UNIT-1 ELECTROSTATICS

2 Marks Question & Answer

1. Define **electric dipole moment**. Give its unit.

Electric dipole moment:

The magnitude of the electric dipole moment ($\boldsymbol{p}$) is equal to the **product of the magnitude of one of the charges** (q) and the distance (2a) between them. (i.e) $|\vec{p}| = \boldsymbol{q.\ 2a}$. Its unit is **Cm.**

2. Define **action of point** or **Corona Discharge**.

The electric field **near this sharp edge is very high and it ionized the surrounding air.** The positive ions are repelled and negative ions are attracted towards the sharp edge.

This **reduces the total charge of the conductor near the sharp edge.** This is called action of points or corona discharge.

3. State **Coulomb's law** in electrostatics.

Coulomb's law: The electrostatic force is directly proportional to the product of the magnitude of the two point charges and is inversely proportional to the square of the distance between the two point charges.

$F \propto \frac{q_1 q_2}{r^2}$

4. Define **electric flux** with SI unit.

The **number of electric field lines crossing a given area** kept normal to the electric field lines is called electric flux (Φ_E). Its **S.I unit is Nm^2C^{-1}.** It is a **scalar quantity**.

5. What is called **electric dipole**? Give an example.

Electric dipole moment and its unit:

The magnitude of the electric dipole moment ($\boldsymbol{p}$) is equal to the **product of the magnitude of one of the charges** (q) and the distance (2a) between them. (i.e) $|\vec{p}| = \boldsymbol{q.\ 2a}$. Its unit is **Cm.**

6. State **Gauss law**.

Gauss law: states that if a **charge 'Q' is enclosed by an arbitrary closed surface**, then the total electric flux through the **closed surface is equal to $\frac{1}{\varepsilon_0}$** times the net charge enclosed by the surface.

$$\frac{1}{\varepsilon_0} = \oint \vec{\mathbf{E}}.\mathbf{d}\vec{\mathbf{A}} = \frac{Q_{inside}}{\varepsilon_0}$$

7. A sample of HCl gas is placed in a uniform electric field of magnitude 3×10^4 N C^{-1}. The dipole moment of each HCl molecule is 3.4×10^{-30} Cm. Calculate the maximum **torque** experienced by each HCl molecule.

The maximum torque experienced by the dipole is when it is aligned **perpendicular to the applied field.**

$\tau_{max} = pE\sin 90^0$; = $3.14\text{x}10^{-19}$ x $3\text{x}10^4$ N m ; $\boldsymbol{\tau_{max}} =$ **$10.2\text{x}10^{-26}$ Nm**

8. Define **one coulomb** (1 C).

The S.I unit of charge is **Coulomb** (C)

One Coulomb is that charge which when placed in free space or air at a distance 1 m from an **equal and similar charge repels** with a force of **$9\text{x}10^9$ N**

9. Give the **vector form of Coulomb's law**.

The force on the point charge q_2 exerted by another point charge q_1 is $\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}_{12}$

Similarly the force on the point charge q_1 exerted by another point charge q_2 is $\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}_{21}$

Here, $\hat{r}_{12} \rightarrow$ unit vector directed from q_1 to q_2

$\hat{r}_{21} \rightarrow$ Unit vector directed from q_2 to q_1

10. Define **superposition principle.**

According to Superposition principle, the total force acting on a given charge is **equal to the vector sum of forces** exerted on it by all the other charges.

3 Marks Question & Answer

11. Discuss the **basic properties of electric charge**.

Basic properties of electric charge:

(i) Electric charge:

Like mass, the electric charge is also an intrinsic and fundamental property of particles. The unit of **electric charge is coulomb**

(ii) Conservation of electric charge:

The total **electric charge in the universe is constant** and **charge can neither be created nor be destroyed.** In any physical process, the net change in charge will be zero. This is called **conservation of charges**.

(iii) Quantization of charge:

The charge 'q' of any object is equal to an **integral multiple of this fundamental unit of charge 'e' (i.e) q = ne.**

Where n → **integer and1.6 x 10^{-19} C**

12. A parallel plate capacitor has square plates of side 5cm and separated by a distance of 1mm. (a) Calculate the **capacitance of this capacitor**.
(b) If a 10V battery is connected to the capacitor, what is the charge stored in any one of the plates? (The value of ε_o=8.85x10^{-12} Nm^{2}C^{-2})

(a) The capacitance of the capacitor is $C = \frac{\epsilon_0 A}{d}$; $\frac{8.854 \times 10^{-12} \times 25 \times 10^{-4}}{1 \times 10^{-3}}$
= 221.2 x 10^{-13} F; ; C = 22.12 x 10^{-12} F; **= 22.12 pF**
(b) The charge stored in any one of the plates is **Q = CV**, Then
Q = 22.12 x 10^{-12} x 10 = 221.2 x 10^{-12}C ; **Q = 221.2 pC**

13. Derive an expression for **energy stored in capacitor**.
Energy stored in capacitor:
Capacitor is a device used to **store charges and energy.**
When a battery is connected to the capacitor, electrons of total charge '-Q' are transferred from one plate to other plate. For this work is done by the battery. This **work done is stored as electrostatic energy in capacitor.**
To transfer 'dQ' for a potential difference 'V', the work done is
$dW = VdQ = \frac{Q}{C} dQ$ [$\because V = \frac{Q}{C}$]
The total work done to charge a capacitor, W = $\int_0^Q \frac{Q}{C} dQ$;
$= \frac{1}{C}\left[\frac{Q^2}{2}\right]_0^Q$; $= \frac{Q^2}{2C}$ This work done is stored as electrostatic energy of the capacitor, (i.e)
$U_E = \frac{Q^2}{2C} = \frac{1}{2} CV^2$ [$\because Q = CV$]

14. Derive an expression for **capacitance of parallel plate capacitor**.

Capacitance of parallel plate capacitor:

Consider a capacitor consists of two parallel plates each of area 'A' separated by a distance 'd'

Let 'σ' be the **surface charge density** of the plates.

The electric field between the plates,

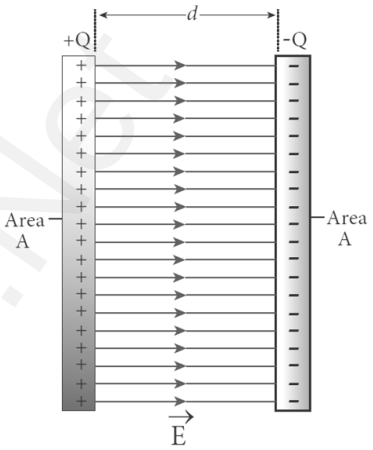
$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\,\varepsilon_0}$..... (1)

Since the field is uniform, the potential difference between the plates,

$V = E.d = \left[\frac{Q}{A\,\varepsilon_0}\right]d$ ..... (2)

Then the capacitance of the capacitor, $C = \frac{Q}{V} = \frac{Q}{\left[\frac{Q}{A\,\varepsilon_0}\right]d}$

$C = \frac{\varepsilon_0 A}{d}$..... (3)



Thus capacitance is,

(i) **Directly proportional to the Area (A) and**

(ii) **Inversely proportional to the separation (d)**

15. Give the **applications** and **disadvantage of capacitors**

Applications of capacitor:

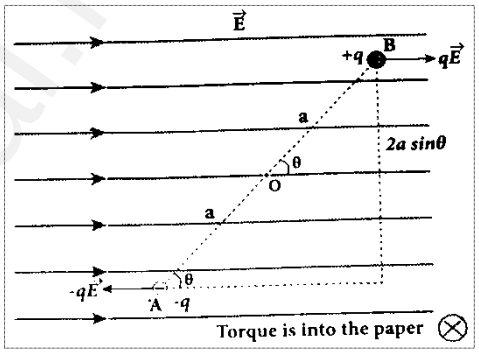
1. **Flash capacitors** are used in **digital camera** to take photographs
2. During cardiac arrest, a device called **heart defibrillator** is used to give a sudden surge of a large amount of electrical energy to the patient's chest to retrieve the normal heart function.
3. Capacitors are used in the ignition system of **automobile engines** to **eliminate sparking.**
4. Capacitors are used to **reduce power fluctuations** in power supplies and to increase the efficiency of power transmission.

Disadvantages:

1. Even after the battery or power supply is removed, the capacitor stores charges and energy for some time. It caused unwanted shock.

16. Derive an expression for **torque experienced by an electric dipole** placed in the uniform electric field.

Torque experienced by the dipole in electric field:



Let a dipole of moment $\vec{p}$ is placed in an uniform electric field $\vec{E}$

The force on '+q' = + q$\vec{E}$; '−q' = − q$\vec{E}$

Then the **total force acts on the dipole is zero.**

The total torque on the dipole about the point 'O' $|\vec{\tau}| = |\overrightarrow{OA}||-q\vec{E}|\sin\theta + |\overrightarrow{OB}||q\vec{E}|\sin\theta$

$\tau = (OA + OB)\, qE \sin$;

$\tau = 2\, aqE \sin\theta \quad \because [OA = OB = a]$

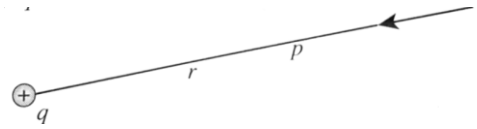
$\tau = pE\sin\theta$ **(Where, 2 $aq = p$ → dipole moment)**

In vector notation, $\vec{\tau} = \vec{p} \times \vec{E}$.

The torque is maximum, when $\theta = 90^0$

17. **Obtain an expression electric potential at a point due to a point charge.**

Potential due to a point charge:



Consider a point charge +q at origin.

'P' be a point at a distance 'r' from origin.

By definition, the electric field at 'P' is $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$

Hence electric potential at 'P' is $V = -\int_{\infty}^{r} \vec{E}.\overrightarrow{dr} = -\int_{\infty}^{r} \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}\ .\overrightarrow{dr}$

$V = -\int_{\infty}^{r} \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}\ .dr\,\hat{r} \quad [\because \overrightarrow{dr} = dr\hat{r}]$

$V = -\frac{q}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{1}{r^2}dr$ $[\because \hat{r}.\hat{r} = 1]$

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

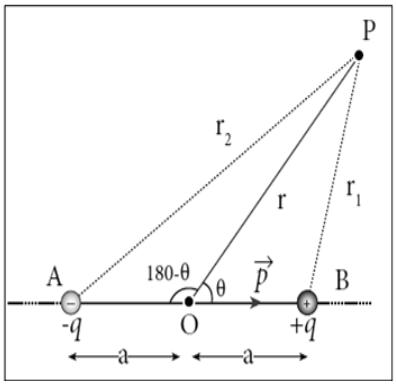
$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$. If the source charge is negative ($-q$),then the potential also negative and it is given by $V = -\frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

5 Marks Question & Answer

18. Derive an expression for **electro static potential** due to **electric dipole**.

Electrostatic potential due to dipole:

Consider a **dipole AB** along X - axis. Its **dipole moment be p = 2qa** and its direction be along− q to + q. Let 'P' be the point at a distance 'r' from the midpoint 'O'



Let $\angle POA = \theta$, BP = r_1 and AP = r_2

Electric potential at P due to +q $V_1 = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_1}$

Electric potential at P due to –q $V_2 = -\frac{1}{4\pi\varepsilon_0}\frac{q}{r_2}$

Then total potential at 'P' due to dipole is

$\mathbf{V = V_1 + V_2}$; $= \frac{1}{4\pi\varepsilon_0}q\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$ ..... (1)

Apply cosine law in Δ BOP

$r_1^2 = r^2 + a^2 - 2ra\cos\theta$; $r_1^2 = r^2\left[1 + \frac{a^2}{r^2} - \frac{2a}{r}\cos\theta\right]$; $\frac{1}{r_1} = \frac{1}{r}\left[1 + \frac{a}{r}\cos\theta\right]$ .....(2)

Apply cosine law in Δ AOP

$r_2^2 = r^2 + a^2 + 2ra\cos(180^0 - \theta)$; $r_2^2 = r^2\left[1 + \frac{a^2}{r^2} + \frac{2a}{r}\cos\theta\right]$; $\frac{1}{r_2}$

$= \frac{1}{r}\left[1 - \frac{a}{r}\cos\theta\right]$...(3)

$= \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}\cos\theta$[p = 2qa] ; Or $V = \frac{1}{4\pi\varepsilon_0}\frac{\vec{p}.\hat{r}}{r^2}$ [$p\cos\theta = \vec{p}.\hat{r}$]

Special cases:

Case (i) If the point P lies on the **axial line** of the dipole on the side of +q, then **θ = 0**. Then the electric potential becomes $\mathbf{V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}}$

Case (ii) If the point P lies on the **axial line** of the dipole on the side of –q, **then θ = 180⁰**, then **V =**$-\frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$

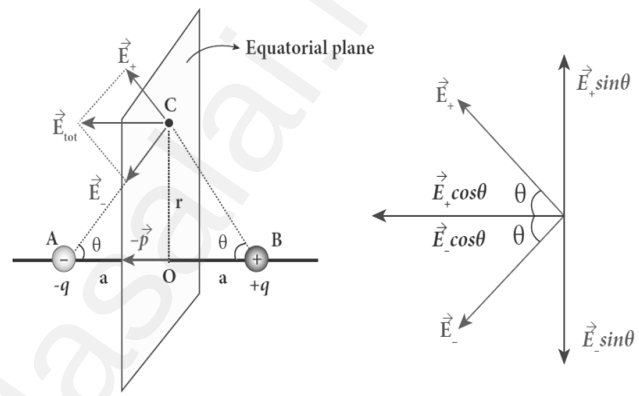
Case (iii) If the point P lies on the **equatorial line** of the dipole, then **θ = 90⁰**. Hence **V = 0**

19. Calculate the electric field due to a dipole on its **equatorial line**.

Electric field due to dipole on its equatorial line:

Consider a dipole AB along X - axis. Its dipole moment be p = **2**qa and its direction be along− q to + q .

Let 'C' be the point at a distance 'r' from the midpoint 'O' on its equatorial plane.



Electric field at C due to +q (along BC)

$$|\vec{E}_+| = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}$$

Electric field at C due to −q (along CA)

$$|\vec{E}_-| = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}$$

Here $|\vec{E}_+| = |\vec{E}_-|$. Resolve $\vec{E}_+$and $\vec{E}_-$in to two components.

Here the **perpendicular components** $|\vec{E}_+|$ **sin**θ **and** $|\vec{E}_-|$ **sin**$\theta$are **equal** and **opposite will cancel** each other.

But the **horizontal components** $|\vec{E}_+|$ **cosθ and** $|\vec{E}_-|$ **cosθ**are **equal** and in **same direction** (−p̂) will added up to give total electric field. Hence

$$\vec{E}_{tot} = |\vec{E}_+| \cos\theta\,(-\hat{p}) + |\vec{E}_-| \cos\theta(-\hat{p}) \text{ (or) } \vec{E}_{tot} = -2|\vec{E}_+| \cos\theta\hat{p}$$

$$\vec{E}_{tot} = -2\left[\frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2+a^2)}\right]\cos\theta\hat{p} \;;\; \vec{E}_{tot} = -\left[\frac{1}{4\pi\varepsilon_0}\frac{2q}{(r^2+a^2)}\right]\frac{a}{(r^2+a^2)^{\frac{1}{2}}}\hat{p}$$

$$\vec{E}_{\text{tot}} = -\frac{1}{4\pi\varepsilon_0}\frac{p\hat{p}}{(r^2+a^2)^{\frac{3}{2}}}$$

. If r > a then neglecting a^2

$$\vec{E}_{\text{tot}} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3} \qquad [q\ 2a\hat{p} = p \quad \hat{p} = \vec{p}]$$

20. Explain in detail the construction and working of **Van de Graff generator**.

Van de Graff Generator:

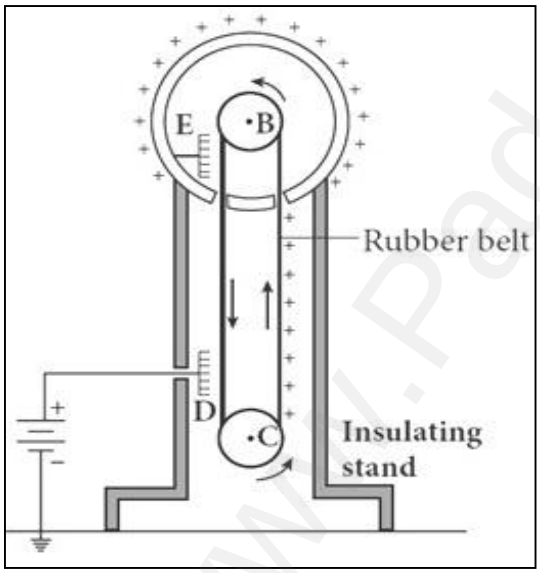
It is designed by Robert Van de Graff.

It produces large **electro static potential difference** of about **10^7V**

Principle:

Electro static induction, Action of points

Construction:



It consists of large **hollow spherical conductor 'A'** fixed on the insulating stand.

Pulley 'B' is mounted at the centre of the sphere and another **pulley 'C'** is fixed at the bottom. A belt made up of insulating material like silk or rubber runs over the pulleys.

The **pulley 'C'** is driven continuously by **the electric motor**. Two comb shaped metallic conductor D and E are fixed near the pulleys. The comb 'D' is maintained at a **positive potential of 10^4V** by a power supply. The upper **comb 'E'** is connected to the inner side of the **hollow metal sphere.**

Working:

Due to the high electric field near comb 'D', air between the belt and comb 'D' gets ionized. **The positive charges are pushed towards the belt and negative charges are attracted towards the comb 'D'.**

The positive charges stick to the belt and move up. When the positive charges reach the comb 'E' a large amount of negative and positive charges are induced on either side of comb 'E' due to electrostatic induction.

The positive charges are pushed away from the **comb 'E' and they reach the outer surface of the sphere.**

The negative charges neutralize the positive charges in the belt due to corona discharge before it passes over the pulley. When the belt descends, it has almost no net charge.

This process continues until the outer surface produces the **potential difference of the order of 10^7V** which is the limiting value.

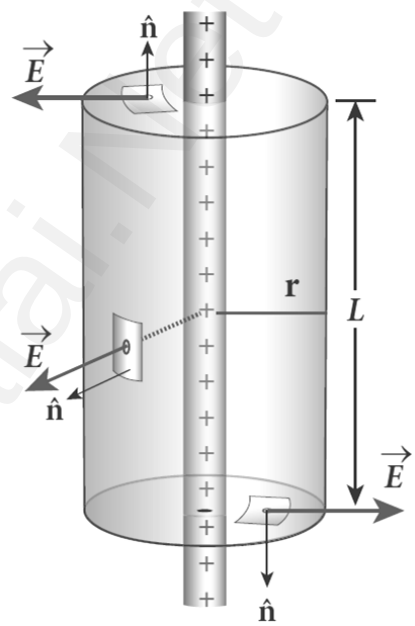
Applications:

The high voltage produced in this **Van de Graff generator** is used to **accelerate positive ions (Protons and Deuterons)** for nuclear disintegrations and other applications.

21. Obtain an expression for **electric field** due to an **infinitely long charged** wire.

Electric field due to infinitely long charged wire:

Consider an infinitely long straight wire of uniform linear charge density 'λ'.Let 'P' be a point at a distance 'r' from the wire. Let 'E' be the electric field at 'P'. Consider a cylindrical Gaussian surface of length 'L' and radius 'r'



The electric flux through the **top surface**,

$\Phi_{tap} = \int \vec{E}.\vec{dA} = \int E\, dA \cos 90^0 = 0$

The electric flux through the **bottom surface**,

$\Phi_{bottom} = \int \vec{E}.\vec{dA} = \int E\, dA \cos 90^0 = 0$

Then the total electric flux through the **Curved surface**,

$\Phi_{curve} = \int \vec{E}.\vec{dA} = \int E\, dA \cos 90^0 = E\int dA$

$\Phi_{curve} = E\, 2\pi rL$

Then the **total electric flux** through the **Gaussian surface**,

$\Phi_E = \Phi_{tap} + \Phi_{bottom} + \Phi_{curve}$; $\Phi_E = E\,(2\pi rL)$

By Gauss law, $\Phi_E = \frac{Q_{in}}{\varepsilon_0}$; $E\,(2\pi rL) = \frac{\lambda L}{\varepsilon_0}$;

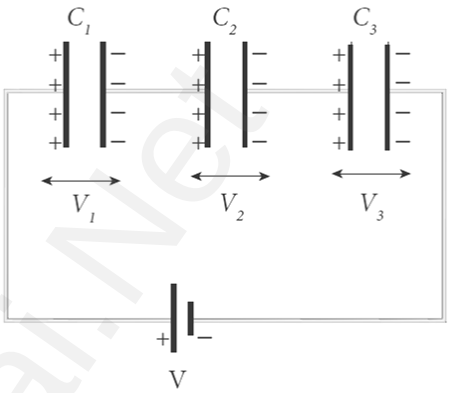
$E = \frac{\lambda L}{2\pi\varepsilon_0 r}$ In vector notation, $\vec{E} = \frac{\lambda L}{2\pi\varepsilon_0}\hat{r}$

Here $\hat{r}$ → unit vector perpendicular to the curved surface outwards.

If $\lambda > 0$, then $\vec{E}$ points perpendicular outward ($\hat{r}$) from the wire and if $\lambda < 0$, then $\vec{E}$ points perpendicular inward ($-\hat{r}$).

22. Derive the expression for **resultant capacitance**, when capacitors are **connected in series and in parallel.**

Capacitors in series:



Consider three capacitors of capacitance C_1, C_2 and C_3 connected in series with a battery of voltage V

In series connection,

1) Each capacitor has same amount of charge (Q)

2) But potential difference across each capacitor will be different.

Let V_1, V_2, V_3be the potential difference across C_1, C_2, C_3respectively, then $V = V_1 + V_2 + V_3$

$$V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} \qquad [\because Q = CV];$$

$$V = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right] \text{ ..... (1)}$$

Let C_S be the equivalent capacitance of capacitor in series connection, then $V = \frac{Q}{C_S}$..... (2)

From (1) and (2) , we have $\frac{Q}{C_S} = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$;

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

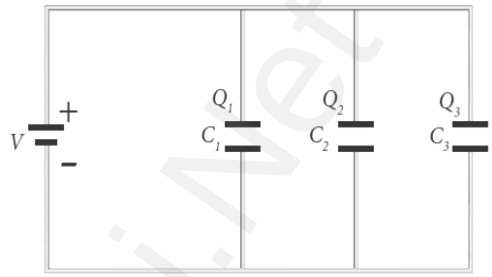
Thus **the inverse of the equivalent capacitance of capacitors connected in series is equal to the sum of the inverses of each capacitance.**

This equivalent capacitance C_S is always less than the smallest individual capacitance in the series.

Capacitors in parallel:

Consider three capacitors of capacitance C_1, C_2 and C_3connected in parallel with a battery of voltage V.

In parallel connection,



1) Each capacitor has same potential difference (V)

2) But charges on each capacitor will be different

Let Q_1 , Q_2 , Q_3be the charge on C_1, C_2, C_3 respectively, then

$Q = Q_1 + Q_2 + Q_3$

$Q = C_1V + C_2V + C_3V$ $[\because Q = CV]$

$Q = V [C_1 + C_2 + C_3]$ ..... (1)

Let C_P be the equivalent capacitance of capacitor in parallel connection, then $Q = C_PV$ ..... (2)

From (1) and (2), $C_PV = V [C_1 + C_2 + C_3]$

$\mathbf{C_P = C_1 + C_2 + C_3}$

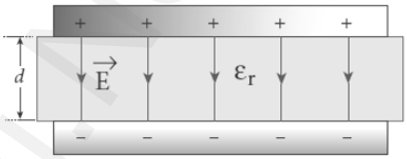
Thus **the equivalent capacitance of capacitors connected in parallel is equal to the sum of the individual capacitances.**

The equivalent capacitance $C_P$in a parallel connection is always greater than the largest individual capacitance.

23. Explain in detail the **effect of dielectric** placed in a parallel plate capacitor when the capacitor is **disconnected from the battery**.

Effect of dielectrics when the capacitor is disconnected from the battery:

Consider a parallel plate capacitor. Area of each plates= A,



Distance between the plates= d ,

Voltage of battery= V_0

Total charge on the capacitor= Q_0. So the capacitance of capacitor without dielectric, $\mathbf{C_0 = \frac{Q_0}{V_0}}$.

Electric field without dielectric= E_0, Electric field with dielectric= E,

Relative permittivity or dielectric constant = ε_r

$\therefore$ $E = \frac{E_0}{\varepsilon_r}$. Since $\varepsilon_r > 1$, we have $E < E_0$

Then the capacitance of a capacitor with dielectric,

$$\mathbf{C = \frac{Q_0}{V} ; = \frac{Q_0}{\left[\frac{V_0}{\varepsilon_r}\right]} ; = \varepsilon_r \frac{Q_0}{V_0} ; \varepsilon_r C_0}$$

Thus insertion of dielectric slab increases the capacitance.

We have, $\mathbf{C_0 = \frac{\varepsilon_0 A}{d} ; C = \frac{\varepsilon_r \varepsilon_0 A}{d} ; C = \frac{\varepsilon A}{d}}$

Where, $\boldsymbol{\varepsilon_r \varepsilon_0 = \varepsilon}$ → permittivity of the dielectric medium.

The energy stored in the capacitor without dielectric,

$$U = \frac{1}{2}\frac{Q_0{}^2}{C} ; = \frac{1}{2}\frac{Q_0{}^2}{\varepsilon_r C_0} ;= \frac{U_0}{\varepsilon_r}$$

Since $\varepsilon_r > 1$, we have $U < U_0$

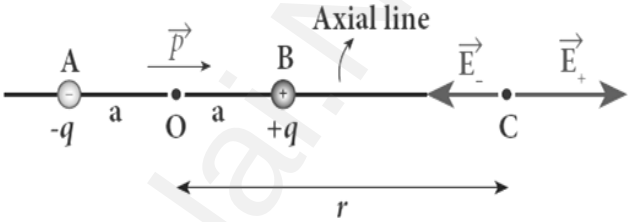
There is a **decrease in energy** because, when the **dielectric is inserted, the capacitors spend some energy to pulling the dielectric slab inside.**

24. Calculate the **electric field** due to a dipole on its **axial line**.

Electric field due to dipole on its axial line:

Consider a **dipole AB** along X - axis. Its **dipole moment** be **p = 2qa** and its direction be along− q to + q .

Let 'C' be the point at a distance 'r' from the midpoint 'O' on its axial line.



Electric field at C due to +q

$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p}$

Electric field at C due to −q

$\vec{E}_- = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$

Since +q is located closer to point 'C' than −q ,$\vec{E}_+ > \vec{E}_-$.

By superposition principle, the total electric field at 'C' due to dipole is,

$\vec{E}_{tot} = \vec{E}_+ + \vec{E}_-$

$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$

$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}q\left[\frac{4ra}{(r^2-a^2)^2}\right]\hat{p}$

Here the direction of total electric field is the dipole moment $\hat{p}$

If $r \gg a$, then neglecting a^2. We get $\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}q\left[\frac{4ra}{r^4}\right]\hat{p}$;

$= \frac{1}{4\pi\varepsilon_0}q\left[\frac{4a}{r^3}\right]\hat{p}$ $\quad \vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$ $\quad$ [q 2a$\hat{p}$ = $\vec{p}$]

UNIT-2 CURRENT ELECTRICITY

2 Marks Question & Answer

25. State **Kirchhoff's first law** (Current rule or Junction rule)

Kirchhoff's first law (current rule or junction rule):

It states that the **algebraic sum of currents at any junction** in a circuit **is zero**. ($\sum I = 0$).It is a statement of conservation of **electric charge.**

26. Define **Peltier effect**.

Peltier effect.

When an electric current is passed through a circuit of a **thermocouple, heat is evolved at one junction** and **absorbed at the other junction**. This is known as Peltier effect. Peltier effect is **reversible**.

27. Current is a **scalar quantity**. Why?

Current is defined as the scalar product of current density ($\vec{J}$) and area vector ($\vec{A}$) in which charges crosses. (i.e.) $\vec{J} \cdot \vec{A}$ = JA cos θ.

The current can be positive or negative depending on the choice of unit vector normal to the surface area A.

