

HIGHER SECONDARY SECOND YEAR

இயற்பியல்

PHYSICS STUDY MATERIAL

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PREPARED BY



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“வாழ்நாள் முழுவதும் ஒவ்வொரு மணித்துளியும்
நேர்மையாய், உன்மையாய் உழைக்கின்றவர்களின்
கரங்களே தூய்மையான கரங்கள்.”

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UNIT - I (ELECTROSTATICS)

TWO MARKS QUESTIONS AND ANSWERS

1. What is Electrostatics?

The branch of electricity which deals with stationary charges is called electrostatics.

2. What is called triboelectric charging?

Charging the objects through rubbing is called triboelectric charging.

3. Like charges repels. Unlike charges attract - Prove.

1. A **negatively charged rubber rod is repelled** by another negatively charged rubber rod.
2. But a negatively charged rubber rod is **attracted by a positively charged glass rod.**
3. This proves **like charges repels and unlike charges attracts.**

4. State conservation of electric charges.

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

5. State quantization of electric charge.

The charge 'q' of any object is equal to an **integral multiple of this fundamental unit of charge 'e'** (i.e) $q=n e$, where, $n \rightarrow$ integer and $e = 1.6 \times 10^{-19} C$

6. State Coulomb's law in electrostatics.

Coulomb's law states that 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.

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

According to Coulomb law, the force on the point charge q_2 exerted by another point charge q_1 is $\vec{F}_{21} = k \frac{q_1 q_2}{r^2} \hat{r}_{12}$, where, $k \rightarrow$ constant
 $\hat{r}_{12} \rightarrow$ Unit vector directed from q_1 to q_2 Coulomb force.

7. 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

$9 \times 10^9 \text{ N}$

8. Define relative permittivity.

From Coulomb's law, the electrostatic force is

$$\vec{F}_{21} = \frac{1}{4\pi\epsilon} \frac{q_1 q_2}{r^2} \hat{r}_{12} = \vec{F}_{21} = \frac{1}{4\pi\epsilon_0\epsilon_r} \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

Here $\epsilon = \epsilon_0 \epsilon_r$ is called permittivity of any medium

ϵ_0 is called permittivity of free space or vacuum and ϵ_r is called relative permittivity.

Thus The **ratio of permittivity of the medium to the permittivity of free space** is called **relative permittivity or dielectric constant**. [$\epsilon_r = \epsilon$].

It has no unit and for air $\epsilon_r = 1$ and for other dielectric medium $\epsilon_r > 1$

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

The force on the point charge q_1 exerted by another point charge q_2 is

$$\vec{F}_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

Similarly the force on the point charge q_1 exerted by another point charge q_2

$$\text{is } \vec{F}_{12} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{21}$$

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. Distinguish between Coulomb force and Gravitational force.

S. No.	Coulomb Force	Gravitational Force
1	It acts between two charges	It acts between two masses
2	It can be attractive or repulsive	It is always attractive
3	It is always greater in magnitude	It is always lesser in magnitude
4	It depends on the nature of the medium	It is independent of the medium
5	If charges are in motion, another force called Lorentz force come in to play in addition to Coulomb force	Gravitational force is the same whether two masses are at rest or in motion
6	The value of the constant k in Coulomb law $k = 9 \times 10^9 \text{ Nm}^2 \text{ C}^{-2}$	The value of the gravitational constant $G = 6.67 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}$

11. 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.

12. Define electric field.

The electric field at a point 'P' at a distance 'r' from the point charge 'q' is the force experienced by a unit charge. **Its S.I unit is N C⁻¹**

13. Define linear charge density.

The **charge per unit length** is called linear charge density. $[\lambda = \frac{q}{l}]$
Its S.I unit is Cm^{-1}

14. Define surface charge density.

Charge per unit area is called surface charge density. $[\sigma = \frac{q}{A}]$,
Its S.I unit is Cm^{-2}

15. Define volume charge density.

Charge per unit volume is called volume charge density. $[\rho = \frac{q}{V}]$
Its S.I unit is Cm^{-3}

16. Define electric field lines.

A set of continuous lines which are the visual representation of the electric field in some region of space is called electric field lines.

17. Two electric field lines never intersect each other. Why?

If two lines cross at a point, then there will be two different electric field vectors at the same point.

If some charge is placed at the intersection point, then it has to move in two different directions at

18. What is called electric dipole? Give an example.

Two equal and opposite charges **separated by a small distance** constitute an electric dipole. **(Eg.) CO, HCl, NH₃, H₂O**

19. Define electric dipole moment. Give its unit.

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

20. Define potential difference. Give its unit.

The electric potential difference is defined as the work-done by an **external force to bring unit positive charge** from one point to another point against the electric field. **Its unit is volt (V).**

21. Define electrostatic potential. Give its unit.

The electric potential at a point is equal to the work done by an external force to bring a unit positive charge with constant velocity from infinity to the point in the region of the external electric field. **Its unit is volt (V).**

22. Obtain the relation between electric field and electric potential.

The work done in moving a unit charge through a distance 'dx' in an electric field 'E' is $dw = - E dx$

Here negative sign indicates work done is against the electric field.

This work done is equal to the potential difference and hence,

$$dv = - E dx \quad (\text{or}) \quad E = - \frac{dv}{dx}$$

Thus the electric field is the negative gradient of electric potential.

23. Define equi-potential surface.

An equi-potential surface is a surface on which all the points are at the same potential.

- 1) For a point charge the **equi-potential surfaces are concentric spherical surfaces.**
- 2) For a uniform electric field, the equi-potential surfaces form a set of planes normal to the electric field.

24. Define electrostatic potential energy.

The electric potential energy of **two point charges is equal to the amount of work-done to assemble the charges** or work-done in bringing a charge from infinite distance. (i.e) $U = W = q V$

25. Define electric flux.

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 Nm²C⁻¹.**

It is a **scalar quantity**.

26. State Gauss law.

Gauss law states that **if a charge Q is enclosed by an arbitrary closed surface, then the total electric flux ϕ_E through the closed surface is**

$$\phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{Encl}}}{\epsilon_0}$$

27. Define electrostatic shielding.

By Gauss law, we conclude that the electric field **inside the charged spherical shell is zero.**

If a conductor has cavity, then whatever the charges at the surfaces or whatever the electrical disturbances outside, **the electric field inside the cavity is zero.**

A sensitive electrical instrument which is to be protected from external electrical disturbance is kept inside this cavity. This is called electrostatic shielding. **(e.g) Faraday cage.**

28. During lightning, it is safer to sit inside bus than in an open ground or under tree. Why?

The metal body of the bus provides electrostatic shielding, where the **electric field is zero**. During lightning the **electric discharge** passes through the body of the bus.

29. Define electrostatic induction.

The phenomenon of **charging without actual contact** of charged body is called electrostatic induction.

30. Define dielectrics or insulators.

A dielectric is a **non-conducting material and has no free electrons**. The electrons in a dielectric are bound within the atoms. **(e.g) Ebonite, Glass and mica**

31. What are called non-polar molecules? Give examples.

A non-polar molecule is one in which **centres of positive and negative charges coincide**. It has no permanent dipole moment. **(e.g) H₂, O₂, CO₂**

32. What are called polar molecules? Give examples.

A polar molecule is one in which **the positive and negative charges are separated** even in the absence of an external electric field.

They have a permanent dipole moment. **(e.g) H₂O, N₂O, HCl, NH₃**

33. Define dielectric polarization.

In the presence of external electric field, dipole moment is induced in the dielectric along the direction of the field.

Polarization (\vec{p}) is defined as **the total dipole moment per unit volume** of the dielectric.

34. Define electric susceptibility.

For dielectrics, the polarization is **directly proportional to the strength of the external electric field**. (i.e) $\vec{p} = \chi_e \vec{E}_{\text{ext}}$.

where χ_e is a constant called the **electric susceptibility** which is defined as **polarization per unit electric field**. Its unit is $C^2N^{-1}m$

35. Define dielectric breakdown.

When the external electric field applied to dielectric is very large, it tears the atoms apart so that the bound charges become free charges. Then the dielectric starts to conduct electricity. This is called dielectric breakdown.

36. Define dielectric strength.

The **maximum electric field the dielectric can withstand before it breakdowns** is called dielectric strength.

The **dielectric strength of air is $3 \times 10^6 \text{ Vm}^{-1}$**

If the applied electric field is increases beyond this, a spark is produced in the air (i.e) it becomes a conductor.

37. What is called a capacitor?

Capacitor is a device **used to store electric charge and electric energy**. It consists of two conducting plates or sheets separated by some distance. Capacitors are widely used in many electronic circuits and in many areas of science and technology.

38. Define capacitance of a capacitor.

The capacitance of a capacitor is defined as **the ratio of the magnitude of charge (Q) on either of the conductor plates to the potential difference (V)** existing between the conductors. (i.e) $C = \frac{Q}{V}$. Its unit is **farad (F) or $C \text{ V}^{-1}$**

39. Define energy density of a capacitor.

The **energy stored per unit volume of space** is defined as energy density and it is derived as, $u_E = \frac{U}{\text{Volume}} = \frac{1}{2} \epsilon_0 E^2$

40. Define action of point or corona discharge.

Smaller the radius of curvature, larger the charge density. Hence charges are accumulated at the sharp points. Due to this, 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

THREE MARKS QUESTIONS AND ANSWERS

41. Discuss the 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 $n \rightarrow$ integer and $1.6 \times 10^{-19} \text{ C}$

42. Define superposition principle. Explain how superposition principle explains the interaction between multiple charges.

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.

Explanation:

Consider a system of 'n' charges q_1, q_2, \dots, q_n

By Coulomb's law, force on q_1 by q_2, \dots, q_n are

$$\vec{F}_{12} = k \frac{q_1 q_2}{r^2} \hat{r}_{21}; \vec{F}_{13} = k \frac{q_1 q_3}{r^2} \hat{r}_{31}; \text{ finally, } \vec{F}_{1n} = k \frac{q_1 q_n}{r^2} \hat{r}_{n1}$$

Then total force action on q_1 due to all charges,

$$\vec{F}_1^{\text{tot}} = \vec{F}_{12} + \vec{F}_{13} + \dots + \vec{F}_{1n};$$

$$\vec{F}_1^{\text{tot}} = k \left[\frac{q_1 q_2}{r_{21}^2} \hat{r}_{21} + \frac{q_1 q_3}{r_{31}^2} \hat{r}_{31} + \dots + \frac{q_1 q_n}{r_{n1}^2} \hat{r}_{n1} \right]$$

43. Explain Electric field at a point due to system of charges (or) Superposition of electric fields.

Superposition of electric field:

The electric field at an arbitrary point due to system of point charges is **simply equal to the vector sum of the electric fields created by the individual point charges**. This is called superposition of electric fields.

Explanation:

Consider a system of 'n' charges q_1, q_2, \dots, q_n

The electric field at 'P' due to 'n' charges

$$\vec{E}_1 = \frac{1}{4\pi\epsilon_0} \frac{q_1}{r_{1p}^2} \hat{r}_{1p}; \vec{E}_2 = \frac{1}{4\pi\epsilon_0} \frac{q_2}{r_{2p}^2} \hat{r}_{2p}; \text{ finally } \vec{E}_n = \frac{1}{4\pi\epsilon_0} \frac{q_{n1}}{r_{np}^2} \hat{r}_{np}$$

The total electric field at 'P' due to all these 'n' charges will be,

$$\vec{E}_{\text{tot}} = \vec{E}_1 + \vec{E}_2 + \dots + \vec{E}_n$$

$$\vec{E}_{\text{tot}} = \frac{1}{4\pi\epsilon_0} \left[\frac{q_1}{r_{1p}^2} \hat{r}_{1p} + \frac{q_2}{r_{2p}^2} \hat{r}_{2p} + \dots + \frac{q_n}{r_{np}^2} \hat{r}_{np} \right]$$

44. List the properties of electric field lines.

Electric field lines:

A set of continuous lines which are the visual representation of the electric field in some region of space.

Properties of electric field lines:

- 1) They starts from **positive charge and end at negative charge** or at infinity.
- 2) The electric field vector at a point in space is tangential to the electric field line at that point.
- 3) The **electric field lines are denser in a region where the electric field has larger magnitude and less dense in region where the electric field is of smaller magnitude.** (i.e) the number of lines passing through a given **surface area perpendicular to the line is proportional to the magnitude of the electric field.**
- 4) **No two electric field lines intersect** each other
- 5) The number of electric field lines that emanate from the positive charge or end at a negative charge is **directly proportional to the magnitude of the charges.**

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

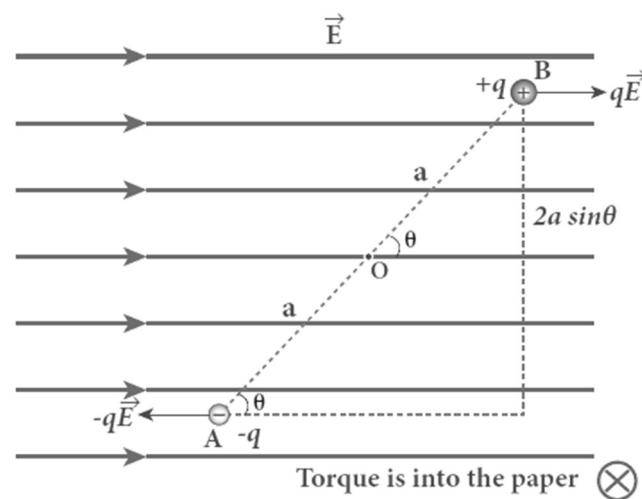
Torque experienced by the dipole in electric field:

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

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

The force on '-q' = $- q\vec{E}$

Then the total force acts on the **dipole is zero.** But these two forces constitute a couple and the dipole experience a torque which tends to rotate the dipole along the field. The total torque on the dipole about the point 'O'



$$\vec{\tau} = \overrightarrow{OA} \times (-q\vec{E}) + \overrightarrow{OB} \times (+q\vec{E}) ;$$

$$|\vec{\tau}| = |\overrightarrow{OA}| |-q\vec{E}| \sin\theta + |\overrightarrow{OB}| |q\vec{E}| \sin\theta$$

$$\tau = (OA + OB) q E \sin \theta ; \tau = 2a q E \sin \theta \quad \because [OA = OB = a]$$

$\tau = pE \sin \theta$ (Where, $2a q = p \rightarrow$ dipole moment)

In vector notation, $\vec{\tau} = \vec{p} \times \vec{E}$. **The torque is maximum, when $\theta = 90^\circ$**

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

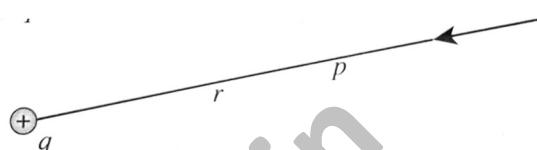
Potential due to a point charge:

Consider a point charge $+q$ at origin.

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

By definition, the electric field at 'P'

$$\text{is } \vec{E} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{r}$$



$$\text{Hence electric potential at 'P' is } V = - \int_{\infty}^r \vec{E} \cdot d\vec{r} = - \int_{\infty}^r \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{r} \cdot d\vec{r}$$

$$V = - \int_{\infty}^r \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{r} \cdot dr \hat{r} \quad [\because d\vec{r} = dr \hat{r}]$$

$$V = - \frac{q}{4\pi\epsilon_0} \int_{\infty}^r \frac{1}{r^2} dr \quad [\because \hat{r} \cdot \hat{r} = 1]$$

$$V = - \frac{q}{4\pi\epsilon_0} \left[-\frac{1}{r} \right]_{\infty}^r ; = \frac{q}{4\pi\epsilon_0} \left[\frac{1}{r} - \frac{1}{\infty} \right]$$

$V = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$. If the source charge is negative ($-q$), then the potential also negative and it is given by $V = - \frac{1}{4\pi\epsilon_0} \frac{q}{r}$

- 47. Obtain an expression for potential energy due to a collection of three point charges which are separated by finite distances.**

Potential energy of system of three charges:

Electrostatic potential energy of a system of charges is defined as the work done to assemble the charges.

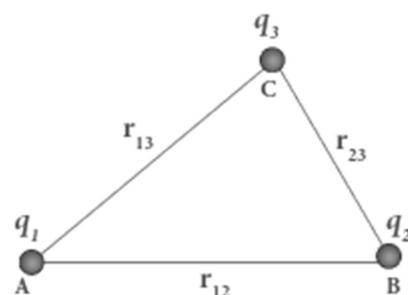
Consider a point charge q_1 at 'A'

Electric potential at 'B' due to q_1 is,

$$V_{1B} = \frac{1}{4\pi\epsilon_0} \frac{q_1}{r_{12}}$$

To bring second charge q_2 to 'B', work has to be done against the electric field created by q_1

$$\text{The work done on the charge } q_2 \text{ is, } w = q_2 V_{1B} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r_{12}}$$



This work done is stored as electrostatic potential energy of system of two charges q_1 and q_2 $U = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r_{12}}$ (1)

The potential at 'C' due to charges q_1 & q_2

$$V_{1C} = \frac{1}{4\pi\epsilon_0} \frac{q_1}{r_{13}} \quad \& \quad V_{2C} = \frac{1}{4\pi\epsilon_0} \frac{q_2}{r_{23}}$$

To bring third charge q_3 to 'C', work has to be done against the electric field due to q_1 & q_2 .

Thus work done on charge q_3 is,

$$W = q_3 (V_{1C} + V_{2C}) = q_3 \frac{1}{4\pi\epsilon_0} \left[\frac{q_1}{r_{13}} + \frac{q_2}{r_{23}} \right] \quad (\text{or}) \quad U = \frac{1}{4\pi\epsilon_0} \left[\frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}} \right] \quad \dots \dots \dots (2)$$

Hence the total electrostatic potential energy of system of three point charges is $U = \frac{1}{4\pi\epsilon_0} \left[\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}} \right]$ (3)

- 48. Obtain an expression for electrostatic potential Energy of a dipole in a uniform electric field.**

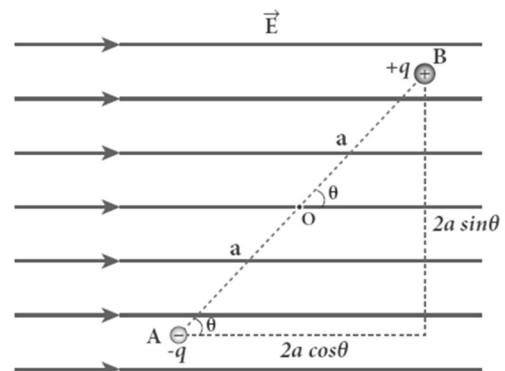
Potential energy of dipole in uniform electric field:

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

Here the dipole experiences torque, which rotates the dipole along the field.

To rotate the dipole from θ' to θ against this torque, work has to be done by an external torque (τ_{ext}) and it is given by,

$$\begin{aligned} W &= \int_{\theta'}^{\theta} \tau_{ext} d\theta \\ &= \int_{\theta'}^{\theta} pE \sin\theta d\theta; \\ &= pE [-\cos\theta]_{\theta'}^{\theta} \\ &= -pE [\cos\theta - \cos\theta'] ; \quad W = pE [\cos\theta' - \cos\theta] \end{aligned}$$



This work done is stored as electrostatic potential energy of the dipole.

Let the initial angle be $\theta' = 90^\circ$, then $U = W = pE [\cos 90^\circ - \cos \theta]$

$$U = -pE \cos \theta ; \quad -\vec{p} \cdot \vec{E}$$

If $\theta = 180^\circ$, then potential energy is maximum

If $\theta = 0^\circ$, then potential energy is minimum

49. Explain the process of electrostatic induction.

Electrostatic induction:

The type of charging without actual contact of charged body is called electrostatic induction. Let a **negatively charged rubber rod** is brought near to spherical conductor, the electrons in the conductor are **repelled** to farther side and hence positive charges are induced near the region of the rod. So the distributions of charges are not uniform, but the total charge is zero

If the **conducting sphere is connected to ground**, the **electrons are flows to the ground**, but the positive charges will not flow to the ground, because they are attracted by the negative charges of the rod.

When the **grounding wire is removed** from the sphere, the **positive charges remain near the rod**.

If the **charged rod is taken away**, the **positive charges are distributed uniformly on the surface** of the sphere. Thus the neutral conducting sphere becomes positively charged without any contact.

50. 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,

$$E = \frac{\sigma}{\epsilon_0} = \frac{Q}{A \epsilon_0} \quad \dots \dots \dots (1)$$

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

$$V = E.d = \left[\frac{Q}{A \epsilon_0} \right] d \quad \dots \dots \dots (2)$$

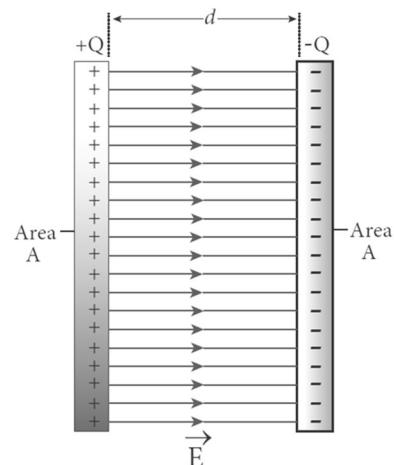
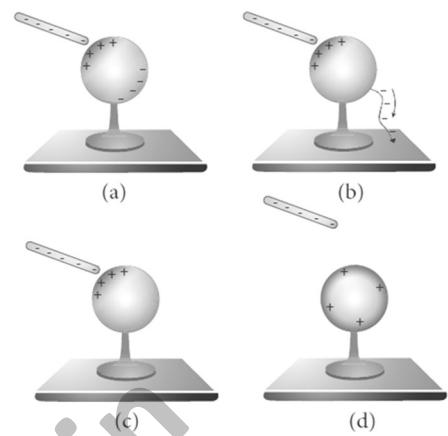
Then the capacitance of the capacitor,

$$C = \frac{Q}{V} = \frac{Q}{\left[\frac{Q}{A \epsilon_0} \right] d}$$

$$C = \frac{\epsilon_0 A}{d} \quad \dots \dots \dots (3)$$

Thus capacitance is,

- (i) **Directly proportional to the Area (A) and**
- (ii) **Inversely proportional to the separation (d)**



51. 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

$$dW = VdQ = \frac{Q}{C} dQ \quad [\because V = \frac{Q}{C}]$$

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)

$$U_E = \frac{Q^2}{2C} = \frac{1}{2} CV^2 \quad [\because Q = CV]$$

Where, know that $V = Ed$ and $C = \frac{\epsilon_0 A}{d}$

$$\therefore U_E = \frac{1}{2} \frac{\epsilon_0 A}{d} (Ed)^2 ; = \frac{1}{2} \epsilon_0 (Ad) E^2$$

(Ad) → Volume

The energy stored per unit volume of space is defined as energy density (u_E)

$$u_E = \frac{U_E}{\text{volume}} ; \quad u_E = \frac{1}{2} \epsilon_0 E^2$$

52. Explain in detail how charges are distributed in a conductor and the principle behind the lightning conductor.

Distribution of charges in a conductor:

Consider two conducting spheres ‘A’ and ‘B’ of radii r_1 and r_2 .

Let $r_1 > r_2$. Let the two spheres are connected by a thin conducting wire.

If a charge ‘Q’ is given to either A or B, this charge is redistributed in both the spheres until their potential becomes same.

Now they are uniformly charged and attain electrostatic equilibrium.

At this stage, let the surface charge densities of A and B are σ_1 and σ_2 respectively, then

$$\text{Charge residing on surface of A} = q_1 = \sigma_1 4\pi r_1^2$$

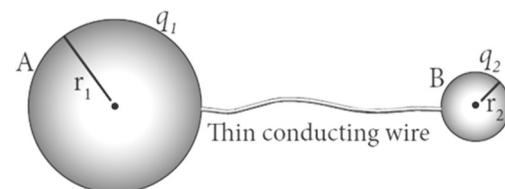
$$\text{Charge residing on surface of B} = q_2 = \sigma_2 4\pi r_2^2$$

$$\text{Then the total charge; } Q = q_1 + q_2$$

There is no net charge inside the conductors.

Electrostatic potential on the surface of A and B is

$$V_A = \frac{1}{4\pi\epsilon_0} \frac{q_1}{r_1} \quad \text{and} \quad V_B = \frac{1}{4\pi\epsilon_0} \frac{q_2}{r_2}$$



Under electrostatic equilibrium, $V_A = V_B$

$$\therefore \frac{1}{4\pi\epsilon_0} \frac{q_1}{r_1} = \frac{1}{4\pi\epsilon_0} \frac{q_2}{r_2};$$

$$\frac{q_1}{r_1} = \frac{q_2}{r_2}; \frac{\sigma_1 4\pi r_1^2}{r_1} = \frac{\sigma_2 4\pi r_2^2}{r_2}$$

$$\sigma_1 r_1 = \sigma_2 r_2$$

(or) σ = Constant. Thus **the surface charge density is inversely proportional to the radius of the sphere.**

Hence for **smaller radius, the charge density will be larger** and vice versa.

Principle of lightning conductor (Action of point):

Action of point is the principle behind the **lightning conductor**. We know that **smaller the radius of curvature, the larger is the charge density**. If the **conductor has sharp end** which has **larger curvature (smaller radius)**, it has a large charge accumulation. As a result, the electric field near this edge is very high and it ionizes the surrounding air. The positive ions are repelled at the sharp edge and negative ions are attracted towards the sharper edge. This **reduces the total charge of the conductor near the sharp edge. This is called action of points or corona discharge.**

53. Explain the principle, construction and action of lightning conductor.

Lightning conductor:

This is a device **used to protect tall building from lightning strikes**; It works on the principle of **action of points or corona discharge**. It consists of a long thick copper rod passing from top of the building to the ground. The upper end of the rod has a sharp spike or a sharp needle.

The lower end of the rod is **connected to the copper plate** which is buried deep in to the ground. When a negatively charged cloud is passing above the building, it induces a positive charge on the spike. Since the charge density is large at the spike, action of point takes place.

This positive charge ionizes the surrounding air which in turn neutralizes the negative charge in the cloud. The negative charge pushed to the spikes passes through the **copper rod and is safely diverted to the Earth**. Thus the lightning arrester does not stop the lightning, but it diverts the lightning to the ground safely

54. Give the applications and disadvantage of capacitors.

Applications of capacitors.

- (a) Flash capacitors are used in digital cameras for **taking photographs**. The flash which comes from the camera when we take photographs is due to **the energy released from the capacitor**, called a flash capacitor.
- (b) 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.
- (c) Capacitors are used in the **ignition system of automobile engines** to eliminate sparking
- (d) Capacitors are used to **reduce power fluctuations in power supplies** and to increase the efficiency of power transmission.

Disadvantage of capacitors.

Even after the battery or power supply is removed, the capacitor stores charges and energy for some time. For example, if the TV is switched off, it is always advisable to **not touch the back side of the TV panel**.

55. Define equipotential surface. Give its properties.

Equipotential surface:

1. An equipotential surface is a **surface on which all the points** are at the **same potential**.
2. For a **point charge** the equipotential surfaces are **concentric spherical** surfaces.
3. For a **uniform electric field**, the equipotential surfaces form a set of **planes** normal to the electric field.

Properties:

The work-done to move a charge 'q' between any two points A and B is $W = q(V_A - V_B)$. If A and B lie on the same equipotential surface, then $V_A = V_B$ Hence work done is zero ($W = 0$). The electric field is always normal to an equipotential surface.

56. Write a note on microwave oven.

Microwave oven:

It works on the principle of **torque acting on an electric dipole**. The food we consume has water molecules which are permanent electric dipoles. Oven produces microwaves that are **oscillating electromagnetic fields** and produce torque on the water molecules. Due to this torque on each water molecule, the molecules **rotate very fast and produce thermal energy**. Thus, heat generated is used to heat the food.

FIVE MARKS QUESTIONS AND ANSWERS

- 57. Explain in detail Coulomb's law and its various aspects.**

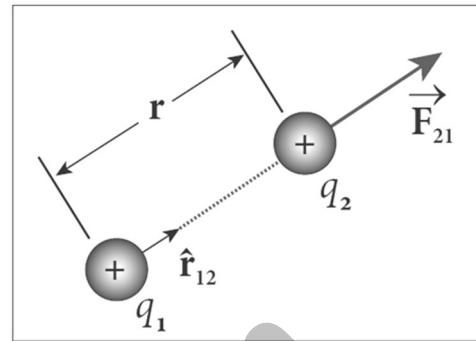
Coulomb's law:

Consider two point charges q_1 and q_2 separated by a distance 'r'

According to Coulomb law, the force on the point charge q_2 exerted by q_1 is

$$\vec{F}_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12} \text{ where, } k \rightarrow \text{constant}$$

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



Important aspects:

Coulomb law states that the electrostatic force is **directly proportional** to the **product of the magnitude of two point charges** and **inversely proportional to the square of the distance** between them. The forces always lie along the line joining the two charges.

In SI units, $k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ Nm}^2 \text{ C}^{-2}$. Here ϵ_0 is the permittivity of free space or

vacuum and its value is $\epsilon_0 = \frac{1}{4\pi k} = 8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$

The **magnitude of electrostatic force between two charges each of 1 C and separated by a distance of 1 m is $9 \times 10^9 \text{ N}$**

The Coulomb laws in vacuum and in medium are,

$$\vec{F}_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12} \text{ and } \vec{F}_{21} = \frac{1}{4\pi\epsilon} \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

where, $\epsilon = \epsilon_0 \epsilon_r \rightarrow$ permittivity of the medium. Thus the relative permittivity of the given medium is defined as, $\epsilon_r = \frac{\epsilon}{\epsilon_0}$. For air or vacuum, $\epsilon_r = 1$

and for all other media $\epsilon_r > 1$

Coulomb's law has same structure as Newton's law of gravitation.

$$(\text{i.e}) F_{\text{Coulomb}} = k \frac{q_1 q_2}{r^2} \text{ and } F_{\text{Newton}} = G \frac{m_1 m_2}{r^2}$$

Here $k = 9 \times 10^9 \text{ Nm}^2 \text{ C}^{-2}$ and $G = 6.626 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}$

Since 'k' is much greater than 'G', the electrostatic force is always greater than gravitational force for smaller size objects. Electrostatic force between two point charges depends on the nature of the medium in which two charges are kept at rest.

Depending upon the nature of the charges, it may either be attractive or repulsive.

If the charges are in motion, another force called Lorentz force come in to play in addition with Coulomb force. Electrostatic force obeys Newton's third law. (i.e) $\vec{F}_{21} = -\vec{F}_{12}$

58. Define electric field. Explain its various aspects.

Electric field:

The electric field at the point 'P' at a distance 'r' from the point charge 'q' is the force experienced by a unit charge and is given by

$$\vec{E} = \frac{\vec{F}}{q_0}; \vec{E} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{r}$$

Important aspects:

If 'q' is positive, the electric field points away and if 'q' is negative the electric field points towards the source charge. The force experienced by the test charge q_0 placed in electric field \vec{E} is, $\vec{F} = q_0 \vec{E}$

The electric field is independent of test charge q_0 and it depends only on source charge q

Electric field is a vector quantity. So it has unique direction and magnitude at every point. SI unit is newton per coulomb (NC^{-1}).

Since **electric field is inversely proportional to the distance, as distance increases the field decreases.** The test charge is made sufficiently small such that it will not modify the electric field of the source charge.

For continuous and finite size charge distributions, integration techniques must be used. There are two kinds of electric field. They are (1) Uniform or constant field, (2) Non uniform field.

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

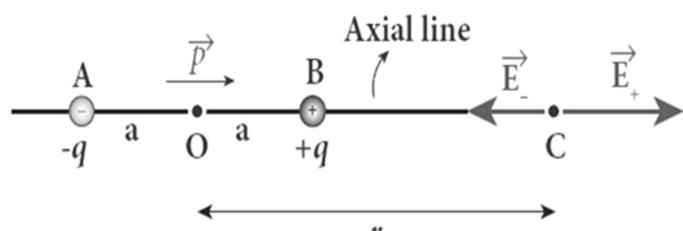
Electric field due to dipole on its axial line:

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 $+q$

$$\vec{E}_+ = \frac{1}{4\pi\epsilon_0} \frac{q}{(r-a)^2} \hat{p}$$



Electric field at C due to $-q$

$$\vec{E}_- = -\frac{1}{4\pi\epsilon_0} \frac{q}{(r+a)^2} \hat{p}$$

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,

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

$$\vec{E}_{\text{tot}} = \frac{1}{4\pi\epsilon_0} \frac{q}{(r-a)^2} \hat{p} - \frac{1}{4\pi\epsilon_0} \frac{q}{(r+a)^2} \hat{p}$$

$$\vec{E}_{\text{tot}} = \frac{1}{4\pi\epsilon_0} q \left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2} \right] \hat{p};$$

$$\vec{E}_{\text{tot}} = \frac{1}{4\pi\epsilon_0} q \left[\frac{(r+a)^2 - (r-a)^2}{(r-a)^2 (r+a)^2} \right] \hat{p}$$

$$\vec{E}_{\text{tot}} = \frac{1}{4\pi\epsilon_0} q \left[\frac{r^2 + a^2 + 2ra - r^2 - a^2 + 2ra}{((r-a) - (r+a))^2} \right] \hat{p}$$

$$\vec{E}_{\text{tot}} = \frac{1}{4\pi\epsilon_0} q \left[\frac{4ra}{(r^2 - a^2)^2} \right] \hat{p}$$

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

If $r \gg a$, then neglecting a^2 . We get $\vec{E}_{\text{tot}} = \frac{1}{4\pi\epsilon_0} q \left[\frac{4ra}{r^4} \right] \hat{p}$;

$$= \frac{1}{4\pi\epsilon_0} q \left[\frac{4a}{r^3} \right] \hat{p}$$

$$\vec{E}_{\text{tot}} = \frac{1}{4\pi\epsilon_0} \frac{2\vec{p}}{r^3} \quad [q 2a\hat{p} = \vec{p}]$$

60. 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 $p = 2qa$ 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. 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)

$$|\vec{E}_+| = \frac{1}{4\pi\epsilon_0} \frac{q}{(r^2 + a^2)}$$

Electric field at C due to $-q$ (along CA)

$$|\vec{E}_-| = \frac{1}{4\pi\epsilon_0} \frac{q}{(r^2 + a^2)}$$

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

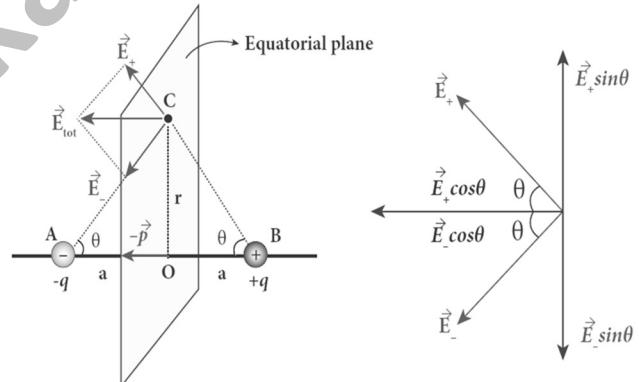
Here the **perpendicular components** $|\vec{E}_+| \sin\theta$ and $|\vec{E}_-| \sin\theta$ are **equal** and **opposite will cancel** each other.

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

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

$$\vec{E}_{\text{tot}} = -2 \left[\frac{1}{4\pi\epsilon_0} \frac{q}{(r^2 + a^2)} \right] \cos\theta \hat{p} ;$$

$$\vec{E}_{\text{tot}} = - \left[\frac{1}{4\pi\epsilon_0} \frac{2q}{(r^2 + a^2)} \right] \frac{a}{(r^2 + a^2)^{\frac{1}{2}}} \hat{p}$$



$$\begin{aligned}\vec{E}_{\text{tot}} &= -\frac{1}{4\pi\epsilon_0} \frac{2qa}{(r^2+a^2)^{\frac{3}{2}}} \hat{p}; \quad \vec{E}_{\text{tot}} = -\frac{1}{4\pi\epsilon_0} \frac{p\hat{p}}{(r^2+a^2)^{\frac{3}{2}}} \\ &= -\frac{1}{4\pi\epsilon_0} \frac{\vec{p}}{(r^2+a^2)^{\frac{3}{2}}} \quad . \text{ If } r > a \text{ then neglecting } a^2 \\ \vec{E}_{\text{tot}} &= -\frac{1}{4\pi\epsilon_0} \frac{\vec{p}}{r^3} \quad [q \cdot 2a\hat{p} = p \cdot \hat{p} = \vec{p}]\end{aligned}$$

61. 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 $+q$

$$V_1 = \frac{1}{4\pi\epsilon_0} \frac{q}{r_1}$$

Electric potential at P due to $-q$

$$V_2 = -\frac{1}{4\pi\epsilon_0} \frac{q}{r_2}$$

Then total potential at 'P' due to dipole is

$$\begin{aligned}V &= V_1 + V_2 \\ &= \frac{1}{4\pi\epsilon_0} q \left[\frac{1}{r_1} - \frac{1}{r_2} \right] \dots\dots\dots (1)\end{aligned}$$

Apply cosine law in ΔBOP

$$r_1^2 = r^2 + a^2 - 2ra \cos\theta;$$

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

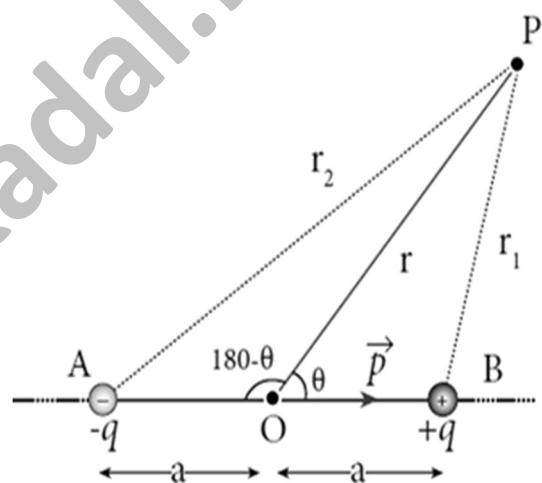
If $a \ll r$ then neglecting $\frac{a^2}{r^2}$;

$$r_1^2 = r^2 \left[1 - \frac{2a}{r} \cos\theta \right]$$

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

$$\frac{1}{r_1} = \frac{1}{r} \left[1 - \frac{2a}{r} \cos\theta \right]^{-\frac{1}{2}}$$

$$\frac{1}{r_1} = \frac{1}{r} \left[1 + \frac{a}{r} \cos\theta \right] \dots\dots\dots (2)$$



Apply cosine law in ΔAOP

$$r_2^2 = r^2 + a^2 + 2ra \cos(180^\circ - \theta);$$

$$r_2^2 = r^2 \left[1 + \frac{a^2}{r^2} + \frac{2a}{r} \cos \theta \right]$$

If $a \ll r$ then neglecting $\frac{a^2}{r^2}$;

$$r_2^2 = r^2 \left[1 + \frac{2a}{r} \cos \theta \right]$$

$$r_2 = r \left[1 + \frac{2a}{r} \cos \theta \right]^{\frac{1}{2}} ; \quad \frac{1}{r_2} = \frac{1}{r} \left[1 + \frac{2a}{r} \cos \theta \right]^{-\frac{1}{2}}$$

$$\frac{1}{r_2} = \frac{1}{r} \left[1 - \frac{a}{r} \cos \theta \right] \quad \dots \dots \dots (3)$$

$$V = \frac{1}{4\pi\varepsilon_0} q \left(\frac{1}{r} \left[1 + \frac{a}{r} \cos \theta \right] - \frac{1}{r} \left[1 - \frac{a}{r} \cos \theta \right] \right)$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r} \left[1 + \frac{a}{r} \cos\theta - \left[1 + \frac{a}{r} \cos\theta \right] \right]$$

$$V = \frac{1}{4\pi\epsilon_0} \frac{q}{r} \frac{2a}{r} \cos\theta ;$$

$$= \frac{1}{4\pi} \frac{2qa}{r^2} \cos \theta$$

$$= \frac{1}{4\pi\epsilon_0} \frac{p}{r^2} \cos\theta \quad [p = 2qa]$$

$$\text{Or } V = \frac{1}{4\pi\epsilon_0} \frac{\vec{p} \cdot \hat{r}}{r^2} \quad [\vec{p} \cos \theta = \vec{p} \cdot \hat{r}]$$

Here $\hat{\mathbf{r}}$ is the unit vector along OP

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 $V = \frac{1}{4\pi\epsilon_0} \frac{p}{r^2}$

Case (ii)

If the point P lies on the **axial line** of the dipole on the side of $-q$, then

$$\theta = 180^\circ, \text{ then } V = -\frac{1}{4\pi\epsilon_0} \frac{p}{r^2}$$

Case (iii)

If the point P lies on the **equatorial line** of the dipole, the $\theta = 90^\circ$. Hence $V = 0$

62. 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**,

$$\Phi_{\text{top}} = \int \vec{E} \cdot d\vec{A} = \int E dA \cos 90^\circ = 0$$

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

$$\Phi_{\text{bottom}} = \int \vec{E} \cdot d\vec{A} = \int E dA \cos 90^\circ = 0$$

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

$$\Phi_{\text{curve}} = \int \vec{E} \cdot d\vec{A} = \int E dA \cos 0^\circ = E \int dA$$

$$\Phi_{\text{curve}} = E 2\pi r L$$

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

$$\Phi_E = \Phi_{\text{top}} + \Phi_{\text{bottom}} + \Phi_{\text{curve}} ; \Phi_E = E (2\pi r L)$$

$$\text{By Gauss law, } \Phi_E = \frac{Q_{\text{in}}}{\epsilon_0} ; E (2\pi r L) = \frac{\lambda L}{\epsilon_0} ;$$

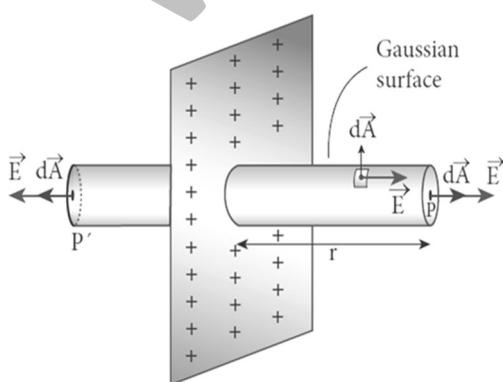
$$E = \frac{\lambda}{2\pi\epsilon_0 r} \quad \text{In vector notation, } \vec{E} = \frac{\lambda}{2\pi\epsilon_0 r} \hat{r}$$

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 ($-\hat{r}$).

63. Obtain an expression for electric field due to an charged infinite plane sheet.

Electric field due to charged infinite plane sheet:



Consider an infinite plane sheet of uniform surface charge density ' σ '. Let 'P' be a point at a distance 'r' from the sheet. Let 'E' be the electric field at 'P'. Here the direction of electric field is perpendicularly outward from the sheet. Consider a cylindrical Gaussian surface of length '2r' and area of cross section 'A'.

The electric flux through plane surface 'P'

The electric flux through the curved surface, The total electric flux through the **plane surface 'P'**

$$\phi_P = \int \vec{E} \cdot \vec{dA} = \int E dA \cos 0^\circ = \int E dA$$

The total electric flux through the **plane surface 'P'**

$$\phi_{P'} = \int \vec{E} \cdot \vec{dA} = \int E dA \cos 0^\circ = \int E dA$$

The total electric flux through the curved surface,

$$\phi_{\text{curve}} = \int \vec{E} \cdot \vec{dA} = \int E dA \cos 90^\circ = 0$$

The total electric flux through the Gaussian surface,

$$\phi_E = \phi_P + \phi_{P'} + \phi_{\text{curve}}$$

$$\phi_F = \int E dA + \int E dA + 0; = 2E \int dA; \phi_E = 2EA$$

$$\text{By Gauss law, } \phi_E = \frac{Q_{\text{in}}}{\epsilon_0}; 2EA = \frac{\sigma A}{\epsilon_0}; E = \frac{\sigma}{2\epsilon_0}$$

In vector notation, $\vec{E} = \frac{\sigma}{2\epsilon_0} \hat{n}$

Here $\hat{n} \rightarrow$ unit vector perpendicular to the plane sheet outwards.

If $\sigma > 0$, then \vec{E} points perpendicular outward (\hat{n}) from the plane sheet and if $\sigma < 0$, then \vec{E} points perpendicular inward ($-\hat{n}$)

- 64. Obtain an expression for electric field due to an uniformly charged spherical shell.**

Electric field due to charged spherical shell:

Consider a uniformly charged spherical shell of radius 'R' and charge 'Q'

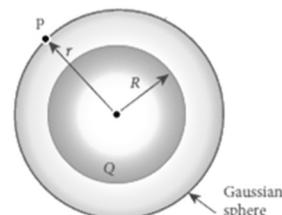
1) At a point outside the shell ($r > R$):

Let P be the point outside the shell at a distance 'r' from its centre. Here electric field points radically outwards if $Q > 0$ and radically inward if $Q < 0$. Consider a spherical Gaussian surface of radius 'r' which encloses the total charge 'Q'. Since \vec{E} and \vec{dA} are along radically outwards, we have $\theta = 0^\circ$.

