Chapter 1
Electric charges and fields

1.When a glass rod is rubbed with silk, glass rod becomes positively charged and silk negative.
When a plastic rod is rubbed with fur, plastic rod becomes negatively charged and fur positive.

2.When a glass rod is rubbed with silk, charges appear on both. Explain how this observation is consistent with law of conservation of energy.

When two bodies are rubbed ,the body which loses electrons, will become positively charged and which gains electrons becomes negatively charged. The two bodies thus acquire equal and opposite charges . The charge is only transformed from one form to another.

3.Write the basic properties of electric charge

- **Quantization of charge** : **According to quantisation of electric charge, charge of a body is an integral multiple of electronic charge.**
  $q=\pm ne$; where, n=1,2,3.........
- **Charge is conserved**: It means that total charge of an isolated system remains constant.
- **Additivity of charge**: The total charge on a surface is the algebraic sum of individual charges present on that surface.

$$q = q_1 + q_2 + q_3 + \dots\dots\dots\dots + q_n$$

4.What do you mean by quantisation of charge

Charge of a body is always an integral multiple of one electronic charge
$Q=\pm ne$ where n=1,2,3.......

5.How many electronic charges form 1 C of charge?

$$q=\pm ne,$$
$$n=\frac{q}{e}$$
$$n=\frac{1}{1.602 \times 10^{-19}} = 6.25 \times 10^{18}$$

6.How many electrons constitute an electric charge of -16μ C of charge?

$$q=\pm ne,$$
$$n=\frac{q}{e}$$
$$n=\frac{-16 \times 10^{-6}}{-1.6 \times 10^{-19}} = 10^{14}$$

7.State coulomb's law.

The force of attraction or repulsion between two stationery electric charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them

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

8.What is the force between two small charged spheres having charges 2 x10^{-7}C and 3x10^{-7}C placed 30cm apart in air.

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

$$= 9x\,10^9 \;\frac{2\,\text{x}10^{-7}\;x\;3\,\text{x}10^{-7}}{(0.3)^2} = 6\text{x}10^{-3}N$$

9.A body of mass m is charged negatively. State whether the following statements are true or false.

a)During charging, there is change in mass of body. True

b) The body can be charged to 2.5e where 'e' is the charge of an electron. False

c) While charging the body by induction new charges are created in it. False

d) The force between two charged objects is less when there is a medium between them (than in vacuum) True

10.Define electric field.

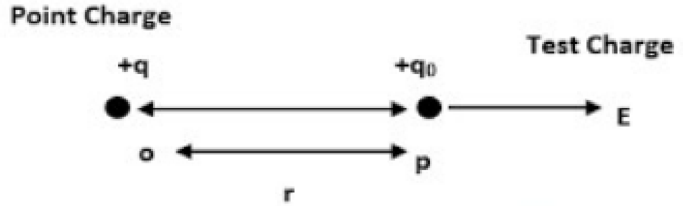
Electric field is the region around a charge where its effect can be felt.

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

11. Write the unit of electrc field.

$$\frac{N}{C} \text{ or } \frac{V}{m}$$

12. Derive the equation for Electric field due to a point charge



By Coulomb's law,

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

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

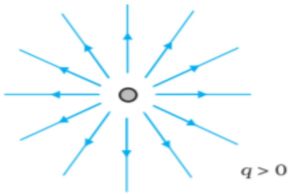
$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

13.Write any four properties of electric field lines

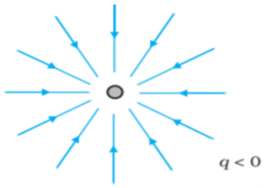
An electric field line is a curve drawn in such a way that the tangent to it at each point is in the direction of the net field at that point.

- Electric Field lines start from positive charge, end at negative charge.
- Electric field lines of a positive charge are radially outwards and that of a negative charge is radially inwards
- Electric field lines Do not form closed loops.
- Two field lines never intersect.(two directions for electric field is not possible at a point)

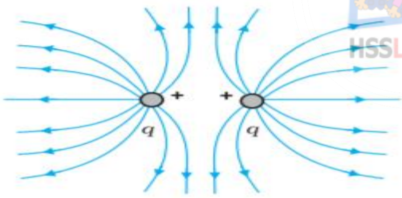
14.Draw the electric field lines of a positive charge



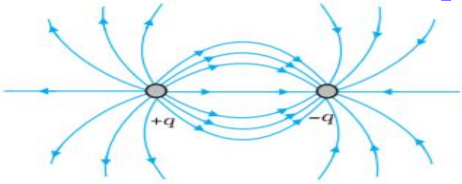
15.Draw the electric field lines of a negative charge



16.Draw the electric field lines of two positive charges



17.Draw the electric field lines of a dipole



18.Define Electric Flux. Write its unit.

The electric flux associated with a surface is the number of electric field lines passing normal through a surface.

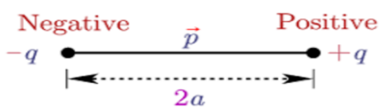
$$\phi = \int E \cdot dS$$

$$\phi = \int E\, dS \cos\theta$$

Unit- Nm^2/C

19.Define electric dipole

An electric dipole is a pair of equal and opposite charges separated by a distance



20.Define electric dipole moment. Write its unit

Electric dipole moment is the product of magnitude of one of the charges and the distance between charges

p=q x 2a

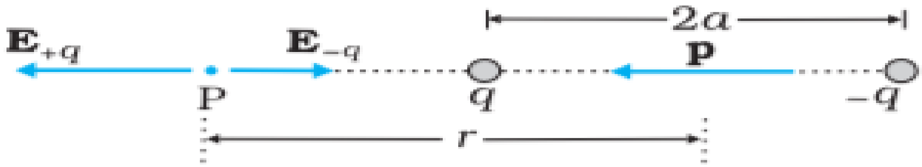
Unit -Cm (coulomb metre)

21.Write the difference between polar and non polar molecules.

In non polar molecules the centres of positive and negative charges coincide. Eg: CO_2, CH_4,

In polar molecules the centres of positive and negative charges do not coincide. Eg : H_2O

22.Derive the equation for electric field due to a dipole along the axial line



$$E_{+q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2} \quad \text{-------------(1)}$$

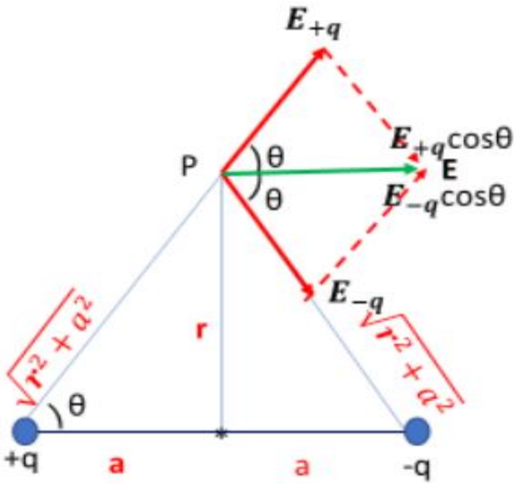
$$E_{-q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2} \quad \text{------------(2)}$$

$$E = E_{+q} - E_{-q}$$

$$E = \frac{q}{4\pi\varepsilon_0}\left[\frac{4ar}{(r^2-a^2)^2}\right] \quad \text{------------(3)}$$

For r≫ a ,we get $\vec{E} = \frac{1}{4\pi\varepsilon_0}\left[\frac{2\vec{p}}{r^3}\right]$ ------------(4)

23.Obtain the equation for electric field due to a dipole along equatorial line



$$E_{+q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+a^2} \quad \text{----------------(1)}$$

$$E_{-q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+a^2} \quad \text{------------------(2)}$$

$$E = E_{+q}cos\theta + E_{-q}cos\theta$$

$$E = 2E_{+q}cos\theta \quad \text{--------------(3)} \quad (E_{+q} = E_{-q})$$

$$Cos\theta = \frac{a}{(r^2+a^2)^{1/2}}$$

$$E = 2 \; x \; \frac{1}{4\pi\varepsilon_0} \quad \frac{q}{r^2 + a^2} \quad x \quad \frac{a}{(r^2+a^2)^{1/2}}$$

For r≫ a ,we get $\vec{E} = \frac{1}{4\pi\varepsilon_0}\left[\frac{\vec{p}}{r^3}\right]$ ----------------(4)

24.Relation connecting Axial field and Equatorial field of a Dipole

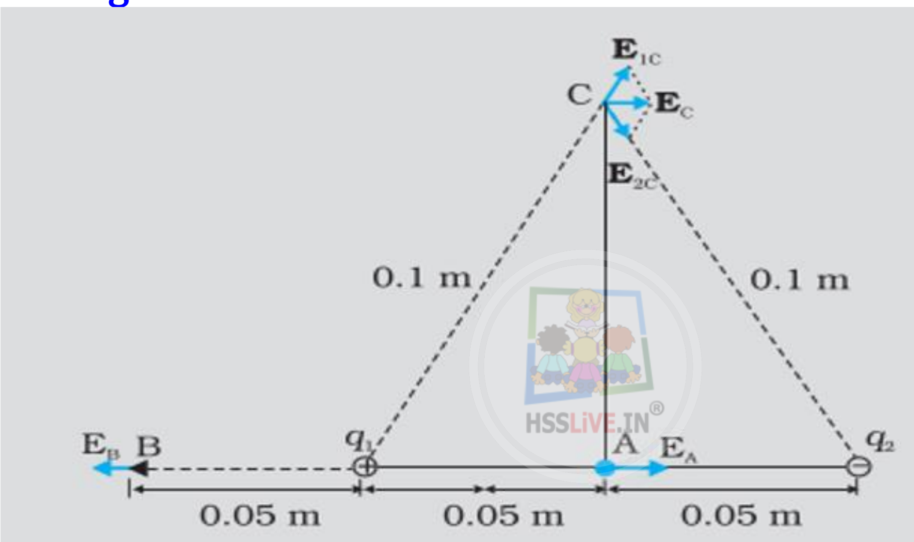
$$E_{Axial} = \frac{1}{4\pi\varepsilon_0}\left[\frac{2\vec{p}}{r^3}\right]$$

$$E_{Equatorial} = \frac{1}{4\pi\varepsilon_0}\left[\frac{\vec{p}}{r^3}\right]$$

$$E_{Axial} = 2 \text{ x } E_{Equatorial}$$

E_{Axial} : $E_{Equatorial}$ =2:1 or $E_{Equatorial}$: E_{Axial} =1:2

25.Two point charges q_1 and q_2 of magnitude 10^{-8}C and -10^{-8}C respectively are placed 0.1m apart. Calculate the electricfields at points A, B and C as shown in figure.



At point A

E_{1A} (to right) and E_{2A} (to right) have same direction

$$E_A = E_{1A} + E_{2A}$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{10^{-8}}{(0.05)^2} + \frac{1}{4\pi\varepsilon_0} \frac{10^{-8}}{(0.05)^2}$$

$$= 9\text{x}10^9 \text{ x } \frac{10^{-8}}{(0.05)^2} + 9\text{x}10^9 \text{ x } \frac{10^{-8}}{(0.05)^2}$$

$$= 3.6 \text{ x}10^4 \text{N C}^{-1} + 3.6 \text{ x}10^4 \text{N C}^{-1}$$

$$= 7.2 \text{ x}10^4 \text{N C}^{-1}$$

E_A is directed towards the right

At point B

E_{1B} (to left)and E_{2B} (to right) have opposite direction

$$E_B = E_{1B} - E_{2B}$$

$$= 9\text{x}10^9 \text{ x } \frac{10^{-8}}{(0.05)^2} - 9\text{x}10^9 \text{ x } \frac{10^{-8}}{(0.15)^2}$$

$$= 3.6 \text{ x}10^4 \text{N C}^{-1} - 0.4 \text{ x}10^4 \text{N C}^{-1} = 3.2 \text{ x}10^4 \text{N C}^{-1}$$

E_B is directed towards the left (as E_{1B} has greater magnitude)

At point C

E_{1C} and E_{2C} have same magnitude.

$$E_{1C} = E_{2C} = 9\text{x}10^9 \text{ x } \frac{10^{-8}}{(0.1)^2} = 9\text{x}10^3 \text{ N C}^{-1}$$

$$E_C = E_{1C} \cos 60 + E_{2C} \cos 60$$

$$= 2\, E_{1C} \cos 60$$

$$= 2\text{x } 9\text{x}10^3 \text{ x } 0.5 \qquad = 9 \text{ x}10^3 \text{N C}^{-1}$$

E_C is directed towards the right.

26.What will happen when a dipole is placed in a uniform external electric field?

In a uniform electric field there will be a net torque on the dipole, and hence it rotates. But the net force will be zero.

27.What will happen when a dipole is placed in a non uniform external electric field?

In a non uniform electric field the dipole experiences a net force as well as a net torque. So there will be both translational and rotational motion.

28.Derive the expression for torque acting on a dipole placed in a uniform external field, at an angle θ with it.

Torque, τ = one of the forces x perpendicular distance between them.

$\tau = qE \text{ x } 2a \sin\theta$

$\tau = pE \sin\theta$

$\vec{\tau} = \vec{P} \times \vec{E}$

29.What is the condition for maximum torque in the above case?

Torque is maximum , when p and E are perpendicular. (θ=90)

$$\tau = pE \sin 90 = pE$$

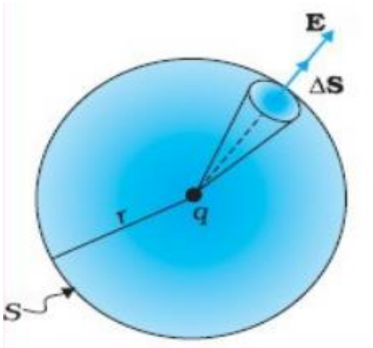
30.State Gauss's theorem.

Gauss's theorem states that the total electric flux through a closed surface is equal to $\frac{1}{\varepsilon_0}$ times the total charge enclosed by the surface.

$$\phi = \oint E \cdot dS = \frac{q}{\varepsilon_0}$$

31.Give proof for Gauss's theorem

Consider a sphere of radius r enclosing a point charge q. the electric flux through the surface dS



$$\phi = \int E \cdot dS$$

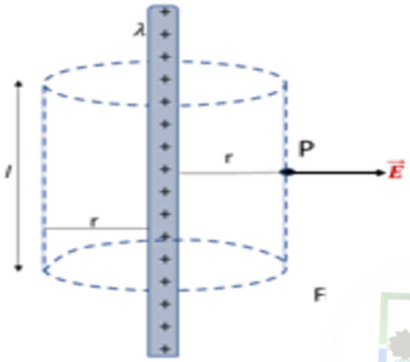
$$\phi = \int E\, dS \cos 0 = \int E\, dS = E\int dS$$

$$\phi = ES$$

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

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

32.Derive the equation for electirc field due to a uniformly charged infinitely long wire

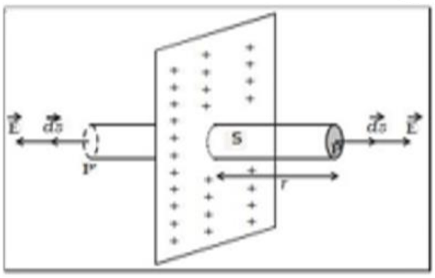


$$\phi = ES = \frac{q}{\varepsilon_0}$$

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

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

33.Derive the equation for electric field due to a uniformly charged infinite plane sheet

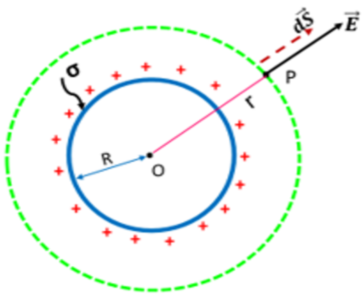


$$\phi = 2\,ES = \frac{q}{\varepsilon_0}$$

$$2\,ES = \frac{\sigma S}{\varepsilon_0}$$

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

34.Derive the equation for electric field due to a uniformly charged spherical shell



(i)Field outside the shell

$$\phi = ES = \frac{q}{\varepsilon_0}$$

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

$$\mathbf{E} = \frac{\sigma R^2}{\varepsilon_0 r^2}$$

(ii)Field on the surface of the shell

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

(iii)Field inside the shell

$$\mathbf{E = 0}$$

35.Features of Gauss's Law

- Gauss's law is true for any surface irrespective of the size and shape.
- The charge includes the sum of all charges enclosed by the surface.
- The surface that we choose for the application of Gauss's law is called the Gaussian Surface.
- Gauss's law is applicable to both symmetric and asymmetric system, but it will be much easier if the system has some symmetry.
- Gauss's law is based on inverse square dependence on distance contained in the Coulomb's law.

36.What is meant by a Gaussian surface?

The surface which we choose for the application of Gauss's law is called Gaussian surface. It is an imaginary three dimensional surface enclosing the charge.

37.The electric flux through any closed spherical surface enclosing a charge q is given by --------

$$\frac{q}{\varepsilon_0}$$

38.A point charge of 2 μc is placed at the centre of a cubic Gaussian surface of side 0.5 cm. What is the next flux through the surface?

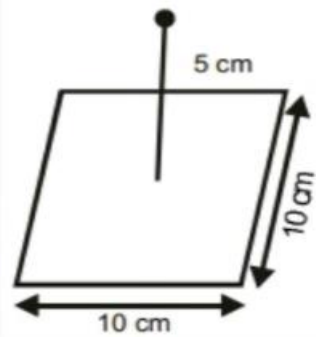
$$\phi = \frac{2\text{ x}10^{-6}}{8.85\text{ x}10^{-12}}$$

$$=2.25\text{ x}10^{6}\ Nm^2/C$$

39.Imagine that a charge 'Q' is situated at the centre of a hollow cube. What is the electric flux through one side of the cube?

$$\phi = \frac{1}{6}\frac{Q}{\varepsilon_0} \quad \text{(cube has 6 sides)}$$

40.A point charge of $+10\mu$ Cis at a distance of 5cm directly above the centre of a square of side 10cm as shown in figure. What is the electric flux through the square?



The given charge can be imagined to be at the centre of a cube.
So electric flux through the square

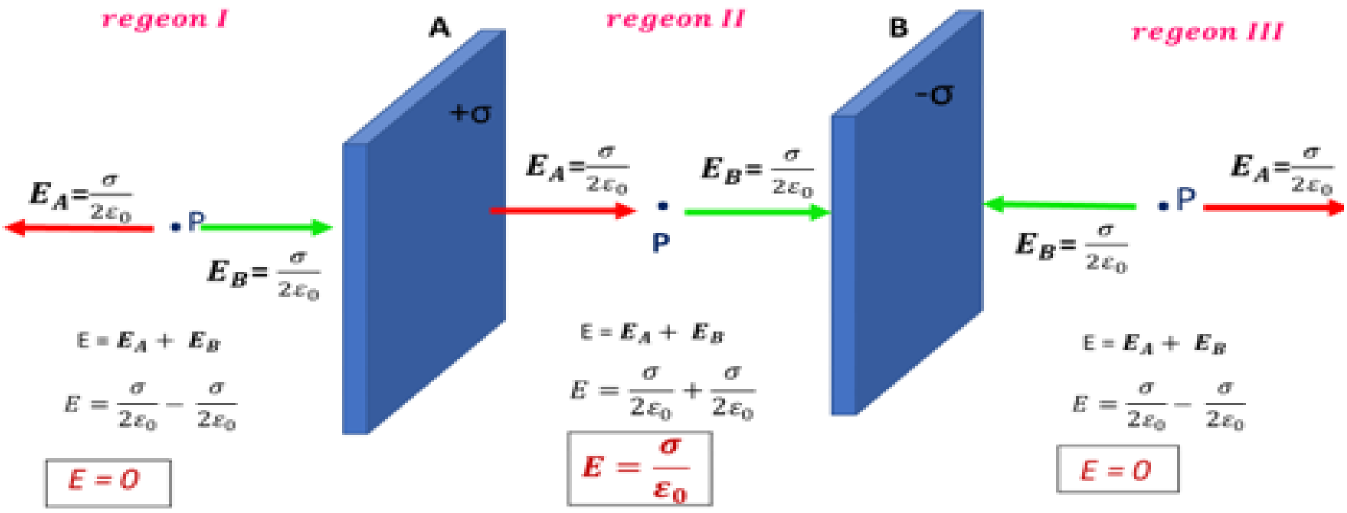
$$\phi = \frac{1}{6}\frac{q}{\varepsilon_0}$$

$$= \frac{1}{6} x \frac{10x10^{-6}}{8.85x10^{-12}} \quad =1.88x10^5\ N\ m^2\ C^{-1}$$

41.A closed surface encloses an electric dipole. What is the electric flux through the surface?

Zero

42.Find electric field due two plane sheets of charge in regions I ,II and III



Chapter 2
Electrostatic Potential and Capacitance

1.Define electrostatic potential energy . Write its unit .

Electric potential energy at a point P in an electric field is defined as the work done by the external force in bringing the charge q from infinity to that point.

$$\mathbf{U = -\int_{\infty}^{P} F \,.\, dr} \qquad \textbf{unit -joule (J)}$$

2. Define electrostatic potential. Write its unit

Electrostatic Potential at a point P in an electric field is the work done by an external force in bringing a unit positive charge from infinity to that point.

$$\mathbf{V = -\int_{\infty}^{P} E \,.\, dr} \qquad \textbf{unit - volt (V)}$$

3. One coulomb of charge initially at rest is accelerated through a potential difference of 1 volt. During this process the kinetic energy acquired by the charge is ....

KE =W=qV =1 x1 =1J

4.Write the relation connecting electric field and potential.

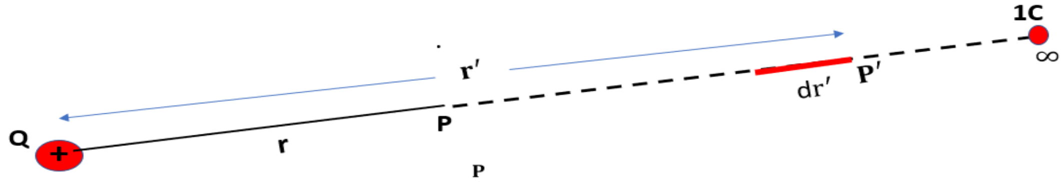
$$V = -\int_{\infty}^{P} E \,.\, dr \quad \text{or} \quad E = \frac{-dV}{dr}$$

5.Define electrostatic potential between two points.

Electrostatic Potential difference between two points in an electric field is the work done by an external force in bringing a unit positive charge from one point to other in that field.

$$V_P - V_R = -\int_{R}^{P} E \,.\, dr$$

6.Obtain the equation for electric field due to a point charge.



$$V = -\int_{\infty}^{P} \mathbf{E} \cdot \mathbf{dr'}$$

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0} \frac{Q}{r'^2}$$

$$V = -\int_{\infty}^{r} \frac{1}{4\,\pi\varepsilon_0} \frac{Q}{r'^2}\, dr'$$

$$V = -\frac{Q}{4\pi\varepsilon_0} \times \left[\frac{-1}{r'}\right]_{\infty}^{r}$$

$$V = -\frac{Q}{4\pi\varepsilon_0}\left[\frac{-1}{r} - \frac{-1}{\infty}\right]$$

$$V = -\frac{Q}{4\pi\varepsilon_0}\left[\frac{-1}{r} - 0\right]$$

$$\mathbf{V = \frac{1}{4\pi\varepsilon_0} \frac{Q}{r}}$$

$$V \propto \frac{1}{r}$$

7) a) calculate the potential at a point P due to a charge of 4×10^{-7}C, located 9 cm away

b) Hence obtain the work done in bringing a charge of 2×10^{-9} C from infinity to the point P. Does the answer depend on the path along which the charge is brought?