28. What are the factors that the **resistances depend** on?

The resistance of the conductor is,

1) **Directly proportional to its length (l)**
2) **Inversely proportional to its area of cross section (A)**

$R = \frac{l}{\sigma A}$; $= \frac{\rho l}{\sigma}$ where, $\boldsymbol{\sigma}$ → conductivity of the conductor

$\boldsymbol{\rho}$ → resistivity of the conductor

29. State **Kirchhoff's second law** (Voltage rule or Loop rule)

It states that in a closed circuit the **algebraic sum of the products** of the **current and resistance of each part of the circuit is equal** to the **total emf** included in the circuit ($\sum I R = \sum \xi$). It is a statement of conservation of energy for an isolated system.

30. Define Seebeck effect.

Seebeck effect :

In a **closed circuit** consisting of **two dissimilar metals**, when the junctions are maintained at **different temperature** an emf is developed. This phenomenon is called Seebeck effect or **thermoelectric effect**.

31. Distinguish **electric energy and electric power**.

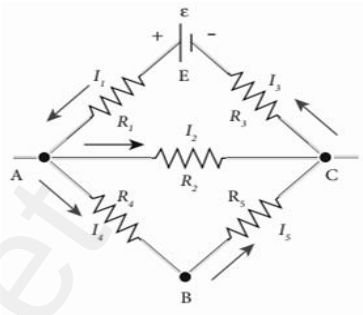
S. No.	Electric Energy	Electric Power
1	dW = dU = VdQ	P = $\frac{dU}{dt}$; = VI
2	Its SI Unit is joule (J)	Its SI Unit is watt (W)
3	Its practical unit is **kilowatt hour (kwh)** **1 kwh = 3.6x10^{6}J**	Its practical unit is **horse power(HP)1 HP = 746 W**

32. A copper wire of cross-sectional area 0.5 mm^2 carries a current of 0.2 A. If the free electron density of copper is 8.4 x 10^{28}m^{-3} then compute the **drift velocity of free electrons**.

The relation between drift velocity of electrons and current in a wire of cross- sectional area A is $V_d = \frac{I}{neA}$; $\frac{0.2}{8.4x\,10^{28}\,x\,1.6\,x\,10^{-19}\,x\,0.5\,x\,10^{-6}}$

V_d = 0.03 x 10^{-3} ms^{-1}

33. The following figure shows a complex network of conductors which can be divided into two closed loops like EACE and ABCA. Apply Kirchhoff's voltage rule (KVR),



Thus applying Kirchhoff 's second law to the closed loop EACE **$I_1R_1 + I_2R_2 + I_3R_3 = \varepsilon$**

and for the closed loop **ABCA $I_4R_4 + I_5R_5 - I_2R_2 = 0$**

34. Resistance of a material at 10^0C and 40^0C are 45 Ω and 85 Ω respectively. Find its **temperature co-efficient of resistance**.

$T_0 = 10^0$C, T = 40^0C, R0= 45 Ω , R = 85 Ω

$\alpha = \frac{1}{R_0}\frac{\Delta R}{\Delta T} \cdot \cdot \cdot \cdot \alpha = \frac{1}{45}\left(\frac{85-45}{40-10}\right) \cdot \cdot \cdot = \frac{1}{45}\left(\frac{40}{30}\right) \cdot \cdot \alpha = 00296\ /^0C$

35. The resistance of a nichrome wire at 0^0C is 10Ω. If its temperature coefficient of resistance is 0.004/^{0}C, find its **resistance at boiling point of water**. **Comment on the result**.

Resistance of nichrome wire at 0^0C, R_0 = 10Ω

Temperature coefficient of resistance α =0.004/^{0}C

Resistance at boiling point of water, R_T = ?

Temperature of boiling point of water, T =100^0C ?

$R_T = R_0 (1 + \alpha T)$; = 10[1+(0.004 x 100^0]

R_T = 10(1+0.4) = 10 x 1.4 ; R_T = 14 Ω

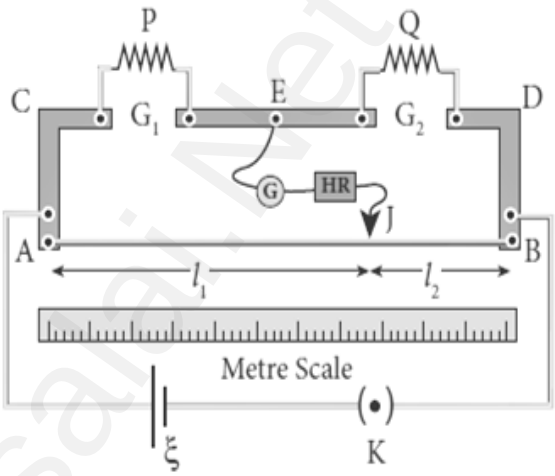
As the temperature increases the resistance of the wire also increases.

3 Marks Question & Answer

36. Explain the determination **of unknown resistance** using **Meter Bridge**.

Metre Bridge:

Metre Bridge is another form of **Wheatstone's bridge.** It consists of **uniform manganin wire AB of 1m length.** This wire is stretched along a metre scale between two copper strips C and D. E is another copper strip mounted with **two gaps G_1 and G_2 .An unknown resistance P is connected in G_1** and standard resistance connected in G_2



A jockey J is connected from E through a galvanometer G and high resistance HR.A Lechlanche cell ξ and key K is connected across the bridge wire. The position of jockey is adjusted so that the **galvanometer shows zero deflection**. Let the point be 'J'

The lengths AJ and JB now replace the resistance R and S of the Wheatstone's bridge. Then $\frac{P}{Q} = \frac{R}{S}$; $= \frac{R'AJ}{R'JB}$

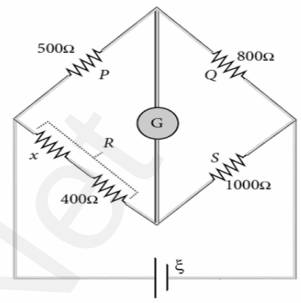
Where $R' \rightarrow$ resistance per unit length, $\frac{P}{Q} = \frac{AJ}{JB} = \frac{l_1}{l_2}$.....(1)

(or) $P = Q\frac{l_1}{l_2}$.....(2)

Due to imperfect contact of wire at its ends, some resistance might be introduced at the contact. These are called end resistances. By interchange P and Q, This error can be eliminated, and the average value of P is found. Let l be the length and r be the radius of wire, its specific resistance (resistivity) is given be. $\rho = \frac{\rho A}{l}$; $= \frac{\rho \pi r^2}{l}$.....(3)

37. What is the value of x when the Wheatstone's network is balanced?

P = 500 Ω, Q = 800 Ω, R = x+ 400, S = 1000 Ω



$\frac{P}{Q} = \frac{R}{S}$; $\frac{500}{800} = \frac{x+400}{1000}$; $\frac{x+400}{1000} = \frac{500}{800}$

x +400 = $\frac{500}{800}$ x 1000 ; $\boldsymbol{x}$ **+400 =** $\frac{5}{8}$ **x 1000**

x +400 = 0.625 × 1000 ; x +400 = 625 ;

x = 625 – 400 ; **x = 225 Ω**

38. A battery has an emf of 12 V and connected to a resistor of 3 Ω. The current in the circuit is 3.93A. Calculate (a) terminal voltage and the internal resistance of the battery (b) power delivered by the battery and power delivered to the resistor.

The terminal voltage of the battery is equal to voltage drop across the resistor **V = IR = 3.93 × 3 = 11.79 V**

r = $\left[\frac{\xi - V}{V}\right]$; $\left[\frac{12 - 11.79}{11.79}\right]$x3 ; = 0.05 Ω

The power delivered by the battery P= Iε = 3.93 × 12 = 47.1 W

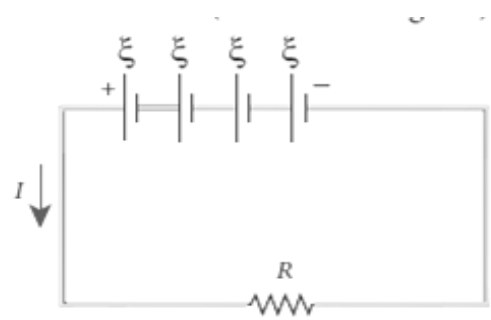
The power delivered to the resistor = I^2R= 46.3 W

The remaining power P = (47.1 – 46.3) = 0.8 W is delivered to the internal resistance and cannot be used to do useful work.

39. Write a note on **electric cells in series**.

Cells in Series:

Let n cells, each of emf ξ volts and internal resistance r ohms are connected in series with an external resistance R.



The total emf of the battery = nξ

The total resistance in the circuit = nr + R

By Ohm's law, the current in the circuit is

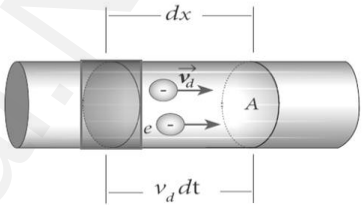
I = $\frac{\text{Totalemf}}{\text{Totalresistance}}$; = $\frac{n\xi}{n\,r+R}$..... (1)

If r << R, equation (1) becomes, **I** = $\frac{n\xi}{R} \approx \boldsymbol{nl_1}$ $\left[\because \frac{\xi}{R} = l_1\right]$

(i.e.), **if r is negligible when compared to R the current supplied by the battery is n times that supplied by a single cell**. If r>>R, equation (1) becomes $\mathbf{I = \frac{n\xi}{n\,r}}$ **;** $= \frac{\xi}{r} \approx \boldsymbol{l_1}$ (i.e) If **r is very very greater than R**, current due to the whole battery is the **same** as that due to a single cell.

40. Derive the relation between **the drift velocity** and the **current**.

Drift velocity and current - Relation:



Area of cross section of the conductor = A

Number of electrons per unit volume= n, Applied electric field=$\vec{E}$; Drift velocity of electrons= $\boldsymbol{vd}$, Charge of an electrons= e . Let 'dx' be the distance travelled by the electron in time 'dt', then $v_d = \frac{dx}{dt}$

$(or) = v_d dt$

The number of electrons available in the volume of length 'dx' is

= A dx X n ; = A $v_d dt$ X n

Then the total charge in this volume element is, $= A\, v_d\, dt\, ne$

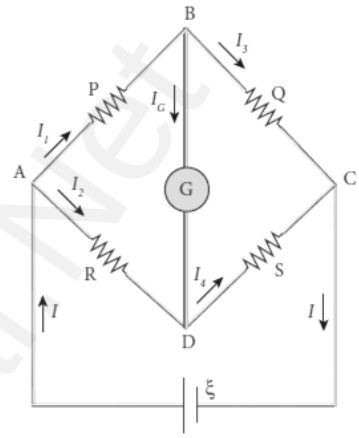
By definition, the current is given by I = $\frac{dQ}{dt}$;

$= \frac{A\, v_d\, dt\, n\, e}{dt}$; **I = n e A V_d**

5 Marks Question & Answer

41. Obtain the condition for bridge balance in Wheatstone's bridge

Wheatstone's bridge:



An important application of **Kirchhoff's laws is the Wheatstone's bridge.** It is **used** to compare resistances and also helps in **determining the unknown resistance in the electrical network**. The bridge consists of four resistances P, Q, R, S connected as shown. A galvanometer 'G' is connected between B and D. A battery 'ξ' is connected between A and C . Let I_1, I_2, I_3, I_4currents through various branches and $\mathbf{I_G}$ be the **current through the galvanometer**.

Applying Kirchhoff's current law at B and D,

$I_1 - I_G - I_3 = 0$ ---- (1)

$I_2 + I_G - I_4 = 0$ ---- (2)

Applying Kirchhoff's voltage law ABDA and ABCDA,

$I_1 P + I_G G - I_2 R = 0$ ---- (3)

$I_1 P + I_3 Q - I_2 R - I_4 S = 0$ ---- (4)

At balanced condition, the potential at B and D are same, and hence the **galvanometer** shows **zero deflection**. So $\mathbf{I_G = 0}$

Put this in equation (1), (2) and (3)

$I_1 - I_3 = 0$ (or) $I_1 = I_3$ ---- (5)

$I_2 - I_4 = 0$ (or) $I_2 = I_4$ ---- (6)

$I_1 P - I_2 R = 0$ (or) $I_1 P = I_2 R$ ---- (7)

Put equation (5) and (6) in (4)

$I_1 P + I_1 Q - I_2 R - I_2 S = 0$; $I_1 (P+Q) - I_2 (R + S) = 0$

$\therefore I_1 (P+Q) = I_2 (R + S)$ ---- (8)

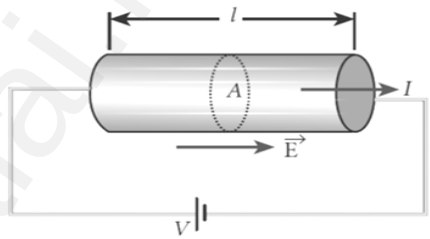
Divide equation (8) by (7)

$\frac{I_1(P+Q)}{I_1P} = \frac{I_2(R+S)}{I_2R}$; $\frac{(P+Q)}{P} = \frac{(R+S)}{R}$

$1 + \frac{Q}{P} = 1 + \frac{S}{R}$; $\frac{Q}{P} = \frac{S}{R}$ (or) $\mathbf{\frac{P}{Q} = \frac{R}{S}}$.....(9)

42. Obtain the **macroscopic form of ohm's law** from its microscopic form and discuss its limitation.

Macroscopic form of Ohm's law:



Consider a segment of wire of length *l* and cross sectional area A.

When a potential difference V is applied across the wire, a net electric field is created in the wire which constitutes the current. **If assume that the electric field is uniform in the entire length of the wire, the potential difference is given by, V = E*l*(or) E = $\frac{V}{l}$**

From the microscopic form of Ohm's law, J = σE ; = $\sigma\frac{V}{l}$

By definition, the Current density is J = $\frac{I}{A}$

Hence, $\frac{I}{A} = \frac{V}{l}$; ∴ V = I $\left[\frac{l}{\sigma A}\right]$; V = IR

Where, $\frac{l}{\sigma A}$ = R →Resistance of the conductor. This is called macroscopic form of Ohm's law.The resistance is the **ratio of potential difference across** the given conductor to the current passing through the conductor.

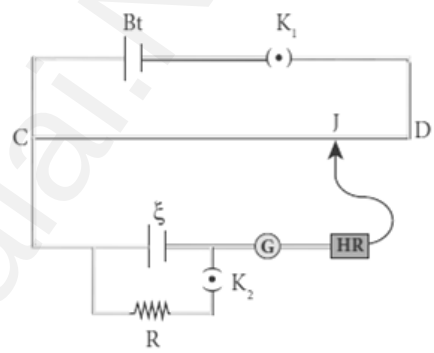
From Ohm's law, the graph between current versus voltage is **straight line with a slope equal to the inverse of resistance R of the conductor**

Materials, for which the current against voltage graph is a straight line through the origin, are said to obey Ohm's law and their behaviour is said to be ohmic.

Materials or devices that **do not follow Ohm's law** are said to be non-ohmic. These materials have more complex (non - linear) **relationships between voltage and current.**

43. Explain the method of **measurement of internal resistance of a cell** using **Potentiometer.**

Internal resistance by potentiometer:



Potentiometer wire CD is connected to battery (Bt) and a key (K_1) in series. This is the primary circuit. The cell ξ whose internal resistance 'r' to be measured is connected to the secondary circuit. A resistance box R and a key K_2 is connected across the cell ξ. With key K_2 open, the balancing point J is found out and balancing length CJ = l_1 is measured.

By the principle, $\boldsymbol{\xi \propto l_1}$ ----(1)

A suitable resistance is included in R and key K_2 is closed. The current flows through R and cell is, I = $\frac{\xi}{R+r}$

Hence potential difference across R , **V = IR =** $\boldsymbol{\frac{\xi}{R+r}}$ **R**

For this potential difference, again the balancing point J is found out and the balancing length CJ = l_2 is measured.

By the Principle $\boldsymbol{\frac{\xi}{R+r}R \propto l_2}$ ..... (2)

Divide equation (1) by (2)

$\frac{\xi}{\left(\frac{\xi}{R+r}R\right)} = \frac{l_1}{l_2}$; $\frac{R+r}{R} = \frac{l_1}{l_2}$; $1 + \frac{r}{R} = \frac{l_1}{l_2}$;

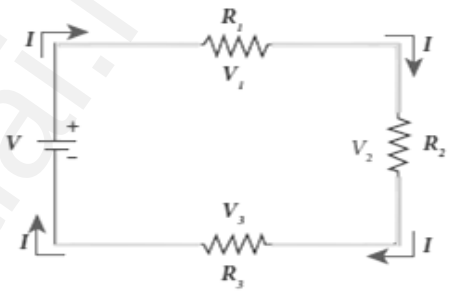
$\frac{r}{R} = \frac{l_1}{l_2} - 1$; $\frac{l_1 - l_2}{l_2}$; $\mathbf{r = R\left[\frac{l_1 - l_2}{l_2}\right]}$..... (3)

By substituting, l_1, l_2 in equation (3) the internal resistance of the cell can be measured. Here **the internal resistance is not constant, and it increased with increase of external resistance R**.

44. Explain the **equivalent resistance of a series** and **parallel resistance** network.

Resistors in Series:

When two or more resistors are connected end to end, they are said to be in series. Let **R_1, R_2, R_3 be the resistances of three resistors connected in series.** Let "**V" be the potential difference** applied across this combination. In series connection i) Current through each resistor will be same (I) ii) But potential difference across different resistor will be different.



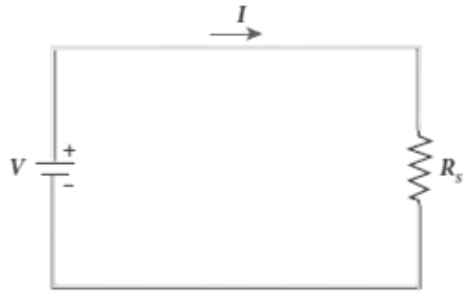
(a) Three resistors in series

Let **V_1, V_2, V_3 be the potential difference** across R_1, R_2, R_3 respectively, then from Ohm's law. $V_1 = IR_1$; $V_2 = IR_2$, $V_3 = IR_3$

Total potential difference, $V = V_1 + V_2 + V_3$;

$= IR_1 + IR_2 + IR_3$

$V = I[R_1 + R_2 + R_3]$ ..... (1)



(b) Equivalent resistance (R_s) has the same current

Let Rs be the equivalent resistance in series connection, then

$V = IR_s$ .....(2)

From equation (1) and (2), we have

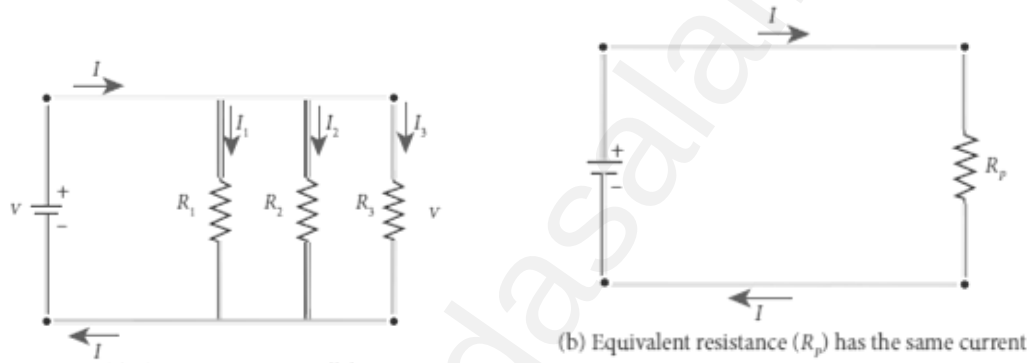
$IR_s = I\,[R_1 + R_2 + R_3]$; $\therefore R_s = R_1 + R_2 + R_3$

When resistances are connected in series, **the equivalent resistance** is the **sum of the individual resistances**. The equivalent resistance in series connection will be **greater than each individual resistance**.

Resistors in Parallel:

When two or more resistors are connected across the same potential difference, they are said to be in parallel. Let **R_1, R_2, R_3 be the resistances of three resistors connected in parallel.** Let "**V" be the potential difference** applied across this combination.

In parallel connection, i) Potential difference across each resistance will be the same (V) ii) But current flows through different resistors will be different.



(a) Three resistors in parallel

(b) Equivalent resistance (R_p) has the same current

Let I_1, I_2, I_3 be the currents flow through R_1, R_2, R_3 respectively, then from Ohm's law. $I_1 = \frac{V}{R_1}$; $I_2 = \frac{V}{R_2}$; $I_3 = \frac{V}{R_3}$

$I = I_1 + I_2 + I_3$; $= \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$; $I = V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$.....(1)

Let R_p be the equivalent resistance in parallel connection, then

$$I = \frac{V}{R_p} \text{..... (2)}$$

From equation (1) and (2), we have $\frac{V}{R_p} = V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$

$$\therefore \frac{1}{R_p} = \left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

When resistances are connected in parallel, the reciprocal of equivalent resistance is **equal to the sum of the reciprocal** of the values of resistance of the individual resistor.

The equivalent resistance in **parallel connection will be lesser than** each individual resistance.

UNIT-3 MAGNETISM AND MAGNETIC EFFECTS OF ELECTRIC CURRENT

2 Marks Question & Answer

45. The repulsive force between two magnetic poles in air is 9×10^{-3}N. If the two poles are equal in strength and are separated by a distance of 10 cm, calculate the **pole strength** of each pole.

The force between two poles are given by $\vec{F} = k\frac{q_{mA}q_{mB}}{r^2}\hat{r}$

The magnitude of the force is $F = k\frac{q_{mA}q_{mB}}{r^2}$

Given : $F = 9 \times 10^{-3}$N, $r = 10$ cm $= 10 \times 10^{-2}$ m

Therefore, $9 \times 10^{-3} = 10^{-7} \times \frac{q_m^2}{(10 \times 10^{-2})^2} \Rightarrow$ **30 NT^{-1}**

46. State **Ampere's circuital law**.

It state that the **line integral of magnetic field over a closed loop** is μ_0 times **net current enclosed by the loop**. $\oint \vec{B}.\vec{dl} = \mu_0 I_0$

47. A coil of 200 turns carries a current of 0.4 A. If the magnetic flux of 4 mWb is linked with the coil, find the **inductance of the coil**.

Number of turns of the coil, N = 200 , Current, I = 0.4 A

Magnetic flux linked with coil, $\phi = 4$mWb $= 4 \times 10^{-3}$ Wb

Inductance of the coil, $L = \frac{N\phi}{I}$; $= \frac{200 \times 4 \times 10^{-3}}{0.4}$;

$= \frac{800 \times 10^{-3}}{0.4}$; **L = 2 H**

48. Why **Phosphor - bronze** is used as suspension wire?

Because, for phosphor - bronze wire, **the couple per unit twist is very small**.

49. An electron moving perpendicular to a uniform magnetic field 0.500 T undergoes circular motion of radius 2.80 mm. What is the **speed of electron**?

Charge of an electron q = -1.60 × 10^{-19} C ⟹ $|q|$ = 1.60 × 10^{-19} C
Magnitude of magnetic field B = 0.500 T
Mass of the electron, m = 9.11 × 10^{-31} kg
Radius of the orbit, r = 2.50 mm = 2.50 × 10^{-3}m
Velocity of the electron, $v = |q|\frac{rB}{m}$
$v = 1.60 \text{ x } 10^{-19} \text{ x } \frac{2.50 \text{ x } 10^{-3} \text{x } 0.500}{9.11 \text{ x } 10^{-31}}$; $\boldsymbol{v = 2.195 \text{ x } 10^{8} \text{ ms}^{-1}}$

50. State **Fleming's Left Hand Rule** (FLHR).
FLHR: Stretch for finger, the middle finger and the thumb of the left hand in mutually perpendicular directions. If,
(i) **Fore finger** points the **direction of magnetic field**,
(ii) The **middle finger** points the **direction of the electric current**, then
(iii) **Thumb** will point the **direction of the force** experienced by the conductor.

51. Define **one ampere**.
One ampere is defined as that current when it is passed through each of the two infinitely long parallel straight conductors kept at a distance of one metre apart in vacuum caused each conductor to experience a force of 2 x 10^{-7} Newton per metre length of conductor.

3 Marks Question & Answer

52. Give the **properties of Lorentz magnetic force**.

Properties of Lorentz magnetic force:

(i) $\vec{F}_m$ is directly proportional to the **magnetic field ($\vec{B}$)**

(ii) $\vec{F}_m$ is directly proportional to the **velocity ($\vec{v}$)**

(iii) $\vec{F}_m$ is directly proportional to **sine of the angle** between the **velocity and magnetic field.**

(iv) $\vec{F}_m$ is directly proportional to the **magnitude of the charge**

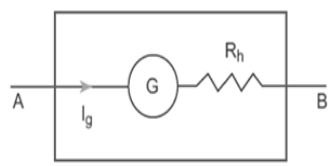
(v) The direction of $\vec{F}_m$ is always perpendicular to $\vec{v}$ and $\vec{B}$

(vi) If the of the charge is along the magnetic field, then $\vec{F}_m$ **is zero.**

53. How **Galvanometer** can be converted in to **Voltmeter**?

Galvanometer to a Voltmeter:

A voltmeter is an instrument used to measure potential difference across any two points. **A galvanometer is converted in to voltmeter by connecting high resistance in series** with the galvanometer. The scale is calibrated in volts.



Voltmeter

Galvanometer resistance= R_G, High resistance= R_h

Current flows through galvanometer= I_G

Voltage to be measured= V, Total resistance of this circuit = $R_G + R_h$

Here the **current in the electrical circuit is same as the current passing through the galvanometer**. (i.e) $I_G = I$

$I_G = \frac{V}{R_G+R_h}$ (or) $R_G + R_h = \frac{V}{I_G}$; $\therefore$ $\mathbf{R_h = \frac{V}{I_G} - R_G}$

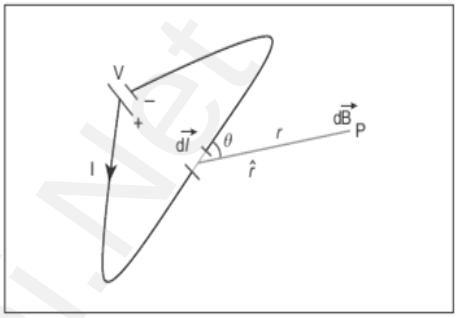
Let R_V be the resistance of voltmeter, then $\mathbf{R_V = R_G + R_h}$. Here, $R_G < R_h < R_v$

Thus an voltmeter is a high resistance instrument, and it always **connected in parallel to the circuit element. An ideal ammeter has zero resistance.**

54. State and explain **Biot-Savart law**.

Biot - Savart law :

According to Biot - Savart law, the magnitude of magnetic field at a point 'P' at a distance 'r' from the small elemental length 'dl' of the current 'I' carrying conductor varies,(i) $dB \propto I$(ii) $dB \propto dl$(iii) $dB \propto \sin\theta$(iv) $dB \propto \frac{1}{r^2}$Hence, dB$\propto \frac{I\, dl\, sin\theta}{r^2}$; (or)



dB=k $\frac{I\, dl\, sin\theta}{r^2}$.....(1)

Where k→constant, SI unit, k = k = $\frac{\mu_0}{4\pi}$

Hence, dB = k = $\frac{\mu_0}{4\pi}\frac{I\, dl\, sin\theta}{r^2}$.....(2)

In vector notation, $\overrightarrow{dB} = \frac{\mu_0}{4\pi}\frac{I\overrightarrow{dl}x\hat{r}}{r^2}$.....(3)

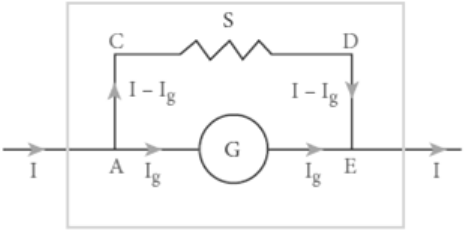
Here $\overrightarrow{dB}$ is perpendicular to both $I\overrightarrow{dl}$ and $\hat{r}$. From superposition principle the **total magnetic field due to entire conductor is,**

$\overrightarrow{B} = \int \overrightarrow{dB} = \frac{\mu_0 I}{4\pi}\int \frac{\overrightarrow{dl}x\hat{r}}{r^2}$

55. How **Galvanometer** can be converted in to **Ammeter**.

Galvanometer to an Ammeter:

Ammeter is an instrument used to measure current. A galvanometer is **converted into an ammeter by connecting a low resistance** called shunt in parallel with the galvanometer. The scale is calibrated in amperes. Galvanometer resistance= R_G; Shunt resistance = S



Ammeter

Current flows through galvanometer= I_G

Current flows through shunt resistance = I_S

Current to be measured= I

The potential difference across galvanometer is same as the potential difference shunt resistance. (i.e.) $V_{Galvanometer} = V_{shunt}$

$I_G R_G = I_S S$; $I_G R_G = (I - I_G) S$ – – –(1) ; $S = \frac{I_G}{I - I_G} R_G$

From equation (1) $I_G R_G = S I - I_G S$

$I_G (S + R_G) = S I$; $I_G = \frac{S}{S + R_G} I$

Let Ra be the resistance of ammeter, then $\frac{1}{R_a} = \frac{1}{R_G} + \frac{1}{S}$

$\Longrightarrow R_a = \frac{R_G S}{R_G + S}$ Here, $\mathbf{R_G > S > R_a}$

Thus an ammeter is a low resistance instrument, and it always **connected in series to the circuit. An ideal ammeter has zero resistance.**

56. What are the **properties of bar magnet**?

Properties of magnet:

(i) A freely suspended **bar magnet** will always point along the **north - south direction.**

(ii) The **attractive property of the magnet is maximum** near its end or pole. This is called pole strength.