The electric flux through the Gaussian surface,

$$\phi_E = \oint \vec{E} \cdot \vec{dA} ; = \oint E dA \cos 0^\circ$$

$$\phi_E = E \oint dA ; = E (4\pi r^2)$$



$$\text{By Gauss law, } \phi_E = \frac{Q_{\text{in}}}{\epsilon_0}; E (4\pi r^2) = \frac{Q}{\epsilon_0}; E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$$

In vector notation, $\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \hat{r}$

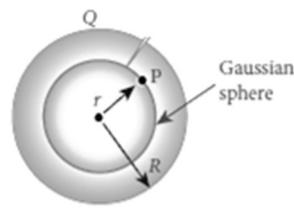
Here $\hat{r} \rightarrow$ unit vector acting radically h outward from the spherical surface.

2) At a point on the surface of the shell ($r = R$):

If the point lies on the surface of the charged shell, then $r = R$. Then the electric field, $\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{Q}{R^2} \hat{r}$

3) At a point inside the shell ($r < R$) :

Let 'P' be the point inside the charged shell at a distance 'r' from its centre. Consider the spherical Gaussian surface of radius 'r'. Since there is no charge inside the Gaussian surface, $Q = 0$.



$$\text{Then from Gauss law, } \phi_E - \oint \vec{E} \cdot d\vec{A} = \frac{Q_{in}}{\epsilon_0}; E(4\pi r^2) = 0; \vec{E} = 0$$

Thus the electric field due to the uniform charged spherical shell is zero at all points inside the shell.

65. Obtain Gauss law from Coulomb's law.

Gauss law from Coulomb's law:

Consider a charged particle of charge '+q'

Draw a Gaussian spherical surface of radius 'r' around this charge.

Due to symmetry, the electric field \vec{E} at all the points on the spherical surface have same magnitude and radially outward in direction.

If a test charge ' q_0 ' is placed on the Gaussian surface,

$$\text{by Coulomb law the force acting it is, } |\vec{F}| = \frac{1}{4\pi\epsilon_0} \frac{Qq_0}{r^2}$$

$$\text{By definition, the electric field, } |\vec{E}| = \frac{|\vec{F}|}{q_0} = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \dots\dots\dots (1)$$

Since the area element is along the electric field, we have $\theta = 0^\circ$.

Hence the electric flux through the Gaussian surface is,

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \oint E dA \cos 0^\circ = E \oint dA$$

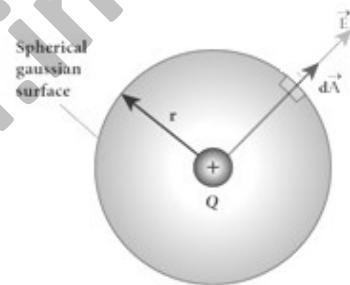
Here $\oint dA = 4\pi r^2 \rightarrow \text{area of Gaussian sphere. put in equation (1)}$

$$\Phi_E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \times 4\pi r^2 ; \therefore \Phi_E = \frac{Q}{\epsilon_0} \text{. This is known as Gauss law.}$$

Result:

The total electric flux through the closed surface depends only on the charges enclosed by the surface and independent of charges outside the surface. The **total electric flux is independent of the location of charges** inside the closed surface and shape on the closed surface.

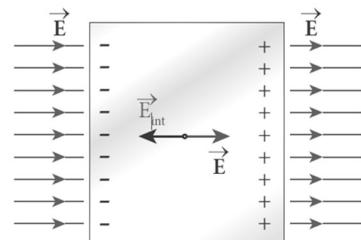
Gauss law is another form of Coulomb law and also applicable to charges in motion.



66. Discuss the various properties of conductors in electrostatic equilibrium.

Properties of conductors in electrostatic equilibrium:

An electrical conductor has a large number of mobile charges which are free to move in the material. The resultant motion is zero and it implies that the conductor is in electrostatic equilibrium. Thus at electrostatic equilibrium, there is no net current in the conductor.



A conductor at electrostatic equilibrium has the following properties.

Property - 1:

The electric field is zero everywhere inside the conductor. This is the regardless of whether the conductor is solid or hollow.

The electric field is not zero inside the metal, and then there will be a force on the mobile charge carriers due to this electric field.

As a result, there will be a net motion of the mobile charges, which contradicts the conductors being in electrostatic equilibrium. Thus the electric field is zero everywhere inside the conductor.

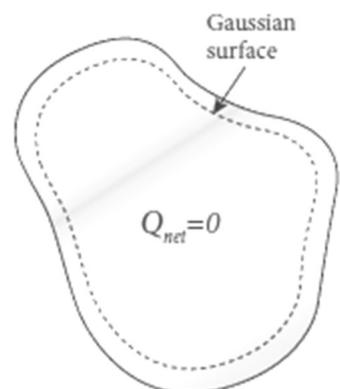
Property - 2:

There is no net charge inside the conductors. The charges must reside only on the surface of the conductors.

From Gauss's law, this implies that there is no net charge inside the conductor. Even if some charge is introduced inside the conductor, it immediately reaches the surface of the conductor.

Property - 3:

The electric field outside the conductor is perpendicular to the surface of the conductor and has a magnitude of $\frac{\sigma}{\epsilon_0}$, where σ is the surface charge density at that point.



If the electric field has components parallel to the surface of the conductor, then free electrons on the surface of the conductor would experience acceleration. This means that the conductor is not in equilibrium.

Therefore, at electrostatic equilibrium, the electric field must be perpendicular to the surface of the conductor.

For cylindrical Gaussian surface, the total electric flux is $\phi_E = EA$ and the total charge inside the surface is $Q = \sigma A$

$$\text{By Gauss law, } \phi_E = \frac{Q}{\epsilon_0} \therefore EA = \frac{\sigma A}{\epsilon_0} \text{ (or) } E = \frac{\sigma}{\epsilon_0}$$

$$\text{In vector notation, } \vec{E} = \frac{\sigma}{\epsilon_0} \hat{n}$$

Property - 4:

The electrostatic potential has the same value on the surface and inside of the conductor. The conductor has no parallel electric component on the surface which means that charges can be moved on the surface without doing any work.

This is possible only if the **electrostatic potential is constant at all points** on the surface and **there is no potential difference between any two points on the surface**.

Since the **electric field is zero inside the conductor, the potential is the same** as the surface of the conductor. Thus at electro static equilibrium, the conductor is always at equipotential.

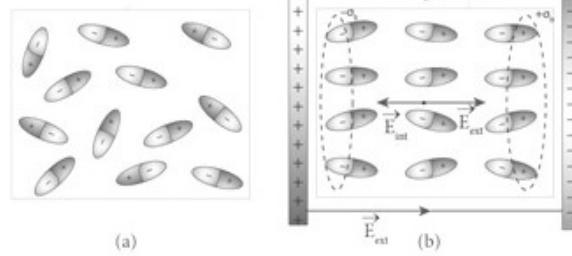
- 67. Explain dielectrics in detail and how an electric field is induced inside a dielectric.**

Electric field induced inside a dielectric:

When an **external electric field is applied on a conductor, the charges are aligned in such a way that an internal electric field** is created which cancels the external electric field. But in dielectric, **which has no free electrons**, the external electric field only realigns the charges so that an internal electric field is produced.

The magnitude of the internal electric field is smaller than that of external electric field.

Therefore, **the net electric field inside the dielectric field is not zero, but is parallel to an external electric field with magnitude less than that of the external electric field.**



For example, let a rectangular dielectric slab is placed between two oppositely charged plates. The uniform electric field between the plate's acts as the external electric field \vec{E}_{ext} which polarizes the dielectric slab, thus positive charges are induced on one side and negative charges are induced on the other side of the slab.

So the dielectric in the external field is equivalent to two oppositely charged sheets with the surface charge densities. These charges are called **bound charges**. They are not free to move like free electrons in conductor.

- 68. 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.

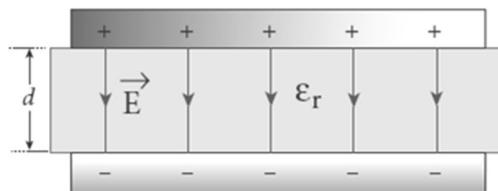
Area of each plates = A,

Distance between the plates = d,

Voltage of battery = V_0

Total charge on the capacitor = Q_0 . So the

capacitance of capacitor without dielectric, $C_0 = \frac{Q_0}{V_0}$.



The battery is then disconnected from the capacitor and the dielectric is **inserted between the plates. This decreases the electric field.**

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

Relative permittivity or dielectric constant = ϵ_r

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

Hence electrostatic potential between the plates is reduced and at the same time the charge Q_0 remains constant.

$$V = Ed ; = \frac{E_0}{\epsilon_r} d ; = \frac{V_0}{\epsilon_r}$$

Then the **capacitance of a capacitor with dielectric**,

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

Since $\epsilon_r > 1$, we have $C > C_0$.

Thus **insertion of dielectric slab increases the capacitance.**

$$\text{We have, } C_0 = \frac{\epsilon_0 A}{d} ; C = \frac{\epsilon_r \epsilon_0 A}{d} ; C = \frac{\epsilon A}{d}$$

Where, $\epsilon_r \epsilon_0 = \epsilon \rightarrow$ permittivity of the dielectric medium.

The **energy stored in the capacitor without dielectric**,

$$U_0 = \frac{1}{2} \frac{Q_0^2}{C_0} ; \text{ after the dielectric is inserted,}$$

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

Since $\epsilon_r > 1$, 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.

- 69. Explain in detail the effect of dielectric placed in a parallel plate capacitor when the battery remains connected to the capacitor.**

Effect of dielectrics when the battery remains connected to the capacitor:

Consider a parallel plate capacitor.

Area of each plates = A, Distance between the plates = d

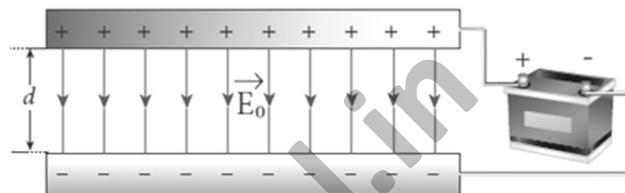
Voltage of battery = V_0

Total charge on the capacitor = Q_0

So the capacitance of capacitor without dielectric,

$$C_0 = \frac{Q_0}{V_0}$$

Dielectric is inserted between the plates and the battery is remains in connected with the capacitor. So the charge stored in the capacitor is increased.



Total charge without dielectric = Q_0

Total charge with dielectric = Q ,

Relative permittivity (dielectric constant) = ϵ_r

$$\therefore Q = \epsilon_r Q_0 \quad \text{Since } \epsilon_r > 1, \text{ we have } Q < Q_0$$

Here the **potential difference between the plates remains constant**.

But the **charges increase** and the new capacitance will be

$$C = \frac{Q}{V_0} ; = \frac{\epsilon_r Q_0}{V_0} ; = \epsilon_r C_0$$

Since $\epsilon_r > 1$, we have $C > C_0$

Hence capacitance increases with the insertion of dielectric slab.

$$\text{We know that, } C_0 = \frac{\epsilon_0 A}{d}. \therefore C = \frac{\epsilon_r \epsilon_0 A}{d} ; = \frac{\epsilon A}{d}$$

Where, $\epsilon_r \epsilon_0 = \epsilon \rightarrow$ permittivity of the dielectric medium

$$\text{The energy stored in the capacitor without dielectric, } U_0 = \frac{1}{2} C_0 V_0^2$$

$$\text{After the dielectric is inserted, } U = \frac{1}{2} C V_0^2 ; = \frac{1}{2} \epsilon_r C_0 V_0^2 ; = \epsilon_r U_0$$

Since $\epsilon_r > 1$, we have $U > U_0$

So there is increase in energy when the dielectric is inserted.

- 70.** 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_3 be the potential difference across C_1 , C_2 , C_3 respectively, then $\mathbf{V} = V_1 + V_2 + V_3$

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

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

Let C_s be the equivalent capacitance of capacitor in series connection, then

$$V = \frac{Q}{C_s} \dots\dots\dots (2)$$

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:

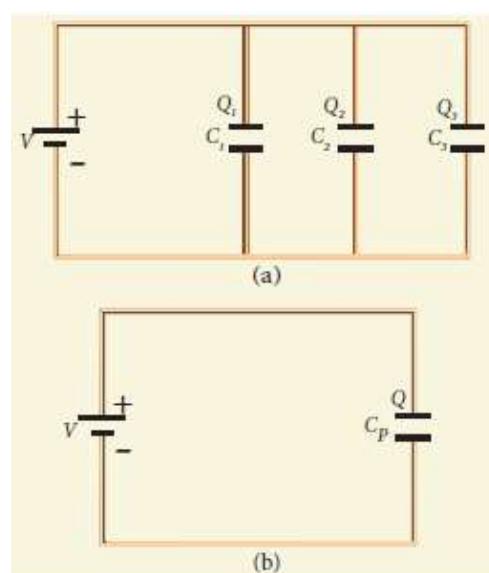
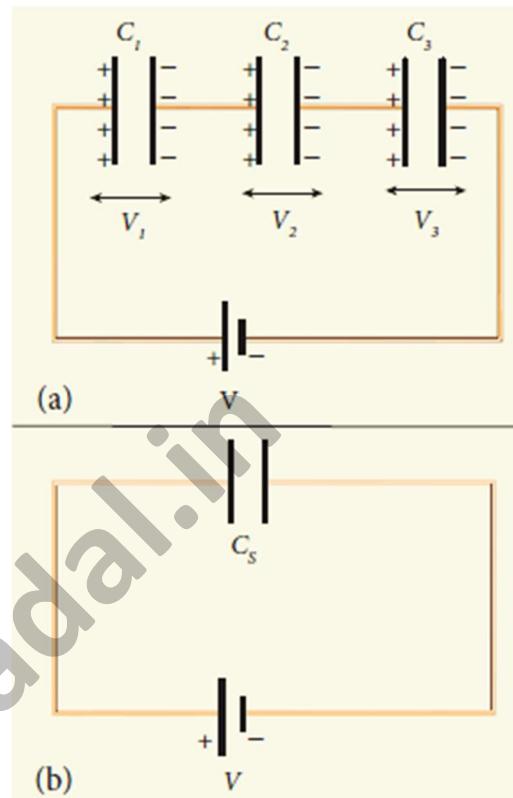
Consider three capacitors of capacitance C_1 , C_2 and C_3 connected in parallel with a battery of voltage V .

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_3 be the charge on C_1 , C_2 , C_3 respectively, then

$$\mathbf{Q} = Q_1 + Q_2 + Q_3$$



$$Q = C_1 V + C_2 V + C_3 V \quad [\because Q = CV]$$

$$Q = V [C_1 + C_2 + C_3] \quad \dots \dots \dots (1)$$

Let C_P be the **equivalent capacitance of capacitor in parallel connection**, then $Q = C_P V \dots \dots \dots (2)$

$$\text{From (1) and (2), } C_P V = V [C_1 + C_2 + C_3]$$

$$C_P = C_1 + C_2 + C_3$$

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.

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

Van de Graff Generator:

It is designed by Robert Van de Graaff.

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

Principle:

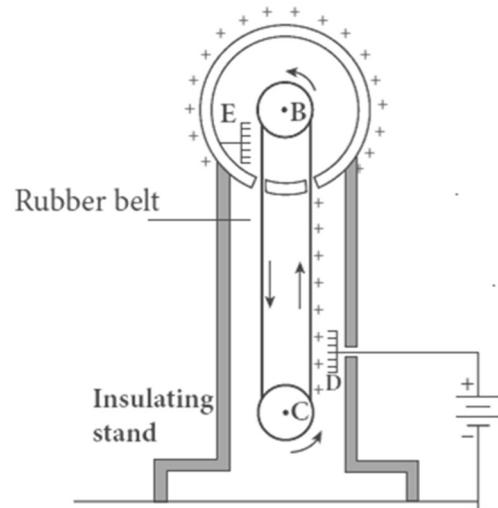
Electro static induction, Action of points

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 10^4 V** 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.

As a result, the positive charges are pushed away from the **comb 'E'** and **they reach the outer surface of the sphere.**

These positive charges are distributed uniformly on the outer surface of the hollow sphere. At the same time, **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 10^7 V** which is the limiting value. Beyond this, the charge starts leaking to the surroundings due to ionization of air. It is prevented by enclosing the machine in a gas filled steel chamber at very high pressure.

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.

UNIT - II (CURRENT ELECTRICITY)

TWO MARKS QUESTIONS AND ANSWERS

1. Define current electricity.

The branch of physics deals with moving charges is called current electricity.

2. Define electric current.

The electric current in a conductor is defined as the rate of flow of charges through a given cross - sectional area. $I = \frac{Q}{t}$ (or) $i = \frac{dQ}{dt}$.

The SI unit of current is **ampere (A)**. It is a scalar quantity.

3. Define one ampere (1 A)

One ampere of current is equivalent to 1 coulomb of charge passing through a perpendicular cross section in 1 second. [**$1\text{ A} = 1\text{ C s}^{-1}$**]

4. What is called conventional current?

By convention, this **flow in the circuit should be from the positive terminal of the battery to the negative terminal**. This is called the conventional current or simply current. It is in the direction in which a positive test charge would move.

5. What are called free electrons and positive ions?

Any material is made up of neutral atoms with equal number of electrons and protons. If the outermost electrons leave the atoms, they become free electrons and are responsible for electric current.

The atoms after losing their outer most electrons will have more positive charges and hence are called positive ions. They will not move freely and hence the positive ions will not give rise to current.

6. Define drift velocity.

The **average velocity acquired** by the **free electrons inside** the conductor when it is subjected to an electric field is called drift velocity (\vec{v}_d). **Its unit is ms⁻¹**

7. Define mobility.

The **magnitude of drift velocity acquired** by the **free electrons** per unit electric field is called mobility (μ). **Its unit is m²V⁻¹ s⁻¹**

8. Define current density.

Current density (J) is defined as the current per unit area of cross section of the conductor. $J = \frac{I}{A}$. Its **unit is Am⁻²**

9. Give the microscopic form of Ohm's law.

The current density is given by, $\vec{J} = ne\vec{v}_d ; = ne\left[\frac{e\tau}{m}\vec{E}\right] ; = \frac{ne^2\tau}{m}\vec{E}$
(or) $\vec{J} = \sigma\vec{E}$

Thus **Current density is directly proportional to the applied electric field**. This is known as microscopic form of Ohm's law.

10. 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.) $\vec{J} \cdot \vec{A} = JA \cos \theta$.**

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

11. Give the macroscopic form of Ohm's law.

Let 'V' be the potential difference, 'I' be the current and 'R' be the resistance, then the macroscopic form of **Ohm's law is $V = IR$**

12. What are called ohmic and non ohmic materials?

Materials for which the current against voltage graph is a straight line through the origin are said to obey Ohm's law and they are called ohmic materials. But materials for which the current against voltage graph is non - linear and they **do not have a constant resistance** are called non - ohmic. They do not obey Ohm's law.

13. Define resistance of the conductor.

The ratio of potential difference (V) across the given conductor to the current (I) passing through the conductor is called resistance (R). $R = \frac{V}{I}$

Its unit is ohm (Ω)

14. 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)

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

$\rho \rightarrow$ resistivity of the conductor

15. Define resistivity of the material.

The electrical resistivity of a material is defined as **the resistance offered to current flow** by a conductor of unit length having unit area of cross section. $\rho = \frac{1}{\sigma} ; = \frac{RA}{l}$

Its unit is ohm - metre (Ωm)

It depends only the type of material and not the dimension of the material.

16. Define conductivity of the material.

The **reciprocal of resistivity** is called conductivity and it is given by, $\sigma = \frac{1}{\rho}$

Its unit is mho- metre⁻¹ ($\Omega^{-1} m^{-1}$). It depends only the type of material and not the dimension of the material.

17. Repairing the electrical connection with the wet skin is always dangerous. Why?

The **human body contains a large amount of water which has low resistance of around 200 Ω and the dry skin has high resistance of 500 k Ω**

But when the skin is wet, the resistance is reduced to 1000 Ω .

By Ohm's law $[R = \frac{V}{I}]$ if resistance decreases, current increases. Hence repairing electric connection with wet skin is dangerous.

18. Define temperature coefficient of resistivity.

It is defined as the **ratio of increase in resistivity per degree rise** in temperature to its resistivity at T_0 . Its unit is per $^{\circ}\text{C}$

19. Define Superconductivity.

The **resistance of certain material become zero below certain temperature** called critical or transition temperature (T_c), **For mercury, $T_c = 4.2 \text{ K}$** . The materials which exhibit this property are known as super conductors. The property of conducting current with zero resistance is called super conductivity. It is discovered by Kammerlingh Onnes.

20. Prove that the expression for power in an electrical circuit is $P = VI$

Electric energy is given by, $dU = VdQ$

By definition, **the rate at which electric potential energy is delivered** is called power. (i.e) $P = \frac{dU}{dt} ; = \frac{VdQ}{dt} ; = V \frac{dQ}{dt}$

But $\frac{dQ}{dt} = I \rightarrow$ electric current . $\therefore P = VI$

21. Distinguish electric energy and electric power.

S. No.	Electric Energy	Electric Power
1	Work has to be done to move the charge from One end to other end of the conductor and this work-done is called electric energy. $dW = dU = VdQ$	The rate at which the electrical potential energy is delivered is called electric power. $P = \frac{dU}{dt} ; = VI$
2	Its SI Unit is joule (J)	Its SI Unit is watt (W)
3	Its practical unit is kilowatt hour (kwh) 1 kwh = 3.6 x 10⁶J	Its practical unit is horse power(HP) 1 HP = 746 W

22. Write down the various equations for power.

The electric power is given by, $P = VI$, By Ohm's law, $V = IR$ and hence

$$P = I^2R, \text{ Also, } I = \frac{V}{R} \text{ and hence, } P = \frac{V^2}{R}$$

23. What is called electric cell (battery)?

An electric cell is a device which **converts chemical energy in to electrical energy to produce electricity**. It contains two electrodes (anode and cathode) immersed in an electrolyte.

24. Define electromotive force.

The amount of work a battery or cell does to move a certain amount of charge around the circuit is called as **electromotive force (E)**. **Its unit is volt (V)**

The emf of a battery or a cell is the voltage provided by the battery when no current flows in the external circuit.

25. Define the internal resistance of the cell.

A real battery is made of electrodes and electrolyte. There is resistance to the flow of charges within the battery and this resistance is called internal resistance (r). A freshly prepared cell has low internal resistance and it increases with ageing.

26. State 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.

27. Give the sign convention followed by the Kirchhoff's current rule.

Current entering the junction is taken as positive and current leaving the junction is taken as negative.

28. 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 ($\sum IR = \sum \xi$). It is a statement of conservation of energy for an isolated system.

29. Give the sign convention followed by the Kirchhoff's voltage rule.

The **product of current and resistance** is taken as **positive** when the direction of the current is followed and is taken as **negative** when the **direction of current is opposite** to the loop.

The emf is considered positive when proceeding from the negative to the positive terminal of the cell and negative when proceeding from the positive to the negative terminal of the cell.

30. What is called Galvanometer?

A galvanometer is an instrument **used for detecting and measuring even very small electric currents**. It is extensively useful to compare the potential difference between various parts of the circuit.

31. State the principle of potentiometer.

Let 'I' be the current, 'r' be the resistance per unit length and 'l' be the balancing length, then emf is $\xi = Ir l$ (or) $\xi \propto l$

The emf is **directly proportional to the balancing length**. This is the principle of potentiometer.

32. What is called Joule's heating effect of current?

When current flows through a resistor, some of the electrical energy delivered to the resistor is converted into heat energy and it is dissipated. This heating effect of current is known as Joule's heating effect.

33. State Joule's law of heating.

It states that the heat develops in an electrical circuit due to the flow, current varies directly as (i) **the square of the current** (ii) **the resistance of the circuit** and (iii) **the time of flow** (i.e) $H = I^2 Rt$

34. What are the properties of the substance used as heating element?

An alloy of nickel and chromium called Nicrome is used as heating element. It has (i) **a high specific resistance** (ii) **high melting point** (iii) **heated to very high temperature without oxidation**.

35. Write a note on electric fuses.

Fuses are connected in series in a circuit to **protect the electric device** from the heat developed by the passage of excessive current. It melts and breaks the circuit if the current exceeds certain value. It is a short length of a wire made of a low melting point material.

36. Write a note on circuit breakers (trippers)

Now a day in housed, circuit breakers are **used instead of fuses**. Whenever there is an excessive current produced due to **faulty wire connection, the circuit breaker switch opens**. After repairing the faulty connection, we can close the circuit breaker switch.

37. Write a note on electric bulb or lamp.

It consists of a tungsten filament kept inside a glass bulb and heated to incandescence by current. Melting point of **tungsten** is **3380°C**. In incandescent electric lamps, only 5% of electric energy is converted into light and the rest is wasted as heat.

38. Define 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. The current that flows due to the emf developed is called thermoelectric current. The two dissimilar metals connected to form two junctions is known as **thermocouple**.

39. What are the applications of Seebeck effect?

Seebeck effect is **used in thermoelectric generators** (Seebeck generators) which are **used in power plants to convert waste heat into electricity**. This effect is **utilized in automobiles as automotive thermoelectric generators for increasing fuel efficiency**

Seebeck effect is **used in thermocouples and thermopiles** to measure the **temperature difference** between the two objects.

40. Define 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.

41. Define Thomson's effect.

If two points in a conductor are **at different temperatures, the density of electrons at these points will differ and as a result the potential difference is created between these points**. Thomson effect is **reversible**.

THREE MARKS QUESTIONS AND ANSWERS

- 42. Obtain an expression for drift velocity. How it is related with the mobility?**

Drift velocity (\vec{v}_d):

If there is no electric field, all the free electrons in a conductor are moves in random directions. As a result, no net flow of electrons in any direction and hence there will not be any current. If the conductor is subjected to an electric field (\vec{E}) free electrons experiences a force given by,

$$\vec{F} = -e\vec{E} \dots\dots\dots(1)$$

So all the **free electrons are accelerated in a direction opposite to the field. By Newton's second law** $\vec{a} = \frac{\vec{F}}{m}; = \frac{-e\vec{E}}{m} \dots\dots\dots(2)$

But the positive ions scatter the electrons and change its direction of motion. So they move in zigzag path.

In addition to the zigzag motion due to collisions, the electrons move slowly along the conductor in a direction opposite to that of \vec{E} .

This average velocity acquired by the free electrons inside the conductors, when it is subjected to the electric field is called drift velocity (\vec{v}_d)

The **average time between successive collisions** is called the **mean free time or relaxation time (τ)**.

$$\text{Hence the drift velocity is given by, } \vec{v}_d = \vec{a} \tau; = \frac{-e\vec{E}}{m} \tau; = -\mu \vec{E}$$

$$\text{Where, } \frac{e\tau}{m} = \mu \rightarrow \text{mobility of electrons}$$

The magnitude of the drift velocity acquired by the free electron per unit electric field is called mobility. $\mu = \frac{|\vec{v}_d|}{\vec{E}}$. **It unit is $m^2V^{-1}s^{-1}$**

- 43. 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 = v_d ,

Charge of an electrons = e

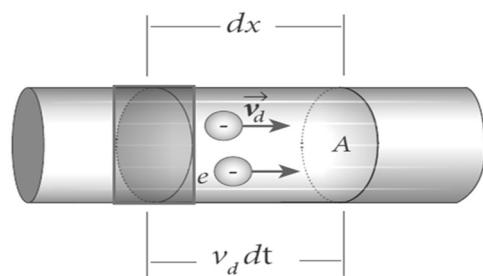
Let 'dx' be the distance travelled by the electron in time 'dt', then

$$v_d = \frac{dx}{dt} \quad (\text{or}) \quad dx = v_d dt$$

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

$$= A dx \times n; = A v_d dt \times n$$

Then the **total charge in this volume element is, $dQ = A v_d dt n e$**



By definition, the current is given by $I = \frac{dQ}{dt} ; I = \frac{A v_d dt n e}{dt} ; I = n e A V_d$

44. Write a note on carbon resistors.

Carbon resistors:

Carbon resistors consist of **a ceramic core on which a thin layer of crystalline carbon is deposited**. They are inexpensive, stable and compact in size. Colour rings drawn over it are used to indicate the value of the resistance according to the rules in the table.

Color	Number	Multiplier
Black	0	1
Brown	1	10^1
Red	2	10^2
Orange	3	10^3
Yellow	4	10^4
Green	5	10^5
Blue	6	10^6
Violet	7	10^7
Grey	8	10^8
White	9	10^9
Color	Multiplier	Tolerance
Gold	10^{-1}	5 %
Silver	10^{-2}	10 %
No Ring (Colourless)		20 %

There are three coloured bands on its left and one metallic coloured band on its right side. The first and second rings are the **significant figures of the resistance** and the **third ring indicate the decimal multiplier** after them. the **fourth metallic ring shows the tolerance of the resistor**.

Example:

For the given carbon resistor, **The first digit = 5 (green), the second digit = 6 (blue), decimal multiplier = 10^3 (orange) and tolerance = 5% (gold)**. The value of resistance = $56 \times 10^3 \Omega$ or $56 \text{ k}\Omega$ with the tolerance value 5%.

45. Define temperature coefficient of resistivity. Obtain an expression for it.

Temperature coefficient of resistivity:

Resistivity of the substance depends on the temperature. Let resistivity at T_0 °C = ρ_0 ; resistivity at T_c °C = ρ_T

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

Where, $\alpha \rightarrow$ Temperature coefficient of resistivity.

From equation (1) $\rho_T = \rho_0 + \rho_0 \alpha (T - T_0)$; $\rho_T - \rho_0 = \rho_0 \alpha (T - T_0)$

$$\alpha = \frac{\rho_T - \rho_0}{\rho_0 \alpha (T - T_0)} ; \gamma = \frac{\Delta \rho}{\rho_0 \Delta T}$$

Where $\Delta\rho = \rho_T - \rho_0 \rightarrow$ Change in resistivity,

$$\Delta T = T - T_0 \rightarrow \text{Change in temperature}$$

It is defined as the ratio of increase in resistivity per degree rise in temperature to its resistivity at T_0 . **Its unit is per°C.**

For conductors α is positive. (i.e) If the temperature of a conductor increases, the average kinetic energy of electrons in the conductor increases.

Thus resistance at $T^{\circ}\text{C}$ $R_T = R_0 [1 + \alpha (T - T_0)]$

For semiconductors α is negative. (i.e) If the temperature increases, resistance decreases. A semiconductor with a negative temperature coefficient of resistance is called a thermistor.

46. 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 = $n\xi$

The total resistance in the circuit = $nr + R$

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

$$I = \frac{\text{Total emf}}{\text{Total resistance}}; \\ = \frac{n\xi}{n r+R} \dots\dots\dots (1)$$

If $r \ll R$, equation (1) becomes, $I = \frac{n\xi}{R} \approx nI_1 \left[\because \frac{\xi}{R} = I_1 \right]$

(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 $r \gg R$, equation (1) becomes

$I = \frac{n\xi}{n r} ; = \frac{\xi}{r} \approx I_1$ (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.

47. Write a note on electric cells in Parallel.

Cells in Parallel:

Let n cells be connected in parallel between the points A and B and a resistance R . Let ξ be the emf and r the internal resistance of each cell.

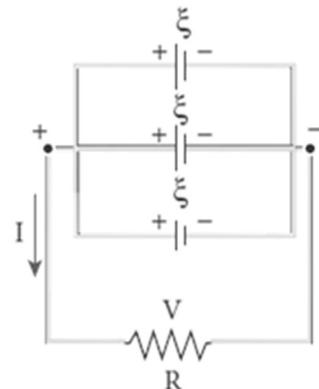
$$\text{The total emf of the battery} = n\xi$$

$$\text{The total resistance in the circuit} = \frac{r}{n} + R$$

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

$$I = \frac{\text{Total emf}}{\text{Total resistance}}$$

$$= \frac{\xi}{\frac{r}{n} + R}; = \frac{n\xi}{nr + R} \dots\dots\dots (1)$$



$$\text{If } r \gg R, \text{ equation (1) becomes, } I = \frac{n\xi}{R} \approx nI_1 \left[\because \frac{\xi}{R} = I_1 \right]$$

(i.e) If r is negligible compared to R the current supplied by the battery is n times the that supplied by the single cell.

$$\text{If } r \ll R, \text{ equation (1) becomes } I = \frac{n\xi}{nr}, = \frac{\xi}{r} \approx I_1$$

i.e) If **r is very very greater than R** , current due to the whole battery is the **same** as due to single cell.

48. Explain the principle of Potentiometer.

Principle of Potentiometer:

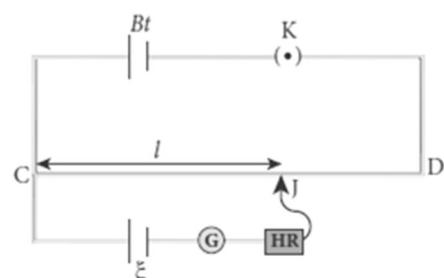
A battery Bt . The battery, key and the potentiometer wire are connected in series forms the primary circuit. The positive terminal of a primary cell of emf ξ is connected to the point C and negative terminal is connected to the jockey through a galvanometer G and a high resistance HR . This forms the secondary circuit.

Let contact be made at any point J on the wire by jockey. If the potential difference across CJ is equal to the emf of the cell ξ then no current will flow through the **galvanometer and it will show zero deflection**. CJ is the balancing length l .

If r is the resistance per unit length of the wire, then by Ohm's law.

$$\text{Potential difference across CJ} = Irl$$

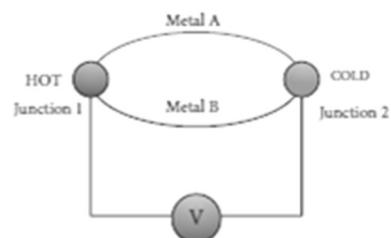
$$\text{Hence } \xi = Irl; \text{ Since } I \text{ and } r, \text{ are constants, } \xi \propto l$$



49. Explain Seebeck effect. Give its applications.

Seebeck effect:

Seebeck discovered that in a closed circuit consisting of two dissimilar metals, **when the junctions are maintained at different temperatures an emf (potential difference) is developed**. This is called Seebeck effect.



The current that flows due to the emf developed is called **thermoelectric current**. The two dissimilar metals connected to form two junctions is known as **thermocouple**. If hot and cold junctions are interchanged, the direction of current also reversed. Hence Seebeck effect is **reversible**.

The magnitude of emf developed in thermocouple depends on,

- (i) Nature of the metals forming thermocouple
- (ii) Temperature difference between the junctions

Applications:

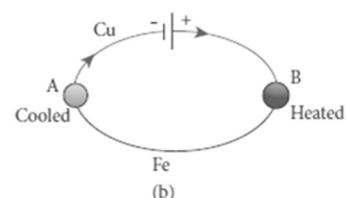
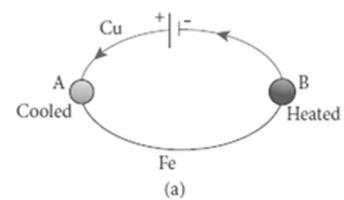
Seebeck effect is used in **thermoelectric generators** (Seebeck generators). This effect is utilized in automobiles as **automotive thermoelectric generators**.

Seebeck effect is **used in thermocouples and thermopiles**.

50. Explain 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. In Cu - Fe thermocouple, the junctions A and B are maintained at the same temperature.



Let a current flow through the thermocouple. At junction 'A', where the current flows from Cu to Fe, heat is absorbed and it becomes cold. At junction 'B', where the current flows from Fe to Cu, heat is liberated and it becomes hot. When the direction current is reversed, junction 'A' becomes hot and junction 'B' becomes cold. Hence **peltier effect is reversible.**

51. Distinguish between Peltier effect and Joule's effect.

S. No.	Peltier Effect	Joule's Effect
1	Both heat liberated and absorbed occur	Heat liberated only occurs
2	Occurs at junctions	Occurs all along the conductor
3	Reversible effect	Irreversible effect

52. Explain Thomson effect.

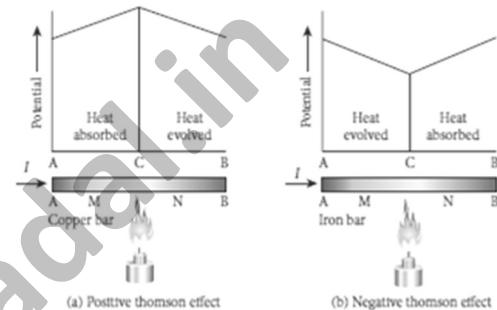
Thomson effect:

Thomson showed that, **if two points in a conductor are at different temperatures, the density of electrons at these points will differ** and as a result the potential difference is created between these points. This is known as Thomson effect.

Thomson effect is reversible. If current passed through **copper bar AB** which is heated at its midpoint C, the point C will be at higher potential.

This indicates that the heat is absorbed along AC and evolved along CB. Thus heat is transferred in the direction of the current. It is called **positive Thomson effect. (e.g.) Ag, Zn, Cd**

When the copper bar is replaced by an **iron bar**, heat is evolved along CA and absorbed along BC. Thus heat is transferred in the direction opposite to the current. It is called **negative Thomson effect. (e.g.) Pt, Ni, Co, Hg**



FIVE MARKS QUESTIONS AND ANSWERS

53. Describe the microscopic model of current and obtain general form of Ohm's law.

Microscopic model of current and Ohm' law:

Area of cross section of the conductor = A

Number of electrons per unit volume = n,

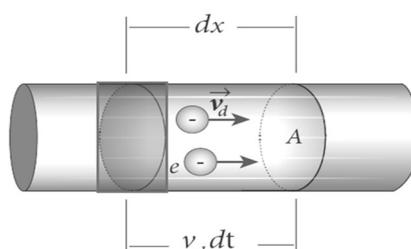
Applied electric field = \vec{E}

Drift velocity of electrons = v_d ,

Charge of an electrons = e

Let 'dx' be the distance travelled by the electron in time 'dt', then

$$v_d = \frac{dx}{dt} \quad (\text{or}) \quad dx = v_d dt$$



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

$$= A dx \times n ; = A v_d dt \times n$$

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

By definition, the current is given by $I = \frac{dQ}{dt} ; = \frac{A v_d dt ne}{dt} ; I = n e A V_d$

Current density (J):

Current density (J) is defined as **the current per unit area of cross section of the conductor.** $J = \frac{I}{A} ; = \frac{n e A v_d}{A}$. $J = ne v_d$. Its **unit is Am⁻²**

$$\text{In vector notation, } \vec{J} = ne \vec{v}_d ; \vec{J} = ne \left[-\frac{e\tau}{m} \vec{E} \right] ; = -\frac{ne^2\tau}{m} \vec{E}$$

$$\text{Where, } \frac{ne^2\tau}{m} = \sigma \rightarrow \text{Conductivity; } \therefore \vec{J} = -\sigma \vec{E}$$

But conventionally, we take the direction of current density as the direction of electric field. So the above equation becomes, $\vec{J} = \sigma \vec{E}$

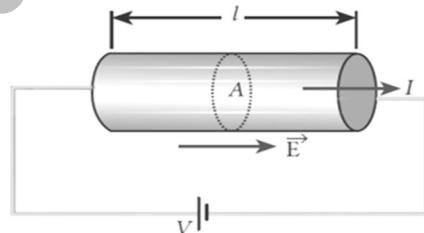
This is called microscopic form of Ohm's law.

- 54. 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, $V = El$ (or) $E = \frac{V}{l}$



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

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

$$\text{Hence, } \frac{I}{A} = \sigma \frac{V}{l} ; \therefore V = I \left[\frac{1}{\sigma A} \right] ; V = IR$$

Where, $\frac{1}{\sigma A} = R \rightarrow$ 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.**

55. 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.

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

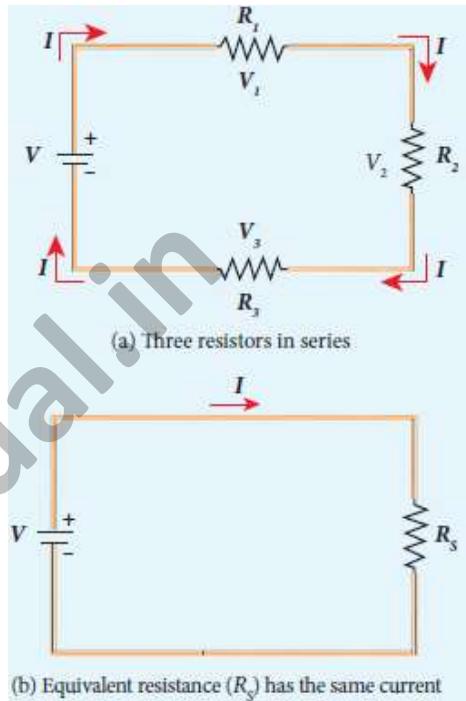
Let R_s be the equivalent resistance in series connection, then

$$V = IR_s \dots \dots \dots (2)$$

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. Let I_1 , I_2 , I_3 be the currents flow through R_1 , R_2 , R_3 respectively, then from Ohm's law.

$$I_1 = \frac{V}{R_1}; \quad I_2 = \frac{V}{R_2}; \quad I_3 = \frac{V}{R_3}$$

$$I = I_1 + I_2 + I_3; = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3};$$

$$I = V \left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right] \dots\dots\dots(1)$$

Let R_p be the equivalent resistance in parallel connection, then

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

From equation (1) and (2),

$$\text{we have } \frac{V}{R_p} = V \left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right]$$

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

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.

56. Explain the determination of the internal resistance of a cell using voltmeter.

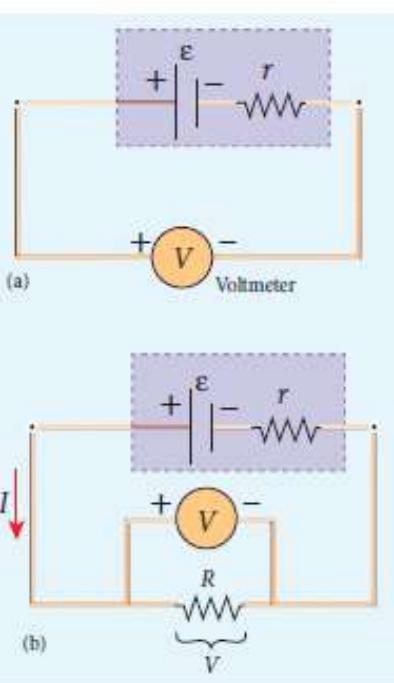
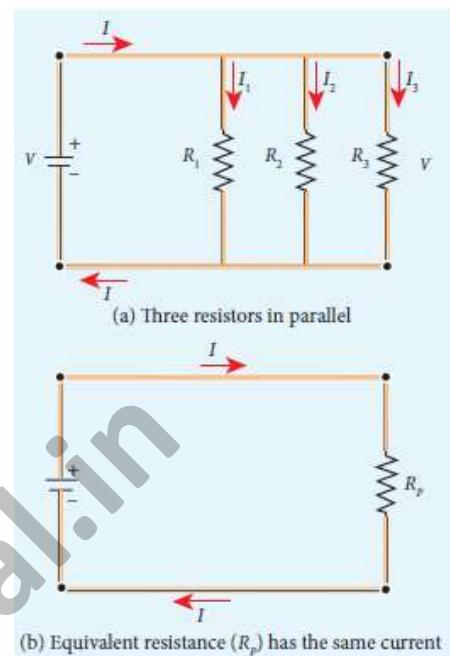
Internal resistance of a cell using voltmeter:

A real battery is made of electrodes and electrolyte. There is resistance to the flow of charges within the battery and this resistance is called internal resistance (r)

The **emf of the cell** is measured by **connecting high resistance** voltmeter across it without connecting the external resistance R . This circuit may be considered as open, the voltmeter reading gives the emf (ξ) of the cell. Then external resistance is included in the circuit and current 'I' is established in the circuit.

This circuit is then considered as close, the voltmeter reading gives the potential difference (V) across 'R'

$$\text{By Ohm's law, } = IR \quad (\text{or}) \quad I = \frac{V}{R} \dots\dots\dots(1)$$



Due to internal resistance of the cell, the voltmeter reads the value "V" which is less than the emf (ξ). It is because, certain amount of voltage (Ir) has dropped across the internal resistance 'r'. Hence

$$V = \xi - Ir \quad \dots \dots \dots (2) \text{ (or)} \quad Ir = \xi - V$$

$$\therefore r = \frac{\xi - V}{I} ; = \left[\frac{\xi - V}{V} \right] R$$

Since ξ , V and R are known, internal resistance 'r' and total current 'I' can be determined.