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

$= 9 \times 10^9 \text{ x } \frac{4 \, x \, 10^{-7}}{0.09}$

$\mathbf{V = 4 \, x \, 10^4 V}$

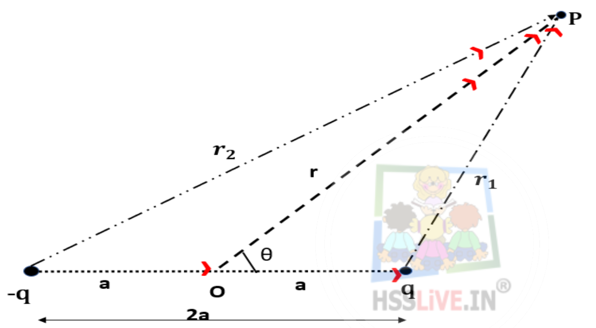
(b) W= qV

$= 2 \, x \, 10^{-9} \text{ x } 4 \, x \, 10^4$

$\mathbf{W = 8 \, x \, 10^{-5} \, J}$

No, work done will be path independent.

8.Derive the expression for potential due to an electric dipole



$$\mathbf{V = V_1 + V_2}$$

$$\mathbf{V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_1} + \frac{1}{4\pi\varepsilon_0}\frac{-q}{r_2}}$$

$$\mathbf{V = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)}$$

$$\mathbf{\frac{1}{r_1} - \frac{1}{r_2} = \frac{2\,a\cos\theta}{r^2}}$$

$$\mathbf{V = \frac{q}{4\pi\varepsilon_0}\frac{2\,a\cos\theta}{r^2}}$$

$$\mathbf{V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}}$$

9.Obtain the expression for potential due to a system of charges

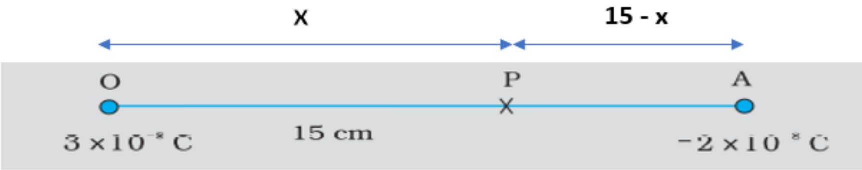
$$V = V_1 + V_2 + \cdots + V_n$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1} + \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_2} + \ldots\ldots\ldots\ldots + \frac{1}{4\pi\varepsilon_0}\frac{q_n}{r_n}$$

$$\mathbf{V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \ldots\ldots\ldots\ldots\ldots + \frac{q_n}{r_n}\right)}$$

10.Two charges $3\ x\ 10^{-8}$C and $-2\ x\ 10^{-8}$ C are located 15 cm apart. At what point on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero.

Let P lies between O and A at a distance x from O,



Potential at P due to charge $3\ x\ 10^{-8}$C

$$V_1 = \frac{1}{4\pi\varepsilon_0}\frac{3\ x\ 10^{-8}}{x}$$

Potential at P due to charge $-2\ x\ 10^{-8}$C

$$V_2 = \frac{1}{4\pi\varepsilon_0}\frac{-2\ x\ 10^{-8}}{15-x}$$

Total potential at P , $\quad V=V_1+V_2=0$

$$\frac{1}{4\pi\varepsilon_0}\frac{3\ x\ 10^{-8}}{x} - \frac{1}{4\pi\varepsilon_0}\frac{2\ x\ 10^{-8}}{15-x}=0$$

$$\frac{1}{4\pi\varepsilon_0}\left[\frac{3\ x\ 10^{-8}}{x} - \frac{2\ x\ 10^{-8}}{15-x}\right]=0$$

$$\left[\frac{3}{x} - \frac{2}{15-x}\right]=0$$

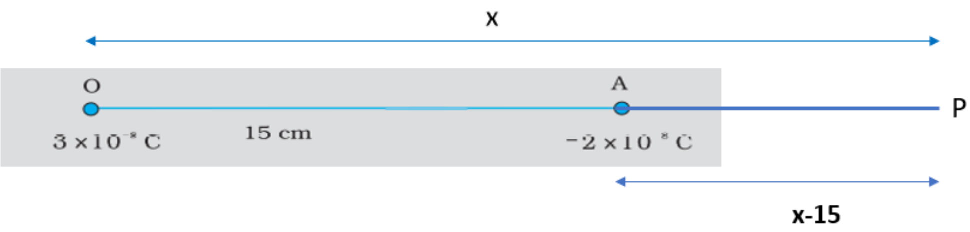
$$\frac{3}{x} = \frac{2}{15-x}$$

$$45-3x=2x$$

$$45=5x$$

$$x=9cm$$

If P lies on the extended line OA,



$$\frac{1}{4\pi\varepsilon_0}\frac{3\ x\ 10^{-8}}{x} - \frac{1}{4\pi\varepsilon_0}\frac{2\ x\ 10^{-8}}{x-15}=0$$

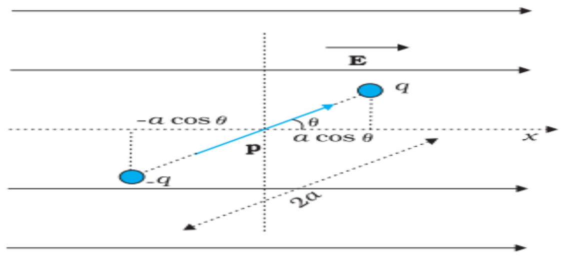
$$\frac{3}{x} = \frac{2}{x-15}$$

$$3x-45=2x$$

$$x=45cm$$

Thus, electric potential is zero at 9 cm and 45 cm away from the positive charge on the side of the negative charge.

11.Derive the expression for potential energy of a dipole placed in an external field.



The workdone by the external torque

$$dW = \tau \, d\theta$$

$$dW = pE\sin\theta \, d\theta$$

$$W = \int pE\sin\theta \, d\theta$$

$$W = -\, pE\cos\theta$$

$$W = -\bar{p} \cdot \bar{E}$$

This work is stored as potential energy

$$\mathbf{U = -\bar{p} \cdot \bar{E}}$$

12. Define Equipotential Surfaces

An equipotential surface is a surface with a constant value of potential at all points on the surface.

13.Write the properties of an equipotential surface

- Constant value of potential at all points on the surface.
- No work is required to move a test charge on the surface.
- Equipotential surface through a point is normal to the electric field at that point

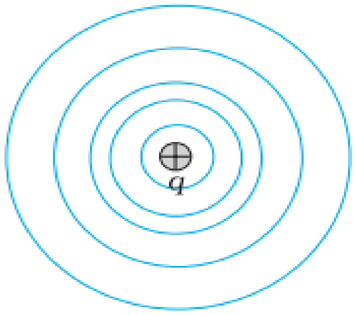
14.The workdone to move a test charge on an equipotential surface is ……..

Zero

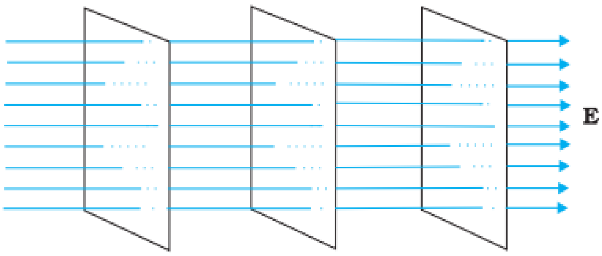
15.What is the amount of workdone in moving a 2C charge between two points at 3cm apart of an equipotential surface?

Zero

16.Draw the equipotential surfaces for a single point charge



17.Draw the equipotential surfaces for a uniform electric field.



18.Electrostatics of conductors

1.Inside a conductor, electrostatic field is zero
2. At the surface of a charged conductor, electrostatic field must be normal to the surface at every point.
3. The interior of a conductor can have no excess charge in the static situation.
4. Electrostatic potential is constant throughout the volume of the conductor and has the same value (as inside) on its surface.
5.Electric field at the surface of a charged conductor $E = \frac{\sigma}{\varepsilon_0}$

19.Explain electrostatic shielding

The electric field inside a cavity of any conductor is zero. This is known as electrostatic shielding. All charges reside only on the outer surface of a conductor with cavity.

20.Why it is safer to be inside a car during lightning?

Due to Electrostatic shielding, electricfield E=0 inside the car.
So it is safer to sit inside a car than standing outside during lightening.

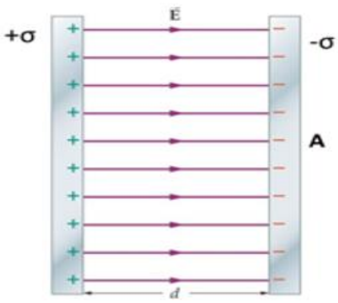
21.Define capacitance. Write its unit.

Capacitance is the ratio of charge to potential

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

The SI unit of capacitance is farad (F).

22. Obtain the equation for capacitance of a parallel plate capacitor



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

$$C = \frac{\sigma A}{\frac{\sigma d}{\varepsilon_0}}$$

$$\boxed{C = \frac{\varepsilon_0 A}{d}}$$

23.How capacitance changes if the distance between the plates of a parallel plate capacitor is halved?

$C=\frac{\varepsilon_0 A}{d/2}=2\frac{\varepsilon_0 A}{d}$ Capacitance doubled

24.What is the area of plates of a 0.1μF parallel plate capacitor ,given that the separation between the plates is 0.1mm

$$C = \frac{\varepsilon_0 A}{d}$$

$$A = \frac{Cd}{\varepsilon_0} = \frac{0.1\ x\ 10^{-6}\ x\ 0.1\ x\ 10^{-3}}{8.85\ x\ 10^{-12}}$$

$$= 10.47\ x 10^3\ m^2$$

25.A dielectric slab is placed between the plates of a parallel plate capacitor. What change will happen to its capacitance?

When dielectric medium of dielectric constant K is placed between the plates, the capacitance ,

$$C_{med} = \frac{K\varepsilon_0 A}{d}$$

$$C_{med} = K\ C_{air}$$

The capacitance increases K times, where K is the dielectric constant.

26.Define dielectric constant in terms of capacitance.

$$\frac{C_{med}}{C_{air}} = \frac{\frac{K\varepsilon_0 A}{d}}{\frac{\varepsilon_0 A}{d}} = K$$

$$K = \frac{C_{med}}{C_{air}}$$

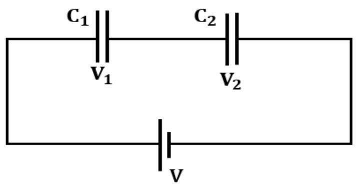
The dielectric constant of a substance is the factor by which the capacitance increases from its vacuum value, when a dielectric is inserted between the plates.

27.A parallel plate capacitor with air between plates has a capacitance of 8µF. What will be the capacitance if distance between the plates is reduced by half and the space between is filled with a medium of dielectric constant 5.

$$C = \frac{\varepsilon_0 A}{d} = 8\mu F$$

$$C' = \frac{K\varepsilon_0 A}{d/2} = 2K\frac{\varepsilon_0 A}{d} = 2\ x\ 5\ x\ 8\mu F = 80\ \mu F$$

28. Obtain the equation for effective capacitance when capacitors are connected in series.

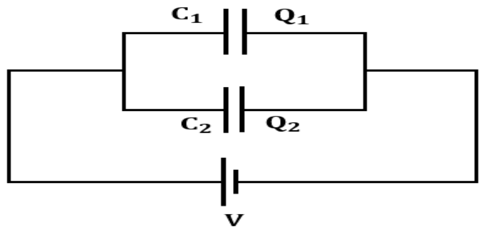


$$V = V_1 + V_2$$

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

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

29. Obtain the equation for effective capacitance when capacitors are connected in parallel.



$$Q = Q_1 + Q_2$$
$$CV = C_1V + C_2V$$
$$C = C_1 + C_2$$

30.You are given two capacitors of 2 μ F and 3 μ F. What are themaximum and minimum values of capacitance that can be obtained by combining them?

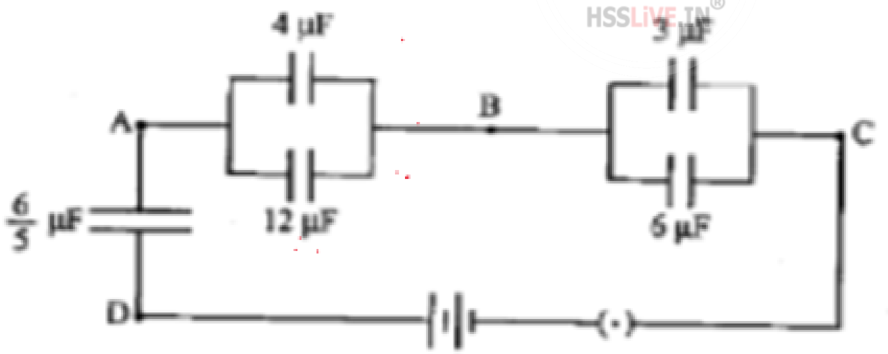
Maximum value is obtained when capacitors are connected in parallel

$$C_{max} = C_1 + C_2 = 2\,\mu + 3\mu = 5\,\mu F$$

Minimum value is obtained when capacitors are connected in series.

$$C_{min} = \frac{C_1\ C_2}{C_1 + C_2} = \frac{2\,x3}{2+3} = \frac{6}{5}\,\mu F$$

31.Find the equivalent capacitance of capacitors given in the network



4µF and 12µF are connected in paraliel.

$$C' = C_1 + C_2$$
$$C' = 4\mu F + 12\mu F$$
$$C' = 16\mu F$$

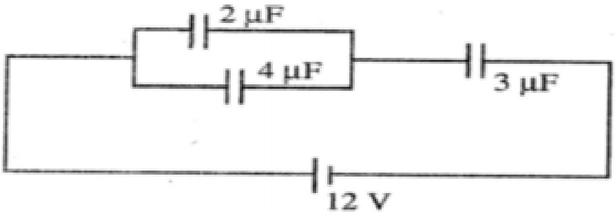
3µF and 6µF are connected in paraliel.

$$C'' = C_1 + C_2$$
$$C'' = 3\mu F + 6\mu F$$
$$C'' = 9\mu F$$

6/5 µF , 16µF and 9µF are connected in series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$
$$\frac{1}{C} = \frac{1}{6/5\ \mu F} + \frac{1}{16\mu F} + \frac{1}{9\mu F}$$
$$\frac{1}{C} = \frac{5}{6\ \mu F} + \frac{1}{16\mu F} + \frac{1}{9\mu F} = 1.0069$$
$$C = \frac{1}{1.0069}$$
$$C = 0.99\mu F$$

32.Three capacitors are connected to a 12Vbattery as shown in figure.



a)What is the effective capacitance of the combination?

2μF and 4μF are connected in paraliel.

$C' = C_1 + C_2$

$C' = 2\mu F + 4\mu F$

$C' = 6\mu F$

6μF and 3μF are connected in series

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$ $\quad C = \frac{C_1 C_2}{C_1 + C_2} = \frac{6\mu \times 3\mu}{6\mu + 3\mu}$

$C = \frac{18\mu x\mu}{9\mu}$

$C = 2\mu F$

b)What is the potential difference across the 2μF capacitor?

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

$Q = CV$

$Q = 2\mu \times 12$

$Q = 24\,\mu C$

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

$V = \frac{24\mu}{6\mu}$

$V = 4\,V$

33.Obtain the expression for energy stored in a capacitor

$dW = V\,dq$

$dW = \frac{q}{C}\,dq$

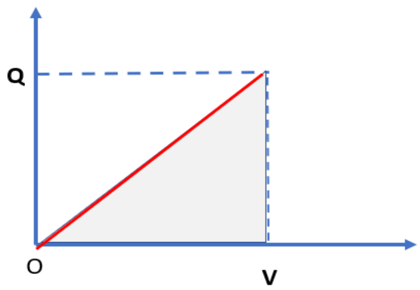
$$W = \int_0^Q \frac{q}{C} \times dq$$

$$W = \frac{Q^2}{2C}$$

$$\mathbf{U = \frac{Q^2}{2C}}$$

34.Obtain the expression for energy stored in a capacitor using Q-V graph

$Q \propto V$



Area under the graph =½ QV =Energy

Area under Q-V graph gives energy stored in a capacitor

35.Where do capacitor store energy ?

Capacitor store energy in the electric field.

3.Obtain the expression for energy density of a capacitor

Energy density is the energy stored per unit volume.

$$U = \frac{1}{2} C V^2$$

$$U = \frac{1}{2} \frac{\varepsilon_0 A}{d} \frac{\sigma^2 d^2}{\varepsilon_0^2}$$

$$U = \frac{1}{2} \varepsilon_0 \frac{\sigma^2}{\varepsilon_0^2} A d$$

$$U = \frac{1}{2} \varepsilon_0 E^2 A d$$

$$\text{Energy density} = \frac{\text{Energy stored}}{\text{volume}}$$

$$u = \frac{U}{Ad}$$

$$u = \frac{\frac{1}{2} \varepsilon_0 E^2 A d}{A d}$$

$$u = \frac{1}{2} \varepsilon_0 E^2$$

Chapter 3
Current Electricity

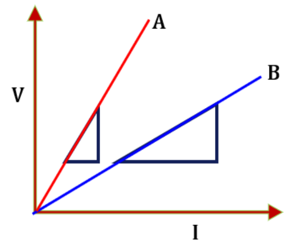
1.State Ohm's law

At constant temperature ,the current flowing through a conductor is directly proportional to the potential difference between the ends of the conductor

$$\frac{V}{I} = R$$

Unit of resistance is Ω(ohm)

2.Which material has more resistance?



Slope of V-I graph gives Resistance. Slope of A is greater than that of B. So material A has more resistance than B.

3.Define conductance

The reciprocal of resistance is called Conductance.

$$C = \frac{1}{R}$$

Unit of conductance is $ohm^{-1}(\Omega^{-1}$or mho) or =siemens

4.What are the factors on which the resistance of a conductor depends?

i)The material of the conductor

ii)Length of the conductor , $R \propto l$

iii) The area of cross section of the conductor, $R \propto \frac{1}{A}$

5.What do you mean by resistivity of a conductor. Write its unit.

The resistance of a conductor is directly proportional to length l of the conductor and inversely proportional to the cross-sectional area, A.

$$\rho = \frac{RA}{l}$$

Unit of resistivity is Ωm.

Resistivity depends on the material of the conductor but not on its dimensions.

6.What happens to the resistivity of the material ,if the conductor is stretched to double its length.

Resistivity does not depend on the dimensions of material.
So resistivity of material does not change.

7.What do you mean by relaxation time?

The average time interval between two successive collisions of free electrons is called relaxation time(τ)

8.Define drift velocity

The average velocity attained by electrons in a conductor due to an electric field is called Drift velocity.

$$\mathbf{v_d = -\frac{eE}{m}\tau}$$

9.Obtain the expression for drift velocity of an electron in an external electric field

Force, $F = qE = -eE$

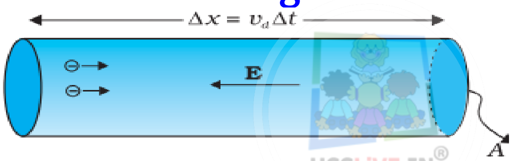
Acceleration , $a = \frac{F}{m} = \frac{-eE}{m}$

If τ is the relaxation time,

Drift velocity, $v_d = a\,\tau$

$$\mathbf{v_d = -\frac{eE}{m}\tau}$$

10.Obtain the relation connecting drift velocity and current



Distance travelled by an electron in time $\Delta t = v_d\,\Delta t$

Volume of conductor $= A\ v_d\ \Delta t$

Let n be the number of electrons per unit volume of conductor

The number of electrons in the conductor= $n\,A\ v_d\ \Delta t$

Total charge of electrons in the conductor , q= $n\,e\,A\ v_d\ \Delta t$

Current $I = \frac{q}{\Delta t}$

$$I = \frac{n\,e\,A\ v_d\ \Delta t}{\Delta t}$$

$$\mathbf{I = n\,e\,A\ v_d}$$

11.Define mobility .

Mobility μ defined as the magnitude of the drift velocity per unit electric field.

$$\mu = \frac{v_d}{E} = \frac{\frac{eE}{m}\tau}{E}$$

$$\mu = \frac{e}{m}\tau$$

12.Define current density. Write its unit.

Current per unit area ,taken normal to the current is called current density.

$$j=\frac{I}{A}$$

Unit -A/m^2

13.Define conductivity

Conductivity is the reciprocal of resistivity

$$\sigma = \frac{1}{\rho}$$

Unit – $\Omega^{-1}m^{-1}$

14.Write Ohms law in vector form

$$\vec{j} = \sigma\vec{E}$$

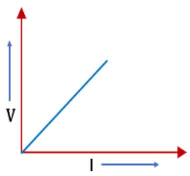
15.Write the limitations of Ohm's Law

- Some materials and devices used in electric circuits do not obey Ohm's law and are called Non – Ohmic conductors.
- V-I graps of non – ohmic conductors not linear.
- Eg:- Semi conductors, Diodes , Transistors.

16.Differentiate Ohmic and non ohmic Conductors

Ohmic Conductors

Conductors which obey Ohm's law are called Ohmic conductors.The Voltage – Current graph of such conductors will be linear .



Eg:- metals ,Nichrome

Non - Ohmic Conductors

The materials and devices which do not obey Ohm's law are called Non – Ohmic conductors. So V-I grapis not linear.

Eg:- Semi conductors, Diodes , Transistors.

17.Write the expression for temperature co-efficient of resistivity. Write its unit and dimension.

$$\rho_T = \rho_0[1 + \alpha(T - T_0)]$$

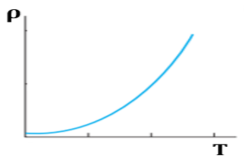
$$\boldsymbol{\alpha = \frac{\rho_T - \rho_0}{\rho_0(T - T_0)}}$$

α is called the temperature co-efficient of resistivity

The dimension of α is $[\text{Temperature}]^{-1}$ and unit is K^{-1}.

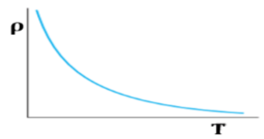
18.How the resistivity of metals vary with temperature?

For metals **α is positive,** i.e.,when temp increases, the resistivity of metals increases,



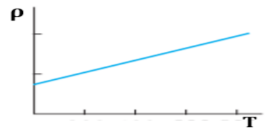
19.How the resistivity of semiconductors and insulators vary with temperature?

For semiconductors and insulators **α is negative,** i.e.,when temp increases, the resistivity of semiconductors and insulators decreases.



20.Why Nichrome, Constantan and Manganin are used as standard resistors?

For Nichrome, Constantan and Manganin $\boldsymbol{\alpha \approx 0}$,i.e., resistivity does not vary considerably with temperature. So these materials are are used as standard resistors.



21.What do you mean by internal resistance of a cell ?