(iii) Two poles of a magnet have **pole strength equal to one another.**

(iv) When a magnet is **broken into pieces, each piece behaves like a magnet** with poles at its ends.

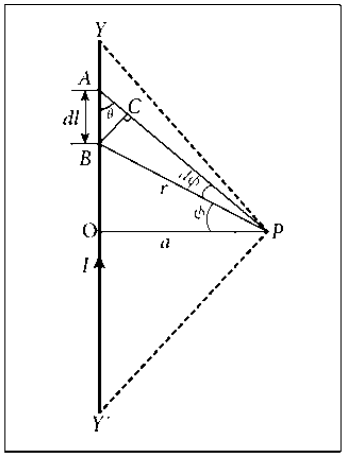
(v) The **length of the bar magnet is called geometrical length** and **length between two magnetic poles in a bar magnet is called magnetic length**. The magnetic length is always slightly smaller than geometrical length.

(i.e.) magnetic length: geometrical length = 5 : 6

5 Marks Question & Answer

57. Deduce the relation for **magnetic induction** at a point due to an infinitely **long straight conductor carrying current**.

Magnetic field due to long straight current carrying conductor:



Consider a long straight wire YY' carrying a current I

Let P be a point at a distance 'a' from 'O'

Consider an **element of length 'dl'** of the wire at a distance 'l' from point 'O' Let $\vec{r}$ be the vector joining the element 'dl' with the point 'P' and 'θ' be the **angle between $\vec{r}$ and $\vec{dl}$.** Then the magnetic field at 'P' due to the element is,

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}\hat{n} \text{ - - - - - (1)}$$

Where, $\hat{n}$ – unit vector normal to both $I\,\vec{dl}$ and $\vec{r}$

To apply trigonometry, draw a perpendicular AC to the line BP

In triangle Δ ABC, $\sin\theta = \frac{AC}{AB} \Longrightarrow \boldsymbol{AC = AB\sin\theta}$

But AB = dl $\Longrightarrow \boldsymbol{AC = dl\sin\theta}$

Let dϕ be the angle subtended between AP and BP

i.e. $\angle APB = \angle BPC = d\phi$

In triangle Δ APC, $\sin(d\phi) = \frac{AC}{AP}$; since, $d\phi$ is very small, $\sin(d\phi) \simeq d\phi$

But AP = r $\Longrightarrow AC = rd\phi$ $\therefore \boldsymbol{AC = dl\sin\theta = rd\phi}$

$\therefore d\vec{B} = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}(rd\phi)\hat{n}$; $= \frac{\mu_0}{4\pi}\frac{Id\phi}{r}\hat{n}$

Let ϕ be the angle between BP and OP

In a Δ OPA, $\cos\phi = \frac{OP}{BP} = \frac{a}{r}$; $\Longrightarrow r = \frac{a}{\cos\phi}$; $d\vec{B} = \frac{\mu_0}{4\pi}\frac{I}{\frac{a}{\cos\phi}}d\phi\,\hat{n}$

$\overrightarrow{dB} = \frac{\mu_0 I}{4\pi a}\cos\phi d\phi.\hat{n}$

The total magnetic field at P due to the conductor YY' is $\vec{B} = \int_{-\phi 1}^{\phi 2} d\vec{B}$

$= \int_{-\phi 1}^{\phi 2} \frac{\mu_0 I}{4\pi a} \cos\phi d\phi . \hat{n}$;

$\frac{\mu_0 I}{4\pi a} [\sin\phi]_{\phi 1}^{\phi 2} \hat{n}$

$\vec{B} = \frac{\mu_0 I}{4\pi a} (\sin\phi + \sin\phi)\ \hat{n}$

For infinitely long conductor , $\boldsymbol{\phi_1 = \phi_2 = 90^0}$

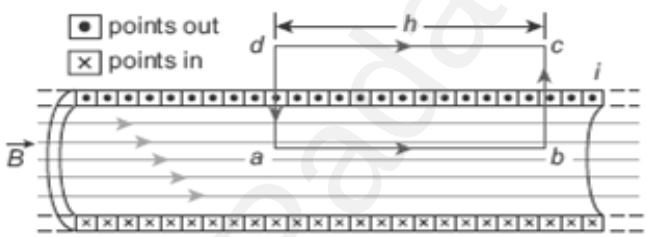
$\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{a} [2]\ \hat{n}$;

$\vec{B} = \frac{\mu_0}{2\pi} \frac{I}{a} \hat{n}$ ---------- (3)

58. Obtain an expression for **magnetic field due to long current** carrying **solenoid.**

Magnetic field due to current carrying solenoid:

Consider a solenoid of length 'L' having 'N' turns. To calculate the magnetic field at any point inside the solenoid,



Magnetic field of a solenoid

consider an Amperian loop 'abcd'. From Ampere circuital law,

$\oint \vec{B}.\vec{dl} = \mu o I_0$ ------ (1)

The LHS of equation (1) can be written as

$\oint \vec{B}.\vec{dl} = \int_a^b \vec{B}.\vec{dl} + \int_b^c \vec{B}.\vec{dl} + \int_c^d \vec{B}.\vec{dl} + \int_d^a \vec{B}.\vec{dl}$

$\int_a^b \vec{B}.\vec{dl} = \int_a^b B\, dl \cos 0^0 = B \int_a^b dl = Bh$

$\int_b^c \vec{B}.\vec{dl} = \int_b^c B\, dl \cos 90^0 = 0$; $\int_c^d = 0$

$\int_d^a \vec{B}.\vec{dl} = \int_d^a B\, dl \cos 90^0 = 0$

Here ab = h . If we take large loop such that it isequal to length of the solenoid, we have $\oint \vec{B}.\vec{dl} = B\, \boldsymbol{L}$ -------- (2)

Let 'I' be the current passing through the solenoidof 'N' turns, then

I_0 = NI– – – – – – – – (3)

Put equation (2) and (3) in (1) BL = μoNI

B = $\mu o \frac{N}{L} I$– – – – – – – – (4)

Let "n" be the number of turns per unit length, then $\frac{N}{L}$ = n. Hence,

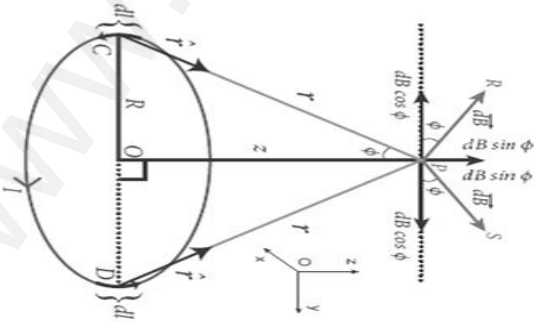
B = $\frac{\mu_0 NI}{L}$ = $\mu o n\, I$– – – – – – – – (5)

Since 'n' and μ0 are constants, for fixed current 'I' the magnetic field 'B' inside the solenoid is also constant.

59. Obtain a relation for the **magnetic induction** at a point along the axis of **a circular coil carrying current**.

Magnetic field due to current carrying circular coil:

Consider a circular coil of radius 'R' carrying a current 'I' in anti-clock wise direction. Let 'P' be the point on the axis at a distance 'z' from centre 'O'. Consider two diametrically opposite line elements of the coil of each of length $\vec{dl}$ at C and D. Let $\vec{r}$be the vector joining the current element $I\vec{dl}$ at C to the point P.



According to Biot - Savart law, The magnitude of $d\vec{B}$ is $d\vec{B} = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}\hat{n}$

The magnetic field at 'P' due to the current element $I\vec{dl}$is, $d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}\hat{n}$

$\because \theta = 90^0$]

Here, $d\vec{B}$can be resolved in to two components.

(i) $d\vec{B}\text{Sin}\theta$ – horizontal component (Y - axis)

(ii) $d\vec{B}\cos\theta$ – vertical component (Z - axis)

Here horizontal components of each element cancel each other.

But vertical components alone contribute to total magnetic field at the point 'P' $\vec{B} = \int d\vec{B} = \int dB \sin\phi\, \hat{k}$;

$$\vec{B} = \frac{\mu_0 I}{4\pi}\int \frac{dl}{r^2}\sin\phi\, \hat{k} \quad \text{..... (1)}$$

Also from ΔOCP, $\sin\phi = \frac{R}{(R^2+Z^2)^{\frac{1}{2}}}$ and $r^2 = R^2 + z^2$

But from equation (1) $\vec{B} = \frac{\mu_0 I}{4\pi}\int \frac{dl}{(R^2+Z^2)}\frac{R}{(R^2+Z^2)^{\frac{1}{2}}}\hat{k}$

$\vec{B} = \frac{\mu_0 I R}{4\pi(R^2+Z^2)^{\frac{3}{2}}}\int dl\, \hat{k}$, Where, $\int dl = 2\pi R$ →total length of the coil.

$\vec{B} = \frac{\mu_0 I R}{4\pi(R^2+Z^2)^{\frac{3}{2}}}[2\pi R]\,\hat{k}$; $\boldsymbol{\vec{B} = \frac{\mu_0 I R^2}{2(R^2+Z^2)^{\frac{3}{2}}}\hat{k}}$

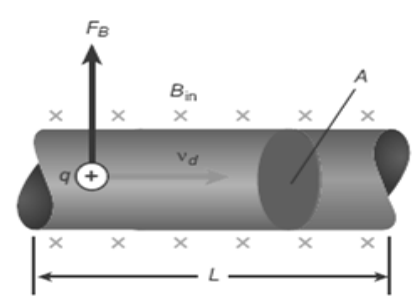
If the circular coil contains N turns , then the magnetic field $\vec{B} = \frac{\mu_0 N I R^2}{2(R^2+Z^2)^{\frac{3}{2}}}\hat{k}$

The magnetic field at the centre of the coil z=0$\vec{B} = \frac{\mu_0 N I}{2R}\hat{k}$

60. Obtain an expression for **<u>the force on a current carrying conductor</u>** placed in a magnetic field.

<u>Force on current carrying conductor in magnetic field:</u>

When a current carrying conductor is placed in a magnetic field, the force experienced by the wire is equal to the sum of Lorentz forces on the individual charge carriers in the wire.



<u>Let a current 'I' flows through a conductor of length 'L' and area of cross-section 'A'. Consider a small segment of wire of length 'dl'</u>

The free electrons drift opposite to the direction of current with velocity vd .

The relation between current and drift velocity is, **$I = nAev_d$**

If the wire is kept in a magnetic field, then average force experienced by the electron in the wire is

$\vec{F} = -e\ (\vec{v}_d \times \vec{B})$. Let 'n' be the number of free electrons per unit volume, then the total number of electrons in the small element of volume ($V = A\ dl$) is $N = nA$. Hence Lorentz force on the small element,

$\boldsymbol{\overrightarrow{dF} = -e\ n\ A\ dl(\vec{v}_d \times \vec{B})}$ ------- (1)

Here length dl is along the length of the wire and hence the current element is= $-nAedl\vec{v}_d$

Put this in equation (1), $\overrightarrow{dF} = I\,\overrightarrow{dl} \times \vec{B}$ ------- (2)

Therefore, the force in a straight current carrying conductor of length '$\boldsymbol{l}$' placed in a uniform magnetic field. $\vec{F} = I\,\vec{l} \times \vec{B}$ ------- (3)

In magnitude, **$F = BIl \sin\theta$** ------- (4)

Special cases:

(i) If the current carrying conductor placed along the direction of magnetic field, then = $0^0 \therefore$ **$F = 0$**

(ii) If the current carrying conductor is placed perpendicular to the magnetic field, then= 90^0 $\therefore$ **$F = BIl$ = maximum.**

61. Describe the principle, construction and working of **moving coil galvanometer.**

Moving coil galvanometer:

It is a device which is used to **indicate the flow of current.**

Principle:

When a **current carrying loop** is placed in a **uniform magnetic field** it experiences a torque.

Construction:

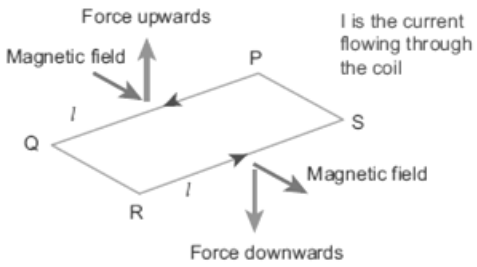
It consists of a rectangular coil PQRS of insulated thin copper wire. A cylindrical soft-iron core is placed symmetrically inside the coil. This **rectangular coil is suspended freely between two pole pieces of a horse-shoe magnet by means of phosphor - bronze wire**. **Lower end of the coil is connected to a hair spring which is also made up of phosphor bronze.**

A **small plane mirror** is attached on the suspension **wire to measure the deflection of the coil with help of lamp and scale arrangement.** In order to pass electric current through the galvanometer, the suspension strip W and the spring S are connected to terminals.

Working:

Consider a single turn of rectangular coil PQRS of length l and breadth b, such that PQ = RS = l ; QR = SP = b

Let 'I' be the electric current flowing through the rectangular coil



The horse-shoe type magnet has hemi-spherical magnetic poles which produces a radial magnetic field. Due to this radial field, the sides

QR and SP are always parallel to the magnetic field 'B' and experience no force. But the **sides PQ and RS are always perpendicular to the magnetic field 'B' and experience force and due to the torque is produced**. For single turn, the deflecting couple is, τ_{def} = **F b = B Il b = B I A**

For coil with N turns, we get τ_{def} = **NBIA** .....(1)

Due to this deflecting torque, **the coil gets twisted and restoring torque is developed. The magnitude of restoring torque is proportional to amount of twist and it is given by τ_{res} = K θ**.....(2)

Where K → restoring couple per unit twists (or) torsional constant

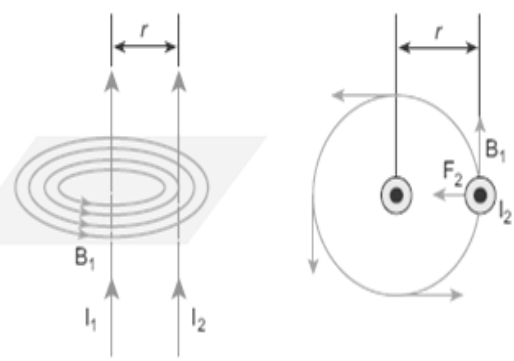
At equilibrium, τ_{def} = τ_{res} ; **NBIA = K θ ; I = $\frac{K}{NBA}$ θ = G θ**.....(3)

Where, G = $\frac{K}{NBA}$ → Galvanometer constant (or) current reduction factor.

62. Obtain a force between two long parallel current carrying conductors.

Force between two parallel conductors carrying current:

Consider two straight parallel current carrying conductors 'A' and 'B' separated by a distance 'r' kept in air. Let I_1 and I_2 be the currents passing through the A and B in same direction (z-direction). The net magnetic field due to I_1 at a distance 'r'.



$$\vec{B}_1 = \frac{\mu_0 I_1}{2\pi r}(-\hat{\imath}) = -\frac{\mu_0 I_1}{2\pi r}\hat{\imath}$$

Here **$\vec{B}_1$ acts perpendicular to plane of paper and inwards.**

Then Lorentz force acts on the length element dl in conductor 'B' carrying current I_2 due to this magnetic field $\vec{B}_1$

$$\vec{dF} = I_2\vec{dl} \times \vec{B}_1 = -I_2 dl\,\hat{k} \times \frac{\mu_0 I_1}{2\pi r}\hat{\imath}$$

$$\vec{dF} = -\frac{\mu_0 I_1 I_2 dl}{2\pi r}(\hat{k} \times \hat{\imath})\ ;\ \vec{dF} = -\frac{\mu_0 I_1 I_2 dl}{2\pi r}\hat{\jmath}$$

By Fleming's left hand rule, this force acts leftwards. The force per unit length of the conductor B. $\frac{\vec{F}}{l} = -\frac{\mu_0 l_1 I_2}{2\pi r}\hat{j}$ – – – – – – (1)

Similarly, net magnetic field due to I_2 at a distance 'r' is $\vec{B}_2 = \frac{\mu_0 l_2}{2\pi r}\hat{\imath}$

Here **$\vec{B}_2$ acts perpendicular to planeof paper and outwards.**

Then Lorentz force acts on the length element dl in conductor 'A' carrying current I_1 due to this magnetic field $\vec{B}_2$.

$$\vec{dF} = I_1\vec{dl} \times \vec{B}_2 = I_1 dl\,\hat{k} \times \frac{\mu_0 l_2}{2\pi r}\hat{\imath}$$

$$\vec{dF} = \frac{\mu_0 l_1 I_2 dl}{2\pi r}(\hat{k} \times \hat{\imath})\ ;\ \vec{dF} = \frac{\mu_0 l_1 I_2 dl}{2\pi r}\hat{j}$$

By Fleming's left hand rule, this force acts rightwards. The force per unit length of the conductor A. $\frac{\vec{F}}{l} = \frac{\mu_0 l_1 I_2 dl}{2\pi r}\hat{j}$ – – – – – – (2)

Thus the force experienced by **two parallel current carrying conductors is attractive if they carry current in same direction**. On the other hand, the force experienced by two parallel current carrying conductors is repulsive if they carry current in opposite direction.

UNIT-4 ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENT

2 Marks Question & Answer

63. Define **RMS value of AC**

RMS value of AC:

The **square root** of the mean of the **square of all currents** over one cycle. $I_{RMS} = \frac{I_m}{\sqrt{2}} = 0.707 I_m$.

64. Define **quality factor** or **Q-Factor**.

Q-Factor : The **ratio of voltage across L or C** to the **applied voltage** at resonance.

65. Define **coefficient of self-induction**.

The **flux linkage of the coil, when 1 A current flows through** it. Its S.I unit is **H (or) WbA^{-1}(or) VsA^{-1}** and its dimension is **$[ML^2T^{-2}A^{-2}]$**

66. How the **current sensitivity of galvanometer** can be increased?

By increasing the number of turns (N)

By increasing the magnetic induction (B)

By increasing the area of the coil (A)

By decreasing the couple per unit twist of the suspension wire

67. Define **Power factor**.

Power factor: The **cosine of the angle of lead or lag**. **Power factor** is also defined as the ratio of **true power to the apparent power.**

68. What the **methods of producing induced emf**?

By changing the magnetic field 'B'

By changing the area 'A' of the coil

By changing the relative orientation θ of the coil with magnetic field.

69. State **Fleming's right hand rule**.

The thumb, index finger and middle finger of right hand are stretched out in mutually perpendicular directions. If **index finger** points the **direction of magnetic field** and the **thumb points** the **direction of motion of the conductor**, then the **middle finger** will indicate the **direction of the induced current**. Fleming's right hand rule is also known as **generator rule**.

70. Define the **efficiency of the transformer**.

The efficiency (η) of a transformer is defined as the **ratio** of the useful **output power to the input power**. $\eta = \frac{Output\ Power}{Input\ Power}$ x 100%

3 Marks Question & Answer

71. Find the impedance of a series RLC circuit if the inductive reactance, capacitive reactance and resistance are 184 Ω, 144 Ω and 30 Ω respectively. Also calculate the **phase angle between voltage and current**.

X_L= 184 Ω; X_C= 144 Ω ; R = 30 Ω

(i) The impedance is Impedance, $Z = \sqrt{R^{2+(X_L-X_C)^2}}$

$= \sqrt{30^{2+}(184-144)^2}$; $= \sqrt{900+1600}$; **Impedance, Z=50Ω**

(ii) Phase angle is $\tan\phi = \frac{X_L-X_C}{R}$; $\frac{184-144}{30}$; = 1.33 ; $\phi = 53.1^0$

Since the phase angle is positive, voltage leads current by **53.1^0** for this inductive circuit.

72. What are the **advantages** and **disadvantages of AC over DC**?

Advantages of AC over DC:

The generation of AC is **cheaper than that of DC**

When AC is supplied at **higher voltages, the transmission losses are small compared to DC transmission**. AC can easily be converted into DC with the help of rectifier.

Disadvantages of AC over DC:

Alternating voltages **cannot be used for certain application**. (e.g) **charging of batteries, electroplating, electric traction etc.,**

At high voltages, it is more dangerous to work with AC than DC.

73. What are the **applications of series RLC resonant** circuit?

Applications of series RLC resonant circuit:

RLC circuits have many applications like **filter circuits, oscillators, voltage multipliers etc**., An important use of series RLC resonant circuits is in the **tuning circuits of radio and TV systems**. To receive the signal of a particular station among various **broadcasting stations at different frequencies, tuning is done.**

74. The equation for an alternating current is given by i = 77 sin 314t. Find the peak value, frequency, time period and instantaneous value at t = 2 ms.

i = 77 sin 314t; t = 2 ms = 2×10^{-3} s

The general equation of an alternating current is $i = I_m \sin\omega t$.

On comparison, (i) Peak value, I_m = 77 A

(ii) Frequency, $\boldsymbol{f} = \frac{\boldsymbol{\omega}}{\boldsymbol{2\pi}} = \frac{\mathbf{314}}{\mathbf{2\ x\ 3.14}}$; = 50Hz

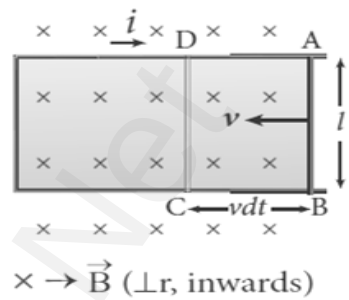
(iii) Time period, T = $\frac{1}{f} = \frac{1}{50}$ = 0.02 s

(iv) At t = 2 m s, Instantaneous value, i = 77 sin (314 x 2×10^{-3})

i = 45.24 A

75. How will you **induce an emf** by **changing the area** enclosed by the coil.

EMF induced by changing area enclosed by the coil:



Consider a conducting rod of length 'l' moving with a velocity 'v' towards left on a rectangular metallic frame work. The whole arrangement is placed in a uniform magnetic field $\vec{B}$ acting **perpendicular to the plane of the coil inwards**. As the rod moves from AB to DC in a time 'dt', the area enclosed by the loop and hence the **magnetic flux through the loop decreases**.

The change in magnetic flux in time 'dt' is $d\phi_B = B\,dA = B(l \times v\,dt)$

$$\frac{d\phi_B}{dt} = \boldsymbol{B\,lv}$$

This change in magnetic flux results and induced emf and it is given by,

$\in = \frac{d\phi_B}{dt}$; $\in = \boldsymbol{B\,lv}$

This emf is called motional emf. **The direction of induced current is found to be clock wise from Fleming's right hand rule.**

76. A 200 turn coil of radius 2 cm is placed co-axially within a long solenoid of 3 cm radius. If the turn density of the solenoid is 90 turns per cm, then calculate **mutual inductance** of the coil.

Number of turns of the solenoid, N_2 = 200;

Radius of the solenoid, r = 2 cm = 2 x 10^{-2} m

Area of the solenoid, A = πr^2 = 3.14 x (2 x 10^{-2})^2 = 1.256 x 10^{-3} m^2

Turn density of long solenoid per cm, N_1 = 90 x 10^2

Mutual inductance of the coil, M $= \frac{\mu_0 N_1 N_2 A}{l}$

$= \frac{4\pi \times 10^{-7} \times 90 \times 10^2 \times 200 \times 1.256 \times 10^{-3}}{1}$

= 283956.48 x 10^{-8} ⟹ **M = 2.84 mH**

77. An ideal transformer has 460 and 40,000 turns in the primary and secondary coils respectively. Find the voltage developed per turn of the secondary if the transformer is connected to a 230 V AC mains. The secondary is given to a load of resistance $10^4\Omega$. Calculate the **power delivered** to the load. **(March 2020)**

NP = 460 turns; NS = 40,000 turns ; VP = 230 V; RS = $10^4\ \Omega$

(i) Secondary voltage, $V_S = \frac{V_P N_S}{N_P} = \frac{230 \times 40000}{460}$; V_S = 20000V

Secondary voltage per turn, $\frac{V_S}{N_S} = \frac{20000}{40000}$; = 0.5 V

(ii) Power delivered = $V_S I_S = \frac{V_S^2}{R_S} = \frac{20000 \times 20000}{10^4}$; = 40 kW

78. Explain various **energy losses in a transformer**.

Energy losses in a transformer:

(i) Core loss or Iron loss:

Hysteresis loss and eddy **current loss** are known as **core loss or Iron loss.** When transformer core is magnetized or demagnetized repeatedly by the alternating voltage applied across primary coil, hysteresis takes place and some energy lost in the form of heat. It is **minimized by using silicone steel in making transformer core.**

Alternating magnetic flux in the core induces eddy currents in it. Therefore there is energy loss due to the flow of eddy current called **eddy current loss.** It is **minimized by using very thin laminations of transformer core.**

(ii) Copper loss:

The primary and secondary coils in transformer have electrical resistance. When an electric current flows through them, some amount of energy is dissipated due to **Joule's heating** and it is known as **copper loss**. It is **minimized by using wires of larger diameter (thick wire)**

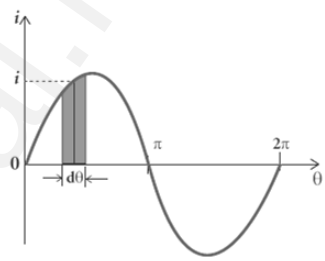
(iii) Flux leakage:

The magnetic flux linked with primary coil is **not completely linked** with secondary. Energy loss due to this flux leakage is **minimize by winding coils one over the other.**

79. Obtain the expression for **average value of alternating current**.

Average or Mean value of AC:

The average value of AC is defined as the **average of all values of current over a positive half-cycle or negative half-cycle.**



Expression:

The average or mean value of AC over one complete cycle is zero. Thus the average or mean value is measured over one half of a cycle.

The alternating current at any instant is

$$i = i_m sin\omega t = i_m sin\theta$$

The sum of all currents over a half-cycle is given by area of positive half-cycle (or) negative half- cycle. Consider an elementary strip of thickness '$d\theta$' in positive half-cycle, Area of the elementary strip = $id\theta$

Then area of positive half-cycle, $= \int_0^{\pi} i\, d\theta = \int_0^{\pi} i_m sin\theta = i_m[-\cos\theta]_0^{\pi}$

$-i_m[\cos\pi - \cos 0]$; $-i_m[-1-1]$; $= 2i_m$

Then Average value of AC,

$$I_{av} = \frac{area\ of\ positive\ or\ negative\ half-cycle}{base\ length\ of\ half-cycle}$$

$$I_{av} = \frac{2I_m}{\pi} ; = 0.637I_m$$

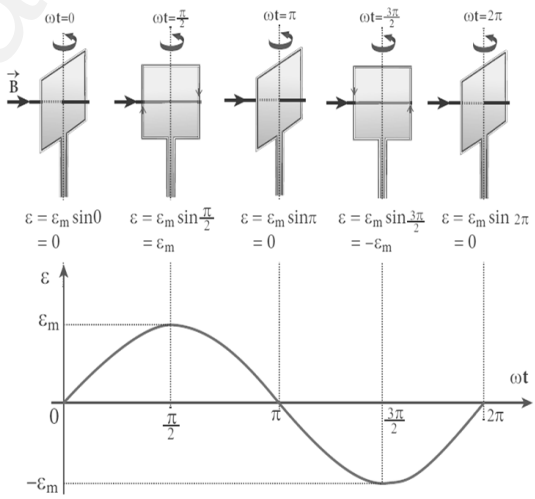
For negative half-cycle ; I_{avg} = $\mathbf{-\ 0.637I_m}$

5 Marks Question & Answer

80. Show mathematically that the rotation of a coil in a magnetic field over one rotation induces an alternating emf of one cycle.