The power delivered to the circuit is, $I = I \xi ; = I (V + Ir) ; = I (IR + Ir)$

$$P = I^2R + I^2r$$

where, $I^2R \rightarrow$ power delivered to R

$I^2r \rightarrow$ power delivered to r

57. Explain Kirchhoff's law.

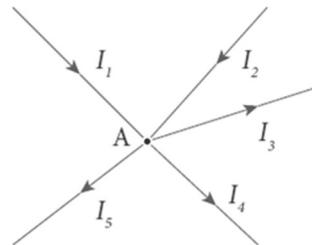
Kirchhoff first law (Current law) :

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

Explanation:

It is a statement of conservation of electric charge. Thus all charges that enter a given junction in a circuit must leave that junction. **Current entering the junction is taken as positive and current leaving the junction is taken as negative.** Applying this law at junction 'A'

$$I_1 + I_2 - I_3 - I_4 - I_5 = 0 \quad (\text{or}) \quad I_1 + I_2 = I_3 - I_4 - I_5$$



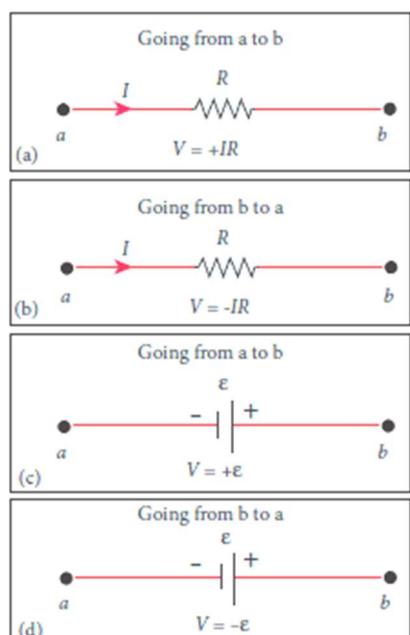
Kirchhoff second law (Voltage law) :

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** ($\sum IR = \sum \xi$)

Explanation:

It is a statement of conservation of energy for an isolated system. The product 'IR' is taken as positive when we proceed along the direction of current and taken as negative when we proceed opposite to the direction of current. Similarly,

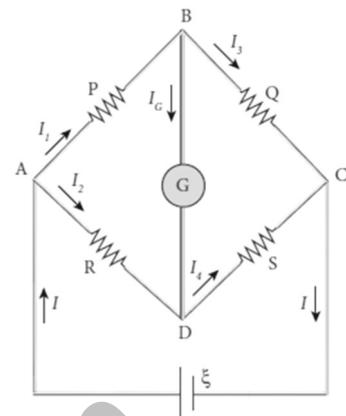
The emf is considered as positive, when we proceed from negative to positive terminal of the cell and as negative, when we proceed from positive to negative terminal of the cell.



58. 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_4 currents through various branches and I_G be the current through the galvanometer.



Applying Kirchhoff's current law at B and D,

$$I_1 - I_G - I_3 = 0 \quad \dots\dots\dots (1)$$

$$I_2 + I_G - I_4 = 0 \quad \dots\dots\dots (2)$$

Applying Kirchhoff's voltage law ABDA and ABCDA,

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

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

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

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

$$I_1 - I_3 = 0 \quad (\text{or}) \quad I_1 = I_3 \quad \dots\dots\dots (5)$$

$$I_2 - I_4 = 0 \quad (\text{or}) \quad I_2 = I_4 \quad \dots\dots\dots (6)$$

$$I_1 P - I_2 R = 0 \quad (\text{or}) \quad I_1 P = I_2 R \quad \dots\dots\dots (7)$$

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

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

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

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

Divide equation (8) by (7)

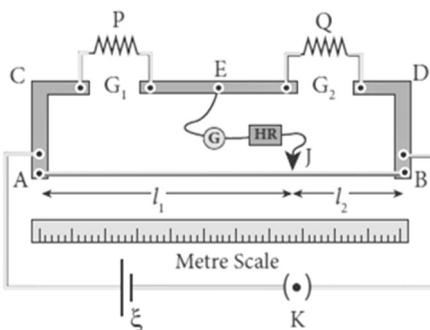
$$\frac{I_1 (P + Q)}{I_1 P} = \frac{I_2 (R + S)}{I_2 R} ; \quad \frac{(P + Q)}{P} = \frac{(R + S)}{R}$$

$$1 + \frac{Q}{P} = 1 + \frac{S}{R} ;$$

$$\frac{Q}{P} = \frac{S}{R} \quad (\text{or}) \quad \frac{P}{Q} = \frac{R}{S} \dots\dots\dots (9)$$

59. Explain the determination of unknown resistance using Meter Bridge.

Meter 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

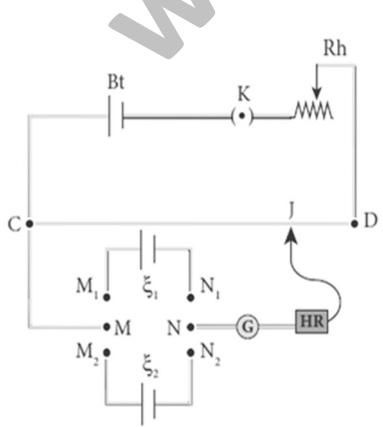
bridge. Then $\frac{P}{Q} = \frac{R}{S} ; = \frac{R'AJ}{R'JB}$. Where $R' \rightarrow$ resistance per unit length,

$$\frac{P}{Q} = \frac{AJ}{JB} = \frac{l_1}{l_2} \dots\dots\dots(1) ; \text{(or)} P = Q \frac{l_1}{l_2} \dots\dots\dots(2)$$

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 by. $\rho = \frac{\rho A}{l} ; = \frac{\rho \pi r^2}{l} \dots\dots\dots(3)$

60. How the emf of two cells are compared using potentiometer?

Comparison of emf of two cells:



Potentiometer wire CD is connected to battery (Bt) and a key (K) in series. This is the primary circuit. The end C is connected to central terminal M of **DPDT switch and another central terminal N** is connected to jockey through a galvanometer G and high resistance HR. This is the secondary circuit.

The cell whose emf ξ_1 and ξ_2 to be compared are connected to M_1N_1 and M_2N_2 of DPDT switch. Initially the cell of emf ξ_1 is included in the

secondary circuit and the balancing length l_1 is found by adjusting jockey for zero deflection. Similarly, the cell of emf ξ_2 is included in the secondary circuit and the balancing length l_2 is found. Let 'r' be the resistance per unit length

and 'I' be the primary current, then by the principle

$$\xi_1 = Irl_1 \quad \dots\dots\dots (1)$$

$$\xi_2 = Irl_2 \quad \dots\dots\dots (2)$$

Divide equation (1) by (2),

$$\frac{\xi_1}{\xi_2} = \frac{Irl_1}{Irl_2} ; \frac{\xi_1}{\xi_2} = \frac{l_1}{l_2} \dots\dots\dots (3)$$

61. Explain the method of measurement of internal resistance of a cell using potentiometer.

Internal resistance of a cell using potentiometer:

Potentiometer wire CD is connected to battery (B_t) 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,

$$\xi \propto l_1 \quad \dots\dots\dots (1)$$

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

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

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

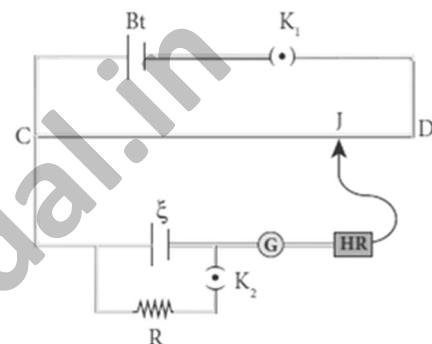
$$\text{By the Principle } \frac{\xi}{R+r} R \propto l_2 \dots\dots\dots (2)$$

Divide equation (1) by (2)

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

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

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.**



UNIT - III (MAGNETISM AND MAGNETIC EFFECTS OF ELECTRIC CURRENT)

TWO MARKS QUESTIONS AND ANSWERS

1. Define magnetism. Give its applications.

The property of attracting iron is called magnetism.

In olden days, **magnets were used as magnetic compass for navigation, magnetic therapy for treatment and magic shows.**

In **modern days** most of the things we use in daily life contains magnets. For example, **loud speaker, motors, dynamo, cell phones, pen-drive, CD, hard disc in laptop etc.**

2. Define Geomagnetism or Terrestrial magnetism.

The branch of physics which deals with the Earth's magnetic field is called Geomagnetism.

3. What are the elements of the Earth's magnetic field?

To specify the Earth's magnetic field, three quantities must be required.

They are

- (i) Magnetic declination (D)
- (ii) Magnetic dip or inclination (I)
- (iii) The horizontal component of the Earth's magnetic field (B_H)

4. Define geographic meridian and magnetic meridian.

A vertical plane passing through the geographic axis is called **geographic meridian** and a great circle perpendicular to Earth's geographic axis is called **geographic equator**.

A vertical plane passing through **magnetic axis** is called magnetic meridian and a **great circle particular to Earth's magnetic axis** is called magnetic equator.

5. Define magnetic declination.

The angle between **magnetic meridian at a point and geographical meridian** is called the magnetic declination (D). At higher latitudes, the declination is greater whereas near the equator, the declination is smaller.

6. For Chennai, the magnetic declination angle is $-1^{\circ} 8'$. Why it is negative?

The negative sign indicates that the magnetic meridian lies west to the geographic meridian.

7. Define magnetic inclination or dip.

The angle subtended by **the Earth's total magnetic field \vec{B}** with the **horizontal in the magnetic meridian** is called dip or magnetic inclination (I)
For Chennai, angle of dip is $14^\circ 16'$

8. Define horizontal component of Earth's magnetic field.

The component of Earth's magnetic field along the horizontal direction in the magnetic meridian is called horizontal component of Earth's magnetic field (B_H)

9. Calculate the tangent of magnetic inclination or angle of dip.

Let B_E be the net Earth's magnetic field at a point 'P' and ' I ' be the angle of dip, then Horizontal component; $B_H = B_E \cos I$,

Vertical component; $B_V = B_E \sin I$

$$\therefore \frac{B_E \sin I}{B_E \cos I} = \frac{B_V}{B_H}; \tan I = \frac{B_V}{B_H}; \text{Also } B_E = \sqrt{B_H^2 + B_V^2}$$

10. Define pole strength of the magnet.

The attracting property of the magnet is **concentrated at its poles only** and this property is called pole strength (q_m).

The S.I unit of **pole strength is Am**

11. Define magnetic dipole moment.

Magnetic dipole moment (p_m) is defined as the **product of the pole strength (q_m) and magnetic length ($2l$)**. i.e $p_m = q_m 2l$

In vector notation; $\vec{p}_m = q_m \vec{d}$ [$\because |\vec{d}| = 2l$]

Its SI unit is **Am²**. Its direction is **from South Pole to North Pole**.

12. Define magnetic field.

The magnetic field \vec{B} at a point is defined as a **force experienced by the bar magnet of unit pole strength**. $\vec{B} = \frac{\vec{F}}{q_m}$. Its **SI unit is NA⁻¹m⁻¹**

13. What are the types of magnet?

Magnets are classified in to **natural magnets and artificial magnets**. **Iron, cobalt, nickel etc... are natural magnets**. Strength of natural magnets are very weak and the shape of the magnet are irregular.

Artificial magnets are **made our desired shape and strength**. Bar magnets, cylindrical magnets, horse shoe magnets are some examples for artificial magnets.

14. Define magnetic flux. Give its unit.

The **number of magnetic field lines crossing per unit area** is called magnetic flux (Φ_B) $\Phi_B = \vec{B} \cdot \vec{A} = B A \cos \theta$

The **SI unit of magnetic flux is Weber (Wb)** and **CGS unit is Maxwell (1 Wb = 10⁸ Maxwell)**. Its dimensional formula is **[ML²T⁻²A⁻¹]**

15. Define magnetic flux density.

The magnetic flux density can be defined as **the number of magnetic field lines crossing unit area** kept normal to the direction of line of force. Its S.I unit is **tesla or Wbm⁻²**

16. Distinguish between uniform and non-uniform magnetic field.

S. No.	Uniform Magnetic field	Non – Uniform Magnetic field
1	Magnetic field is said to be uniform If it has the same magnitude and direction at all the points in a given region.	Magnetic field is said to be non-uniform If the magnitude or direction or both varies at all its points.
2	(e.g) Locally Earth's magnetic field is uniform	(e.g) Magnetic field of a bar magnet

17. Discuss the types of force between two magnetic pole strength.

When North Pole (N) of magnet A and North Pole (N) of magnet B or south pole (S) of magnet A and south pole (S) of magnet B are **brought close together, they repel each other.**

On the other hand, when North Pole of magnet A and South Pole of magnet B or South Pole of magnet A and north pole of magnet B are **brought close together they attracts each other.** Thus like poles repels and unlike poles attracts.

18. State Coulomb's inverse square law of magnetism.

The force of attraction or repulsion between two magnetic poles is **directly proportional to the product of their pole strengths** and **inversely proportional to the square of the distance** between them. $\vec{F} \propto \frac{Q_{mA} Q_{mB}}{r^2} \hat{r}$

19. What happens when a bar magnet is freely suspended in uniform and non-uniform magnetic field?

Even though Earth has non- uniform magnetic field, it is locally (at particular place) taken as uniform. So bar magnet suspended freely in uniform magnetic field experience only torque (rotational motion)

When a bar magnet is freely suspended in non- uniform magnetic field, it undergoes translator motion due to net force and rotational motion due to torque.

20. State tangent law.

When a magnetic needle or magnet is freely suspended in two mutually **perpendicular uniform magnetic fields**, it will come to rest in the direction of the resultant of the two fields.

21. Define magnetizing field.

The magnetic field which is used to **magnetize a sample** or specimen is called the magnetizing field (\vec{H}). Its unit is **Am⁻¹**

22. Define magnetic permeability.

Magnetic permeability is defined as **the measure of ability of the material to allow the passage of magnetic lines through it or measure of the capacity** of the substance to take magnetization or the degree of penetration of magnetic field through the substance.

23. Define relative permeability.

The relative permeability (μ_r) is defined as **the ratio between absolute permeability (μ) of the medium to the permeability of free space (μ_0)**. It has no unit and it is dimensionless quantity. $\mu_r = \frac{\mu}{\mu_0}$

24. Define intensity of magnetization.

The **net magnetic moment per unit volume of the material** or is known as intensity of magnetization or magnetization vector or magnetization. For magnet the intensity of magnetization can be defined as the pole strength per unit area. $M = \frac{p_m}{V} = \frac{q_m}{A}$. Its unit **Am⁻¹**. It is a **vector quantity**.

25. Define magnetic induction or total magnetic field.

The magnetic induction (\vec{B}) inside the specimen is equal to the sum of the magnetic field (\vec{B}_0) produced in vacuum due to magnetizing field and the magnetic field (\vec{B}_m) due to the induce magnetization of the substance, $[\vec{B} = \vec{B}_0 + \vec{B}_m]$

26. Define magnetic susceptibility.

Magnetic susceptibility (χ_m) is defined as **the ratio of the intensity of magnetization (\vec{M}) induced in the material due to the magnetizing field (\vec{H})**. It is a dimensionless quantity.

27. What are the classifications of magnetic materials?

- Magnetic materials are generally classified in to three types. They are
- (i) **Diamagnetic material (e.g.) bismuth, copper, water**
- (ii) **Paramagnetic material (e.g.) Aluminum, platinum, chromium**
- (iii) **Ferro magnetic material (e.g.) Iron, nickel, cobalt**

28. Define Meissner effect.

Super conductors are perfect diamagnetic materials.

The exclusion of magnetic flux from a **super conductor during its transition** to the **superconducting state** is known as Meissner effect

29. Define Curie's law.

The susceptibility of the material is inversely proportional to its Kelvin temperature. (i.e.) the **magnetic susceptibility decreases with increase in temperature**. $\chi_m \propto \frac{1}{T}$ (or) $\chi_m = \frac{C}{T}$. Where, C → **curie constant**, this is called Curie law.

30. Define Curie temperature.

As **temperature increases, the ferromagnetism decreases** due to the increased thermal agitation of the atomic dipoles. At a particular temperature, ferromagnetic material becomes paramagnetic. This temperature is known as Curie temperature (T_c).

31. State Curie - Weiss law.

The susceptibility of the material above the Curie temperature is given by $\chi_m = \frac{C}{T-T_0}$ Where, C → Curie law; T → Kelvin temperature

This relation is called **Curie - Weiss law**.

32. What is Hysteresis?

Hysteresis means '**lagging behind**'. The phenomenon of **lagging of magnetic induction (B)** behind the magnetizing field (H) is called hysteresis.

33. Define hysteresis loss.

During the magnetization of the specimen through a cycle, **there is loss of energy in the form of heat**. This is known as hysteresis loss.

The **energy lost per unit volume of the material** when it is carried through one cycle of magnetization is equal to the area of the hysteresis loop.

34. What are the types of ferromagnetic materials?

Based on the shape and size of the hysteresis loop, ferromagnetic materials are classified as two types.

They are

- (i) **Hard magnetic material - (e.g) Steel**
- (ii) **Soft magnetic material - (e.g) Soft iron**

35. State Right Hand Thumb Rule.

If we hold the current carrying conductor in our right hand such that the **thumb points in the direction of current flow**, then the fingers encircling the wire points in the direction of the magnetic field lines produced.

36. State Maxwell's right hand cork screw rule.

This rule is used **to determine the direction of the magnetic field**. If we advance a right handed **screw along the direction of current**, then the **direction of rotation of the screw gives the direction of the magnetic field**.

37. Define magnetic dipole moment of current loop.

The magnetic dipole moment of any **current loop is equal to the product of the current** and area of the loop. $[\vec{p}_m = I \vec{A}]$

38. State Right Hand Thumb Rule.

This rule is used to determine the direction of magnetic moment. If we curl the fingers of right hand in **the direction of current in the loop**, then **the stretched thumb gives the direction of the magnetic moment associated with the loop**.

39. Define gyro-magnetic ratio.

The ratio of magnetic moment (μ_L) of the electron to its angular momentum (L) is called gyro-magnetic ratio. $\frac{\mu_L}{L} = \frac{e}{2m} = 8.78 \times 10^{10} \text{ CKg}^{-1}$

40. Define Bohr Magnetron.

It is the unit of atomic magnetic moment. The **minimum value of atomic magnetic moment** is called Bohr magnetron.

$$1 \text{ Bohr magnetron} = \mu_B = \frac{e h}{4\pi m} = 9.27 \times 10^{-24} \text{ A m}^2$$

41. 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. $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_0$

42. Define Lorentz force.

If the charge is moving in the electric field (\vec{E}) and magnetic field (\vec{B}), the total force experienced by the charge is given by

$$\vec{F} = q[\vec{E} + (\vec{v} \times \vec{B})].$$

It is known as Lorentz force.

43. Define one tesla.

The strength of the magnetic field is one tesla if unit charge moving in it with unit velocity experiences unit force.

44. What are the limitations of cyclotron?

- i) The speed of the ion is limited.
- (ii) Electron cannot be accelerated.
- iii) Uncharged particles cannot be accelerated.

45. Write a note on fast-neutron cancer therapy.

When a deuteron is bombarded with a beryllium target, a beam of high energy neutrons are produced. These high energy neutrons are sent into the patient's cancerous region to break the bonds in the DNA of the cancer cells. This is used in treatment of fast-neutron cancer therapy.

46. State Fleming's Left Hand Rule (FLHR).

Stretch forefinger, 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.

47. 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 **2×10^{-7} Newton per metre length** of conductor.

48. Define figure of merit of a galvanometer.

It is defined as the current which produces a deflection of one scale division in the galvanometer.

49. Define current sensitivity of a galvanometer.

It is defined as the deflection produced per unit current flowing through it.
$$I_s = \frac{\theta}{I} ; = \frac{NBA}{K} ; = \frac{1}{G}$$

50. 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

51. Why Phosphor - bronze is used as suspension wire?

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

52. Define voltage sensitivity of the galvanometer.

It is defined as the deflection produced per unit voltage applied across galvanometer. $V_s = \frac{\theta}{V}$; $V_s = \frac{\theta}{IR_g} ; = \frac{NBA}{KR_g} ; = \frac{1}{GR_g} ; = \frac{I_s}{R_g}$

53. How galvanometer can be converted in to ammeter?

A galvanometer is converted in to an ammeter by **connecting a low resistance (shunt) in parallel** with the galvanometer.

54. How galvanometer can be converted in to voltmeter?

A galvanometer is converted into a voltmeter by connecting **high resistance in series** with galvanometer.

55. Why ammeter should always have connected in series to the circuit?

The ammeter must offer low resistance such that it will not change the current passing through it. So ammeter is connected in series to measure the circuit current. **An ideal ammeter has zero resistance.**

56. Why voltmeter should always have connected in parallel to the circuit?

The voltmeter must offer high resistance so that it will not draw appreciable current. So, voltmeter is connected in parallel to measure the potential difference. **An ideal voltmeter has infinite resistance.**

THREE MARKS QUESTIONS AND ANSWERS

57. 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

58. Write a note on pole strength.

Pole strength:

The attracting property of the magnet is concentrated at its poles only and this property is called **pole strength** (q_m). It is a **scalar quantity** with **dimension [L A]**. Its **SI unit is Am (or) NT⁻¹**

North Pole of the magnet experiences a force in the direction of the magnetic field and South Pole experiences force opposite to the magnetic field. Pole strength depends on the nature of materials of the magnet, area of cross-section and the state of magnetization.

If a magnet is cut in to two equal halves along the length, then pole strength is reduced to half. If the magnet is cut into two equal halves perpendicular to the length, then pole strength remains same. If we cut the magnet in to two pieces, we will not separate north and south poles. Instead we get two magnets. (i.e) isolated mono pole does not exist in nature.

59. Give the properties of magnetic field lines.

Properties of magnetic field lines:

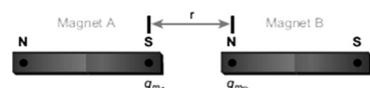
They are **continuous closed lines**. Their direction is from North Pole to South Pole outside the magnet and South Pole to North Pole inside the magnet. The tangent drawn at any point on the magnetic field lines gives the direction of magnetic field at that point.

They **never intersect each other**. The degree of closeness of the field lines determines the relative strength of the magnetic field. **The magnetic field is strong where magnetic field lines crowd and weak where magnetic field lines thin out.**

60. Explain Coulomb's inverse square law in magnetism.

Coulomb' inverse square law in magnetism:

Consider two bar magnets A and B as shown.



Let, Pole strength of A = Q_{mA} ; Pole strength of B = Q_{mB}

Distance between A and B= r

Then by Coulomb's law, the force of attraction or repulsion between two magnetic poles is **directly proportional to the product of their pole strengths and inversely proportional to the square of the distance** between them. Hence

$$\vec{F} \propto \frac{Q_{mA} Q_{mB}}{r^2} \hat{r} \quad (\text{or}) \quad \vec{F} = k \frac{Q_{mA} Q_{mB}}{r^2} \hat{r}$$

In magnitude, $f = k \frac{Q_{mA} Q_{mB}}{r^2}$; Where, $k \rightarrow$ proportionality constant.

In SI unit, the value of k is, $k = \frac{\mu_0}{4\pi} \cong 10^{-7} \text{Hm}^{-1}$; Then the force, $F = \frac{\mu_0}{4\pi} \frac{Q_{mA} Q_{mB}}{r^2}$.

Where, $\mu_0 \rightarrow$ permeability of free space or vacuum [$\mu_0 = 4\pi \times 10^{-7} \text{Hm}^{-1}$]

61. Calculate the torque acting on a bar magnet in uniform magnetic field.

Torque acting on a bar magnet in uniform magnetic field:

Consider a magnet of length ' $2l$ ' of pole strength ' q_m ' kept in uniform magnetic field \vec{B} .

Force experienced by the North Pole along the direction of the field.

$$\vec{F}_N = q_m \vec{B}$$

Force experienced by the South Pole opposite to the direction of the field

$$\vec{F}_S = -q_m \vec{B} \text{ Hence total force; } \vec{F} = \vec{F}_N + \vec{F}_S = \vec{0}$$

So, that there is no translator motion.

But these two forces constitute a couple, which tends to rotate the magnet along the direction of the field \vec{B} .

Hence **moment of force or torque** about 'O' is

$$\vec{\tau} = \vec{ON} \times \vec{F}_N + \vec{OS} \times \vec{F}_S ; = \vec{ON} \times (q_m \vec{B}) + \vec{OS} \times (-q_m \vec{B})$$

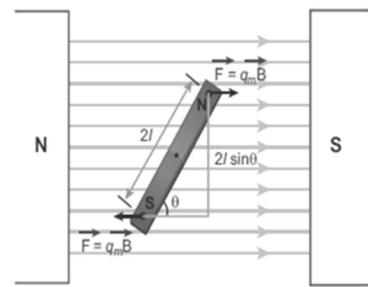
Here, $|\vec{ON}| = |\vec{OS}| = l$ and $|q_m \vec{B}| = |(-q_m \vec{B})|$

Hence the magnitude of the torque,

$$\tau = lq_m B \sin \theta + lq_m B \sin \theta$$

$$\tau = 2lq_m B \sin \theta \quad [q_m 2l = pm]$$

$$\tau = p_m B \sin \theta ; \text{ In vector notation, } \vec{\tau} = \vec{p}_m \times \vec{B}$$



62. Obtain an expression for potential energy of a bar magnet placed in an uniform magnetic field.

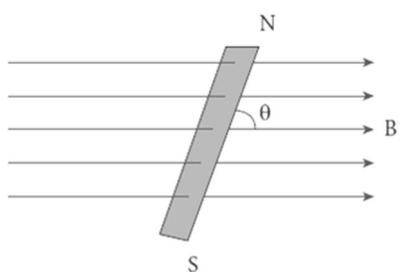
Potential energy of a bar magnet:

Let a bar magnet of dipole moment \vec{p}_m is placed in a uniform magnetic field \vec{B} . at an angle. The magnitude of the torque acting on the dipole is $\tau = p_m B \sin \theta$

So work done bt external torque (τ_{ext}) for a small angular displacement against the torque (τ) is $dw = \tau_{ext} d\theta = \tau d\theta ; = p_m B \sin \theta d\theta$.

Hence the **total work done to rotate the bar magnet from θ' to θ** is ,

$$W = \int_{\theta'}^{\theta} dW ; \int_{\theta'}^{\theta} p_m B \sin \theta d\theta ; W = p_m B [-\cos \theta]_{\theta'}^{\theta} ; \\ = - p_m B [\cos \theta - \cos \theta']$$



This **work done is stored as potential energy of the bar magnet.**

Hence $U = -p_m B [\cos \theta - \cos \theta']$ if initial angle be $\theta' = 90^\circ$ then $U = -p_m B \cos \theta$. The potential energy stored in a bar magnet placed in a uniform magnetic field is, $U = -p_m \cdot \vec{B}$

- i) If $\theta = 0^\circ$ then: $U = -p_m B = \text{minimum}$.
- ii) If $\theta = 180^\circ$ then: $U = p_m B = \text{maximum}$.

Thus the potential energy of a bar magnet is minimum when it is aligning along the external field and maximum when it aligns anti parallel with the external field.

63. What are the precautions taken while using tangent galvanometers (TG)

Precautions:

All the nearby magnets and magnetic materials are kept away from the instrument. Using spirit level, the leveling screws at the base are adjusted so that the small magnetic needle is exactly horizontal and also the circular coil is exactly vertical. The plane of the coil is kept along the magnetic meridian. The pointer in the compass box should read $0^\circ - 0^\circ$

64. Using the relation $\vec{B} = \mu_0 (\vec{H} + \vec{M})$, show that $\chi_m = \mu_r - 1$

Proof: The total magnetic induction, $\vec{B} = \mu_0 (\vec{H} + \vec{M}) \dots\dots\dots (1)$

$$\text{By definition, } \chi_m = \frac{\vec{M}}{\vec{H}} \text{ (or) } \vec{M} = \chi_m \vec{H} \text{ & } \vec{B} = \mu \vec{H}$$

$$\text{Put this in equation (1)} \mu \vec{H} = \mu_0 (\vec{H} + \chi_m \vec{H})$$

$$\mu \vec{H} = \mu_0 \vec{H} (1 + \chi_m); \frac{\mu}{\mu_0} = 1 + \chi_m$$

$$(\text{or}) \mu_r = 1 + \chi_m; \therefore \chi_m = \mu_r - 1$$

65. What are called dia, para and ferro magnetic material?

Materials which exhibit **weak magnetism** in the direction opposite to the applied field are known as **diamagnetic materials**. They are repelled by the magnet. (**e.g.**) **Bismuth, Copper, Water**

Materials which exhibit **weak magnetism** in the direction of the applied field are known as **paramagnetic materials**. They are feebly attracted by the magnets. (**e.g.**) **Aluminium, Platinum, Chromium**

Materials which exhibit **strong magnetism** in the direction of the applied field are known as **ferromagnetic materials**. They are strongly attracted by the magnets. (**e.g.**) **Iron, Cobalt, Nickel**

66. Explain dia magnetism.

Diamagnetic material:

The orbital motion of electron produces a magnetic field perpendicular to the plane of the orbit. Thus each electron orbit has finite orbital magnetic dipole moment. But the resultant magnetic moment for each atom is zero.

In the presence of an external magnetic moment, some electrons are speeded up and some are slowed down. According to Lenz's law, **the electrons whose moments were anti-parallel are speeded up which produces induced magnetic moment in a direction opposite to the field.**

The induced moment disappears as soon as the external field is removed. When placed in a non-uniform magnetic field, it has tendency to move the material from stronger to weaker part of the field. This action is called **diamagnetic action** and such materials are known as diamagnetic materials. (e.g.) **Bismuth, Copper, Water**

67. Explain paramagnetism.

Paramagnetic material:

In some magnetic material, each atom or molecule has net dipole magnetic moment which is vector sum of orbital and spin magnetic moments of electrons. But due to random orientation of these moments, the net magnetic moment of the material is zero.

In the presence of external magnetic field, the torque acting on the atomic dipoles will align them in the field direction. Thus a **net magnetic dipole moment induced in the direction of the applied field.**

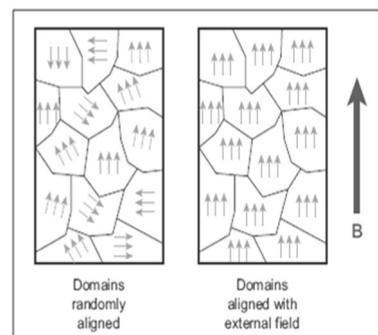
The induced dipole moment is present as long as the external field exists. When placed in a non-magnetic field, these materials will have a tendency to move from weaker to stronger part of the field. Materials which exhibit weak magnetism in the direction of the applied field are known as **paramagnetic materials. (e.g.) Aluminium, Platinum, Chromium**

68. Explain ferro magnetism.

Ferromagnetic material:

Ferro magnetic material also possesses net magnetic dipole moment as paramagnetic material. A ferro magnetic material is made up of smaller regions called ferromagnetic domain.

Within each domain, the magnetic moments are aligned in same direction due to strong interaction arising from electron spin. So each domain has net magnetization in a direction. But the



direction of magnetization is different for different domains. Hence the net magnetization of the specimen is zero.

In the presence of external magnetic field, the domain having magnetic moments parallel to the field grow in size and the other domains are aligned with the field. It results; a strong net magnetization of the material in the direction of the applied field is produced. Materials which exhibit strong magnetism in the direction of the applied field is called **ferro magnetic materials. (e.g.) Iron, Nickel, Cobalt**

69. List the properties of Diamagnetic materials.

Properties of Diamagnetic materials:

Magnetic susceptibility is negative. Relative permeability is slightly less than one. The magnetic field lines are excluded by diamagnetic materials when placed in a magnetic field. **Susceptibility is nearly temperature independent.**

70. List the properties of Paramagnetic materials.

Properties of Paramagnetic materials:

Magnetic susceptibility is small positive value. Relative permeability is greater than one. The magnetic field lines are attracted in to paramagnetic materials when placed in a magnetic field. **Susceptibility is inversely proportional to temperature.**

71. List the properties of Ferromagnetic materials.

Properties of Ferromagnetic materials:

Magnetic susceptibility is positive and large, Relative permeability is very, very greater than one, the magnetic field lines are strongly attracted in to the ferromagnetic materials when placed in a magnetic field. **Susceptibility is inversely proportional to temperature.**

72. Explain the applications of hysteresis loop.

Applications of hysteresis loop:

The main significance of hysteresis loop is that it provides the following information. (i) Retentivity (ii) Coercivity (iii) Permeability (iv) Susceptibility (v) Energy loss during on cycle of magnetization

This information will help us in selecting proper and suitable material for a given purpose. **For example, the materials (Steel and Alnico) with high retentivity, high coercivity and high permeability are suitable for making permanent magnets.**

The **materials (Soft iron and Mumetal)** with high initial permeability, low retentivity, low coercively and thin hysteresis loop with smaller area are preferred to make **electro magnet**. The materials (Soft iron) with high initial permeability, large magnetic induction and thin hysteresis loop with smaller area are needed to design transformer cores.

73. What are the differences between soft and hard ferromagnetic materials?

Soft ferromagnetic materials:

When external field is removes, its magnetization will disappear.

Area of the loop is small, Low retentivity, Low coercively High susceptibility and magnetic permeability, less hysteresis loss Used as solenoid core, transformer core and electromagnets,

(e.g.) **Soft iron, Mumetal, Stelloy**

Hard ferromagnetic materials:

When external field is removes, its magnetization will persist.

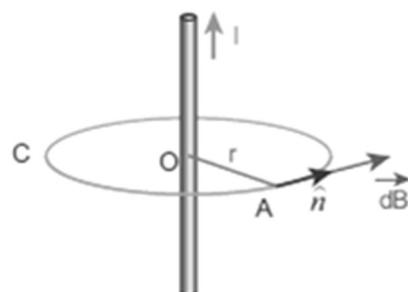
Area of the loop is large, High retentivity, High coercively, Low susceptibility and magnetic permeability, more hysteresis loss, Used as permanent magnets
(e.g.) **Steel, Alnico, Lodestone.**

74. Explain the magnetic field around a straight current carrying conductor.

Current carrying straight conductor:

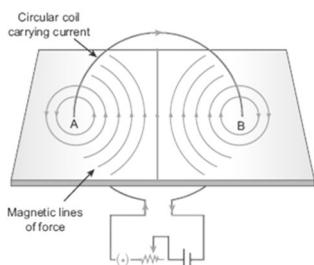
When a magnetic compass is kept near a current carrying straight conductor, the magnetic needle deflects which indicates there exists, a magnetic field. If we trace the direction shown by the magnetic needle, we can draw the magnetic field lines which are concentric circles having their centre at the axis of the conductor.

It may be either clockwise or anti-clock wise depending on the direction of current in the conductor. If strength of the **current is increased, then the density of the magnetic field will also increase. The strength of the magnetic field decreases at the distance from the conductor increases.**



75. Explain the magnetic field around the current carrying circular loop.

Circular coil carrying current:



If we keep a magnetic compass near a current carrying circular conductor, then the magnetic needle deflects which indicates the existence of magnetic field. Tracing the direction of the deflection, it shows the magnetic lines are circular near A and B and nearly parallel to each other near the centre of the loop.

Thus the field present near the centre of the coil is almost uniform. The strength of the magnetic field is increased if either the current in the coil or the number of turns or both are increased. The polarity (North Pole or South Pole) depends on the direction of current in the loop.

76. 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) directly as the strength of the current I
- (ii) directly as the magnitude of the length

element \vec{dl}

- (iii) directly as the sine of the angle θ between \vec{dl} and \vec{r}

- (iv) inversely as the square of the distance r between the point P and length

element \vec{dl}

$$\text{Hence, } dB \propto \frac{I dl \sin\theta}{r^2} ; \text{ (or) } dB = k \frac{I dl \sin\theta}{r^2} \dots\dots\dots(1)$$

Where $k \rightarrow \text{constant}$,

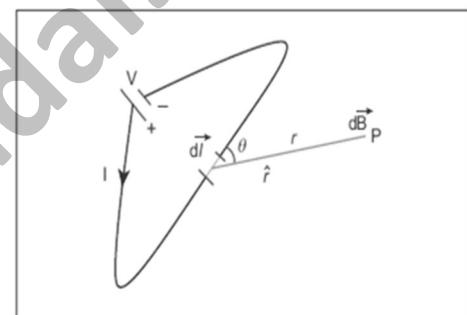
$$\text{SI unit, } k = \frac{\mu_0}{4\pi}$$

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

$$\text{In vector notation, } \vec{dB} = \frac{\mu_0}{4\pi} \frac{I \vec{dl} \times \hat{r}}{r^2} \dots\dots\dots(3)$$

Here \vec{dB} is perpendicular to both $I \vec{dl}$ and \hat{r} . From superposition principle

the total magnetic field due to entire conductor is, $\vec{B} = \int \vec{dB} = \frac{\mu_0 I}{4\pi} \int \frac{\vec{dl} \times \hat{r}}{r^2}$



77. Give the difference between Coulomb's law and Biot-savart's law.

S. No.	Coulomb's law	Biot-savart's law
1	Electric field is calculated	Magnetic field is calculated
2	Produced by a scalar source (i.e) charge 'q'	Produced by vector source (i.e.) current element $I\vec{dl}$
3	It is directed along the position vector joining the source and the point at which the field is calculated.	It is directed perpendicular to the position vector and the current element
4	Does not depend on angle	Depends on the angle between and $I\vec{dl}$ and \hat{r}

78. Explain the current loop acts as a magnetic dipole and calculate its dipole moment.

Biot-Savart's law. Current loop as a magnetic dipole:

The magnetic field from the centre of a current loop of radius

$$\text{'R' along the axis. } \vec{B} = \frac{\mu_0 I R^2}{2(R^2 + Z^2)^{\frac{3}{2}}} \hat{k};$$

At larger distance, $Z \gg R$ and hence $R^2 + Z^2 \approx Z^2$

$$\vec{B} = \frac{\mu_0 I R^2}{2 Z^3} \hat{k}; = \frac{\mu_0 I \pi R^2}{2 \pi Z^3} \hat{k} \text{ Here } \pi R^2 \rightarrow \text{area of the loop}$$

$$\vec{B} = \frac{\mu_0 I A}{2 \pi Z^3} \hat{k}; = \frac{\mu_0}{4 \pi} \frac{2 I A}{Z^3} \hat{k} \dots \dots \dots (1)$$

We know that, magnetic field at a distance 'z' along the axial line is

$$\vec{B} = \frac{\mu_0}{4 \pi} \frac{2 \vec{p}_m}{Z^3} \dots \dots \dots (2)$$

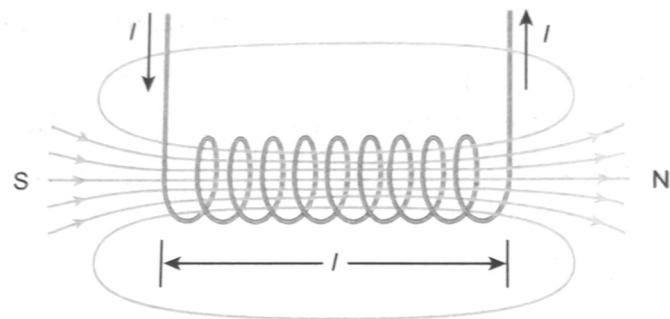
Compare equation (1) and (2) $\vec{p}_m = 1 \vec{A}$ (or) $p_m = I A$

This implies that a current carrying circular loop behaves as a magnetic dipole of dipole moment p_m . So the magnetic **dipole moment of any current loop is equal to the product of the current and area of the loop.**

- 79. Explain current carrying solenoid behaves like a bar magnet.**

Current carrying conductor:

A solenoid is a long coil of wire closely wound in the form of helix. When current flows through the solenoid, magnetic field is produced. It is due to the superposition of magnetic fields of each turn of the solenoid.



Inside the solenoid, the magnetic field is nearly uniform and parallel to its axis. But outside the solenoid, the field is negligibly small. Depending on the direction of current, **one end of the solenoid behaves like North Pole and the other end behaves like South Pole.**

The direction of magnetic field is given by right hand palm rule. (i.e.) if the current carrying solenoid is held in right hand such that the fingers curl in the direction of current, then extended thumb gives the direction of magnetic field. Hence magnetic field of a solenoid looks like the magnetic field of a bar magnet.

Uses:

Solenoid can be **used as electromagnets which produces strong magnetic field that can be turned ON or OFF.**

The strength of the magnetic field can be increased by keeping iron bar inside the solenoid. They are **useful in designing variety of electrical appliances.**

- 80. Write a note in MRI.**

MRI:

MRI is **Magnetic Resonance Imaging** which helps the physicians to diagnose or monitor treatment for a variety of abnormal conditions happening within the **head, chest, abdomen and pelvis**. It is a non-invasive medical test.

The patient is placed in a **circular opening** and **large current** is sent through the super conduction wire to produce a strong magnetic field. This magnetic field produces radio frequency pulses which are fed to a computer which produce pictures of **organs which helps the physicians to examine various parts of the body**

81. Define Lorentz force. Give the properties of Lorentz magnetic force.

Lorentz force:

When an electric charge 'q' moves in the magnetic field \vec{B} , it experiences a force called Lorentz magnetic force.

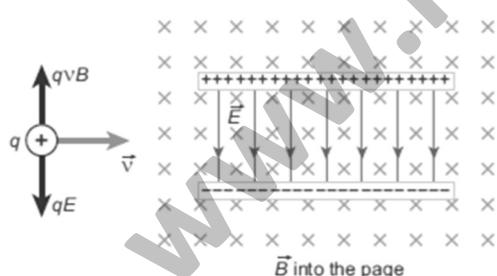
$$F_m = Bqv \sin \theta ; \text{ In vector notation, } \vec{F}_m = q(\vec{v} \times \vec{B})$$

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) The direction of \vec{F}_m on negative charge is opposite to the direction of \vec{F}_m on positive charge
- (vii) If the charge is along the magnetic field, then \vec{F}_m is zero.

82. Write a note on velocity selector.

Velocity selector:



Let an electric charge 'q' of mass 'm' enters in to a region of uniform magnetic field \vec{B} with velocity \vec{v} . Due to Lorentz force, the charged particle moves in helical path. By applying proper electric field \vec{E} , the Lorentz force can be balanced by Coulomb force. Here

Coulomb force acts along the direction of electric field, whereas the Lorentz force is perpendicular to the direction of magnetic field.

Therefore, in order to balance these forces, both electric and magnetic fields must be perpendicular to each other. Such an arrangement of perpendicular electric and magnetic fields are known as cross fields. The force on electric charge due to these fields is, $\vec{F} = q[\vec{E} + (\vec{v} \times \vec{B})]$

For a positive charge, the electric force on the charge acts in downward direction whereas the Lorentz forces acts upwards. When these two forces balance one another, the net force $\vec{F} = 0$. Hence $qE = Bqv_0$

$$\therefore v_0 = \frac{E}{B}$$

This means for a given magnitude of electric field \vec{E} and magnetic field \vec{B} , the forces act only for the particle moving with particular speed v_0 . This speed is independent of mass and charge,

- (i) If $v > v_0$, then charged particle deflects in the direction of Lorentz force.
- (ii) If $v < v_0$, then charged particle deflects in the direction of Coulomb force.
- (iii) If , then no deflection and the charged particle moves in straight line.

Thus by proper choice of electric and magnetic fields, the particle with particular speed can be selected. Such an arrangement of fields is called a velocity selector. This principle is used in Bainbridge mass spectrograph to separate the isotopes.

83. 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

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.) $V_{\text{galvanometer}} = V_{\text{shunt}}$

$$I_g R_g = I_s S$$

$$I_g R_g = (I - I_g) S \quad \dots \dots \quad (1) ; \quad S = \frac{I_g}{I - I_g} R_g$$

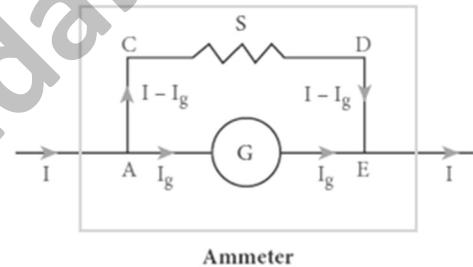
From equation (1) $I_g R_g = S I - I_g S$

$$I_g (S + R_g) = S I ; \quad I_g = \frac{S}{S + R_g} I$$

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

$$\Rightarrow R_a = \frac{R_g S}{R_g + S} \quad \text{Here, } R_g > S > R_a$$

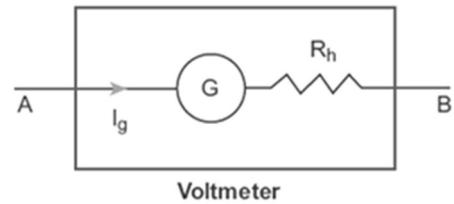
Thus an ammeter is a low resistance instrument, and it always **connected in series to the circuit. An ideal ammeter has zero resistance.**



84. 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.