Resistance offered by the electrolytes to the flow of current through it is called internal resistance of the cell

22. Write the relation connecting emf and terminal potential difference

$$V = \varepsilon - Ir$$

23.Differentiate emf and terminal voltage of a cell

The emf ε is the potential difference between the positive and negative electrodes of a cell in an open circuit, i.e., when no current is flowing through the cell.

The terminal voltage (V) is the potential difference between the positive and negative electrodes of a cell in a closed circuit, i.e., when current is flowing through the cell.

24.A battery of emf10V and internal resistance 3 Ω is connected to an external resistor. If the current in the circuit is 0.5A,
a)what is the value of the external resistance?
b) What is the terminal voltage of the battery when the circuit is closed?

a)

$$V = \varepsilon - Ir$$

$$IR = \varepsilon - Ir$$

$$R = \frac{\varepsilon - Ir}{I}$$

$$= \frac{10 - 0.5x3}{0.5} = \frac{8.5}{0.5} = 17\ \Omega$$

b)

$$V=IR=0.5x17=8.5V$$

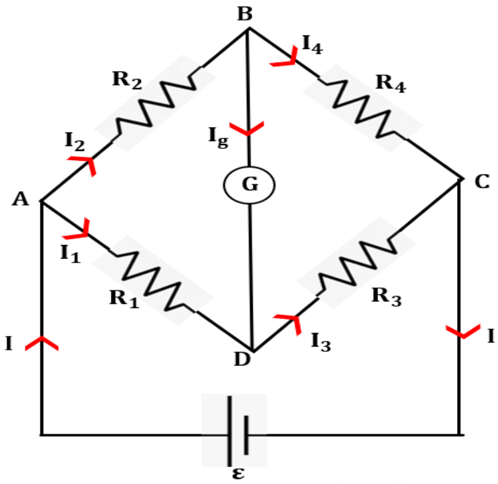
25. State Kirchhoff's junction rule or current law.

At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction . $\sum I = 0$

26. State Kirchhoff's loop rule or voltage law.

The algebraic sum of changes in potential around any closed loop is zero. $\sum \Delta V = 0$

27.Obtain Wheatstone bridge principle.



For a balanced Wheatstone's bridge, current through the galvanometer $I_g = 0$.

At junctions B, $I_2 = I_4$ -------------(1)

At junctions D , $I_1 = I_3$ -------------(2)

For loop ABDA , $I_1 R_1 = I_2 R_2$ ----------------(3)

For loop CBDC , $I_3 R_3 = I_4 R_4$ ---------------(4)

$$\frac{\text{eq }(3)}{\text{eq }(4)} \text{-----} \frac{I_1 R_1}{I_3 R_3} = \frac{I_2 R_2}{I_4 R_4}$$

Using eq(1) and(2) $\frac{R_1}{R_3} = \frac{R_2}{R_4}$

$$\mathbf{\frac{R_2}{R_1} = \frac{R_4}{R_3}}$$

28.What is the principle behind the working of meter bridge. State the principle.

Wheatstone bridge principle

Wheatstone principle says that when the Wheatstone bridge is balanced,

i.e., when $I_g = 0$, $\frac{R_2}{R_1} = \frac{R_4}{R_3}$.

Chapter 4
Moving Charges and Magnetism

1.Write Lorentz force equation.

$$F = q[E + (v \times B)]$$

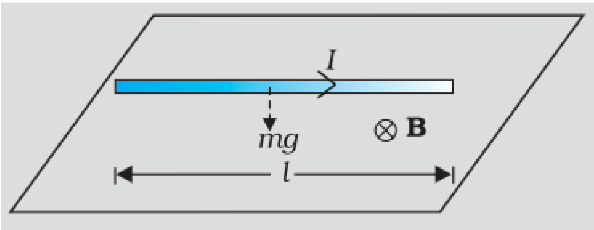
2.Write the equation for magnetic Lorentz force.

$$F = q(v \times B)$$

3. Write the expression for magnetic force on a current-carrying conductor

$$F = I(\,l \times B\,)$$

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



There is an upward force F, of magnitude I l B,. For mid-air suspension, this must be balanced by the force due to gravity:

$$m\,g = I\,lB$$

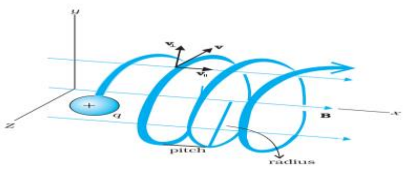
$$B = \frac{mg}{Il} = \frac{2 \times 9.8}{2 \times 1.5} = 0.65\ T$$

5.A charged particle moving in the direction or opposite direction of magnetic field moves …………………… undeflected.

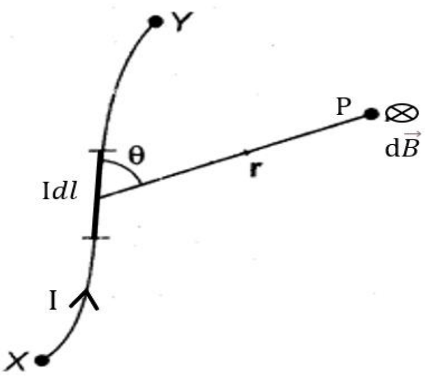
6.A charged particle entering perpendicular to a magnetic field moves in a ………………. path. Circular.

7.A charged particle moves at an arbitrary angle θ with the manetic field. What will be the shape of its path?

It move in a helical path.



8. State Biot-Savart Law



The magnetic field at a point due to a small element of a current carrying conductor is directly proportional to the current (I) , the length of the element dl , sine of the angle between r and dl and inversely proportional to the square of the distance r.

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin\theta}{r^2}$$

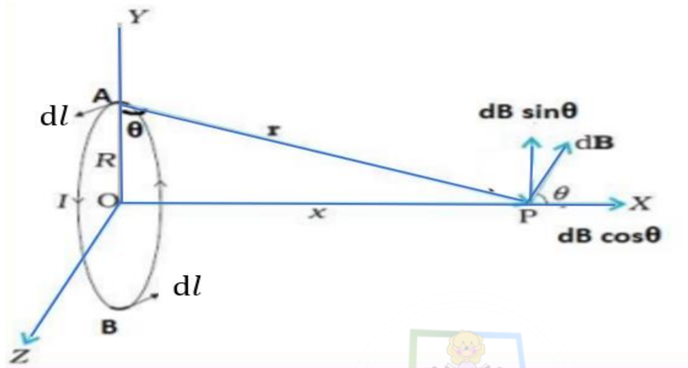
9. Write the vector form of Biot-Savart Law in vector form

$$dB = \frac{\mu_0}{4\pi}\frac{I\,\overline{dl}\times\bar{r}}{r^3}$$

10. a)Name the law which explains the the relation between current and the magnetic field produced by the current
b)Using this Law, obtain the expression for Magnetic Field on the Axis of a Circular Current Loop.
c)Also obtain the magnetic field at the centre of this loop.

a) Biot-Savart Law , $dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,sin\theta}{r^2}$

b)



$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin 90}{r^2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}$$

$$r^2 = x^2 + R^2$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{x^2+R^2}$$

$$\cos\theta = \frac{R}{r} = \frac{R}{(x^2+R^2)^{1/2}}$$

Total field $B = \int dB\cos\theta$

$$B = \int \frac{\mu_0}{4\pi}\frac{Idl}{x^2+R^2}\frac{R}{(x^2+R^2)^{1/2}}$$

$$B = \frac{\mu_0}{4\pi}\frac{IR}{(x^2+R^2)^{3/2}}\int dl$$

$$B = \frac{\mu_0}{4\pi}\frac{IR}{(x^2+R^2)^{3/2}}\,x2\pi R$$

$$B = \frac{\mu_0 IR^2}{2(x^2+R^2)^{3/2}}$$

c) At the centre x=0

$$B = \frac{\mu_0 IR^2}{2R^3}$$

$$\mathbf{B = \frac{\mu_0 I}{2R}}$$

11. State Ampere's Circuital theorem.

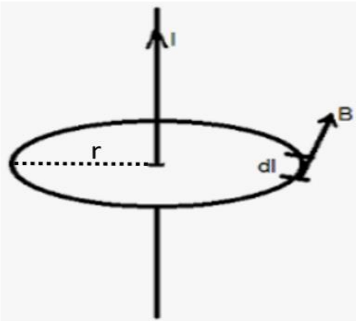
The line integral of magnetic field over a closed loop is equal to μ_0 times the total current passing through the surface.

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

12.a) Using Ampere's Circuital theorem ,obtain the expression for the magnetic field due to a straight infinite current-carrying wire .

b) Draw the graph showing the variation on intensity of magnetic field with the distance from the axis of this conductor

a)



By Ampere's Circuital Law

$$\oint \vec{B}.d\vec{l} = \mu_0 I$$

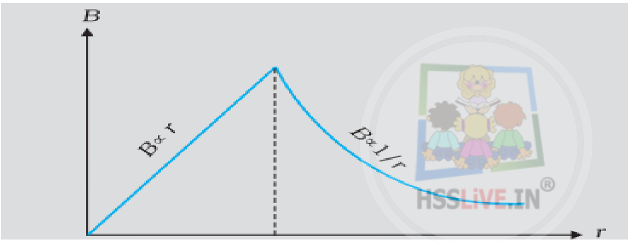
$$\oint Bdl\cos 0 = \mu_0 I$$

$$B\oint dl = \mu_0 I$$

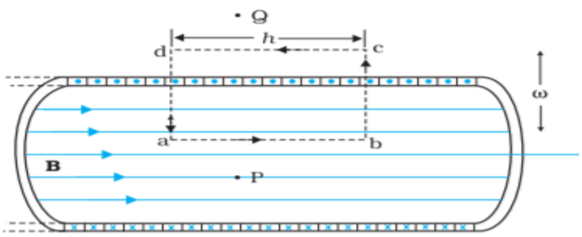
$$B \times 2\pi r = \mu_0 I$$

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

b)



13.Using Ampere's circuital theorem obtain the expression for mangnetic field due to a solenoid.



$$\oint_{abcd} \vec{B}.d\vec{l} = \oint_{ab} \vec{B}.d\vec{l} + \oint_{bc} \vec{B}.d\vec{l} + \oint_{cd} \vec{B}.d\vec{l} + \oint_{da} \vec{B}.d\vec{l} \text{ ------------ } (1)$$

$$\oint_{abcd} \vec{B}.d\vec{l} = Bl + 0 + 0 + 0$$

$$\oint_{abcd} \vec{B}.d\vec{l} = Bl \text{ -------------} (2)$$

By Ampere's Circuital Law for N turns of solenoid

$$\oint B.d\vec{l} = \mu_0 NI \text{ ---------------} (3)$$

From eqns (2) and (3)

$$Bl = \mu_0 NI$$

$$B = \frac{\mu_0 NI}{l}$$

$$\mathbf{B = \mu_0 nI} \qquad \text{where } n = \frac{N}{l}$$

14.A long straight conductor carries 35A current. Find the magnetic field produced due to this conductor at a point 20cm away from the centre of the wire.

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi x 10^{-7} x\, 35}{2\pi\, x 0.2} = 13.5\, x 0^{-5} T$$

15.A solenoid of length 0.5 m has a radius of 1 cm and is made up of 500 turns. It carries a current of 5 A. What is the magnitude of the magnetic field inside the solenoid?

The number of turns per unit length , $n = \frac{N}{l}$

$$= \frac{500}{0.5} = 1000$$

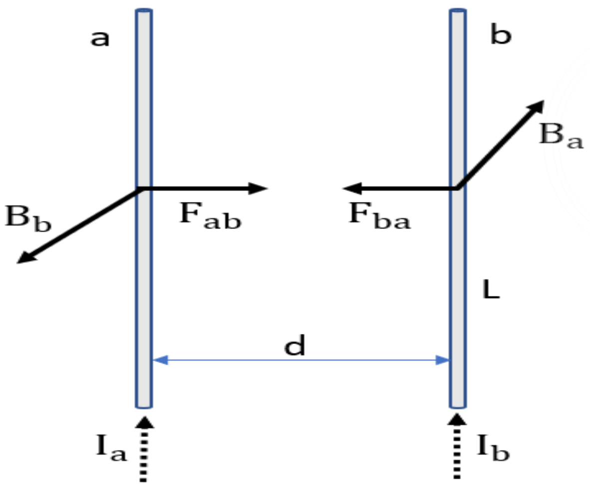
$$B = \mu_0 n I$$

$$= 4\pi \times 10^{-7} x 1000 x 5 = 6.28 \times 10^{-3}\ T$$

16. a)Obtain the expression for force per unit length between two parallel current carrying condutors.

b) Use the above relation to define the unit of current ampere)

a)



$$B_a = \frac{\mu_0 I_a}{2\pi d}$$

Force acting on conductor b due to this field B_a,

$$\boxed{\vec{F} = I(\vec{l} \times \vec{B})}$$

$$F_{ba} = I_b L B_a$$

$$F_{ba} = I_b L \frac{\mu_0 I_a}{2\pi d}$$

$$F_{ba} = \frac{\mu_0 I_a I_b L}{2\pi d}$$

The force F_{ba} per unit length,

$$f_{ba} = \frac{\mu_0 I_a I_b}{2\pi d}$$

b)Definition of ampere

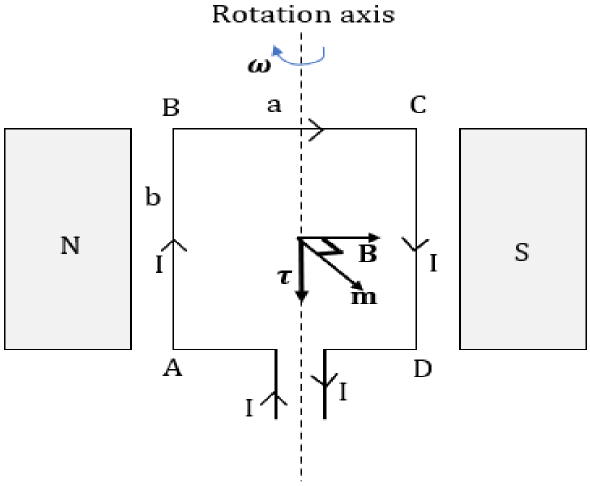
$$f_{ba} = \frac{\mu_0 I_a I_b}{2\pi d}$$

If $I_a = I_b = 1A$ and , $d=1m$

$$f_{ba} = \frac{\mu_0}{2\pi} = \frac{4\pi\, x\, 10^{-7}}{2\pi} = 2\, x\, 10^{-7} N/m$$

The ampere is that current which, when flaws through two very long, straight, parallel conductors placed one metre apart in vacuum, would produce a force equal to2 x 10^{-7}N/m on each other.

17.A rectangular current loop carrying current is placed in a uniform magnetic field. Obtain the expression for the torque acting on the loop.



Force on AD and BC is zero

Force on AB =Force on CD = IbB sin 90=IbB

Forces on AB and CD are equal and oppsite and produces a torque.

Torque , τ =Force x perpendicular distance

$\tau = IbB \times a$

When the plane of the loop, makes an angle with the magnetic field.

$\tau = IbB \times a \sin\theta$

$\tau = IAB \sin\theta$

We define the magnetic moment of the current loop as, m = I A

$\vec{\tau} = mB \sin\theta$

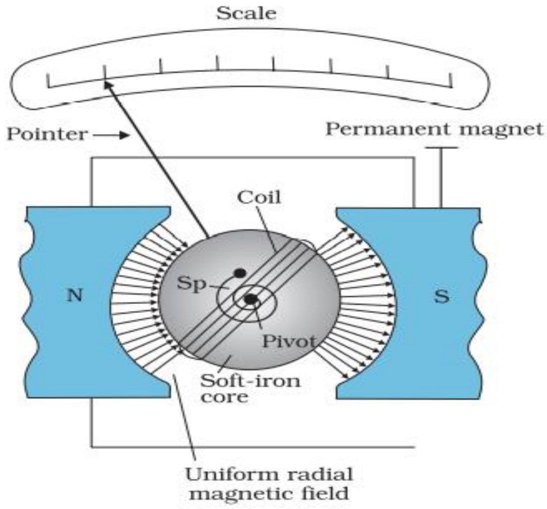
$\vec{\tau} = \vec{m} \times \vec{B}$

18.Write the principle of a moving coil galvanometer.

A current carrying coil placed in a magnetic field experiences a torque and it deflects. The deflection produced in the coil is directly proportional to the current through the coil.

$\phi \propto I$

19.Explain the working of a moving coil galvanometer



Torque on the coil due to current

$$\tau = NI\,AB\text{-------------}(1)$$

The counter torque in the spring,

$$\tau = k\phi\ \text{----------------}(2)$$

where k is the torsional constant of the spring; i.e. the restoring torque per unit twist.

In equilibrium, $k\phi = NI\,AB$ -------------(3)

$$\boldsymbol{\phi = \left(\frac{N\,AB}{k}\right) I}$$

$$\boldsymbol{\phi \propto I}$$

Thus the deflection produced in the coil is directly proportional to the current through the coil.

20.What is current sensitivity of the galvanometer

Current sensitivity of the galvanometer is defined as the deflection per unit current.

$$\frac{\phi}{I} = \left(\frac{N\,AB}{k}\right)$$

Current sensitivity can be increased by increasing the number of turns N.

21.What is voltage sensitivity of the galvanometer?

Voltage sensitivity of the galvanometer is defined as the deflection per unit voltage.

$$\frac{\phi}{V} = \left(\frac{N\,AB}{k}\right)\frac{I}{V} = \left(\frac{N\,AB}{k}\right)\frac{1}{R}$$

$$\frac{\phi}{V} = \left(\frac{N\,AB}{k}\right)\frac{1}{R}$$

22.Increasing the current sensitivity may not necessarily increase the voltage sensitivity. Justify.

If $N \rightarrow 2N$, i.e., we double the number of turns, then current sensitivity,

$$\frac{\phi}{I} = \left(\frac{2N\,AB}{k}\right) \rightarrow 2\,\frac{\phi}{I}$$

Thus, the current sensitivity doubles.

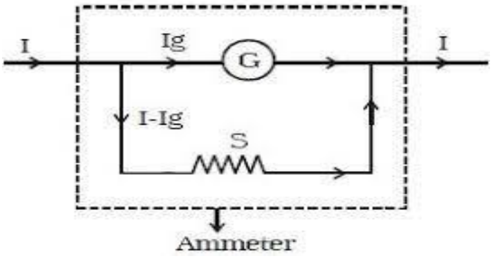
If $N \rightarrow 2N$, then $R \rightarrow 2R$ then the voltage sensitivity,

$$\frac{\phi}{V} = \left(\frac{2N\,AB}{k}\right)\frac{1}{2R} = \left(\frac{N\,AB}{k}\right)\frac{1}{R} = \frac{\phi}{V}$$

Thus, the voltage sensitivity remains unchanged.

23.How will you convert a galvanometer to ammeter?

To convert a Galvanometer to an Ammeter ,a small resistance , called shunt resistance S ,is connected in parallel with the galvanometer coil.

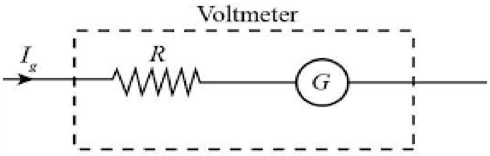


$$I_gG = (I - I_g)S$$

$$S = \frac{I_gG}{I - I_g}$$

24.How will you convert a galvanometer to voltmeter?

To convert a Galvanometer to a volteter a high resistance , R is connected in series with the galvanometer coil.



$$V = I_g(R + G)$$

$$R + G = \frac{V}{I_g}$$

$$R = \frac{V}{I_g} - G$$

25. A galvanometer with coil resistance 12Ω shows full scale deflection for a current of 2.5mA. How will you convert it into an ammeter of range 0 – 7.5 A?

$$S = \frac{I_gG}{I - I_g}$$

$$S = \frac{2.5 \times 10^{-3} \times 12}{7.5 - 2.5 \times 10^{-3}}$$

$$S = \frac{2.5 \times 10^{-3} \times 12}{7.5 - 0.0025} = 4 \times 10^{-3}\ \Omega$$

A resistance of 4×10^{-3} Ω is to be connected in parallel to the galvanometer coil to convert it into an ammeter.

26. A galvanometer with coil resistance 12Ω shows full scale deflection for a current of 3mA. How will you convert it into a voltmeter of range 0 – 18V?

$$R = \frac{V}{I_g} - G$$

$$R = \frac{18}{3 \times 10^{-3}} - 12$$

$$= 6 \times 10^{3} - 12$$

$$= 6000 - 12 = 5988\ \Omega$$

A resistance of 5988 Ω is to be connected in seriesl to the galvanometer coil to convert it into a voltmeter.

Chapter 5
Magnetism and Matter

1.Write the properties of Magnetic Field Lines

- The magnetic field lines of a magnet form continuous closed loops.
- The tangent to the field line at a given point represents the direction of the net magnetic field B at that point.
- The larger the number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field B.
- The magnetic field lines do not intersect.

2.The Dipole Analogy

	Electrostatics	Magnetism
	$\frac{1}{\varepsilon_0}$	μ_0
Dipole moment	$\vec{p}$	$\vec{m}$
Axial Field for a short dipole	$\frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$	$\frac{\mu_0}{4\pi}\frac{2\vec{m}}{r^3}$
Equatorial Field for a short dipole	$\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}$	$\frac{\mu_0}{4\pi}\frac{\vec{m}}{r^3}$
Torque in an external field	$\vec{\tau} = \vec{p} \times \vec{E}$	$\vec{\tau} = \vec{m} \times \vec{B}$
Energy in an external field	$\vec{U} = -\vec{p}.\vec{E}$	$\vec{U} = -\vec{m}.\vec{B}$

3.Define magnetic flux

Magnetic flux through a plane of area A placed in a uniform magnetic field B can be written as

$$\phi_B = \text{B . A} = \text{BA cos}$$

The SI unit of magnetic flux is weber (Wb) or tesla meter squared (T m^2).

4. State Gauss's Law in magnetism.

Gauss's law for magnetism states that the net magnetic flux through any closed surface is zero.

$$\phi = \oint \vec{B} \cdot d\vec{s} = 0$$

5.Why does Gauss's Law in magnetism give a null result.

Gauss's Law in magnetism give a null result as isolated magnetic poles(monopole) do not exist.

6. Define Magnetisation(M). Write its unit and dimension.

The net magnetic dipole moment developed per unit volume of a material is called Magnetisation(M).

$M = \frac{m_{net}}{V}$ unit is Am^{-1},dimensions AL^{-1}

7.Define Magnetic intensity or Magnetising field(H). Write its unit and dimension.

$$H = \frac{B}{\mu_0} - M$$ unit is Am^{-1},dimensions AL^{-1} (same as magntisation)

8. Define Magnetic Susceptibility

$$\chi = \frac{M}{H}$$ (no unit and dimension)

9.Define magnetic permeability

$$\mu = \frac{B}{H}$$

10. Obtain the relation connecting relative permeability and magnetic susceptibility.

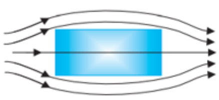
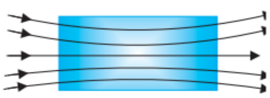
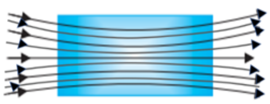
Consider a long solenoid of n turns per unit length and carrying a current I.

$$B = \mu_0(H + M)$$
$$B = \mu_0(H + \chi H)$$
$$B = \mu_0(1 + \chi)H) \text{ --------------(1)}$$
$$B = \mu_0\mu_r H \quad \text{-----------------(2)}$$
$$B = \mu H$$

From (1) and (2)

$$\mu_r = 1 + \chi$$
$$\boldsymbol{\chi = \mu_r - 1}$$

11.Write the differences between dia, para and ferro magnetic materials.