Induction of emf by changing relative orientation of the coil with the magnetic field:

Consider a rectangular coil of '**N' turns kept in a uniform magnetic field 'B'.** The coil rotates in anti-clockwise direction with an angular velocity 'ω' about an axis. Initially let the plane of the coil be **perpendicular to the field** (θ = 0) and the flux linked with the coil has its maximum value. (i.e.) $\Phi_m = BA$



In time 't', let the coil be rotated through an angleθ (= ωt), then the total flux linked is,

$$\mathbf{N\Phi_B = N\,B\,A\cos\omega t = N\Phi_m\cos\omega t}$$

According to Faraday's law, the emf induced at that instant is,

$$\in = -\frac{d}{dt}(N\Phi_B) = -\frac{d}{dt}(N\Phi_m\cos\omega t)$$
$$-N\Phi_m(-\sin\omega t)$$

$$\in = N\Phi_m\,\omega\sin\omega t \text{ ..... (1)}$$

When θ = 90°, then the induced emf becomes maximum and it is given by,$\in_m = N\Phi_m\omega$; = N B A ω ..... (2)

Therefore the value of induced emf at that instant is then given by,

$$\in = \in_m \sin\omega t \text{..... (3)}$$

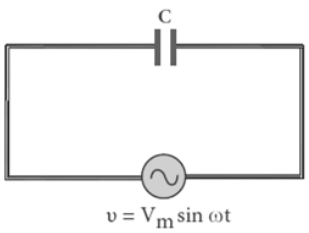
Thus the induced emf varies as sine function of the time angle and this is called sinusoidal emf or alternating emf.

If this alternating voltage is given to a closed circuit, a sinusoidal varying current flows in it. This current is called alternating current an is given by, = $I_m \sin\omega t$ ------ (4)

Where, I_m → peak value of induced current

81. Find out the phase relationship between voltage and current in a pure capacitive circuit.

AC circuit containing pure capacitor:



Let a pure capacitor of capacitance 'C' connected across an alternating voltage source 'v'. The instantaneous value of the alternating voltage is given by, $= \sin \omega t$ ---- (1)

Let 'q' be the instantaneous charge on the capacitor. The emf across the capacitor at that instant is,

$\in = \frac{q}{C}$ ---- (2)

From Kirchhoff's loop rule, $v - \in = 0$ (or) $v = \in$

$V_m \sin \omega t = \frac{q}{C} \therefore q = CV_m \sin \omega t$

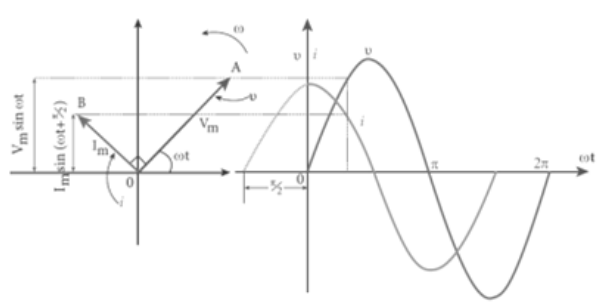
By the definition of current, $i = \frac{dq}{dt}$; $CV_m \frac{d(\sin \omega t)}{dt}$; = $CV_m(\cos\omega t)\omega$

$i = \omega CV_m \sin\left(\frac{\pi}{2} + \omega t\right)$;= $\frac{v_m}{\left(\frac{1}{\omega_C}\right)} \sin\left(\frac{\pi}{2} + \omega t\right)$

$i = I_m \sin\left(\omega t + \frac{\pi}{2}\right)$ ---- (3)

Where, $\frac{v_m}{\left(\frac{1}{\omega_C}\right)} = Im$ → Peak value of AC

From equation (1) and (3), it is **clear that current leads the applied voltage by $\frac{\pi}{2}$** .This is indicated in the phasor and wave diagram.



Capacitive reactance (X_C) :

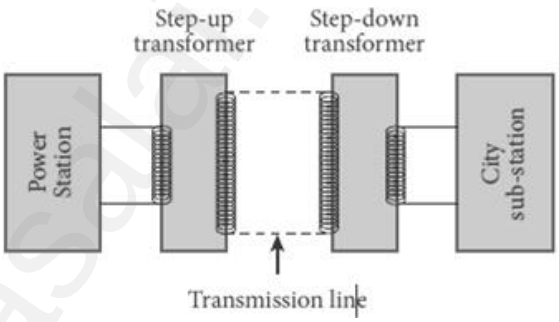
In pure capacitive circuit, '$\frac{1}{\omega_c}$' is the resistance offered by the capacitor and it is called capacitive reactance (X_C). Its unit is ohm (Ω)

$$X_C = \frac{1}{\omega_c} = \frac{1}{2\pi f c}$$

82. Discuss the advantages of AC in **long distance power transmission**.

Long distance power transmission:

The **electric power is generated in power stations** using **AC generators** are transmitted over long distances through transmission lines to reach towns or cities. This process is called power transmission.



But during power transmission, due to **Joule's heating ((I^2R) in the transmission lines**, sizable fraction of electric power is lost. This power loss can be **reduced either by reducing current (I) or by reducing resistance (R)**

Here the resistance 'R' can be **reduced with thick wires of copper or aluminium**. But this increases the cost of production of transmission lines and hence this method is not economically viable.

Thus by using transformer, the current is reduced by stepped up the alternating voltage and thereby reducing power losses to a greater extent.

Illustration:

Let an electric power of 2 MW is transmitted through the transmission lines of resistance 40 Ω at 10 kv and 100 kv

(i) P = 2 MW, R = 40 Ω, V = 10 kv, then $I = \frac{P}{V} = \frac{2 \times 10^6}{10 \times 10^3} = 200A$

Power loss = $I^2R = (200)^2 \times 40$ = **$1.6 \times 10^6 W$ $1.6 \times 10^6 W$**

% of Power loss = $\frac{1.6 \times 10^6}{2 \times 10^6}$ = 0.8 = **80 %**

(ii) P = 2 MW, R = 40 Ω, V = 100 kv , then

$I = \frac{P}{V} = \frac{2 \times 10^6}{100 \times 10^3} = 20A$

Power loss = $I^2R = (20)^2 \times 40 = 0.016 \times 10^6$w 0.016×10^6 W

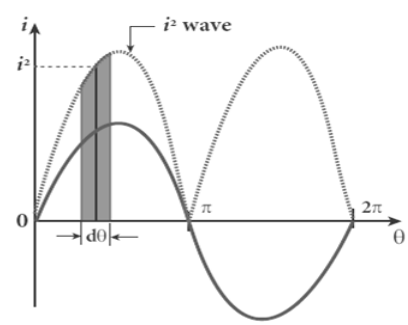
% of Power loss = $\frac{0.016 \times 10^6}{2 \times 10^6}$ = 0.008 = **0. 8** %

Thus it is clear that, **when an electric power is transmitted at high voltage, the power loss is reduced to a large extent.**

So at transmitting point the **voltage is increased** and the corresponding **current is decreased by using step-up transformer**. At receiving point, the **voltage is decreased** and the **current is increased** by using **step-down transformer.**

83. Obtain an expression for **RMS value of alternating current**.

RMS value of AC (I_{RMS}) :



The root mean square value of an alternating current is defined as **the square root of the mean of the squares of all currents over one cycle.**

Expression:

The alternating current at any instant is $\boldsymbol{i = i_m sin\omega t = i_m sin\theta}$

The sum of the squares of all currents over one cycle is given by the area of one cycle of squared wave. Consider an elementary area of thickness '$d\theta$' in the first half-cycle of the squared current wave.

Area of the element = $i^2 d\theta$

Area of one cycle of squared wave,

$$= \int_0^{2\pi} i^2 d\theta = \int_0^{2\pi} I_m^2 \, sin^2\theta \, d\theta \; ; = I_m^2 \int_0^{2\pi} \left[\frac{1-\cos 2\theta}{2}\right] d\theta$$

[∴ cos 2θ = 1 – 2 sin$^2\theta$]

$= \frac{I_m^2}{2}\left[\int_0^{2\pi} d\theta - \int_0^{2\pi} \cos 2\theta \, d\theta\right]$; $= \frac{I_m^2}{2}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{2\pi}$

$= \frac{I_m^2}{2}\left[2\pi - \frac{\sin 4\pi}{2} - 0 + \frac{\sin 0}{2}\right]$ [$\therefore \sin 0 = \sin 4\pi = 0$] ;

$= \frac{I_m^2}{2}[2\pi]$; $= I_m^2\pi$

Hence, $I_{RMS} = \sqrt{\frac{area\ of\ one\ cycle\ of\ squared\ wave}{base\ length\ of\ one\ cycle}}$

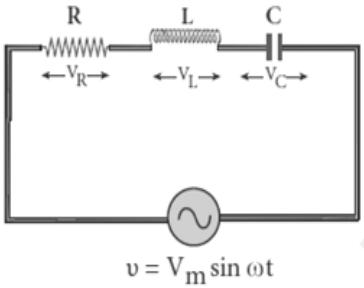
$I_{RMS} = \sqrt{\frac{I_m^2\pi}{2\pi}} = \sqrt{\frac{I_m^2}{2}}$ $I_{RMS} = \frac{I_m}{\sqrt{2}} = 0.707\ I_m$

Similarly for alternating voltage, it can be shown that,

$$\mathbf{V_{RMS} = \frac{V_m}{\sqrt{2}} = 0.707\ V_m}$$

84. Derive an expression for phase angle between the applied voltage and current in a series RLC circuit.

Series RLC circuit:



Consider a circuit containing a resistor of resistance **'R', a inductor of inductance 'L' and a capacitor of capacitance 'C' connected** across an alternating voltage source.

The applied alternating voltage is given by,

$$v = v_m \sin \omega t \quad ------ (1)$$

Let 'i' be the current in the circuit at that instant.

Hence the voltage developed across R, L and C

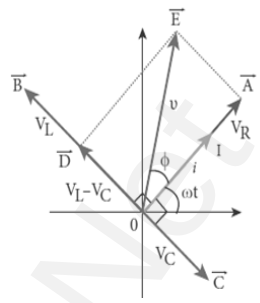
$V_R = iR$ **(V_R is in phase with i)** ; $V_L = iX_L$ **(V_L leads i by $\frac{\pi}{2}$)**

$V_C = iX_C$ **(V_C lags i by $\frac{\pi}{2}$)**

The Phasor diagram is drawn by representing current along $\overrightarrow{OI}$, V_R along $\overrightarrow{OA}$, V_L along $\overrightarrow{OB}$ and V_C along $\overrightarrow{OC}$,

If $V_L > V_C$ then the net voltage drop across LC combination is ($V_L - V_C$) which is represented by $\overrightarrow{AD}$

By parallogram law, the diagonal $\overrightarrow{OE}$ gives the resultant voltage"v"



$$v = \sqrt{V_R^2 + (V_L - V_C)^2}\ ;$$

$$v = \sqrt{i^2R^2 + (iX_L - iX_C)^2}$$

$$v = i\sqrt{R^2 + (X_L - X_C)^2} \text{ (or)}$$

$$i = \frac{v}{\sqrt{R^2+(X_L-X_C)^2}} \text{ (or) } i = \frac{v}{Z}$$

Where, **$Z = R^2 + (X_L - X_C)^2$ is called impedance of the circuit**, which refers to the effective opposition to the circuit current by the series RLC circuit.

From the Phasor diagram, the phase angle between 'v' and 'i' is found out by $\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$

85. Explain the **principle, construction and working of transformer**.

Transformer:

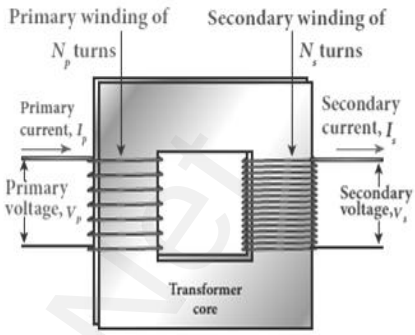
It is a stationary device used to transform electrical power from one circuit to another without changing its frequency. It is done with either increasing or decreasing the applied alternating voltage with corresponding decrease or increase of current in the circuit.

If the transformer **converts an alternating current with low voltage in to an alternating current with high voltage,** it is called **step-up transformer**. If the **transformer converts an alternating current with high voltage in to an alternating current with low voltage**, it is called **step-down transformer**.

Principle:

Mutual induction between two coils.

Construction:



It consists of two coils of high mutual inductance wound over the same transformer core made up of silicone steel. To avoid eddy current loss, the core is generally laminated. The alternating voltage is applied across primary coil (P), and the output is taken across secondary coil (S)

The assembled core and coils are kept in a container which is filled with suitable medium for better insulation and cooling purpose.

Working:

The **alternating voltage given to the primary coil**, set up an **alternating magnetic flux in the laminated core**. As the result of **flux change**, emf is induced in both primary and secondary coils.

The emf induced in the primary coil '$\in_P$' is almost equal and opposite to the applied voltage 'VP' and is given by,

$V_P = \in_P = -N_P \frac{d\phi_B}{dt}$--------- (1)

The frequency of alternating magnetic flux is same as the frequency of applied voltage. Therefore induced in secondary will also have same frequency as that of applied voltage, The emf induced in the secondary coil '$\in_S$' is, $V_S = \in_S = -N_S \frac{d\phi_B}{dt}$--------- (2)

Dividing equating (1) by (2), $\frac{V_S}{V_P} = \frac{N_S}{N_P}$--------- (3)

Where, K → Transformation ratio

For an **ideal transformer, Input Power = Output Power**

$V_P i_P = V_S i_S$; $\frac{V_S}{V_P} = \frac{i_P}{i_S}$--------- (4)

From equation (3) and (4), we have

$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{i_P}{i_S} = K$ --------- (5)

(i) If K > 1 (or) $N_S > N_P$, then $V_S > V_P$ and $i_s < i_P$

This is **step up transformer** in which **voltage increased** and the corresponding **current is decreased**.

(ii) If K < 1 (or) $N_S < N_P$, then $V_S < V_P$ and $i_s > i_P$

This is **step down transformer** in which **voltage decreased** and the corresponding **current is increased**.

Efficiency of a transformer:

The efficiency (η) of a transformer is defined as **the ratio of the useful output power to the input power.**

$$\eta = \frac{Output\ Power}{Input\ Power} \times 100\%$$

UNIT-5 ELECTROMAGNETIC WAVES

2 Marks Question & Answer

86. If the relative permeability and relative permittivity of the medium is 1.0 and 2.25, respectively. Find the **speed of the electromagnetic wave** in this medium.

Speed of electromagnetic wave, $v = \frac{1}{\sqrt{\mu\epsilon}}$

$= \frac{1}{\sqrt{\mu_r\mu_0\epsilon_r\epsilon_0}}$; $= \frac{C}{\sqrt{\mu_r\epsilon_r}}$ $\left[\text{Where, } C = \frac{1}{\sqrt{\mu_0\epsilon_0}}\right]$

$= \frac{3 \times 10^8}{\sqrt{1 \times 2.25}}$; $= \frac{3 \times 10^8}{1.5}$; $v = 2 \times 10^8$ **ms^{-1}**

87. Define **Fraunhofer lines**.

When the spectrum obtained from the Sun is examined, it consists of **large number of dark lines** (line absorption spectrum).These dark lines in the solar spectrum are known as Fraunhofer lines.

88. What are the **uses of Fraunhofer lines**?

The absorption spectra for various materials are compared with the Fraunhofer lines in the solar spectrum, which **helps to identifying elements present in the Sun's atmosphere.**

89. A pulse of light of duration 10^{-6} s is absorbed completely by a small object initially at rest. If the power of the pulse is 60×10^{-3} W, calculate the final **momentum of the object**.

Final momentum of the object, $P = \frac{U}{C}$

Velocity of light, $C = 3 \times 10^8$; Energy U = power x time

Momentum, $P = \frac{60 \times 10^{-3} \times 10^{-6}}{3 \times 10^8}$; $P = 20 \times 10^{-17}$ kg ms^{-1}

90. Write any four **applications of ultra violet rays**.

(i) **Destroy bacteria** (ii) **Sterilizing the surgical instruments,**

(iii) **Burglar alarm** (iv) **Detect the invisible writing, finger prints** and (v) **Study of molecular structure**

91. Define **absorption spectra**.

Absorption spectra:

When light is allowed to pass through an absorbing substance, then the spectrum obtained is known as absorption spectrum. It is the **characteristic of absorbing substance.**

92. Give the **modified form of Ampere's circuital law**.

If I_C and I_D are the conduction and displacement current, then the modified Ampere's circuital law is given by, $\oint \vec{B}.\vec{dl} = \mu_0(I_C + I_D)$ (or)

$$\oint \vec{B}.\vec{dl} = \mu_0 I_C + \mu_0 \varepsilon_0 \frac{d}{dt}\int \vec{E}.\vec{dA}$$

This is also known as Ampere - Maxwell's law.

93. What is called **pointing vector**? Give its unit.

The **rate of flow of energy crossing a unit area** is known as pointing vector for electromagnetic waves. The pointing vector at any point gives the direction of energy transport from that point. The **unit for pointing vector** is **Wm^{-2}**

3 Marks Question & Answer

94. Write a note on **ultra violet rays and radio waves**.

Ultra violet rays: It is **used to,**

(i) **Destroy bacteria (ii) Sterilizing the surgical instruments**,

(iii) **Burglar alarm** (iv) Detect the invisible writing, finger prints and

(v) **Study of molecular structure**

Radio waves: It is **used in,**

(i) Radio and television **communication systems**

(ii) Cellular phones to **transmit voice communication** in the ultra high frequency band.

95. Write a note on **infrared rays**.

Infrared rays:

It is produced from hot bodies and also when the molecules undergo rotational and vibrational transitions.

It provides electrical energy to satellites by means of solar cells

It is **used in,**

(i) **Producing dehydrated fruits**

(ii) **Green housed** to keep the plants warm,

(iii) **Heat therapy for muscular pain** or sprain

(iv) **TV remote as a signal carrier**, to look through haze off or mist

(v) **Night vision** or infrared photography

5 Marks Question & Answer

96. Write down **Maxwell equations in integral form**.

Maxwell equations-Integral form:

Electrodynamics can be summarized into four basic equations, known as Maxwell's equations. Maxwell's equations completely explain the behaviour of charges, currents and properties of electric and magnetic fields.

This equation ensures the existence of electromagnetic waves.

Equation - 1 :

The net electric flux to net electric charge enclosed in a surface.

Gauss law is expressed as, $\oint \vec{\boldsymbol{E}}.\vec{\boldsymbol{dA}} = \frac{Q_{Closed}}{\varepsilon_0}$.....(1)

Here, $\vec{E}$ →Electric field, Q_{Closed} →Charge enclosed

Equation - 2 :

It has no name. But this law of similar to Gauss law in electrostatics. Hence this law can be called as **Gauss's law in magnetism**. The surface integral of **magnetic field over a closed surface is zero.**

Mathematically, this law can be expressed as, $\oint \vec{\boldsymbol{B}}.\vec{\boldsymbol{dA}} = \mathbf{0}$.....(2)

$\vec{B}$ → Magnetic field.

This equation implies that the magnetic field lines form a continuous closed path. (i.e.) no isolated magnetic monopole exists

Equation - 3 :

This is **Faraday's laws of electromagnetic induction.**

, $\oint \vec{\boldsymbol{E}}.\vec{\boldsymbol{dl}} = \frac{d\phi_B}{dt}$.....(3) ; $\vec{E}$ →Electric field

Equation - 4 :

It is modified Ampere's circuital law and also **called as Ampere - Maxwell's law**. This law relates the magnetic field around any closed path to the conduction current and displacement current through that path.

Mathematically, $\oint \vec{B}.\vec{dl} = \mu_0(I_C + I_D)$ (or)

$\oint \vec{B}.\vec{dl} = \mu_0 I_C + \mu_0\varepsilon_0 \frac{d}{dt}\int \vec{E}.\vec{dA}$. Here, $\vec{B}$ →Magnetic field.

It implies that both conduction and displacement current produces magnetic field.

97. Explain the **modification of Ampere's circuital law**.

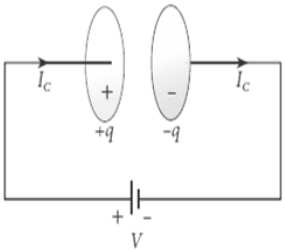
Ampere's circuital law:

According to Faraday's law of electromagnetic induction, the change in magnetic field produces an electric field. Mathematically

$$\oint \vec{E}.\vec{dl} = -\frac{\partial}{\partial t}\phi_B = -\frac{\partial}{\partial t}\oint \vec{B}.\vec{dA}$$

It implies that the electric field $\vec{E}$ is induced along a closed loop by the changing magnetic flux ϕB in the region encircled by the loop.

The converse of this statement that is **change in electric flux produces magnetic field is explained by Maxwell.**

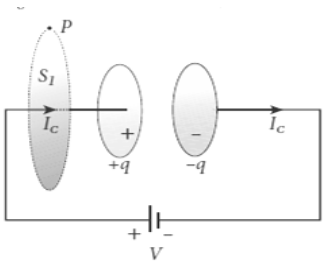


$$\oint \vec{B}.\vec{dl} = -\frac{\partial}{\partial t}\phi_{BE} = -\frac{\partial}{\partial t}\oint \vec{E}.\vec{dA}$$

This is known as Maxwell's law of induction.

To understand how the changing electric field produces magnetic field, let us consider the situation of charging a parallel plate capacitor.

The electric current passing through the wire is the conduction current 'I_C'.

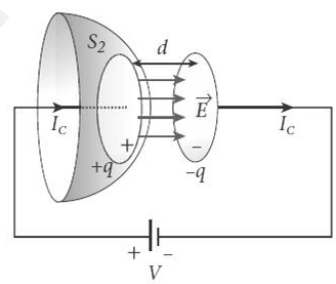


This current generates magnetic field around the wire connected across the capacitor. To calculate the magnetic field at a point 'P' near the wire, let us consider an amperian loop which encloses the surface S_1 . Thus from Ampere circuital law, $\oint \vec{B}.\vec{dl} = \mu_0 I_C$.....(1)

Suppose the same loop is enclosed by balloon shaped surface S_2, then the boundaries of two surfaces are same but shape of the enclosing surfaces are different. **Ampere's law does not depend on shape of the enclosing surface and hence the integrals will give the same answer.**

But there is no current in between the plates of the capacitor, the magnetic field on the surface is zero. So the magnetic field at 'P' is zero. Hence, $\oint \vec{B}.\vec{dl} = 0$.....(2)

Here there is an inconsistency between equation(1) and (2). Maxwell resolved this inconsistency as follows.



Due to external source, the capacitor gets charged up because of current flowing through the capacitor. This produces an increasing electric field between the capacitor plates. **This time varying electric field (or flux) existing between the plates of the capacitor also produces a current known as displacement current.**

From Gauss's law, $\phi_E = \oint \vec{E}.\vec{dA} = EA = \frac{q}{\varepsilon_0}$

The change in electric flux is, $\frac{d\phi_B}{dt} = \frac{1}{\varepsilon_0}\frac{dq}{dt} = \frac{1}{\varepsilon_0} I_d$

$\therefore I_d = \varepsilon_0 \frac{d\phi_B}{dt}$. Where, $\frac{dq}{dt} = I_d$ →Displacement Current

The displacement current can be defined as the current which comes in to play in the region in which the electric field and the electric flux are changing with time.

So Maxwell modified Ampere's law as

$\oint \vec{B}.\vec{dl} = \mu_0 I = (I_c + I_d)$.....(3)

Where, $I = I_c + I_d$ →Total Current

98. Explain the **properties of electromagnetic waves**.

Properties of electromagnetic waves:

Electromagnetic waves are **produced by any accelerated charge.** They **do not require any medium for propagation**. So electromagnetic waves are **non-mechanical wave**. They are **transverse in nature**, (i.e) the oscillating electric field vector, oscillation magnetic field vector and direction of propagation are mutually perpendicular to each other. **They travel with speed of light in vacuum or free space** and it is given by,

$C = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 3\text{x}10^8 \text{ms}^{-1}$

In a medium with permittivity 'ε' and permeability 'μ', the speed of electromagnetic wave is **less than speed in free space or vacuum**.

(i.e.) $v < c$

Hence, refractive index of the medium is, $\mu = \frac{c}{v} = \sqrt{\varepsilon_r \mu_r}$

They are **not deflected by electric or magnetic field**.

They show **interference, diffraction and polarization**.

The energy density (energy per unit volume) associated with and electromagnetic wave propagating in free space is $u = \varepsilon_0 E^2 = \frac{1}{\mu_0} B^2$

The average energy density for electromagnetic wave is

$$(u) = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2\mu_0} B^2$$

The energy crossing per unit area per unit time and perpendicular to the direction of propagation of electromagnetic wave is called the intensity.

They **carry energy and momentum**. The force exerted by an electromagnetic surface is called radiation pressure.

If the electromagnetic **wave incident on a material surface is completely absorbed, then the energy delivered is 'U' and the momentum imparted on the surface is $p = \frac{U}{c}$,**

If the incident electromagnetic wave of energy 'U' is totally reflected from the surface, then the momentum delivered to the surface is

$$\Delta p = \frac{U}{c} - \left(-\frac{U}{c}\right) = 2\frac{U}{c}$$

The rate of flow of energy crossing a unit area is known as pointing vector for electromagnetic waves. $\vec{S} = \frac{1}{\mu_0}\left(\vec{E} \times \vec{B}\right) = c^2\varepsilon_0\left(\vec{E} \times \vec{B}\right)$

99. Explain in detail the **emission spectra**.

Emission spectra: The light from self-luminous source gives emission spectrum. Each source has its own characteristic emission spectrum.

The emission spectrum can be divided in to three types;

(i) Continuous emission spectra:

Incandescent solids, liquids give continuous spectra.

It consists of wavelengths containing all the visible colours ranging from **violet to red**.

(e.g.)Spectrum obtained from carbon arc, incandescent filament lamp, etc

(ii) Line emission spectra:

Light from excited atoms gives line spectrum. They are also known as discontinuous spectra. The line spectra are **sharp lines of definite wavelengths** or frequencies. It is different for different elements

(e.g.) spectra of atomic hydrogen, helium, etc

(iii) Band emission spectra:

The light from excited molecules gives band spectrum. It consists of **several numbers of very closely spaced spectral lines** which overlapped together forming specific coloured bands. This spectrum has a **sharp edge** at **one end and fades out at the other end.**

Band spectrum is the characteristic of the molecule.

(e.g.) spectra of hydrogen gas, ammonia gas in the discharge tube, etc

100. Explain in detail the **absorption spectra.**

When light is allowed to pass through an absorbing substance, then the spectrum obtained is known as absorption spectrum. It is characteristic of the absorbing substance.

Absorption spectrum is classified into three types;

(i) Continuous absorption spectrum:

When the light is passed through a medium, it is dispersed by the prism, we get continuous absorption spectrum. For instance, when we pass white light through a blue glass plate, it absorbs everything except blue. This is an example for continuous absorption spectrum.

(ii) Line absorption spectrum:

When light from incandescent lamp is passed through cold gas, the spectrum obtained through the dispersion due to the prism is line absorption spectrum.For example, when light from carbon arc is made to pass through sodium vapour, a continuous spectrum of carbon arc with two dark lines in the yellow region of sodium vapour is obtained.

iii) Band absorption spectrum:

When the **white light is passed through the iodine vapour, dark bands on continuous bright background** is obtained. This is known as band absorption spectra. It is also obtained when white light is passed through diluted solution of blood or chlorophyll or through certain solutions of organic and inorganic compounds.

UNIT-6 ORAY OPTICS

2 Marks Question & Answer

101. What are the **conditions to achieve total internal reflection**?

1) Light must travel from **denser to rarer** medium

2) Angle of incidence must be **greater than critical angle ($i > i_C$)**

102. One type of transparent glass has refractive index 1.5. What is the **speed of light** through this glass?

n = $\frac{c}{v}$; $v = \frac{c}{n}$; $v = \frac{3 \times 10^8}{1.5}$; = **2×10^8 ms^{-1}**

Light travels with a speed of 2×10^8 ms^{-1} through this glass.

103. State the **laws of reflection**.

Laws of reflection:

(1) The **incident ray, reflected** ray and the **normal** to the surface all are coplanar.

(2) The **angle of incidence** (i) is **equal** to **angle of reflection** (r). $\boldsymbol{i = r}$

104. State the **laws of refraction.**

The **incident ray, refracted ray and normal are all coplanar**.