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) $I_g = I$

$$I_g = \frac{V}{R_g + R_h} \quad (\text{or}) \quad R_g + R_h = \frac{V}{I_g}; \therefore R_h = \frac{V}{I_g} - R_g$$

Let R_v be the resistance of voltmeter, then $R_v = R_g + R_h$. 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 voltmeter has infinity.**

85. Differentiate Scalar, Vector and Tensor.

Scalar:

It has only one component. It has no direction (i.e) no unit vector

Since it has no direction, its rank is zero.

Vector:

It has resolved in to components. It has only one direction. (i.e.) has one-unit vector. Since each component have one direction, its rank is one

Tensor:

It has resolved into components. It has more than one direction (i.e) has more than one-unit vector. If each component associated with two directions, then its rank is two and if each component associated with three directions, then its rank is three.

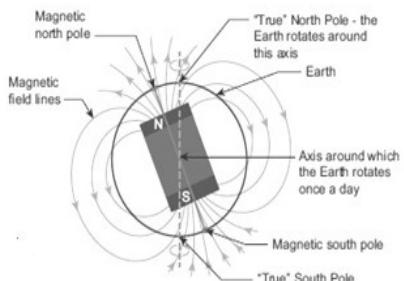
In general, if each component associated with 'n' direction, then it is called tensor of rank 'n'

FIVE MARKS QUESTIONS AND ANSWERS

86. Discuss Earth's magnetic field in detail.

Earth's magnetic field:

A freely suspended magnet comes to rest approximately along the geographical north - south direction.



To explain this, William Gilbert proposed that, Earth itself like a gigantic powerful magnet, but this theory was not accepted.

Gover suggested that the Earth's magnetic field is due to hot rays coming out from the Sun. So many theories have been proposed, but none of the theory completely explains the cause for the

Earth's magnetism.

The north pole of magnetic compass needle is attracted towards the magnetic south pole of the Earth which is near the geographic North Pole. Similarly, the south pole of magnetic compass needle is attracted towards the magnetic north pole of the Earth which is near the geographic South Pole.

The branch of physics which deals with the Earth's magnetic field is called **Geomagnetism (or) Terrestrial magnetism**.

The Earth spins about an axis called geographic axis and vertical line passing through the geographic axis is called geographic meridian, and a great circle perpendicular to Earth's geographic axis is called **geographic equator**.

The straight line which connects magnetic poles of Earth is known as magnetic axis and the vertical lies passing through magnetic axis is called **magnetic meridian** and a great circle perpendicular to Earth's magnetic axis is called **magnetic equator**.

The angle between magnetic meridian at a point and geographical meridian is called the magnetic declination (D). The angle subtended by the Earth's total magnetic field with the horizontal direction in the **magnetic meridian is called dip or magnetic inclination (I)** at that point.

The component of Earth's magnetic field along the horizontal direction in the magnetic meridian is called horizontal component of Earth's magnetic field (B_H). Let B_E be the net Earth's magnetic field at a point on the surface of the Earth, then Horizontal component; $B_H = B_E \cos I$ (1)

Vertical component; $B_V = B_E \sin I$ (2)

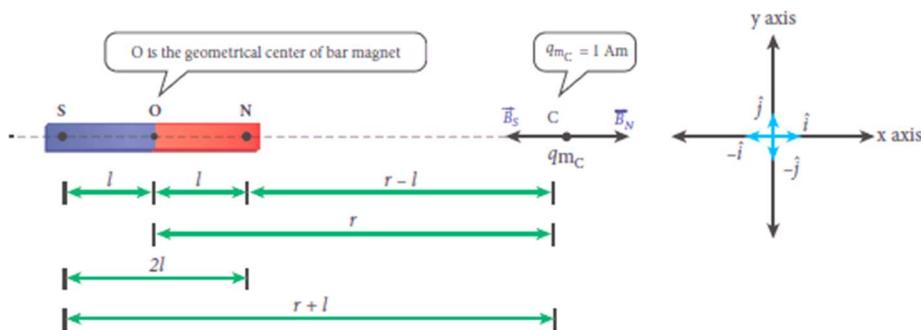
$$\text{Equation (2) divides by equation (1) } \tan I = \frac{B_H}{B_V}$$

i) At magnetic equator: At magnetic equator, $I = 0^\circ$, then $B_H = B_E$, $B_V = 0$

ii) At magnetic poles: At magnetic poles, $I = 90^\circ$, then $B_H = 0$, $B_V = B_E$

87. Calculate the magnetic induction at a point on the axial line of a bar magnet.

Magnetic field at axial line (\vec{B}_{axis}):



Consider a bar magnet 'NS' of moment $pm = q_m 2l$

Let C be the point on its axis at a distance 'r' from centre 'O'

Let unit north pole ($q_m C = 1 \text{ Am}$) is placed at 'C'

The repulsive force experienced by unit North Pole (i.e.) magnetic field

$$\text{at 'C' due to North Pole. } \vec{B}_N = \frac{\vec{F}_N}{q_{mc}} ; = \frac{\mu_0}{4\pi} \frac{q_m}{(r-l)^2} \hat{i} \quad \dots \dots \dots (1)$$

The attractive force experienced by unit North Pole (i.e.) magnetic field

$$\text{at 'C' due to South Pole. } \vec{B}_S = \frac{\vec{F}_S}{q_{mc}} ; = - \frac{\mu_0}{4\pi} \frac{q_m}{(r+l)^2} \hat{i} \quad \dots \dots \dots (2)$$

Then total magnetic field at "C" is $\vec{B}_{\text{axis}} = \vec{B}_N + \vec{B}_S$

$$\begin{aligned} &= \frac{\mu_0}{4\pi} \frac{q_m}{(r-l)^2} \hat{i} + \left[- \frac{\mu_0}{4\pi} \frac{q_m}{(r+l)^2} \hat{i} \right] ; = \frac{\mu_0}{4\pi} q_m \left[\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2} \right] \hat{i} \\ &= \frac{\mu_0}{4\pi} q_m \left[\frac{(r+l)^2 - (r-l)^2}{(r-l)^2 (r+l)^2} \right] \hat{i} ; = \frac{\mu_0}{4\pi} q_m \left[\frac{r^2 + l^2 + 2rl - r^2 - l^2 + 2rl}{\{(r-l)(r+l)\}^2} \right] \hat{i} \\ &= \frac{\mu_0}{4\pi} q_m \frac{4rl}{(r^2 - l^2)^2} \hat{i} ; = \frac{\mu_0}{4\pi} \frac{2rqm2l}{(r^2 - l^2)^2} \hat{i} ; \\ \vec{B}_{\text{axis}} &= \frac{\mu_0}{4\pi} \frac{2r p_m}{(r^2 - l^2)^2} \hat{i} \quad \dots \dots \dots (3) \end{aligned}$$

Where $q_m 2l = p_m \rightarrow \text{magnetic dipole moment.}$

If $r \gg l$, then $(r^2 - l^2)^2 \approx r^4$. So $\vec{B}_{\text{axis}} = \frac{\mu_0}{4\pi} \frac{2r p_m}{r^4} \hat{i}$

$$\vec{B}_{\text{axis}} = \frac{\mu_0}{4\pi} \frac{2 p_m}{r^3} \hat{i} \quad [p_m \hat{i} = \vec{p}_m]$$

$$\vec{B}_{\text{axis}} = \frac{\mu_0}{4\pi} \frac{2 \vec{p}_m}{r^3} \quad \dots \dots \dots (4)$$

- 88. Obtain the magnetic induction at a point on the equatorial line of a bar magnet.**

Magnetic field at equatorial line:

Consider a bar magnet 'NS' of moment

$$p_m = q_m 2l$$

Let C be the point on its equatorial line at a distance 'r' from centre 'O' Let unit north pole

($q_{mc} = 1 \text{ Am}$) is placed at 'C'

The repulsive force experienced by unit North Pole (i.e.) magnetic field at 'C' due to North Pole

$$B_N = \frac{F_N}{q_{mc}} = \frac{\mu_0 q_m}{4\pi r^2} \text{ (along NC)} \quad \dots \dots \dots (1)$$

The attractive force experienced by unit North Pole (i.e.) magnetic field

$$\text{at 'C' due to South Pole } B_S = \frac{F_S}{q_{mc}} = \frac{\mu_0 q_m}{4\pi r^2} \text{ (along CS)} \quad \dots \dots \dots (2)$$

Here, $B_N = B_S$

Resolve these two magnetic fields into their components. Hence

$$\vec{B}_N = -B_N \cos \theta \hat{i} + B_N \sin \theta \hat{j}$$

$$\vec{B}_S = -B_S \cos \theta \hat{i} - B_S \sin \theta \hat{j}$$

Then the total magnetic field at 'C' is $\vec{B}_{\text{equator}} = \vec{B}_N + \vec{B}_S$

$$= -B_N \cos \theta \hat{i} + B_N \sin \theta \hat{j} - B_S \cos \theta \hat{i} - B_S \sin \theta \hat{j}$$

$$\vec{B}_{\text{equator}} = -B_N \cos \theta \hat{i} - B_S \cos \theta \hat{i}$$

$$\vec{B}_{\text{equator}} = -2 \cos \theta \hat{i} \quad [\because B_N = B_S]$$

$$= -2 \frac{\mu_0 q_m}{4\pi r^2} \cos \theta \hat{i}$$

$$\vec{B}_{\text{equator}} = -\frac{\mu_0}{4\pi} \frac{2 q_m}{(r^2+l^2)^2} \cos \theta \hat{i} \quad \dots \dots \dots (3)$$

$$\text{But } \Delta NOC, \cos \theta = \frac{ON}{CN} = \frac{l}{r} = \frac{l}{(r^2+l^2)^{\frac{1}{2}}}$$

Then equation (3) becomes,

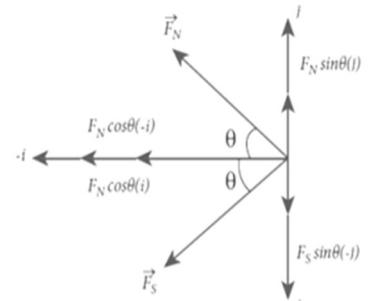
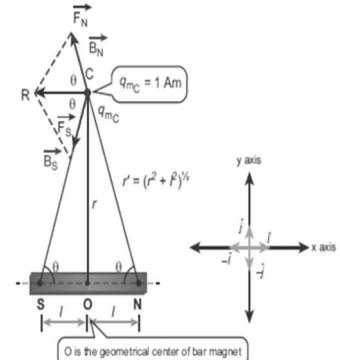
$$\vec{B}_{\text{equator}} = -2 \frac{\mu_0}{4\pi} \frac{q_m}{(r^2+l^2)^{\frac{1}{2}}} \frac{l}{(r^2+l^2)^{\frac{1}{2}}} \hat{i}$$

$$\vec{B}_{\text{equator}} = -\frac{\mu_0}{4\pi} \frac{q_m 2l}{(r^2+l^2)^{\frac{3}{2}}} \hat{i}; \vec{B}_{\text{equator}} = -\frac{\mu_0}{4\pi} \frac{p_m}{(r^2+l^2)^{\frac{3}{2}}} \hat{i}$$

Where $q_m 2l = p_m \rightarrow$ magnetic dipole moment.

If $r \gg l$, then $(r^2 + l^2)^{\frac{3}{2}} \approx r^3$. So

$$\vec{B}_{\text{equator}} = \frac{\mu_0}{4\pi} \frac{p_m}{r^3} \hat{i} \quad [p_m \hat{i} = \vec{p}_m]; \vec{B}_{\text{equator}} = \frac{\mu_0}{4\pi} \frac{\vec{p}_m}{r^3} \quad \dots \dots (4)$$



- 89. What is tangent law? Discuss in detail. Explain the principle, construction and working of tangent galvanometer.**

Tangent Galvanometer:

It is a device used to **measure very small currents**.

It is a moving magnet type galvanometer. Its working is based on **tangent law**.

Tangent law:

When a magnetic needle or magnet is freely suspended in two mutually perpendicular uniform magnetic fields, it will come to rest in the direction of the resultant of the two fields.

Let B be the magnetic field produced by passing current through the coil of tangent galvanometer and B_H be the horizontal component of Earth's magnetic field.

Under the action of two magnetic fields, the needle comes to rest at an angle with B_H , such that $B = B_H \tan\theta$

Construction:

It consists of copper coil wound on a non-magnetic circular frame. It is fixed vertically on a horizontal turn table providing with three leveling screws. At centre, a compass box is placed which consists of a small magnetic needle which is pivoted at its centre. **A thin aluminium pointer is attached to the magnetic needle normally and moves over circular scale.**

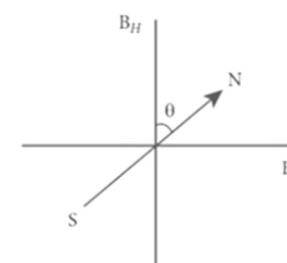
The circular scale is divided in to four quadrants and graduated in degrees. In order to avoid parallax error in measurement, a mirror is placed below the aluminium pointer. Here the centre of magnetic needle will exactly coincide with the centre of the circular coil.

The coil has **three sections of 2, 5 and 50 turns** which are different thickness and are used to measuring currents of different strengths.

Theory:

When no current is passed through the coil, the small magnetic needle lies along horizontal component of Earth's magnetic field

When current pass through the coil, it produces magnetic field in direction perpendicular to the plane of the coil. Now there are two fields, which are acting mutually perpendicular to each other.



They are, (i) The magnetic field 'B' due to current in the coil

(ii) Horizontal component of Earth's magnetic field ' B_H '

Thus the magnetic needle deflects through an angle ' θ '. By tangent law,

$$B = B_H \tan \theta \quad \dots \dots \dots (1)$$

When current 'I' passing through a circular coil of radius 'R' having 'N' turns,

$$\text{the magnitude of magnetic field at the centre is, } B = \frac{\mu_0 NI}{2R} \quad \dots \dots \dots (2)$$

Put equation (2) in (1)

$$\frac{\mu_0 NI}{2R} = B_H \tan \theta ; B_H = \frac{\mu_0 N}{2R} \left(\frac{I}{\tan \theta} \right) \dots\dots\dots (3)$$

Also the current is, $I = \frac{2R B_H}{\mu_0 N} \tan \theta = K \tan \theta \dots\dots\dots (4)$

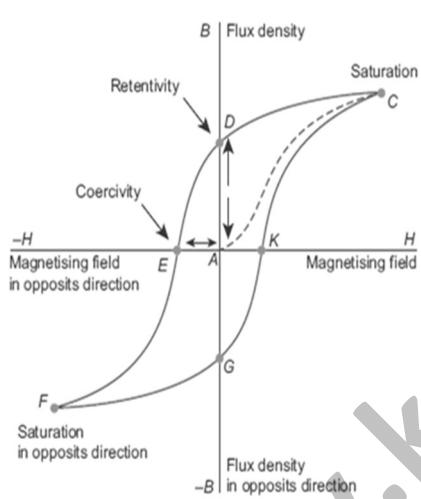
Where, $K = \frac{2R B_H}{\mu_0 N}$ → Reduction factor of TG

90. Define Hysteresis. Explain it with help of diagram.

Hysteresis:

Hysteresis means '**lagging behind**', The phenomenon of lagging of magnetic induction (\vec{B}), behind the magnetizing field (\vec{H}) is called hysteresis.

Hysteresis loop:



Let a Ferro magnetic material (iron) is magnetized slowly by a magnetizing field \vec{H} . The magnetic induction \vec{B} increases from point A and attains saturated level at C. This is shown by the path AC.

The maximum point up to which the material can be magnetized by applying the magnetizing field is called **Saturation magnetization**.

If magnetizing field is now reduced, the magnetic induction also decreases but in different path CA.

When magnetizing field is zero, the magnetic induction is not zero and it has positive value. (i.e.) some magnetism is left in the material even when $H=0$.

The ability of the material to retain the magnetism in them even magnetizing field vanishes is called remanence or retentively.

To remove the remanence, the magnetizing field is gradually increased in the reverse direction, so that **the magnetic induction decreases** along DE and becomes zero at 'E'

The magnitude of the reverse magnetizing field for which the residual magnetism of the material vanishes is called its coercively. Further increase of in the reverse direction, **the magnetic induction increases** along EF until it reaches saturation at F in the reverse direction. If magnetizing field is decreased and then increased with direction reversed, the magnetic induction traces the path FGK.

This closed curve **ACDEFGKC** is called hysteresis loop and it represents a cycle of magnetization. In the entire cycle, the magnetic induction 'B' lags behind the magnetizing field 'H'. This phenomenon is called hysteresis

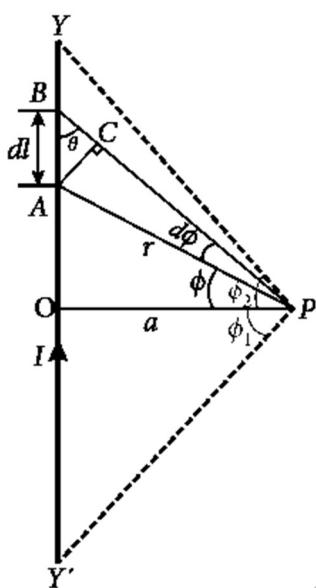
Hysteresis Loss:

Due to hysteresis there is a loss of energy in the form of heat and It is found that the energy lost per unit volume of the material when it is carried through one cycle of magnetization is equal to the area of the hysteresis loop. Thus the loss of energy for a complete cycle is, $\Delta E = \oint \vec{H} \cdot d\vec{B}$

- 91. 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 $d\vec{l}$** . Then the magnetic field at 'P' due to the element is,

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

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

$$\text{In triangle } \triangle ABC, \sin\theta = \frac{AC}{AB} \Rightarrow AC = AB \sin\theta$$

$$\text{But } AB = dl \Rightarrow AC = dl \sin\theta$$

Let $d\phi$ be the angle subtended between AP and BP

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

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

But $AP = r \Rightarrow AC = rd\phi \therefore AC = dl \sin\theta = rd\phi$

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

Let ϕ be the angle between AP and OP

$$\text{In a } \triangle OPA, \cos\phi = \frac{OP}{AP} = \frac{a}{r} ; \Rightarrow r = \frac{a}{\cos\phi} ; d\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{a} \frac{1}{\cos\phi} d\phi \hat{n}$$

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

The total magnetic field at P due to the conductor YY' is $\vec{B} = \int_{-\phi_1}^{\phi_2} \vec{dB}$

$$= \int_{-\phi_1}^{\phi_2} \frac{\mu_0 I}{4\pi a} \cos\phi d\phi \hat{n} ;$$

$$\frac{\mu_0 I}{4\pi a} [\sin\phi]_{-\phi_1}^{\phi_2} \hat{n}$$

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

For infinitely long conductor, $\phi_1 = \phi_2 = 90^\circ$

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

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

- 92.** 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 $d\vec{l}$ at C and D. Let \vec{r} be the vector joining the current element $I d\vec{l}$ at C to the point P.

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

The magnetic field at 'P' due to the current element $I d\vec{l}$ is, $d\vec{B} = \frac{\mu_0 I d\vec{l}}{4\pi r^2} \hat{n} \because \theta = 90^\circ$

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

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

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

Here horizontal components of each element cancel each other.

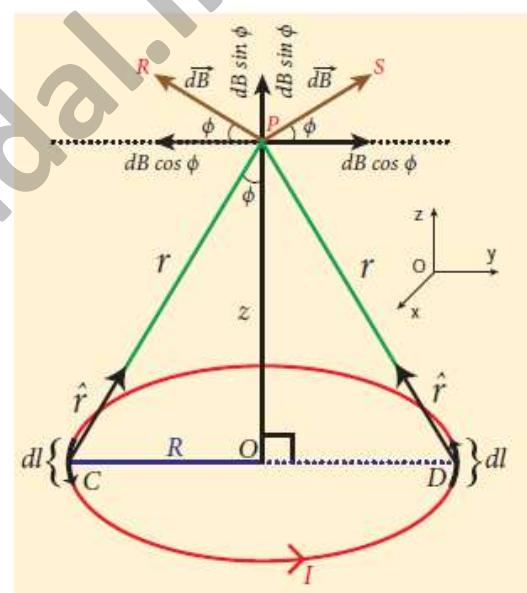
But vertical components alone contribute to total magnetic field at the point 'P' $\vec{B} = \int d\vec{B} = \int dB \sin\phi \hat{k}$;

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

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, $\int dl = 2\pi R \rightarrow$ total length of the coil.



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

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 $z=0$; $\vec{B} = \frac{\mu_0 N I}{2R} \hat{k}$

- 93. Compute the magnetic dipole moment of revolving electron. And hence define Bohr magneton.**

Magnetic dipole moment of revolving electron:

Let an electron moves in circular motion around the nucleus. The circulating electron in a loop is like current in a circular loop.

The magnetic dipole moment due to current carrying circular loop is, $\vec{\mu}_L = I \vec{A}$.

In magnitude, $\mu_L = I A \dots \dots \dots (1)$

If T is the time period of an electron, the current due to revolving electron is, $I = -\frac{e}{T}$, where ‘-e’ → charge of an electron.

If ‘R’ be the radius and ‘v’ be the velocity of electron in the circular orbit,

$$\text{then } T = \frac{2\pi}{\omega} = \frac{2\pi R}{v}$$

$$\text{Then equation (1) becomes, } \mu_L = -\frac{e}{T} A = -\frac{e}{\frac{2\pi R}{v}} \pi R^2$$

Where, $A = \pi R^2 \rightarrow \text{area of the circular orbit}$

$$\therefore \mu_L = -\frac{eV R}{2} \dots \dots \dots (2)$$

By definition, angular momentum of the electron about ‘O’ is

$$\vec{L} = \vec{R} \times \vec{p}$$

In magnitude, angular momentum is given by,

$$L = R_p = mvR \dots \dots \dots (3)$$

$$\text{Dividing equation (2) by (3), } \frac{\mu_L}{L} = -\frac{eV R}{2 m v R} ; = -\frac{e}{2 m}$$

$$\text{In vector notation, } \vec{\mu}_L = -\frac{e}{2 m} \vec{L} \dots \dots \dots (4)$$

Here **negative sign indicates that the magnetic dipole moment and angular momentum are in opposite direction.**

In magnitude, $\frac{\mu_L}{L} = \frac{e}{2 m} = 8.78 \times 10^{10} \text{ Ckg}^{-1} = \text{Constant.}$

This constant is called **gyro-magnetic ratio**.

According to Bohr quantization rule, angular momentum of an electron is,

$$L = n\hbar = n \frac{h}{2\pi} ; \text{ Where, } h \rightarrow \text{Plank's constant } (h = 6.63 \times 10^{-34} \text{ Js})$$

$n \rightarrow$ Positive integer ($n = 1, 2, 3, \dots$)

$$\therefore \mu_L = \frac{e}{2m} L; = \frac{e}{2m} n \frac{h}{2\pi}; \mu_L = n \frac{eh}{4\pi m} \quad \dots \dots \quad (5)$$

The minimum magnetic moment can be obtained by substituting $n = 1$

$$(\mu_L)_{\min} = \mu_B = \frac{eh}{4\pi m} = 9.27 \times 10^{-24} \text{ Am}^2$$

The **minimum value of magnetic moment** of revolving electron is called **Bohr magneton** (μ_B)

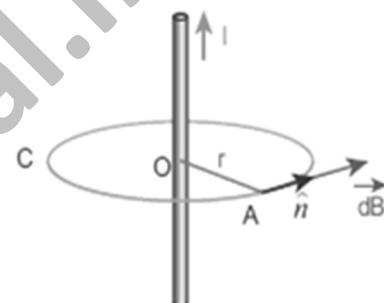
- 94.** Using Ampere's law, obtain an expression for magnetic field due to the current carrying wire of infinite length.

Magnetic field due to current carrying straight wire using Ampere's law:

Consider a straight conductor of infinite length carrying current 'I'

Imagine an Amperian circular loop at a distance 'r' from the centre of the conductor. From Ampere's circuital law, $\oint \vec{B} \cdot d\vec{l} = \mu_0 I$

Here $d\vec{l}$ is the line element along the tangent to the Amperian loop. So, the angle between \vec{B} and $d\vec{l}$ is zero ($\theta = 0^\circ$). Thus, $\oint \vec{B} \cdot d\vec{l} = \mu_0 I$



Due to symmetry, the magnitude of the magnetic field is uniform over the Amperian loop and hence, $B \oint dl = \mu_0 I$

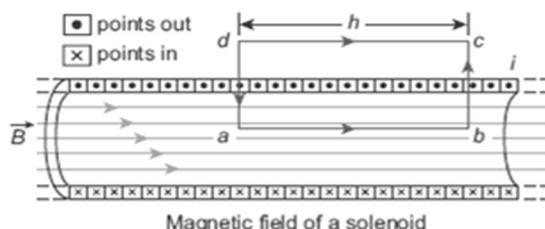
For circular loop, $\oint dl = 2\pi r \quad B(2\pi r) = \mu_0 I$

$$B = \frac{\mu_0 I}{2\pi r} \hat{n}, \text{ In vector notation, } \vec{B} = \frac{\mu_0 I}{2\pi r} \hat{n}$$

95. 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,



consider an Amperian loop ‘abcd’. From Ampere circuital law,

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_0 \quad \dots \dots \dots \quad (1)$$

The LHS of equation (1) can be written as

$$\begin{aligned} \oint \vec{B} \cdot d\vec{l} &= \int_a^b \vec{B} \cdot d\vec{l} + \int_b^c \vec{B} \cdot d\vec{l} + \int_c^d \vec{B} \cdot d\vec{l} + \int_d^a \vec{B} \cdot d\vec{l} \\ \int_a^b \vec{B} \cdot d\vec{l} &= \int_a^b B dl \cos 0^\circ = B \int_a^b dl = BL \\ \int_b^c \vec{B} \cdot d\vec{l} &= \int_b^c B dl \cos 90^\circ = 0; \int_c^d \vec{B} \cdot d\vec{l} = 0 \\ \int_d^a \vec{B} \cdot d\vec{l} &= \int_d^a B dl \cos 90^\circ = 0 \end{aligned}$$

Here $ab = h$. If we take large loop such that it is equal to length of the solenoid, we have $\oint \vec{B} \cdot d\vec{l} = BL \dots \dots \dots \quad (2)$

Let ‘I’ be the current passing through the solenoid of ‘N’ turns, then

$$I_0 = NI \quad \dots \dots \dots \quad (3)$$

Put equation (2) and (3) in (1) $BL = \mu_0 NI$

$$B = \mu_0 \frac{N}{L} I \quad \dots \dots \dots \quad (4)$$

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

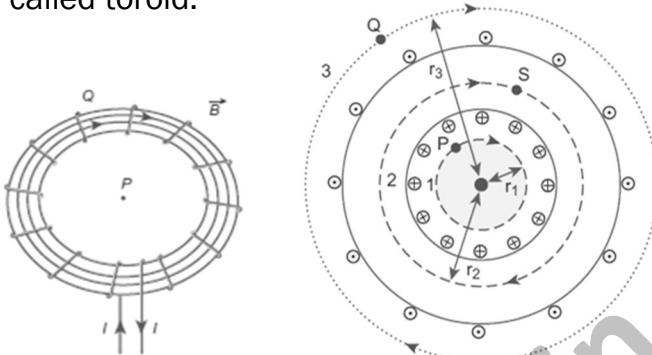
$$B = \frac{\mu_0 NI}{L} = \mu_0 n I \quad \dots \dots \dots \quad (5)$$

Since ‘n’ and μ_0 are constants, for fixed current ‘I’ the magnetic field ‘B’ inside the solenoid is also constant.

96. Obtain the magnetic fields at various points on the toroid.

Toroid:

A solenoid is bent in such a way its ends are joined together to form a closed ring shape is called toroid.



Open space interior to the toroid (P):

To calculate the magnetic field \mathbf{B}_P at 'P', consider an Amperian loop (1) of radius r_1 . Then Amperian circuital law for loop 1 is $\oint \mathbf{B}_P \cdot d\mathbf{l} = \mu_0 I_0$

Since the loop 1 encloses no current, $I_0 = 0$,
then $\oint \mathbf{B}_P \cdot d\mathbf{l} = 0 \therefore \mathbf{B}_P = \mathbf{0}$

Open space exterior to the toroid (Q):

To calculate magnetic field \mathbf{B}_Q at 'Q' construct Amperian loop (3) of radius r_3 . Then Amperian circuital law for loop 3 is $\oint \mathbf{B}_Q \cdot d\mathbf{l} = \mu_0 I_0$

Since in each turn of the toroid loop, current coming out of the plane of paper is cancelled by the current going into plane of the paper, Thus $I_0 = 0$

$$\oint \mathbf{B}_Q \cdot d\mathbf{l} = 0 \therefore \mathbf{B}_Q = \mathbf{0}$$

Inside the toroid (S) :

To calculate magnetic field \mathbf{B}_S at 'S' construct Amperian loop (2) of radius r_2 . The length of the loop 2; $L_2 = 2\pi r_2$ and the loop encloses the current ; $I_0 = NI$, Then Amperian circuital law for loop 2 is $\oint \mathbf{B}_S \cdot d\mathbf{l} = \mu_0 I_0$

$$\mathbf{B}_S \oint d\mathbf{l} = \mu_0 NI ; B_S (2\pi r_2) = \mu_0 NI$$

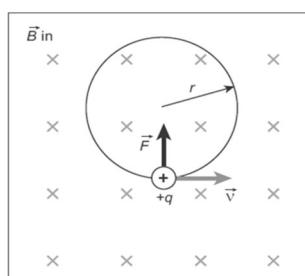
$$B_S = \frac{\mu_0 NI}{2\pi r_2}$$

Let 'n' be the number of turns per unit length, then $\frac{N}{2\pi r_2} = n$.

$$\text{Hence, } B_S = \mu_0 n I$$

97. Obtain the expression for force on a moving charge in a magnetic field.

Force on moving charge in a magnetic field:



Consider a charged particle of charge 'q' having mass 'm' enters perpendicular to uniform magnetic field 'B' with velocity \vec{v}

So this charged particle experience Lorentz force which acts perpendicular to both \vec{B} and \vec{v} it is

$$\vec{F} = q(\vec{v} \times \vec{B})$$

Since Lorentz force alone acts on the particle, the magnitude of this force is $F = Bqv [\theta = 90^\circ]$

Hence charged particle moves in a circular orbit and the necessary centripetal force is provided by Lorentz force. (i.e.) $Bqv = \frac{mv^2}{r}$

$$\text{The radius of the circular path is, } r = \frac{mv}{Bq} = \frac{p}{Bq} \quad \dots \dots \dots (1)$$

Where, $m v = p \rightarrow$ linear momentum

$$\text{Let 'T' be the time period, then } T = \frac{2\pi r}{v} = \frac{2\pi m v}{v Bq}$$

$$T = \frac{2\pi m}{Bq} \quad \dots \dots \dots (2) \text{ It is called cyclotron time period.}$$

$$\text{Let 'f' be the frequency, then } f = \frac{1}{T} = \frac{Bq}{2\pi m} \quad \dots \dots \dots (3)$$

$$\text{In terms of angular frequency, } \omega = 2\pi f = \frac{Bq}{m} \quad \dots \dots \dots (4)$$

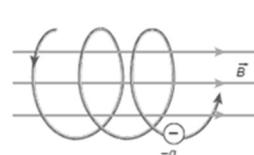
It is called **cyclotron frequency or gyro-frequency**.

From equation (2), (3) and (4), we infer that time period (T), frequency (f) and angular frequency (ω) depends only on specific charge, but not velocity or the radius of the circular path.

Special cases:

If a charged particle moves in uniform magnetic field, such that its velocity is not perpendicular to the magnetic field, then its velocity is resolved into two components.

One component is parallel to the field and the other component is perpendicular to the field.



Here parallel component remains unchanged and the perpendicular component keeps on changing due to Lorentz force. Hence the path of the particle is not circle; it is helix around the field.

98. Describe the principle, construction and working of Cyclotron.

Cyclotron:

It is a device used to **accelerate the charged particles to gain large kinetic energy**. It is also called as **high energy accelerator**. It is invented by Lawrence and Livingston.

Principle:

When a **charged particle** moves normal to the **magnetic field**, it experience **magnetic Lorentz force**.

Construction:

It consists **two semicircular metal** containers called Dees.

The **Dees are enclosed in an evacuated chamber** and it is kept in a region of uniform magnetic field acts normal to the plane of the Dees.

The two Dees are kept separated with a **gap and the source 'S'** of charged particles to be accelerated is placed at the centre in the gap between the Dees.

Dees are **connected to high frequency** alternating potential difference.

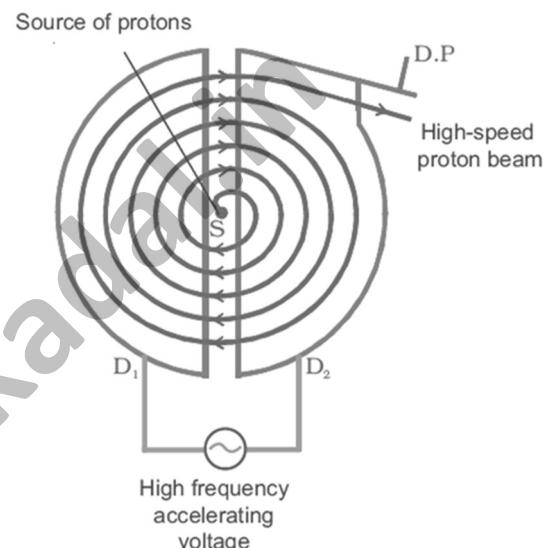
Working:

Let the positive ions are ejected from source 'S'. It is accelerated towards a **Dee-1 which has negative potential at that instant**. Since the magnetic field is normal to the plane of the Dees, the ion undergoes circular path. After **one semi-circular path in Dee-1, the ion reaches the gap between Dees**.

At this time the polarities of the Dees are reversed, so that the ion is now accelerated towards Dee-2 with a greater velocity. For this circular motion, **the centripetal force of the charged particle is provided by Lorentz force**,

$$\text{then } \frac{mv^2}{r} = Bqv ; r = \frac{mv}{Bq} ; \therefore r \propto v$$

Thus the **increase in velocity increases the radius of the circular path**. Hence the particle undergoes **spiral path of increasing radius**. Once it reaches near the edge, it is taken out with help of deflector plate and allowed to hit the target T. The important condition in cyclotron is the resonance condition. (i.e.) the frequency 'f' of the charged particle must be equal to the frequency of the electrical oscillator ' f_{osc} '. Hence $f_{osc} = \frac{Bq}{2\pi m}$



The time period of oscillation is, $T = \frac{2\pi}{Bq}$,

The kinetic energy of the charged particle is, $KE = \frac{1}{2}mv^2 = \frac{B^2q^2r^2}{2m}$

Limitations of cyclotron:

- (i) The speed of the ion is limited
- (ii) Electron cannot be accelerated
- (iii) Uncharged particles cannot be accelerated.

99. Obtain an expression for the force on a current carrying conductor placed in a magnetic field.

Force on current carrying conductor in magnetic field:

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.

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'

The free electrons drift opposite to the direction of current with velocity v_d . The relation between current and drift velocity is,

$$I = n A e v_d$$

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 $N = n A dl$. Hence Lorentz force on the small element,

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

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

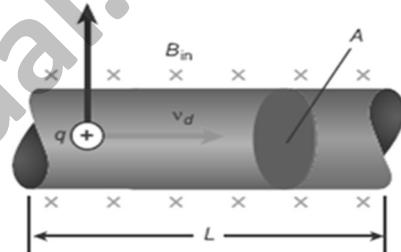
$$\text{Put this in equation (1), } \vec{dF} = I \vec{dl} \times \vec{B} \quad \dots \dots \dots (2)$$

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

$$\text{In magnitude, } F = BIl \sin\theta \quad \dots \dots \dots (4)$$

Special cases:

- (i) If the current carrying conductor placed along the direction of magnetic field, then $\theta = 0^\circ \quad \therefore F = 0$
- (ii) If the current carrying conductor is placed perpendicular to the magnetic field, then $\theta = 90^\circ \quad \therefore F = BIl = \text{maximum.}$



- 100. Obtain a force between two long parallel current carrying conductors.
Hence define ampere.**

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'.

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

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

$$d\vec{F} = I_2 dl \times \vec{B}_1 = -I_2 dl \hat{k} \times \frac{\mu_0 I_1}{2\pi r} \hat{i} ; d\vec{F} = -\frac{\mu_0 I_1 I_2 dl}{2\pi r} (\hat{k} \times \hat{i}) ; d\vec{F} = -\frac{\mu_0 I_1 I_2 dl}{2\pi r} \hat{j}$$

By Fleming's left hand rule, this force acts left wards. The force per unit length of the conductor B. $\frac{\vec{F}}{l} = -\frac{\mu_0 I_1 I_2}{2\pi r} \hat{j} \quad \dots \dots \dots (1)$

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

Here \vec{B}_2 acts perpendicular to plane of 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 .

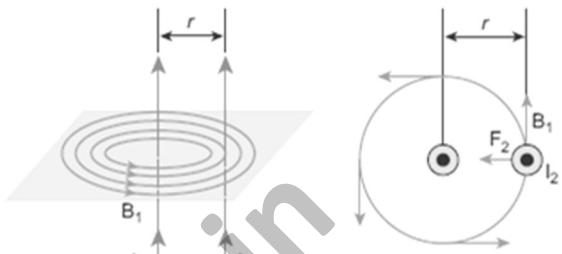
$$d\vec{F} = I_1 dl \times \vec{B}_2 = I_1 dl \hat{k} \times \frac{\mu_0 I_2}{2\pi r} \hat{i} ; d\vec{F} = \frac{\mu_0 I_1 I_2 dl}{2\pi r} (\hat{k} \times \hat{i}) ; d\vec{F} = \frac{\mu_0 I_1 I_2 dl}{2\pi r} \hat{j}$$

By Fleming's left hand rule, this force acts right wards. The force per unit length of the conductor A. $\frac{\vec{F}}{l} = \frac{\mu_0 I_1 I_2}{2\pi r} \hat{j} \quad \dots \dots \dots (2)$

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.

Definition of ampere:

One ampere is defined as that current when it is passed through each of two infinitely long parallel conductors kept a distance of one metre apart in vacuum causes each conductor experience a force of **2×10^{-7} Newton per meter length of conductor.**



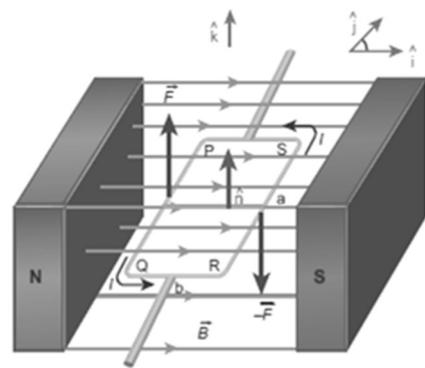
- 101. Deduce an expression for torque on a current loop placed in magnetic field when unit vector \hat{n} is perpendicular to \vec{B} .**

Torque on a current loop:

Consider a rectangular current loop PQRS kept in uniform magnetic field \vec{B} with its plane parallel to the field. Let $PQ = RS = a \rightarrow$ Length of the loop $QR = SP = b \rightarrow$ Breadth of the loop

Let \hat{n} be the unit vector normal to the plane of the current loop.

Let the loop is divided in to four sections PQ, QR, RS and SP. The Lorentz force on each loop can be calculated as follows.



Force on section PQ

$$\vec{F}_{PQ} = I \vec{PQ} \times \vec{B} ; \vec{F}_{PQ} = I(PQ) (-\hat{j}) \times B\hat{i} ; = -IaB(\hat{j} \times \hat{i}) \\ \vec{F}_{PQ} = IaB\hat{k} \quad \dots \quad (1)$$

Force on section QR

$$\vec{F}_{QR} = I \vec{QR} \times \vec{B} ; \vec{F}_{QR} = I(QR) (\hat{i}) \times B\hat{i} ; = IbB(\hat{i} \times \hat{i}) \\ \vec{F}_{QR} = \vec{0} \quad \dots \quad (2)$$

Force on section RS

$$\vec{F}_{RS} = I \vec{RS} \times \vec{B} ; \vec{F}_{RS} = I(RS) \hat{j} \times B\hat{i} ; = IaB(\hat{j} \times \hat{i}) \\ \vec{F}_{RS} = -IaB\hat{k} \quad \dots \quad (3)$$

Force on section SP

$$\vec{F}_{SP} = I \vec{SP} \times \vec{B} ; \vec{F}_{SP} = I(SP) (\hat{i}) \times B\hat{i} ; = -IbB(\hat{i} \times \hat{i}) \\ \vec{F}_{SP} = \vec{0} \quad \dots \quad (4)$$

The **net force** on the rectangular loop is,

$$\vec{F}_{res} = \vec{F}_{PQ} + \vec{F}_{QR} + \vec{F}_{RS} + \vec{F}_{SP} \\ \vec{F}_{res} = IaB\hat{k} + \vec{0} + -IaB\hat{k} + \vec{0} \\ \vec{F}_{res} = \vec{0}$$

Hence the net force on the rectangular loop in this configuration is zero. But the net torque due to these forces about an axis passing through the centre, $\vec{\tau}_{res} = \vec{r}_1 \times \vec{F}_{PQ} + \vec{r}_2 \times \vec{F}_{QR} + \vec{r}_3 \times \vec{F}_{RS} + \vec{r}_4 \times \vec{F}_{SP}$

$$\vec{\tau}_{res} = \frac{b}{2} (-\hat{i}) \times IaB\hat{k} + \vec{0} + \frac{b}{2} \hat{i} \times IaB(-\hat{k}) + \vec{0}$$

$$\vec{\tau}_{res} = -\frac{b}{2} \times IaB(\hat{i} \times \hat{k}) - \frac{b}{2} \times IaB(\hat{i} \times \hat{k})$$

$$\vec{\tau}_{res} = -\frac{b}{2} \times IaB(\hat{j}) - \frac{b}{2} \times IaB(-\hat{j})$$

$$\vec{\tau}_{\text{res}} = \frac{b}{2} I a B \hat{j} + \frac{b}{2} I a B \hat{j}$$

$$\vec{\tau}_{\text{res}} = \mathbf{ab} I \mathbf{B} \hat{\mathbf{j}} = A I B \hat{\mathbf{j}} \dots\dots\dots (5)$$

Where, $a b = A \rightarrow$ area of the rectangular loop.

- 102. Deduce an expression for torque on a current loop placed in magnetic field when unit vector \hat{n} is at an angle with \vec{B} .**

Torque on a current loop:

Consider a rectangular current loop PQRS kept in uniform magnetic field \vec{B} with its plane inclined to the field.

Let $PQ = RS = a \rightarrow$ Length of the loop ,
 $QR = SP = b \rightarrow$ Breadth of the loop

Let \hat{n} be the unit vector normal to the plane of the current loop.