Diamagnetic	Paramagnetic	Ferromagnetic
▪ weakly magnetised opposite to the direction of external magnetic field.	▪ weakly magnetised in the direction of external magnetic field.	▪ strongly magnetised in the direction of external magnetic field.
▪ move from stronger to the weaker part of the external magnetic field,	▪ move from weaker to stronger part of the external magnetic field,	▪ move from weaker to stronger part of the external magnetic field,
▪ χ is negative, $\chi < 0$	▪ χ is positive and small, $\chi > 0$	▪ χ is positive and large, $\chi >> 1$
▪ $\mu_r < 1$	▪ $\mu_r > 1$	▪ $\mu_r >> 1$
▪ Eg:water , sodium chloride	▪ Eg: aluminium, sodium, calcium	▪ Eg: iron, cobalt, nickel
▪ the field lines are expelled inside the material	▪ the field lines gets concentrated inside the material.	▪ the field lines gets highly concentrated inside the material
		

12.How will you classify magnetic materials in terms of their susceptibility.

Diamagnetic - χ is negative. $\chi < 0$

Paramagnetic - χ is positive and small, $\chi > 0$

Ferromagnetic - χ is large and positive, $\chi >> 1$

13.How will you classify magnetic materials in terms of their relative permeability.

Diamagnetic - $\mu_r < 1$

Paramagnetic - $\mu_r > 1$

Ferromagnetic - $\mu_r >> 1$

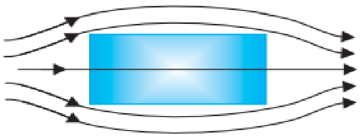
14.Write two examples each for diamagnetic, paramagnetic and ferromagnetic materials.

Diamagnetic- water , sodium chloride, diamond, gold.

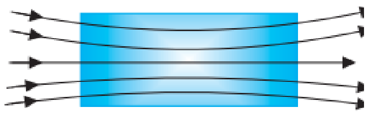
Paramagnetic - aluminium, sodium, calcium, magnesium, platinum, tungsten

Ferromagnetic - iron, cobalt, nickel, gadolinium,Fe_2O_3

15.The behaviour of magnetic field lines inside two magnetic materials are given in figure. Identify the materials as diamgetic and paramagnetic .



Diamagnetic



Paramagnetic

16.Mention the behaviour of a dia and ferromagnetic materials when they are placed in a non uniform magnetic field.

- Diamagnetic substances move from stronger to the weaker part of the external magnetic field.
- Ferromagnetic substances move from weaker to stronger part of the external magnetic field.

17.What are super conductors

These are metals, when cooled to very low temperatures ,exhibits both perfect conductivity and perfect diamagnetism.

$\chi = -1$ and $\mu_r = 0$ for super conductors.

32.Differentiate hard ferromagnets and soft ferromagnets

The ferromagnetic materials in which the magnetisation persists, ,even when the external field is removed are called **hard ferromagnets**. Such materials are used to make permanent magnets.

Eg: Alnico, lodestone

The ferromagnetic materials in which the magnetisation disappears on the removal of the external field are called **soft ferromagnets.**

Eg: Soft iron .

33.At high enough temperature, a ferromagnet becomes ....

paramagnet.

Chapter 6
Electromagnetic Induction

1.State Faraday's Law of Induction

Faraday's Law of Electromagnetic induction states that the magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit.

$$\varepsilon = \frac{-d\phi}{dt}$$

2.State Lenz's law

The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.

$$\varepsilon = -\frac{d\phi}{dt}$$

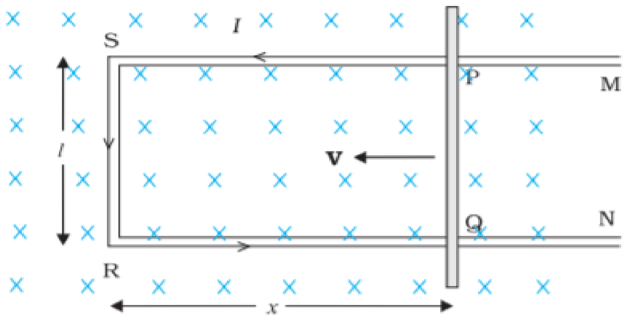
3.Lenz's Law is in accordance with the law of Conservation of Energy. Justify.

The current induced in the coil is opposite to the direction of changing magnetic flux. Then the bar magnet experiences a repulsive force due to the induced current. Therefore, a person has to do work in moving the magnet. This energy(work) is dissipated by Joule heating produced by the induced current. Thus Lenz's law is in accordance with law of conservation of energy.

4.What is motional emf?

When a conducting rod is moved through a constant magnetic field, an emf is developed between the ends of the rod. This emf is known as Motional Emf. $\varepsilon = Blv$

5.Derive the expression for Motional Electromotive Force



The magnetic flux , $\phi = Blx$

$$\varepsilon = -\frac{d\phi_B}{dt} = \frac{d}{dt}(Blx)$$

$$\varepsilon = -Bl\frac{dx}{dt}$$

$v = \frac{-dx}{dt}$ is the speed of the conductor

$$\varepsilon = Blv$$

6.Define self induction

The phenomenon of production of induced emf in an isolated coil by varying current through the same coil is called self-induction.

7.Define self inductance of a coil

The flux linked with the coil is proportional to the current through the coil.

$$\phi \alpha \, I$$

$$\phi = L\,I$$

where L is called self-inductance or coefficient of self-induction of the coil.

8.Write the unit of inductance.

Henry(H)

9.The self inductance of a coil is 2mH. If a current of 1A is switched off in a time of one millisecond, what is the induced emf in it?

$$\varepsilon = L\frac{dI}{dt}$$

$$L = 2x10^{-3}H$$

$$dI = 1\text{-}0 = 1A$$

$$dt = 1x10^{-3}$$

$$\varepsilon = 2x10^{-3}\,x\,\frac{1}{1x10^{-3}} = 2V$$

10.The current in a circuit falls from 5A t0 1A in 0.1second. If an average emf of 200 volts is induced,find the self inductance of the coil.

$$\varepsilon = L\frac{dI}{dt}$$

$$\varepsilon = 200V$$

$$dI = 5\text{-}1 = 4A$$

$$dt = 0.1s$$

$$200 = L\,\frac{4}{0.1}$$

$$L = \frac{200x0.1}{4} = 5H$$

11.Obtain the expression for self inductance of a long solenoid

The total flux linked with the solenoid ,

$$\phi = NB\,A$$

$$\phi = nl\,(\mu_0\,n\,I\,)\,A$$

$$\phi = \mu_0\,n^2\,AlI \text{ ------------(1)}$$

But, $\phi = LI$ -----------------(2)

From eq (1) and (2)

$$LI = \mu_0\,n^2\,AlI$$

$$\mathbf{L = \mu_0\,n^2\,A\mathit{l}} \text{ -----------(3)}$$

12.Obtain the energy stored in an inductor

$$dW = LI\,dI$$

$$W = \int_0^I LI\,dI$$

$$W = \frac{1}{2}LI^2$$

This work is stored in the magnetic field as energy in an inductor

$$\mathbf{U = \frac{1}{2}LI^2}$$

Where do an inductor store energy?

An inductor store energy in the magnetic field.

13.Calculate the energy stored in an inductor of inductance 50mH when a current of 2A is passed through it.

$$U = \frac{1}{2}LI^2$$

$$= \frac{1}{2}50x10^{-3}\,x\,2^2 = 0.1J$$

14.Define mutual induction

The phenomenon of production of induced emf in a coil by varying the current through a neighbouring coil is called mutual-induction.

15.The coefficient of mutual inductance of two coils is 1H. Current in one of the coil is increased from 4 to 5A in 1ms. What average emf will be induced in the other coil

$$\varepsilon = M\frac{dI}{dt}$$

$$M = 1H$$

$$dI = 5\text{-}4 = 1A$$

$$dt = 1x10^{-3}s$$

$$\varepsilon = 1\,x\,\frac{1}{1x10^{-3}} = 1000V$$

16.Define mutual inductance of a coil

The flux linked with the coil is proportional to the current through the neighbouring coil.

$$\phi\ \alpha\ I$$

$$\phi = M\,I$$

where M is called **mutual-inductance or the coefficient of mutual-induction** of the coil.

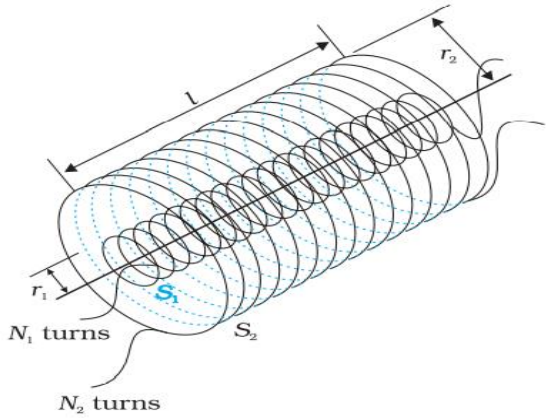
17.The self-induced emf is also called the back emf . Why?

The self-induced emf is also called the back emf as it opposes any change in the current in a circuit.

18.The electromagnetic analogue of mass is ....

Self inductance

19.Derive the expression for mutual inductance of two co-axial solenoids



The current I_2 in S_2 sets up a magnetic flux

$$\phi_1 = N_1 B_2 A_1$$

$$\phi_1 = (n_1 l)(\mu_0 n_2 I_2) A_1$$

$$\phi_1 = \mu_0 n_1 n_2 A_1 l I_2 \text{ -------------(1)}$$

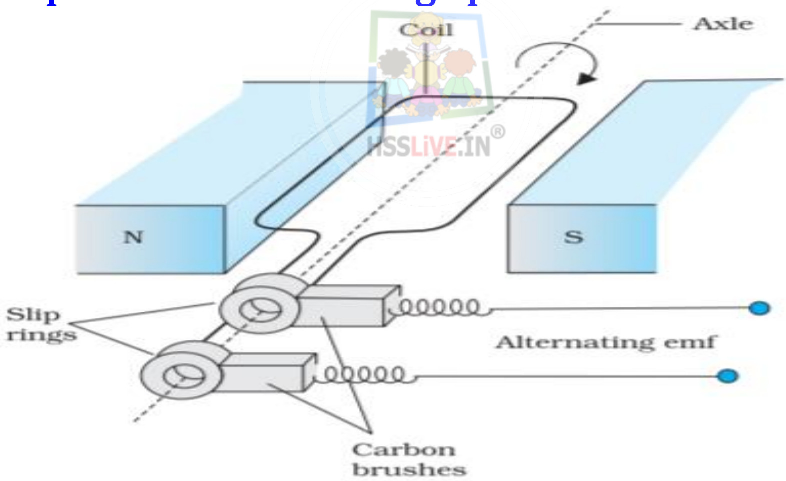
But, $\phi_1 = M I_2$ -------------(2)

From eq(1) and (2)

$$M I_2 = \mu_0 n_1 n_2 A_1 l I_2$$

$$\boldsymbol{M = \mu_0 n_1 n_2 A_1 l}$$

20.Obtain the expression for ac voltage produced in an ac generator.



The magnetic flux at any time t is

$$\phi = BA\cos\theta = BA\cos\omega t$$

From Faraday's law, the induced emf for the rotating coil of N turns is

$$\varepsilon = -N\frac{d\phi}{dt}$$

$$\varepsilon = -N\frac{d}{dt}BA\cos\omega t$$

$$\varepsilon = -NBA\frac{d}{dt}\cos\omega t$$

$$\varepsilon = NBA\omega \sin\omega t$$

$$\varepsilon = \varepsilon_0 \sin\omega t$$

where ε_0 =NBAω is the maximum value of the emf.

Chapter 7
Alternating Current

1.What are phasors?

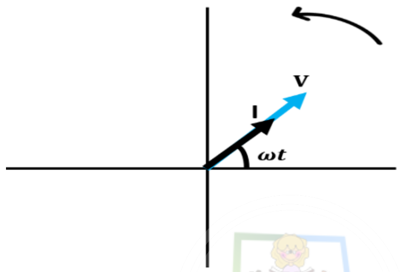
A phasor is a vector which rotates about the origin in anticlockwise direction with angular speed ω.

2. a)Obtain the expression for current when an AC voltage is applied to a resistor.
b)Draw the phasor representation for voltage and current in the circuit.

a)

$$v_m \sin \omega t = iR$$
$$i = \frac{v_m}{R} \sin \omega t$$
$$\mathbf{i = i_m \sin \omega t} \qquad \text{where} \quad \mathbf{i_m = \frac{v_m}{R}}$$

b)



3.Obtain the expression for power dissipated in the resistor when an AC voltage is applied to it.

$$p = vi$$
$$p = v_m \sin \omega t \; i_m \sin \omega t$$
$$p = v_m i_m \sin^2 \omega t$$

Avearage power consumed over one complete cycle

$$\bar{p} = \; < v_m i_m \sin^2 \omega t >$$
$$\bar{p} = v_m i_m < \sin^2 \omega t >$$

$$< sn^2 \omega t > = \frac{1}{2}$$

$$\bar{p} = \frac{1}{2} v_m i_m$$
$$P = \left(\frac{v_m}{\sqrt{2}}\right)\left(\frac{i_m}{\sqrt{2}}\right)$$
$$\mathbf{P = VI}$$

4.Write the expression for rms current

$$\mathbf{I = \frac{i_m}{\sqrt{2}} = 0.707\, i_m}$$

5.Write the expression for rms voltage

$$V_{rms} = \frac{v_m}{\sqrt{2}} = 0.707\, v_m$$

6.Why a shock from 220V ac is more fatal than that from 220Vdc?

The household line voltage of 220 V is an rms value.

$$V = 220V$$

Its peak voltage $v_m = \sqrt{2}\,V$

$$= 1.414 \times 220\ V \ = 311\ V$$

At some instant peak value of ac may reach upto 311V .So a shock from 220V ac is more fatal than that from 220Vdc.

7.A light bulb is rated at 100W for a 220 V supply. Find
(a) the resistance of the bulb
(b) the peak voltage of the source
(c) the rms current through the bulb.

(a) We are given $P = 100$ W and $V = 220$ V. The resistance of the bulb is

$$R = \frac{V^2}{P} = \frac{(220\ V)^2}{100\ W} = 484\Omega$$

(b) The peak voltage of the source is

$$v_m = \sqrt{2}V = 311\ V$$

(c) Since, $P = I\ V$

$$I = \frac{P}{V} = \frac{100\ W}{220\ V} = 0.450A$$

8. a) Show that the current lags the voltage by π/2 when an ac voltage applied to an inductor
b) Draw phasor representation for voltage and current in the circuit

a)

$$v_m \sin \omega t = L\frac{di}{dt}$$

$$\frac{di}{dt} = \frac{v_m \sin \omega t}{L}$$

$$di = \frac{v_m}{L}\sin \omega t\, dt$$

$$i = \frac{v_m}{L}\int \sin \omega t\, dt$$

$$i = \frac{v_m}{L} \times \frac{-\cos \omega t}{\omega}$$

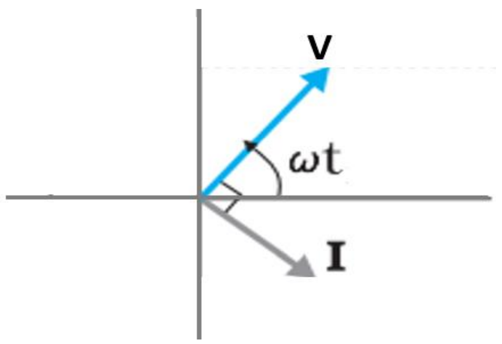
$$i = -\frac{v_m}{\omega L}\cos \omega t$$

$$i = -i_m \cos \omega t$$

$$\mathbf{i = i_m \sin\left(\omega t - \frac{\pi}{2}\right)} \quad \textbf{where} \quad \mathbf{i_m = \frac{v_m}{\omega L}}$$

In a pure inductor, current lags the voltage by π/2 or one-quarter (1/4) cycle.

b)



9. a)Show that the current leads the voltage by π/2 when an ac voltage applied to an capacitor

b)Draw the phasor representation for voltage and current in the circuit

a)

$$v_m \sin \omega t = \frac{q}{C}$$

$$q = C\, v_m \sin \omega t$$

$$i = \frac{d}{dt}(C\, v_m \sin \omega t)$$

$$i = C\, v_m \frac{d}{dt}(\sin \omega t)$$

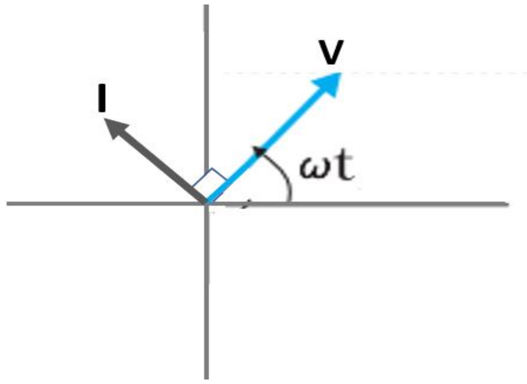
$$i = C\, v_m\, \omega \cos \omega t$$

$$i = \omega C\, v_m \cos \omega t$$

$$i = i_m \cos \omega t$$

$$\mathbf{i = i_m \sin\left(\omega t + \frac{\pi}{2}\right)} \quad \textbf{where } \mathbf{i_m = \omega C\, v_m}$$

b)



10.Write the equation for inductive reactance

$$\mathbf{X_L = \omega L = 2\pi f L}$$

11.A pure inductor of 25.0 mH is connected to a source of 220 V. Find the inductive reactance and rms current in the circuit if the frequency of the source is 50 Hz.

$$\text{Inductive reactance, } X_L = \omega L = 2\pi f L$$
$$= 2\text{x } 3.14\text{x}50\text{x}25\text{x}10^{-3}$$
$$= 7.85\Omega$$

The rms current in the circuit is, $I = \frac{V}{X_L}$

$$I = \frac{220}{7.85} = 28A$$

12.Write the equation for capacitive reactance

$$\mathbf{X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}}$$

13.A 15.0 μF capacitor is connected to a 220 V, 50 Hz source. Find the capacitive reactance and the current (rms and peak) in the circuit. If the frequency is doubled, what happens to the capacitive reactance and the current?

$$\text{The capacitive reactance } X_C = \frac{1}{\omega C}$$
$$= \frac{1}{2\pi f C}$$
$$= \frac{1}{2\text{x } 3.14\text{x}50\text{x}15\text{x}10^{-6}} = 212\Omega$$

The rms current is , $I = \frac{V}{X_C}$

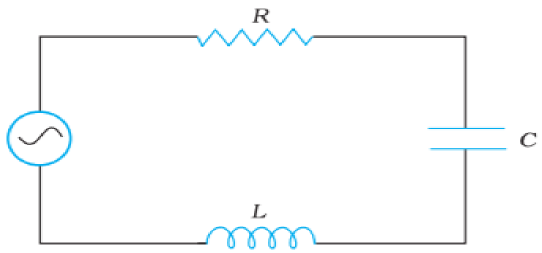
$$I = \frac{220}{212} = 1.04A$$

The peak current is $i_m = \sqrt{2}\ I$

$$= 1.414 \text{ x}1.04$$
$$= 1.47A$$

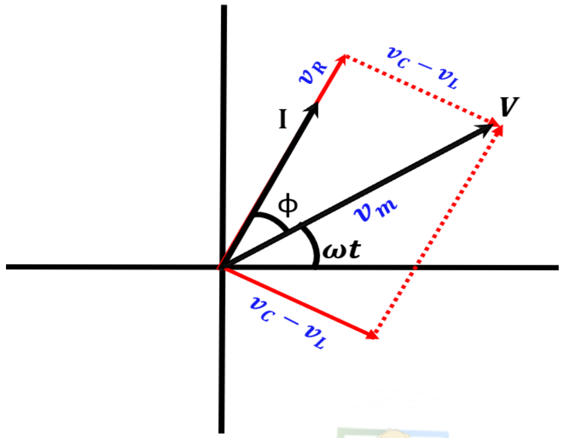
If the frequency is doubled, the capacitive reactance is halved , and consequently, the current is doubled.

14.Obtain the expression for current when an ac voltage applied to a series LCR circuit using phasor diagram



$$v_m \sin \omega t = iR + L\frac{di}{dt} + \frac{q}{C}$$

Phasor-diagram solution



From phasor diagram, current leads the voltage by an angle ϕ

$$\mathbf{i = i_m \sin(\omega t + \phi)}$$

To find the value of i_m

$$v_m^2 = v_R^{\ 2} + (v_C - v_L)^2$$

$$v_m^2 = (i_m R)^2 + (i_m X_C - i_m X_L)^2$$

$$v_m^2 = i_m^2\ [(R)^2 + (X_C - X_L)^2]$$

$$i_m^2 = \frac{v_m^2}{(R)^2+(X_C-X_L)^2}$$

$$i_m = \frac{v_m}{\sqrt{(R)^2+(X_C-X_L)^2}}$$

$$\mathbf{i_m = \frac{v_m}{Z}}$$

where $\mathbf{Z=\sqrt{(R)^2 + (X_C - X_L)^2}}$ is called impedance

15.Write the expression for Impedance of a series LCR circuit

$$Z = \sqrt{(R)^2 + (X_C - X_L)^2}$$

or

$$Z = \sqrt{(R)^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}$$

16.A sinusoidal voltage of peak value 283 V and frequency Hz is applied to a series LCR circuit in which R=3Ω, L=25.48 mH and C=796μF. Find the impedance of the circuit.

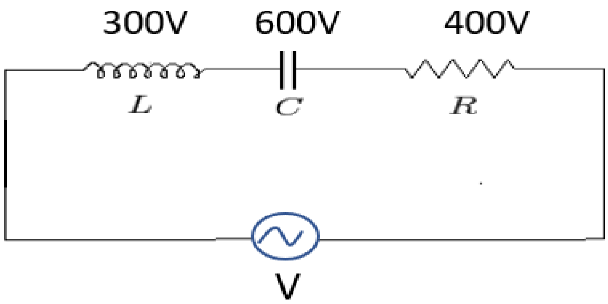
$$\mathbf{Z} = \sqrt{(\mathbf{R})^2 + \left(\frac{\mathbf{1}}{\boldsymbol{\omega}\mathbf{C}} - \boldsymbol{\omega L}\right)^{\mathbf{2}}}$$

$$= \sqrt{(\mathrm{R})^2 + \left(\frac{1}{2\pi \mathrm{f} \mathrm{C}} - 2\pi \mathrm{f} L\right)^2}$$

$$= \sqrt{(3)^2 + \left(\frac{1}{2\mathrm{x}3.14\mathrm{x}50\mathrm{x}796\mathrm{x}10^{-6}} - 2\mathrm{x}3.14\mathrm{x}50\mathrm{x}25.48\mathrm{x}10^{-3}\right)^2}$$

$$= \sqrt{9 + (4-8)^2} = \sqrt{9+16} = 5\ \Omega$$

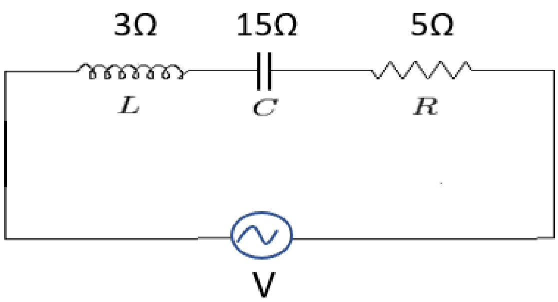
17.In the following circuit,find the impedance



$$\mathrm{V} = \sqrt{\mathrm{v_R}^{\ 2} + (\mathrm{v_C} - \mathrm{v_L})^2}$$

$$= \sqrt{400^2 + (600-300)^2} = 500\mathrm{V}$$

18. In the following circuit ,find the impedance



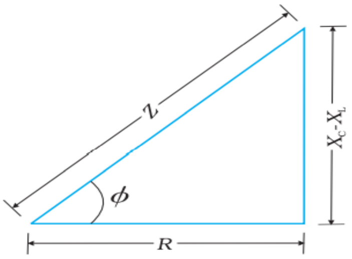
$$\mathrm{Z} = \sqrt{(\mathrm{R})^2 + (\mathrm{X_C} - \mathrm{X_L})^2}$$

$$= \sqrt{5^2 + (15-3)^2} = \sqrt{169} = 13\Omega$$

19.Write ant two factors on which the impedance of a series LCR crcuit depends.