The **ratio of angle of incident 'i' in the first medium to the angle of reflection 'r' in the second medium** is **equal to** the **ratio of refractive index of the second medium 'n_2'** to that of the refractive index of the first medium 'n_1'

$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$ (or) $\boldsymbol{n_1 \sin i = n_2 \sin r}$

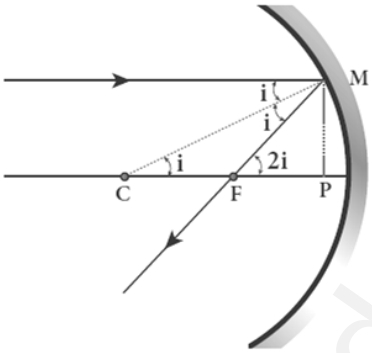
3 Marks Question & Answer

105. Obtain the relation between **focal length (f) and radius of curvature (R)** of the spherical mirror.

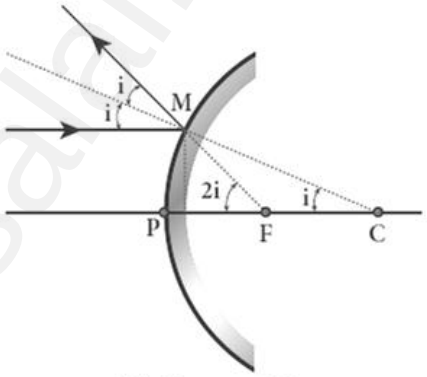
Relation between f and R :

Let 'C' be the centre of curvature of the mirror.

Consider a light ray parallel to the principal axis and incident at 'M' on the mirror. After reflection, it will passes through principal focus 'F'. The line 'CM' is the normal to the mirror at 'M'. From the figure (a),



(a) Concave mirror



(b) Convex Mirror

Angle of incidence; $= \angle i$;

Angle of reflection; $= \angle CMF$

By the **law of reflection**. we have, $\boldsymbol{i = r}$

Thus, , $\angle MCP = i$ & $\angle MFP = 2\ i$

From ΔMCP and Δ ; $\tan i = \frac{PM}{PC}$; $\tan 2i = \frac{PM}{PF}$

As the **angles are small, we have $\tan i \approx i$ and $\tan 2i \approx 2i$**. So

$i = \frac{PM}{PC}$.....(1) ; $2i = \frac{PM}{PF}$.....(2)

Put equation (1) in equation (2)

$2\frac{PM}{PC} = \frac{PM}{PF}$ (or) 2 PF = PC (or)

$2f$ = R ; $\boldsymbol{f = \frac{R}{2}}$**.....(**3

106. What is the focal length of the combination if the lenses of focal lengths –70 cm and 150 cm are in contact? What is the **power of the combination**?

Equation for focal length of lenses in contact, $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

Substituting the values, $\frac{1}{F} = \frac{1}{-70} + \frac{1}{150}; = -\frac{1}{70} + \frac{1}{150}$

$\frac{1}{F} = \frac{-150+70}{70 \text{ x } 150}; = \frac{-80}{70 \text{ x } 150}$;

$= -\frac{80}{10500}$; F = $-\frac{1050}{8}; = -$**131.25 cm**

As the focal length is negative, the combination of two lenses is a diverging system of lenses.

The power of combination is, P = $\frac{1}{F} = \frac{1}{-1.3125\, m}$ = **–0.76 diopter**

107. The thickness of a glass slab is 0.25 m. it has a refractive index of 1.5. A ray of light is incident on the surface of the slab at an angle of 60^0. Find the **lateral displacement of the light** when it emerges from the other side of the mirror.

Given, thickness of the lab, t = 0.25 m,

Refractive index, n = 1.5, angle of incidence,

i = 60^0. Using Snell's law, 1 × sin i = n sin r ;

sin r = $\frac{\sin i}{n} = \frac{\sin 60}{1.5}$ = 0.58

R = $\sin^{-1}$ 0.58 = 35.25^0

Lateral displacement is, L = t$\left(\frac{\sin(i-r)}{\cos(r)}\right)$;

L = (0.25) x $\left(\frac{\sin(60-35.25)}{\cos(35.25)}\right)$; = 0.1281 m

The lateral displacement is, L = 12.81 cm

108. Calculate the **distance** for which ray optics is good approximation for an aperture of 5 mm and wavelength 500 nm.

a = 5 mm = 5 x 10^{-3}m, λ = 500nm = 500 x 10^{-9}m ; z = ?

Equation for Fresnel's distance, z = $\frac{a^2}{2\lambda}$

Substituting, z = $\frac{(5 \times 10^{-3})^2}{2 \times 500 \times 10^{-9}}$; = $\frac{25 \times 10^{-6}}{1 \times 10^{-6}}$; **z = 25 m**

109. Why does **cloud appears** as **white colour**?

When size of particles or water drops are greater than the wavelength of light ($a \gg \lambda$), the **intensity of scattering is equal for all the wavelength.**

Since clouds contains large amount of dust and water droplets, all the colours get equally scattered irrespective of wavelength.

This is the reason for the whitish appearance of cloud. But the rain clouds appear dark because of the condensation of water droplets on dust particles that make the cloud become opaque.

110. Find **the dispersive power of flint glass** if the refractive indices of flint glass for red, green and violet light are 1.613, 1.620 and 1.632 respectively.

Given, n_V =1.632; n_R =1.613; n_G =1.620

Equation for dispersive power is, $\omega = \frac{(n_V - n_R)}{(n_G - 1)}$

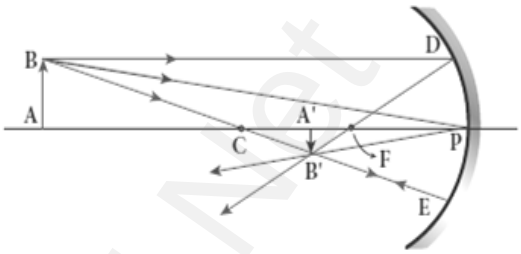
Substituting the values, $\omega = \frac{1.632 - 1.613}{1.620 - 1}$; = $\frac{0.019}{0.620}$; = 0.0306

The dispersive power of flint glass is, $\omega = 0.0306$

5 Marks Question & Answer

111. Derive the **mirror equation** and the equation for lateral magnification.

Mirror equation: The equation which gives the **relation between object distance (u), image distance (v) and focal length (f) is of spherical mirror is called mirror equation.** Let an object AB is placed on the principle axis of a concave mirror beyond the centre of curvature 'C'



The real and inverted image $A'B'$ is formed between C and F

By the laws of reflection,

Angle of incidence (i) = angle of reflection (r) $\angle BPA = \angle B'PA'$

From figure, ΔBPA and $\Delta B'PA'$ are similar triangles. So

$\frac{A'B'}{AB} = \frac{PA'}{PA}$..... (1)

From figure, ΔDPF and $\Delta B'FA'$ are similar triangles.

So $\frac{A'B'}{PD} = \frac{A^1F}{PF}$ [PD = AB] $\frac{A'B'}{AB} = \frac{A^1F}{PF}$..... (2)

From equation (1) and (2), $\frac{PA'}{PA} = \frac{A'F}{PF}$; $\frac{PA'}{PA} = \frac{PA'-PF}{PF}$.....(3)

By applying sign conventions, $PA = -u; PA' = -v\,; PF = -f$

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

Dividing both sides by ; $\frac{1}{u} = \frac{1}{f} - \frac{1}{v}$; $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$..... (4)

This is called **mirror equation**. It is also valid for **convex mirror**.

Lateral Magnification:

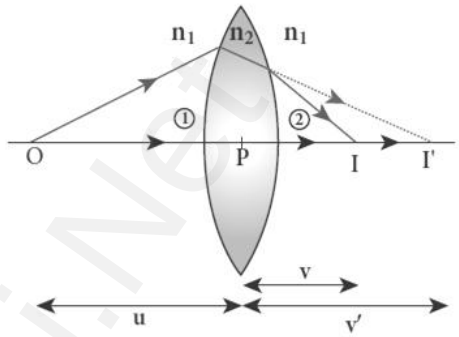
It is defined as the ratio of the height of the image (h^1) to the height of the object (h). From equation (1) $\frac{A'B'}{AB} = \frac{PA'}{PA}$; $\frac{-h^1}{h} = \frac{-v}{-u}$

Hence magnification, $m = \frac{h^1}{h} = -\frac{v}{u}$..... (5)

Using equation (4) $\boldsymbol{m} = \frac{h^1}{h} = \frac{f-v}{f} = \frac{f}{f-u}$..... (6)

112. Obtain **Lens maker formula** and mention its significance

Lens maker's formula:



A thin lens of refractive index n_2 is placed in a medium of refractive index n_1. Let R_1 and R_2 be radii of curvature of two spherical surfaces ① and ② respectively

Let P be pole of the lens and O be the Point object.

Here I' be the image to be formed due the refraction at the surface ① and I be the final image obtained due the refraction at the surface ②

We know that, equation for single spherical surface $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$

For refracting surface ①, the light goes from n_1 to n_2, Hence

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

For refracting surface ②, the light goes from n_2 to n_1, Hence

$$\frac{n_1}{v} - \frac{n_2}{v'} = \frac{n_1 - n_2}{R_1} \text{..... (2)}$$

Adding equation (1) and (2), we get,

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

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

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

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \text{.....(3)}$$

If the object is at infinity, the image is formed at the forcus of the lens.

Thus, $u = \infty, v = f$

Then equation becomes, $\frac{1}{f} - \frac{1}{\infty} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \text{.....(4)}$$

Here first medium is air and hence $n_1 = 1$ and let the refractive index of second medium be $n_2 = n$. Therefore $\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$.....(5)

The above equation is called lens maker's formula.

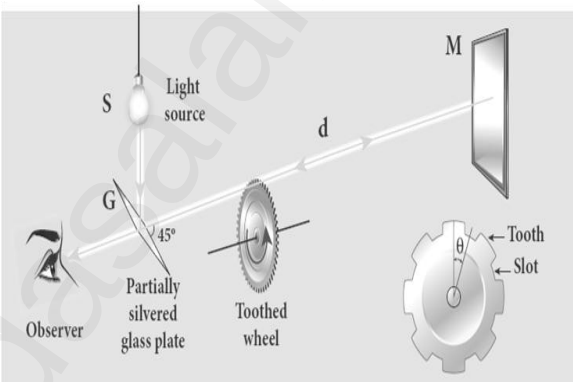
By comparing equation (3) and (4) $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

This equation is known as lens equation

113. Describe the **Fizeau's method** to determine **speed of light**.

Fizeau's method:

The light from the source S was first allowed to fall on a partially silvered glass plate G kept at an **angle of 45^0** to the vertical. The light then allowed to pass through a rotating toothed-wheel with N -teeth and N -cuts.



The speed of rotation of the wheel could be varied through an external mechanism. **The light passing through one cut in the wheel get reflected by a mirror M kept at a long distance 'd'(about 8 km) from the toothed wheel**. If the toothed wheel was not rotating, the reflected light from the mirror would again pass through the same cut and reach the observer through G.

Working: The **angular speed of the rotation of the toothed wheel was increased until light passing through one cut would completely be blocked by the adjacent tooth**. Let that angular speed be ω

The total distance traveled by the light from the toothed wheel to the mirror and back to the wheel is '2d' and the time taken be 't'.

Then **the speed of light in air,** $v = \frac{2d}{t}$

But the angular speed is, $\omega = \frac{\theta}{t}$

Here θ is angle between the tooth and the slot which is rotated by the toothed wheel within that time "t". Then,

$$\theta = \frac{Total\ angle\ of\ the\ circle\ in\ radian}{Number\ of\ teeth + Number\ of\ cuts}\ ;\ \ \theta = \frac{2\pi}{2N} = \frac{\pi}{N}\ ;$$

Hence, angular speed, $\omega = \frac{\left(\frac{\pi}{N}\right)}{t} = \frac{\pi}{Nt}$ (or) $t = \frac{\pi}{N\omega}$

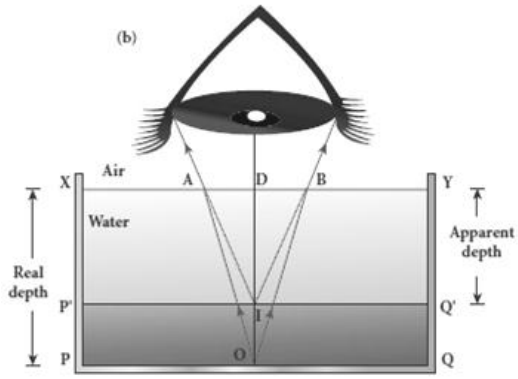
Therefore the speed of light in air, $= \frac{2\,d}{t} = \frac{2d}{\left(\frac{\pi}{N\omega}\right)}$; $v = \frac{\mathbf{2\,d\,N\omega}}{\boldsymbol{\pi}}$

The speed of light in air was determined as , $v = 2.99792 \times 10^8\ ms^{-1}$

114. Obtain the equation for **apparent depth**.

Apparent depth:

We observe that the bottom of a tank filled with water with water appears raised as shown. Light OB from the object 'O' passes through water get refracted in air. The refracted ray BC appears to come from 'I' which is just above 'O' (i.e) the object is appears to be at 'I'



Refractive index of water = n_1,

Refractive index of air = n_2

Angle of incidence in water = i,

Angle of incidence in air = r

Original depth of tank = DO = d,

Apparent depth of tank = DI = d'

Here $n_1 > n_2$. Hence, $i < r$,

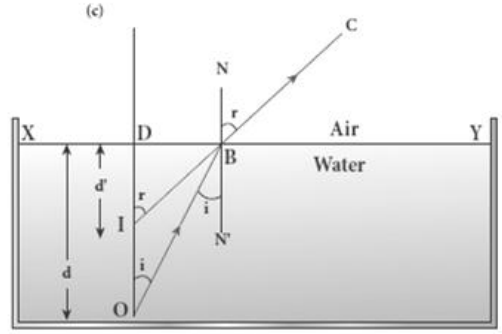
By Snell's law in product from,

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

As the angles are small, we can write

$\sin i \approx \tan i$ and $\sin r \approx \tan r$

Hence, $\boldsymbol{n_1 \tan i = n_2 \tan r}$.....(1)



In ΔDOB and ΔDIB, $\tan i = \frac{DB}{DO} = \frac{DB}{d}$, $\tan r = \frac{DB}{DI} = \frac{DB}{d'}$

Put this in equation (1) $n_1 \left[\frac{DB}{d}\right] = n_{12} \left[\frac{DB}{d'}\right]$

$n_1 \frac{1}{d} = n_1 \frac{1}{d'}$; $\therefore d' = \frac{n_2}{n_1} d$

For air ; n_2= 1 and let n_2= n, then apparent depth $d' = \frac{d}{n}$

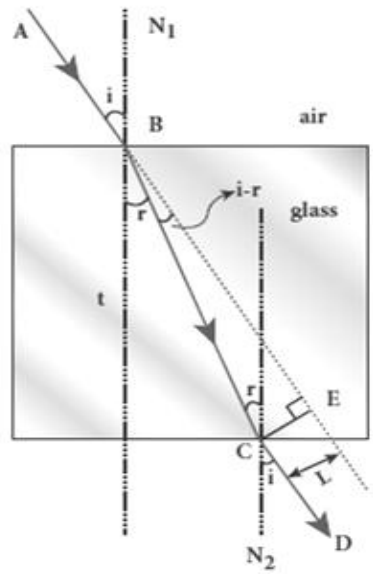
Thus the bottom appears to be elevated by $(d - d')$

$d - d' = d = \frac{d}{n} = d\left(1 - \frac{1}{n}\right)$

115. Obtain the equation for **lateral displacement** of light passing through a glass slab.

Refraction through a glass slab:

Consider a glass slab of thickness t and refractive index n kept in air medium. If the path of the light is ABCD, the refractions occur at two points B and C in the glass slab. The angles of incidence i and refraction r are measured with respect to the normal N_1 and N_2 at the two points B and C respectively. The lateral displacement L is the perpendicular distance CE drawn between the paths of the deviated light and the un-deviated light at point C. The perpendicular distance "CE" between refracted ray and incident ray at C gives the lateral displacement (L).



InΔBCE, $\sin(i - r) = \frac{L}{BC}$;

$BC = \frac{L}{\sin\ (i-r)}$

In ΔBCE, cos r = $\frac{t}{BC}$;

$BC = \frac{t}{\cos r}$

Hence, $\frac{L}{\sin\,(i-r)} = \frac{t}{\cos r}$;

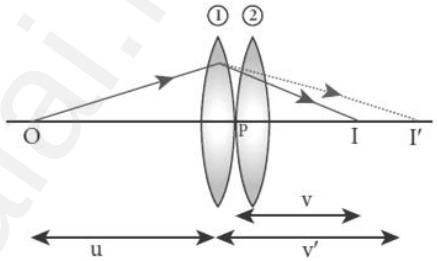
L = t$\left[\frac{\sin(i-r)}{\cos r}\right]$

Therefore, lateral displacement depends on,

Thickness of the glass slab, Angle of incidence.

116. Derive the equation for effective focal length for lenses in contact.

Focal length of lenses in contact:



Let us consider two lenses ① and ② of focal lengths f_1 and f_2 placed co-axially in contact with each other. Let the object is placed at 'O' beyond the principal focus of ① on the principal axis.

It forms an image at ′ . This image I' acts as an object for lens ② and hence the final image is formed at 'I'

Writing the lens equation for lens ① $\frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1}$.....(1)

Writing the lens equation for lens ② $\frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2}$.....(2)

Adding equation (1) and (2), we get, $\frac{1}{v'} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v'} = \frac{1}{f_1} + \frac{1}{f_2}$

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

If this combination acts as a single lens of focal length "F", then,

$\frac{1}{v} - \frac{1}{u} = \frac{1}{F}$..... (4)

Compare equation (3) and (4) $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$..... (5)

For any number of lenses, $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \frac{1}{f_4} + \cdots$

Let P_1, P_2, P_3, P_4 .... be the power of each lens then the net power of the lens combination, P = P_1 + P_2 + P_3 + P_4 + ...

Let m_1, m_2, m_3, m_4 .... be the magnification of each lens then the net magnification of the lens combination, m = m_1 x m_2 x m_3 x m_4 x ....

UNIT-7 WAVE OPTICS

2 Marks Question & Answer

117. Why does **sky and Sun looks reddish** during **sunset and sunrise**?

During sunset or sunrise, the light from **Sun travels a greater distance through atmosphere**. Hence the **blue light which has shorter wavelength** is scattered away and **less scattered red light of longer wavelength** reaches observer. This is the reason for reddish appearance of sky and Sun during sunrise and sunset.

118. Why does **sky appear blue**?

According to Rayleigh's scattering, **shorter wavelengths (violet) scattered much more than longer wavelengths (Red)**. As our eyes are more sensitive to blue colour than violet, the sky appears blue during day time.

119. A beam of light of wavelength 600 nm from a distant source falls on a single slit 1 mm wide and the resulting diffraction pattern is observed on a screen 2 m away. What is the distance between the first dark fringes on either side of the central bright fringe?

Fringe width in single slit experiment $\boldsymbol{\beta} = \frac{\lambda D}{d}$

$\beta = 600\text{x}10^{-9} \text{ x } \frac{2}{(1\text{X}10^{-3})}$;

β =1.2 mm

Distance between dark fringes which are on either side of the central bright fringe =2x12=24 mm

120. What **is bandwidth** of **interference** pattern?

The **distance between any two consecutive bright or dark fringes**.

What are the conditions for obtaining clear and broad interference bands?

(1) The screen should be as **far away from the source** as possible.

(2) The **wavelength** of light used **must be larger**.

(3) **Two coherent sources** must be as **close** as possible

121. A monochromatic light is incident on an equilateral prism at an angle 30^0 and emerges at an angle of 75^0. What is **the angle of deviation** produced by the prism?

Given, as the prism is equilateral,

$A=60^0$; $i_1 = 30^0$; $i_2 = 75^0$

Equation for angle of deviation, $\mathbf{d = i_1 + i_2 - A}$

Substituting the values, $\mathbf{d = 30^0 + 75^0 - 60^0 = 45^0}$

The angle of deviation produced is, $d = 45^0$

122. What is **Rayleigh's scattering**?

The **scattering of light by atoms and molecules which have size (a) very less than that of the wavelength (λ) of light** is called Rayleigh's scattering. (i.e) condition for Rayleigh's scattering is $a << \lambda$

123. State **Rayleigh's scattering law**.

The intensity (I) of Rayleigh's scattering is **inversely proportional to fourth power of wavelength (λ)** . $I \propto \frac{1}{\lambda^4}$

124. State **Huygens's principle**.

Huygens's principle:

Each point of the wave front is the source of secondary wavelets which **spreading out in all directions with speed of the wave**. The envelope to all this wavelet gives the position and shape of the new wave front at a later time.

125. State **Malus' law**.

Malus's law :

When a beam of plane polarized light of intensity I_0 is incident on an analyzer, **the light transmitted of intensity I from the analyzer** varies directly as the square of the **cosine of the angle θ between the transmission axis of polarizer and analyzer.** This is known as **Malus' law.**

$$\mathbf{I = I_0 Cos^2\theta}$$

126. Distinguish between **interference** and **diffraction.**

Interference	Diffraction
Superposition of **two waves**	Bending of waves around edges
Superposition of waves from two **Coherent sources.**	Superposition wave fronts emitted from various points of the same **wave front**.
Equally spaced fringes.	**Unequally** spaced fringes
Intensity of all the bright fringes is **almost same**	**Intensity** falls rapidly for **higher orders**
Large number of fringes are obtained	**Less number** of fringes are obtained

3 Marks Question & Answer

127. In Young's double slit experiment, 62 fringes are seen in visible region for sodium light of wavelength 5893 Å. If violet light of wavelength 4359 Å is used in place of sodium light, then what is the number of fringes seen?

$\lambda_1 = 5893$ Å; $\lambda_2 = 4359$ Å , $n_1 = 62$, $n_2 = ?$

From young's double slit experiment. $\frac{n_1\lambda_1 D}{d} = \frac{n_2\lambda_2 D}{d}$

The above condition is total extent of fringes is constant for both wavelengths. $\frac{62 \text{ x } 5893 \text{ x } 10^{-10} \text{ x D}}{\text{d}} = \frac{\text{n}_2 \text{x } 5893 \text{ x } 10^{-10} \text{ x D}}{\text{d}}$;

$n_2 = \frac{62 \text{ x } 5893}{4359}$; $= \frac{365366}{4359}$; $= 83.8$

128. The angle of minimum deviation for a prism is 37^0. If the angle of prism is 60^0, find the **refractive index of the material of the prism**.

Equation for refractive index is, $n = \frac{\sin\left(\frac{A+D}{2}\right)}{\text{Sin}\left(\frac{A}{2}\right)}$

Substituting the values, $n = \frac{\sin\left(\frac{60^0+37^0}{2}\right)}{\text{Sin}\left(\frac{60^0}{2}\right)}$; $= \frac{\sin(48.5^0)}{\text{Sin}(30^0)}$; $= \frac{0.75}{0.5}$; $= 1.5$;

The refractive index of the material of the prism is, n = 1.5

129. What are called **constructive** and **destructive interference**?

Constructive interference:

During superposition of two coherent waves, **the points where the crest of one wave meets the crest of other (or) the trough of one wave meets the trough of the other wave, the waves are in-phase**. Hence the displacement is maximum and these points appear as bright.

This type of interference is said to be constructive interference.

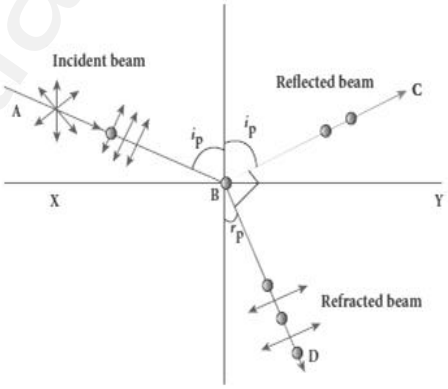
Destructive interference:

During superposition of two coherent waves, **the points where the crest of one wave meets the trough of other (or) vice versa, the waves are out-of-phase.** Hence the displacement is minimum and these points appear as dark. This type of interference is said to be destructive interference.

130. State and prove **Brewster's law**.

Brewster's law:

The angle of incidence at which a beam of un-polarized light falling on a transparent surface is reflected as a beam of plane polarized light is called polarizing angle or Brewster's angle (i_P). Sir David Brewster found that, at polarizing angle, the reflected and transmitted rays are perpendicular to each other.



Let, incident polarizing angle = Angle of refraction (r)

From the figure,

$\boldsymbol{i_P + 90^0 + r_P = 180^0}$; $\boldsymbol{r_P = 90^0 - i_P}$ ----(1)

From Snell's law $\frac{\sin i_p}{\sin r_p} = n$; $\frac{\sin i_p}{\sin(90^0 - i_p)} = n$; $\boldsymbol{\frac{\sin i_p}{\cos i_p} = n}$; $\boldsymbol{\tan i_P = n}$

This relation is known as Brewster's law. This law states that, **the tangent of the polarizing angle for a transparent medium is equal to its refractive index.**

131. Two light sources with amplitudes **4 units and 2 units** respectively interfere with each other. Calculate the ratio of **maximum and minimum intensities.**

Amplitudes, $a_1 = 4$, $a_2 = 2$

Resultant amplitude, **A =** $\sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}$

Resultant amplitude is, maximum when,

$\phi = 0$, $\cos 0 = 1$, $A_{max} = \sqrt{a_1^2 + a_2^2 + 2a_1a_2}$

$A_{max} = \sqrt{(a_1 + a_2)^2}$; $= \sqrt{(4+2)^2}$; $= \sqrt{(6)^2}$; **= 6 units**

Resultant amplitude is, minimum when,

$\phi = \pi$, $\cos \pi = -1$, $A_{min} = \sqrt{a_1^2 + a_2^2 - 2a_1a_2}$

$A_{min} = \sqrt{(a_1 - a_2)^2}$; $= \sqrt{(4-2)^2}$; $= \sqrt{(2)^2}$; = **2 units**

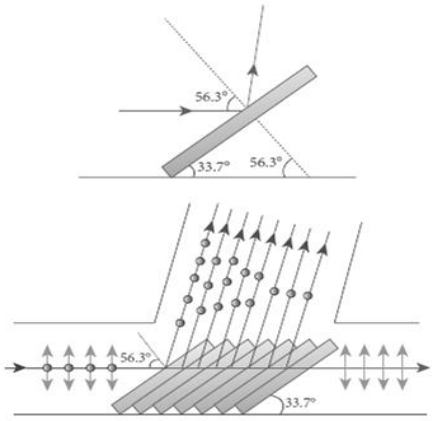
$I \propto A^2$; $\frac{I_{max}}{I_{min}} = \frac{(A_{max})^2}{(A_{min})^2}$; Substituting $\frac{I_{max}}{I_{min}} = \frac{(6)^2}{(2)^2}$; $= \frac{36}{4}$; 9 **$I_{max} : I_{min}$ = 9 : 1**

132. Write a note on **pile of plates**.

Pile of plates:

It works on the principle of **polarization by reflection.**

It consists of a number of glass plates placed one over the other in a tube. These plates are inclined at an **angle 33.7^0 to the axis of the tube.**



A beam of un-polarized light is allowed to fall on the pile of plates along the axis of the tube. So the **angle of incidence of light will be 56.3^0** which is the polarizing angle for glass.

The vibrations perpendicular to the plane of incidence are reflected at each surface and those parallel to it are transmitted. The pile of plates is used as a **polarizer and also as an analyzer.**

133. A microscope has an objective and eyepiece of focal lengths 5 cm and 50 cm respectively with tube length 30 cm. Find the **magnification of the microscope** in the (i) near point and (ii) normal focusing.

f_0 = 5cm = 5 x 10^{-2} m ; f_e = 50 cm = 50 x 10^{-2} m

L = 30 cm = 30 x 10^{-2}m ; D = 25 cm = 25 x 10^{-2} m

(i) **The total magnification m in near point focusing is ,**

$$\mathbf{m = m_o m_e = \left(\frac{L}{f_0}\right)\left(1+\frac{D}{f_e}\right)}$$

Substituting, $m_o m_e = \left(\frac{30 \times 10^{-2}}{5 \times 10^{-2}}\right)\left(1+\frac{25 \times 10^{-2}}{50 \times 10^{-2}}\right)$; = **(6) (1.5) = 9**

(ii) **The total magnification m in normal focusing is,**

$$\mathbf{m = m_o m_e = \left(\frac{L}{f_0}\right)\left(\frac{D}{f_e}\right)}$$

Substituting, $m_o m_e = \left(\frac{30 \times 10^{-2}}{5 \times 10^{-2}}\right)\left(\frac{25 \times 10^{-2}}{50 \times 10^{-2}}\right)$; = **(6) (0.5) = 3**

134. List the **uses of Polaroid's**.

Uses of Polaroid's:

Used in goggles and **cameras to avoid glare of light**

Used in **holography** (three dimensional motion pictures)

Used to improve contrast in **old oil paintings**

Used in optical **stress analysis**.