Let θ be the angle between normal vector \hat{n} and magnetic field \vec{B}

Force on section PQ,

Force on section PQ

$$\vec{F}_{PQ} = I \vec{PQ} \times \vec{B} ; \vec{F}_{PQ} = I(PQ) (-\hat{j}) \times B \hat{i} ; = - I a B (\hat{j} \times \hat{i})$$

$$\vec{F}_{PQ} = -I a B \hat{k} \dots\dots\dots (1)$$

Force on section QR

$$\vec{QR} = b \cos(90^\circ - \theta) \hat{i} + b \sin(90^\circ - \theta) \hat{k}$$

$$\vec{QR} = b \sin \theta \hat{i} - b \cos \theta \hat{k} ; \vec{F}_{QR} = I \vec{QR} \times \vec{B}$$

$$\begin{aligned} \vec{F}_{QR} &= I [b \sin \theta \hat{i} - b \cos \theta \hat{k}] \times B \hat{i} \\ &= -I b B \cos \theta (\hat{k} \times \hat{i}) \end{aligned}$$

$$\vec{F}_{QR} = -I b B \cos \theta \hat{j} \dots\dots\dots (2)$$

Force on section RS

$$\vec{F}_{RS} = I \vec{RS} \times \vec{B} ; \vec{F}_{RS} = I(RS) \hat{j} \times B \hat{i} ; = I a B (\hat{j} \times \hat{i})$$

$$\vec{F}_{RS} = -I a B \hat{k} \dots\dots\dots (3)$$

Force on section SP

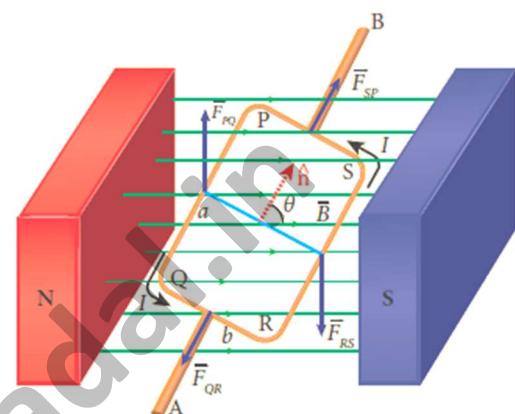
$$\vec{SP} = b \cos(90^\circ + \theta) (-\hat{i}) + b \sin(90^\circ + \theta) \hat{k}$$

$$\vec{SP} = -b \sin \theta \hat{i} + b \cos \theta \hat{k} ; \vec{F}_{SP} = I \vec{SP} \times \vec{B}$$

$$\begin{aligned} \vec{F}_{SP} &= I [-b \sin \theta \hat{i} + b \cos \theta \hat{k}] \times B \hat{i} \\ &= I b B \cos \theta (\hat{k} \times \hat{i}) \end{aligned}$$

$$\vec{F}_{SP} = I b B \cos \theta \hat{j} \dots\dots\dots (4)$$

The **net force** on the rectangular loop is,



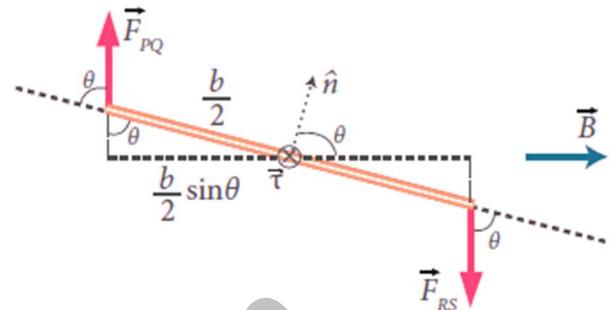
$$\vec{F}_{\text{res}} = \vec{F}_{\text{PQ}} + \vec{F}_{\text{QR}} + \vec{F}_{\text{RS}} + \vec{F}_{\text{SP}}$$

$$\vec{F}_{\text{res}} = I_a B \hat{k} - I_b B \cos \theta \hat{j} - I_a B \hat{k} + I_b B \cos \theta \hat{j}$$

$$\vec{F}_{\text{res}} = \vec{0}$$

Since the forces on sections QR and

SP are equal in magnitude, opposite in direction and in same line, no torque produce by these two sections. On the other hand, forces on sections PQ and RS are equal and opposite but in different lines and hence these two forces constitute a couple.



Hence the net torque produced by these two forces about the axis of the rectangular loop is

$$\vec{\tau}_{\text{res}} = \overrightarrow{OA} \times \vec{F}_{PQ} + \overrightarrow{OB} \times \vec{F}_{RS}$$

$$\vec{\tau}_{\text{res}} = \frac{b}{2} [\cos(90^\circ - \theta)(-\hat{i}) + \sin(90^\circ - \theta)\hat{k}] \times I a B \hat{k}$$

$$+ \frac{b}{2} [\cos(90^\circ - \theta)(\hat{i}) + \sin(90^\circ - \theta)(-\hat{k})] x - I a B \hat{k}$$

$$\vec{\tau}_{\text{res}} = \frac{b}{2} [-\sin \theta \hat{i} + \cos \theta \hat{k}] \times I a B \hat{k} - \frac{b}{2} [\sin \theta \hat{i} - \cos \theta \hat{k}] \times I a B \hat{k}$$

$$\vec{\tau}_{\text{res}} = \frac{b}{2} \sin \theta \ I a B (-\hat{j}) + 0 - \frac{b}{2} \sin \theta \ I a B (-\hat{j})$$

$$\vec{\tau}_{\text{res}} = -\frac{b}{2} \sin \theta \mathbf{I} \mathbf{a} \mathbf{B} \hat{\mathbf{j}} + \frac{b}{2} \sin \theta \mathbf{I} \mathbf{a} \mathbf{B} \hat{\mathbf{j}}$$

But magnetic dipole moment; $p_m = I A$, then

$$\vec{\tau}_{\text{res}} = p_m B \sin \theta \hat{j} = \vec{p}_m \times \vec{B}$$

Special Case:

i) $\theta = 90^\circ$, then $\vec{\tau}_{\text{res}} = p_m B \hat{j} = A I B \hat{j} = \text{max.}$

ii) $\theta = 0^\circ$, then $\vec{\tau}_{\text{res}} = 0$

iii) $\theta = 180^\circ$, then $\vec{\tau}_{\text{res}} = 0$

- 103. 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**.

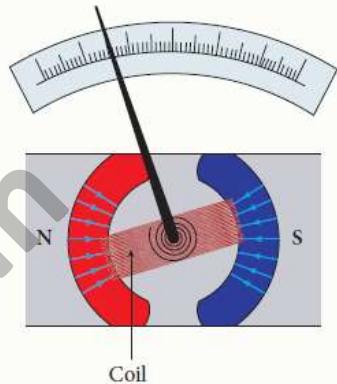
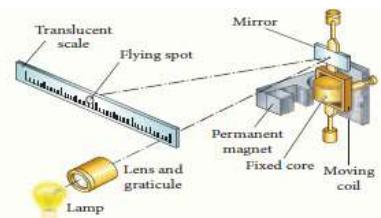
Principle:

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

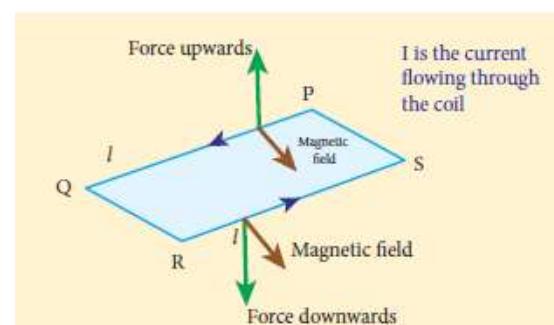
The horse-shoe type magnet has hemispherical magnetic poles which produces a radial magnetic field. Due to this radial field, the sides QR and SP are always parallel to the magnetic field 'B' and experience no force. But the sides PQ and RS are always perpendicular to the magnetic field 'B' and experience force and due to the torque is produced. For single turn, the deflecting couple is, $\tau_{\text{def}} = F b = B I l b = B I A$

For coil with N turns, we get $\tau_{\text{def}} = NBIA \dots\dots\dots(1)$

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 $\tau_{\text{res}} = K\theta \dots\dots\dots(2)$

Where $K \rightarrow$ restoring couple per unit twists (or) torsional constant

At equilibrium, $\tau_{\text{def}} = \tau_{\text{res}} ; NBIA = K\theta ; I = \frac{K}{NB} \theta = G\theta \dots\dots\dots(3)$



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

UNIT - IV (ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENT)

TWO MARKS QUESTIONS AND ANSWERS

1. Define magnetic flux.

The magnetic flux through an area 'A' in a magnetic field is defined as the **number of magnetic field lines passing through that area** normally. The S.I unit of **magnetic flux** is **Tm² (or) weber**

2. Define electromagnetic induction.

Whenever **the magnetic flux linked with a closed coil changes, an emf is induced and hence an electric current flows in the circuit**. This emf is called induced emf and the current is called induced current. This phenomenon is called electromagnetic induction.

3. What is the importance of electromagnetic induction?

There is an ever growing demand for electric power for the operation of almost all the devices used in present day life. All these are met with the help of electric generators and transformer which function on electromagnetic induction.

4. State Faraday's laws of electromagnetic induction.

- (i) Whenever **magnetic flux linked with a closed circuit** changes, an **emf is induced in the circuit**.
- (ii) The magnitude of induced emf in a closed circuit is equal to the time rate of change of magnetic flux linked with the circuit.

5. State Lenz's law.

Lenz's law states that the direction of the **induced current** is such that is **always opposes** the cause responsible for its production.

6. 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**.

7. What are called eddy currents? How are they produced?

When magnetic flux linked with a conductor in the form of a sheet or a plate changes, an emf is induced. As a result, the induced current flow in concentric circular paths which resembles eddies of water. Hence these are known as **Eddy currents or Foucault currents**.

- 8.** A spherical stone and a spherical metallic ball of same size and mass are dropped from the same height. Which one will reach earth's surface first? Justify your answer.

The stone will reach the earth's surface earlier than the metal ball. Because when **the metal ball falls through the magnetic field of earth, the eddy currents are produced in it which opposed its motion.** But in the case of stone, no eddy currents are produced and it falls freely.

- 9.** What is called inductor?

Inductor is a device used to store energy in a magnetic field when an electric current flows through it. (e.g.) solenoids and toroids

- 10.** What is called self-induction?

The phenomenon of inducing an emf in a coil, when the magnetic flux linked with the coil itself changes is called **self-induction.** The emf induced is called self-induced emf.

- 11.** Define self-inductance or coefficient of self-induction.

Self-inductance of a coil is defined as **the flux linkage of the coil, when 1 A current flow through it.** Its S.I unit is **H (or) WbA⁻¹ (or) VsA⁻¹** and its dimension is **[ML²T⁻²A⁻²]**

- 12.** Define the unit of self-inductance (one Henry)

The inductance of the coil is one Henry, if a current changing at the rate of **1 A s⁻¹** induces an opposing emf of 1 V in it.

- 13.** What is called mutual induction?

When an electric current passing through a coil changes with time, an emf is induced in the neighbouring coil. This phenomenon is known as mutual induction and the emf is called mutually induced emf.

- 14.** Define mutual inductance or coefficient of mutual induction.

Mutual inductance is also defined as the opposing emf induced in the one coil, when the rate of change of current through the other coil is **1 A s⁻¹** Its S.I unit is **H (or) WbA⁻¹ (or) VsA⁻¹** and its dimension is **[ML²T⁻²A⁻²]**

- 15.** 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.

16. How an emf is induced by changing the magnetic field?

Change in magnetic flux of the field is brought about by,

- (i) The relative motion between the circuit and the magnet
- (ii) Variation in current flowing through the nearby coil

17. What is called AC generator or alternator?

AC generator is a device which converts mechanical energy used to rotate the coil or field magnet into electrical energy.

18. State the principle of AC generator (alternator)

It works on the principle of **electromagnetic induction**. (i.e.) The relative motion between a conductor and a magnetic field changes the magnetic flux linked with the conductor which in turn induces an emf.

The magnitude of the induced emf is given by Faraday's law and its direction by **Fleming's right hand rule**.

19. State single phase AC generator.

In a single phase AC generator, the armature conductors are connected in series so as to form a single circuit which generates a single - phase alternating emf and hence it is called single-phase alternator.

20. State three phase AC generators.

If there are three separate coils, which would give three separate emf's then they are called three phase AC generators.

21. What are the advantages of three phase AC generators?

For a given dimension of the generator, three - phase machine produces higher power output than a single -phase machine. For the same capacity, three phase alternator is smaller in size when compared to single phase generators.

Three phase transmission system is cheaper. A relatively thinner wire is sufficient for transmission of three phase power.

22. What is called transformer?

It is a stationary device used to **transform electrical power from one circuit to another without changing its frequency**. The applied alternating voltage is either increased or decreased with corresponding decrease or increase in current in the circuit.

23. Distinguish between step up and step down transformer.

Step up transformer	Step down transformer
If the transformer converts an alternating current with low voltage in to an alternating current with high voltage is called step up transformer.	If the transformer converts an alternating current with high voltage in to an alternating current with low voltage is called step down transformer.

24. State the principle of transformer.

The principle of transformer is the **mutual induction between two coils**. (i.e.) when an electric current passing through a coil changes with time, and emf is induced in the neighbouring coil.

25. 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**.
$$\eta = \frac{\text{Output Power}}{\text{Input Power}} \times 100\%$$

26. Define Sinusoidal alternating voltage.

If the waveform of alternating voltage is a sine wave, then it is known as sinusoidal alternating voltage and it is given by, $V = V_m \sin \omega t$

27. Define mean value or average value of AC.

The mean or average value of alternating current is defined as the **average of all values of current over a positive half cycle or negative half cycle**. $I_{avg} = \frac{2 I_m}{\pi} = 0.6371 I_m$.

28. Define RMS value of AC.

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

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

29. Define effective value of alternating current.

RMS value of AC is also called effective value of AC. The effective value of AC (I_{eff}) is defined as **the value of steady current which when flowing through a given circuit for a given time produces the same amount of heat** as produced by the alternating current when flowing through the same circuit for the same time.

- 30. The common house hold appliances, the voltage rating is specified as 230 V, 50 Hz. What is the meaning of it?**

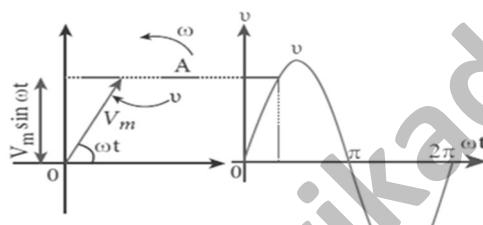
The voltage rating specified in the common house hold appliances indicates the RMS value or effective value of AC. (i.e.) $V_{\text{eff}} = 230 \text{ V}$

Its peak value will be, $V_m = V_{\text{eff}} \sqrt{2} = 230 \times 1.414 = 325 \text{ V}$. Also 50 Hz indicates, the frequency of domestic AC supply.

- 31. Define phasor and phasor diagram.**

A sinusoidal alternating voltage or current can be represented by a vector which **rotates about the origin in anti-clockwise direction at a constant angular velocity ' ω '**. Such a rotating vector is called a phasor. The diagram which shows various phasors and phase relations is called phasor diagram.

- 32. Draw the phasor diagram for an alternating voltage $v = V_m \sin \omega t$**



- 33. Define inductive reactance.**

The **resistance offered by the inductor in an ac circuit** is called inductive reactance and it is given by $X_L = \omega L = 2\pi fL$; Its unit is ohm (Ω)

- 34. An inductor blocks AC but it allows DC. Why?**

The DC current flows through an inductor produces uniform magnetic field and the **magnetic flux linked remains constant**. Hence there is no self-induction and self-induced emf (opposing emf). So DC flows through an inductor.

But AC flows through an inductor produces time varying magnetic field which in **turn induces self-induced emf and this opposes any change in the current**. Since AC varies both in magnitude and direction, it flow is opposed by the back emf induced in the inductor and hence inductor blocks AC.

- 35. Define capacitive reactance.**

The resistance offered by the capacitor in an ac circuit is called capacitive reactance and it is given by $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$; Its unit is **ohm (Ω)**

36. A capacitor blocks DC but it allows AC. Why?

When DC flows through capacitor, electrons flows from negative terminal and accumulated at one plate making it negative and hence another plate becomes positive. This process is known as **charging and once capacitor is fully charged, the current will stop** and we say capacitor blocks DC.

But AC flows through capacitor, the electron flow in one direction while charging the capacitor and its direction is reversed while discharging. Though electrons flow in the circuit, **no electrons crosses the gap between the plates**. In this way, AC flows through a capacitor.

37. Define resonance.

When the frequency of the applied source is equal to the natural frequency of the RLC circuit, the current in the circuit reaches its maximum value. Then the circuit is said to be in electrical resonance. **The frequency at which resonance takes place** is called **resonant frequency**. Hence the condition for resonance is: $X_L = X_C$

38. What are the 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.

39. Resonance will occur only in LC circuits. Why?

When the circuits contain both L and C, then voltage across L and C cancel one another when V_L and V_C are **180 out of phase** and the circuit becomes purely resistive. This implies that resonance will not occur in a RL and R_C circuits.

40. Define Q - factor or quality factor.

Q - Factor is defined as the **ratio of voltage across L or C to the applied voltage** at resonance.

$$Q\text{-factor} = \frac{\text{Voltage across L or C at resonance}}{\text{Applied Voltage}} ; Q\text{-factor} = \frac{1}{R} \sqrt{\frac{L}{C}} ;$$

$$Q\text{-factor} = \frac{L}{R\sqrt{LC}}$$

41. Define power in an AC circuits.

Power of a circuit is defined as the rate of consumption of electric energy in that circuit. It is the product of the voltage and current.

42. Define power factor.

Power factor ($\cos \phi$) of a circuit is defined as the **cosine of the angle of lead or lag**. **Power factor** is also defined as the ratio of **true power** to the **apparent power**.

43. Define wattless current.

If the **power consumed by an AC circuit is zero**, then the current in that circuit is said to be watt-less current. This wattless current happens in a purely inductive or capacitive circuit.

44. What are called LC oscillations?

Whenever energy is given to a circuit containing **a pure inductor of inductance L and a capacitor of capacitance C, the energy oscillates back and forth between the magnetic field of the inductor and the electric field** of the capacitor. Thus the electrical oscillations of definite frequency are generated. These oscillations are called LC oscillations.

45. Define Flux linkage.

The **product of magnetic flux (ϕ_B) linked with each turn of the coil and the total number of turns (N) in the coil** is called flux linkage ($N\phi_B$)

46. Define impedance of RLC circuit.

The effective opposing by resistor, inductor and capacitor to the circuit current in the series RLC circuit is called impedance (Z)

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

THREE MARKS QUESTIONS AND ANSWERS

- 47.** Establish the fact that the relative motion between the coil and the magnet induces an emf in the coil of a closed circuit.

Faraday's experiment - 1:

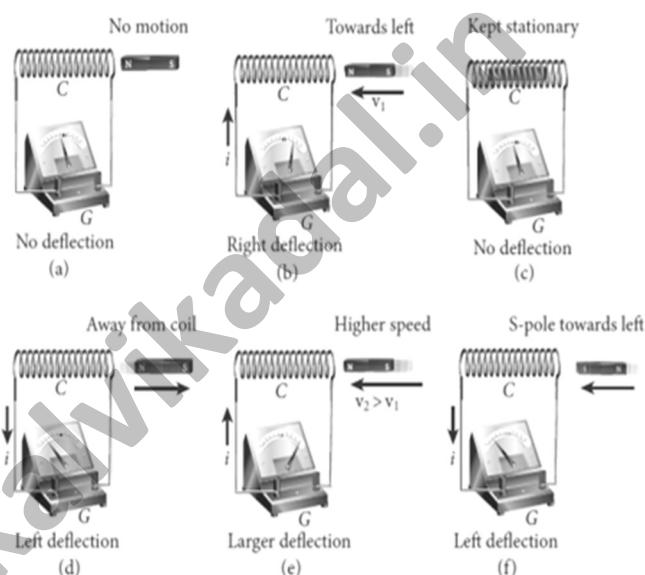
Consider a closed circuit consisting of a coil 'C' and a galvanometer 'G'. Initially the galvanometer shows no deflection. When a bar magnet moves towards the stationary coil with its north pole (N) facing the coil, there is a momentary deflection in the galvanometer.

This indicates that an electric current is set up in the coil. If the **magnet is kept stationary inside the coil, the galvanometer does not indicate deflection.**

The bar magnet is now withdrawn from the coil; the galvanometer again gives a momentary deflection but is opposite direction. This indicates current flows in opposite direction.

Now if the **magnet is moved faster**, it gives a **larger deflection** due to a **greater current** in the circuit. The **bar magnet is reversed** (i.e.) the south pole now faces the coil and the experiment is repeated, same results are obtained but the **directions of deflection get reversed**. Similarly, if the magnet is kept stationary and the coil moved towards or away from the coil, similar results are obtained.

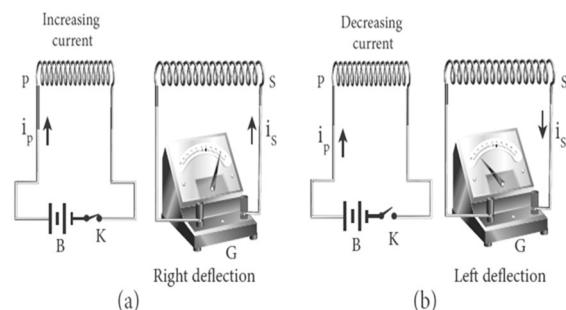
Thus the above experiments concluded that, whenever there is a relative motion between the coil and the magnet, there is a deflection in the galvanometer, indicating the electric current set up in the coil.



- 48.** Prove that experimentally if the current in a one closed circuit changes, an emf is induced in another circuit.

Faraday's experiment - 2 :

Consider a closed circuit called primary consisting of coil 'P', a battery 'B' and a key 'K'. Consider an another closed circuit called secondary consisting of coil 'S' and a galvanometer 'G'. Here the two coils 'P' and 'S' are kept at rest in close proximity with respect to one another.



When the primary circuit is closed, current starts flowing in this circuit. At this time, the galvanometer gives a momentary deflection. After that, when current reaches a steady value, no deflection is observed in the galvanometer.

Similarly, if the **primary circuit is broken**, **current starts decreasing** and there is again a **momentary deflection but in the opposite direction**. When current becomes zero, the **galvanometer shows no deflection**. From the above observations, it is concluded that whenever the electric current in the primary changes, the galvanometer in secondary shows a deflection.

- 49.** How we understood the conclusions obtained from Faraday's experiment.

Faraday's experiment - Explanation:

Experiment - 1 :

In the first experiment, when a bar magnet is placed close to a coil, then there is some magnetic flux linked with the coil. **When the bar magnet and coil approach each other, the magnetic flux linked with the coil increases and this increase in magnetic flux induces an emf and hence a transient current flows in one direction.** At the same time, when they recede away from one another, the magnetic flux linked with the coil decreases.

The decrease in magnetic flux again induces an emf in opposite direction and hence an electric current flows in opposite direction. So there is deflection in the galvanometer, when there is a relative motion between the coil and the magnet.

Experiment - 2 :

In the second experiment, when the primary coil 'P' carries an electric current, a magnetic field is established around it. The magnetic lines of this field pass through itself and the neighbouring secondary coil 'S'. When the primary circuit is open, **no current flows in it and hence the magnetic flux linked with secondary coil is zero.**

When the primary circuit is closed, the increasing current increases the magnetic flux linked with primary as well as secondary coil. This increasing flux induces a current in the secondary coil.

When the current in the primary coil reaches a steady value, the magnetic flux linked with the secondary coil does not change and the current in it will disappear.

Similarly, when the **primary circuit is broken, the decreasing current induces an electric current** in the secondary coil, but in opposite direction.

So there is a deflection in the galvanometer, whenever there is a change in the primary current.

50. State and explain Faraday's laws of electromagnetic induction.

Faraday's first law:

Whenever **magnetic flux linked** with a **closed circuit** changes, an emf is induced in the circuit. The induced emf lasts so long as the change in magnetic flux continues.

Faraday's second law:

The magnitude of induced emf in a closed circuit is **equal to the time rate of change of magnetic flux linked with the circuit**. If magnetic flux linked with the coil changes by $d\Phi_B$ in time dt , then the induced emf is given by,

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

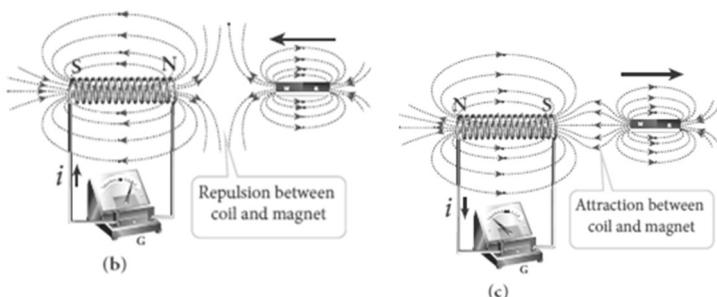
The negative sign in the above equation gives the direction of the induced current. If a coil consisting of 'N' turns, then $\varepsilon = -N \frac{d\Phi_B}{dt}$

$$\varepsilon = - \frac{d(N\Phi_B)}{dt} . \text{ Here } N\Phi_B \text{ is called flux linkage.}$$

51. Give an illustration of determining direction of induced current by using Lenz's law.

Explanation of Lenz's law:

Let a bar magnet move towards the solenoid with its north pole pointing the solenoid. This motion increases the magnetic flux linked with the solenoid and hence an electric current is induced.



Due to the flow of induced current, the coils become a magnetic dipole whose two magnetic poles are on either end of the coil. Here the cause producing the induced current is the movement of the magnet.

According to Lenz's law, the induced current should flow in such a way that it opposed the movement of the North Pole towards coil. It is possible if the end nearer to the magnet becomes North Pole.

Then it repels the north pole of the bar magnet and opposed the movement of the magnet. Once pole end are known, the direction of the induced current could be found by using right hand thumb rule.

When the bar magnet is withdrawn, the nearer end becomes South Pole which attracts North Pole of the bar magnet, opposing the receding of the magnet. Thus the direction of the induced current can be found from Lenz's law.

52. Show that Lenz's law is in accordance with the law of conservation of energy.

Conservation of energy - Lenz's law:

According to Lenz's law, when a magnet is moved either towards or away from a coil, the induced current produced opposes its motion. As a result, there will always be a resisting force on the moving magnet.

So work has to be done by some external agency to move the magnet against this resistive force. Here the mechanical energy of the moving magnet is converted into the electrical energy which in-turn gets converted in to Joule heat in the coil. (i.e) energy is conserved from one form to another

On the contrary to Lenz's law, let us assume that the induced current helps the cause responsible for its production. If we push the magnet little bit towards the coil, the induced current helps the movement of the magnet towards the coil.

Then the magnet starts moving towards the coil without any expense of energy, which is impossible in practice. Therefore, the assumption that the induced current helps the cause is wrong.

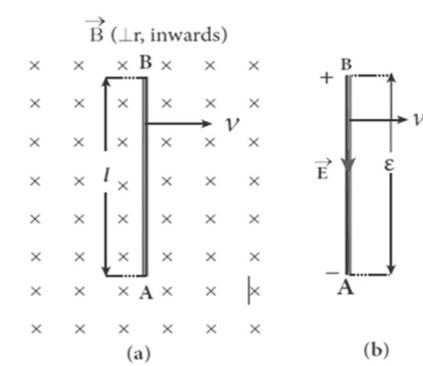
53. Obtain an expression for motional emf from Lorentz force.

Motional emf from Lorentz force:

Consider a straight conductor rod AB of length ' l ' in a uniform magnetic field \vec{B} , which is directed perpendicularly in to plane of the paper. Let the rod move with a constant velocity \vec{v} towards right side. When the rod moves, the free electrons present in it also move with same velocity \vec{v} in \vec{B} .

As a result, the Lorentz force acts on free electron in the direction from B to A and it is given by,

$$\vec{F}_B = -e(\vec{v} \times \vec{B}) \dots\dots\dots (1)$$



Due to this force, all the free electrons are accumulate at the end A which produces the potential difference across the rod which in-turn establishes an electric field \vec{E} directed along BA. Due to the electric field, the Coulomb force starts acting on the free electron along AB and it is given by,

$$\vec{F}_E = -e \vec{E} \quad \dots \dots \dots (2)$$

$$\text{At equilibrium, } |\vec{F}_B| = |\vec{F}_E| ; |e(\vec{v} \times \vec{B})| = |-e \vec{E}|$$

$$B e v \sin 90^\circ = e E ; Bv = E \dots \dots \dots (3)$$

The potential difference between two ends of the rod is, $V = E l = Bvl$
Thus the Lorentz force on the free electrons is responsible to maintain this potential difference and hence produces an emf

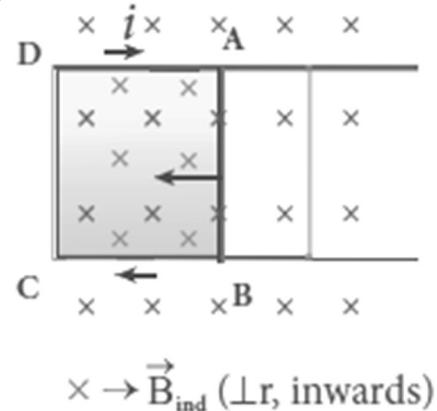
$$\epsilon = B l v \quad \dots \dots \dots (4)$$

Since this emf is produced due to the movement of the rod, it is often called as motional emf.

54. Obtain an expression for motional emf from Faraday's law.

Motional emf from Faraday's law:

Consider a rectangular loop of width ' l ' in a uniform magnetic field \vec{B} which is directed perpendicularly in to plane of the paper. A part of the loop is in the magnetic field, while the remaining part is outside the field. If the loop is pulled with a constant velocity \vec{v} towards right side, then the magnetic flux linked with the loop will decrease. According to Faraday's law, current is induced in the loop which flows in a direction so as to oppose the pull of the loop.



Let ' x ' be the length of the loop which is still within the magnetic field, then its area = $l x$. Then the magnetic flux linked with the loop is,

$$\Phi_B = \int \vec{B} \cdot d\vec{A} = \int B dA \cos 0^\circ = B A = Blx$$

As this magnetic flux decreases, the magnitude of the induced emf is given by, $\epsilon = \frac{d\Phi_B}{dt} = \frac{d}{dt} (Blx) = Bl \frac{dx}{dt} ; \epsilon = B l v \dots \dots \dots (1)$

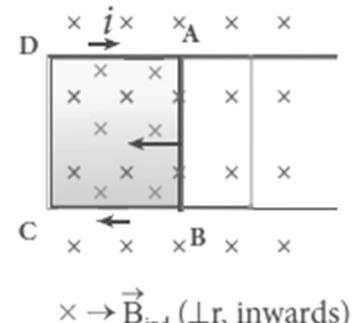
This emf is known as motional emf, since it is produced due to the movement of the loop in the magnetic field. From Lenz's law, it is found that the induced current flows in clockwise direction.

55. Explain energy conservation.

Energy conservation:

Let a loop placed in a magnetic field \vec{B} is pulled with a constant velocity \vec{v} towards right side. Due to this movement, the loop experiences magnetic forces.

Let $\vec{F}_1, \vec{F}_2, \vec{F}_3$ forces acting on the three segments of the loop. Here \vec{F}_2 , and \vec{F}_3 are equal in magnitude and opposite in direction and cancel each other. Therefore the force \vec{F}_1 alone acts on the left segment towards left side which is given by, $\vec{F}_1 = i \vec{l} \times \vec{B}$ (or) $F_1 = i l B \sin 90^\circ$ $F_1 = i l B$ (1)



In order to move the loop a constant force \vec{F} is applied which is equal to the magnetic force \vec{F}_1 . So, $\vec{F} = -\vec{F}_1$

$$\text{In magnitude, } F_1 = i l B = \frac{\epsilon}{R} l B ; \frac{Blv}{R} l B$$

$$F = \frac{B^2 l^2 v}{R} \quad \dots \dots \dots \quad (2)$$

Where, R → resistance of the loop, ε → emf

The rate at which the mechanical work is done to pull the loop (i.e.) the power is $P = \vec{F} \cdot \vec{v} ; Fv \cos 0^\circ = Fv ; P = \left[\frac{B^2 l^2 v}{R} \right] v ; P = \frac{B^2 l^2 v^2}{R}$ (3)

When the induced current flows in the loop, Joule heating takes place. The rate at which thermal energy (i.e.) power dissipated in the loop is,

$$P = i^2 R = \left[\frac{\epsilon}{R} \right]^2 R ; = \left[\frac{B l v}{R} \right]^2 R ; P = \frac{B^2 l^2 v^2}{R} \quad \dots \dots \dots \quad (4)$$

Thus equation (3) and (4) are same. (i.e.) the mechanical work done in moving the loop appears as thermal energy in the loop.

56. Define eddy currents. Demonstrate the production of eddy currents.

Eddy currents:

When magnetic flux linked with a conductor in the form of a sheet or a plate changes, an emf is induced. As a result, the **induced current flow in concentric circular paths which resembles eddies of water**. Hence these are known as **Eddy currents or Foucault currents**.

Demonstration:

Let a pendulum that can be freely suspended between the poles of a powerful electromagnet. Keeping the magnetic field switched off, If the pendulum is made to oscillate, it executes a large number of oscillations before stops. Here air friction is an only damping force.

When the electro magnet is switched on, and the pendulum is made to oscillate, it comes to rest within a few oscillations. Because eddy currents are produced in it and it will oppose the oscillations (Lenz's law).

However, some slots are cut in the disc, the eddy currents are reduced and now the pendulum executes several oscillations before coming to rest. This clearly demonstrates **the production of eddy current in the disc of the pendulum.**

57. What are the drawbacks of Eddy currents? How it is minimized?

Drawbacks of Eddy currents:

When eddy currents flow in the conductor, a **large amount of energy is dissipated in the form of heat**. The energy loss due to flow of eddy current is inevitable but it can be reduced.

To **reduce eddy current losses, the core of the transformer** is made up of thin **laminas insulated** from one another. In case of electric motor, the winding is made up of a group of wire insulated from one another.

The insulation used **does not allow huge eddy currents to flow** and hence **losses are minimized**.

58. Explain self-induction and define coefficient of self-induction on the basis of (1) Magnetic flux and (2) induced emf Self-induction:

When an electric current flowing through a coil changes, an emf is induced in the same coil. This phenomenon is known as self-induction. The emf induced is called self-induced emf.

Let ϕ_B be the magnetic flux linked with each turn of the coil of turn 'N', then total flux linkage ($N\phi_B$) is directly proportional to the current ' i '.

Where, $L \rightarrow$ constant called coefficient of self-induction (or) self-inductance. When the current (i) changes with time, an emf is induced in the

coil and it is given by, $\varepsilon = -\frac{d(N\phi_B)}{dt} ; = -\frac{d(Li)}{dt} ; = -L \frac{di}{dt}$

$$\therefore L = - \frac{\epsilon}{\left(\frac{di}{dt} \right)} \dots \dots \dots (2)$$

Coefficient of self-induction - Definition:

Self-inductance of a coil is defined as the flux linkage of the coil, when 1 A current flows through it. Self-inductance of a coil is also defined as **the opposing emf induced in the coil, when the rate of change of current through the coil is 1 A s^{-1}**

59. How will you define the unit of inductance?

Unit of inductance:

Inductance is a scalar and its unit is **WbA⁻¹ (or) VsA⁻¹ (or) Henry (H)**

It dimension is [ML²T⁻²A⁻²]

Definition - 1 :

The self-inductance is given by, $L = \frac{N \phi B}{i}$

The inductance of the coil is one Henry if a current of 1 A produces unit flux linkage in the coil.

Definition - 2 :

The self-inductance is given by, $L = -\frac{\epsilon}{(\frac{di}{dt})}$

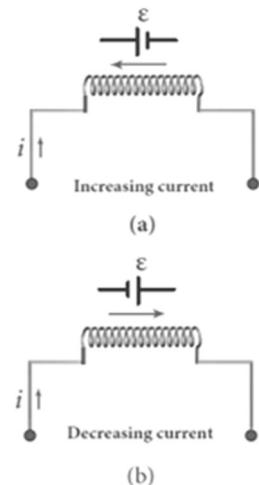
The inductance of the coil is one Henry if a current changing at the rate of **1 As⁻¹** induces an opposing emf of 1 V in it.

60. Discuss the physical significance of inductance.

Physical inductance of inductance:

Generally, inertia means opposition to change the state of the body. In translational motion, mass is a measure of inertia, whereas in rotational motion, moment of inertia is a measure of rotational inertia. Similarly, inductance plays the same role in a circuit as the mass and moment of inertia play in mechanical motion.

When a circuit is switched on, the increasing current induces an emf which opposes the growth of current in a circuit. Similarly, when a circuit is broken, the decreasing current induces an emf in the reverse direction which opposed the decay of the current. Thus inductance on the coil opposes any change in current and tries to maintain the original state.



61. Assuming that the length of the solenoid is large when compared to its diameter, find the equation for its inductance.

Self-inductance of a long solenoid (L):

Consider a long solenoid of length 'l', area of cross section 'A' having 'N' number of turns. Let 'n' be number of turns per unit length (i.e.) turn density. When an electric current 'i' is passed through the coil, a magnetic field at any point inside the solenoid is, $B = \mu_0 n i$

Due to this field, the magnetic flux linked with the solenoid is,

$$\phi_B = \oint \vec{B} \cdot d\vec{A} = \oint B A \cos 90^\circ = B A$$

$$\phi_B = [\mu_0 n i] A$$

Hence the total magnetic flux linked (i.e.) flux linkage

$$N\phi_B = N \mu_0 n i A = (n l) \mu_0 n i A$$

$$N\phi_B = \mu_0 n^2 i A l$$

Let 'L' be the self-inductance of the solenoid, then

$$L = \frac{N\phi_B}{i} = \frac{\mu_0 n^2 i A l}{i}; L = \mu_0 n^2 A l$$

If the solenoid is filled with a dielectric medium of relative permeability ' μ_r ', then $L = \mu_0 \mu_r n^2 A l = \mu n^2 A l$

Thus, the inductance depends on

- (i) Geometry of the solenoid
- (ii) Medium present inside the solenoid

62. An inductor of inductance 'L' carries an electric current 'i'. How much energy is stored while establishing the current in it?

Energy stored in an solenoid:

Whenever a current is established in the circuit, the inductance opposes the growth of the current. To establish the current, work has to done against this opposition.

This work done is stored as magnetic potential energy. Consider an inductor of negligible resistance, the induced emf ' ϵ ' at any instant 't' is

$$\epsilon = -L \frac{di}{dt}$$

Let 'dW' be the work done in moving a charge 'dq' in a time 'dt' against the opposition, then

$$dW = -\epsilon dq = -\epsilon i dt$$

$$dW = - \left[-L \frac{di}{dt} \right] i dt = L i di$$

Total work done in establishing the current 'i' is

$$W = \int dW = \int L i di = L \left[\frac{i^2}{2} \right]_0^i = \frac{1}{2} L i^2$$

This work done is stored as magnetic potential energy. (i.e)

$$u_B = \frac{1}{2} L i^2$$

The energy stored per unit volume of the space is called energy density

$$(u_B) \text{ and it is given by, } u_B = \frac{\text{energy (u}_B\text{)}}{\text{Volume A l}}$$

$$= \frac{\frac{1}{2} L i^2}{A l}; = \frac{1}{2} \frac{(\mu_0 n^2 A l)i^2}{A l}; u_B = \frac{\mu_0 n^2 i^2}{2}$$

$$u_B = \frac{B^2}{2\mu_0} \quad [\because B = \mu_0 n i]$$

63. Explain mutual induction. Define coefficient of mutual induction on the basis of (1) magnetic flux and (2) induced emf Mutual induction:

When an electric current passing through a coil changes with time, an emf is induced in the neighbouring coil. This phenomenon is known as mutual induction and the emf is called mutually induced emf.

Consider two coils 1 and 2 which are placed close to each other. If an electric current ' i_1 ' is sent through coil -1, the magnetic field produced by it also linked with the coil -2

Let ' Φ_{21} ' be the magnetic flux linked with each turn of the coil-2 of N_2 turns due to coil -1, then the total flux linked with coil -2 is proportional to the current ' i_1 ' in the coil -1 (i.e.)

$$N_2 \phi_{21} \propto i_1 \quad (\text{or}) \quad N_2 \phi_{21} = M_{21} i_1 \\ \therefore M_{21} = \frac{N_2 \phi_{21}}{i_1} \quad \dots \quad (1)$$

Here $M_{21} \rightarrow$ constant called coefficient of mutual induction or mutual inductance coil -2 with respect to coil -1 . When the current ' i_1 ' changes with time, an emf ' ϵ_2 ' is induced in coil -2 and it is given by,

$$\epsilon_2 = - \frac{d(N_2 \phi_{21})}{dt} = - \frac{d(M_{21} i_1)}{dt} = -M_{21} \frac{di_1}{dt} \\ \therefore M_{21} = - \frac{\epsilon_2}{\frac{di_1}{dt}} \quad \dots \quad (2)$$

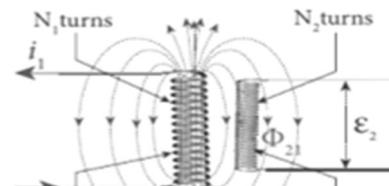
$$\text{Similarly, } M_{12} = \frac{N_1 \phi_{12}}{i_{12}} \quad \dots \quad (3)$$

$$\& M_{12} = - \frac{\epsilon_1}{\frac{di_2}{dt}} \quad \dots \quad (4)$$

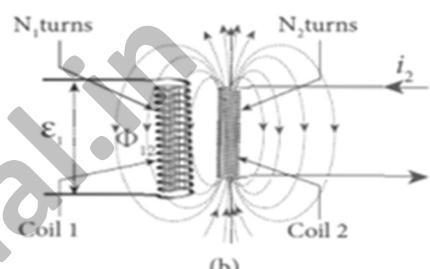
Here $M_{21} \rightarrow$ constant called coefficient of mutual induction or mutual inductance coil -2 with respect to coil -1

Coefficient of mutual induction - Definition:

The mutual inductance is defined as the **flux linkage of the one coil, when 1 A current flow through other coil**. Mutual inductance is also the opposing emf induced in one coil, when the rate of change of current through other coil is 1 As^{-1}



(a)



(b)

64. Show that the mutual inductance between a pair of coils is same ($M_{12} = M_{21}$).

Mutual inductance between a pair of coils:

Consider two long co-axial solenoids of same length. Let A_1 and A_2 be the area of cross section of the solenoids. Here $A_1 > A_2$

Let the turn density of these solenoids are n_1 and n_2 respectively. Let ' i_1 ' be the current flowing through solenoid -1, then the magnetic field produced inside it is, $B_1 = \mu_0 n_1 i_1$

Hence the magnetic flux linked with each turn of solenoid -2 due to solenoid -1 is $\phi_{21} = \oint \vec{B}_1 \cdot d\vec{A}_2 = \oint B_1 dA_2 \cos 0^\circ = B_1 A_2$

$$\phi_{21} = (\mu_0 n_1 i_1) A_2$$

Then total flux linkage of solenoid -2 of N_2 turns is $N_2 \phi_{21} = (N_2 l) \mu_0 n_1 i_1 A_2$

$$N_2 \phi_{21} = \mu_0 n_1 n_2 l i_1 A_2 \quad \dots \dots \dots (1)$$

So the mutual inductance of solenoid -2 with respect to solenoid -1 is given by, $M_{21} = \frac{N_2 \phi_{21}}{i_1} = \frac{\mu_0 n_1 n_2 l i_1 A_2}{i_1}$

$$M_{21} = \mu_0 n_1 n_2 l A_2 \quad \dots \dots \dots (2)$$

Similarly, Let ' i_2 ' be the current flowing through solenoid -2, then the magnetic field produced inside it is, $B_2 = \mu_0 n_2 i_2$

Hence the magnetic flux linked with each turn of solenoid -1 due to

solenoid -2 is $\phi_{12} = (\oint \vec{B}_2 \cdot d\vec{A}_1 = \oint B_2 dA_1 \cos 0^\circ = B_2 A_1$

$$\phi_{12} = (\mu_0 n_2 i_2) A_1$$

Then total flux linkage of solenoid -1 of N_1 turns is

$$N_1 \phi_{12} = (N_1 l) \mu_0 n_2 i_2 A_1$$

$$N_1 \phi_{12} = \mu_0 n_1 n_2 l i_2 A_1 \quad \dots \dots \dots (3)$$

So the mutual inductance of solenoid -1 with respect to solenoid -2 is

given by, $M_{12} = \frac{N_1 \phi_{12}}{i_2} = \frac{\mu_0 n_1 n_2 l i_2 A_1}{i_2}$

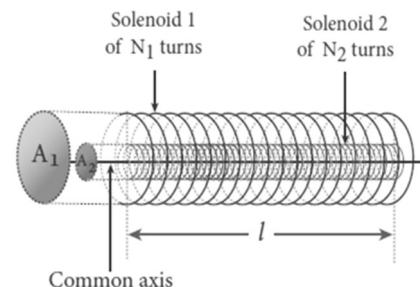
$$M_{12} = \mu_0 n_1 n_2 l A_1 \quad \dots \dots \dots (4)$$

From equation (2) and (4), $M_{12} = M_{21}$

In general, the mutual inductance between two long co-axial solenoids is given by $M = \mu_0 n_1 n_2 l A_2$

If the solenoid is filled with a dielectric medium of relative permeability ' μ_r ', then $M = \mu_0 \mu_r n_1 n_2 A_2 l = \mu n_1 n_2 A_2 l$

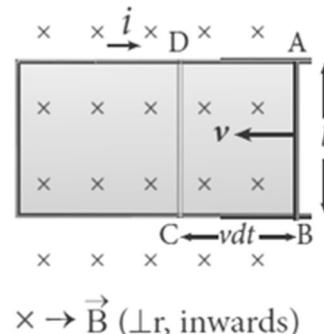
Thus, the **inductance depends** on (i) Geometry of the solenoids
(ii) Medium present inside the solenoids
(iii) Proximity of the two solenoids



65. 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

$$d\phi_B = B dA = B(l \times v dt)$$

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

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

$$\epsilon = \frac{d\phi_B}{dt}; \epsilon = B lv$$

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

66. What are the advantages of stationary armature - rotating field alternator?

Advantages of stationary armature - rotating field alternator:

The current is drawn directly from fixed terminals on the stator without the use of brush contacts. The insulation of stationary armature winding is easier.

