\lambda}$$

So half life of the radioactive substance is inversely proportional to decay constant.

**<u>SEMICONDUCTOR ELECTRONICS & COMMUNICATION SYSTEMS.</u>**

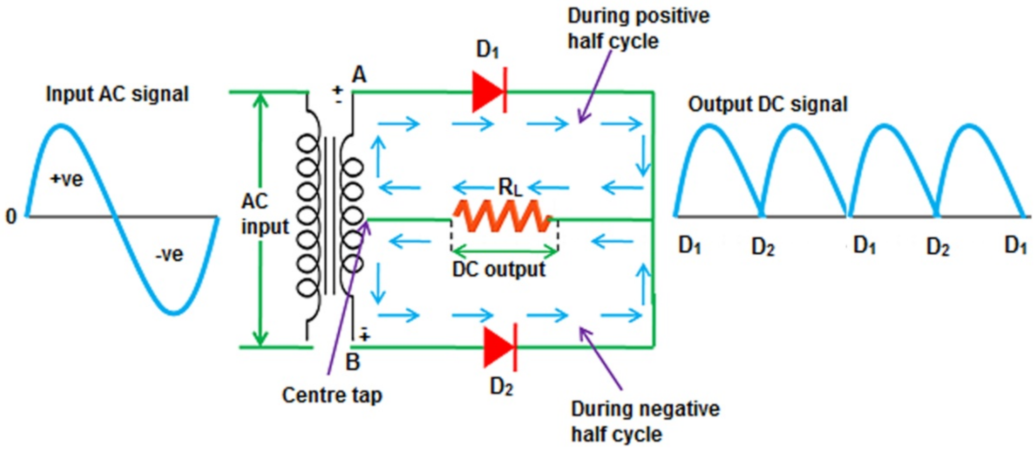
**3. What is a rectifier ? With neat circuit diagram explain the working of a full wave rectifier. Discuss the nature of the output voltage and current. Mention it's efficiency.**

A rectifier is a device which converts A.C. into D.C.

**<u>Centre-Tap full wave rectifier</u>**: In half wave rectifier only one half of the input wave is utilised. So to utilise both half cycles of input A.C. we use a full wave rectifier.

**Principle**: A diode conducts only when forward biased.

**Construction**: The circuit contains two diodes $D_1$ and $D_2$. A centre tapped secondary winding is used with the diodes connected. So that each diode uses one half of inputa. c. voltage. The input signal is connected to primary. T is an iron core centre taped transformer.




**Operation**: During the +ve half cycle of secondary voltage, end A of secondary winding becomes +ve and end B is -ve. This makes $D_1$ forward bias and diode $D_2$ reverse bias. So $D_1$ conducts and $D_2$ does not. The conventional current flow is through $D_1$, load resistor $R_L$and upper half of secondary. During -ve half cycle, end A become -ve and end B +ve. So $D_2$ will conduct and not $D_1$. The conventional current flow through $D_2$, $R_L$ and lower half winding takes place. Thus the current in $R_L$ is in same direction for both the half cycles of input a.c. voltage. So a pulsating d.c. is obtained across $R_L$ which can be further smoothed by using a $\pi$filter circuit.

**Output d.c. power**

The output is pulsating d.c. so in order to find out put d.c. power, average power has to be found out. For a full wave rectifier

$$I_{avg} = I_{dc} = \frac{2}{\pi} I_0$$

Where $I_0$ is peak current.

$(P_{dc})_{out\ put}$ = Output d.c. power

$$= I_{dc}^2 R_L = \left(\frac{2I_0}{\pi}\right)^2 R_L$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

$(P_{ac})_{input}$ =Input a.c. power

$$= I_{rms}^2 (R_L + r_f)$$

Where $r_f$ is forward resistance of each diode.

**<u>Efficiency (η)</u>**

$$\eta = \frac{(P_{dc})_{output}}{(P_{ac})_{input}}$$

$$= \frac{\left(\frac{2I_0}{\pi}\right)^2 R_L}{\left(\frac{I_0}{\sqrt{2}}\right)^2 (R_L + r_f)}$$

$$= \frac{0.812\ R_L}{R_L + r_f}$$

$$= \frac{0.812}{1 + \frac{r_f}{R_L}}$$

If $r_f \ll R_L$

$$\therefore \eta_{max} = 0.812 = 81.2\%$$

**4. Describe the construction and action of a n-p-n transistor with neat circuit diagram. Discuss its input and output characteristics in common emitter configuration.**

**Construction** : A transistor (PNP or NPN) has three sections of doped semiconductor. Thesection on one side is emitter and the section on opposite side is collector. The middle sectionis the base.

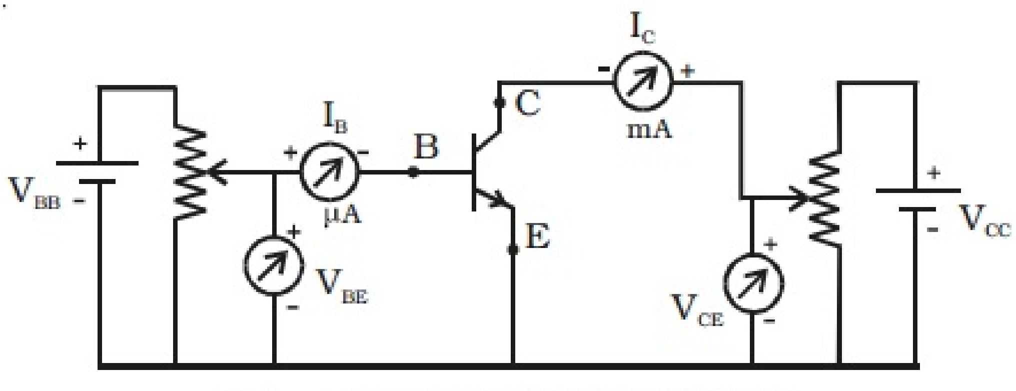


*Fig Transistor circuit in CE mode.*

**Circuit diagram for NPN transistor in CE mode :**

i) **Emitter** : The section on one side that supplies charge carriers (electrons or holes) is called emitter. It is always forward biased w.r.t. base. It is heavily doped and is of moderate size.