Used as window **glasses to control the intensity of incoming light**

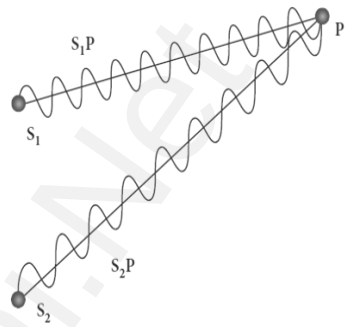
Polarized needle beam acts as **needle to read/write** in compact discs (CDs)

Polaroid produce **polarized lights to be used in liquid crystal display LCD)**

5 Marks Question & Answer

135. Obtain the equation **for resultant intensity due to interference of light**.

Resultant intensity due to interference:



Let S_1 and S_2 are the two light waves meeting at a point 'P' At any instant 't', the displacement equations,

$$y_1 = a_1 \sin \omega t \quad ---- \quad (1)$$

$$y_2 = a_2 \sin (\omega t + \phi) \quad ---- \quad (2)$$

Where, $\phi \rightarrow$ phase difference between them

Then the resultant displacement,

$$y = y_1 + y_2$$

$$y = a_1 \sin \omega t + a_2 \sin(\omega t + \phi)$$

By solving this, we get, $y = A \sin(\omega t + \theta) \quad ---- (3)$

Where, $A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2 \cos\phi}$ and $\theta = \tan^{-1}\left[\frac{a_2 \sin\phi}{a_1 + a_2 \cos\phi}\right]$

(1) When, $\phi = 0, \pm 2\pi, \pm 4, \ldots \ldots$ .the resultant intensity becomes maximum.

$$\mathbf{A_{max} = \sqrt{(a_1 + a_2)^2}}$$

(2) When, $\phi = \pm\pi, \pm 3\pi, \pm 5\pi \ldots \ldots$ the resultant intensity becomes minimum.

$$\mathbf{A_{min} = \sqrt{(a_1 - a_2)^2}}$$

The intensity of light is directly proportional to the square of the amplitude. $I \propto A^2$; $I \propto a_1^2 + a_2^2 + 2a_1a_2 \cos\phi$

$$I \propto \boldsymbol{I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi} ---- \quad (4)$$

1) When, $\phi = 0, \pm 2\pi, \pm 4, \ldots \ldots$ .the resultant intensity becomes maximum. This is called constructive interference. $I_{max} \propto (a_1 + a_2)^2$

$$I_{max} \propto I_1 + I_2 + 2\sqrt{I_1 I_2} ---- \quad (5)$$

(2) When, $\phi = \pm\pi, \pm 3\pi, \pm 5\pi$ … …. the resultant intensity becomes minimum.

This is called destructive interference. $I_{min} \propto (a_1 - a_2)^2$

$$I_{min} \propto I_1 + I_2 - 2\sqrt{I_1 I_2} - - - - \quad (6)$$

Special case:

If $a_1 = a_2 = a$, then resultant amplitude,

$$A = \sqrt{a^2 + a^2 + 2a^2 \cos\phi} \; ; \; A = \sqrt{2a^2 + 2a^2 \cos\phi}$$

$$A = \sqrt{2a^2(1 + \cos\phi)} \; ; \; A = \sqrt{2a^2\left[2\cos^2\left(\frac{\phi}{2}\right)\right]}$$

$$A = 2a\cos\left(\frac{\phi}{2}\right) - - - - \quad (7)$$

If $I_1 = I_2 = I_0$, then the resultant intensity, $I \propto A^2$;

$$I \propto 4a^2\cos^2\left(\frac{\phi}{2}\right) ; \quad I = 4\,I_0\cos^2\left(\frac{\phi}{2}\right) \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

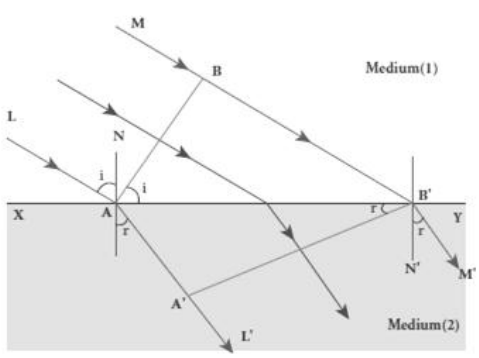
When, $\phi = 0, \pm 2\pi, \pm 4, \ldots \ldots I_{max} = 4\,I_0$ and

$\phi = \pm\pi, \pm 3\pi, \pm 5\pi \ldots \ldots I_{min} = 0$

Thus the phase difference between the two waves decides the intensity of light at the point, where the two waves meet.

136. Prove **laws of refraction** using **Huygens' Principle**.

Laws of refraction - Proof:



Let XY be the refracting surface.

$AA' = v_2 t$ and $BB' = v_1 t$

$$\therefore \frac{BB'}{AA'} = \frac{v_1}{v_2} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Law (1):

The incident rays, refracted rays and the normal are in the same plane.

Law (2):

Angle of incidence, $\angle i = \angle NAL = 90^0 - \angle NAB = \angle BAB'$

Angle of refraction, $\angle r = \angle N'B'M' = 90^0 - \angle N'B'A' = \angle A'B'A$

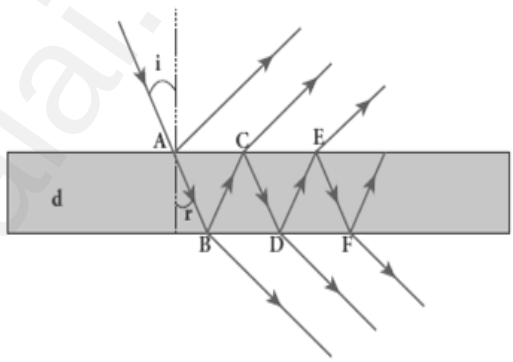
From $\Delta ABB'$ and $\Delta B'A'A$; $\frac{Sin\ i}{Sin\ r} = \frac{\left(\frac{BB'}{AB'}\right)}{\left(\frac{AA'}{AB'}\right)} = \frac{BB'}{AA'} = \frac{v_1}{v_2} = \frac{\left(\frac{C}{n_1}\right)}{\left(\frac{C}{n_2}\right)} = \frac{n_2}{n_1}$

In product form, $\underline{\boldsymbol{n_1 \sin i = n_2 Sin\ r}}$

137. Obtain the equations for **constructive and destructive interference** for transmitted and **reflected waves in thin films.**

Interference in thin films:

Consider a thin film of transparent material of refractive index "μ" and thickness "t". A parallel beam of light is incident on the film at an angle 'i'



At upper surface, the light wave is divided in to two parts. One part is reflected and other part is refracted.

Interference due to transmitted light:

If we approximate the incidence to be nearly normal (i = 0), then the points 'B' and 'D' are very close to each other. The extra distance travelled by the wave transmitted at 'D' is (BC +CD). Hence the path difference between the waves transmitted from 'B' and 'D' is

$\delta = \mu\ (BC + CD) = \mu\ (d + d)$

$\boldsymbol{\delta = 2\mu d}$ $---$ (1)

(1) The condition for constructive interference in transmitted ray is, $\delta = n\lambda$

(or) $\boldsymbol{2\mu = n\lambda}$ $---$ (2)

(2) The condition for destructive interference in transmitted ray is, $\boldsymbol{\delta}$ $=(2n-1)\frac{\lambda}{2}(or)$ $\boldsymbol{2\mu d} = (2n-1)\frac{\lambda}{2}$ .....(3)

Interference due to reflected light:

When light travelling in a rarer medium and getting reflected by a denser medium, undergoes a phase change ofπ.

Hence an additional path difference of $\frac{\lambda}{2}$ is introduced.

Again for normal incidence (i = 0), the points 'A' and 'C' are very close to each other. The extra distance travelled by the wave coming out from 'C' is $(AB + BC)$. Hence the path difference between the waves reflected at 'A' and 'C' is$\delta = \mu\ (AB + BC) = \mu\ (d + d) = 2\ \mu d$

Since additional path difference $\frac{\lambda}{2}$ is introduceddue to reflection at A, the total path difference, = $\boldsymbol{2\mu d} + \frac{\lambda}{2}$.....(4)

1) The condition for constructive interference in reflected ray is

$\delta = n\lambda$ (or) $\boldsymbol{2\mu d} + \frac{\lambda}{2} =$ (or) $\boldsymbol{2\mu d} = (2n-1)\frac{\lambda}{2}$ .....(5)

2) The condition for destructive interference in reflected ray is,

$\boldsymbol{\delta} = (2n+1)\frac{\lambda}{2}$ (or) $\boldsymbol{2\mu d} + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$ (or)

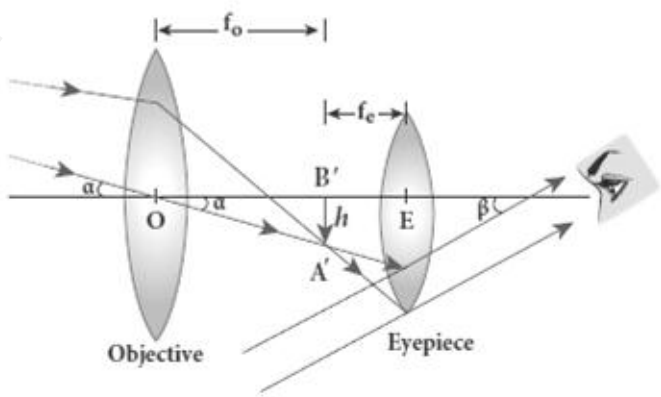
$\boldsymbol{2\mu d = n\lambda}$.....(6)

Equation (5) and (6) shows that the bright and darkfringes are of same width equally spaced on either side of central bright fringe

138. Discuss about **astronomical telescope**.

Astronomical telescope:

An astronomical telescope is **used to get the magnification of distant astronomical objects like stars, planets.** The image formed by this will be inverted. It has an objective of long focal length and a much larger aperture than eye piece. **Light from a distant object enters the objective and a real image is formed in the tube at its second focal point.**



The eye piece magnifies this image producing a final inverted image.

Magnification (m) :

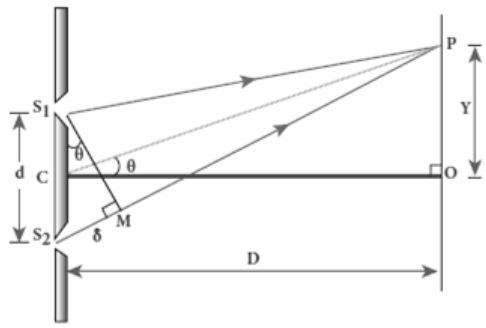
The magnification 'm' is the ratio of the angle β subtended at the eye by the final image to the angle α which the object subtends at the lens or the eye. $m = \frac{\beta}{\alpha}$

From figure, $= \frac{\left[\frac{h}{f_e}\right]}{\left[\frac{h}{f_0}\right]}$; $m = \frac{f_0}{f_e}$

The length of the telescope is approximately, $L = f_0 + f_e$

139. Obtain the equation for Path difference and bandwidth in **Young's double slit experiment**.

Path difference (δ) :



Let distance between S_1 *and* S_2 $= d$,
Distance of the screen from double slit = D,
Wavelength of coherent light wave= λ

Hence path difference between the light waves from S_1 *and* S_2 to the point 'P' is $\delta = S_2P - S_1P = s_2P - MP = S_2M$

From the figure, $\angle OCP = \angle S_2S_1M = \theta$

In ΔS_2S_1M , $Sin\,\theta = \frac{S_2M}{S_1S_2} = \frac{\delta}{d}$; $\therefore \boldsymbol{\delta = Sin\,\theta . d}$

Here θ is small. Hence, $Sin\,\theta \approx tan\,\theta \approx \theta$

$\boldsymbol{\delta = \theta . d}$..... (1)

Also. in $\Delta OCP, \theta \approx \tan\theta = \frac{OP}{OC} = \frac{y}{D}$

Put this in equation (1) $\boldsymbol{\delta = \frac{y}{D} d}$---------- (2)

Point 'P' may be appear either bright or dark depending on the path difference.

Condition for bright fringe (maxima):

For **constructive interference**, the path difference will be,

$\delta = n\lambda \ [n = 0, 1, 2, \ldots]$; $\frac{y}{D}d = n\lambda$

Thus the distance of the nth bright fringe from "O" is

$\boldsymbol{y_n = \frac{D}{d} n\lambda}$---------- (3)

Condition for dark fringe (minima):

For **destructive interference**, the path difference will be,

$\delta = (2n-1)\frac{\lambda}{2} \ \ [n = 1, 2, \ldots]$

$\frac{y}{D}d = (2n-1)\frac{\lambda}{2}$

Thus the distance of the nth dark fringe from "O" is

$\boldsymbol{y_n = \frac{D}{d}(2n-1)\frac{\lambda}{2}}$ ---- (4)

Band width (β) :

The band width is defined as **the distance between any two consecutive bright or dark fringes.** The distance between (n+1)th and nth consecutive bright fringes from 'O' is $\beta = y_{n+1} - y_n$

$$\beta = \frac{D}{d}(n+1)\lambda - \frac{D}{d}n\lambda \ ; \beta = \frac{D}{d}\lambda \ \text{---------- (5)}$$

Similarly the distance between (n+1)th and nth Consecutive dark fringes from 'O' is $\beta = y_{n+1} - y_n$

$$\beta = \frac{D}{d}[2(n+1)-1]\frac{\lambda}{2} - \frac{D}{d}(2n-1)\frac{\lambda}{2}$$

$$\boldsymbol{\beta = \frac{D}{d}\lambda} \text{---------- (6)}$$

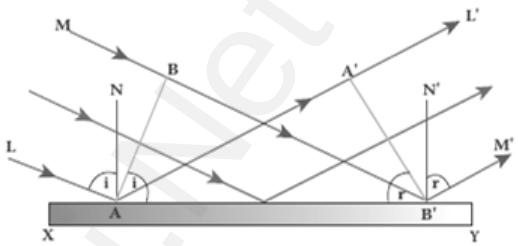
Equation (5) and (6) shows that the bright and dark fringes are of same width equally spaced on either side of central bright fringe.

140. Prove laws of **reflection** using **Huygens principle**.

Laws of reflection - Proof:

XY – Reflecting surface, AB –Incident plane wave front.

The incident rays from L and M are perpendicular to this incident wave front. Initially the point 'A' reaches reflecting surface.



Then the successive points between AB reach the surface.

Finally, by the time B reaches B', the point A would have reached A'

This is applicable to all the points on the wave front AB. Thus the reflected wave front$A'B'$ emanates as a plane wave front.

The line from $L'$and M' perpendiculars to $A'B$ represent reflected rays.

.As the reflection happens in the same medium, the speed of light is same before and after reflection. Hence, $AA' = BB'$

Law (1):

The incident rays, the reflected rays and the normal are in the same plane. Law (2):

Angle of incidence, $\angle i = \angle NAL = 90^0 - \angle NAB = \angle BAB'$

Angle of reflection, $\angle r = \angle N'B'M' = 90^0 - N'B'A' = \angle A'B'A$

In $\Delta ABB'$and $\Delta B'A'A$, $\angle B = \angle A' = 90^0$; $AA' = BB'$ and

Hypotenuse AB' is common

Thus the two triangles are congruent. (i.e) $\angle BAB' = \angle A'B'A$

$\therefore \angle i = \angle r$

Hence laws of reflection are proved.

UNIT-8 DUAL NATURE OF RADIATION AND MATTER

2 Marks Question & Answer

141. **How many photons of frequency** 10^{14} Hz will make up 19.86 J of energy?

Total energy emitted per second = **Power x time**

19.86 = Power x 1 s ; ∴ Power = 19.86 W

Number of photons, n = $\frac{P}{E} = \frac{P}{h\upsilon}$; = $\frac{19.86}{6.6 \text{ x } 10^{-34} \text{x } 10^{14}}$

= 3.009 x 10^{20} n = 3 x 10^{20} ; **n_p = 3 x 10^{20}**

142. List the **properties of X-rays**.

Properties of X - rays:

They **travel in straight line** with the velocity of light

They are **not deflected both by electric and magnetic field**

X-ray **photons are highly energetic**

They pass through materials which are **opaque to visible light.**

143. Define **work function** of a metal. Give its unit.

Work function of a metal.

The **minimum energy needed for an electron to escape from the metal surface** is called work function of that metal. It is denoted by ϕ_0.

Its unit is **electron volt (eV).**

144. Define **threshold frequency**.

Threshold frequency:

For a giver surface, the emission of photo electrons takes place only if the **frequency of incident light is greater than a certain minimum frequency** called threshold frequency.

145. Define **stopping potential.**

The **negative or retarding potential given to collecting electrode** which is just sufficient to stop the most energetic photoelectrons emitted and make the photo current zero is called stopping potential or cut - off potential.

3 Marks Question & Answer

146. Derive an expression for **de-Broglie wavelength of electrons.**

de-Broglie wavelength of electrons:

An electron of mass m is accelerated through a potential difference of V volt. The kinetic energy acquired by the electron is given by $\frac{1}{2}mv^2 = ev$

Hence the speed of the electron is , $v^2 = \frac{2\,e\,V}{m}$; $v = \sqrt{\frac{2\,e\,V}{m}}$.....(1)

The de Broglie wavelength of electron is $\lambda = \frac{h}{mv} = \frac{h}{m\sqrt{\frac{2\,e\,V}{m}}}$

$\lambda = \frac{\mathrm{h}}{\sqrt{2\,\mathrm{m\,e\,V}}}$.....(2)

Where, h = 6.626 x 10^{-34} JS. **e = 1.6 x 10^{-19} C. m = 9.11 x 10^{-31} kg**

$\therefore\ \boldsymbol{\lambda} = \frac{\mathbf{12.27\,x10^{-10}}}{\sqrt{\mathbf{V}}} = \frac{\mathbf{12.27}}{\sqrt{\mathbf{V}}}$ Å

147. Derive the expression of **de-Broglie wavelength of matter waves**.

De-Broglie wavelength of matter waves:

The momentum of photon of frequency 'v' is,

$$\mathbf{p} = \frac{\mathbf{E}}{\mathbf{c}} = \frac{\mathbf{hv}}{\mathbf{c}} = \frac{\mathbf{h}}{\boldsymbol{\lambda}} \quad [c = \lambda v]$$

According to de Broglie, this equation is applicable to matter particle also. Let 'm' be the mass and '$\boldsymbol{v}$' be the velocity of the particle, then the wavelength. $\boldsymbol{\lambda} = \frac{\mathbf{h}}{\mathbf{mv}} = \frac{\mathbf{h}}{\mathbf{p}}$

This wavelength of the matter waves is known as de Broglie wavelength.

148. Explain the **applications of X -rays**

(1) Medical diagnosis:

X - Rays can pass through flesh more **easily than through bones**. Thus X - ray radiograph containing a deep shadow of the bones and a light shadow of flesh. So X -rays radiographs are used **to detect fractures, foreign bodies, diseased organs etc.,**

(2) Medical therapy:

X - ray can kill diseased tissues. So they are employed to **cure skin diseases, malignant tumours etc.,**

(3) Industry:

They are used to check for flaws in **welded joints, motor tyres, tennis balls and wood**, At the custom post, they are used **for detection of contraband goods.**

(4) Scientific Research:

X - ray diffraction is important tool to study the structure of the crystalline materials (i.e) the **arrangement of atoms and molecules** in crystals.

149. Calculate the de Broglie wavelength of a proton whose kinetic energy is equal to 81.9×10^{-15} J. (Given: mass of proton is 1836 times that of electron).

Mp = 1.67×10^{-27} kg, KE = 81.9×10^{-15} J

de Broglie wavelength of a proton, $\lambda = \frac{h}{\sqrt{2mK}}$

$= \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 1.67 \times 10^{-27} \times 81.9 \times 10^{-15}}}$;

$= \frac{6.6 \times 10^{-34}}{1.6539 \times 10^{-20}}$; = 3.99×10^{-14}

$\lambda = 4 \times 10^{-14}$ m

150. List out the **laws of photoelectric effect**.

Laws of photoelectric effect:

For a given frequency of incident light, the number of photoelectrons emitted is directly proportional to the intensity of the incident light.

The saturation current is also **directly proportional to the intensity of incident light.**

Maximum kinetic energy of the photo electrons is **independent of intensity of the incident light**.

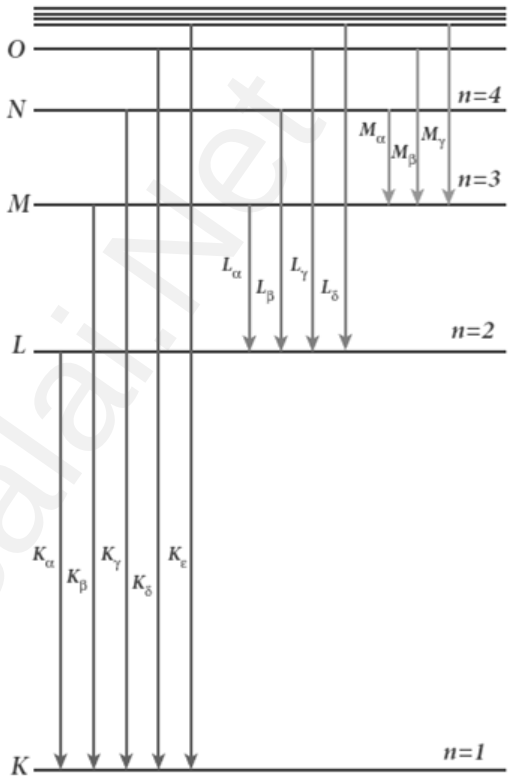
Maximum kinetic energy of the photo electrons from a given metal is **directly proportional to the frequency of incident light.**

For a given surface, the emission of photo electrons takes place only if the **frequency of incident light is greater than a certain minimum frequency** called the **threshold frequency**.

There is **no time lag between incidence of light and ejection of photoelectrons**. (i.e.) photo electric effect is an instantaneous process

151. Write a note on **characteristic X - ray spectra.**

When the target is hit by fast electrons, the obtained X - ray spectra shows some narrow peaks at some well-defined wavelength.



The line spectrum showing these peaks is called characteristic X - ray spectrum. This X -ray spectrum is due to the **electronic transitions** within the atoms. For example, when an energetic electron penetrates in to the target atom and removes the electrons in K - shell and create a vacancy in it.

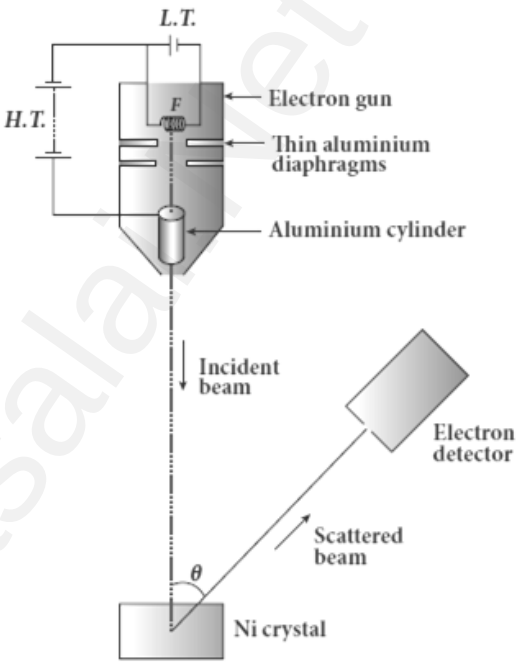
Such wavelengths, characteristic of the target, constitute the line spectrum. It is evident that **K - series** of lines in the X - ray spectrum arise due to the electronic transitions from L, M. N, O, ...shells to K - shell.

Similarly **L - series** originates due to electronic transition from M, N, O, ... shells to L - shell.

5 Marks Question & Answer

152. Describe briefly **Davisson-Germer experiment** which **demonstrated the wave nature of electron.**

Davisson - Gerner experiment:



De Broglie hypothesis of matter waves was experimentally confirmed by Clinton Davisson and Lester Germer in 1927.They demonstrated that **electron beams are diffracted when they fall on crystalline solids.** Since crystal can act as a three-dimensional diffraction grating for matter waves, the electron waves incident on crystals are diffracted off in certain specific directions.

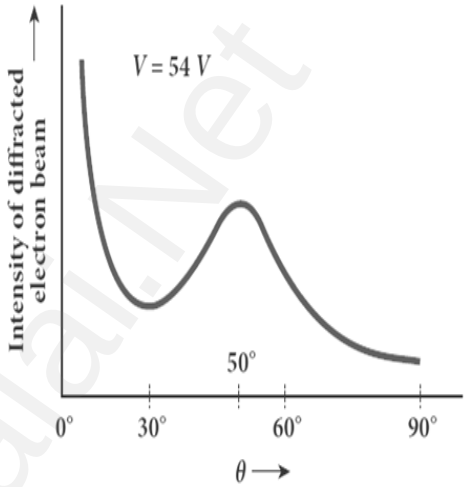
The filament F is heated by a low tension **(L.T.) battery so that electrons are emitted from the hot filament** by thermionic emission. They are then accelerated due to the potential difference between the filament and the anode aluminium cylinder by a high tension (H.T.) battery.

Electron beam is collimated by using two thin aluminium diaphragms and is allowed to strike a **single crystal of Nickel**. The electrons scattered by **Ni atoms in different directions are received by the electron detector which measures the intensity of scattered electron beam.**

The detector is rotatable in the plane of the paper so that the angle θ between the incident beam and the scattered beam can be changed at

our will. **The intensity of the scattered electron beam is measured as a function of the angle θ.**

The graph shows the variation of intensity of the scattered electrons with the angle θ for the **accelerating voltage of 54V.**For a given accelerating voltage V, the scattered wave shows a peak or **maximum at an angle of 50^0** to the incident electron beam. This peak in intensity is attributed to the constructive interference of electrons diffracted from various atomic layers of the target material.



From the known value of inter planar spacing of Nickel, the wavelength of the electron wave has been experimentally calculated as **1.65Å.**

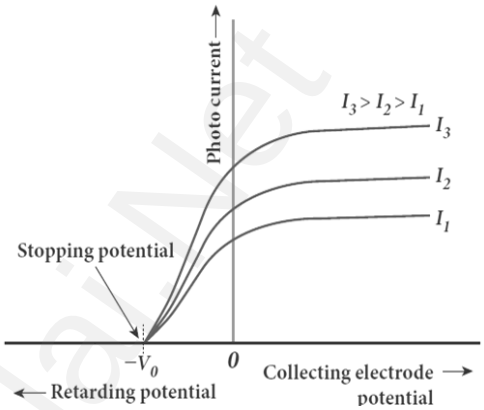
The wavelength can also be calculated from de Broglie relation for V = 54 V as $\lambda = \frac{12.27}{\sqrt{V}}\text{Å} = \frac{12.27}{\sqrt{54}}\text{Å}$ **= 1.67Å**

This value agrees well with the experimentally observed wavelength of 1.65Å.Thus this experiment directly verifies de Broglie's hypothesis of the wave nature of moving particles.

153. Explain the **effect of potential difference** on photo electric current.

Effect of potential difference on photoelectric current:

Let the frequency and intensity of the incident light are kept constant. Now, the potential of A is increased and the corresponding photocurrent is noted. Similarly, a negative (retarding) potential is applied to A and again the photocurrent is noted. Plot a graph by taking anode potential along x -axis and photo current along y - axis



From the graph,

(1) When the **potential of A increases, the photo current also increases and reaches a saturation value** called **saturation current.**

(2) **When a negative potential is applied to A, the photo current does not immediately drop to zero, because the photo electrons are emitted with some definite and different kinetic energies**.