The number of slip rings is reduced. Moreover, the sliding contacts are used for low-voltage DC source. Armature windings can be constructed more rigidly to prevent deformation due to any mechanical stress.

67. 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 is 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.**

68. 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 40Ω at 10 kv and 100 kv

(i) $P = 2 \text{ MW}$, $R = 40 \Omega$, $V = 10 \text{ kv}$, then

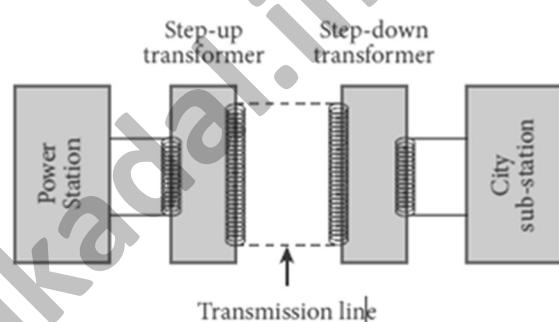
$$I = \frac{P}{V} = \frac{2 \times 10^6}{10 \times 10^3} = 200\text{A}$$

$$\text{Power loss} = I^2R = (200)^2 \times 40 = 1.6 \times 10^6 \text{ W} ; \quad \mathbf{I^2R = 1.6 \times 10^6 \text{ W}}$$

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

(ii) $P = 2 \text{ MW}$, $R = 40 \Omega$, $V = 100 \text{ kv}$, then

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



$$\text{Power loss} = I^2 R = (20)^2 \times 40 = 0.016 \times 10^6 \text{ W} ; \quad \mathbf{I^2 R = 0.016 \times 10^6 \text{ W}}$$

$$\% \text{ of Power loss} = \frac{0.016 \times 10^6}{2 \times 10^6} = 0.008 = 0.8 \%$$

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**.

- 69. 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 'dθ' in positive half-cycle, Area of the elementary strip = $i d\theta$

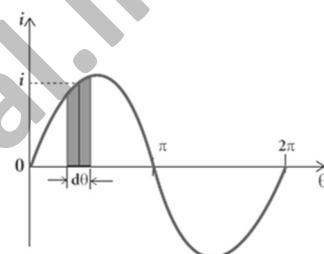
$$\text{Then area of positive half-cycle, } = \int_0^{\pi} i d\theta = \int_0^{\pi} i_m \sin \theta d\theta = i_m [-\cos \theta]_0^{\pi} \\ = -i_m [\cos \pi - \cos 0] ; -i_m [-1 - 1] ; = 2i_m$$

Then Average value of AC,

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

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

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



70. 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**

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

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.

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

Area of one cycle of squared wave,

$$\begin{aligned} &= \int_0^{2\pi} i^2 d\theta = \int_0^{2\pi} I_m^2 \sin^2 \theta d\theta ; = I_m^2 \int_0^{2\pi} \left[\frac{1 - \cos 2\theta}{2} \right] d\theta \\ &\quad [\because \cos 2\theta = 1 - 2 \sin^2 \theta] \\ &= \frac{I_m^2}{2} \left[\int_0^{2\pi} d\theta - \int_0^{2\pi} \cos 2\theta d\theta \right] ; = \frac{I_m^2}{2} \left[\theta - \frac{\sin 2\theta}{2} \right]_0^{2\pi} \\ &= \frac{I_m^2}{2} \left[2\pi - \frac{\sin 4\pi}{2} - 0 + \frac{\sin 0}{2} \right] [\because \sin 0 = \sin 4\pi = 0] \\ &= \frac{I_m^2}{2} [2\pi] ; = I_m^2 \pi \end{aligned}$$

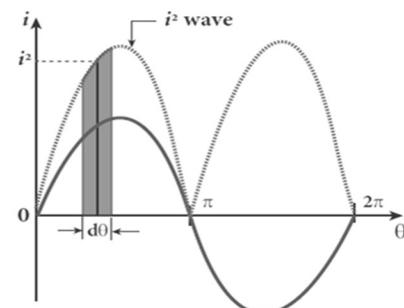
Hence, $I_{\text{RMS}} = \sqrt{\frac{\text{area of one cycle of squared wave}}{\text{base length of one cycle}}}$

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

Similarly, for alternating voltage, it can be shown that,

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

RMS value of AC is also called effective value (I_{eff})



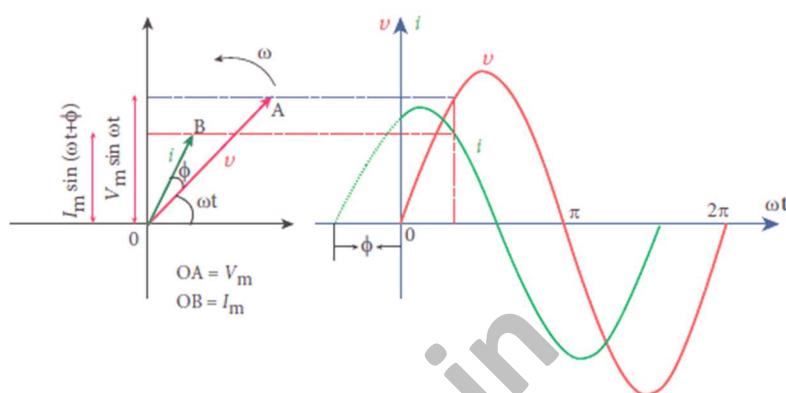
- 71. Draw the phasor diagram and wave diagram for that current 'i' leads the voltage 'V' by phase angle of ' ϕ '**

Phasor and wave diagram of 'i' leads 'V' by ' ϕ '

Let the alternating current and voltage at any instant is,

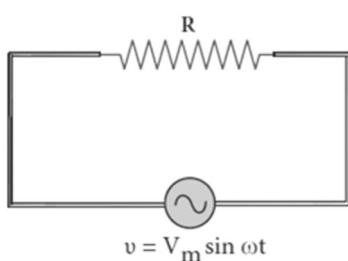
$$v = V_m \sin \omega t$$

$$i = I_m \sin (\omega t + \phi)$$



- 72. Find out the phase relationship between voltage and current in a pure resistive circuit.**

AC circuit containing pure resistor:



Let a pure resistor of resistance "R" connected across an alternating voltage source "v". The instantaneous value of the alternating voltage is given by

$$v = V_m \sin \omega t \dots\dots\dots(1)$$

Let 'i' be the alternating current flowing in the circuit due to this voltage, then the potential drop across "R" is

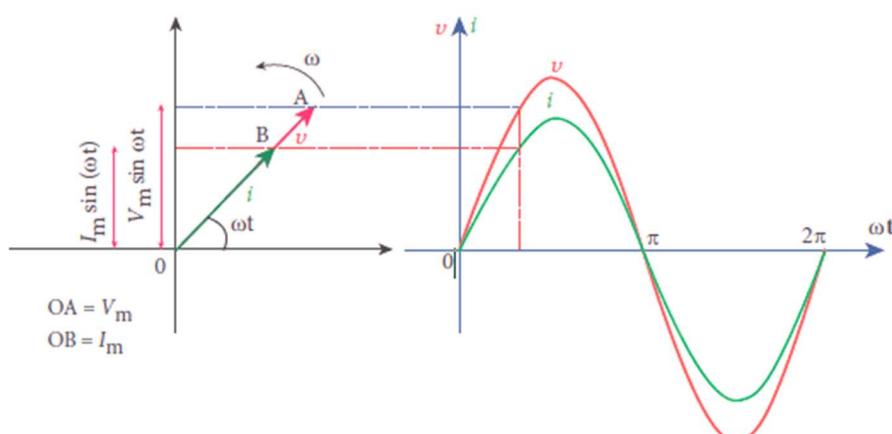
$$V_R = i R \dots\dots\dots(2)$$

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

$$V_m \sin \omega t = i R ; i = \frac{V_m}{R} \sin \omega t ; i = I_m \sin \omega t \dots\dots\dots(3)$$

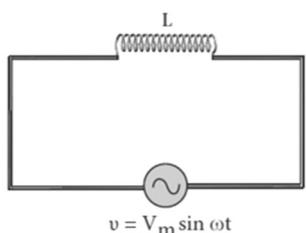
Here, $\frac{V_m}{R} = I_m \rightarrow$ Peak value of AC

From equation (1) and (3), it is clear that, the applied voltage and the current are in phase with each other. This is indicated in the phasor and wave diagram.



- 73. Find out the phase relationship between voltage and current in a pure inductor circuit.**

AC circuit containing pure Inductor:



Let a pure inductor of inductance 'L' connected across an alternating voltage source 'v'. . The instantaneous value of the alternating voltage is given by,

$$v = V_m \sin \omega t \quad \dots \dots \dots (1)$$

Let 'i' be the alternating current flowing in the circuit due to this voltage, which induces a self-induced emf (back emf) across "L" and it is given by

$$\epsilon = - L \frac{di}{dt} \quad \dots \dots \dots (2)$$

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

$$V_m \sin \omega t = -(-L \frac{di}{dt}); V_m \sin \omega t = L \frac{di}{dt}$$

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

Integrate on both sides,

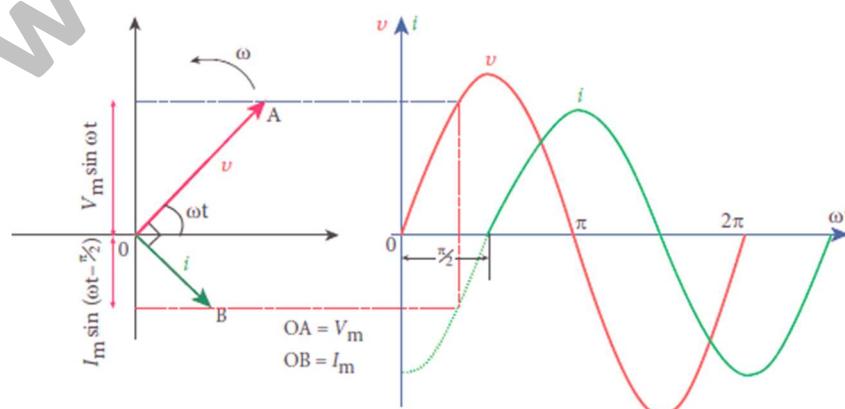
$$i = \frac{V_m}{L} \int \sin \omega t dt; i = \frac{V_m}{L} \left(\frac{-\cos \omega t}{\omega} \right);$$

$$i = \frac{V_m}{\omega L} \left[-\sin \left(\frac{\pi}{2} - \omega t \right) \right]; i = \frac{V_m}{\omega L} \sin \left(\omega t - \frac{\pi}{2} \right)$$

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

Where, $\frac{V_m}{\omega L} = I_m \rightarrow$ Peak value of AC

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



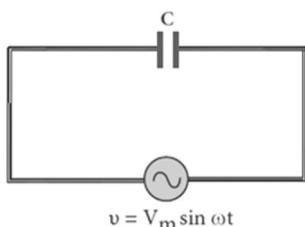
Inductive reactance (X_L) :

In pure inductive circuit, ' ωL ' is the resistance offered by the inductor and it is called inductive reactance (X_L). Its unit is ohm (Ω)

$$X_L = \omega L = 2\pi f L$$

- 74. 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, $v = V_m \sin \omega t$ —— (1)

Let 'q' be the instantaneous charge on the capacitor. The emf across the capacitor at that instant is, $\epsilon = \frac{q}{C}$ —— (2)

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

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

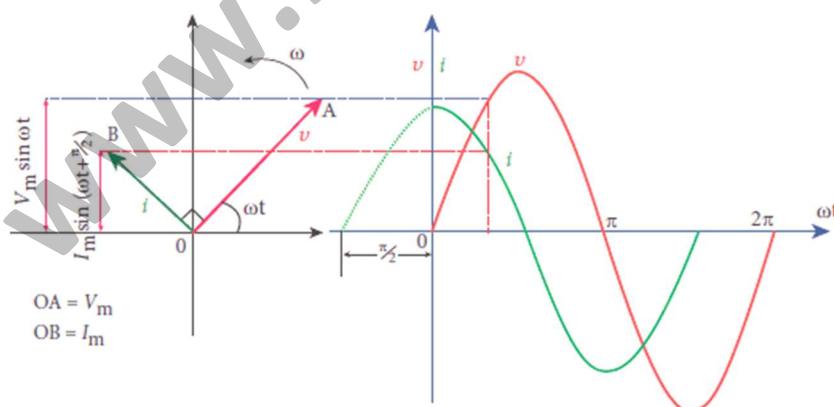
By the definition of current, $i = \frac{dq}{dt}; C V_m \frac{d(\sin \omega t)}{dt} ; = C V_m (\cos \omega t) \omega$

$$i = \omega C V_m \sin \left(\frac{\pi}{2} + \omega t \right) ; = \frac{V_m}{\left(\frac{1}{\omega_c} \right)} \sin \left(\frac{\pi}{2} + \omega t \right)$$

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

Where, $\frac{V_m}{\left(\frac{1}{\omega_c} \right)} = I_m \rightarrow$ 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)

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

75. Explain resonance in series RLC circuit.

Resonance on series in RLC circuit:

When the frequency of applied alternating source is increases, the inductive reactance (X_L) increases, whereas capacitive reactance (X_C) decreases. At particular frequency (ω_R), $X_L = X_C$

At this stage, the frequency of applied source (ωR) is equal to the natural frequency of the RLC circuit; the current in the circuit reaches its maximum value.

Then the circuit is said to be in electrical resonance. The frequency at which resonance takes place is **called resonant frequency**.

Thus at resonance, $X_L = X_C$

$$\omega_R L = \frac{1}{\omega_R C} ; \omega_R^2 = \frac{1}{LC}$$

Hence the resonant angular frequency,

$$\omega_R = \frac{1}{\sqrt{LC}} ; \text{ and resonant frequency, } f_R = \frac{1}{2\pi\sqrt{LC}}$$

Effects of series resonance:

When series resonance occurs, the impedance of the circuit is minimum and is equal to the resistance of the circuit. So the current in the circuit becomes maximum. (i.e.) At resonance, $Z = R$ and $I_m = \frac{V_m}{R}$

The maximum current at resonance depends on the value of resistance (R). **For smaller resistance, larger the current with sharper curve is obtained. But for larger resistance, smaller the current with flat curve is obtained.**

76. Define quality factor. Obtain an expression for it. Definition:

Q - Factor is defined as the ratio of voltage across L (or) C to the applied voltage at resonance.

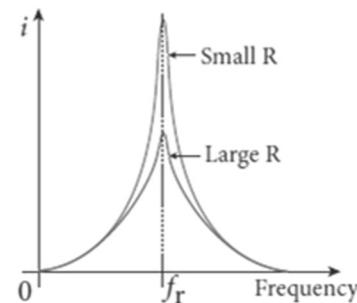
Expression:

The current in the series RLC circuit becomes maximum at resonance. Due to the increase in current, the voltage across L and C are also increased, This magnification of voltages at series resonance is termed as Q - factor.

$$\text{By definition, Q factor} = \frac{\text{Voltage across L (or) C}}{\text{Applied Voltage}} ; \text{Q factor} = \frac{I_m X_L}{I_m R}$$

$$\text{Q factor} = \frac{X_L}{R} ; \text{Q factor} = \frac{\omega_R L}{R} ; \text{Q factor} = \frac{1}{\sqrt{LC}} \frac{L}{R} ; \text{Q factor} = \frac{1}{R} \sqrt{\frac{L}{C}}$$

The physical meaning is that Q - factor indicates the number of times the voltage across L (or) C is greater than the applied voltage at resonance.



- 77. Obtain an expression for average power of AC over a cycle. Discuss its special cases.**

Average power of AC:

Power of a circuit is defined as the rate of consumption. It is given by the product of the voltage and current. The alternating voltage and alternating current in the series RLC circuit at an instance are given by,

$$v = V_m \sin \omega t$$

$$i = I_m \sin(\omega t + \phi)$$

Then the instantaneous power is given by,

$$P = v i = V_m \sin \omega t I_m \sin (\omega t + \phi)$$

$$P = V_m I_m \sin \omega t (\sin \omega t \cos \phi - \cos \omega t \sin \phi)$$

$$P = V_m I_m (\sin^2 \omega t \cos \phi - \sin \omega t \cos \omega t \sin \phi)$$

Here the average of $\sin^2 \omega t$ over a cycle is $\frac{1}{2}$ and that of $\sin \omega t \cos \omega t$ is zero.

Thus average power over a cycle is

$$P_{avg} = V_m I_m \left(\frac{1}{2} \cos \phi \right) = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos \phi$$

$$P_{avg} = V_{RMS} I_{RMS} \cos \phi$$

Where $V_{RMS} I_{RMS} \rightarrow$ apparent power, $\cos \phi \rightarrow$ power factor.

The average power of an AC circuit is also known as the true power of the circuit.

Special Cases

- (i) For a purely resistive circuit, $\phi = 0$ and $\cos \phi = 1$. $\therefore P_{avg} = V_{RMS} I_{RMS}$
- (ii) For a purely inductive or capacitive circuit,

$$\phi = \frac{\pi}{2} \text{ and } \cos \phi = 0 \therefore P_{avg} = 0$$

- (iii) For series RLC circuit, $\phi = \tan^{-1} \left[\frac{X_L - X_C}{R} \right]$ $\therefore P_{avg} = V_{RMS} I_{RMS} \cos \phi$

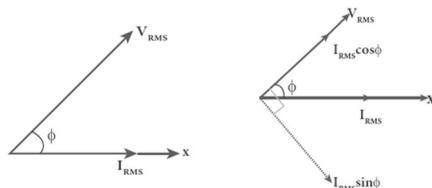
- (iv) For series RLC circuit at resonance

$$\phi = 0 \text{ and } \cos \phi = 1. \therefore P_{avg} = V_{RMS} I_{RMS}$$

78. Write a note on watt-full current and wattles current.

Watt-full current and Watt-less current:

Consider an AC circuit in which the voltage (V_{RMS}) leads the current (I_{RMS}) by phase angle ' ϕ '. Resolve the current in to two perpendicular components,



- (i) $I_{\text{RMS}} \cos \phi$ - Component along V_{RMS}
- (ii) $I_{\text{RMS}} \sin \phi$ - Component perpendicular to V_{RMS}

Here the component of current ($I_{\text{RMS}} \cos \phi$) which is in-phase with the voltage is called active component. The power consumed by this component

$$= V_{\text{RMS}} I_{\text{RMS}} \cos \phi . \text{It is known as watt-full current}$$

The other component of current which has a phase angle of with the voltage is called **reactive component**. The power consumed by this current is zero. It is known as wattles current.

79. Define power factor in various ways. Give some examples for power factor.

Power factor - Definitions:

- (i) The cosine of the angle lead or lag is called power factor
(Power factor = $\cos \phi$)

$$(ii) \text{ Power factor} = \frac{R}{Z} = \frac{\text{Resistance}}{\text{impedance}}$$

$$(iii) \text{ Power factor} = \frac{VI \cos \phi}{VI} = \frac{\text{True Power}}{\text{Apparent power}}$$

Examples:

For purely resistive circuit, $\phi = 0$ and $\cos \phi = 1$

For purely inductive or capacitive circuit, $\phi = \pm \frac{\pi}{2}$ and $\cos \phi = 0$

For RLC circuit, power factor lies between 0 and 1

80. 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.

81. Show that the total energy is conserved during LC oscillations.

Conservation of energy LC oscillations:

During LC oscillations, the energy of the system oscillates between the electric field of the capacitor and the magnetic field of the inductor.

Although these two energies vary with time, the total energy remains constant. (i.e) $U = U_E + U_B = \frac{q^2}{2C} + \frac{1}{2} Li^2 = \text{Constant}$

Case (i) When the charge in the capacitor, $q = Q_m$ and the current through the inductor, $i = 0$, $U = \frac{Q_m^2}{2C} + 0 ; = \frac{Q_m^2}{2C} \dots\dots\dots(1)$

The total energy is wholly electrical.

Case (ii) When charge $q = 0$; current $= I_m$, the total energy is

$$U = 0 + \frac{1}{2} LI_m^2 ; = \frac{1}{2} LI_m^2$$

$$\therefore i = \frac{dq}{dt} ; = - \frac{d}{dt} (Q_m \cos \omega t) ; = Q_m \omega \sin \omega t ; = I_m \sin \omega t$$

$$\text{Hence, } I_m = Q_m \omega = \frac{Q_m}{\sqrt{LC}} ; \therefore U = \frac{1}{2} L \left[\frac{Q_m^2}{LC} \right] = \frac{Q_m^2}{2C} \dots\dots\dots(2)$$

The total energy is wholly magnetic.

Case (iii) When charge $= q$; current $= i$, then the total energy is

$$U = \frac{q^2}{2C} + \frac{1}{2} Li^2. \text{ Here } q = Q_m \cos \omega t \text{ & } i = Q_m \omega \sin \omega t$$

$$U = \frac{Q_m^2 \cos^2 \omega t}{2C} + \frac{1}{2} L Q_m^2 \omega^2 \sin^2 \omega t$$

$$\text{Since, } \omega^2 = \frac{1}{LC} ; U = \frac{Q_m^2 \cos^2 \omega t}{2C} + \frac{L Q_m^2 \sin^2 \omega t}{2LC}$$

$$U = \frac{Q_m^2}{2C} (\cos^2 \omega t + \sin^2 \omega t) ; = \frac{Q_m^2}{2C} \dots\dots\dots(3)$$

From equation (1), (2) and (3) it is clear that the total energy of the system remains constant

FIVE MARKS QUESTIONS AND ANSWERS

- 82. Explain the applications of eddy currents (or) Foucault currents.**

Induction stove:

It is used **to cook food quickly and safely with less consumption.**

Below the cooking zone, there is a tightly wound coil of insulated wire. A suitable cooking pan is placing over the cooking zone. When the stove is switched on, an AC flowing in the coil produces high frequency alternating magnetic field which induces very strong eddy currents in the cooking pan.

The **eddy currents in the pan produce so much of heat due to Joule heating which is used to cook the food.**

Eddy current brake:

This types of brakes are generally **used in high speed trains and roller coasters. Strong electromagnets are fixed just above the rails.** To stop the train, electromagnets are switched on. The magnetic field of these magnets induces eddy currents in the rails which oppose the movement of the train. This is eddy current linear brake.

In some cases, **the circular disc connected in train is made to rotate in between the pole of a electromagnet.** When there is a relative motion between the disc and the magnet, eddy currents are induced in the disc which stop the train. This is eddy current circular brake.

Eddy current testing:

It is one of the non - destructive testing methods **to find defects like surface crakes, air bubbles present in a specimen.**

A coil of insulated wire is given an alternating electric current, so that it produces an alternating magnetic field.

When this coil is brought near the test surface, eddy current is induced in it, and the presence of defects caused the change in phase and amplitude of the eddy current. Thus the defects present in the specimen are identified.

Electromagnetic damping:

The armature of the galvanometer coil is wound on a soft iron cylinder. Once the armature is deflected, the relative motion between the soft iron cylinder and the radial magnetic field induces eddy current in the cylinder.

The damping force due to the flow of eddy current brings the armature to rest immediately and the galvanometer shows a steady deflection. This is called electromagnetic damping.

- 83. 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 ($\theta = 0$) and the flux linked with the coil has its maximum value.

$$(\text{i.e.}) \Phi_m = BA$$

In time 't', let the coil be rotated through an angle ($\theta=\omega t$), then the total flux linked is,

$$N\Phi_B = N B A \cos \omega t = N\Phi_m \cos \omega t$$

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

$$\begin{aligned} \epsilon &= -\frac{d}{dt}(N\Phi_B) = -\frac{d}{dt}(N\Phi_m \cos \omega t) \\ &= -N\Phi_m (-\sin \omega t) \\ \epsilon &= N\Phi_m \omega \sin \omega t \quad \dots \dots \dots (1) \end{aligned}$$

When $\theta = 90^\circ$, then the induced emf becomes maximum and it is given by, $\epsilon_m = N\Phi_m \omega ; = N B A \omega \quad \dots \dots \dots (2)$

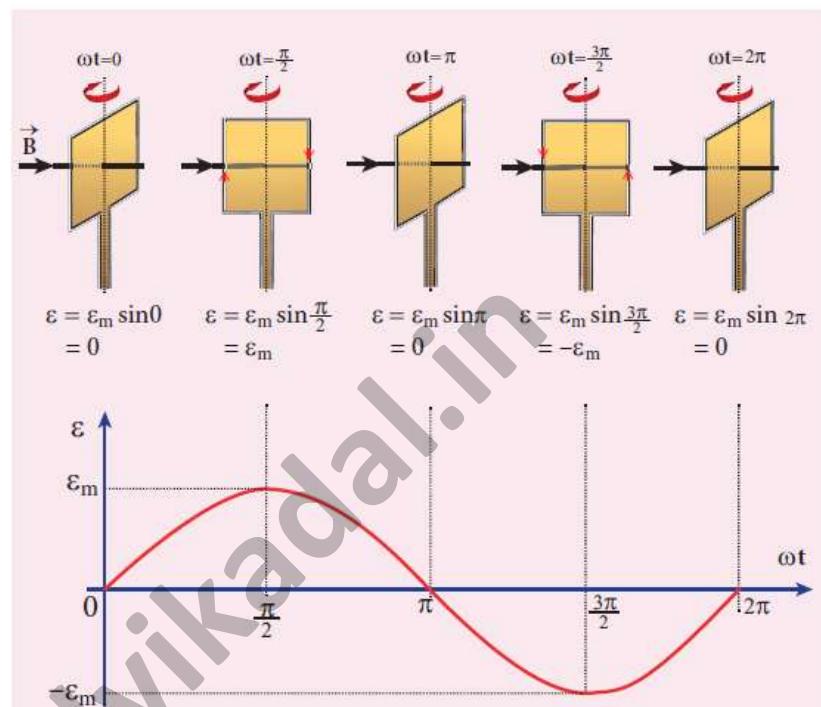
Therefore, the value of induced emf at that instant is then given by,

$$\epsilon = \epsilon_m \sin \omega t \quad \dots \dots \dots (3)$$

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 and is given by, $i = I_m \sin \omega t \quad \dots \dots \dots (4)$

Where, $I_m \rightarrow$ peak value of induced current



84. Elaborate the standard construction details of AC generator.

AC generator - construction:

AC generator (alternator) is an **energy conversion** device. It converts **mechanical energy** used to rotate the coil or field magnet in to electrical energy.

It works on the **principle of electromagnetic induction**. It consists of two major parts stator and rotor. In commercial alternators, the armature winding is mounted on stator and the field magnet on rotor

Stator: It has three components

(i) Stator frame:

It is used for holding stator core and armature windings in proper position. It provides best ventilation with the help of holes provided in the frame itself.

(ii) Stator core (Armature) :

It is made up of **iron or steel alloy**. It is a hollow cylinder and is laminated to **minimize eddy current loss**. The slots are cut on inner surface of the core to accommodate armature windings.

(iii) Armature windings:

It the coil wound on slots provided in the armature core. One or more than one coil may be employed, depending on the type of alternator. Two types of windings are commonly used and they are **single-layer winding and double-layer winding**.

Rotar :

It consists **magnetic field windings**. The magnetic poles are magnetized by DC source. The ends of field windings are connected to a pair of slip rings, attached to a common shaft about which rotor rotates. **Slip rings rotate along with rotor**. To maintain connection between the DC source and field windings, two brushed are used which continuously slide over the slip rings

There are two types, namely

(i) Salient pole rotor:

The word salient means projecting. This rotor has a number of projecting poles having their bases riveted to the rotor. It is **mainly used in low-speed alternators**

(ii) Cylindrical pole rotor:

This rotor consists of a smooth solid cylinder. The slots are cut on the outer surface of the cylinder along its length. It is suitable for **very high speed alternators**. The frequency of alternating emf induced is **directly proportional to the rotor speed**. In order to **maintain the frequency constant**, the **rotors run at a constant speed**.

- 85. Explain the working of a single - phase AC generator with necessary diagram.**

Single phase AC generator:

In a single phase AC generator, the armature conductors are connected in series so as to form a single circuit which generates a single-phase alternating emf and hence it is called single-phase alternator.

Principle:

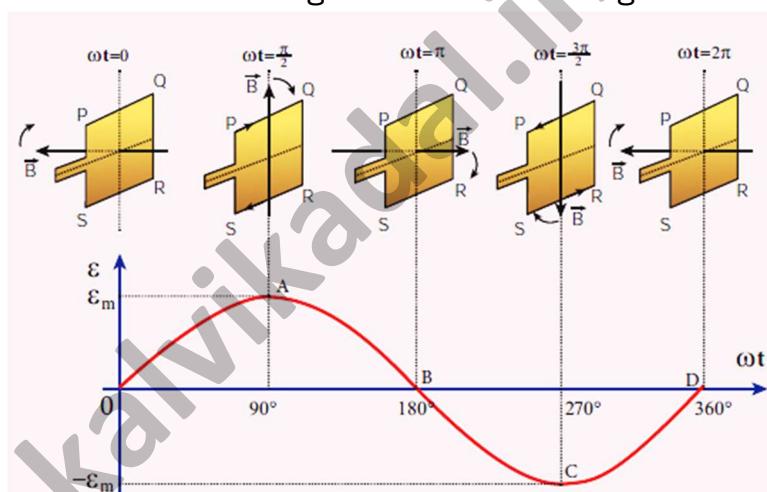
Electromagnetic induction

Construction:

Consider a stator core consisting of 2 slots in which 2 armature conductor PQ and RS are mounted to form single - turn rectangular loop PQRS Rotor has 2 salient poles with field windings which can be magnetized by means of DC source.

Working:

The loop PQRS is stationary and is perpendicular to the plane of the paper. Assume the initial position of the field magnet is horizontal. At that instant, **the direction of magnetic field is perpendicular to the plane of the loop PQRS. The induced emf is zero.**



It is represented by origin 'O' in the graph. Let the magnetic field rotate in clock-wise direction.

When the field magnet rotates through **90**, **the magnetic field becomes parallel** to PQRS. The induced emf's across PQ and RS would become maximum. **According to Fleming's right hand rule, the direction of induced emf for PQ is downwards and for RS is upwards.** Therefore, the current flows along PQRS. The point A in the graph represents this maximum emf.

When field magnet rotates **180^o**, the field is again **perpendicular** to PQRS and the induced emf becomes zero. This is represented by point B

When field magnet rotates **270^o**, the field is again **parallel** to PQRS, the induced emf is maximum but the direction is reversed.

Thus the current flows along SRQP. This is represented by point C. On completion of **360**, **the induced emf becomes zero** and it is represented by the point D.

From the graph, it is **clear that, when field magnet completes one rotation, the emf induced in PQRS is alternating in nature.**

- 86. How are the three different emfs generated in a three-phase AC generator? Show the graphical representation of these three emfs.**

Three phase AC generator:

If the AC generator consists three separate coils, which would give three separate emfs, then it is called three-phase generators.

Construction:

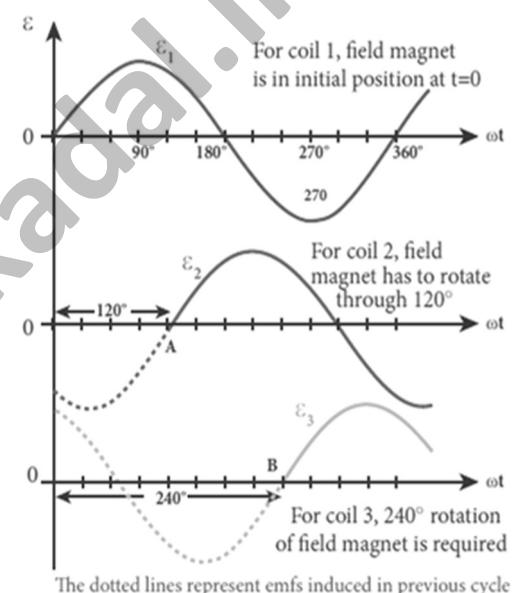
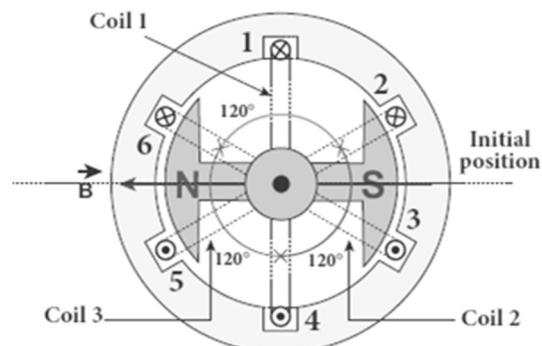
It has 6 slots, cut in its inner rim. Each slot is 60° away from one another. six armature conductors are mounted in these slots. The conductors 1 - 4, 2 - 5 and 3 - 6 are joined in series to form coils 1, 2 and 3 So these coils are rectangular in shape and are 120° apart from one another.

Working:

The initial position of the field magnet is horizontal and field direction is perpendicular to the plane of the coil - 1. When it rotated from that position in clockwise direction, alternating emf ' ϵ_1 ' in coil - 1 begins a cycle from origin 'O'

When it rotated through 120° , alternating emf ' ϵ_2 ' in coil - 2 starts at point 'A'

When it rotated through 240° , alternating emf ' ϵ_3 ' in coil - 3 starts at



point 'B'

Thus these emf produced in the three phase AC generator have 120° phase difference between one another.

87. 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.

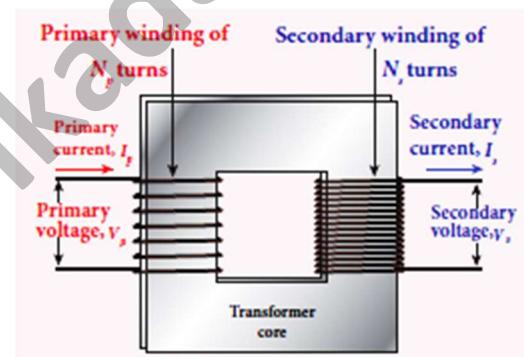
Principle:

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 ' ϵ_P ' is almost equal and opposite to the applied voltage ' V_P ' and is given by, $V_P = \epsilon_P = -N_P \frac{d\phi_B}{dt}$ ----- (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 ' ϵ_S ' is, $V_S = \epsilon_S = -N_S \frac{d\phi_B}{dt}$ ----- (2)

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

Where, K → Transformation ratio

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

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

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

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

(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**.

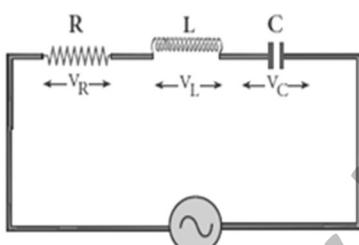
Efficiency of a transformer:

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

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

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

Series RLC circuit:



$$v = V_m \sin \omega t$$

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,

$$v = V_m \sin \omega t \quad \dots \dots \dots (1)$$

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

Hence the voltage developed across R, L and C

$$V_R = iR \quad (V_R \text{ is in phase with } i)$$

$$V_L = iX_L \quad (V_L \text{ leads } i \text{ by } \frac{\pi}{2})$$

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

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 parallelogram law, the diagonal \overrightarrow{OE} gives the resultant voltage "v"

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

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

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

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

$$i = \frac{v}{Z}$$

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

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

Special cases:

(i) When $X_L > X_C$, $X_L - X_C$ the phase angle ϕ is **Positive**.

It means that v leads i by ϕ .

$$(i.e.) i = I_m \sin \omega t ; v = v_m \sin(\omega t + \phi)$$

This circuit is inductive.

(ii) When $X_L < X_C$, $X_L - X_C$ the phase angle ϕ is **negative**.

It means that v lags behind i by ϕ .

$$(i.e.) i = I_m \sin \omega t ; v = v_m \sin(\omega t - \phi)$$

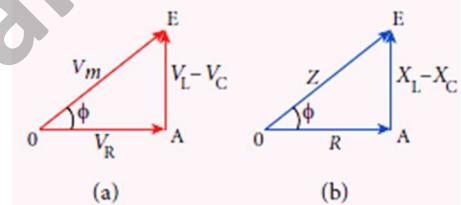
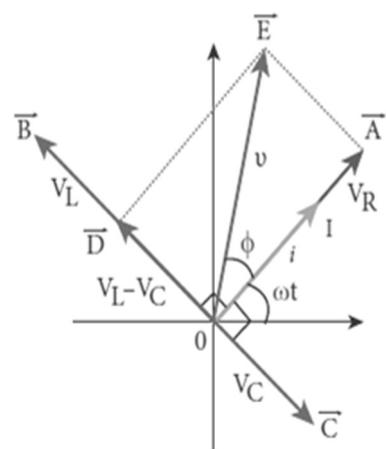
This circuit is capacitive

(iii) When $X_L = X_C$ the phase angle ϕ is **zero**.

It means that v in-phase with i

$$(i.e.) v = V_m \sin \omega t \quad \& \quad i = I_m \sin \omega t$$

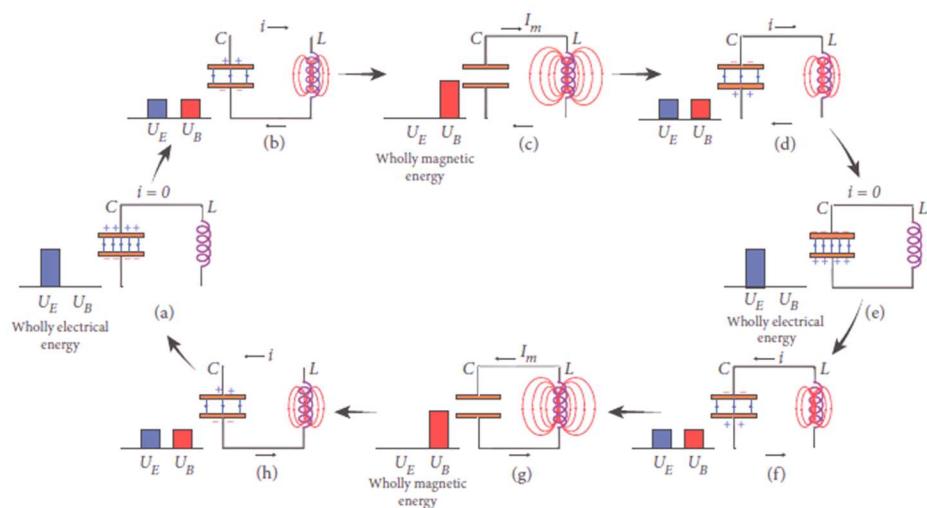
This circuit is resistive



89. What are called LC oscillations? Explain the generation of LC oscillations.

LC oscillations:

Whenever energy is given to a circuit containing a pure inductor of inductance L and a capacitor of capacitance C , the energy oscillates back and forth between the magnetic field of the inductor and the electric field of the capacitor. Thus the electrical oscillations of definite frequency are generated. These oscillations are called LC oscillations.



Generation of LC oscillations:

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Thus the electrical oscillations of definite frequency are generated. These oscillations are called LC oscillations.

Generation of LC - oscillations:

Stage -1 :

Consider the capacitor is fully charged with maximum charge Q_m . So that the **energy stored in the capacitor is maximum (i.e.)** $U = \frac{Q_m^2}{2C}$

As there is no current in the inductor, $U_B = 0$. Therefore, the total energy is wholly electrical.

Stage - 2 :

The capacitor now begins to discharge through the inductor that establishes current ‘ i ’ clockwise direction. This current produces a magnetic field around the inductor and energy stored in the inductor which is given by

$U_B = \frac{Li^2}{2}$. As the charge in the **capacitor decreases, the energy stored in it also**

decreases and is given by $U_B = \frac{q^2}{2C}$. Thus the total energy is the sum of electrical and magnetic energies.

Stage - 3 :

When the charge in the **capacitor becomes zero, its energy becomes zero (i.e.)** $U_E = 0$

In this stage maximum current (I_m) flows through inductor and its energy becomes maximum. (i.e.) $U_B = \frac{LI_m^2}{2}$. Thus the total energy is wholly magnetic.

Stage - 4 :

Even though the charge in the capacitor is zero, the current will continue to flow in the same direction. Since the current flow is in decreasing magnitude, the capacitor begins to charge in the opposite direction.

Thus a part of the energy is transferred from the inductor back to the capacitor. The total energy is the sum of the electrical and magnetic energies.

Stage - 5 :

When the current in the circuit reduces to zero, the capacitor becomes fully charged in the opposite direction. Thus the **energy stored in the capacitor becomes maximum and the energy stored in the inductor is zero**. So the total energy is wholly electrical.

Stage - 6 :

This state of the circuit is similar to the initial state but the difference is that the capacitor is charged in opposite direction. So it will start discharge through inductor in anti-clockwise direction. The total energy is the sum of the electrical and magnetic energies.

Stage - 7 :

The processes are repeated in opposite direction and finally the circuit returns to the initial state. Thus when the circuit goes through these stages, an alternating current flows in the circuit. As this process is repeated again and again, the electrical oscillations of definite frequency are generated. These are known as LC oscillations.

90. Compare the electromagnetic oscillations of LC circuit with the mechanical

Oscillations of block-spring system to find the expression for angular frequency of LC oscillators mathematically.

Analogies between LC oscillations and simple harmonic oscillations:

Electromagnetic Oscillation	Mechanical Oscillation
This circuit consists inductor and capacitor	This circuit consists spring and block
Charge "q"	Displacement "x"
Current $i = \frac{dq}{dt}$	Velocity $v = \frac{dx}{dt}$
Inductance "L"	Mass "m"
Reciprocal in capacitance $\frac{1}{C}$	Force constant "k"
Electrical Energy = $\frac{1}{2} \left[\frac{1}{C} \right] q^2$	Potential Energy = $\frac{1}{2} kx^2$
Mechanical Energy = $\frac{1}{2} Li^2$	Kinetic Energy = $\frac{1}{2} mv^2$
Electromagnetic energy = $\frac{1}{2} \left[\frac{1}{C} \right] q^2 + \frac{1}{2} Li^2$	Mechanical Energy = $\frac{1}{2} kx^2 + \frac{1}{2} mv^2$

Angular frequency of LC Oscillations:

The electromagnetic energy is $U = \frac{1}{2} \left[\frac{1}{C} q^2 + \frac{1}{2} L i^2 \right] = \text{Constant}$

$$\text{Differentiate, } \frac{dU}{dt} = \frac{1}{2C} \left(2q \frac{dq}{dt} \right) + \frac{1}{2} L \left(2i \frac{di}{dt} \right) = 0$$

$$\frac{dU}{dt} = \frac{q}{C} \frac{dq}{dt} + L \frac{dq}{dt} \left[\frac{d}{dt} \left(\frac{dq}{dt} \right) \right] = 0 \quad \therefore \left[i = \frac{dq}{dt} \right]$$

$$(\text{or}) L \frac{d^2q}{dt^2} + \frac{q}{C} = 0 \quad \dots \dots \dots (1)$$

Its solution is, $q(t) = Q_m \cos(\omega t + \phi)$

Differentiate with respect to "t"

$$i(t) = \frac{dq}{dt} = \frac{d}{dt} [Q_m \cos(\omega t + \phi)]$$

$$i(t) = -Q_m \omega \sin(\omega t + \phi) = -I_m \sin(\omega t + \phi)$$

Again differentiate with respect "t"

$$\frac{d^2q}{dt^2} = -Q_m \omega^2 \cos(\omega t + \phi) = -I_m \omega \cos(\omega t + \phi)$$

Put this in equation (1), the angular frequency of

$$\text{LC oscillations is, } \omega = \frac{1}{\sqrt{LC}}$$

UNIT - V (ELECTROMAGNETIC WAVES)

TWO MARKS QUESTIONS AND ANSWERS

1. Define displacement current.

The displacement current can be defined as **the current which comes into play in the region in which the electric field and the electric flux are changing with time**. That is whenever the change in electric field takes place, displacement current is produced.

2. Define electromagnetic waves.

Electromagnetic waves are **non-mechanical waves** which move with speed equals to the speed of light (in vacuum)

3. Define intensity of electromagnetic wave.

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

4. Define radiation pressure.

The force exerted by an electromagnetic wave on unit area of a surface is called radiation pressure.

5. 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.

SI unit of **pointing vector** is **Wm⁻²**.

6. 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, $\oint_s \vec{B} \cdot d\vec{l} = \mu_0(I_C + I_D)$ (or)

$$\oint_s \vec{B} \cdot d\vec{l} = \mu_0 I_C + \mu_0 \epsilon_0 \frac{d}{dt} \oint_s \vec{E} \cdot d\vec{A} - \text{Ampere - Maxwell's law.}$$

7. Define electromagnetic spectrum.

The orderly distribution of electromagnetic waves in terms of wavelength or frequency is called electromagnetic spectrum.

8. Define dispersion.

When white light is made to pass through the prism, it is split in to its seven constituent colours. This phenomenon is known as dispersion of light.

The pattern of colours obtained on the screen after dispersion is called **spectrum**.