**ii) Collector** : The section on the other side that collects charge carriers is called the collector. The collector is always reverse biased. It is moderately doped and its size is more than that of emitter

**iii) Base** : The middle section is the base. The base emitter junction is forward biased and base collector junction is reverse biased. It is very lightly doped and is very thin.

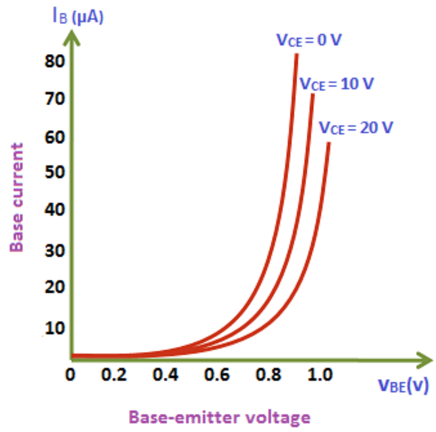
**Working of npn transistor :**

The forward biased emitter base junction causes the electrons in the n-type emitter to flow towards base. This constitutes emitter current$I_E$. As these electrons flow through P-type base, they tend to combine with holes in the base region. As the base is lightly doped and very thin only a few electrons (less than 5%) combine with holes to constitute base current $I_B$. More than 95% cross over the base into the collector region and constitute collector current $I_C$. The emitter current is the sum of collector current and base current.

$$I_E = I_B + I_C$$

**Characteristics of common emitter connection.**

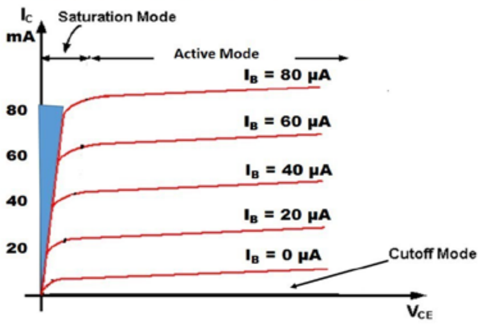
(i) **Input characteristics** : It is the curve between base current **($I_B$)** and base emitter voltage **($V_{BE}$)** at constant collector- emitter voltage **($V_{CE}$).** Keeping ($V_{CE}$)constant (say 10 volt), note the base current **($I_B$)** for various values of **($V_{BE}$).** Then plot the readings on a graph. The graph gives the input characteristics at $V_{CE}$=10 volt. The characteristics curve resembles that of a forward biased diode curve.



I/P characteristics CE configuration

(ii) **Output characterisistics**: It is the curve between collector current **($I_E$)**

and collector emitter voltage **($v_{CE}$)** at constant base current **($I_B$).** Keeping **($I_B$)** fixed (say $5\mu A$), note **($I_C$)** for various values of **($v_{CE}$).** Then plot the readings on a graph. The graph gives the output characteristics at $I_B=5\mu A$. process is repeated for $10\mu A$, $15\mu A$and so on.




$I_E$ varies with $v_{CE}$ between zero & one volt only. After this $I_C$ becomes almost constant and independent of $v_{CE}$. This value of $v_{CE}$upto which $I_C$changes is called knee voltage ($v_{knee}$)

**Input resistance (r) :-**

The ratio of small change in base emitter voltage $(\Delta V_{BE})$ to the corresponding change in base current $(\Delta I_B)$ at constant collecter emitter voltage $(V_{CE})$ is called input resistance.

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}\ constant}$$

Value of $r_i$ is of the order of few hundred ohm.

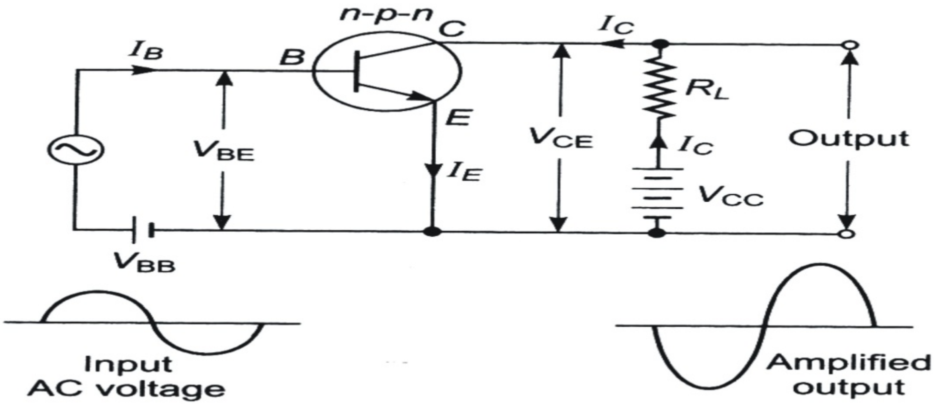
**Output resistance ($r_0$) :**

The ratio of small change in collector emitter voltage $(\Delta V_{CE})$ to the corresponding change in collector current ($I_C$) at constant base current **($I_B$)** is called output resistance.

$$r_0 = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{i_B constant}$$

Value of $r_o$ is of the order of $50K\Omega$

5. **With the help of a neat circuit diagram, explain the working of a npn transistor as an amplifier (Common emitter configuration). What is the phase relationship between input and outputvoltages? Determine its current gain, voltage gain and power gain.**




**$n-p-n$ transistor as a common emitter amplifier,**

The output resistance of a transistor is high in comparison to input resistance in common emitter configuration. The output collector current is many times larger than the input base current. When an ac signal is applied across the input the base current flows through the small resistance. So there is a low potential difference across the input. The current of larger magnitude flowing through the output produces large output voltage. So a small signal applied across the input appears as a large signal across the load in the output circuit causing amplification.