Resistance, Capacitance, Inductance, Frequency of AC

20.Using Impedance diagram(impedance triangle) obtain the expression for phase difference between voltage and current in a series LCR circuit



$$\tan\phi = \frac{X_C - X_L}{R}$$

$$\phi = \tan^{-1}\frac{X_C - X_L}{R}$$

21.What is the principle behind tuning of radio or TV Resonance or At what condition a series LCR circuit is used for tuning.

Resonance

22.What is the condition for resonance in a series LCR circuit

$$\mathbf{X_C = X_L}$$

$$\frac{1}{\omega_0 C} = \omega_0 L$$

23.Obtain the expression for resonant frequency

At resonance, $X_C = X_L$

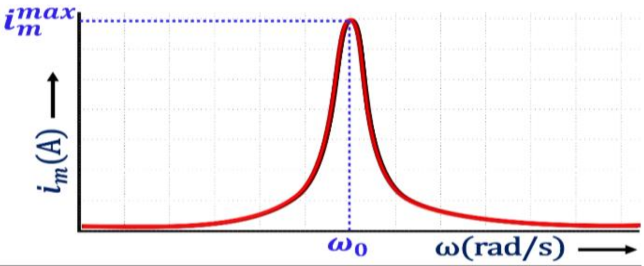
$$\frac{1}{\omega_0 C} = \omega_0 L$$

$$\omega_0^2 = \frac{1}{LC}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

ω_0 is called Resonant frequency

24.Draw the graphical variation of current amplitude i_m with frequency ω



25.Obtain the expression for power in an ac circuit

$$p = v\,i$$

$$p = v_m \sin\omega t \; i_m \sin(\omega t + \phi)$$

$$P = \frac{v_m i_m}{2}\langle\cos\phi - \cos(2\omega t + \phi)\rangle$$

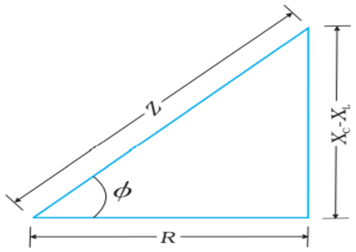
$$P = \frac{v_m i_m}{2}\cos\phi$$

$$P = \frac{v_m}{\sqrt{2}}\frac{i_m}{\sqrt{2}}\cos\phi$$

$$P = V\; I\cos\phi$$

The quantity $\cos\phi$ is called the **power factor.**

26.Draw the Impedance diagram(impedance triangle) and write the expression for power factor from it.

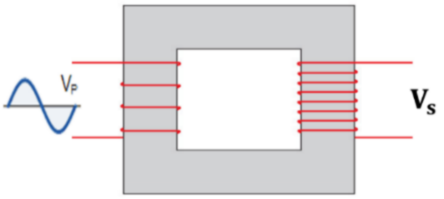


$$\cos\phi = \frac{R}{Z}$$

27.What is the principle of transformer

Mutual Induction

28.Explain with the help of a neat diagram the working of a transformer



Transformer works on the Principle of Mutual Induction

When an alternating voltage is applied to the primary, the resulting current produces an alternating magnetic flux which links the secondary and induces an emf in it.

$$V_P = -N_P\frac{d\phi}{dt}$$

$$V_s = -N_s\frac{d\phi}{dt}$$

$$\frac{V_s}{V_P} = \frac{N_s}{N_P} \text{ -------------------- } (1)$$

If the transformer is 100% efficient

Power input= power output

$$I_P V_P = I_S V_S$$

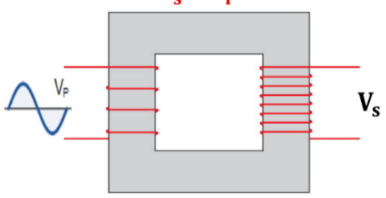
$$\frac{I_P}{I_S} = \frac{V_s}{V_P} \text{ ------------- } (2)$$

From eq(1) and (2)

$$\frac{I_P}{I_S} = \frac{V_s}{V_P} = \frac{N_s}{N_P}$$

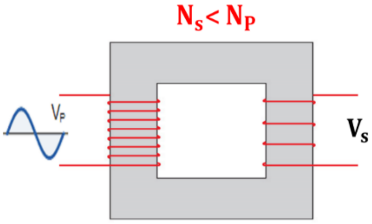
29.What is a step-up transformer

$N_s > N_P$



- For a step up transformer the number of turns in the secondary will be greater than that in the primary($N_s > N_P$)
- $V_s > V_P$)
- $I_s < I_P$)

30.What is a step-down transformer



- For a step down transformer the number of turns in the secondary will be less than that in the primary($N_S < N_P$)
- $V_S < V_P$)
- $I_S > I_P$)

31.A power transmission line feeds input power at 3300 V to a step-down transformer with its primary windings having 6000 turns. What should be the number of turns in the secondary in order to get output power at 220 V?

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

$$N_S = \frac{V_S}{V_P} x N_P$$

$$N_S = \frac{220}{3300} x6000 = 400$$

32.Explain briefly the energy losses in a transformer and the method to minimise these losses.

(i)Flux Leakage:

- Not all of the flux due to primary passes through the secondary .
- It can be reduced by winding the primary and secondary coils one over the other.

(ii)Resistance of the windings :

- The energy is lost due to heat produced in the wire as I^2R.
- these are minimised by using thick wire.

(iii)Eddy currents loss:

- The alternating magnetic flux induces eddy currents in the iron core and causes heating.
- The effect is reduced by having a laminated core.

(iv)Hysteresis loss:

- The repeated magnetisation and demagnetisation of the core produces hysteresis loss as heat.
- This can be minimised by using soft iron as core which has a low hysteresis loss.

Chapter 8
Electromagnetic Waves

1.What is Displacement Current?

The current due to changing electric field or electric flux is called called displacement current.

$$i_d = \varepsilon_0 \frac{d\phi_E}{dt}$$

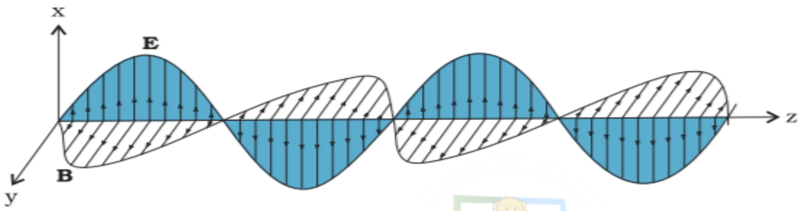
2.Write Ampere-Maxwell law (or)Maxwell's mlodification to Ampere's circuital theorem.

$$\oint B \cdot dl = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$$

3.............................. is the source of electromagnetic waves.

An oscillating charge (accelerating charge)

4.A typical plane electro magnetic wave propagating along Z-direction is shown in figure.



Write the equation for electric and magnetic fields

$$E_x = E_0 \sin(kz - \omega t)$$
$$B_y = B_0 \sin(kz - \omega t)$$

5. List the properties of electromagnetic waves (any four)

- In an e.m waves are transverse waves in which the electric and magnetic fields are perpendicular to each other, and also to the direction of propagation.
- The speed of e.m.wave in vacuum is,

  $$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

  The speed of of electromagnetic waves in a material medium is

  $$v = \frac{1}{\sqrt{\mu\varepsilon}} \quad \text{or} \quad v = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}} \quad \text{or} \quad v = \frac{c}{\sqrt{\mu_r \varepsilon_r}}$$

- The electric and the magnetic fields in an electromagnetic wave are related as $\frac{E_0}{B_0} = c$
- No material medium is required for the propagation of e.m.wave.
- Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields.
- Electromagnetic waves transport momentum as well. When these waves strike a surface, total momentum delivered to this surface is,

  $p = \frac{U}{c}$ where U is the energy

6.A plane electromagnetic wave of frequency 25 MHz travels in free space along the x-direction. At a particular point in space and time, E = 6.3ĵ V/m. What is B at this point?

$$\frac{E_0}{B_0} = c$$

$$B_0 = \frac{E_0}{c} = \frac{6.3}{3 \text{ x } 10^8} = 2.1 \text{ x} 10^{-8} \text{ T}$$

E is along y-direction and the wave propagates along x-axis.
Therefore, B should be in a direction perpendicular to both x- and y-axes.
i.e., B is along z-axis.

7.The magnetic field in a plane electromagnetic wave is given by $B_y = 2 \times 10^{-7} \sin(0.5\times10^3 x + 1.5\times10^{11} t)$ T.

a) What is the wavelength and frequency of the wave?

b) Write an expression for the electric field.

(a) $$B_y = 2 \times 10^{-7} \sin(0.5\times10^3 x + 1.5\times10^{11} t)$$

$$B_y = B_0 \sin(kx - \omega t)$$

$$k = 0.5\times10^3$$

$$k = \frac{2\pi}{\lambda} = 0.5\times10^3$$

$$\lambda = \frac{2\pi}{0.5\times10^3} = 12.56 \times 10^{-3} \text{ m}$$

$$\omega = 1.5\times10^{11}$$

$$\omega = 2\pi v = 1.5\times10^{11}$$

$$v = \frac{1.5\times10^{11}}{2\pi} = 0.24 \text{ x} 10^{11} \text{ Hz}$$

b) B is along y-direction and the wave propagates along x-axis.
Therefore, E should be in a direction perpendicular to both x- and y-axes.
i.e., E is al ong z-axis.

So expression for electric field is ,

$$E_z = E_0 \sin(k x - \omega t)$$

$$\frac{E_0}{B_0} = c$$

$$E_0 = B_0 \, x \, c$$

$$= 2 \times 10^{-7} \text{ x } 3 \times 10^8 = 60 \text{ V/m}$$

$$E_z = 60 \sin(0.5\times10^3 x + 1.5\times10^{11} t) \text{ V/m}$$

8.Arrange electromagnetic waves in the increasing order of wavelength(or decreasing order of frequency.

Gamma rays . X-rays , Ultraviolet rays, Visible rays, Infrared waves , Microwaves, Radio waves

9.How radio waves are produced ?

Radio waves are produced by the accelerated motion of charges in conducting wires.

10.Write the uses of radio waves.

- They are used in radio and television communication systems.
- Cellular phones use radio waves.

11.How microwaves are produced?

- Microwaves are produced by special vacuum tubes called, klystrons, magnetrons and Gunn diodes.

12.Write the uses of microwaves.

- Used for radar systems used in aircraft navigation .
- Used in speed guns used to time fast balls, tennis serves, and automobiles.
- Microwaves are used in microwave ovens , for cooking.

13.How is food cooked in microwave ovens?

In microwave ovens, the frequency of the microwaves is selected to match the resonant frequency of water molecules so that energy from the waves is transferred efficiently to the kinetic energy of the molecules. This raises the temperature of any food containing water.

14.How infrared waves are produced?

Infrared waves are produced by hot bodies and molecules.

15.Write the uses of infrared waves.

- Infrared lamps are used in physical therapy.
- Infrared radiation plays an important role in maintaining the earth's warmth or average temperature through the greenhouse effect.
- Infrared detectors are used in Earth satellites, both for military purposes and to observe growth of crops.
- LEDs emit infrared waves, which are used in the remote switches of TV sets, video recorders and hi-fi systems.

16.Why IR waves are called heat waves?

Infrared waves are sometimes referred to as heat waves. This is because water molecules present in most materials readily absorb infrared waves After absorption, their thermal motion increases, that is, they heat up and heat their surroundings.

17.Explain Greenhouse Effect.

Incoming visible light is absorbed by the earth's surface and reradiated as infrared (longer wavelength) radiations. This radiation is trapped by greenhouse gases such as carbon dioxide and water vapour. This trapped Infrared radiation maintains the earth's warmth.

18.How ultraviolet rays are produced?

Ultraviolet (UV) radiation is produced by special lamps and very hot bodies. The sun is an important source of ultraviolet light.

19.Write the uses of UV rays.

- UV radiations are used in LASIK (Laser assisted in situ keratomileusis) eye surgery.
- UV lamps are used to kill germs in water purifiers.

20.How x-rays are used?

One common way to generate X-rays is to bombard a metal target by high energy electrons.

21.Write the uses of x- rays.

- X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer.

22.How gamma rays are produced?

This high frequency radiation is produced in nuclear reactions and also emitted by radioactive nuclei.

23.Write the uses of gamma rays.

- They are used in medicine to destroy cancer cells.

24.Why is depletion of ozone layer , a matter of international concern?

UV light in large quantities has harmful effects on humans. Most of the UV rays from sun is absorbed in the ozone layer in the atmosphere. Ozone layer in the atmosphere plays a protective role, and hence its depletion by chlorofluoro-carbons (CFCs) gas (such as freon) is a matter of international concern.

Chapter 9
Ray Optics and Optical Instruments

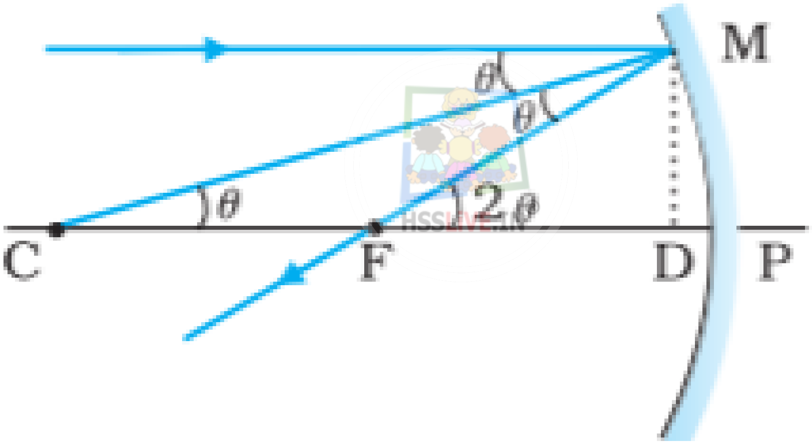
1.Write the laws of reflection

1)The angle of incidence is equal to the angle of reflection(i=r).
2)The incident ray, reflected ray and the normal to the reflecting surface at the point of incidence lie in the same plane.

2.Write the Cartesian sign convention to measure distances.

1) All distances are measured from the pole of the mirror or the optical centre of the lens.
2) The distances measured in the same direction as the incident light are taken as positive and those measured in the direction opposite to the direction of incident light are taken as negative.
3) The heights measured upwards with respect to principal axis of the mirror/ lens are taken as positive .The heights measured downwards are taken as negative.

3.Obtain the relation between Focal Length and Radius of Curvature



Let f be the focal length and R be the radius of curvature of lens

From figure , $\tan\theta = \frac{MD}{R}$, $\theta = \frac{MD}{R}$ ------(1)

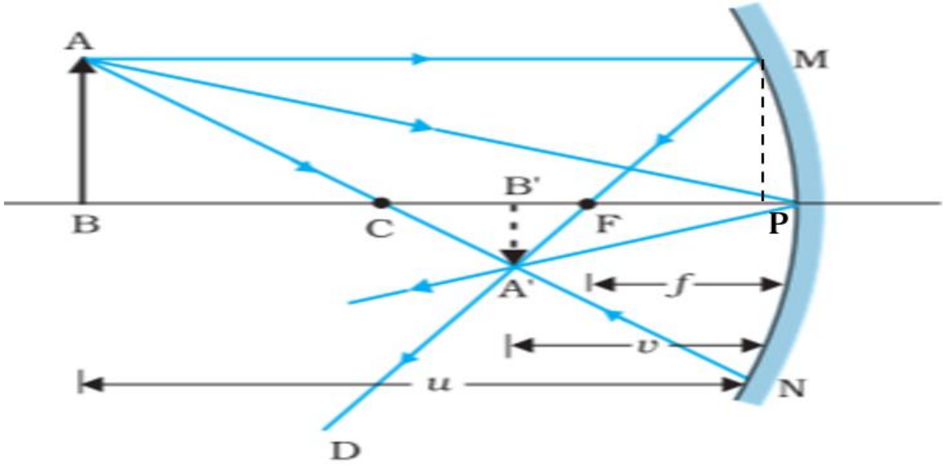
$\tan 2\theta = \frac{MD}{f}$, $2\theta = \frac{MD}{f}$ -----(2) $(\tan 2\theta \approx 2\theta)$

Substituting θ from eq(1) in eq(2), $2\frac{MD}{R} = \frac{MD}{f}$

$$\frac{2}{R} = \frac{1}{f}$$

$$\mathbf{f = \frac{R}{2}}$$

4.Obtain the mirror equation



The two right-angled triangles A′B′F and MPF are similar

$$\frac{B'A'}{PM} = \frac{B'F}{FP}$$

$$\frac{B'A'}{BA} = \frac{B'F}{FP} \text{------------}(1) \quad (\text{since } PM = AB)$$

The right angled triangles A′B′P and ABP are also similar.

$$\frac{B'A'}{BA} = \frac{B'P}{BP} \text{------------}(2)$$

From eqns(1) and (2)

$$\frac{B'F}{FP} = \frac{B'P}{BP}$$

$B'P = v$, $BP = u$, $B'F = v\text{-}f$, $FP = f$,

$$\frac{v-f}{f} = \frac{v}{u}$$

Applying sign convention ,

$$\frac{-v- -f}{-f} = \frac{-v}{-u}$$

$$\frac{v}{f} - 1 = \frac{v}{u}$$

Dividing by v

$$\frac{1}{f} - \frac{1}{v} = \frac{1}{u}$$

$$\mathbf{\frac{1}{u} + \frac{1}{v} = \frac{1}{f}}$$

This relation is known as the mirror equation.

5.An object is placed at (i) 10 cm, (ii) 5 cm in front of a concave mirror of radius of curvature 15 cm. Find the position, nature, and magnification of the image in each case.

The focal length $f = -15/2$ cm $= -7.5$ cm

(i) The object distance $u = -10$ cm. Then Eq. (9.7) gives

$$\frac{1}{v}+\frac{1}{-10}=\frac{1}{-7.5}$$

or $$v=\frac{10\times7.5}{-2.5}=-30 \text{ cm}$$

The image is 30 cm from the mirror on the same side as the object.

Also, magnification $m = -\frac{v}{u}=-\frac{(-30)}{(-10)}=-3$

The image is magnified, real and inverted.

(ii) The object distance $u = -5$ cm. Then from Eq. (9.7),

$$\frac{1}{v}+\frac{1}{-5}=\frac{1}{-7.5}$$

or $$v=\frac{5\times7.5}{(7.5-5)}=15 \text{ cm}$$

This image is formed at 15 cm behind the mirror. It is a virtual image.

Magnification $m = -\frac{v}{u}=-\frac{15}{(-5)}=3$

The image is magnified, virtual and erect.

6.State the laws of refraction

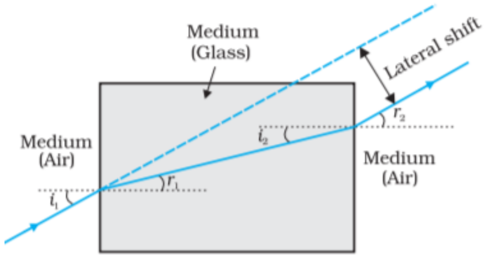
(i) The incident ray, the refracted ray and the normal to the interface at the point of incidence, all lie in the same plane.

(ii) The ratio of the sine of the angle of incidence to the sine of angle of refraction is constant.**(Snell's Law)**

$$\frac{\sin i}{\sin r}=n_{21}$$

7.Some applications of refraction

1. Lateral shift
2. Apparent depth



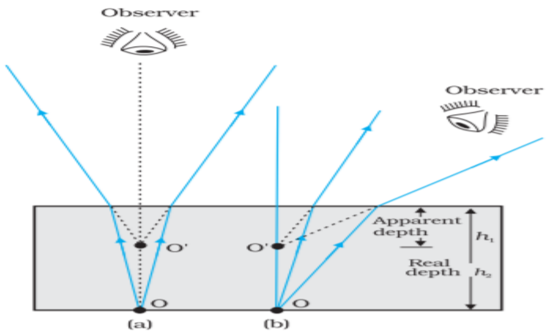
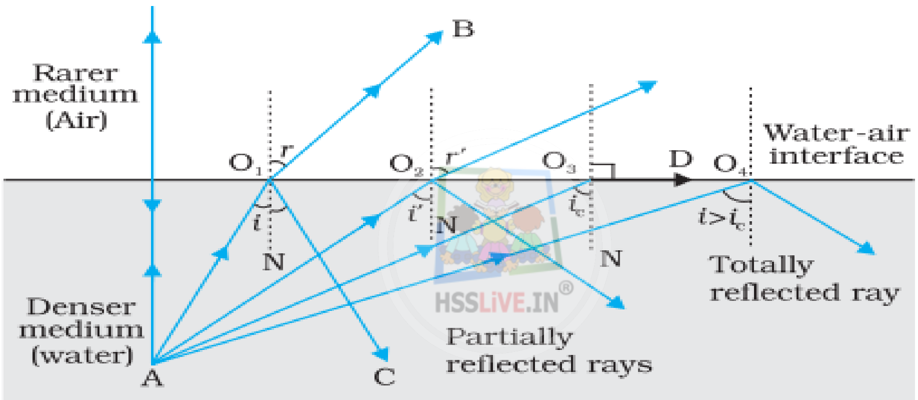


FIGURE 9.10 Apparent depth for (a) normal, and (b) oblique viewing.

8.What is total internal reflection ?

When a ray of light enters from a denser medium to a rarer medium, if the angle of incidence is greater than the critical angle (i_c) for the given pair of media, the incident ray is totally reflected. This is called total internal reflection.



9.What are the conditions for total internal reflection?

- The ray of light should enter from a denser medium to a rarer medium.
- The angle of incidence should be greater than the critical angle (i_c) for the given pair of media .

10.Define Critical Angle.

The angle of incidence in the denser medium, for which the angle of refraction becomes 90º, is called the critical angle (i_c) for the given pair of media.