(3) If the negative or retarding potential of A gradually increased, **the photo current starts decreasing and becomes zero** at one particular negative potential v_0

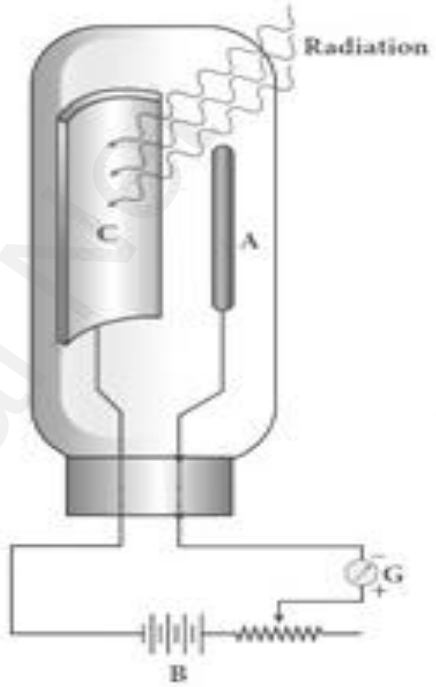
(4) The value of negative or retarding potential give to anode A which is just Sufficient to stop the most energetic **photo electrons emitted and make the photo current zero** is called stopping potential or cut-off potential (v_0)

(5) Here the **initial kinetic energy of the fastest electron** (0 is equal to the work done by the stopping potential to stop it. (i.e.)

$$ev_0 = \frac{1}{2}mv_{max}^2 \quad \text{(or)} \quad v_{max} = \sqrt{\frac{2\,e\,v_0}{m}} = 5.93 \times 10^5\sqrt{v_0}$$

154. Give the **construction, working and applications** of **photo emissive cell**.

Photo emissive cell:



It consists of an **evacuated glass** or **quartz bulb** in which two metallic **electrodes a cathode and an anode** are fixed. The **cathode C is semi- cylindrical in shape** and is coated with a photosensitive material. The **anode A is a thin rod** or wire kept along the axis of the semi- cylindrical cathode.

A **potential difference is applied** between the **anode and the cathode** through a galvanometer G.

Working:

When cathode is illuminated, electrons are emitted from it.

These **electrons are attracted by anode** and hence a **current is produced which is measured by the galvanometer**. For a given cathode, the magnitude of the **current depends** on(1)**the intensity to incident radiation** and (2)**the potential difference between anode and cathode.**

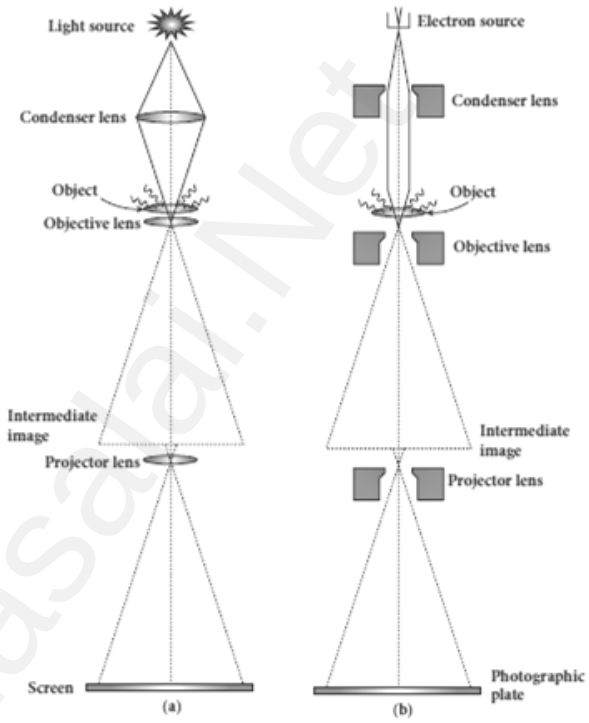
Applications of photo cells:

1) **Switches and sensors. Automatic lights that turn on when it gets dark use photocells**,
2) Photo cells are used for **reproduction of sound in motion pictures**.
3) **Measure the speeds of athletes** during a race.
4) **Photography are used to measure the intensity**

155. Briefly explain the principle and working of electron microscope.

Electron microscope:

Principle:



The wave nature of the electron is used in the construction of microscope called electron microscope. **The resolving power of a microscope is inversely proportional to the wavelength of the radiation used**. Thus higher resolving power can be obtained by employing the waves of shorter wavelengths.

De Broglie wavelength of electron is very much less than (a few thousands less) that of the visible light. As a result, the microscopes employing de Broglie waves of electrons have very much higher resolving power than optical microscope. **Electron microscopes giving magnification more than 2,00,000 times are common in research laboratories.**

Working:

The construction and working of an electron microscope is similar to that of an **optical microscope** except that in electron microscope focusing of electron beam is done by the **electrostatic or magnetic lenses**.

The electron beam passing across a suitably arranged either electric or magnetic fields undergoes divergence or convergence thereby focusing of the beam is done

The electrons emitted from the source are accelerated by high potentials. **The beam is made parallel by magnetic condenser lens.**

When the beam passes through the sample whose magnified image is needed, the beam carries the image of the sample. With the help of magnetic objective lens and magnetic projector lens system, the magnified image is obtained on the screen. These electron microscopes are being used in almost all branches of science.

156. Obtain **Einstein's photoelectric equation** with necessary explanation.

Einstein's explanation of photoelectric equation:

When a photon of energy 'hv' is incident on a metal surface, it is completely absorbed by a single electron and the electron is ejected.

In this process, the energy of incident photon is utilized in two ways.

(1) Part of the photon energy is used for the ejection of the electrons from the metal surface and it is called work function (ϕ_0)

(2) Remaining energy as the kinetic energy (K) of the ejected electron.

From the law of conservation of energy,$hv = \phi_0 + K$ (or)

$hv = \phi_0 + \frac{1}{2}mv^2$..... (1)

Where m →mass of the electron and υ → velocity

At threshold frequency, the kinetic energy of ejected electrons will be zero. (i.e.)when$v = v_0$ then $K = 0$ Thus equation (1) becomes

$hv_0 = \phi_0$ .....(2)

Put equation (2) in (1)$hv = hv_0 + \frac{1}{2}mv^2$..... (3)

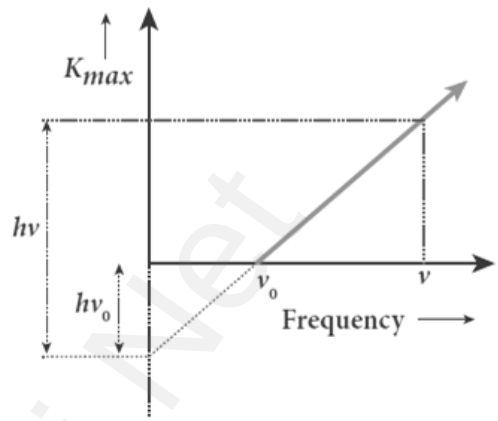
The equation (3) is known as Einstein's photoelectric equation.

K_{max}. Then $hv = hv_0 + \left[\frac{1}{2}mv^2\right]_{max}$

(or) $\frac{1}{2}mv_{max}^2 = hv - hv_0$ (or)

$K_{max} = hv - \phi_0$..... (4)

A graph between maximum kinetic energy K_{max} of the photoelectron and frequency ν of the incident light is a straight line.



UNIT-9 ATOMIC AND NUCLEAR PHYSICS

2 Marks Question & Answer

157. What is meaning by **decay rate**? Give its unit.

Activity: or decay rate which is the **number of nuclei decayed per second** and it is denoted as R. R = $\frac{dN}{dt}$. Its unit is **Becquerel (Bq)** and **curie (Ci)**

158. Give the **symbolic representation of alpha decay**.

Alpha decay:

When unstable nuclei decay by emitting an α-particle ($^4_2$He), its **Atomic number (Z) decreases by2, the mass number (A) decreases by 4.**The α- decay process symbolically written as

$^{A}_{Z}X \rightarrow ^{A-4}_{Z-2}Y + ^{4}_{2}He$. (e.g.)$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$

159. Define **one Becquerel**.

One Becquerel (Bq) is **equal to one decay per second**.

$\mathbf{1}\boldsymbol{Bq} = \mathbf{1\ decay\ /second}$

160. What is **radio carbon dating**?

Radioactive dating or carbon dating: The technique to **estimate the age of ancient object** by using **radio carbon isotope (14C)**

161. Define **one curie.**

One curie:

One curie was defined as **number of decays per second in 1 g of radium. 1 Ci =3.7x10^{10} decay / second.**

162. Define **impact parameter**.

The impact parameter (b) is defined as **the perpendicular distance between the centre of the gold nucleus and the direction of velocity vector of alpha particle** when it is at a large distance.

163. Define **ionization potential**.

Ionization potential is defined as **ionization energy per unit charge.** The ionization potential of hydrogen atom is, $V_{ionizasion} = 13.6\ V$

164. Give the **properties of nuclear forces**?

Properties of Nuclear forces:

The strong nuclear force is of very short range, acting only up to a distance of a few Fermi. **Nuclear force is the strongest force in nature.** The strong nuclear force is attractive and acts with **an equal strength** between **proton-proton, proton-neutron, and neutron – neutron.**

Strong nuclear force does not act on the electrons. So it does not alter the chemical properties of the atom.

165. Define **radioactivity.**

The phenomenon of **spontaneous emission of highly penetrating radiations such as α, β and γ** rays by an element is called radioactivity and the substances which emit these radiations are called radioactive elements.

166. State the **properties of neutrino**.

Properties of neutrino:

It has **zero charge**; It has an antiparticle called anti-neutrino.

Recent experiments showed that the **neutrino has very tiny mass**.

It interacts very weakly with the matter. Therefore, it is very difficult to detect.

3 Marks Question & Answer

167. Explain any three **important inferences** of the **average binding energy** curve.

Binding energy:

(1) The value of $\overline{BE}$ rises as the mass number A increases until it reaches a maximum value of **8.8 MeV for A = 56(iron) and then it slowly decreases.**

(2) The average binding energy per nucleon is about **8.5 MeV** for nuclei having mass number between **A = 40 and 120**. These elements are comparatively **more stable and not radioactive**.

(3) For higher mass numbers, the curve reduces lowly and for **uranium is about 7.6 MeV. They are unstable and radioactive**.

(4) If two light nuclei with **A<28 combine** to form heavier nucleus, the binding energy per nucleon is more for final nucleus than initial nuclei. Thus, if **the lighter elements combine** to produce a nucleus of medium value A, a **large amount of energy will be released**. This is the basis of nuclear fusion and is the principle of the **hydrogen bomb.**

(5) If a nucleus of **heavy element is split (fission)** into two or more nuclei of medium value A, the **energy released** would again be large. The **atom bomb** is based on this principle.

168. Give the **properties of cathode rays**.

Properties of cathode rays:

1) Cathode rays possess energy and momentum
2) They travel in a straight line with **high speed of the order of 10^7m s^{-1}.**
3) It can be deflected by both electric and magnetic fields.
4) The direction of deflection indicates that they are negatively charged particles.
5) When the cathode rays are allowed to fall on matter, they produce heat.
6) They affect the photographic plates
7) They produce fluorescence
8) When the cathode rays fall on a material of high atomic weight, x-rays are produced. Cathode rays ionize the gas through which they pass.
9) The speed of cathode rays is up to $\left(\frac{1}{10}\right)^{th}$ of the speed of light.

169. Give the **symbolic** representation of **alpha decay, beta decay** and **gamma decay**.

(1) Alpha decay:

When unstable nuclei decay by emitting an α-particle(^4_2He), its **Atomic number (Z)decreases by 2, the mass number(A) decreases by 4.** The α- decay process symbolically written as

$^A_ZX \rightarrow {}^{A-4}_{Z-2}Y + {}^4_2He$. (e.g.)$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^4_2He$

(2) Beta decay:

In **β− - decay**, the **atomic number of the nucleus increases by one but mass number remains the same.**

$^A_ZX \rightarrow {}_{Z+1}^{A}Y + {}_{-1}^{0}e + \bar{\nu}$. (e.g.)$^{14}_4C \rightarrow {}^{14}_7N + {}_{-1}^{0}e + \bar{\nu}$

In **β+ - decay,** the **atomic number of thenucleus decreases by one but mass number remains the same**.

$^{A}_{Z}X \rightarrow {}_{Z-1}^{A}Y + {}^{0}_{1}e + v$. (e.g.)$^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + {}^{0}_{1}e + v$

(3) Gamma decay:

In α and β decay, the **daughter nucleus is in the excited state most of the time.** So this excited state nucleus immediately returns to the ground state or lower energy state by emitting highly energetic photons called γ rays.

During gamma decay there is **no change in atomic number and mass number**. $^{A}_{Z}X^{*} \rightarrow {}^{A}_{Z}X$ +gamma rays (γ)

(e.g.)$^{12}_{5}B \rightarrow {}^{12}_{6}C^{*} + {}_{-1}^{0}e + \bar{v}$; $^{12}_{6}C^{*} \rightarrow {}^{12}_{6}C + \gamma$

170. Write a note on **proton - proton cycle.**

According to Hans Bethe, the sun is powered by proton-proton cycle of fusion reaction.

This cycle consists of three steps:

Step – 1 : $\boldsymbol{^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{2}_{1}H + {}^{0}_{1}e + v}$ **;**

Step – 2 : $\boldsymbol{^{1}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + v}$

Step – 3 : $\boldsymbol{^{3}_{2}He + {}^{3}_{2}He \rightarrow {}^{4}_{2}He + {}^{1}_{1}H + {}^{1}_{1}H}$

In general, the above three steps can be written as.

$$\boldsymbol{4{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2{}^{1}_{1}H + 2{}^{0}_{1}e + 2v + 27\ MeV}$$

171. Characol pieces of tree is found from an archeological site. The carbon-14 content of this characol is only 17.5% that of equivalent sample of carbon from a living tree. What is the **age of tree**?

R_0 = 100% , R = 17.5%, $\boldsymbol{\lambda} = \frac{\mathbf{0.6931}}{\mathbf{T_{1/2}}}$, $T_{1/2}$ = 5730 years

According to radioactive law $\mathbf{R = R_0 e^{-\lambda t}}$; $\boldsymbol{e^{\lambda t} = \frac{R_0}{R}}$

Taking log on both sides t = $\frac{1}{\lambda}$ ln $\left(\frac{R_0}{R}\right)$;

Half-life of carbon, $T_{1/2}$ = 5730 years

T = $\frac{T_{1/2}}{0.6931}$ in $\left(\frac{1}{0.175}\right)$; $\frac{\mathbf{5730\ years}}{\mathbf{0.6931}}$ x 1.74297

= 14409.49 years; **t = 1.44 x 10^4 years**

172. Calculate the energy released per fission:

$^{235}_{92}\mathrm{U} + ^{1}_{0}n \rightarrow ^{141}_{56}\mathrm{Ba} + ^{92}_{36}\mathrm{Kr} + 3\ ^{1}_{0}n + Q$

Energy released in one fission:

Consider the following fission reaction.

$^{235}_{92}\mathrm{U} + ^{1}_{0}n \rightarrow ^{141}_{56}\mathrm{Ba} + ^{92}_{36}\mathrm{Kr} + 3\ ^{1}_{0}n + Q$

Total mass before fission;

Mass of $^{235}_{92}\mathrm{U}$	=	235.045733 u
Mass of $^{1}_{0}n$	=	1.008665 u
	=	**236.054398 u**

Total mass after fission;

Mass of $^{141}_{56}\mathrm{Ba}$	=	140.9177 u
Mass of $^{92}_{36}\mathrm{Kr}$	=	91.8854 u
Mass of3 $^{1}_{0}n$	=	3.025995 u
	=	**235.829095 u**
Mass defect; Δ_m	=	236.054398 u
	(−) =	235.829095 u
	Δ_m =	**0.225303 u**

Then energy released during this fission reaction,

Q = Δ_mx 931 MeV ; Q = 0.225303 x 931 MeV ; Q = 200MeV

173. Find the (i) **angular momentum** (ii) **velocity of the electron** in the 5th orbit of hydrogen atom.

Solution:

(i) Angular momentum is given by$= n\hbar = \frac{nh}{2\pi}$; $= \frac{5 \text{ x } 6.6 \text{ x}10^{-34}}{2 \text{ x } 3.14}$

= 5.25 x 10^{-34} kgm^2s^{-1}

(ii) Velocity is given by velocity, $= \frac{l}{mr}$ **;** $= \frac{(5.25 \text{ x } 10^{-34} \cancel{kg} m^{\cancel{2}} s^{-1})}{(9.1 \text{ x } 10^{-31} \cancel{kg})\,(13.25 \text{ x } 10^{-10} \cancel{m})}$

$\boldsymbol{v}$ =4.4 x 10^5 ms^{-1}

174. State the **postulates of Bohr's atom model**.

Postulates of Bohr's atom model:

Postulate (1):

The **electron in an atom moves around nucleus in circular orbits under the influence of Coulomb electrostatic force of attraction**. This Coulomb force gives **necessary centripetal force for the electron to undergo circular motion.**

Postulate (2):

Electrons in an atom revolve around the nucleus only in certain discrete orbits called **stationary orbits** where it **does not radiate electromagnetic energy**. The angular momentum (l) of the electron in these stationary orbits are quantized (i.e.) integral multiple of $\frac{h}{2\pi}$; $\boldsymbol{l = n\frac{h}{2\pi} = n\hbar}$ **.** Where n → principal quantum number. This condition is known as angular momentum quantization condition.

Postulate (3) :

Energy of orbits are not continuous but discrete. This is called the quantization of energy. **An electron can jump from one orbit to another orbit by absorbing or emitting a photon whose energy is equal to the difference in energy (ΔE) between the two orbital levels**.

$\Delta E = E_f - E_i = hv = h\frac{c}{\lambda}$;Where c → speed of light

λ → wavelength of the radiation used and $\boldsymbol{v}$→ frequency of the radiation

175. Calculate the time required **for 60% of a sample of radon** undergo decay. (Given $T_{½}$ of radon =3.8 days.)

Here consider R_n – 222 with a half-life of 3.823 days.

From decay equation, Current amount = Initial amount x $(2)^{-n}$

$\mathbf{N = N_0\,(2)^{-n}\ ;\ \frac{N}{N_0} = (2)^{-\frac{t}{T_{1/2}}}}$

$\log\left(\frac{N}{N_0}\right) = \log(2) \times \left(-\frac{t}{T_{1/2}}\right)$; $\frac{\log\left(\frac{N}{N_0}\right)}{\log(2)} = \left(-\frac{t}{T_{1/2}}\right)$

$t = \frac{\log(0.4)}{\log(2)} \times (-3.823)$; **time t = 5.05 days**.

176. What are the constituent **particles of neutron and proton**?

Protons and neutrons are made up of quarks which are now considered as elementary particles. According to quark model,

(1) Proton is made up of two up quarks $\left(+\frac{2}{3}e\right)$ and one down quark $\left(-\frac{1}{3}e\right)$

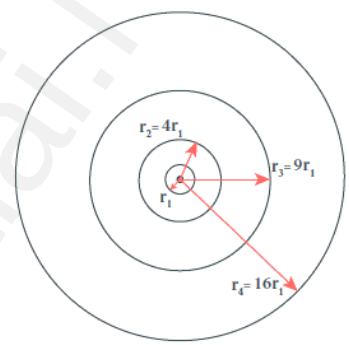
(2) Neutron is made up of one up quark $\left(+\frac{2}{3}e\right)$ and two down quarks $\left(-\frac{1}{3}e\right)$ 1

5 Marks Question & Answer

177. Derive the energy expression for an **electron is the hydrogen** atom using Bohr atom model.

Radius of nth orbit:

Consider an atom which contains the nucleus at rest which is made up of protons and neutrons. Let an electron revolving around the state nucleus



Atomic number= Z,

Total charge of nth nucleus= + e;

Charge of an electron= −e ,

Mass of the electron= m

From Coulomb's law, the force of attraction between the nucleus and the electron

is $\vec{F}_{Coulomb} = \frac{1}{4\pi\epsilon_0}\frac{(+Ze)(-e)}{r_n^2}\hat{r}$; $\vec{F}_{Coulomb} = -\frac{1}{4\pi\epsilon_0}\frac{Ze_2}{r_n^2}\hat{r}$

This force provides necessary centripetal force given by.

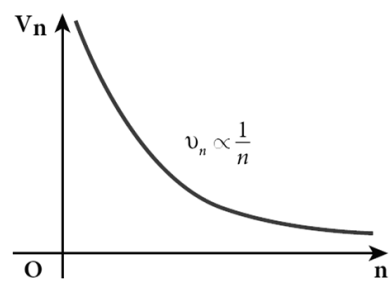
$\vec{F}_{Centripetal} = -\frac{mv_n^2}{r_n}\hat{r}$;

At equilibrium, $\vec{F}_{Coulomb} = \vec{F}_{Centripetal}$

$-\frac{1}{4\pi\epsilon_0}\frac{Ze_2}{r_n^2}\hat{r} = -\frac{mv_n^2}{r_n}\hat{r}$; $\frac{1}{4\pi\epsilon_0}\frac{Ze_2}{r_n^2} = \frac{mv_n^2}{r_n}$ ..... (1)

$r_n = \frac{(4\pi\epsilon_0)\, m\, v_n^2\, r_n^2}{Z\, e^2}$; $r_n = \frac{(4\pi\epsilon_0) m^2 v_n^2\, r_n^2}{Z\, e^2 m}$; $r_n = \frac{(4\pi\epsilon_0)[m\, v_n r_n]^2}{Z\, e^2 m}$

From Bohr's Postulate, $l_n = mv_n r_n = n\frac{h}{2\pi} = n\hbar$



Hence, $r_n = \frac{(4\pi\epsilon_0)[l_n]^2}{Z\, e^2 m}$; $r_n = \frac{(4\pi\epsilon_0)\left[\frac{nh}{2\pi}\right]^2}{Z\, e^2 m}$

$r_n = \frac{(4\pi\epsilon_0) n^2 h^2}{Z\, e^2 m \times 4\pi^2}$; $r_n = \left[\frac{h^2\epsilon_0}{\pi\, m\, e^2}\right]\frac{n^2}{Z}$..... (2)

$r_n = \alpha_0 \frac{n^2}{Z}$..... (3)

Where, $\alpha_0 \rightarrow \frac{h^2\epsilon_0}{\pi\, m\, e^2}$ = **0.529Å →Bohr Radius**

For hydrogen, (Z = 1), So radius of nth orbit, $r_n = \alpha_0 n^2$..... (4)

For first orbit, n = 1, (ground level) $r_1 = \alpha_0$ = 0.529Å

For second orbit, n = 2, (first excited level)

$r_2 = 4\alpha_0$ = 4 x 0.529Å = 2.116 Å

For third orbit, n = 3, (second excited level)

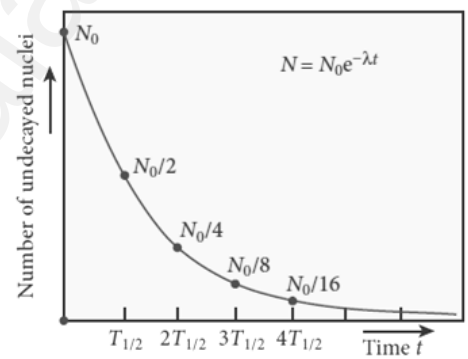
$r_3 = 9\alpha_0$ = 9 x 0.529Å = 4.761 Å

Thus, radius of the orbit, $\boldsymbol{r_n \propto n^2}$

178. Obtain the law of radioactivity (**radioactive decay**)

Law of radioactivity:

At any instant t, **the number of decays per unit time, called rate of decay$\left(\frac{dN}{dt}\right)$ is proportional to the number of nuclei (N) at the same instant. This is called law of radioactive decay.**



Expression:

Let N_0 be the number of nuclei at initial time (t = 0)

Let 'N' be the number of un-decayed nuclei at any time 't'

If 'dN' be the number of nuclei decayed in time 'dt' then,

rate of decay = $\frac{dN}{dt}$

From law of radioactivity, $\boldsymbol{\frac{dN}{dt} \propto N}$ **(or)** $\boldsymbol{\frac{dN}{dt} = -\lambda N}$ – – – – – (1)

Here, $\lambda \rightarrow$ decay constant

Decay constant (λ) is different for different radioactive sample and the negative sign in the equation implies that the N is decreasing with time.

By rewriting the equation (1), we get $\boldsymbol{\frac{dN}{dt} = -\lambda dt}$

Integrating on both sides, $\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_0^t dt$; $[In\ N]_{N_0}^{N} = -\lambda t$

$[In\ N - In\ N_0] = -\lambda t$; $\ln\left[\frac{N}{N_0} = -\lambda t\right]$

Taking exponential on both sides, $\boldsymbol{\frac{N}{N_0} = e^{-\lambda t}}$ **; N = $N_o e^{-\lambda t}$** – – – – – (2)

Equation (2) is called the law of radioactive decay. Here **the number of atoms is decreasing exponentially over the time.**

This implies that the time taken for all the radioactive nuclei to decay will be infinite.

179. Explain the **J.J. Thomson experiment** to **determine the specific charge** of electron.

Specific charge of electron - J J Thomson Experiment:

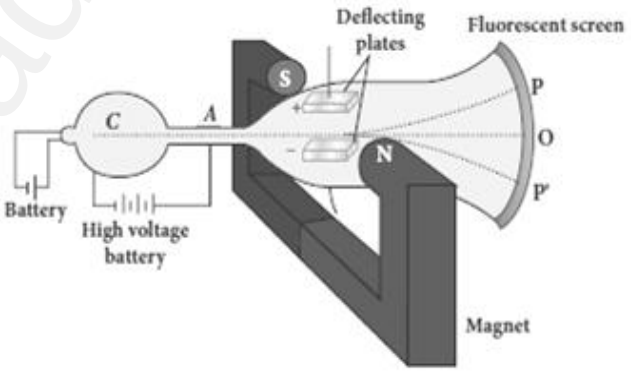
Charge per unit mass of an electron is called specific charge $\left(\frac{e}{m}\right)$

Principle:

Cathode a ray (electron beam) deflects by **both electric and magnetic fields** is the principle involved in this method.

Set up:

It is highly evacuated discharge tube. Cathode rays (electron beam) produced at cathode 'C' are attracted towards anode disc A which allow only a narrow beam of cathode rays.

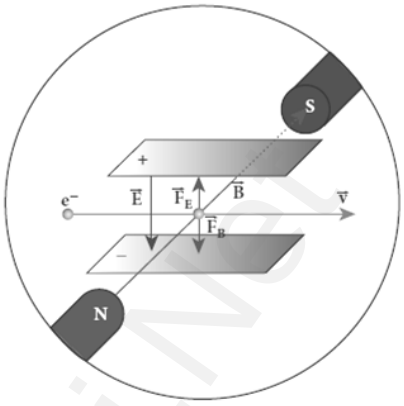


These cathode rays are now allowed to pass through the parallel plates and strike the screen coated with ZnS, a light spot is observed at O

The metal plates are maintained at high voltage.

Further, this gas discharge tube is kept in between pole pieces of magnet such that both electric and magnetic fields are perpendicular to each other.

Velocity of cathode rays (v):



Let 'e' be the charge of cathode ray particle. **The upward force acting on cathode rays due to electric field 'E' is; $F_E = eE$**

The downward force acting on cathode rays due to magnetic field is ;

$$F_B = eBv$$

In un-deflected equilibrium position, $F_E = F_B$; $eE = eBv$

$$v = \frac{E}{B} \text{.....(1)}$$

Method (1) - To find specific charge:

Let 'V' be the potential difference between anode and cathode.

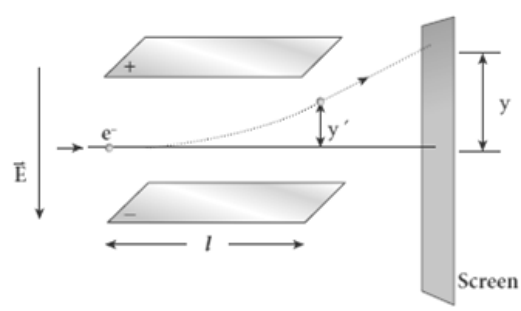
Since the cathode rays (electron beam) are accelerated from cathode to anode, **the potential energy 'eV' of the electron beam at the cathode is converted into kinetic energy of the electron beam at the anode**.

Hence,

$$eV = \frac{1}{2}mv^2 \; ; \therefore \frac{e}{m} = \frac{1}{2}\frac{v^2}{V} = \frac{1}{2}\frac{E^2}{VB^2}$$

The value of specific charge is , $\frac{e}{m}$ **=1.7 x 10^{11}Ckg^{-1}m**

Method (2) - Deflection due to electric field:



When the magnetic field is turned off ($B = 0$), the deflection is only due to electric field. Let 'm' be the mass of the electron, the upward acceleration due to electric field 'E' is $a_E = \frac{F_E}{m} = \frac{eE}{m}$

Upward initial velocity; = 0

Let 'l' be the length of the deflecting plate, then time taken to travel in electric field is, $t = \frac{l}{v}$

Hence the deflection at the end of the electric field $y' = ut + \frac{1}{2}at^2$

$= 0 + \frac{1}{2}a_E t^2$; $y' = \frac{1}{2}\frac{eE}{m}\left(\frac{l}{v}\right)^2$;

$y' = \frac{1}{2}\frac{eE}{m}\frac{l^2}{v^2}$; $y' = \frac{1}{2}\frac{eE}{m}\frac{l^2B^2}{E^2}$

$$\boldsymbol{y' = \frac{1}{2}\frac{e}{m}\frac{l^2B^2}{E^2}} \text{ ..... (2)}$$

Then the deflection on the screen, $y \propto y'$ (or) $y = Cy'$

C →Proportionality constant.