The figure shows Common emitter npn transistor amplifier circuit. The emitter base junction is forward biased and emitter collector junction is reverse biased. An input signal to be amplified is superimposed on dc voltage $V_{BB}$ in the emitter base circuit. This dc voltage is called bias voltage and its magnitude is such that it always keeps emitter-base junction forward biased irrespective of polarity of the signal. A load resistance $R_L$ is connected across the collector emitter circuit. When current $I_c$ flows in the output circuit the potential drop across the load resistance is $I_C R_L$.

Hence the output voltage is

$V_0=V_{CE}=V_{CC}-I_C R_L$

When the input signal is fed to the base emitter circuit, the base emitter voltage changes. This changes emitter current hence collector current. So output voltage changes. These variation in collector voltage appears as amplified output.

**Phase relation between input and output signal :**

During +ve half cycle of the signal the forward bias across the emitter base junction increases. Therefore more electrons flow from the emitter to collector and causes increase in collector current. This increased collector current produces a greater voltage drop across the load resistance $R_L$, which makes output voltage $V_0$ less +ve or more negative. So as the input signal goes through +ve half cycle the amplified output signal goes through -ve half cycle and vice versa. Hence in a common emitter amplifier, the input and output voltage are (180° out of phase ) in opposite phase.

**AC Current Gain** ($\beta_{ac}$)*:*

The ratio of small change in collector current to the small change in base current at constant collector-emitter voltage ($V_{CE}$) is called current gain

$$\beta_{ac} = \left(\frac{\Delta I_C}{\Delta I_B}\right) V_{CE}\ constant$$

**AC Voltage gain** ($A_v$):

The ratio of change in output voltage ($V_{CE}$) to the small change in input voltage ($V_{BE}$) is called voltage gain.

$$A_V = \frac{\Delta V_0}{\Delta V_i} = \frac{\Delta V_{CE}}{\Delta V_{BE}} = \frac{\Delta I_C R_{out}}{\Delta I_B R_{in}} = \beta \times \frac{R_0}{R_{in}}$$

= Voltage gain

**AC Power gain** ($A_p$):

The ratio of small change in output power to small change in input power is called ac power gain.

$$A_p = \frac{Change\ in\ output\ power}{Change\ in\ input\ power}$$

$$= \frac{(\Delta I_C)^2 R_L}{(\Delta I_B)^2 R_i} = \beta^2 \frac{R_{out}}{R_{in}}$$

# CHAPTER TWELVE

## SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS

**1. Assertion (A): The temperature increases the conductivity of the material**

**Reason (R): Increase in temperature allows electrons to jump to the conduction band**

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

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

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

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

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

**Explanation:** When the temperature of the material is increased, electrons present in valance band attain enough energy to jump across the energy gap. When energy gap is less than 3 eV then the electrons can jump even at room temperature but if the value of $E_g > 3$, then the electrons need certain amount of energy to jump across the energy gap which is given by increasing the temperature.

**2. The following table provides the set of values of V and I obtained for a given diode. Assuming the characteristics to be nearly linear, calculate the forward and reverse bias resistance of a given diode.**

| | V | 1 |
|---|---|---|
| Forward-biasing | 2.0V | 60mA |
| | 2.4V | 80mA |
| Reverse-biasing | 0V | $0\mu A$ |
| | -2V | $-0.25\mu A$ |

**Ans.** For forward biasing:

$$\Delta V = 2.4 - 2.0 = 0.4V$$

$$\Delta I = 80 - 60mA = 20mA$$

$$r_d = \frac{\Delta V}{\Delta I} = \frac{0.4V}{20 \times 10^{-3}A} = 20\Omega$$

For reverse biasing:

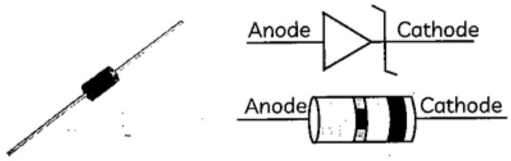
$$\Delta V = -2 - 0 = -2V$$

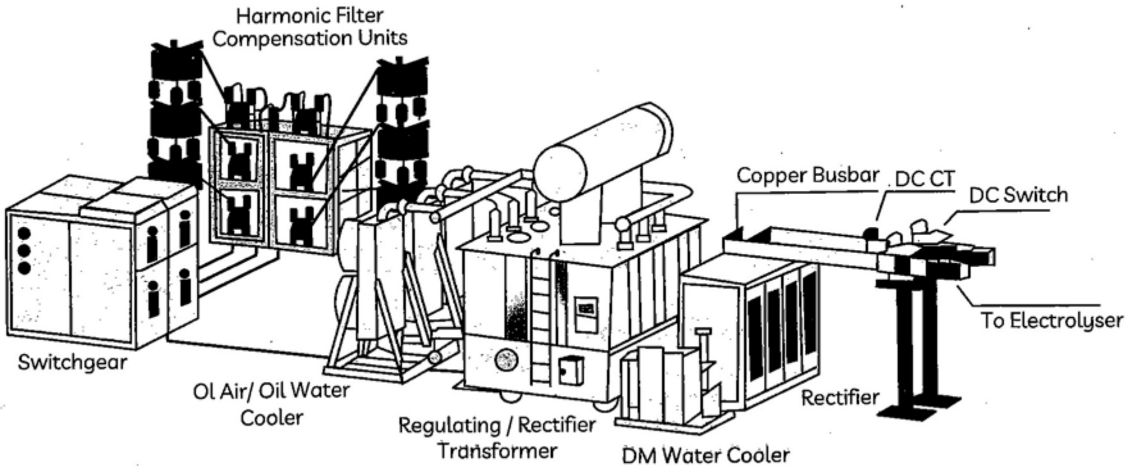
$$\Delta I = -0.25 - 0\mu A = -0.25\mu A$$

$$r_d = \frac{\Delta V}{\Delta I} = \frac{-2V}{0.25 \times 10^{-6}A}$$
$$= 8 \times 10^6\Omega$$