11.Write the relation connecting critical angle and refractive index

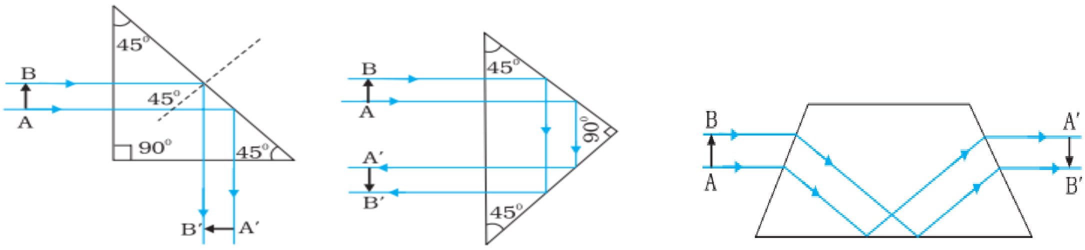
$$n=\frac{1}{\sin i_c}$$

12.The critical angle of diamond is 24.4^0 . Find the refractive index of diamond.

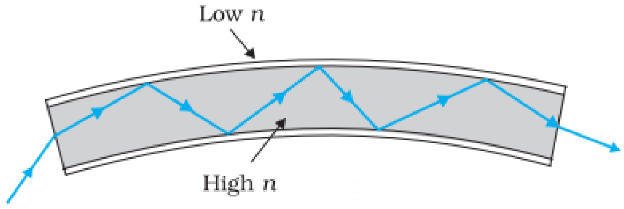
$$n=\frac{1}{\sin i_c}=\frac{1}{\sin 24.4}=2.42$$

13.Write some applications of total internal reflection

(i)Total reflecting Prisms



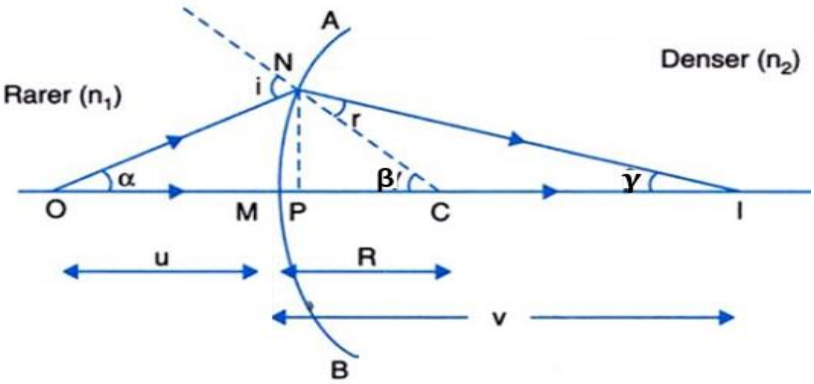
(ii) Optical fibres:



14.Obtain the relation between object distance u, image distance v, radius of curvatures and refractive indices of two media, when refraction occurs through a spherical surface.

or

Derive the relation $\frac{n_2}{v}-\frac{n_1}{u}=\frac{n_2-n_1}{R}$ when refraction occurs through a spherical surface.



$$\tan\alpha=\frac{MN}{OM}$$

$$\tan\beta=\frac{MN}{MC}$$

$$\tan\gamma=\frac{MN}{MI}$$

For small values of α , β and γ

$$\alpha = \frac{MN}{OM}$$

$$\beta = \frac{MN}{MC}$$

$$\gamma = \frac{MN}{MI}$$

From ΔNOC, $i = \alpha + \beta$--------------(1)

From ΔNIC, $\beta = r + \gamma$

$r = \beta - \gamma$---------------(2)

From Snell's law

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

$$n_1 \sin i = n_2 \sin r$$

$$n_1\, i = n_2 r$$

Substituting fron eqn (1) and (2)

$$n_1\,(\alpha + \beta) = n_2\,(\beta - \gamma)$$

$$n_1\left(\frac{MN}{OM} + \frac{MN}{MC}\right) = n_2\left(\frac{MN}{MC} - \frac{MN}{MI}\right)$$

$$\frac{n_1}{OM} + \frac{n_1}{MC} = \frac{n_2}{MC} - \frac{n_2}{MI}$$

$$\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2}{MC} - \frac{n_1}{MC}$$

$$\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$$

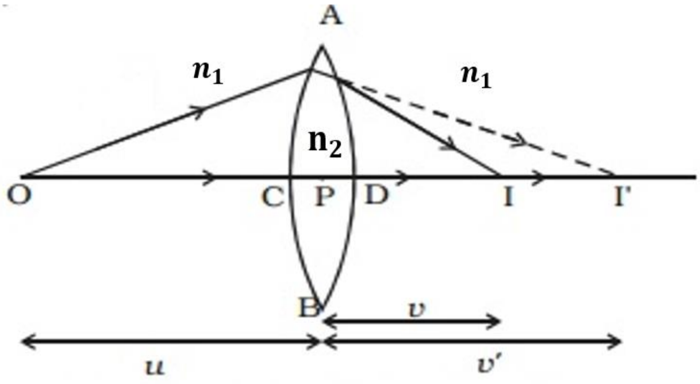
Applying the Cartesian sign convention,

OM = −u, MI = +v, MC = +R

$$\frac{n_1}{-u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}$$

$$\boldsymbol{\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}}$$

15.Derive Lens maker's formula



For the first surface

$$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \text{----------}(1)$$

For the second surface

$$\frac{n_1}{v} - \frac{n_2}{v'} = \frac{n_1 - n_2}{R_2} \text{-------------}(2)$$

Eqns (1) + (2)

$$\frac{n_2}{v'} - \frac{n_1}{u} + \frac{n_1}{v} - \frac{n_2}{v'} = \frac{n_2 - n_1}{R_1} + \frac{n_1 - n_2}{R_2}$$

$$\frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Dividing throughout by n_1

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

If $n_2 = n$, $n_1 = 1$

$$\frac{1}{v} - \frac{1}{u} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \text{------------}(3)$$

When u=∞ (infinity) , v=f

$$\mathbf{\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \text{-----------}(4)}$$

16. The radii of curvature of the faces of a double convex lens are 10cm and 15cm.Its focal length is 12cm.What is the refractive index of glass?

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{12} = (n-1)\left(\frac{1}{10} - \frac{1}{-15}\right)$$

$$\frac{1}{12} = (n-1)\left(\frac{1}{10} + \frac{1}{15}\right)$$

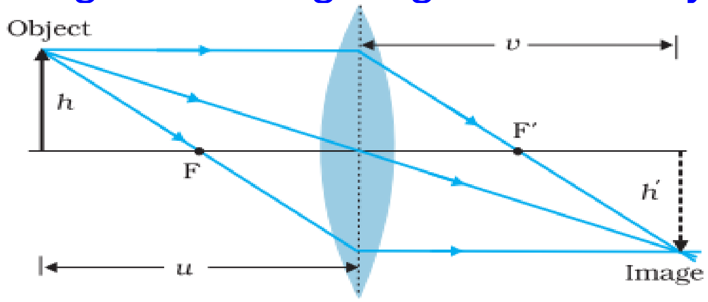
$$\frac{1}{12} = (n-1) x \frac{1}{6}$$

$$n-1 = \frac{6}{12} = \frac{1}{2} = 0.5$$

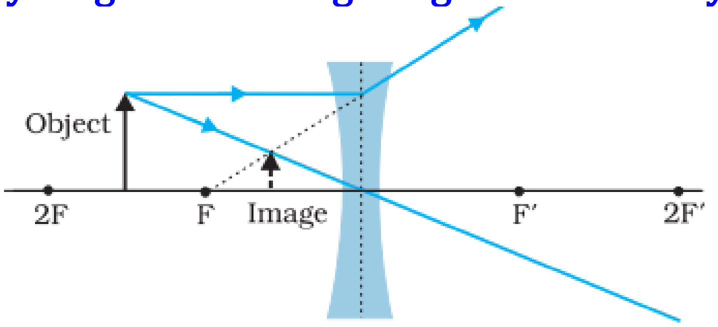
n= 0.5+1

n=1.5

17.Draw a ray diagram showing image formation by a convex lens



18.Draw a ray diagram showing image formation by a concave lens



19.. Define Power of a lens. Write its unit.

Power of a lens is the reciprocal of focal length expressed in metre

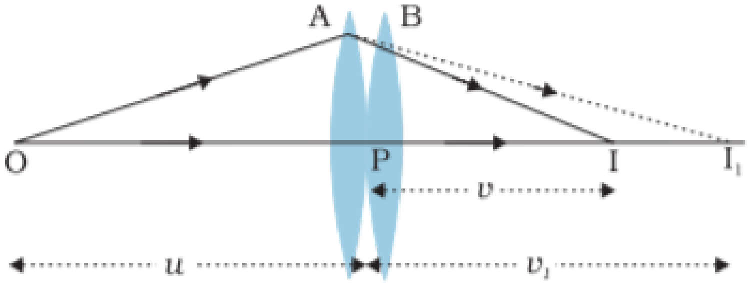
$$p = \frac{1}{f}$$

The SI unit for power of a lens is **diopter (D)**.

20.One diopter is the power of a lens of focal length ....

1m (1 metre)

21.Obtain the expression for effective focal length when two thin lenses are kept in contact



For the first lens A,

$$\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f_1} \text{ -----------(1)}$$

For the second lens B,

$$\frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_2} \text{ -----------(2)}$$

Eqn (1) +(2)

$$\frac{1}{v_1} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \text{ -----------(3)}$$

If the two lens-system is replaced by a single lens of focal length f,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \text{---------------}(4)$$

From eqn (3) and (4) $\mathbf{\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}}$

22.Two lenses of powers +7D and -3D are combined. Find the focal length of the combination.

$P = P_1 + P_2$

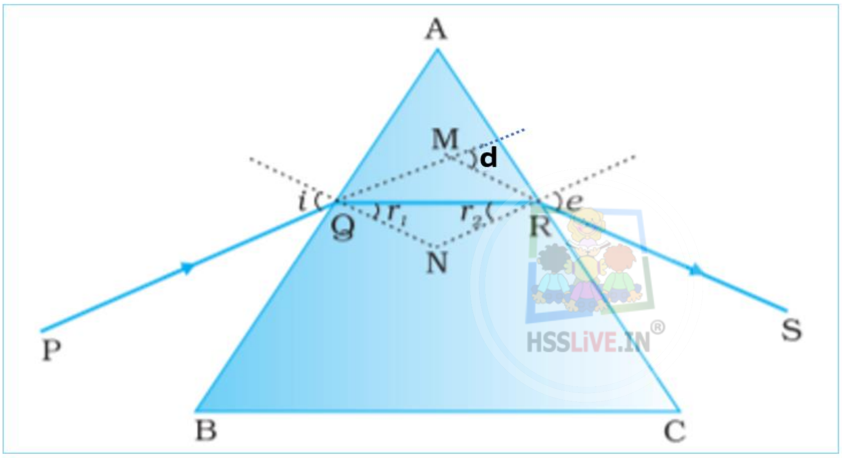
$P = 7-3 = 4D$

$P = \frac{1}{f}$

$f = \frac{1}{P} = \frac{1}{4}$

$= 0.25m = 25cm$

23.Draw the path of the ray which is refracted through a prism and obtain the equation for refractive index of material of prism. Draw the i-d curve



$\angle A + \angle QNR = 180^{\circ}$

$r_1 + r_2 + \angle QNR = 180^{\circ}$

$r_1 + r_2 = A \text{------------------}(1)$

The total deviation ,

$d = (i - r_1) + (e - r_2)$

$d = i + e - (r_1 + r_2)$

$\mathbf{d = i + e - A} \text{-----------------}\mathbf{(2)}$

At the minimum deviation

$d = D, \quad i = e, \quad r_1 = r_2 = r$

From eqn (1)

$2r = A$

$\mathbf{R = \frac{A}{2}} \text{----------------}\mathbf{(3)}$

From eqn (2)

$d = 2i - A$

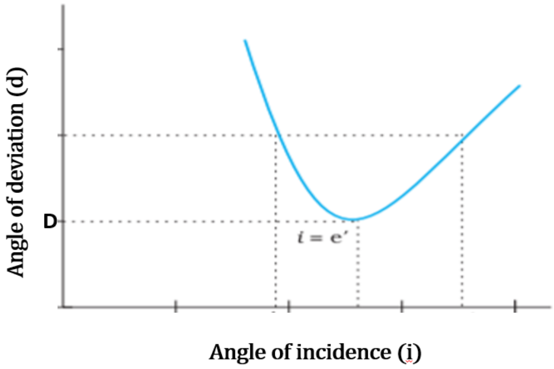
$\mathbf{i = \frac{A+D}{2}} \text{-------------}\mathbf{(4)}$

By Snell's law the refractive index of prism

$$n = \frac{\sin i}{\sin r}$$

$$n = \frac{\sin \frac{A+D}{2}}{\sin \frac{A}{2}}$$

i-d curve



24.Obtain the expression for deviation for thin prism.

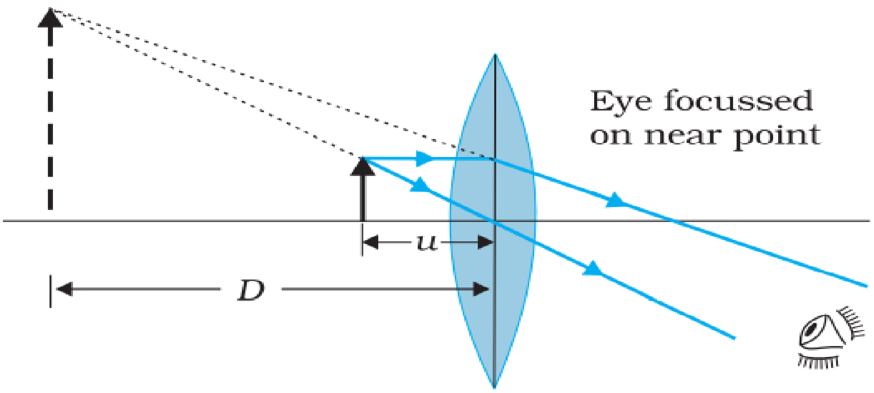
For a small angle prism, i.e., a thin prism, D is also very small,

$$n = \frac{\frac{A+D}{2}}{\frac{A}{2}}$$

$$n = 1 + \frac{D}{A}$$

$$D = (n-1)A$$

24.Draw a ray diagram showing the image formation at near point for a simple microscope.



The image is erect, magnified and virtual .

25.Write the expression for magnifying power(linear magnification) of a simple microscope.

$m = 1 + \frac{D}{f}$ (when image is at near point D)

$m = \frac{D}{f}$ (when image is at infinity)

26.Derive the expression for linear magnification simple microscope .

$$m=\frac{v}{u}$$

$$=v\left(\frac{1}{v}-\frac{1}{f}\right)$$

$$m=1-\frac{v}{f}$$ (when image is at near point v=-D)

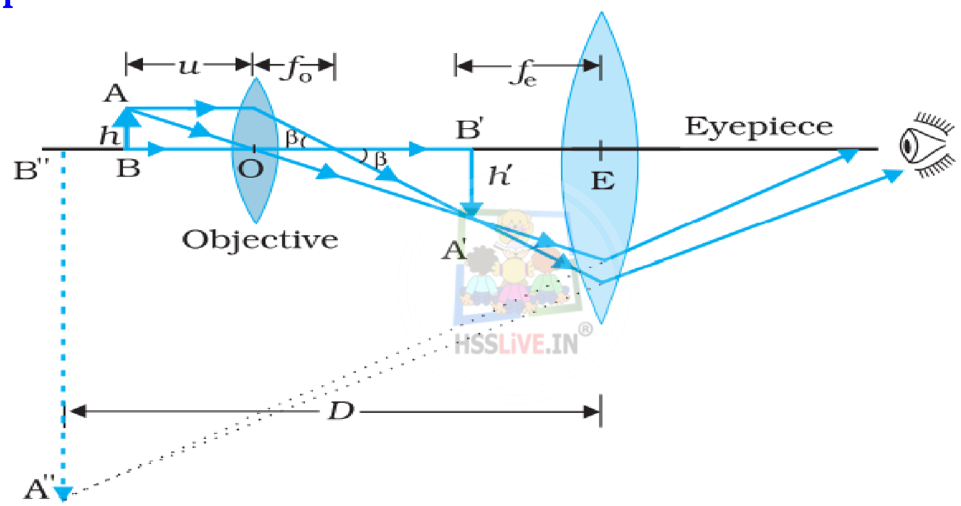
$$\mathbf{m=1+\frac{D}{f}}$$

$$\mathbf{m=\frac{D}{f}}$$ (when image is at infinity)

27.A thin convex lens of focal length 5cm is used as a simple microscope by a person with normal near point(25cm).What is the magnifying power of this microscope?

$$m=1+\frac{D}{f}=1+\frac{25}{5}=6$$

28.Draw the ray diagram showing the image formationby a compound microscope.



The image is real, inverted and magnified.

29.Obtain the expression for the magnification produced by a compound microscope when the image is formed at near point

Magnifiction, $m= m_o \times m_e$ -----------(1)

$$m_0=\frac{L}{f_0}$$

When the final image is formed at near point,

$$m_e=1+\frac{D}{f_e}$$

Substituting in eqn(1) $\mathbf{m=\frac{L}{f_0}\left(1+\frac{D}{f_e}\right)}$

30.Write the expression for the magnification produced by a compound microscope when the image is formed at infinity

$$m=\frac{L}{f_0}\times\frac{D}{f_e}$$

31.For large magnification for a compound microscope

The objective and eyepiece should have small focal lengths

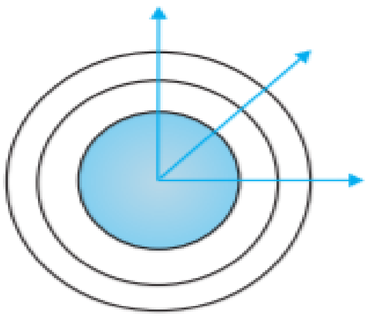
Chapter 10
Wave Optics

1.Define wavefront

Wavefront is the locus of points, which oscillate in phase or a wavefront is defined as a surface of constant phase.

2.Draw the wavefronts very near to a point source.

The wavefronts will be spherical .

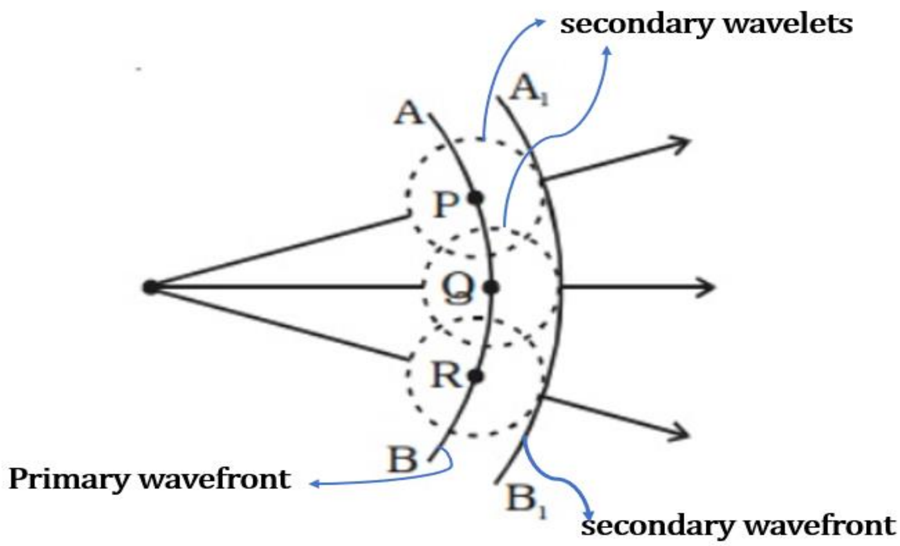


3.Draw wavefronts at large distance from a source.

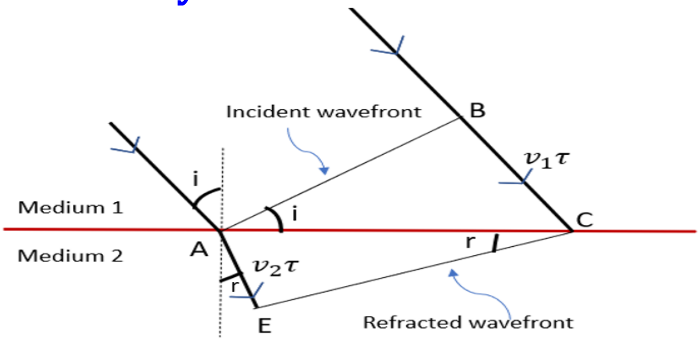
These are plane Wavefronts

4.Explain Huygens Principle

According to Huygens principle, each point of the wavefront acts as a source secondary wavelets and if we draw a common tangent to all these secondary wavelets, we obtain the new position of the wavefront at a later time.



5.Using Huygen's theory obtain the law of refraction of a Plane Wave. or Using Huygen's theory derive Snell's law of refraction.



$$\sin i = \frac{BC}{AC} = \frac{v_1\tau}{AC} \text{----------}(1)$$

$$\sin r = \frac{AE}{AC} = \frac{v_2\tau}{AC} \text{----------}(2)$$

$$\text{eqn}\frac{(1)}{(2)} \qquad \frac{\sin i}{\sin r} = \frac{v_1}{v_2} \text{--------------}(3)$$

$$n_1 = \frac{c}{v_1}$$

$$n_2 = \frac{c}{v_2}$$

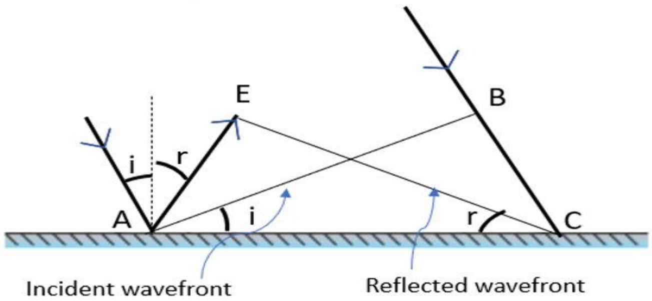
$$\frac{n_2}{n_1} = \frac{v_1}{v_2} \text{-----------}(4)$$

Substituting in eqn (3)

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} \text{-----------}(5)$$

This is the Snell's law of refraction.

6.Using Huygen's theory obtain the law of reflection of a plane wave. Or Using Huygen's theory prove that angle of incidence is equal to angle of reflection.



$$AE = BC = v\tau$$

$$AC = AC \text{ (common side)}$$

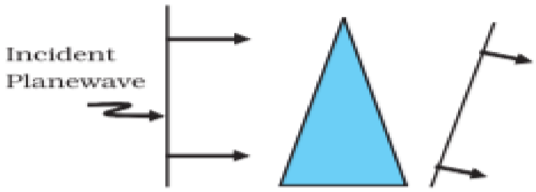
So the triangles EAC and BAC are congruent .

Therefore . **i =r**

Angle of incidence=Angle of reflection

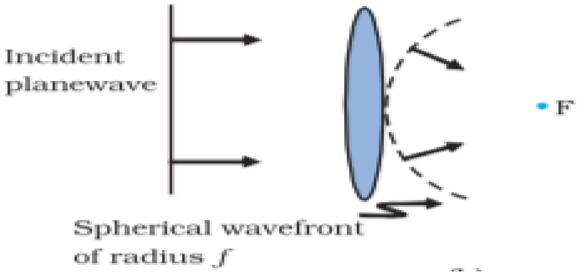
This is the law of reflection.