9. Define emission spectra.

The **spectrum obtained from a self-luminous source of light** is called emission spectrum. Each source has its own characteristic emission spectrum.

10. Define 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.

11. 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.

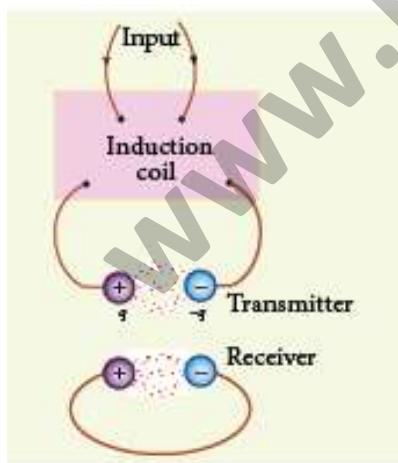
12. What are the uses of Fraunhofer lines?

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**.

THREE MARKS QUESTIONS AND ANSWERS

13. Discuss briefly the experiment conducted by Hertz to produce and detect electromagnetic spectrum.

Hertz experiment:



The theoretical prediction of existence of electromagnetic wave by Maxwell was experimentally confirmed by Henrich Hertz. His experimental set up consists of two metal electrodes which are made of small spherical metals.

These are connected to larger spheres and the ends of them are connected to induction coil which produces very high emf. Due to this high voltage, the air between the electrodes gets ionized and spark is produced.

A receiver (ring electrode) kept at a distance also gets spark which implies that the energy is transmitted from electrode to the receiver as a wave known as electromagnetic waves. If the receiver is rotated by 90° , then no spark is observed by the receiver.

This confirms that **electromagnetic waves are transverse waves as predicted by Maxwell**. Hertz detected radio waves and also computed the speed of radio waves which is equal to the speed of light ($3 \times 10^8 \text{ ms}^{-1}$).

- 14.** Obtain an expression for energy density associated with an electromagnetic wave propagating in vacuum or free space.

Energy density of electromagnetic wave:

The energy per unit volume (i.e.) the energy density of electromagnetic wave is, $u = u_E + u_B$; $u = \frac{1}{2} \epsilon_0 E^2 + \frac{1}{2\mu_0} B^2$ (1)

Where, $u_E = \frac{1}{2} \epsilon_0 E^2$ → Energy density in electric field.

$u_E = \frac{1}{2\mu_0} B^2$ → Energy density in magnetic field.

The velocity of electromagnetic waves, $C = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$ (or) $C^2 = \frac{1}{\epsilon_0 \mu_0}$

If $E = BC$ then, $u_E = u_m$. Hence equation (1) becomes

$$u = \epsilon_0 E^2 = \frac{1}{\mu_0} B^2$$

The average energy density for electromagnetic waves,

$$(u) = \frac{1}{2} \epsilon_0 E^2 = \frac{1}{2\mu_0} B^2$$

- 15.** Explain the sources of electromagnetic waves.

Sources of electromagnetic waves:

Any stationary source charge produces only electric field. When the charge moves with uniform velocity, it produces steady current which gives rise magnetic field around the conductor in which charge flows. If the charged particle accelerates, in addition to electric field, it also produces magnetic field.

Here both electric and magnetic fields are time varying fields. The linked electric and magnetic fields have wave properties which propagate in the direction perpendicular to the plane containing electric and magnetic field vectors.

This is known as electromagnetic waves and it **is transverse in nature**. Any oscillatory motion is also an accelerating motion, so when the charge oscillates about their mean position, it produces electromagnetic waves.

Let, electric and magnetic vectors are given by,

$$E_y = \sin(kz - \omega t)$$

$$E_x = \sin(kz - \omega t)$$

then the direction of propagation of electromagnetic waves are along Z-axis

Here the frequency of the electromagnetic wave is equal to the frequency of the source (oscillation charge)

In free space or vacuum, the ratio between E_0 and B_0 is equal to the speed of electromagnetic wave which is equal to speed of light (c) $C = \frac{E_0}{B_0}$

16. Write a note on Radio waves.

Radio waves:

It is produced by **accelerated motion of charges in conducting wires**.

The **frequency range is from a few Hz to 10^9 Hz**.

They **obey reflection and diffraction**

It is **used in**,

- (i) **Radio and television** communication systems
- (ii) **Cellular phones** to transmit voice communication in the ultra-high frequency band

17. Write a note on infra microwaves.

Microwaves:

It is **produced by special vacuum tubes such as klystron, magnetron and gunndiode**.

The **frequency range of microwaves is 10^9 Hz to 10^{11} Hz**.

They obey reflection and polarization

It is **used in**,

- (i) Radar system for **aircraft navigation**,
- (ii) Speed of the vehicle,
- (iii) Microwave oven **for cooking**
- (iv) Very long distance **wireless communication** through satellites

18. Write a note on Infra-red rays.

Infra-red rays:

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

The frequency range is 10^{11} Hz to 4×10^{14} Hz.

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

19. Write a note visible light.

Visible light:

It is produced by incandescent bodies and also it is radiated by excited atoms in gases.

The frequency range is from 4×10^{14} Hz to 8×10^{14} Hz.

It obeys the laws of reflection, refraction, interference, diffraction, polarization, photo-electric effect and photographic action.

It can be **used to**,

- (i) Study the structure of molecules
- (ii) **Arrangement of electrons** in eternal shells of atoms and
- (iii) Sensation of our eyes

20. Write a note on ultra violet rays.

Ultra violet rays:

It is produced by Sun, arc and ionized gases.

Its frequency range is from 8×10^{14} Hz to 10^{17} Hz.

It has **less penetrating power**

It can be absorbed by atmospheric ozone and harmful to human body.

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

21. Write a note on X - rays.

X - Rays:

It is produced when there is a sudden deceleration of high speed electrons at high atomic number target, also by electronic transitions among the innermost orbits of atoms.

The frequency range of X-rays is from 10^{17} Hz to 10^{19} Hz.

It has more penetrating power than UV - rays.

It is **used in**,

- (i) Studying structures of **inner atomic electron shell** and crystal structures.
- (ii) Detecting **fracture, diseased organs, formation of bones** and stones, observing the progress of healing bones
- (iii) **Detect faults, cracks, flaws and holes** in a finished metal product

22. Write a note on gamma rays.

Gamma rays:

It is produced by transitions of atomic nuclei and decay of certain elementary particles.

The frequency range is 10^{18} Hz and above.

They produce chemical reactions on photographic plates, fluorescence, ionization, diffraction.

Its penetrating power is higher than X-rays and UV rays.

It has no charge but harmful to human body.

It is **used in**,

- (i) Providing information about the structure of atomic nuclei
- (ii) Radio therapy for the **treatment of cancer** and **tumour**
- (iii) Food industry to kill **pathogenic micro organism**

FIVE MARKS QUESTIONS AND ANSWERS

23. 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 :

It is nothing but Gauss's law

It relates the net electric flux to net electric charge enclosed in a surface.

Mathematically, **Gauss law is expressed as**, $\oint_s \vec{E} \cdot d\vec{A} = \frac{Q_{\text{closed}}}{\epsilon_0}$ (1)

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

This equation is true for either discrete or continuous distribution of charges. It also indicates that the electric field lines start from positive charge and terminate at negative charge.

The electric field lines do not form a continuous closed path (i.e.) isolated positive or negative charges can exist.

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**. According to this law, the surface integral of magnetic field over a closed surface is zero.

Mathematically, **this law can be expressed as**, $\oint_s \vec{B} \cdot d\vec{A} = 0$ (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. This law relates **electric field with the changing magnetic flux**. This equation implies that, the **line integral of the electric field around any closed path is equal to the rate of change of magnetic flux through the closed path bounded by the surface.**

$$\text{Mathematically it is expressed as, } \oint_L \vec{E} \cdot d\vec{l} = - \frac{d\Phi_B}{dt} \dots\dots\dots(3)$$

\vec{E} → Electric field

The electrical energy supplied to our houses from electricity board by using Faraday's law of induction.

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.

$$\text{Mathematically, } \oint_S \vec{B} \cdot d\vec{l} = \mu_0(I_C + I_D) \text{ (or)}$$

$$\oint_L \vec{B} \cdot d\vec{l} = \mu_0 I_C + \mu_0 \epsilon_0 \frac{d}{dt} \oint_S \vec{E} \cdot d\vec{A} \text{ Here, } \vec{B} \rightarrow \text{Magnetic field.}$$

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

24. Explain the modification of Ampere's circuital law.

Maxwell's corrections to Ampere's circuital law:

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

$$\oint_L \vec{E} \cdot d\vec{l} = - \frac{\partial}{\partial t} \Phi_B = - \frac{\partial}{\partial t} \oint_S \vec{B} \cdot d\vec{A}$$

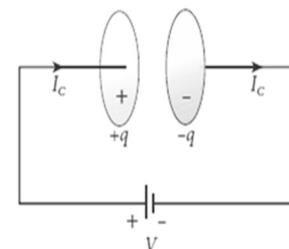
It implies that the electric field \vec{E} is induced along a closed loop by the changing magnetic flux Φ_B in the region encircled by the loop.

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

$$\oint_L \vec{B} \cdot d\vec{l} = - \frac{\partial}{\partial t} \Phi_E = - \frac{\partial}{\partial t} \oint_S \vec{E} \cdot d\vec{A}$$

This is known as Maxwell's law of induction.

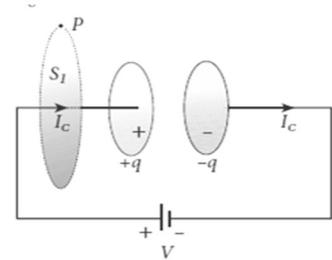
To understand how the changing electric field produces magnetic field, let us consider the situation of charging a parallel plate capacitor.



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 .

$$\text{Thus from Ampere circuital law, } \oint_{\text{enclosing } S_1} \vec{B} \cdot d\vec{l} = \mu_0 I_c \quad \dots \dots \dots (1)$$



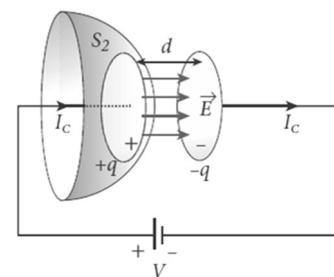
Suppose the same loop is enclosed by balloon shaped surface S_2 , then the boundaries of two surfaces are same but shape of the enclosing surfaces are different. Ampere's law does not depend on shape of the enclosing surface and hence the integrals will give the same answer.

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.

$$\text{Hence, } \oint_{\text{enclosing } S_2} \vec{B} \cdot d\vec{l} = 0 \quad \dots \dots \dots (2)$$

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.



$$\text{From Gauss's law, } \Phi_E = \oint_S \vec{E} \cdot d\vec{A} = EA = \frac{q}{\epsilon_0}$$

$$\text{The change in electric flux is, } \frac{d\Phi_E}{dt} = \frac{1}{\epsilon_0} \frac{dq}{dt} = \frac{1}{\epsilon_0} I_d$$

$$\therefore I_d = \epsilon_0 \frac{d\Phi_E}{dt}. \text{ Where, } \frac{dq}{dt} = I_d \rightarrow \text{Displacement Current}$$

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

$$\oint_l \vec{B} \cdot d\vec{l} = \mu_0 I_c + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

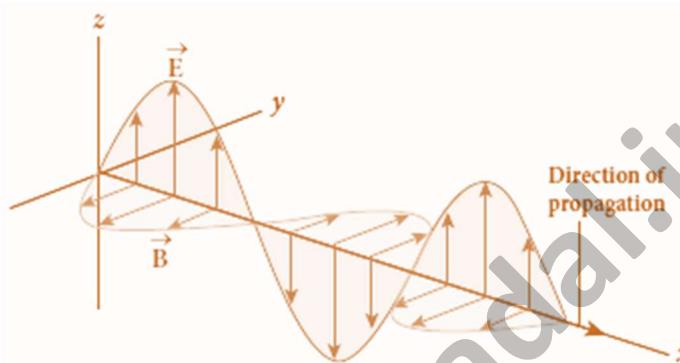
$$\oint_l \vec{B} \cdot d\vec{l} = \mu_0 I = (I_c + I_d) \quad \dots \dots \dots (3)$$

Where, $I = I_c + I_d \rightarrow \text{Total Current}$

25. Explain the properties of electromagnetic waves.

Properties of electromagnetic waves:

- 1) Electromagnetic waves are **produced by any accelerated charge**.
- 2) They **do not require any medium** for propagation. So **electromagnetic waves are non-mechanical wave**.
- 3) 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.



- 4) They **travel with speed of light in vacuum or free space** and it is given by, $C = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = 3 \times 10^8 \text{ ms}^{-1}$
- 5) 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.) ($v < c$)

$$\text{Hence, refractive index of the medium is, } \mu = \frac{c}{v} = \frac{1/\sqrt{\epsilon_0 \mu_0}}{1/\sqrt{\epsilon \mu}}$$

$$\therefore n = \sqrt{\epsilon_r \mu_r}$$

where ϵ_r is the relative permittivity of the medium (also known as dielectric constant) and μ_r is the relative permeability of the medium.

- 6) They are **not deflected by electric or magnetic field**.
- 7) They **show interference, diffraction and polarization**.
- 8) Like other waves, electromagnetic waves also **carry energy, linear momentum and angular momentum**.
- 9) 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 $p = \frac{U}{C}$,
- 10) If the incident electromagnetic wave of energy 'U' is **totally reflected from the surface, then the momentum delivered to the surface** is

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

26. 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 into three types;

(i) Continuous emission spectrum (or continuous spectrum):

If the light from **incandescent lamp (filament bulb)** is allowed to pass through **prism** (simplest spectroscope), it **splits up into seven colours**. Thus, it consists of wavelengths containing all the **visible colours ranging from violet to red**.

Examples: spectrum obtained from carbon arc and incandescent solids.



(ii) Line emission spectrum (or line spectrum):

Suppose light from **hot gas** is allowed to pass through **prism**, line spectrum is observed. Line spectra are also known as discontinuous spectra. The line spectra consist of **sharp lines of definite wavelengths or frequencies**. Such spectra arise due to excited atoms of elements. These lines are the characteristics of the element and are **different for different elements**.
Examples: spectra of atomic hydrogen, helium, etc.



(iii) Band emission spectrum (or band spectrum):

Band spectrum consists of **several number of very closely spaced spectral lines** which overlap together forming specific bands which are separated by **dark spaces**. This **spectrum has a sharp edge at one end and fades out at the other end**. Such spectra arise when the molecules are excited. Band spectrum is the characteristic of the molecule and hence the structure of the molecules can be studied using their band spectra.

Example: spectra of ammonia gas in the discharge tube etc.

27. Explain in detail the 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 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 - VI (RAY OPTICS)

TWO MARKS AND THREE MARKS QUESTIONS AND ANSWERS

1. Define reflection.

The bouncing back of light in to the same medium when it encounters a reflecting surface is called reflection of light.

2. State the 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)**.
That is $i = r$

3. What is the angle of deviation due to reflection?

The **angle between the incident and deviated ray** is called angle of deviation (d) of the light ray.



From figure (a),

$$= 180^\circ - (i + r) \quad [i = r]$$

$$d = 180^\circ - 2i$$

The **angle between the incident ray and the reflecting surface** is called **glancing angle (α)**. From figure (b),

$$d = \angle BOY + \angle YOC = \alpha + \alpha = 2\alpha$$

4. What are the characteristics of the image formed by the plane mirror?

Characteristics of the image of the plane mirror:

Virtual, erect and laterally inverted. Size of image is equal to the size of the object. The distance of the image behind the mirror is equal to the distance of object in front of it. If an object placed between two plane mirrors inclined at an angle θ , then the number (n) of images formed is,

- 1) If $\left[\frac{360^\circ}{\theta}\right]$ even, then ; $n = \left[\frac{360^\circ}{\theta} - 1\right]$ for objects placed symmetrically or un-symmetrically.
- 2) If $\left[\frac{360^\circ}{\theta}\right]$ odd, then ; $n = \left[\frac{360^\circ}{\theta} - 1\right]$ for objects placed symmetrically.
- 3) If $\left[\frac{360^\circ}{\theta}\right]$ odd, then ; $n = \left[\frac{360^\circ}{\theta}\right]$ for objects placed un-symmetrically

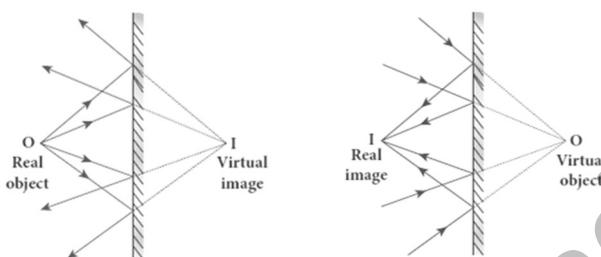
5. Write a note on real and virtual images formed by a plane mirror.

Virtual image:

When a real object is placed at a point 'O' in front of a plane mirror, it produces divergent rays in all directions. After reflection at plane mirror, they appear to come from a point 'I' behind the mirror. This **image cannot be formed on the screen but only seen with eyes**. It is called virtual image.

Real image:

If convergent rays incident on a plane mirror and after reflection, they pass through a point ' I ' in front of the mirror. This **image can be formed on a screen and can also be seen with eyes**. It is called real image.



6. What are the conditions for nature of objects and images regarding plane mirror

Nature of Object / Image	Condition
Real Image	Rays actually converge at the image
Virtual Image	Rays appear to diverge from the image
Real Object	Rays actually diverge from the object
Virtual Object	Rays appear to converge at the object

7. Distinguish convex mirror and concave mirror?

Convex Mirror	Concave Mirror
It is a spherical mirror in which reflection takes place at the convex surface and other surface is silvered	It is a spherical mirror in which reflection takes place at the concave surface and other surface is silvered

8. Define (1) centre of curvature, (2) Radius of curvature (3) pole, (4) principal axis, (5) focus or focal point, (6) focal length, (7) focal plane

(1) Centre of curvature:

The **centre of the sphere of which the mirror is a part** is called centre of curvature (C)

(2) Radius of curvature:

The **radius of the sphere of which the spherical mirror** is a part is called the radius of curvature (R) of the mirror.

(3) Pole:

The **middle point on the spherical surface of the mirror** (or) the **geometrical centre of the mirror** is called the pole (P) of the mirror.

(4) Principal axis:

The **line joining the pole (P) and the centre of curvature (C)** is called the principal axis (or) optical axis of the mirror.

(5) Focus or Focal point:

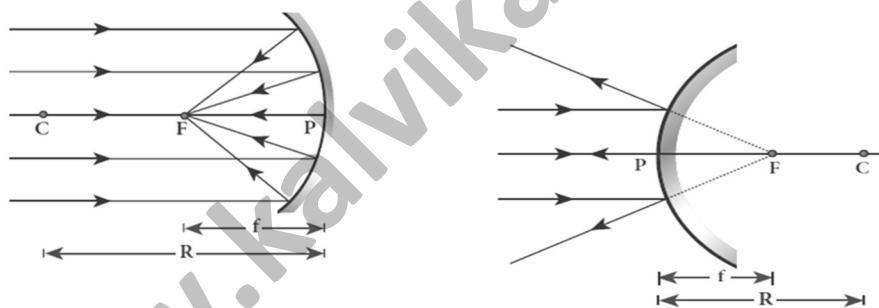
Light rays travelling parallel and close to the principal axis when incident on a spherical mirror, **converge at a point for concave mirror** or **appears to diverge from a point for convex mirror on the principal axis**. This point is called the focus or focal point (F) of the mirror

(6) Focal length:

The **distance between the pole (P) and the Focus (F)** is called the focal length (f) of the mirror.

(7) Focal plane:

The **plane through the focus and perpendicular to the principal axis** is called the focal plane of the mirror.



9. Define paraxial rays and marginal rays.

Paraxial rays:

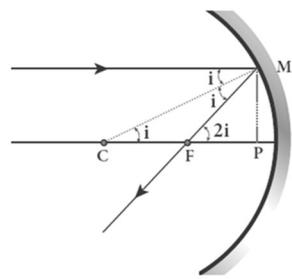
The **rays travelling very close to the principal axis and make small angle with it** are called paraxial rays.

Marginal rays:

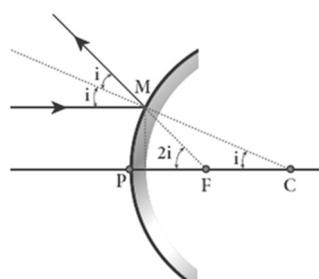
The **rays travelling far away from the principal axis and fall on the mirror far away from the pole** are called as marginal rays.

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

Relation between f and R :



(a) Concave mirror



(b) Convex Mirror

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 pass through principal focus 'F'. The line 'CM' is the normal to the mirror at 'M'.

From the figure (a),

Angle of incidence; = $\angle AMC$

Angle of reflection; = $\angle CMF$

By the law of reflection, we have, $i = r$

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

From ΔMCP and ΔMFP

$$\tan i = \frac{PM}{PC}; \tan 2i = \frac{PM}{PF}$$

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

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

Put equation (1) in equation (2)

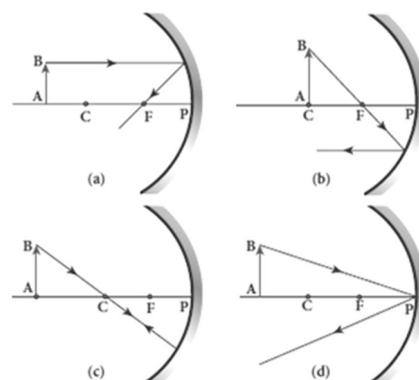
$$2 \frac{PM}{PC} = \frac{PM}{PF} \text{ (or)} 2PF = PC \text{ (or)} 2f = R$$

$$f = \frac{R}{2} \dots\dots\dots(3)$$

- 11. How we locate the image formation in spherical mirrors?**

Image formation in spherical mirrors:

- a) A ray parallel to the principal axis after reflection will pass through or **appear to pass through the principal focus**.
- b) A ray passing through or appear to pass through the principal focus, **after reflection will travel parallel to the principal axis**,

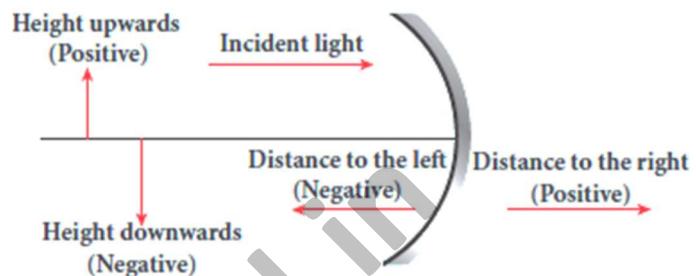


- c) A ray passing through the centre of curvature retraces its path after reflection as it is a case of normal incidence.
- d) A **ray falling on the pole will get reflected as per law of reflection** keeping principal axis as the normal.

12. What are the Cartesian sign conventions for spherical mirrors?

Cartesian sign convention:

1. The incident light is taken from left to right.
2. All the distances are measured from the pole.
3. The distance measured to the **right of pole** along the principal axis are taken as positive
4. The **distance measured to the left** of pole along the **principal axis** are taken as **negative**
5. **Heights measured in the upward** perpendicular direction to the **principal axis is taken as positive**
6. **Heights measured in the downward** perpendicular direction to the principal axis is taken as **negative**.



13. Define refractive index.

Refractive index (n) of a transparent medium is defined as **the ratio of speed of light in vacuum (or air) to the speed of light on that medium**. $n = \frac{c}{v}$

14. Define optical path.

Optical path of a medium is defined as **the distance (d') light travels in vacuum in the same time it travels a distance (d) in the medium**.

If ' n ' is the refractive index of the medium, then optical path is; $d' = n d$

15. What is called refraction?

Refraction is passing through of light from one optical medium to another optical medium through a boundary.

16. State the laws of refraction.

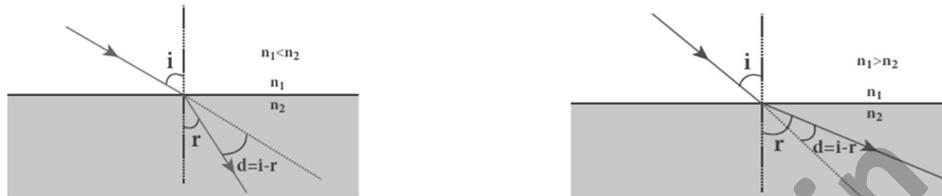
The **incident ray, refracted ray and normal are all coplanar**.

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 '.

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

17. What is the angle of deviation due to refraction? Angle of deviation due to refraction:

1. The **angle between the incident and deviated ray** is called angle of deviation.
2. **When light travels from rarer to denser medium it deviates towards normal.** Hence the angle of deviation; $d = i - r$
3. When light travels from denser to rarer medium it deviates away normal. Hence the angle of deviation; $d = r - i$



18. Write the characteristics of refraction.

Characteristics of refraction:

- (1) **When light passes from rarer to denser medium** it deviates towards normal in the **denser medium**.
- (2) **When light passes from denser to rarer medium** it deviates away from normal in the **rarer medium**.
- (3) In any refracting surface, there will also be some reflection takes place. This phenomenon in which light undergoing reflection and refraction at the same time at same surface is called simultaneous reflection or simultaneous refraction.

19. What is the principle of reversibility?

The principle of reversibility states that, light **will be following exactly the same path if its direction of travel is reversed**. This is true for both reflection and refraction.

20. Define relative refractive index.

From Snell's law, $\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$. Here the term $\left[\frac{n_2}{n_1}\right]$ is called relative refractive index of second medium with respect to the first medium and it is denoted by n_{21} . (i.e.) $n_{21} = \frac{n_2}{n_1}$

21. 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 $i \leq r$.

By Snell's law in product form

$$n_1 \sin i \equiv n_2 \sin r$$

As the angles are small, we can write

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

$$\text{Hence, } n_1 \tan i = n_2 \tan r \quad \dots \dots \dots (1)$$

In ADOR and ADIB

$$\tan i = \frac{DB}{DO} = \frac{DB}{d}, \tan r = \frac{DB}{DI} = \frac{DB}{d'}$$

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 $(d - d')$

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

22. Define Critical angle.

The angle of incidence in the denser medium for which the refracted ray grazes the boundary is called critical angle i_c

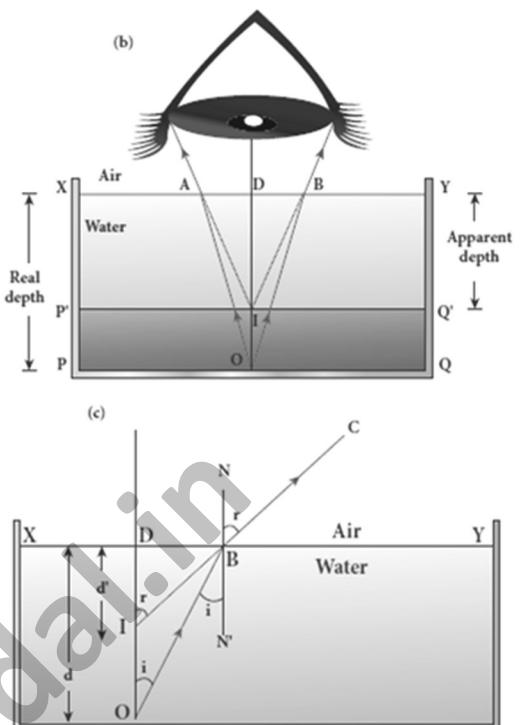
23. Define total internal reflection.

If the angle of incidence in the denser medium is greater than the critical angle, there is no refraction possible in the rarer medium. The entire light is **reflected back in to the denser medium** itself; this phenomenon is called total internal reflection.

24. What are the conditions to achieve total internal reflection?

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

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



25. Obtain an expression for critical angle.

Critical angle:

When light ray passes from denser medium to rarer medium, it bends away from normal. So $i < r$

As i increases, r also increases rapidly and at a certain stage it just grazes the boundary ($r = 90^\circ$). The **corresponding angle of incidence** is called critical angle (i_c)

From Snell's law of product form

$$n_1 \sin i = n_2 \sin r, \text{ When } i = i_c, \text{ then } r = 90^\circ$$

$$n_1 \sin i_c = n_2 \sin 90^\circ, n_1 \sin i_c = n_2; \sin i_c = \frac{n_2}{n_1}$$

If the rarer medium is air, then $n_2 = 1$ and $n_1 = n$, then

$$\sin i_c = \frac{1}{n} \quad (\text{or}) \quad i_c = \sin^{-1}\left(\frac{1}{n}\right)$$

26. Obtain the reason for glittering of diamond.

Glittering of diamond:

The glittering of diamond is due to **the total internal reflection** of light happens inside the diamond. **The refractive index of diamond is 2.417** and the **critical angle is 24.4°**. Diamond has large number of cut plan faces.

So light entering the diamond get total internally reflected from many cut faces before getting out. This gives a sparkling effect for diamond.

27. What are mirage and looming?

Mirage:

In hot places, air near the ground is hotter than air at a height. Hot air less dense. **The refractive index of air increases with increase in density.**

Because of this, the air near hot ground acts as rarer medium than the air at height.

When light from tall object like tree, passes through a medium whose refractive index decreases towards the ground, it successively deviates away from the normal and undergoes total internal reflection when the angle of incidence near the ground exceeds the critical angle. This gives an illusion as if the light comes from somewhere below the ground.

For of the shaky nature of the layers of air, the observer feels as wet surface beneath the object. This phenomenon is called mirage.

Looming:

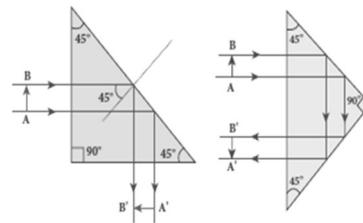
In cold places, the refractive index increases towards the ground, because the temperature of air close to the ground is less than the air at height. So, in cold regions like glaciers and frozen lakes and seas, the reverse effect of mirage will happen. Hence **an inverted image is formed little above the surface.** This phenomenon called looming.

28. Write a note on the prisms making using of total internal reflection.

Prisms making using **use of total internal reflection**

Prisms can be **designed to reflect light by 90° or by 180° by making use of total internal reflection.**

In both cases, the critical angle of material of the prism must be **less than 45° .** This is true for both **crown glass and flint glass**



29. What is Snell's window (or) Radius of illumination?

Snell's window:

When a **light source like electric bulb is kept inside a water tank, the light from the source travels in all direction inside the water.** The light that incident on water surface at an angle less than the critical angle will undergo refraction and emerge out from the water.

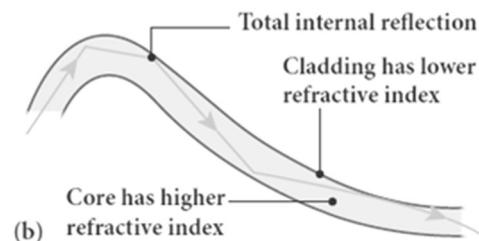
The **light incident at an angle greater than the critical angle will undergo total internal reflection.** But the light, incident at critical angle graces the surface and hence the entire surface of water appears illuminated when seen from outside.

On the other hand, when light entering water from outside is seen from inside the water, the view is restricted to a particular angle equal to the critical angle i_c . The restricted illuminated circular area is called Snell's window.

30. Write a note on Optical fibres.

Optical fibre:

Transmitting signals from one end to another end due to the phenomenon of **total internal reflection** is called optical fibres. It consists of inner part called core and outer part called **cladding or sleeving**.



The refractive index of the core must be higher than that of the cladding. Signal in the form of light is made to incident inside the core-cladding boundary at an angle greater than the critical angle. Hence it undergoes repeated total internal reflections along the length of the fibre without undergoing any refraction.

Even while bending the optic fibre, it is done in such a way that the condition for total internal reflection is ensured at every reflection.

31. Write a note on an endoscope.

Endoscope:

An endoscope is an instrument used by doctors which has a bundle of optical fibres that are used **to see inside a patient's body**. It works on the phenomenon of total internal reflection. It is inserted in to the body through mouth or nose or a special hole made in the body. The necessary instruments for operation is attached at their ends.

32. Define primary and secondary focal points.

Primary focal point (F_1):

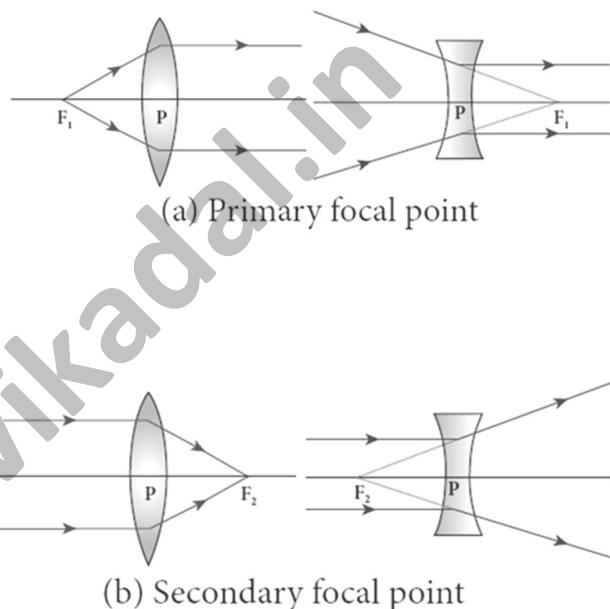
It is defined as a point, where an object should be placed to give **parallel emergent ray to the principal axis**. For convergent lens such an object is real and for divergent lens, the object is virtual.

Here,

$$PF_1 = f_1 \rightarrow \text{principal focal length.}$$

Secondary focus point (F_2):

It is defined as a point, where all the parallel rays travelling close to the **principal axis converge to form an image on the principal axis**. For convergent lens such an image is real and for divergent lens, the image is virtual. Here, $PF_2 = f_2 \rightarrow$ secondary focal length.



33. What are the sign conventions for lens on focal length?

The sign of focal length is not decided on **the direction of measurement of the focal length** from the pole of the lens as they have two focal lengths on either side of the lens. **The focal length of thin lens is taken as positive for a converging lens and negative for a diverging lens.**

34. Define power of a lens.

The power 'P' of a lens is defined as **the reciprocal of its focal length (f)**.

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

The **unit of power is diopter (D)**, Power is positive for converging lens and negative for diverging lens.

35. Write a note on prism.

A prism is a **triangular block of glass or plastic** which is bounded by the **three plane faces not parallel to each other**. It's **one face is grounded** which is called **base**. The other **two faces** are **polished** which are called **refracting faces of the prism**. The **angle between the two refracting faces** is called angle of prism (A)

36. Define angle of minimum deviation.

The **angle between incident ray and emergent ray** is called angle of deviation (d). **When the angle of incidence increases, the angle of deviation decreases**, reaches a minimum value and then continues to increase.

The **minimum value of angle of deviation** is called angle of minimum deviation (D).

37. What is called dispersion of light?

The **splitting of white light** in to its constituent colours is called **dispersion of light**. This band of colours of light is called its spectrum.

The spectrum consists **seven colours in the order VIBGYOR**

38. Define dispersive power.

Dispersive power (ω) is the ability of the material of the prism to cause dispersion. It is defined as the **ratio of the angular dispersion for the extreme colours to the deviation for any mean colour**.

39. 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 $a \ll \lambda$

40. State Rayleigh's scattering law.

The intensity (I) of Rayleigh's scattering is **inversely proportional to fourth power of wavelength (λ)**. $I \propto \frac{1}{\lambda^4}$

41. Why does sky appears blue colour?

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.

42. 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.

43. 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.

44. How are rainbows formed?

Formation of rainbows:

Rainbows are formed **due to dispersion of sunlight through droplets of water during rainy days**. Rainbow is observed during rainfall or after rainfall or looking water fountain provided the Sun is at the back of the observer.

When **sun light falls on the water drop suspended air**, it splits in to its constituent seven colours. Here water drops act as a glass prism. Primary rainbow is formed when one total internal reflection takes place inside the drop.

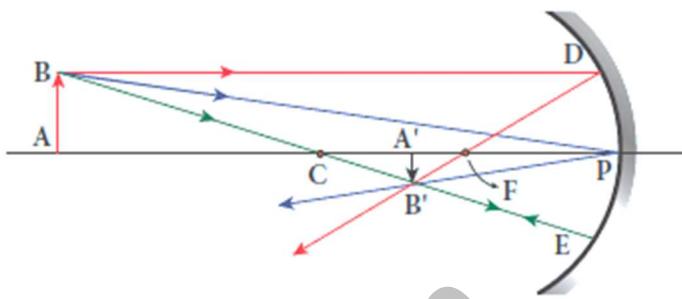
The **angle of view for violet to red in primary rainbow is 40° to 42°** Secondary rainbow is formed when two total internal reflections takes place inside the drop. The **angle of view for violet to red in primary rainbow is 52° to 54°**

FIVE MARKS QUESTIONS AND ANSWERS

- 45. 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) 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,

$$\text{Angle of incidence } (i) = \text{angle of reflection } (r)$$

$$\angle BPA = \angle B'PA'$$

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

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

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

$$\frac{A'B'}{PD} = \frac{A'F}{PF} \quad [PD = AB]$$

$$\frac{A'B'}{AB} = \frac{A'F}{PF} \dots\dots\dots (2)$$

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

$$\frac{PA'}{PA} = \frac{PA' - PF}{PF} \dots\dots\dots (3)$$

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

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

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

Dividing both sides by v ; $\frac{1}{u} = \frac{1}{f} - \frac{1}{v}$;

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \dots\dots\dots (4)$$

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) $\frac{A'B'}{AB} = \frac{PA'}{PA}$; $\frac{-h^1}{h} = \frac{-v}{-u}$

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

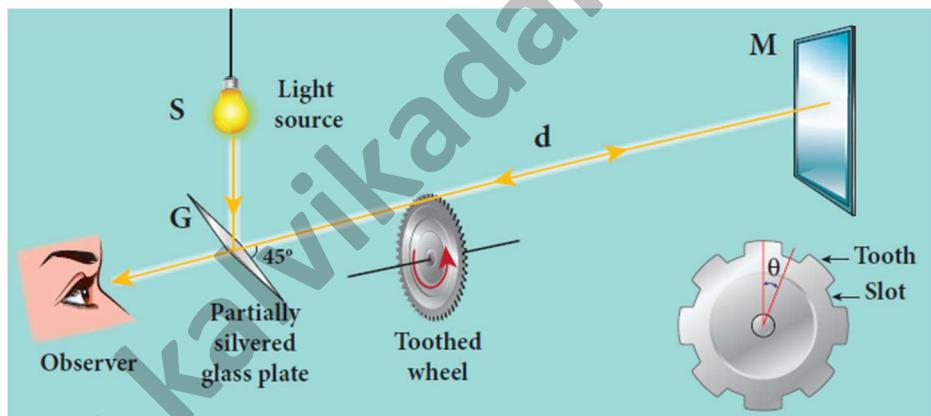
$$\text{Using equation (4) } m = \frac{h^1}{h} = \frac{f-v}{f} = \frac{f}{f-u} \dots\dots\dots (6)$$

46. 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°** 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.



If the toothed wheel was rotating, the reflected light from the mirror would not pass through the same cut and would not 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,

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

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

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

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

47. Obtain the equation for radius of illumination (or) Snell's window.

Radius of Snell's window:

Light is seeming from a point 'A' at a depth 'd'

Applying Snell's law in product form at point 'B'.

$$n_1 \sin i_c = n_2 \sin 90^\circ ; n_1 \sin i_c = n_2$$

$$(or) \sin i_c = \frac{n_2}{n_1} \dots \dots \dots (1)$$

$$\ln \Delta ABC, \sin i_c = \frac{CB}{AB} = \frac{R}{\sqrt{R^2+d^2}} \dots \dots \dots (2)$$

Compare equation (1) and (2) $\frac{R}{\sqrt{R^2+d^2}} = \frac{n_2}{n_1}$ (or)

$$\frac{R^2}{R^2+d^2} = \left(\frac{n_2}{n_1}\right)^2 \quad (\text{or}) \quad \frac{R^2+d^2}{R^2} = \left(\frac{n_1}{n_2}\right)^2$$

$$1 + \frac{d^2}{R^2} = \left(\frac{n_1}{n_2}\right)^2;$$

$$\frac{d^2}{R^2} = \left(\frac{n_1}{n_2}\right)^2 - 1; \frac{n_1^2}{n_2^2} - 1$$

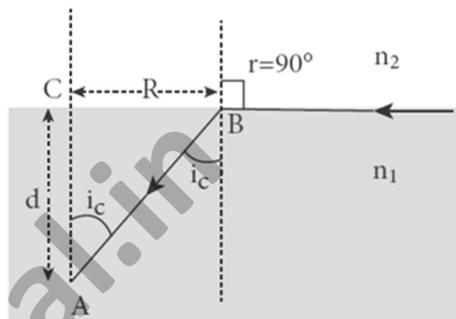
$$\frac{d^2}{R^2} = \frac{n_1^2 - n_2^2}{n_2^2} \text{ (or)} \quad \frac{R^2}{d^2} = \frac{n_2^2}{n_1^2 - n_2^2};$$

$$R^2 = d^2 \left[\frac{n_2^2}{n_1^2 - n_2^2} \right]$$

$$R = d \sqrt{\frac{n_2^2}{n_1^2 - n_2^2}}$$

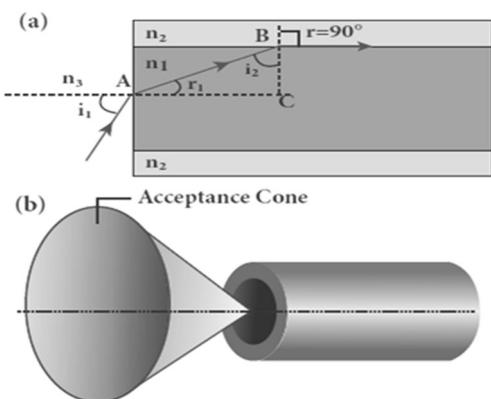
If the rarer medium outside air, then $n_2 = 1$ and let $n_1 = n$, then

$$R = d \left[\frac{1}{\sqrt{n^2 - 1}} \right]$$



- 48. Derive the equation for acceptance angle and numerical aperture of optical fibre.**

Acceptance angle:



To ensure the critical angle incidence in the core- cladding boundary inside the optical fibre, the light should be incident at a certain angle at the end of the optical fibre while entering in to it. This angle is called acceptance angle.

Applying Snell's law at point 'A',

$$\frac{\sin i_a}{\sin r_a} = \frac{n_1}{n_3} \dots\dots\dots(1)$$

To have total internal reflection inside

optical fibre, the angle of incidence at the core-cladding interface at B should be at-least Critical angle (i_c)

Applying Snell's law at point 'B' $\frac{\sin i_c}{\sin 90^\circ} = \frac{n_2}{n_1}$ (or) $\sin i_c = \frac{n_2}{n_1} \dots\dots\dots(2)$

From ΔABC , $i_c = 90^\circ - r_a$

Then equation (2) becomes, $\sin(90^\circ - r_a) = \frac{n_2}{n_1}$

$$(\text{or}) \cos r_a = \frac{n_2}{n_1} \therefore \sin r_a = \sqrt{1 - \cos^2 r_a} = \sqrt{1 - \left(\frac{n_2}{n_1}\right)^2}$$

$$\sin r_a = \sqrt{\frac{n_1^2 - n_2^2}{n_1^2}} = \frac{\sqrt{n_1^2 - n_2^2}}{n_1}$$

Put this in equation (1), $\frac{\sin i_a}{\left(\frac{\sqrt{n_1^2 - n_2^2}}{n_1}\right)} = \frac{n_1}{n_3}$

$$\frac{\sin i_a}{\sqrt{n_1^2 - n_2^2}} = \frac{1}{n_3}; \sin i_a = \frac{\sqrt{n_1^2 - n_2^2}}{n_3} = \sqrt{\frac{n_1^2 - n_2^2}{n_3^2}}$$

$$i_a = \sin^{-1} \left[\sqrt{\frac{n_1^2 - n_2^2}{n_3^2}} \right]$$

If the outer medium is air, then $n_3 = 1$. The acceptance angle

$$\text{becomes, } i_a = \sin^{-1} \left(\sqrt{n_1^2 - n_2^2} \right)$$

Light can have any angle of incidence from 0 to i_a with the normal at the end of the optical fibre forming a conical shape called acceptance cone.