3. **Case Based:**

P-n Junction is made by placing p-type semiconductor in close contact with n-type semiconductor forming a p-n junction diode. These diodes can be made forward biased or reverse biased on the basis of the voltage applied. If the positive terminal of the battery is connected to p-side of the diode, it is said to be forward \ biased and if positive terminal of the battery is connected to n-side of the diode, it is said to be reverse biased. The diodes are not used in reverse biasing generally due to the possibility of damaging the diode. A forward biased diode is used in rectifier for rectification. It is a process of converting a.c current into d.c current. The process is generally used in transformers. There are two types of rectifier. Half wave rectifier which operates in positive half cycle (When diode is positive). It is less efficient. In full wave rectifier, two diodes are used to provide current through load resistance in positive half and negative half of the cycle. The alteration is eliminated by each diode. As the current passes through diode only in forward biasing, the diodes are forward biased. Special reverse biased diode is known as zener diode which is operational only in break down region. It is heavily doped, due to which the size of depletion layer decreases ($< 10^{-7}m$) and high electric field is generated ($4 \times 10^7\ Vm^{-1}$)




**(A) During reverse bias, a small current develops known as**

(a) Forward current

(b) Reverse current

(c) Reverse saturation current

(d) Active current

**(B) The voltage of the potential barrier is $V_0$. A voltage V applied to the input. At what moment will the barrier disappear?**

(a) $V < V_0$

(b) $V = V_0$

(c) $V > V_0$

(d) $V \ll V_0$

**(C) When the diode is reversed bias, with a voltage of 6 V and $V_B$ = 0.63 V. Calculate the total potential**

(a) 6V

(b) 6.63V

(c) 5.27V

(d) 0.63V

**(D) A simple rectifier has ripples in the output wave which make it unsuitable as DC source. To overcome this one can use**

(a) A capacitor in series with tiny load resistance

(b) A capacitor parallel to the load resistance

(c) An inductor parallel to load resistance

(d) None of the above

**(E) Zener diodes are also called**

(a) Forward bias diode

(b) Voltage regulator

(c) Breakdown diode

(d) None of the above

**Ans. (A) (c) Reverse saturation current**

**Explanation:** When diode is reverse biased, small current flows between the $p-n$ junction which is of the order of $\mu A$. This current is known as reverse saturation current.

**(B) (b)** $\boldsymbol{V = V_0}$

**Explanation:** When the voltage will be same as that of the potential barrier, the potential barrier disappears resulting in flow of current

**(C) (b)** $\boldsymbol{6.63\ eV}$

**Explanation:** Total voltage $V_t = V_B + V =$

$$6\,V + 0.63$$

$$= 6.63\ eV$$

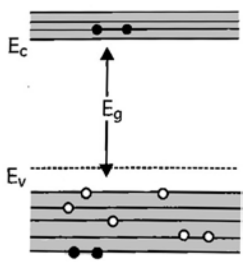
**(D) (b) A capacitor parallel to the load resistance**

Explanation: When the voltage across the capacitor is rising the capacitor is charged and when there is no load across the resistance, it is uncharged. To smoothen the signal in rectifier circuit in each cycle, we use capacitor in parallel or inductor in parallel to the load resistance

**(E) (c) Breakdown diode**

Explanation: Zener diode are used as voltage regulators but they aren't called voltage regulators. They operate in breakdown region, hence they are called breakdown diode.

**4. In the energy band diagram of a material shown below, the open circles and filled circles denote holes and electrons respectively.**



**The material is**

(a) an insulator

(b) a metal

(c) an n-type semiconductor

(d) a p-type semiconductor

Ans. (d) a p-type semiconductor

**Explanation:** The material is a p-type semiconductor because holes are the majority charge carries in the valence band.

**5. The conductivity of a semiconductor increases with increase in temperature because**

(a) number density of free current carriers increases.

(b) relaxation time increases.

(c) both number density of carriers and relaxation time increase.

(d) number density of current carriers increases, relaxation time decreases but effect of decrease in relaxation time is much less than increase in number density.

**Ans.** (d) number density' of .current carriers increases, relaxation time decreases but effect of decrease in relaxation time is much iess than increase in number density.

**Explanation:** $\sigma = \frac{ne^2\tau}{m}$

So , $\sigma \propto n\tau$

In semiconductor, conductivity increases with increase in temperature because number density of current carriers increases, relaxation time decreases but effect of decrease in relaxation time is much less than increase in number density.

**6. Application of a forward bias to p-n junction.**

(a) widens the depletion zone

(b) increases the potential difference across the depletion zone

(c) increases the number of donors on the n side

(d) decreases the electric field in the depletion zone.

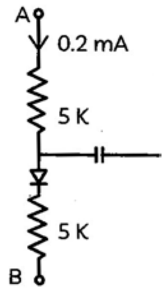
**Ans.** (d) decreases the electric field In the depletion zone.