Using equation (2), $\mathbf{y = C\frac{1}{2}\frac{e}{m}\frac{l^2B^2}{E^2}}$;

$$\boldsymbol{\frac{e}{m} = \frac{2yE}{Cl^2B^2}} \text{ ..... (3)}$$

By substituting the known values, we get $\boldsymbol{\frac{e}{m}}$ = **1.7 x 10^{11}Ckg^{-1}m**

Method (3) - Deflection due to magnetic field:

When the electric field is turned off (E = 0), the deflection is only due to magnetic field. **The magnetic force provides the centripetal force, the electron beam undergoes semi-circular path**. Hence, $e\,v\,B = \frac{mv^2}{R}$

$e\,B = \frac{mv}{R}$; $e\,B = \frac{m\left(\frac{E}{B}\right)}{R}$; $\frac{m\,E}{B\,R}$

$\frac{e}{m} = \frac{E}{B^2R}$ ..... (4)

The specific charge is independent of (1) Gas used

(2) Nature of the electrodes

180. Explain the **spectral series of hydrogen atom**.

Spectral series of hydrogen atom:

When an electron jumps from n^{th} orbit to nth orbit, a spectral line was obtained whose wave number (i.e.) reciprocal of wave length is,

$\bar{v} = \frac{1}{\lambda} = R\left[\frac{1}{n^2} - \frac{1}{m^2}\right]$. Here, R →Rydberg Constant

(R = 1.097 x 10^7 ms^{-1})

From m>n, various spectral series are obtained.

(1) Lyman Series:

n = 1 and m = 2, 3, 4, ...

Hence the wave number, $\bar{v} = \frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{m^2}\right]$

They lie in **ultra violet region.**

(2) Balmer Series:

n = 2 and m = 3, 4, 5, ...

Hence the wave number, $\bar{v} = \frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{m^2}\right]$

They lie in **visible region**.

(3) Paschen Series:

n = 3 and m = 4, 5, 6,.....

Hence the wave number, $\bar{v} = \frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{m^2}\right]$

They lie in **infra red region**.

(4) Brackett Series:

n = 4 and m = 5, 6,7,.....

Hence the wave number, $\bar{v} = \frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{m^2}\right]$

They lie in **middle infra red region**.

(5) Pfund Series:

n = 5 and m = 6, 7, 8,.....

Hence the wave number, $\bar{v} = \frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{m^2}\right]$

They lie in **far infra red region**.

181. Describe the **working of nuclear reactor.**

(1) Fuel:

The commonly used fuels are $^{235}_{92}$U and $^{239}_{94}Pu$

Naturally occurring **uranium contains only 0.7% of $^{235}_{92}U$ and 99.3% are only $^{238}_{92}$U**. So the $^{238}_{92}U$must be enriched such that it92contains at least 2 to 4% of $^{235}_{92}$U.

(2) Neutron source:

A neutron source is required to initiate the chain reaction for the first time. A **mixture of beryllium with plutonium or polonium** is used as the **neutron source.**

(3) Moderators:

The probability of initiating fission by fast neutron in another nucleus is very low. Therefore, slow neutrons are preferred for sustained nuclear reactions. The **moderator is a material used to convert fast neutrons into slow neutrons.**

Usually the **moderators having mass comparable to that of neutrons.** Hence, these light nuclei undergo collision with fast neutrons and the speed of the neutron is reduced. **Most of the reactors use water, heavy water (D_2O) and graphite as moderators.**

(4) Control rods:

The control rods are used **to adjust the reaction rate**. During each fission, on an **average 2.5 neutrons are emitted**. In order to have the controlled chain reactions, only one neutron is allowed to cause fission and the remaining neutrons are absorbed by the control rods. **Usually cadmium or boron acts as control rod material.**

(5) Coolants:

The cooling system removes the **heat generated in the reactor core**. Ordinary water, heavy water and liquid sodium are used as **coolant** since they have very high specific heat capacity and have large boiling point under high pressure. This **coolant passes through the fuel block and carries away the heat to the steam generator through heat exchanger**. The steam runs the turbines which produces electricity in power reactors.

UNIT-10 ELECTRONICS AND COMMUNICATION

2 Marks Question & Answer

182. List the **applications of Zener diode**.

Give the applications of Zener diode.

Voltage regulators, Peak clippers, **Calibrating voltages**, Provide fixed reference voltage in a **network for biasing**, Meter protection against damage from accidental application of excessive voltage/

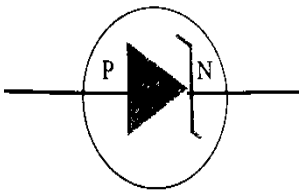
183. What is meant by **rectification**?

Rectification:

The process of **converting alternating current into direct current is called rectification**. The device used for rectification is called rectifier. A P-N junction diode is used as rectifier.

184. What is called **Zener diode**? Give its circuit symbol.

Zener diode is a **reverse biased heavily doped Silicon diode** which is specially designed to be operated in the **breakdown region**. The circuit symbol of Zener diode is given.



185. Define **Doping**.

The process of **adding impurities to the intrinsic semiconductor** is called doping. The **impurity atoms** are called doping.

186. In a transistor connected in the common base configuration, a α =0.95 , $I_E = 1$ mA . Calculate the values of I_C and I_B .

$\alpha = \frac{I_C}{I_B}$; $I_C = \alpha I_E$ = 0.95 x 1 = 0.95 mA

$I_E = I_B + I_C$ $\therefore I_B = I_C - I_E$; = **1 – 0.95 = 0.05 mA**

187. What is an **extrinsic semiconductor**?

The semiconductor obtained by doping either **pentavalent impurity** or **trivalent impurity** is called extrinsic semiconductor. (e.g.) P - type and N-type semiconductor.

3 Marks Question & Answer

188. Give the **limitations of amplitude modulation (AM)** and **frequency modulation (FM).**

Limitations of amplitude modulation (AM):

Noise level is high, Low efficiency, Small operating range

Limitations of frequency modulation (FM):

FM requires a much **wider channel**.

FM transmitters and receivers are **more complex and costly.**

In FM reception, **less area is covered** compared to AM.

189. Give the relation between **α and β**.

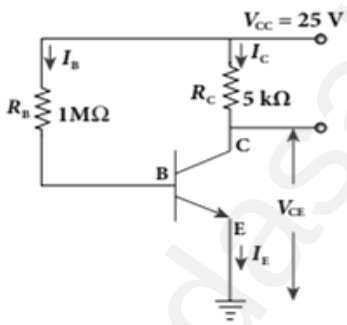
Forward current gain in common base mode, $\alpha = \left[\frac{\Delta I_C}{\Delta I_E}\right]_{V_{CE}}$

Forward current gain in common emitter mode, $\beta = \left[\frac{\Delta I_C}{\Delta I_B}\right]_{V_{CE}}$

From the above two equations, we have

$\alpha = \frac{\beta}{1+\beta}$ (or) $\beta = \frac{\alpha}{1-\alpha}$

190. The current gain of a common emitter transistor circuit shown in figure is 120. **Draw the DC load line** and mark the Q point on it. (V_{BE} to be ignored).



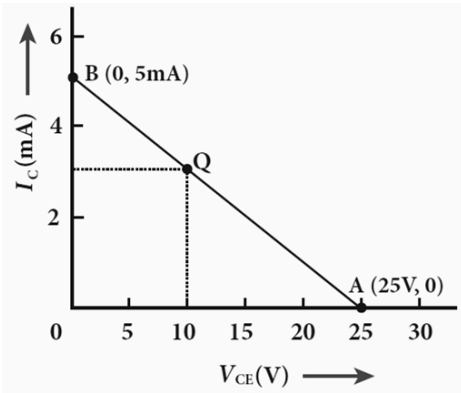
Base current, $I_B = \frac{25\,V}{1\,M\Omega} = \frac{25}{1x10^6}$; **I_B =25μA**

We know that $\beta = \frac{I_C}{I_B}$ (or)

$I_C = \beta I_B$ = 120x25μA ; 3000 μA = 3mA

$V_{CE} = V_{CC} - I_C R_C$

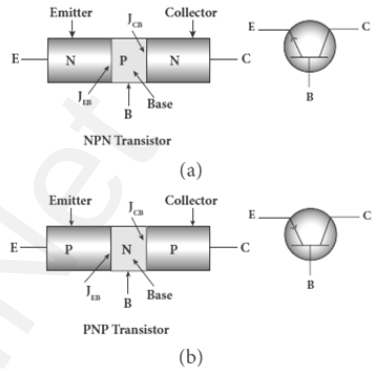
V_{CE} =25 – (3mA x 5k) = 10V



191. Write a note on **bipolar junction transistor (BJT).**

Bipolar junction transistor (BJT):

The bipolar junction transistor (BJT) **consists of a semiconductor** (Silicon or Germanium) crystal in which an **N-type material is sandwiched between two P-type materials called PNP transistor** or a **P -type material sandwiched between two N-type materials called NPN transistor.**

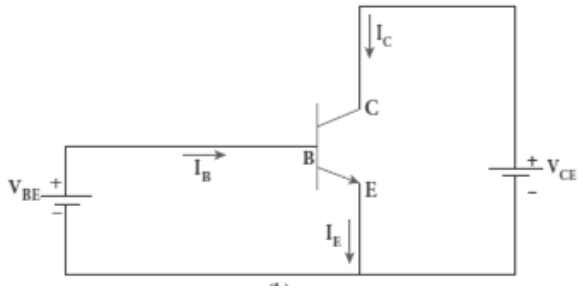


The three regions formed are called **emitter(E), base(B) and collector(C).**

192. **Draw the circuit diagram of common emitter configurations of NPN transistor.**

Input terminal – Base, Output terminal-Collector, Common terminal -Emitter, Input current= I_B; Output current=I_C

The input signal (V_{BE}) is applied across base - emitter junction. The output signal (V_{CE}) is measured across collector - emitter junction.



193. What is called **modulation**? Give its types.

For **long distance transmission, the low frequency base band signal** (input signal) is **superimposed on to a high frequency carrier signal** (radio signal) by a process called modulation.

(1) **Amplitude Modulation (AM)**

(2) **Frequency Modulation (FM)**

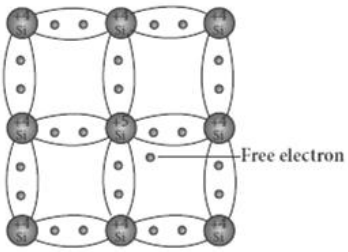
(3) **Phase Modulation (PM)**

5 Marks Question & Answer

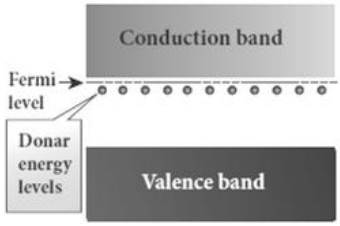
194. Elucidate the formation of **n-type extrinsic semiconductor**.

N-type semiconductors:

A n-type semiconductor is obtained by doping a pure Silicon (or Germanium) crystal with a doping from pentavalent elements like Phosphorus, Arsenic, and Antimony. **The doping has five valence electrons while the Silicon atom has four valence electrons.**



(a)



During the process of doping, four of the five valence electrons of the impurity atom are bound with the 4 valence electrons of the neighbouring replaced Silicon atom. The fifth valence electron of the impurity atom will be loosely attached with the nucleus as it has not formed the covalent bond.

The energy level of the loosely attached fifth electron is found just below the conduction band edge and is called the **donor energy level**.

The energy required to set free a **donor electron is only 0.01 eV for Ge and 0.05 eV for Si.**

At room temperature, these electrons can easily move to the conduction band with the absorption of thermal energy.

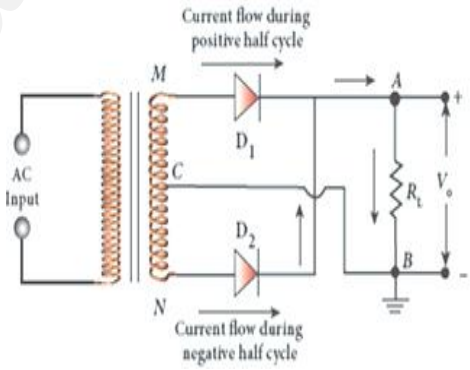
The **pentavalent** impurity atoms donate electrons to the conduction band and are called **donor impurities.** Therefore, each impurity atom provides one extra electron to the conduction band in addition to the thermally generated electrons

Hence, in an **N - type semiconductor, the majority carriers - Electrons minority carriers – Holes.**

195. Explain the construction and working of a **full wave rectifier**.

Full wave rectifier:

The positive and negative half cycles of the AC input signal pass through this circuit and hence it is called the full wave rectifier.

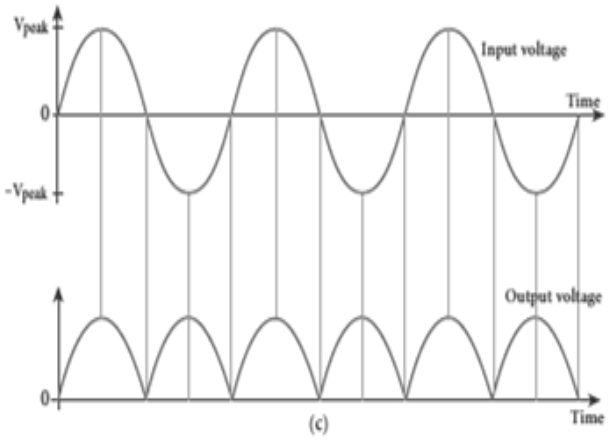


It consists of two P-N junction diodes, a center tapped transformer, and a load resistor (R_L).

The centre (C) is usually taken as the ground or zero voltage reference point. Due to the centre tap transformer, the output voltage rectified by each diode is only one half of the total secondary voltage.

During positive half cycle of input AC	**During negative half cycle of input AC**
Terminal **M is positive**, G is at zero potential and **N is at negative** potential.	Terminal **M is negative**, G is at zero potential and **N is at positive** potential.
Diode **D_1 is forward biased.** Diode **D_2 is reverse biased**.	Diode **D_1 is reverse biased.** Diode **D_2 is forward biased.**

D_1 conducts and current flows along the **path MD_1AGC**	D_2 conducts and current flows along the **path ND_2BGC**
The voltage appears across R_L in the direction G to C	The voltage appears across R_L in the same direction G to C



Hence in a full wave rectifier **both positive and negative half cycles of the input signal pass through the circuit in the same direction.** The output waveform is shown.

Though both positive and negative half cycles of ac input are rectified, the output is still pulsating in nature. The efficiency (η) of full wave rectifier is twice that of a **half wave rectifier and is found to be 81.2 %.**

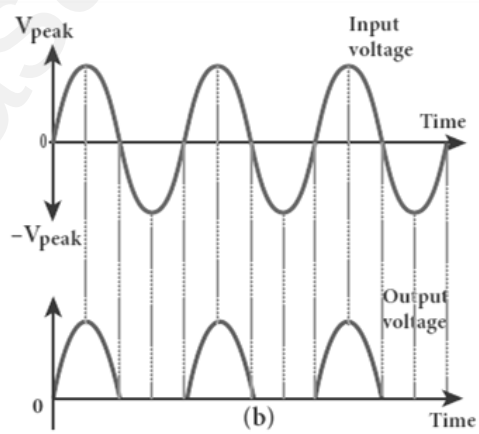
196. Draw the circuit diagram of **a half wave rectifier** and explain its working**.**

In a half wave rectifier circuit, either a positive half or the negative half of the AC input is passed through while the other half is blocked**. Only one half of the input wave reaches the output. Therefore, it is called half wave rectifier**.

This circuit consists of a transformer, a P-N junction diode and a resistor (R_L)here, P-N junction diode acts as a rectifying diode.

During positive half cycle of input AC	**During negative half cycle of input AC**
Terminal **A becomes positive** with respect to terminal B	Terminal **B becomes positive** with respect to terminal A.
The diode is **forward biased** and hence it **conducts**	The diode is **reverse biased** and hence it **does not conducts**
The current flows through the load resistor R_L and AC voltage developed across R_L constitutes the output voltage v_0	No current passes through R_L and there is no voltage the drop across R_L. (The reverse saturation current in a diode is negligible)

The output waveform is shown below.



The output of the half wave rectifier is not a steady dc voltage but a pulsating wave. A constant or a steady voltage is required which can be obtained with the help of filter circuits and voltage regulator circuits.

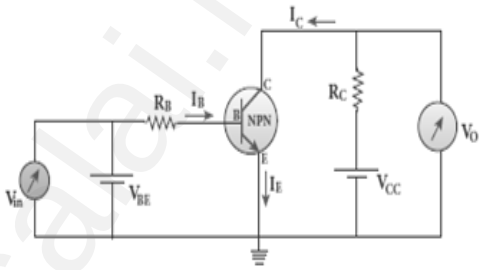
Efficiency (η) is the ratio of the output dc power to the ac input power supplied to the circuit. Its **value for half wave rectifier is 40.6 %**

197. Explain **Transistor functions as a switch.**

Transistor as a switch:

The transistor in saturation and cut-off regions functions like an electronic switch that helps to turn ON or OFF a given circuit by a small control signal.

Presence of dc source at the input (saturation region):



When a high input voltage (V_{in} = +5 V) is applied, **the base current (I_B) increases and in turn increases the collector current. The transistor will move into the saturation region (turned ON).The increase in collector current (I_C) increases the voltage drop across RC, thereby lowering the output voltage, close to zero.** The transistor acts like a closed switch and is equivalent to ON condition.

Absence of dc source at the input (cutoff region):

A low input voltage (V_{in} = 0 V), decreases the base current (I_B) and in turn decreases the collector current (I_C). The transistor will move into the cut-off region (turned OFF). **The decrease in collector current (IC) decreases the drop across RC, thereby increasing the output voltage, close to +5 V.**

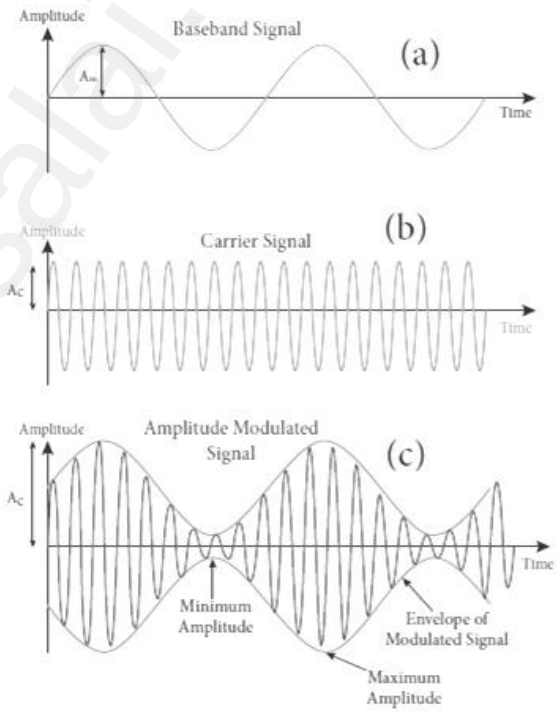
The transistor acts as an open switch which is considered as the OFF condition. It is manifested that, a high input gives a low output and a low input gives a high output. Therefore, a transistor can be used as an inverter in computer logic circuitry.

198. What is called **modulation**? Explain the **amplitude modulation** with help of necessary diagrams.

Modulation:

For long distance transmission, the **low frequency baseband signal (input signal) is superimposed onto a high frequency radio signal** by a process called **modulation**. In the modulation process, a very high frequency signal called carrier signal (radio signal) is used to carry the baseband signal.

Amplitude modulation (AM) :



If the amplitude of the carrier signal is modified according to the instantaneous amplitude of the baseband signal, then it is called amplitude modulation. Here **the frequency and the phase of the carrier signal remain constant. We can see clearly that the carrier wave is modified in proportion to the amplitude of the baseband signal.** Amplitude modulation is used in radio and TV broadcasting.

Advantages of AM :

Easy transmission and reception, lesser bandwidth requirements , Low cost

Limitations of AM:

Noise level is high, Low efficiency, Small operating range

199. State and prove **De Morgan's First** and **Second theorems.**

De Morgan's First Theorem:

The **complement of the sum of two logical inputs is equal to the product of its complements**. $\overline{A+B} = \overline{A}.\overline{B}$

Proof:

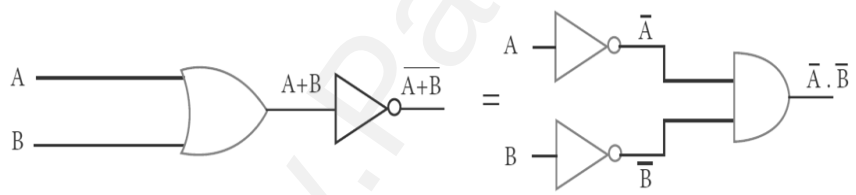
The Boolean equation for NOR gate is Y = $\overline{A+B}$

The Boolean equation for a bubbled AND gate is Y = $\overline{A}.\overline{B}$

A	**B**	**A+B**	$\overline{A+B}$	$\overline{A}$	$\overline{B}$	$\overline{A}.\overline{B}$
0	0	0	**1**	1	1	**1**
0	1	1	**0**	1	0	**0**
1	0	1	**0**	0	1	**0**
1	1	1	**0**	0	0	**0**

Thus De Morgan's First Theorem is proved. It also says that a NOR gate is equal to a bubbled AND gate.

The corresponding logic circuit diagram.



De Morgan's Second theorem:

The complement of the product of two logical inputs is equal to the sum of its complements. $\overline{A.B} = \overline{A} + \overline{B}$

Proof:

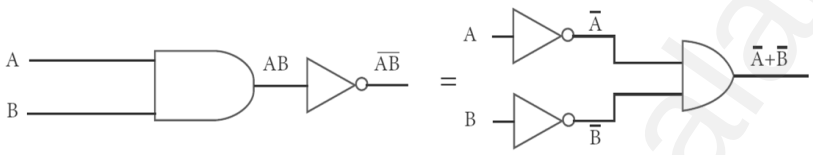
The Boolean equation for NAND gate is Y = $\overline{A.B}$

The Boolean equation for a bubbled OR gate is Y = $\overline{A} + \overline{B}$

A	B	A.B	$\overline{A.B}$	$\overline{A}$	$\overline{B}$	$\overline{A}+\overline{B}$
0	0	0	**1**	1	1	**1**
0	1	0	**1**	1	0	**1**
1	0	0	**1**	0	1	**1**
1	1	1	**0**	0	0	**0**

Thus De Morgan's First Theorem is proved. It also says, a NAND gate is equal to a bubbled OR gate.

The corresponding logic circuit diagram



UNIT-11 RECENT DEVELOPMENT IN PHYSICS

2 Marks Question & Answer

200. List the **applications of Nano technology**.

Energy storage, Defense and security, Metallurgy and materials
Electronics, Optical engineering and communication
Biomedical and drug delivery, Agriculture and food, Cosmetics and paints
Bio-technology, Textiles

201. What is **artificial intelligence**? What are its work?

The aim of artificial intelligence is to bring in human like behaviour in robots. It works on, (1) **Face recognition**

(2) Providing response to **player's actions is computer games**

(3) Taking decisions based on previous actions

(4) To **regulate the traffic by analyzing the density of traffic** on roads

(5) **Translate words from one language to another**

202. Give the **applications of robot** in various fields.

Applications of robot:

Weaponry, packing, Lawn mowing, cutting, under water, agriculture, pool cleaning Welding, cutting, assembling, litter robot, transport.

Vacuum cleaners, hospitals, surgery, laboratory Exploring stars, planets etc., investigation of the mineralogy of the rocks and soils on Mars, analysis of elements found in rocks and soils.

3 Marks Question & Answer

203. Explain how **nano structures** are made in the laboratory?

Nano in laboratories:

The nano structures made in the laboratory mimic some of the nature's amazing nano structures.

There are two ways of preparing the nano materials. They are.

(1) Top - Down approach, (2) Bottom - Up approach

(1) Top - Down approach:

Nano materials are synthesized by breaking down bulk solids in to nano sizes. (e.g) Ball milling, sol-gel, lithography

(**2) Bottom - up approach**:

Nano materials are synthesized by assembling the atoms or molecules together. Selectively atoms are added to create structures.

(e.g.) plasma etching and chemical vapour deposition

204. What **is particle physics**? Write down its **recent development**.

Particle physics and its development:

The **study of the theory of fundamental particles of nature** is called particle physics. Initially it was thought that atom is the fundamental entity of matter. But in **1930, it was established that atoms are made up of electrons, Protons and neutrons.**

In 1960, it was discovered that **protons and neutrons** were made up **of quarks**. Later it was found that quarks interact through gluons. **Recently in 2013, famous Higgs particles also known as God particles** were discovered which gives mass to many particles like protons, neutrons etc .,

205. What are called **gravitational waves**?

The **disturbance in the curvature of space-time** is called gravitational waves. Its **travels with speed of light, any accelerated charge emits electromagnetic waves.** Similarly any accelerated mass emits gravitational waves. But these gravitational waves are very weak even for masses like earth. **The strongest sources of gravitational waves are black holes**.

The recent discoveries of gravitational waves are emitted by two black holes when they merge to a single black hole. In 1915, **Albert Einstein theoretically proposed the existence of gravitational waves.** After 100 years, it is experimentally proved that his predictions are correct.

5 Marks Question & Answer

206. Mention the **advantages** and **disadvantages of Robotics**.

Advantages of robotics:

The robots are **much cheaper than humans**. Robots **never get tired like humans**. Hence absenteeism in work place can be reduced. Robots are **more precise and error free in performing the task**.

Stronger and faster than humans Robots can work in extreme **environmental conditions**: **extreme hot or cold, space or underwater**.

In dangerous situations like bomb detection and bomb deactivation, In warfare, robots can save human lives. Robots are **significantly used in handling materials in chemical industries** especially in nuclear plants which can lead to health hazards in humans.

Disadvantages of robotics:

Robots have **no sense of emotions or conscience**; they lack empathy and hence **create an emotionless workplace**. If ultimately robots would do all the work, and the humans will just sit and monitor them, health hazards will increase rapidly. Unemployment problem will increase.

Robots can perform defined **tasks and cannot handle unexpected situations the robots are well programmed to do a job and if a small thing goes wrong it ends up in a big loss to the company.** If a robot malfunctions, it takes time to identify the problem, rectify it, and even reprogram if necessary.

This process requires significant time. **Humans cannot be replaced by robots in decision making.**

Till the robot reaches the level of human intelligence, the humans in work place will exit.

207. Explain the various **components of robotics**.

Power conversion unit:

Robots are powered by **batteries, solar power, and hydraulics**.

Actuators:

Converts energy into movement. The majority of the actuators **produce rotational or linear motion**.

Electric motors:

They are used to actuate the parts of the robots like wheels, arms, fingers, legs, sensors, camera, weapon systems etc. **Different types of electric motors are used. The most often used ones are AC motor, Brushed DC motor, Brushless DC motor, Geared DC motor, etc.**

Pneumatic Air Muscles:

They are devices that can **contract and expand when air is pumped inside. It can replicate the function of a human muscle.** eye contract almost 40% when the air is sucked inside them.

Muscle wires:

They are thin strands of wire made of shape memory alloys. eye can contract by 5% when electric current is passed through them.

Piezo Motors and Ultrasonic Motors:

Basically, we use it for industrial robots.

Sensors:

Generally used in task environments as it provides information of real-time knowledge.

Robot locomotion:

Provides the types of movements to a robot. The different types are (a) Legged, (b) Wheeled, (c) Combination of Legged and Wheeled Locomotion, (d)Tracked slip/skid

உங்களை வெற்றி பெற
எவரும் பிறக்கவில்லை என்பது பொய்.
பிறரைத் தோற்கடிக்க
நீங்கள் பிறந்து இருக்கிறீர்கள் என்பதே மெய்.
சுயமாக முன்னேறியவர் என்று
எவரும் கிடையாது
நீங்கள் உழைக்கத் தயார் என்றால்
பலர் உங்களை உயர்த்தத் தயாராக இருக்கிறார்கள்.

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