7.A plane wavefront is incident on a thin prism . Sketch the refracted wavefront



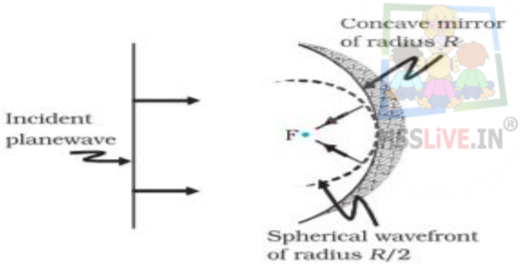
The emerging wavefront is also plane wavefront, but tilted.

8.A plane wavefront is incident on a convex lens . Sketch the refracted wavefront



The emerging wavefront is spherical and converges to the point F which is known as the focus.

9.A plane wavefront is incident on a concave mirror . Sketch the reflected wavefront



The reflected wavefront is a spherical converging to the focal point F.

10.What are coherent sources?

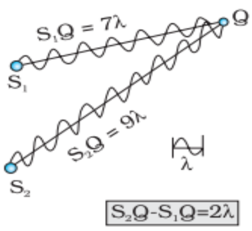
Two sources are said to be coherent if they emit light waves of same frequency and same phase or constant phase difference.

11.Define Interference.

Interference is the phenomenon in which two waves superpose to form a resultant wave of greater or lower amplitude.

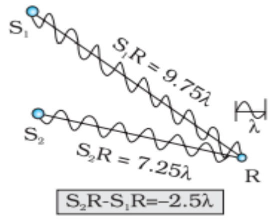
12.Write the Condition for constructive interference

If the path difference at a point is an integral multiple of λ, there will be constructive interference and a bright fringe is formed at that point



$$S_2P - S_1P = n\lambda \qquad \text{where } (n = 0, 1, 2, 3,...)$$

13.Write the condition for destructive interference



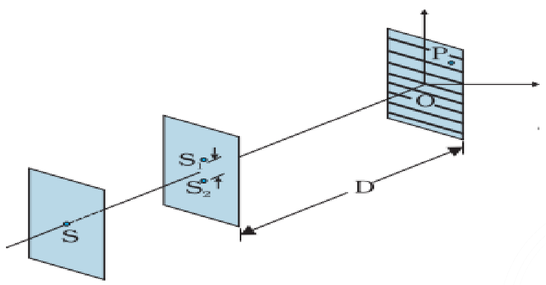
If the path difference at a point is an odd integral multiple of $\lambda/2$, there will be destructive interference and a dark fringe is formed at that point

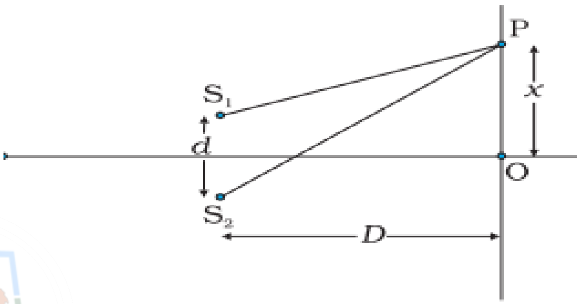
$$S_2 - S_1P = = (n+\frac{1}{2})\,\lambda \quad \text{where } (n = 0, 1, 2, 3,...)$$

14.Two sodium lamps illuminating two pinholes cannot produce interference fringes. Why?

The light waves coming out from two independent sources of light(like a sodium lamp) will not have any fixed phase relationship and would be incoherent and cannot produce interference pattern.

15.Explain Young's double slit experiment to produce interference Pattern.





Thomas Young made two pinholes S_1 and S_2 (very close to each other) on an opaque screen. These were illuminated by another pinholes which is illuminated by a bright source. Light waves spread out from S and fall on both S_1 and S_2. S_1 and S_2 then behave like two coherent sources and interference pattern with alternate bright and dark fringes is formed on the screen. The central fringe will be bright.

For bright band path difference , $\frac{xd}{D} = n\lambda$

$$x_n = \frac{n\lambda D}{d} \quad , \quad n=0, \pm1, \pm2,....$$

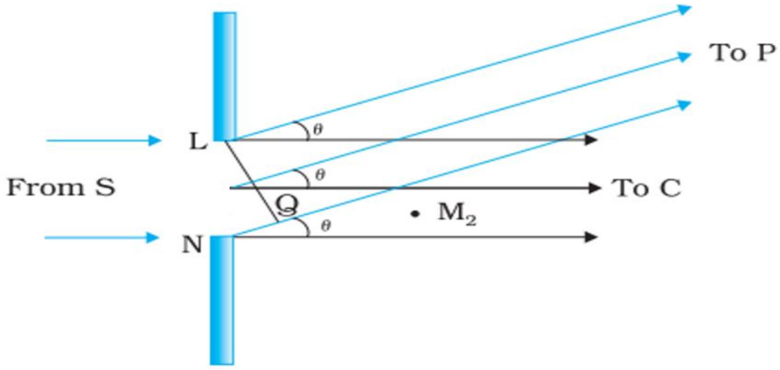
For dark band path difference, $\frac{xd}{D} = (n+\frac{1}{2})\,\lambda$

$$x_n = (n + \frac{1}{2})\,\frac{\lambda D}{d} \quad , \quad n=0, \pm1, \pm2,....$$

16.What is Diffraction?

Diffraction is the phenomenon of bending of light around the corners of an obstacle , into the region of geometrical shadow of the obstacle.

17. Draw a neat diagram of single slit diffraction experiment and write the condition for central maximum ,secondary maxima and minima.



For central maximum the angle θ =0

For secondary maxima , $\theta = (n+\frac{1}{2})\frac{\lambda}{a}$ **where n = ±1, ±2, ±3, ...**

For secondary minima, $\theta = n\frac{\lambda}{a}$ **where n = ±1, ±2, ±3, ...**

18.What is polarisation of light?

The phenomenon of restricting the electric field vibrations of light to one plane is called polarisation.

19.What is plane polarised light?

For a plane polarised light, the vibrations of electric field vector are restricted in one direction .

20.What type of waves show the property of polarisation, transverse or longitudinal?

Transverse waves

21.What are Polaroids?

If an unpolarised light passes through a polaroid ,we get plane polarised light. Polaroids are thin plastic like sheets, which consists of long chain molecules aligned in a particular direction. The electric vectors along the direction of the aligned molecules get absorbed.

22.Uses of polaroids ,

In sunglasses, wind screens in trains and aeroplanes, in 3D cameras

23. State Malus' Law

When an unpolarised light is passed through two polaroids P_1 and P_2 and if the angle between the polaroids is varied from 0º to 90º, the intensity of the7 transmitted light will vary as:

$$I = I_0 \cos^2\theta$$

Where I_0 is the intensity of the polarized from P_1.

Chapter 11
Dual Nature of Radiation and Matter

1.What are the different mehods of electron emission from a metal surface

Thermionic emission
Field Emission
Photo-electric emission

2.What is photoelectric Effect

The phenomenon of emission of electrons when photosensitive substances are illuminated by light of suitable frequency is called photoelectric effect. **i.e., the photocurrent increases linearly with intensity of incident light.**

3. Define work function

The minimum energy required by an electron to escape from a metal surface is called work function

$\phi_0 = h\nu_0$ (where ν_0 is threshold frequency)

work function is expressed in electron volt(eV)

4.Define threshold frequency

The minimum frequency of incident radiation below which photo electric emission is not possible is called threshold frequency(ν_0).

$$\nu_0 = \frac{\phi_0}{h}$$

Greater the work function ,greater the threshold frequency.

5.Define stopping potential

The stopping potential is the minimum negative potential applied to the anode at which the photo emission stops.

6.Obtain Einstein's Photoelectric Equation

Energy of photon =work function + KE of electrons

$$h\nu = \phi_0 + K_{max}$$

$$K_{max} = h\nu - \phi_0$$

$$\frac{1}{2} mv^2 = h\nu - \phi_0$$

7.At stopping potential V_0, Einstein's Photoelectric Equation can be expressed as

$$K_{max} = e V_0$$

$$e V_0 = h\nu - \phi_0$$

8.The work function of a metal is 6eV. If two photons each having energy 4 eV strike the metal surface. Will the emission be possible? Why?

No, photo emission is not possible.

Photo emission is possible only if $h\nu > \phi_0$

Here energy of incident photon is less than work function and hence photo emission is not possible.

9.The work function of caesium is 2.14 eV.
a) Find the threshold frequency for caesium.
b) the wavelength of the incident light if the photocurrent is brought to zero by a stopping potential of 0.60 V.

a) $$\nu_0 = \frac{\phi_0}{h}$$

ϕ_0 =2.14 eV =2.14 x1.6x10^{-19} J
h=6.63 x10^{-34}Js

$$\nu_0 = \frac{2.14\ \text{x}1.6\text{x}10^{-19}}{6.63\ \text{x}10^{-34}} = 5.16\ \text{x}10^{14}\ \text{Hz}$$

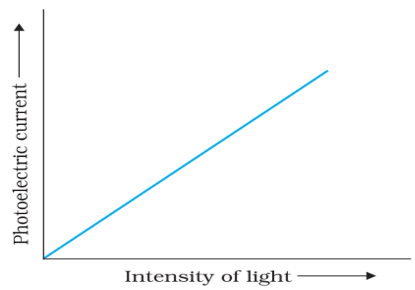
b) $$e V_0 = h\nu - \phi_0$$
$$h\nu = e V_0 - \phi_0$$
$$h\frac{c}{\lambda} = e V_0 - \phi_0$$
$$\lambda = \frac{hc}{eV_0 - \phi_0}$$
$$= \frac{6.63\ \text{x}10^{-34} x 3\ \text{x}10^{8}}{1.6\ \text{x}10^{-19} x 0.6 - 2.14\ \text{x}1.6\text{x}10{-19}} = 454\ \text{nm}$$

10.The work function of caesium is 2.14 eV. When light of frequency 6x10^{14} Hz is incident on the metal surface, photo emission of electrons occurs.(h=6.6x10^{-34})
a) Calculate the maximum kinetic energy of the emitted electrons
b) Calculate the stopping potential.

a) $$K_{max} = h\nu - \phi_0$$
=6.6x10^{-34} x6x10^{14} -2.14x1.6x10^{-19}
=3.96 x10^{-19}-3.42x10^{-19}
=0.54x10^{-19} J =0.54eV

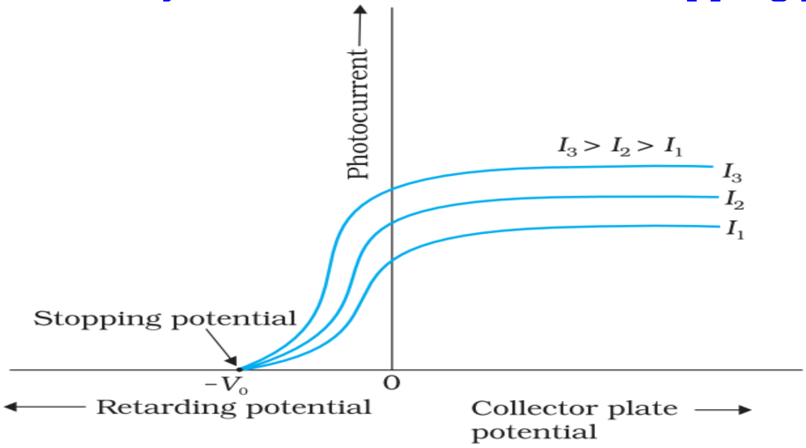
b) $$K_{max} = e V_0$$
$$V_0 = \frac{K_{max}}{e} = \frac{0.54\text{x}10^{-19}}{1.6\ x10^{-19}} = 0.34\ \text{V}$$

11.Draw a graph showing the variation of photocurrent with intensity of light.



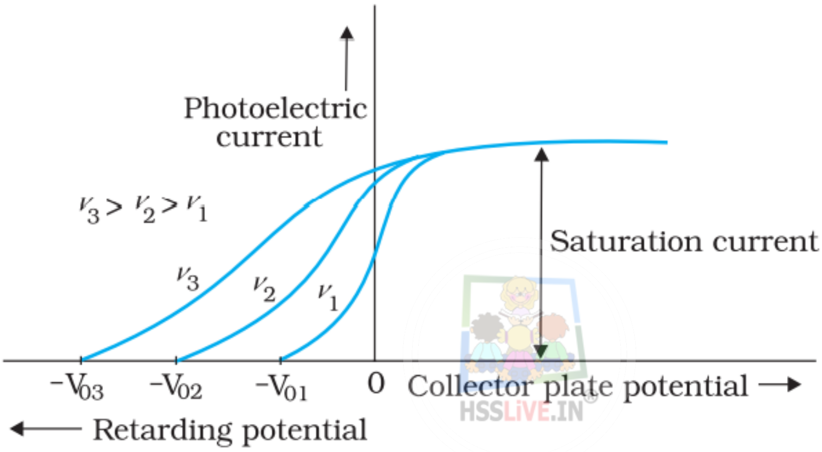
When intensity of incident radiation is increased the number of photoelectrons emitted per second increases and hence the photoelectric current also increases.

12.Effect of Intensity of incident radiation on stopping potential



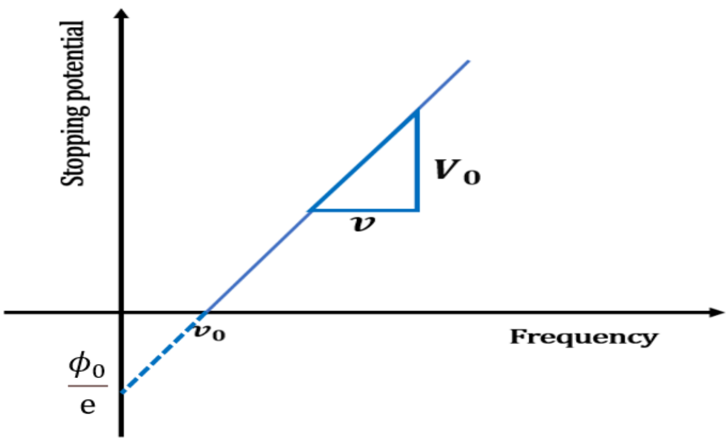
For a given frequency of incident radiation, the stopping potential is independent of intensity of radiation.

13.Effect of frequency of incident radiation on stopping potential



The stopping potential increases with increase in frequency of incident radiation.

14.Draw the graphical variation of stopping potential V_0 and frequency ν. What is the slope and y- intercpt of this graph?



From graph , slope $= \frac{V_0}{\nu} = \frac{h}{e}$

The y- intercept $= \frac{\phi_0}{e}$

15. Write the properties of photon
or
Explain particle nature of light –The Photon

1) In the interaction of light with matter , light behaves as if it is made up of particles called photon.
2) Each photon has energy, E=hν and momentum p= hν/c and Speed c= $3x\ 10^8$m/s
3)All photons of light of a particular frequency ν, or wavelength λ, have the same energy and momentum p, whatever the intensity of radiation may be.
4) When intensity of light is increased only the number of photons increases, but the energy of photon is independent of intensity of light.
5) Photons are electrically neutral. They are not deflected by electric and magnetic fields.
6) In photon-particle collision total energy and total momentum are conserved. However, the number of photons may not be conserved in a collision. The photon may be absorbed or a new photon may be created.

16.Write de Broglie Relation -Wavelength of matter wave

$$\lambda = \frac{h}{p} = \frac{h}{mv} \text{ -------------(1)}$$

17.Why macroscopic objects in our daily life do not show wave-like properties?

The wavelength associated with macroscopic objects is so small that it is beyond any measurement. So macroscopic objects in our daily life do not show wave-like properties.

18.Find the de Broglie wavelength of a ball of mass 0.12 kg moving with a speed of 20 m s^{-1} .

$$\lambda = \frac{h}{mv} = \frac{6.6\ x10^{-34}}{0.12\ x20}$$
$$= 2.76x10^{-34} \text{ nm}$$

This wavelength is so small that it is beyond any measurement.

19.What is the de Broglie wavelength associated with an electron moving with a speed of 5.4×10^6 m/s?

$$\lambda = \frac{h}{mv} = \frac{6.6\ x10^{-34}}{9.1\ x\ 10^{-31} x\ 5.4\ x10^{6}} = 0.135 \text{ nm}$$

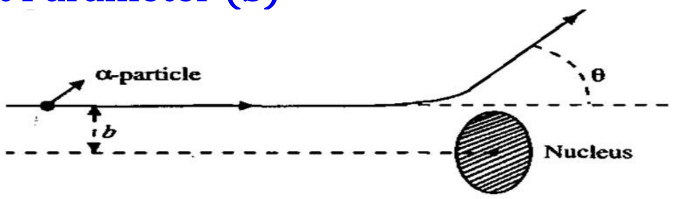
This wavelength is measurable. i.e., in the sub-atomic domain, the wave character of particles is significant and measurable.

Chapter 12
Atoms

1.Write the postulates of Rutherford's nuclear model of the atom

- Most of an atom is empty space.
- The entire positive charge and most of the mass of the atom are concentrated in the nucleus with the electrons some distance away.
- The electrons would be moving in orbits about the nucleus just as the planets do around the sun.
- The size of the nucleus to be about 10^{-15} m to 10^{-14} m.
- The electrostatic force of attraction, between the revolving electrons and the nucleus provides the centripetal force to keep them in their orbits.

2.Define Impact Parameter (b)



Impact parameter is the perpendicular distance of the initial velocity vector of the α particle from the centre of the nucleus.

3.What is the importance of impact parameter on determining the trajectory of α particle

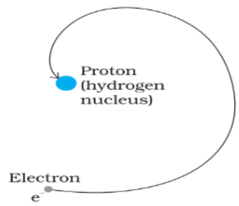
- For head on collision, the impact parameter b=0 and α particle rebounds back ie,
- For large impact parameter, the angle of scattering will be small ($\theta \approx 0^0$) and such α particles go undeviated.

4.What is the angle of scattering for an impact parameter=0

angle of scattering $\theta = 180^0$.

5.Write the limitations of Rutherford Model

(a) Rutherford model could not explain stability of matter. The accelerated electrons revolving around the nucleus loses energy and must spiral into the nucleus. This contradicts the stability of matter.



(b) It cannot explain the characteristic line spectra of atoms of different elements.

6.Write the postulates of Bohr atom model.

First postulate : An electron in an atom revolves in certain stable orbits without the emission of radiant energy.

Second postulate :The orbital angular momentum of electon is an integral multiple of h/2π

$$mvr = \frac{nh}{2\pi} \quad ,\text{where } n = 1,2,3.........$$

Third postulate : When an electron make a transition from higher energy level to lower energy level a photon is emitted having energy equal to the energy difference between the initial and final states.

$$h\nu = E_i - E_f$$

7. Write the expression for radius of Hydrogen atom.

$$r_n = \frac{n^2h^2\varepsilon_0}{\pi me^2} \quad \text{or} \quad r_n = 0.53\ n^2 \text{Å}$$

8.Write the expression for energy of Hydrogen atom

$$E_n = \frac{-me^4}{8n^2{\varepsilon_0}^2h^2} \quad \text{or} \quad E_n = \frac{-13.6}{n^2}\text{eV}$$

The negative sign of the total energy of an electron moving in an orbit means that the electron is bound with the nucleus.

9.Derive the expression for Energy of Hydrogen Atom

Total Energy = KE + PE

$$E = \frac{e^2}{8\pi\varepsilon_0 r} + \frac{-e^2}{4\pi\varepsilon_0 r}$$

$$\mathbf{E = \frac{-e^2}{8\pi\varepsilon_0 r}}$$

For the $\boldsymbol{n^{th}}$ energy level

$$\mathbf{E_n = \frac{-e^2}{8\pi\varepsilon_0 r_n}}$$

Substituting for $r_n = \frac{n^2h^2\varepsilon_0}{\pi me^2}$

$$\mathbf{E_n} = \frac{-e^2}{8\pi\varepsilon_0\ \left(\frac{\mathbf{n^2h^2\varepsilon_0}}{\mathbf{\pi me^2}}\right)}$$

$$\mathbf{E_n = \frac{-me^4}{8n^2{\varepsilon_0}^2h^2}}$$

$$\mathbf{E_n = \frac{-13.6}{n^2}\ eV}$$

10.Find the energy of different energy levels

For ground state(First energy level)

$$n=1 \qquad E_1 = \frac{-13.6}{1^2}\text{eV} = -13.6\text{ eV}$$

For first excited state (second energy level)

$$n = 2, \qquad E_2 = \frac{-13.6}{2^2}\, eV = -3.4\ eV$$

For second excited state (third energy level)

$$n = 3, \qquad E_3 = \frac{-13.6}{9^2}\, eV = -1.51\ eV$$

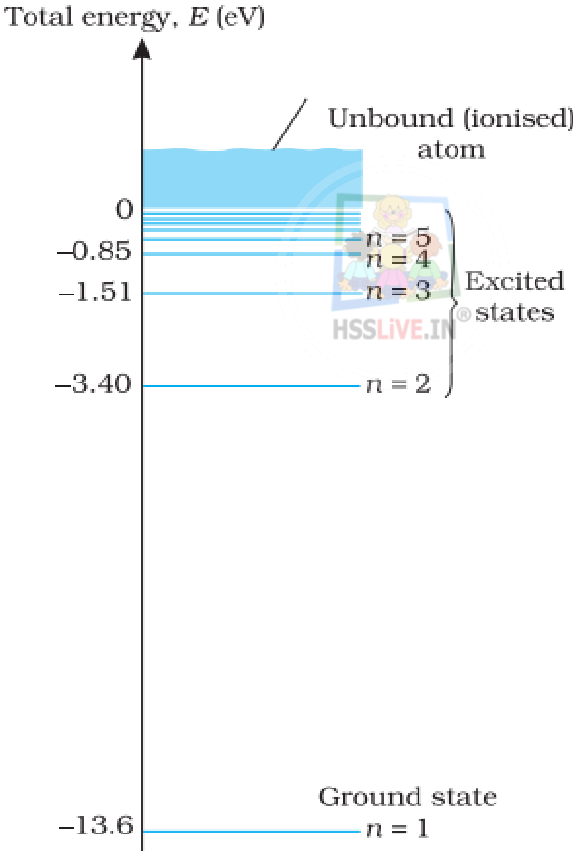
11. Define Ionisation Energy

The minimum energy required to free the electron from the ground state of the atom is called the Ionisation energy.

12. Write the Ionisation energy of Hydrogen atom.

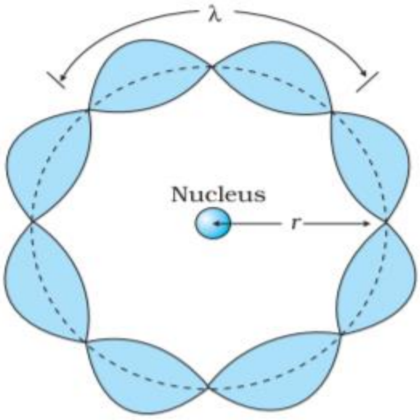
Ionisation energy of Hydrogen atom is $+13.6$ eV

13.Draw the energy level diagram for the hydrogen atom



14.Explain how de Broglie Explained Bohr's second postulate of Quantisation.

De Broglie argued that electron in its circular orbit behaves as a particle wave. The particle wave can produce standing wave under resonant condition.