**Explanation:** The application of forward bias to a p-n junction decreases the barrier field in the depletion region.

**7. In the circuit shown in Fig., 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




**Ans.** (b) 2.3 V

**Explanation:** Let the potential difference between A and B is $V_{AB}$

Then,

$$V_{AB} - 0.3 = [(r_1 + r_2)10^3] \times (0.2 \times 10^{-3})$$

$$= [(5 + 5)10^3] \times (0.2 \times 10^{-3})$$

$$= 2$$

$$\Rightarrow V_{AB} = 2 + 0.3 = 2.3V$$

**8. If a full wave rectifier circuit is operating from 50 Hz mains, the fundamental frequency in the ripple will be**

(a) 24 Hz (b) 50 Hz

(c) 70.7 Hz (d) 100 Hz

**Ans.** (d) 100 Hz

**Explanation:** In a full wave rectifier, fundamental frequency in the ripple = 2× input frequency

$$= 2 \times 50 = 100\ Hz.$$

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## ASSERTION-REASON QUESTIONS

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

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

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

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

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

**9. Assertion (A): A pure semiconductor has negative temperature coefficient of resistance.**

**Reason (R): On raising the temperature, more charge carries are released, conductance increases and resistance decreases.**

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

**10. Assertion (A): In a transistor amplifier, the output voltage is always out of phase with the input voltage.**

**Reason (R): The emitter base junction is reverse biased and the base collector junction is forward biased.**

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

**11. Assertion (A): Gallium arsenide phosphide is used for making LEDs.**

**Reason (R): Valence and conduction bands overlap in case of semiconductors.**

**Ans.** (b) Both A and R are true but R is NOT the correct explanation of A.

**Explanation:** Gallium arsenide phosphite has a minimum band gap pf 1,8 eV required for emission of visible light,

**12. Give the ratio of the number of holes and the number of conduction electron in an intrinsic semiconductor.**

**Ans.** The ratio of the number of holes and the number of conduction electrons in an intrinsic . semiconductor is equal to one. Because the number of electrons is equal to the number of holes.

**13. Why can't we take one slab of p-type semiconductor and physically join it to another slab of n-type semiconductor to get $p-n$ junction?**

**Ans.** A slab of *p*-type or *n*-type semiconductor, howsoever flat, will have roughness much larger than the interatomic crystal spacing. Hence, on joining *p*- and *n*-type slabs continuous contact at the atomic level is not possible and the two will not join together. In fact the junction will behave as a discontinuity.

**14. In a full wave rectifier, the input as has rms value of 12 V. The transformer used is a step up one having transformation ratio 1:2. The dc voltage in the rectified output.**

**(a) 20.9 V** **(b) 21V**

**(c) 21.6V** **(d)22V**

**Ans. (C) 21.6V**

**Explanation:** Here, input, $V_{rms} = 12\ V$

Peak input voltage,

$$V_0 = \sqrt{2}\, V_{rms} = 12\sqrt{2}\, V$$

Since, the transformer is a step up transformer, having turns ratio 1 : 2, so the maximum output voltage of the transformer applied to the diodes will be

$$V_0' = 2V_0 = 2 \times 12\sqrt{2}$$

$$= 24\sqrt{2}V$$

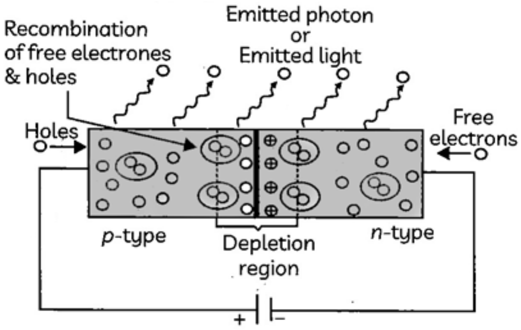
D.C. voltage output,

$$V_{dc} = \frac{2V_0}{\pi} = \frac{2 \times 24\sqrt{2}}{3.14}$$

$$= 21.63V$$

$$D_{dc} = 21.6V$$

**15.** A LED display is a flat panel display that uses an array of light- emitting diodes as pixels for a video display. Their brightness allows them to be used outdoors where they are visible in the sun for store signs and billboards. In recent years, they have also become commonly used in destination signs on public transport vehicles, as well as variable - message signs on highways. LED displays are capable of providing general illumination in addition to visual display, as when used for stage lighting or other decorative (as opposed to informational) purposes.



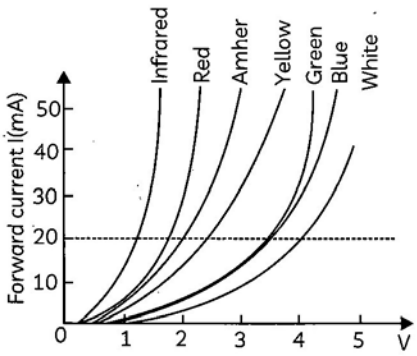

**(A) State two advantage of LED lamps over conventional incandescent lamps. Draw the V-l characteristic of LED.**

**(B)Distinguish between the light emitting diode and the photo diode.**

**Ans.** (A) Advantages of LEDs over conventional lamps:

1. Low operational voltage and less power consumption.

2. Long life and ruggedness. V-l characteristic



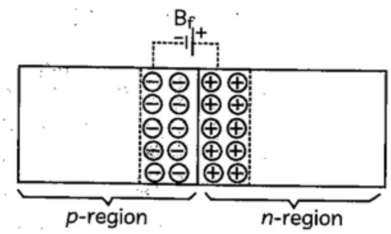

(B) Difference between light emitting diode and photo diode

| Light Emitting Diode LED | Photodiode |
|---|---|
| 1. It is forward biased. | 1. It is reverse biased. |
| 2. Recombination of electrons and holes takes place at the junction and emits e.m. radiation | 2. Energy (hv) is supplied by light to take an electron from valence band to conduction band. |

**16. Define the terms 'depletion layer' and 'barrier potential' for a p-n junction. How does (A) an increase in the doping concentration, and (B) biasing across the junction, affect the width of the depletion layer?**

**Ans.** Formation of depletion layer: When p-n junction is prepared, electrons from n-region diffuse into p-region and holes diffuse from n-p, it leaves behind an ionized donor on n-side. This ionized donor (positive charge) is immobile as it is bonded to the surrounding atoms. Thus, due to diffusion of electrons from n-p, a layer of positive space charge is developed on n-side of the junction. Similarly due to diffusion of holes from p-n a layer of negative space charge on the p-side of the junction is developed. This space charge region on either side of the junction together is known as the "depletion region" or "depletion layer".

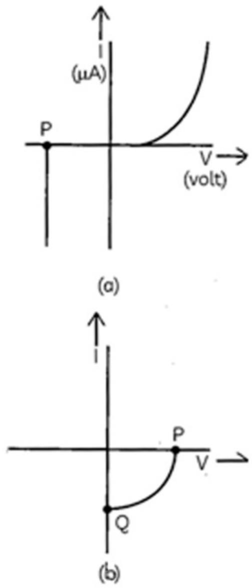
**Barrier potential:** Due to diffusion of holes from p-region to *n*-region and diffusion of electrons in the reverse direction, part of depletion, layer on *n*-side of junction becomes positively. charged and the part of depletion layer on *p*-type of junction becomes negatively charged. Thus, a junction potential is developed, which opposes further diffusion of holes/ electrons. Hence, this potential acts as a barrier and is known as "barrier potential$V_B$ –




(1) The width of the depletion Layer decreases on increasing the doping concentration.

(2) In forward biasing arrangement the .width of depletion layer decreases but in reverse b iasing the width of depletion layer increases..

17.




**(A) Name the type of a diode whose characteristics are shown in Fig. (a) and Fig.(b).**

**(B) What does the point P in fig. (b) represent?**

**(C) What does the points P and Q in Fig.(b) represent?**

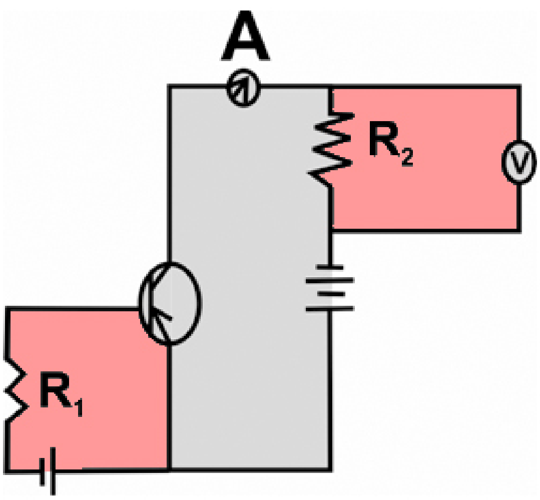
**Ans.** (A) Fig. (a) shows the characteristics of Zener diode and (b) is of solar cell.

(B) Point P in fig. (a) represents Zener breakdown voltage.

(C) The point Q in fig. (b) represents the short circuit current.

The point P in fig. (b) represents open circuit voltage.

**18. If the resistance $R_1$ is increased (Fig.), how will the readings of the ammeter and voltmeter change?**




**Ans.** Base current $I_B = (V_{BB} - V_{BE})/\ R_1$

So, $R_1$ is increased, $1_B$ is decreased. Now, the current in ammeter is collector current $I_c$ Since, $I_C = \beta I_B$ as $I_B$ is decreased, $I_C$ is also decreased and the reading of voltmeter and ammeter also decreased.

**19. Distinguish between an intrinsic semiconductor and p-type semiconductor. Give reason, why, p-type semiconductor crystal is electricity neutral, although $n_h \gg n_e$?**

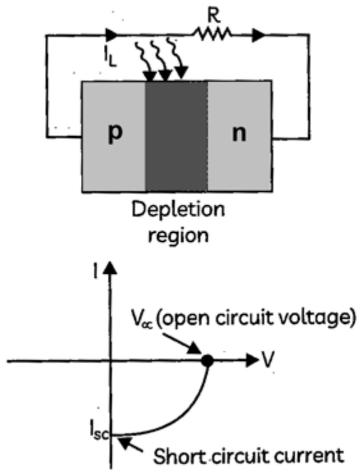
**Ans.** Intrinsic semiconductor is a pure semiconductor which is free from any impure atoms.

**P-type semiconductor:** When a semiconductor is doped with a trivalent atoms like indium, boron or aluminium (acceptor atom) the resulting material has excess holes and is called p-type semiconductor. In p-type semiconductor $n_h \gg n_e$.

A p-type semiconductor is electrically neutral, because the charge of additional charge is just equal and opposite to that of the ionized cores in the lattice.

**20. Draw a circuit diagram to show biasing of a solar cell. Draw its characteristic curve and explain it.**

**Ans.** A circuit diagram showing biasing of a typical p-n junction solar celt has been given in fig (a) When light (with photon energy $h\nu$ falls at the junction, electron-hole pairs are generated which move in mutually opposite directions due to the junction field. If no external load is connected or if the circuit of solar cell is open, electrons and holes are collected at the two sides of the junction giving a photo-voltage $V_{oc}$. When external load R is connected, a photo-current $I_L$ flows, For R = 0, the current has a maximum value $I_{SC}$ which is known as short circuit current. V-I characteristics is shown in fig (b). The graph is in the fourth quadrant because a solar cell does not draw current but supplies current to the load.