For n^{th} orbit of radius r_n , the resonant condition is

$$2 \pi r_n = n \lambda \text{----------- (1)}$$

Where n=1,2,3.....

But by de Broglie hypothesis , for matter waves

$$\lambda = \frac{h}{mv} \text{---------------(2)}$$

Substituting eqn (2) in eqn (1),

$$2 \pi r_n = n \frac{h}{mv}$$

$$mv\, r_n = \frac{nh}{2 \pi} \quad \text{where } n=1,2,3......$$

This Bohr's second postulate of Quantisation.

15.Write the limitations of Bohr Atom Model

(i) The Bohr model is applicable to hydrogenic atoms. It cannot be extended two or more electron atoms.

(ii) The Bohr model is unable to explain the intensity variations of the frequencies in hydrogen spectrum

Chapter 13
Nuclei

1.Define atomic mass unit (u)

Atomic mass unit (u) is defined as 1/12th of the mass of the carbon (^{12}C) atom.

$$1u = \frac{\text{mass of the one C}-12\text{ atom}}{12}$$

$$=1.660539\ 10^{-27}\ kg$$

2.What are Isotopes?

Isotpes are different types of atoms of the same element, with same atomic number ,but different mass number .

Hydrogen has three isotopes , proton(^1_1H), deuterium(^2_1H) and tritium(^3_1H).

3.What are isobars?

All nuclides with same mass number A , but with different atomic number are called isobars.

For example, the nuclides (^3_1H) and (^3_2He)are isobars.

4.What are isotones?

Nuclides with same neutron number N but different atomic number Z are called isotones.

For example $^{198}_{80}Hg$ $^{197}_{79}Au$ are isotones.

5.Chlorine has two isotopes having masses 34.98 u and 36.98 u. The relative abundances of these isotopes are 75.4 and 24.6 per cent, respectively. Find the average mass of a chlorine atom.

$$= \frac{75.4\ x34.98+\ 24.6x\ 36.98}{\mathbf{100}} \quad = 35.47\ u$$

6.Write the expression for radius of nucleus.

$$R = R_0\ A^{1/3}$$

where $R_0 = 1.2 \times 10^{-15}$ m.

7.Two nuclei have mass numbers in the ratio 1:64. What is the ratio of their nuclear radii?

$$R_1 = R_0\ A_1^{1/3}$$

$$R_2 = R_0\ A_2^{1/3}$$

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{64}\right)^{1/3} = \frac{1}{4}$$

$R_1:R_2 = 1:4$

8.Write Einstein's mass-energy equivalence relation

$$E = mc^2$$

9.Calculate the energy equivalent of 1 g of substance.

$$E = mc^2$$
$$= 1\times10^{-3} \times (3 \times 10^8)^2$$
$$= 10^{-3} \times 9 \times 10^{16} \quad = 9 \times 10^{13}\ J$$

10.Find the energy equivalent of one atomic mass unit, first in Joules and then in MeV.

$$1u = 1.6605 \times 10^{-27}\ kg$$
$$E = mc^2$$
$$= 1.6605 \times 10^{-27} x(3\ x\ 10^8)^2 = \mathbf{1.4924 \times 10^{-10}\ J}$$

Energy equivalent in MeV.

$$1eV = 1.602\ x10^{-19} J$$

$$E = \frac{1.4924 \times 10{-}10}{1.602\ x10{-}19} = 0.9315 \times 10^9\ eV\ \mathbf{= 931.5\ MeV}$$

11.What is mass defect ?

The difference in mass of a nucleus and its constituents is called the mass defect. $\Delta M = [Z\, m_p + (A - Z)m_n] - M$

12.What is binding energy?

The energy equivalent of mass defect is called binding energy.

$$E_b = \Delta Mc^2$$
$$E_b = ([Z\, m_p + (A - Z)m_n] - M)c^2$$

13.What do you mean by binding energy per nucleon

The binding energy per nucleon, E_{bn}, is the ratio of the binding energy Eb of a nucleus to the number of the nucleons, A, in that nucleus.

$$E_{bn} = E_b / A$$

14.The nucleus with highest binding energy per nucleon is..............

^{56}Fe **nucleus**

15.How can you explain nuclear fission and nuclear fusion based on the values of binding energy per nucleon values of nuclei?

(i) A very heavy nucleus, say A = 240, has lower binding energy per nucleon .Such a heavy nucleus breaks into two lighter nuclei, thereby increasing the binding energy per nucleon and the nucleons get more tightly bound. Energy would be released in the process and this is an implication of fission.

(ii) Two very light nuclei ($A \leq 10$) have lower binding energy per nucleon .They join to form a heavier nucleus , thereby increasing the binding energy per nucleon and the nucleons get more tightly bound. Energy would be released in such a process and this is an implication of fusion.

16.Write the characteristics of nuclear force?

The nuclear force binds the nucleons together inside the nucleus.

(i) The nuclear force is much stronger than the Coulomb repulsive force between protons inside the nucleus and the gravitational force between the masses.

(ii) The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few femtometres.

(iii) The force is attractive for distances larger than 0.8 fm and repulsive if they are separated by distances less than 0.8 fm.

(iv) The nuclear force between neutron-neutron, proton-neutron and proton-proton is approximately the same. The nuclear force does not depend on the electric charge.

17.Radioactivity was discovered by..........................

Henry Becquerel

18. Write three types of radioactive decay occur in nature.

1.Alpha decay
2.Beta decay
3.Gamma decay

19.What is nuclear fission?

Nuclear fission is the process in which a heavier nucleus splits into lighter nuclei with the release of large amount of energy.

Example: ${}_{0}^{1}\text{n} + {}_{92}^{235}\text{U} \rightarrow {}_{92}^{236}\text{U} \rightarrow {}_{56}^{144}\text{Ba} + {}_{36}^{89}\text{Kr} + 3\,{}_{0}^{1}\text{n}$

20.The energy released (the Q value) in the fission reaction of nuclei like uranium is of the order of .... per fissioning nucleus.

200 MeV

21.What is nuclear fusion ?

Nuclear fusion is the process in which two light nuclei combine to form a single larger nucleus, with the release of a large amount of energy.

Examples are

$${}_{1}^{1}\text{H} + {}_{1}^{1}\text{H} \rightarrow {}_{1}^{2}\text{H} + e^{+} + \nu + 0.42\ \text{MeV}$$

22.What is thermonuclear fusion?

For nuclear fusion to occur in bulk matter the temperature of the material is to be raised until the particles have enough energy to penetrate the coulomb barrier. This process is called thermonuclear fusion.

23.The energy generation in stars takes place via thermonuclear fusion.

24.Write the proton-proton (p, p) cycle through which energy is generated in sun.

$$ {}_1^1\mathrm{H} + {}_1^1\mathrm{H} \rightarrow {}_1^2\mathrm{H} + e^+ + \nu + 0.42\ \mathrm{MeV} $$

$$ e^+ + e^- \rightarrow \gamma + \gamma + 1.02\ \mathrm{MeV} $$

$$ {}_1^2\mathrm{H} + {}_1^1\mathrm{H} \rightarrow {}_3^2\mathrm{He} + \gamma + 5.49\ \mathrm{MeV} $$

$$ {}_2^3\mathrm{H} + {}_2^3\mathrm{H} \rightarrow {}_2^4\mathrm{He} + {}_1^1\mathrm{H} + {}_1^1\mathrm{H} + 12.86\ \mathrm{MeV} $$

The combined reaction is

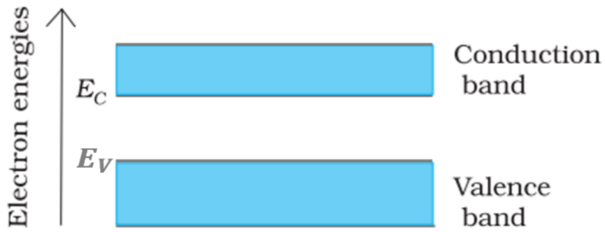
$$ 4\ {}_1^1\mathrm{H} + 2\ e^- \rightarrow {}_2^4\mathrm{He} + 2\nu + 6\gamma + 26.7\ \mathrm{MeV} $$

$$ \text{Or } (4\ {}_1^1\mathrm{H} + 4\ e^-) \rightarrow ({}_2^4\mathrm{He} + 2e^-) + 2\nu + 6\gamma + 26.7\ \mathrm{MeV} $$

Chapter 14

Semiconductor Electronics:
Materials ,Devices and Simple Circuits

1.Draw energy bands in solids

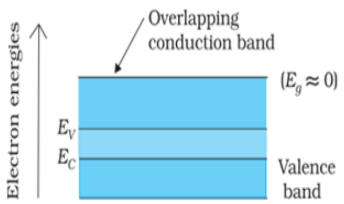
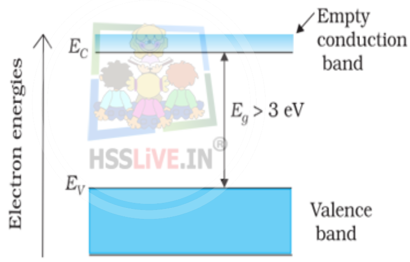
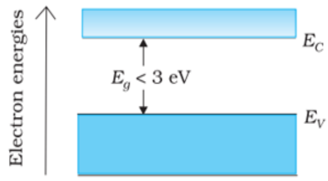


2.Define energy gap or band gap. Write the unit in which band gap is measured.

The energy difference between the top of the valence band and bottom of the conduction band is called the energy band gap (Energy gap E_g).

It is measured in electron volt.

3.Classification of Metals, Conductors and Semiconductors on the basis of energy bands

Metals	Insulators	Semiconductors
		
The conduction and valance bands overlap.	A large band gap , $E_g > 3$ eV.	A small band gap $E_g < 3$ eV

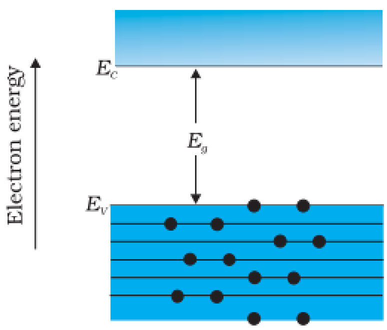
4.What are Intrinsic Semiconductors?

Pure semiconductors are called ‘intrinsic semiconductors’.

$$n_e = n_h = n_i$$

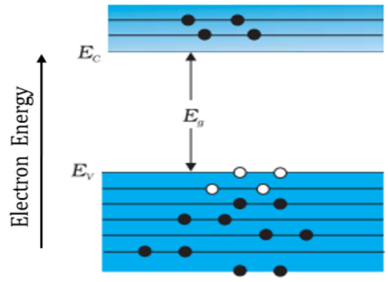
5.Draw the energy-band diagram of an intrinsic semiconductor at t=0k

An intrinsic semiconductor will behave like an insulator at T = 0 K .



6.Draw the energy-band diagram of an intrinsic semiconductor at t > 0k

At temperatures (T > 0K), some electrons are excited from the valence band to the conduction band, leaving equal number of holes there.



7.What are Extrinsic Semiconductor?

When a small amount of a suitable impurity is added to the pure semiconductor, the conductivity of the semiconductor is increased . Such materials are known as extrinsic semiconductors or impurity semiconductors. There are two types of extrinsic semiconductors –

(i) n-type semiconductor
(ii) p-type semiconductor

8.What is doping and dopants?

The deliberate addition of a desirable impurity is called doping and the impurity atoms are called dopants. Such a material is also called a doped semiconductor.

9.What are n-type semiconductors?

n-type semiconductor is obtained by doping Si or Ge with pentavalent atoms (donors) like Arsenic (As), Antimony (Sb), Phosphorous (P),etc.

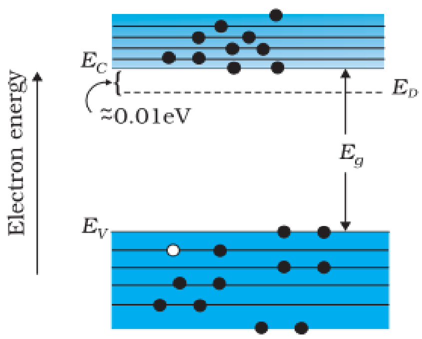
For n-type semiconductors, $n_e >> n_h$

10.What are p-type semiconductors?

p-type semiconductor is obtained when Si or Ge is doped with a trivalent impurity like Indium (In), Boron (B), Aluminium (Al), etc.

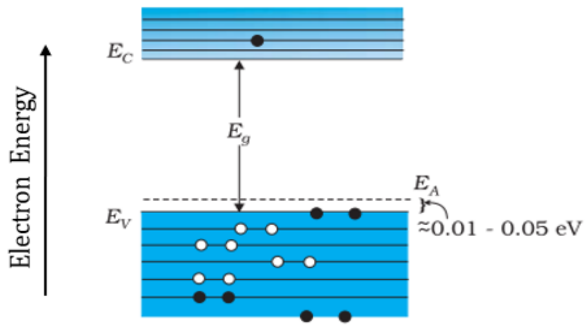
For p-type semiconductors, $n_h >> n_e$

11.Draw the energy bands of n-type semiconductor at T > 0K



(a) $T > 0K$

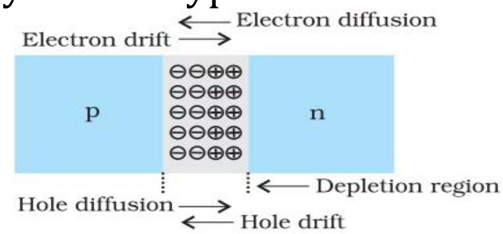
12.Draw the energy bands of p-type semiconductor at T > 0K



(b) $T > 0K$

13.How a p-n junction is formed?

A p-n junction can be formed by adding a small quantity of pendavalent impurity to a p-type semiconductor or by adding a small quantity of trivalent impurity to an n-type semiconductor.



14.What is Diffusion current?

The holes diffuse from p-side to n-side (p → n) and electrons diffuse from n-side to p-side (n → p). This motion of charge carriers give rise to Diffusion current across the junction.

15.What is drift?

The motion of minority charge carriers across p-n junction due to electricfield is called called drift.

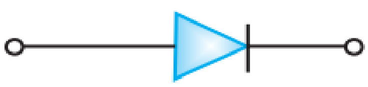
16.What is Depletion region (Depletion layer)

The space-charge region on either side of the junction together is known as depletion region. The depletion layer consist of immobile ion-cores and no free electrons or holes. This is responsible for a junction potential barrier.

17.Barrier Potential

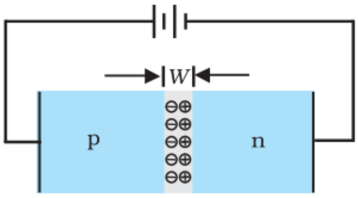
The loss of electrons from the n-region and the gain of electron by the p-region causes a difference of potential across the junction of the two regions. Since this potential tends to prevent the movement of electron from the n region into the p region, it is called a barrier potential.
The barrier potential of a Ge diode is 0.2Vand that of a Si diode is 0.7V.

18.Draw the symbol of a p-n junction Diode



19.What is forward biasing of a p-n junction diode ?

If p-side of the diode is connected to the positive terminal and n-side to the negative terminal of the battery, it is said to be forward biased.

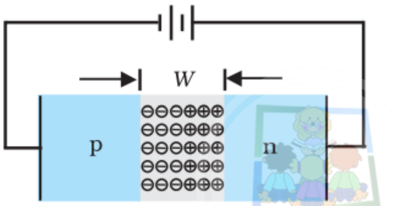


20.Write specific features of forward biased p-n junction diode.

- The depletion layer width decreases and the barrier height is reduced.
- The effective barrier height is (V_0 – V).
- The motion of majority carriers on either side gives rise to diffusion current.
- The magnitude of this current is usually in mA.

21.What is reverse biasing of a p-n junction diode ?

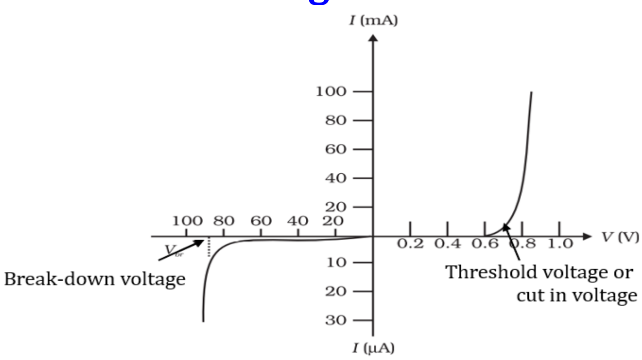
If n-side of the diode is connected to the positive terminal and p-side to the negative terminal of the battery, it is said to be reverse biased.



22.Write specific features of reverse biased p-n junction diode.

- The depletion layer width increases and the barrier height is incresaed.
- The effective barrier height is (V_0 + V)..
- The drift of minority carriers gives rise to drift current.
- The drift current is of the order of a few μA.

23.Draw the V-I characteristics of a silicon diode and mark threshold voltage and break-down voltage.



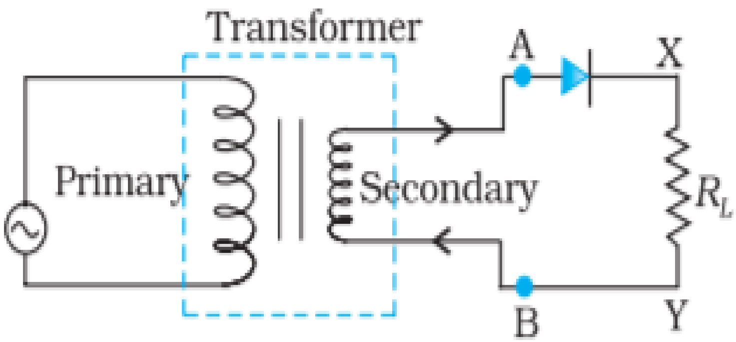
24.Define threshold voltage of a p-n junction diode.

The forward voltage beyond which the diode current increases significantly is called threshold voltage or cut-in voltage or knee voltage.

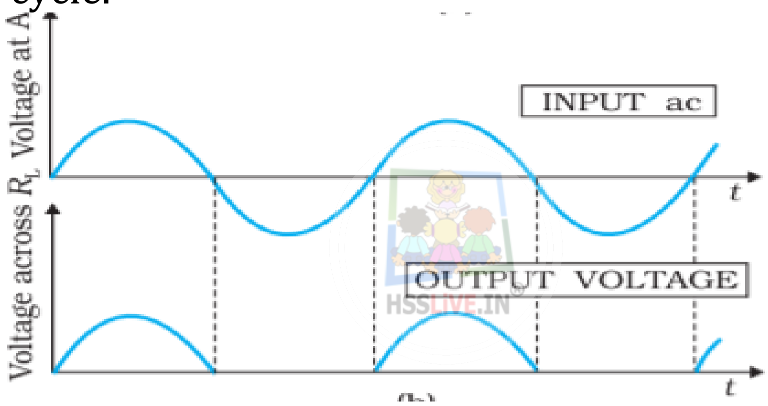
25.Define break down voltage of a p-n junction diode.

The reverse voltage at which the reverse current increases suddenly is called break-down voltage.

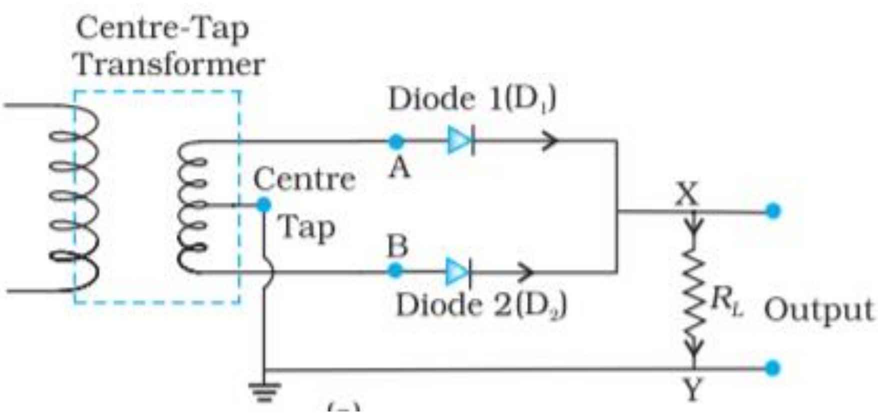
26.Explain a half wave rectifier Draw the input and output voltage waveforms.



In the positive half-cycle of ac there is a current through the load resistor R_L and we get an output voltage, whereas there is no current in the negative half cycle.

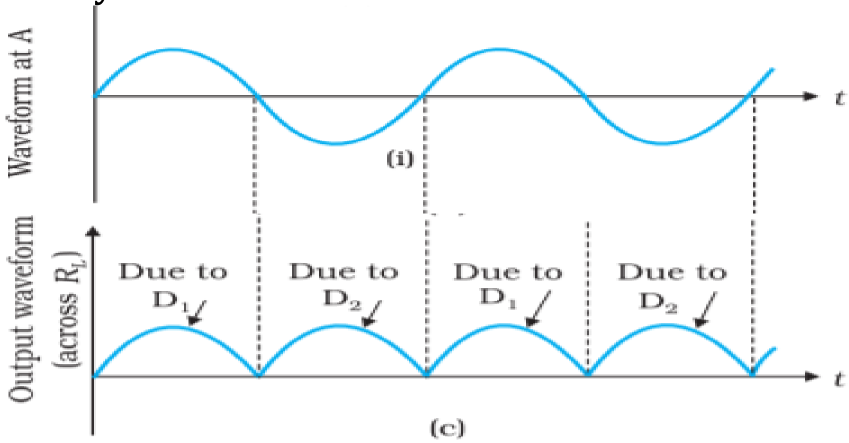


27. Explain a full wave rectifier . Draw the input and output voltage waveforms.



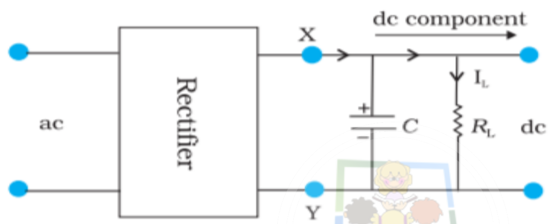
During this positive half cycle, diode D_1 gets forward biased and conducts ,while D_2 being reverse biased is not conducting. Hence we get an output current and a output voltage across the load resistor R_L.
During negative half cycle, diode D_1 would not conduct but diode D_2 conducts, giving an output current and output voltage across R_L in the same directionas in positive half.

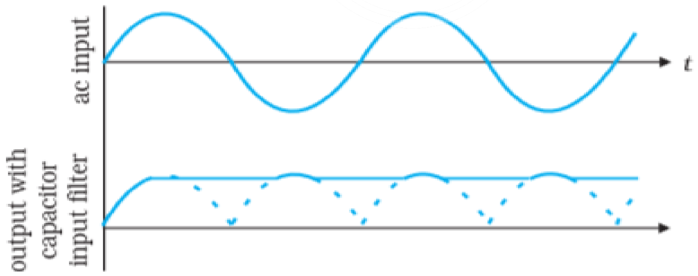
Thus, we get output voltage during both the positive as well as the negative half of the cycle.



28.What are filters? Draw the input and output waveforms of filter circuit

The cicuits that filter out the ac ripple and give a pure dc voltage are called filters.





Seema Elizabeth ,
HSST Physics
MARM Govt HSS Santhipuram
Thrissur