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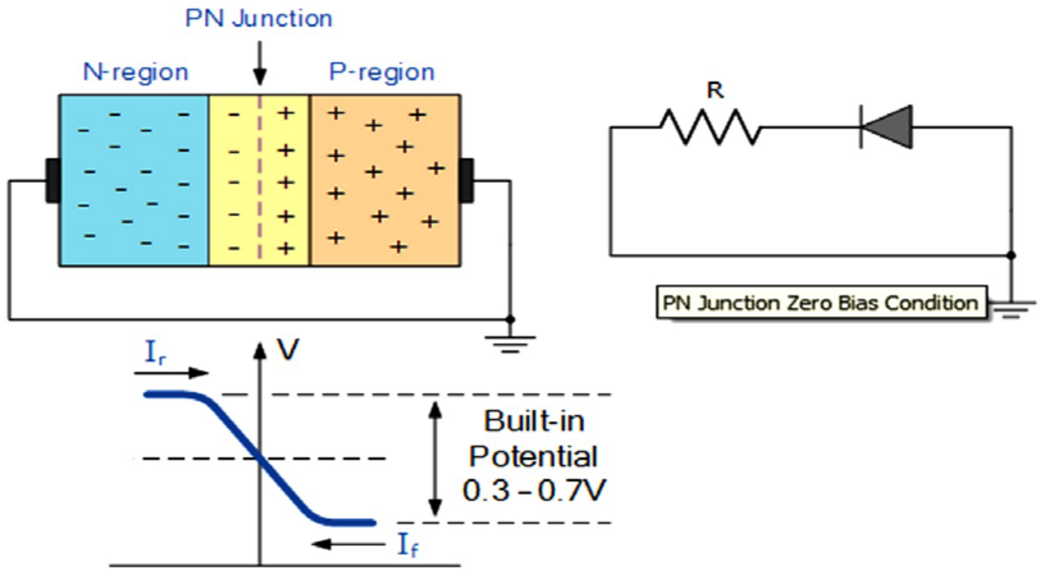
## LONG QUESTION WITH ANSWER

**21. What is a PN Junction Diode with a neat sketch describe its performance. Explain barfly the IV characteristic of a PN junction Diode.**



**PN Junction Diode**

A PN-junction diode is formed when a p-type semiconductor is fused to an n-type semiconductor creating a potential barrier voltage across the diode junction

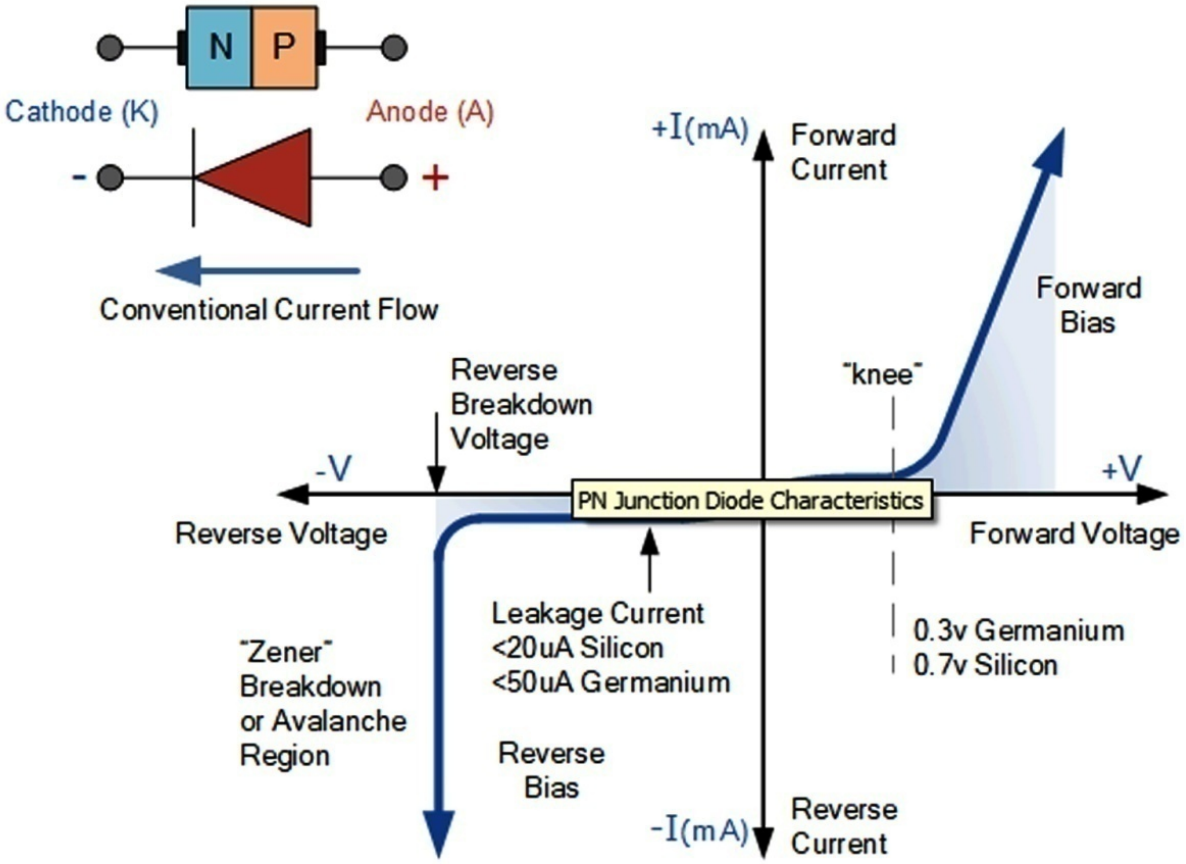
A *PN Junction Diode* is one of the simplest semiconductor devices around, and which has the characteristic of passing current in only one direction only. However, unlike a resistor, a diode does not behave linearly with respect to the applied voltage as the diode has an exponential current-voltage ( I-V ) relationship and therefore we can not describe its operation by simply using an equation such as Ohm's law.

If a suitable positive voltage (forward bias) is applied between the two ends of the PN junction, it can supply free electrons and holes with the extra energy they require to cross the junction as the width of the depletion layer around the PN junction is decreased.

By applying a negative voltage (reverse bias) results in the free charges being pulled away from the junction resulting in the depletion layer width being increased. This has the effect of increasing or decreasing the effective resistance of the junction itself allowing or blocking the flow of current through the diodes pn-junction.

Then the depletion layer widens with an increase in the application of a reverse voltage and narrows with an increase in the application of a forward voltage. This is due to the differences in the electrical properties on the two sides of the PN junction resulting in physical changes taking place.

**Junction Diode Symbol and Static I-V Characteristics**




But before we can use the PN junction as a practical device or as a rectifying device we need to firstly **bias** the junction, that is connect a voltage potential across it. On the voltage axis above, "Reverse Bias" refers to an external voltage potential which increases the potential barrier. An external voltage which decreases the potential barrier is said to act in the "Forward Bias" direction.

There are two operating regions and three possible "biasing" conditions for the standard **Junction Diode** and these are:

1. Zero Bias – No external voltage potential is applied to the PN junction diode.

2. Reverse Bias – The voltage potential is connected negative, (-ve) to the P-type material and positive, (+ve) to the N-type material across the diode which has the effect of **Increasing** the PN junction diode's width.

3. Forward Bias – The voltage potential is connected positive, (+ve) to the P-type material and negative, (-ve) to the N-type material across the diode which has the effect of **Decreasing** the PN junction diodes width.

**Increase in the Depletion Layer due to Reverse Bias**

This condition represents a high resistance value to the PN junction and practically zero current flows through the junction diode with an increase in bias voltage. However, a very small **reverse leakage current** does flow through the junction which can normally be measured in micro-amperes, ( μA).

**Reverse Characteristics Curve for a Junction Diode**

Sometimes this avalanche effect has practical applications in voltage stabilising circuits where a series limiting resistor is used with the diode to limit this reverse breakdown current to a preset maximum value thereby producing a fixed voltage output across the diode. These types of diodes are commonly known as Zener Diodes and are discussed in a later tutorial.

**Forward Characteristics Curve for a Junction Diode**

The application of a forward biasing voltage on the junction diode results in the depletion layer becoming very thin and narrow which represents a low impedance path through the junction thereby allowing high currents to flow. The point at which this sudden increase in current takes place is represented on the static I-V characteristics curve above as the "knee" point.

**Reduction in the Depletion Layer due to Forward Bias**

This condition represents the low resistance path through the PN junction allowing very large currents to flow through the diode with only a small increase in bias voltage. The actual potential difference across the junction or diode is kept constant by the action of the depletion layer at approximately 0.3v for germanium and approximately 0.7v for silicon junction diodes.

Since the diode can conduct "infinite" current above this knee point as it effectively becomes a short circuit, therefore resistors are used in series with the diode to limit its current flow. Exceeding its maximum forward current specification causes the device to dissipate more power in the form of heat than it was designed for resulting in a very quick failure of the device.

**22. What are energy bands? How are these formed? Distinguish between a conductor, an insulator and a semiconductor on the basis of energy band diagram.**

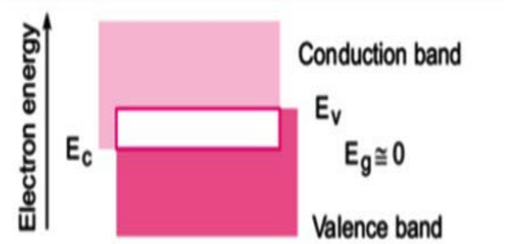
**Ans.** In solids due to strong overlapping of different atomic orbitals, electron energies reveal themselves in the form of a group of energy levels belonging to that solid as a whole. These are called energy bands.

**Formation of energy bands:** In a crystal containing N atoms there are discrete energy levels for the electrons. When atoms, are isolated, electron energy levels are identical in each one of them. When atoms begin to come closer to form a solid these electrons (mainly electrons in the outermost orbit) interact with each other and with: neighbouring atomic cores. Due to these interaction energies of the . electrons in the outermost orbit change. These energies spread out to form an energy band. Finally, if distance between atoms approaches the actual interatomic spacing of the solid then energy bands again split and are separated by an energy gap $E_g$.

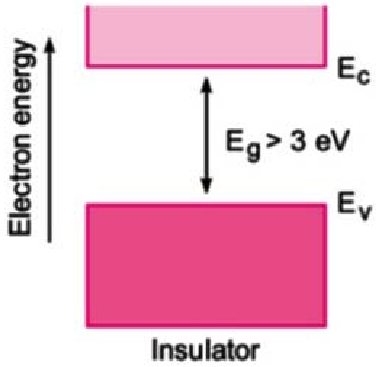
The band which is completely filled is called valence band and the band completely empty is known as conduction band.

At equilibrium spacing, the lowest conduction band energy is $E_c$ and highest valence band energy is $E_v$. The gap between the top of the valence band and bottom of the conduction band is **called energy band gap.**

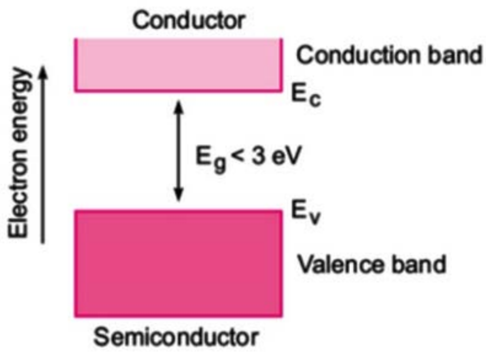
**Conductors:** In case of conductors conduction and valence bands overlap, i.e., $E_g = 0$. Large no. of electrons are there for electrical conduction. Therefore, resistance of conductors is low and conductivity is high.




**Insulators:** In insulators a large band gap $E_g$ exists $(E_g > 3eV)$. There are no electrons in the conduction band. Thus no electrical conduction possible.




Semiconductor: In semiconductors these is a finite but small band gap ($E_g$< 3 eV). Some electrons can be thermally excited to conduction band. Hence, resistance would not be asihigh as that of the insulates.

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