The term $(n_3 \sin i_a)$ is called numerical aperture NA of the optical fibre.

$$NA = n_3 \sin i_a = \sqrt{n_1^2 - n_2^2}$$

- 49.** Derive 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 undeviated light at point C.**

In the right angle triangle

$$\Delta BCE, \sin(i - r) = \frac{L}{BC};$$

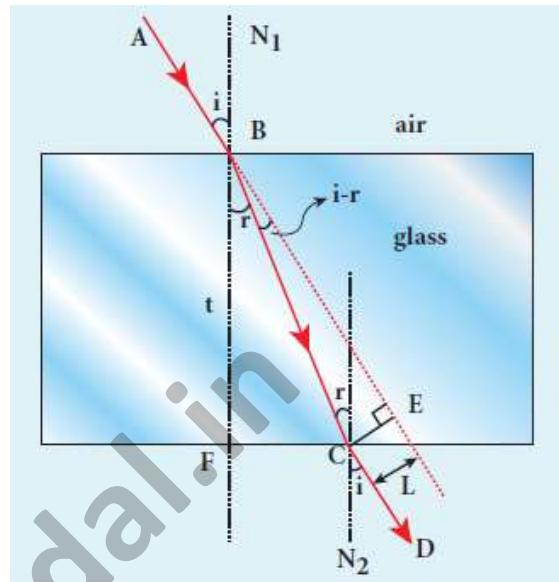
$$BC = \frac{L}{\sin(i - r)}$$

$$\text{In the right angle triangle } \Delta BCE, \cos r = \frac{t}{BC}; BC = \frac{t}{\cos r}$$

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

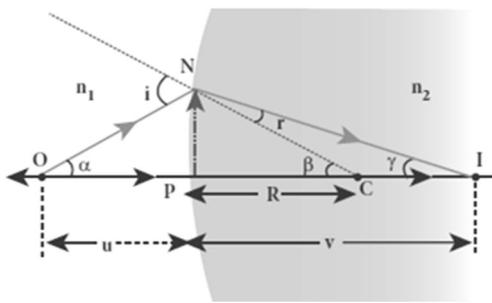
$$\text{After rearranging, } L = t \left[\frac{\sin(i - r)}{\cos r} \right]$$

The lateral displacement depends upon (i) the thickness of the slab, (ii) the angle of incidence and (iii) the refractive index of the slab which decides the angle of refraction. Thicker the slab, larger will be the lateral displacement. Greater the angle of incidence, larger will be the lateral displacement. Higher the refractive index, larger will be the lateral displacement.



50. Derive equation for refraction at single spherical surface.

Refraction at single spherical surface:



Refractive index of rarer medium = n_1

Refractive index of spherical medium = n_2

Centre of curvature of spherical surface = C

Point object in rarer medium = O

Point images formed in denser medium = I

Apply Snell's law of product form at the point N

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

Since the angles are small, we have $\sin i \approx i$ and $\sin r \approx r$

$$\therefore \mathbf{n}_1 \mathbf{i} = \mathbf{n}_2 \mathbf{r} \quad \dots \dots \dots \quad (1)$$

Let, $\angle NOP = \alpha$, $\angle NCP = \beta$, $\angle NIP = \gamma$, then

$$\tan \alpha = \frac{PN}{PO} \text{ (or)} \quad \alpha = \frac{PN}{PO}; \quad \tan \beta = \frac{PN}{PC} \text{ (or)} \quad \beta = \frac{PN}{PC}$$

$$\tan \gamma = \frac{PN}{PI} \text{ (or) } \gamma = \frac{PN}{PI}$$

From figure, $i = \alpha + \beta$ and $\beta = r + \gamma$ (or) $r = \beta - \gamma$

Put the values of i and r in equation (1)

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

$$n_1\alpha + n_1\beta = n_2\beta - n_2\gamma \text{ (or)}$$

$$n_1\alpha + n_2\gamma = n_2\beta - n_1\beta \text{ (or)}$$

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

Put α , β and γ , We have $n_1 \left[\frac{P_N}{P_O} \right] + n_2 \left[\frac{P_N}{P_I} \right] = (n_2 - n_1) \left[\frac{P_N}{P_C} \right]$ (or)

$$\frac{n_1}{PQ} + \frac{n_2}{PI} = \frac{n_2 - n_1}{PC}$$

Using Cartesian sign conversion, we get

$$PO \equiv -u; PI \equiv +v; PC \equiv +R$$

$$\therefore \frac{n_1}{-11} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}; \text{ (or)}$$

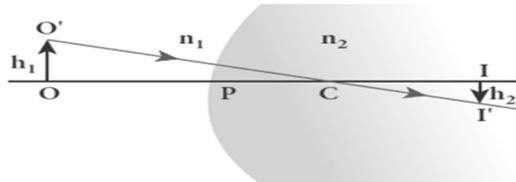
$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R} \dots\dots (2)$$

Here rarer medium is air and hence $n_1 = 1$ and let the reference index of second medium be $n_2 \equiv n$.

$$\text{Therefore } \frac{n}{v} - \frac{1}{u} = \frac{n-1}{p} \dots\dots (3)$$

51. Obtain an equation for lateral magnification due to single spherical surface.

Lateral magnification in single spherical surface:



Height of object: $OO' = h_1$;

Height of image: $II' = h_2$;

Refractive index of first medium = n_1

Refractive index of second medium = n_2

Centre of curvature of spherical surface = C

The ratio between image height to the object height is called lateral magnification (m), i.e $m = \frac{II'}{OO'}$ (1)

$\Delta COO'$ and $\Delta CII'$ are similar triangles. So. $\frac{II'}{OO'} = \frac{CI}{CO}$ (or)

$$\frac{II'}{OO'} = \frac{PI-PC}{PC+PO}$$

Using Cartesian sign conversion, we get $m = \frac{-h_2}{h_1} = \frac{v-R}{R+(-u)}$ (or)

$$m = \frac{h_2}{h_1} = - \left[\frac{v-R}{R-u} \right] = \frac{R-v}{R-u} \quad \dots \dots \dots (2)$$

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

$$\frac{n_2u - n_1v}{vu} = \frac{n_2 - n_1}{R} \quad (\text{or})$$

$$R = \frac{n_2vu - n_1vu}{n_2u - n_1v}$$

$$\text{Thus, } R - u = \frac{n_2u(v-u)}{n_2u - n_1v};$$

$$R - v = \frac{n_1v(v-u)}{n_2u - n_1v}$$

Put this equation (2), we get $m = \frac{h_2}{h_1} = \frac{\left[\frac{n_2u(v-u)}{n_2u - n_1v} \right]}{\left[\frac{n_1v(v-u)}{n_2u - n_1v} \right]}$

$$m = \frac{h_2}{h_1} = \frac{n_1v}{n_2u} \quad \dots \dots \dots (3)$$

52. 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

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

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

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

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

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

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

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

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

If the object is at infinity, the image is formed at the focus of the lens. Thus, $u = \infty, v = f$

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

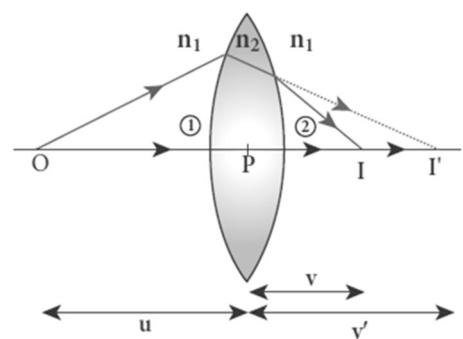
$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1 \right) \left[\frac{1}{R_1} - \frac{1}{R_2} \right] \dots\dots\dots (4)$$

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

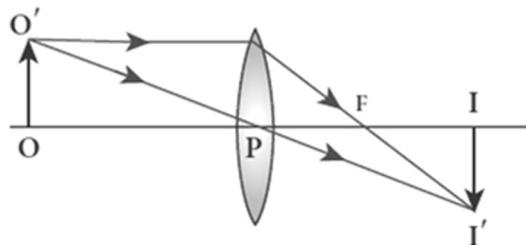
This equation is known as **lens equation**.



53. Derive the equation for thin lens and obtain its magnification.

Magnification of thin lens:

Let an object $O O'$ is placed on the principal axis with its height perpendicular to the principal axis. The ray $O'P$ passing through the pole of the lens goes un-deviated. But the ray parallel to principal axis, after refraction it passes through secondary focus 'F'. At the point of intersection of these two rays an inverted real image $I I'$ is formed.



Height of object: $OO' = h_1$: Height of image: $II' = h_2$

The lateral magnification (m) is defined as the ratio of the height of the image to that of the object.

$$\mathbf{m} = \frac{\mathbf{H'}}{90'} \quad \dots \dots \dots \quad (1)$$

$\Delta POO'$ and $\Delta PII'$ are similar triangles. So, $\frac{II'}{OO'} = \frac{PI}{PO}$

Using Cartesian sign conversion, we get $m = \frac{-h_2}{h_1} = \frac{v}{-u}$ (or)

$$m = \frac{h_2}{h_1} = \frac{v}{u} \dots \dots \dots (2)$$

The **magnification** is negative for real image and positive for virtual image. Thus for convex lens, the magnification is negative, and for concave lens, the magnification is positive.

Combining the lens equation and magnification equation, we get

$$m = \frac{h_2}{h_1} = \frac{f}{f+u} \text{ (or) } m = \frac{h_2}{h_1} = \frac{f-v}{f}$$

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

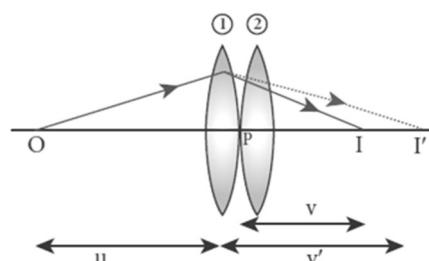
Focal length of lenses in contact:

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 I' . 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, $\frac{1}{v'} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v'} = \frac{1}{f_1} + \frac{1}{f_2}$

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

If this combination acts as a single lens of focal length “F”, then,

$$\frac{1}{V} - \frac{1}{U} = \frac{1}{F} \quad \dots \dots \dots \quad (4)$$

Compare equation (3) and (4) $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$ (5)

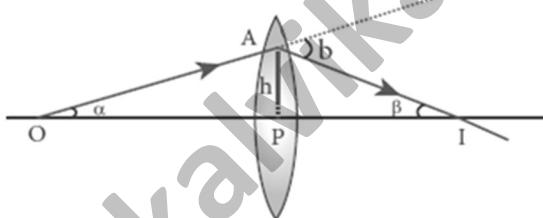
For any number of lenses, $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \frac{1}{f_4} + \dots$

Let $P_1, P_2, P_3, P_4 \dots$ be the power of each lens then the net power of the lens combination, $P = P_1 + P_2 + P_3 + P_4 + \dots$

Let $m_1, m_2, m_3, m_4 \dots$ be the magnification of each lens then the net magnification of the lens combination, $m = m_1 \times m_2 \times m_3 \times m_4 \times \dots$

55. Derive the equation for effective focal length for lenses in out of contact.

Focal length for lenses in out of contact:



OA - incident ray, AI - Refracted ray , Let, $\angle AOP = \alpha$ and $\angle AIP = \beta$.

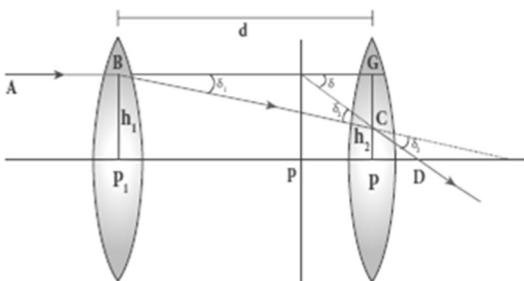
From ΔOAI , the angle of deviation, $\delta = \alpha + \beta$ (1)

In $\triangle OAP$ and $\triangle PAI$, the angles α and β are small.

$$\text{Hence, } \tan \alpha = \frac{PA}{PO} \text{ (or) } \alpha = \frac{PA}{PO}; \tan \beta = \frac{PA}{PI} \text{ (or) } \beta = \frac{PA}{PI}$$

$\delta = \frac{PA}{PO} + \frac{PA}{PI}$. Here PA = h, PO = -u, PI = v. Then

$$\delta = \frac{h}{-u} + \frac{h}{v} = h \left[\frac{1}{v} - \frac{1}{u} \right] = \frac{h}{f} \quad \dots \dots \dots (1)$$



Let f_1 and f_2 be the focal length and “d” be separation between two lenses, then the net deviation is, $\delta = \delta_1 + \delta_2$ [By equation (1)]

$$\frac{h_1}{f} = \frac{h_1}{f_1} + \frac{h_2}{f_2} \dots\dots\dots(2)$$

From figure, $h_2 - h_1 = P_2 G - P_2 C = CG$

$h_2 - h_1 = BG \tan \delta_1 \approx BG \delta_1 \approx d \delta_1$

$$h_2 - h_1 = d \frac{h_1}{f_1} \text{ (or) } h_2 = h_1 + d \frac{h_1}{f_1} \dots\dots\dots(3)$$

$$\text{Put equation (3) in (2)} \frac{h_1}{f} = \frac{h_1}{f_1} + \frac{h_2}{f_2} + \frac{h_1 d}{f_1 f_2} \text{ (or)}$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{d}{f_1 f_2} \dots\dots\dots(4)$$

- 56.** Derive the equation for angle of deviation produced by a prism and thus obtain the equation for refractive index of material of the prism.

Angle of deviation (d) :

Let 'ABC' be the section of triangular prism.

Here face 'BC' is grounded and it is called base of the prism.

The other two faces 'AB' and 'AC' are polished which are called refracting faces. The angle between two refraction faces is called angle of the prism 'A'

Here, 'PQ' be incident ray, 'QR' be refracted ray and 'RS' be emergent ray. The angle between incident ray and emergent ray is called angle of deviation (d). Let QN and RN be the normal drawn at the points Q and R

The incident and emergent ray meet at a point M

From figure, $\angle MQR = d_1 = i_1 - r_1$ and $\angle MRQ = d_2 = i_2 - r_2$

Then total angle of deviation, $d = d_1 + d_2$

$$d = (i_1 - r_1) + (i_2 - r_2); d = (i_1 + i_2) + (r_1 + r_2) \dots\dots\dots(1)$$

In the quadrilateral AQNR, $\angle Q = \angle R = 90^\circ$

$$\text{Hence } A + \angle QNR = 180^\circ \text{ (or) } A = 180^\circ - \angle QNR \dots\dots\dots(2)$$

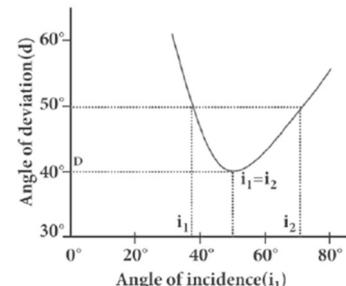
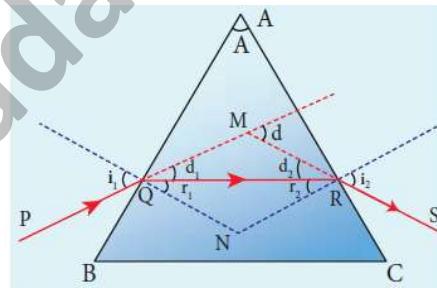
$$\text{In } \Delta QNR, r_1 + r_2 + \angle QNR = 180^\circ; r_1 + r_2 = 180^\circ - \angle QNR \dots\dots\dots(3)$$

$$\text{From equation (2) and (3) } A = r_1 + r_2 \dots\dots\dots(4)$$

$$\text{Put equation (4) in equation (1), } d = (i_1 + i_2) - A \dots\dots\dots(5)$$

Thus the angle of deviation depends on,

- (1) The angle of incidence (i_1)
- (2) The angle of the prism (A)
- (3) The material of the prism (n)
- (4) The wavelength of the light (λ)



Angle of minimum deviation (D):

A graph is plotted between the angle of incidence along x-axis and angle of deviation along y-axis. From the graph, as angle of incidence increases, the angle of deviation decreases, reaches a minimum value and then continues to increase.

The **minimum value of angled of deviation** is called angle of minimum deviation (D).

At minimum deviation, (1) $i_1 + i_2$ (2) $r_1 + r_2$

(3) Refracted ray 'QR' is parallel to the base 'BC' of the prism.

Refractive index of the material of the prism (n):

At angle of minimum deviation, $i_1 = i_2 = i$; $r_1 = r_2 = r$

i_1 and r_1 values substitute in equation (4) and (5)

$$A = r + r = 2r \text{ (or)} r = \frac{A}{2} \quad \dots \dots \dots \quad (6)$$

and $D = (i + i) - A = 2i - A$ (or) $2i = A + D$

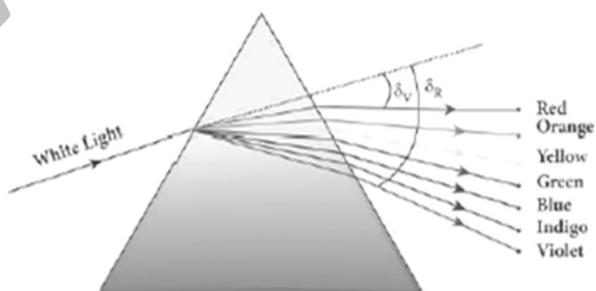
$$i = \frac{A+D}{2} \quad \dots (7); \text{ Then by Snell's law, } n = \frac{\sin i}{\sin r}; \quad n = \frac{\sin \left[\frac{A+D}{2} \right]}{\sin \left[\frac{A}{2} \right]} \quad \dots \dots \dots (8)$$

57. What is dispersion? Obtain the equation for dispersive power of a medium.

Dispersion:

Splitting of white light into its constituent colours is called dispersion.

The coloured band obtained due to dispersion is called spectrum.



Dispersive power:

Dispersive power (ω) is the ability of the material of the prism to cause dispersion.

It is defined as the ratio of the angular dispersion for the extreme colours to the deviation for any mean colour.

Let A be the angle of prism and D be the angle of minimum deviation.

then the refractive index of the material of the prism is $n = \frac{\sin\left[\frac{A+D}{2}\right]}{\sin\left[\frac{A}{2}\right]}$

[2]

If the angle of prism is small of the order of 10° , the prism is said to be a small angle prism. When rays of light pass through such prisms,

The angle of deviation also becomes small. If A be the angle of a small angle prism and δ_m be the angle of minimum deviation then the refractive index n is given by

$$\text{index } n = \frac{\sin\left[\frac{A+\delta}{2}\right]}{\sin\left[\frac{A}{2}\right]} \quad \dots \dots \dots \quad (1)$$

Since A and δ are small, we may write, $\sin \left[\frac{A+\delta}{2} \right] \approx \left[\frac{A+\delta}{2} \right]$

$$\sin \left[\frac{A}{2} \right] \approx \left[\frac{A}{2} \right] ;$$

$$\text{Put this in equation (1)} n = \frac{\sin \left[\frac{A+\delta}{2} \right]}{\sin \left[\frac{A}{2} \right]} = \frac{A+\delta}{A}$$

$$nA = A + \delta \text{ (or) } \delta = nA - A$$

$$\therefore \delta = (n - 1)A \dots\dots\dots (2)$$

Thus, angle of deviation for Violet and Red light,

$$\delta_V = (n_V - 1)A \dots\dots\dots (3)$$

$$\delta_R = (n_R - 1)A \dots\dots\dots (4)$$

The angular dispersion is given by, $\delta_V - \delta_R = (n_V - 1)A - (n_R - 1)A$

$$\delta_V - \delta_R = n_V A - A - n_R A + A$$

$$\delta_V - \delta_R = (n_V - n_R) A \dots\dots\dots (5)$$

Let δ be the angle of deviation for mean ray (Yellow) and n be the corresponding refractive index, then $\delta = (n - 1)A \dots\dots\dots (6)$

By definition, dispersive power

$$\omega = \frac{\text{Angular Dispersion}}{\text{Mean Deviation}} ; \frac{\delta_V - \delta_R}{\delta} ;$$

$$\omega = \frac{(n_V - n_R) A}{(n - 1)A}$$

$$\omega = \frac{(n_V - n_R)}{(n - 1)} \dots\dots\dots (7)$$

Dispersive power is a dimensionless quantity. It has no unit. It is always positive.

UNIT - VII (WAVE OPTICS)

TWO MARKS AND THREE MARKS QUESTIONS AND ANSWERS

1. What are the salient features of corpuscular theory of light?

Corpuscular theory:

Sir Isaac Newton proposed **corpuscular theory** of light.

According to this theory, light is emitted as tiny, mass less and perfectly elastic particles called corpuscles.

As the corpuscles are **very small**, the source of light does not suffer appreciable loss of mass even if it emits light for a long time. They travel with high speed and they are unaffected by the force of gravity. So their path is a straight line.

The **energy of light is the kinetic energy of these corpuscles**. When they impinge on the retina of the eye, the vision is produced. The different size of the corpuscles is the reason for different colours of light.

The reflection of light is due to repulsion of the corpuscles by the medium and refraction of light is due to the attraction of the corpuscles by the medium.

This **theory could not explain why speed of light is lesser in denser medium than rarer medium and also interference, diffraction and polarization**.

2. Write a note on wave theory of light.

Wave theory of light:

Christian Huygens proposed the **wave theory of light**.

According to wave theory, light is a disturbance from a source that travels as longitudinal mechanical wave through the ether medium that was presumed to pervade in all space.

This theory could **successfully explain reflection, refraction, interference, and diffraction. But polarization could not explain** by this theory as it is the property of **only transverse waves**. Later the existence of ether in all space was proved to be wrong.

3. Write a note on electromagnetic wave theory.

Electromagnetic wave theory of light:

Maxwell proposed **electromagnetic theory of light**. According to electromagnetic wave theory, light is an electromagnetic wave which is transverse in nature carrying electromagnetic energy.

No medium is necessary for the propagation of electromagnetic waves. All the phenomenon of light could be successfully explained by electromagnetic theory.

But the interaction of light with matter like **photoelectric effect, Compton Effect could not be explained by this theory.**

4. Write a short note on quantum theory of light.

Quantum theory of light:

By extending Max Plank quantum ideas, **Albert Einstein** proposed **quantum theory of light**. According to **quantum theory, light is not continuous but it propagated in the form of discrete packets of energy called photon.**

Each photon has energy 'E' of $E = h \nu$ Here h → Plank's constant ($h = 6.625 \times 10^{-34} \text{ Js}$)

5. What is Dual nature of light?

A light has both waves as well as particle nature and hence it is said to have dual nature.

- (1) Light propagated as a wave
- (2) Light interacts with matter as a particle

6. Write a note on wave nature of light.

Wave nature of light:

1. Light is transverse electromagnetic wave.
2. The wave nature of light was confirmed by the experiments on interference and diffraction.
3. Like electromagnetic wave, light can travel through vacuum.
4. The transverse nature of light was proved by polarization.

7. Define wave front.

A wave front is the locus of points which are in the same state or phase of vibration.

- (1) A point source located at a finite distance gives spherical wave front.
- (2) A line source gives cylindrical wave front.
- (3) A point source located at infinite distance gives plane wave front.

8. 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.

9. Define interference.

The phenomenon of superposition of two light waves which produces **increase in intensity at some points and decrease in intensity** at some other points is called interference of light.

10. Give the relation between phase difference and path difference.

Phase is the angular position of a vibration.

In the path of the wave, one wavelength λ corresponds to a phase of 2π

Hence the path difference δ corresponds to a phase difference ϕ is

$$\delta = \frac{\lambda}{2\pi} \phi$$

11. What are called coherent sources?

Two light sources are said to be **coherent**, if they produce waves which have same phase or constant phase difference, same frequency or wavelength, same waveform and preferably same amplitude.

12. Can two independent monochromatic sources acts as coherent sources?

Two independent monochromatic sources never be coherent, because they may emit waves of same frequency and same amplitude, but not with same phase. Due to thermal vibrations, the atoms while emitting light undergoes this change in phase.

13. Give the methods to obtain coherent light waves.

Coherent waves are obtained by following three techniques.

- (1) Intensity or amplitude division
- (2) Wave front division
- (3) Source and images

14. Write a note on intensity or amplitude division.

Intensity or amplitude division:

If light is incident on a partially silvered mirror, both reflection and refraction takes place simultaneously. As the two light beams are obtained from the same light source, the two divided light beams will be coherent beams. They will be either in-phase or at constant phase difference.

(e.g.) Michelson's interferometer

15. Write a note on wave front division.

Wave front division:

1. It is the common method used for producing two coherent sources.
2. We know all the points on the wave front are at the same phase.
3. If two points are chosen on the wave front by using a double slit, the two points will act as coherent sources. (e.g.) **Young's double slit method**

16. Write a note on Source and images method.

Source and images:

In this method, a source and its image will act as a set of coherent source, because the source and its image will have wave's in-phase or constant phase difference.

(e.g.) Fresnel' bi-prism - two virtual sources as coherent sources

Lloyd's mirror - the source and its virtual image as coherent sources

17. 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.

18. What is bandwidth of interference pattern?

The band width (β) is defined as the **distance between any two consecutive bright or dark fringes**.

19. 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

20. Brilliant colours are exhibited by the surface of oil films and soap bubbles.

Why?

The colours exhibited by the surface of oil films and soap bubbles are **due to interference of white light undergoing multiple reflections** from the top and bottom surfaces of thin films.

The colour depends upon,

- (1) Thickness of the film
- (2) Refractive index of the film
- (3) Angle of incidence of the light

21. What is diffraction?

Diffraction is bending of waves around sharp edges into the geometrically shadowed region. We observe diffraction only when the size of the obstacle is comparable to the wavelength.

22. Distinguish between Fresnel and Fraunhofer diffraction.

Fresnel diffraction	Fraunhofer diffraction
Spherical or cylindrical wave front undergoes diffraction	Plane wave front undergoes diffraction
Light wave is from a source at finite distance	Light wave is from a source at infinity
For laboratory conditions, convex lenses need not be used	In laboratory conditions, convex lenses are to be used
difficult to observe and analyze	Easy to observe and analyze

23. What is diffraction grating?

Grating is a plane sheet of transparent material on which opaque rulings are made with a **fine diamond pointer**. Thus grating has multiple slits with equal widths of size comparable to the wavelength of light. **The modern commercial grating contains about 6000 lines per centimeter.**

24. Define grating element and corresponding points.

The combined width of a ruling (b) and a slit (a) is called grating element ($e = a + b$). Points on successive slits separated by a distance equal to the grating element are called corresponding points.

25. 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

26. What is Fresnel's distance? Obtain an expression for it.

Fresnel's distance:

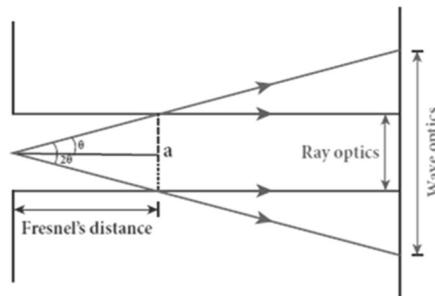
Fresnel's distance is the distance upto which ray optics is obeyed and beyond which ray optics is not obeyed but, wave optics becomes significant.

Let Fresnel distance = Z. From the diffraction equation for first minimum,

$$\sin \theta = \frac{\lambda}{a} \quad (\text{or}) \quad \theta = \frac{\lambda}{a}$$

From the definition of Fresnel's distance, $\sin 2\theta = \frac{a}{z}$ (or) $2\theta = \frac{a}{z}$

$$\text{Equating the above two equations, } 2 \frac{\lambda}{a} = \frac{a}{z}; z = \frac{a^2}{2\lambda}$$



27. Give the reason for colourful appearance of the Compact Disc.

On the read or writable side which is polished, there are many narrow circular tracks with widths comparable to the wavelength of visible light. Hence, the diffraction takes place after reflection for incident white light to give colourful appearance. The **tracks act as reflecting grating**.

28. What are resolution and resolving power?

Two point sources must be imaged in such a way that their images are sufficiently far apart that their **diffraction patterns do not overlap**. This is called resolution.

The **inverse of resolution** is called resolving power. The ability of an optical instrument to separate or distinguish small or closely adjacent objects through the image formation is said to be resolving power of the instrument.

29. What is Rayleigh's criterion?

According to Rayleigh's criterion, for two point objects to be just resolved, the minimum distance between their diffraction images must be in such a way that the central maximum of one coincides with the first minimum of the other and vice versa.

30. Define polarization.

The phenomenon of **restricting the vibrations of light to a particular direction perpendicular to the direction of wave propagation motion** is called polarization.

31. Distinguish between polarized and un-plane polarized light.

Polarized light	Un-polarized light
Consists of waves having their electric field vibrations in a single plane normal to the direction of ray.	Consists of waves having their electric field vibrations equally distributed in all directions normal to the direction of ray.
Asymmetrical about the ray direction	Symmetrical about the ray direction
It is obtained from un-polarized light with the help of polarizer's	Produced by conventional light sources.

32. Define plane of vibration and plane of polarization.

Plane of vibration:

The plane containing the vibrations of the electric field vector is known as plane of vibration.

Plane of polarization:

The plane perpendicular to the plane of vibration and containing the ray of light is known as the plane of polarization.

33. How an un-polarized light can be polarized?

The un-polarized light can be polarized by following techniques.

- (1) Polarization by selective absorption
- (2) Polarization by reflection
- (3) Polarization by double refraction
- (4) Polarization by scattering

34. Discuss polarization by selective absorption.

Polarization by selective absorption (Polaroid's) :

Selective absorption is the property of a material which transmits waves whose electric field vibrate in a plane parallel to a certain direction of orientation and absorbs all other waves.

The Polaroid's or polarizer using this property of selective absorption to produce intense plane polarized light.

Selective absorption is also called as **dichroism**. Edwin Land developed polarizer's in the form of thin sheets. **Tourmaline is a natural polarizing material. But Polaroid's are also made artificially.**

A number of needle shaped crystals of **quinine iodosulphate** with their axes parallel to one another packed in between two transparent plastic sheets serve as a good Polaroid. Recently new types of Polaroid's are prepared in which thin film of **polyvinyl alcohol** (Colour less crystals) is used.

35. What is polarizer and analyzer?

Polarizer:

The Polaroid which plane polarizes the **un-polarized light passing through it** is called a polarizer.

Analyzer:

The Polaroid which is used **to examine whether a beam of light is polarized or not** is called analyzer.

36. Discuss how a plane polarized and partially polarized light will be analyzed using analyzer?

Plane polarized light:

If the intensity of light varies from maximum to zero for every rotation of 90° of the analyzer, the light is said to be plane polarized.

Partially polarized light:

If the intensity of light varies from maximum to minimum for every rotation of 90° of the analyzer, the light is said to be partially polarized.

37. State and prove 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**. $I = I_0 \cos^2 \theta$

Proof:

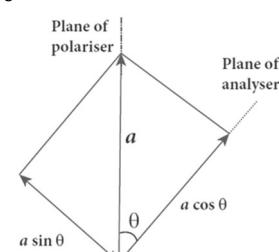
Let the angle between plane of polarizer and analyzer = θ

Intensity of electric vector transmitted by the polarizer = I_0

Amplitude of this electric vector = a

The amplitude of the incident light was resolved in to two components,

- (1) $a \cos \theta$ - parallel component to the axis of transmission of the analyzer
- (2) $a \sin \theta$ - perpendicular component to the axis of transmission of the analyzer



Here only the parallel component ($a \cos \theta$) will be transmitted by the analyzer. Hence ht intensity of the transmitted light is,

$$\begin{aligned} I &\propto (a \cos \theta)^2 ; I = (a \cos \theta)^2 \\ &= k a^2 \cos^2 \theta ; I = I_0 \cos^2 \theta \end{aligned}$$

- (1) When $\theta = 0^\circ$, $I = I_0$ (2) When $\theta = 90^\circ$, $I = 0$

38. 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 laser beam acts as **needle to read/write** in compact discs (CDs)

Polarized lights to be used in liquid crystal display (LCD)

39. Defined angle of polarization.

The angle of incidence at which the reflected beam is plane polarized is called polarizing angle or Brewster's angle (i_p)

The polarizing angle for glass is ; $i_p = 57.50^\circ$

40. Explain polarization by reflection.

Polarization by reflection:

It is the simplest method to produce plane polarized light.

It is discovered by Malus.

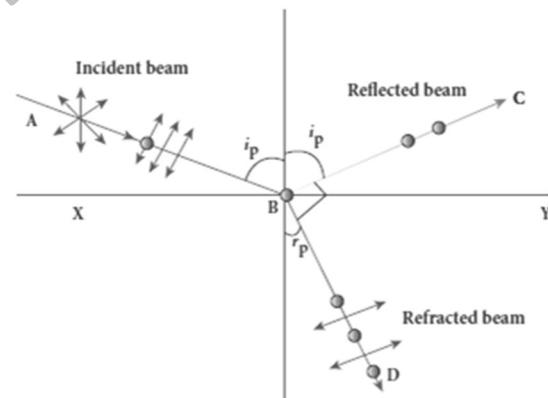
Here, XY - reflecting surface

AB - incident un-polarized light beam

BC - reflecting light beam

BD - refracted light beam

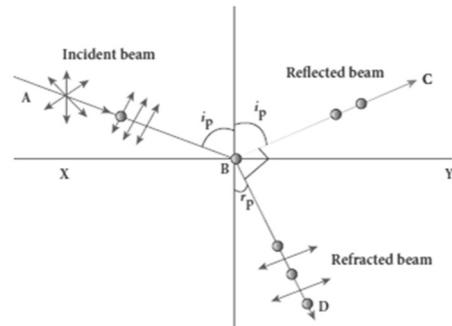
On examining the reflected beam 'BC' with an analyzer, it is found that the ray is partially plane polarized. When the light is allowed to be incident on particular angle, the reflected beam is found to be plane polarized. That angle of incidence is called polarizing angle (i_p)



41. 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 = i_p



$$\text{Angle of refraction} = r$$

From the figure,

$$i_p + 90^\circ + r_p = 180^\circ; \quad r_p = 90^\circ - i_p \dots\dots(1)$$

$$\text{From Snell's law } \frac{\sin i_p}{\sin r_p} = n; \frac{\sin i_p}{\sin(90^\circ - i_p)} = n$$

$$\frac{\sin i_p}{\cos i_p} = n; \tan i_p = n$$

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.**

42. 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.

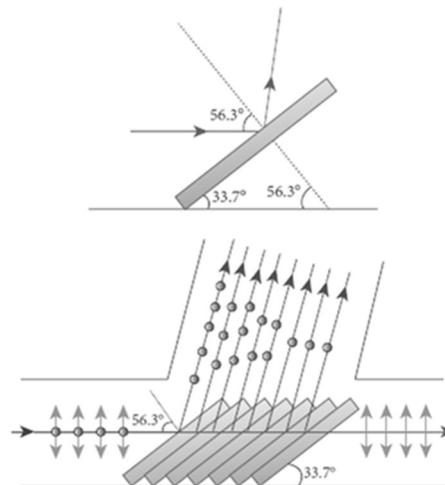
These plates are inclined at an **angle 33.7° to the axis of the tube.**

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°** 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 larger the number of surfaces, the greater the intensity of the reflected plane polarized light.

The pile of plates is used as a **polarizer and also as an analyzer**.



43. Define double refraction.

When a ray of un-polarized light is incident on a calcite crystal, two refracted rays are produced. Hence two images of a single object are formed. This phenomenon is called double refraction.

The **obtained images** are called as,

- (1) Ordinary image
- (2) Extra ordinary image

Double refraction is also called bi-refringence.

44. Distinguish between ordinary ray and extra ordinary ray.

Ordinary Ray	Extraordinary Ray
They obey the laws of refraction	They do not obey the laws of refraction
Inside the crystal, they travel with same velocity in all directions	Inside the crystal, they travel with different velocities along different directions
A point source inside the crystal produces spherical wave front for ordinary ray	A point source inside the crystal produces elliptical wave front for extra ordinary ray

45. Define Optic axis.

Inside the double refracting crystal, there is a particular direction in which both the ordinary and extraordinary rays travel with same velocity. This direction is called optic axis. Along optic axis, the refractive index is same for both rays.

46. Define uni-axial crystal and biaxial crystal.

Crystals like **calcite, quartz, tourmaline** and ice having **only one optic axis** are called **uniaxial crystals**. Crystals like **mica, topaz, selenite and aragonite having two optic axes** are called **biaxial crystals**.

47 Discuss about Nicol prism.

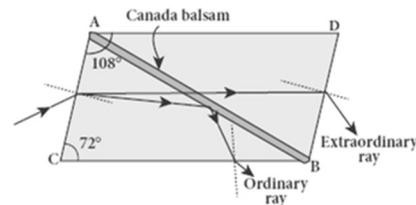
Uses:

It produces plane polarized light and functions as a polarizer.

It can also use as an **analyzer**.

Nicol prism:

Nicol prism is made by **calcite crystal** which is double refracting crystal. ABCD is the principal section of a calcite crystal with its length is three times of its breadth. The face angles are **72°** and **108°**. It is cut in to two



halves along the diagonal AB and joined together by a layer of canada balsam, a transparent cement.

Let an un-polarized light from monochromatic source is incident on the face AC of the Nicol prism. Here double refraction takes place, and the ray 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.**

48. What are the uses and drawbacks of Nicol prism?

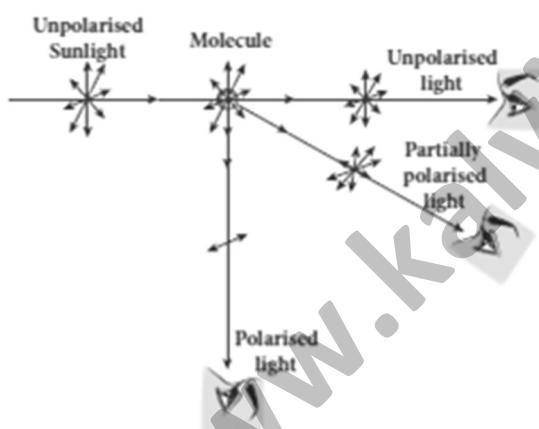
Drawbacks:

Its cost is very high due to scarcity of large and flawless calcite crystal.

Due to extraordinary ray passing obliquely through it, the emergent ray is always displaced a little to one side. The effective field of view is quite limited. Light emerging out of it is not uniformly plane polarized.

49. Explain polarization by scattering.

Polarization by scattering:



The light from a clear blue portion of the sky shows a rise and fall of intensity when viewed through a Polaroid which is rotated. This is because of sunlight, which has changed its direction on encountering the molecules of the earth's atmosphere. The electric fields of light interact with the electrons present in the air molecules.

Under the influence of the electric field of the incident wave the electrons in the molecules acquire components of motion in both these directions. We have shown an observer looking at 90° to the direction of the sun. Clearly, charges accelerating parallel do not radiate energy towards this observer since their acceleration has no transverse component. The radiation scattered by the molecule is therefore polarized perpendicular to the plane of the paper. This explains the reason for polarization of sunlight by scattering.

50. Discuss about simple microscope and obtain the equations for magnification for near point focusing.

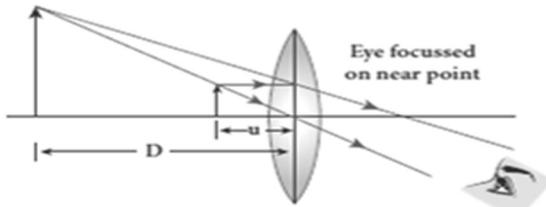
Simple microscope - Near point focusing:

A simple microscope is a single magnifying lens of small focal length. In near point focusing, object distance ‘u’ is less than ‘f’. The image is formed at near point or least distance ‘D’ of distinct vision.

The magnification 'm' is given by, $m = \frac{v}{u}$

Using lens equation, $m = 1 - \frac{v}{f}$; substitute, $v = -D$

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



- 51.** Discuss about simple microscope and obtain the equations for magnification for near point focusing and normal focusing.

Simple microscope - Normal focusing:

Here the image is formed at infinity. So we will not get direct practical relation for magnification. Hence we can practically use the angular magnification.

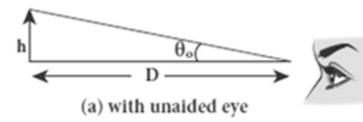
The angular magnification is defined as the ratio of angle (θ_i) subtended by the image with aided eye to the angle (θ_o) subtended by the object with unaided eye. That is,

$$m = \frac{\theta_o}{\theta_i} \dots \quad (1)$$

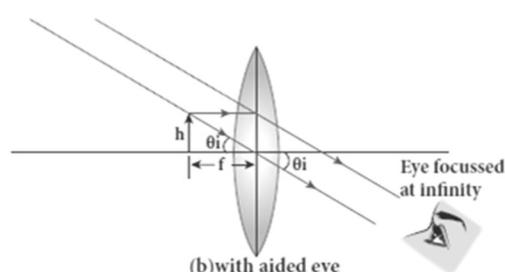
For unaided eye, $\tan\theta_0 \approx \theta_0 = \frac{h}{D}$

For aided eye, $\tan\theta_i \approx \theta_i = \frac{h}{f}$

Thus equation (1) becomes, $m = \frac{\theta_0}{\theta_i} = \frac{\left(\frac{h}{D}\right)}{\left(\frac{h}{f}\right)}$; $m = \frac{D}{f}$



(a) with unaided eye



(b)with aided eye

52. Distinguish between near point focusing and normal focusing.

Near Point Focusing	Normal Focusing
The image is formed at near point	The image is formed at infinity
In this position, the eye feel little strain	In this position, the eye is most relaxed to view the image
Magnification is high $m = 1 + \frac{D}{f}$	Magnification is low $m = \frac{D}{f}$

53. Why is oil immersed objective preferred in a microscope?

The ability of microscope depends not only in magnifying the object but also in resolving two points on the object separated by a small distance

$$\left(d_{\min} = \frac{1.22\lambda}{2 \sin\beta} \right)$$

That is, smaller the value of ' d_{\min} ' better will be the resolving power of the microscope.

To further reduce the value of, the optical path of the light is increased by immersing the objective of the microscope in to a bath containing oil of refractive index 'n'. (i.e) $\left(d_{\min} = \frac{1.22\lambda}{2n \sin\beta} \right)$

Such an objective is called oil immersed objective. The term ' $n \sin \beta$ ' is called numerical aperture (NA)

54. What are the merits and demerits of reflecting telescope?

Merits:

Only one surface is to be polished and maintained. Support can be given from the entire back of the mirror rather than only at the rim for lens. Mirror weigh much less compared to lens.

Demerits:

The objective mirror would focus the light inside the telescope tube. One must have an eye piece inside obstruction some light.

55. What is the use of an erecting lens in a terrestrial telescope?

A terrestrial telescope is used to see object at long distance on the surface of earth. Hence image should be erect. So an additional erecting lens is used to make the final image enlarged and erect.

56. What is the use of spectrometer?

The collimator is an arrangement to produce a parallel beam of light.

57. What are the uses of spectrometer?

Spectrometer is an optical instrument used to,

- (1) **Study the spectra** of different sources of light
- (2) **Measure the refractive index** of materials

58. What is myopia? What is its remedy?

A person suffering from **myopia or nearsightedness cannot see distant objects clearly**. It occurs when the eye lens has too short focal length due to thickening of the lens or larger diameter of the eyeball than usual. Using **concave lens this defect can be rectified**.

59. What is hypermetropia? What is its remedy?

A person suffering from **hypermetropia or farsightedness cannot see objects close to the eye**. It occurs when the eye lens has too long focal length due to thinning of eye lens or shortening of the eyeball than normal. Using **convex lens this defect can be rectified**.

60. What is presbyopia?

The least distance for clear vision for aged people is appreciably more than **25 cm** and the person has to keep the object inconveniently away from the eye. Thus rearing or viewing smaller things held in the hands is difficult for them. This kind of **farsightedness arising due to aging** is called presbyopia.

61. What is astigmatism?

Astigmatism is the **defect arising due to different curvatures** along different planes in the eye lens. **Astigmatic person cannot see all the directions equally well**. Lenses with different curvatures in different planes called cylindrical lens is used to rectify astigmatism defect.

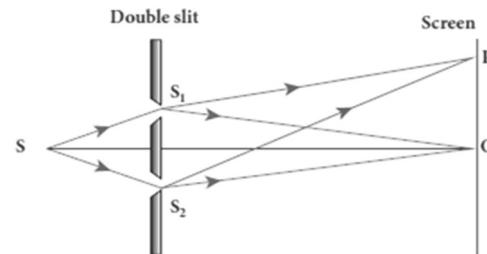
62. What are called Air's discs?

When a circular aperture like a lens or the iris of eye forms an image of a point object, the image formed will not be a point, but a diffraction pattern of concentric circles that becomes fainter while moving away from the centre. These are known as Air's discs.

63. Explain Young's double slit method.

Young' s double slit experiment:

Thomas Young used an opaque screen with two small openings called double slit S_1 and S_2 kept equidistance from a source 'S'. **The width of each slit is about 0.03 mm and they are separated by a distance of about 0.3 mm.**



As S_1 and S_2 are equidistant from 'S', the light waves from 'S' reach S_1 and S_2 in phase.

So S_1 and S_2 act as coherent sources which are the requirement of obtaining interference pattern. The wave fronts from S_1 and S_2 get superposed on the other side of the double slit.

When screen is placed at a distance of about 1 m from double slit, equally spaced alternate bright and dark fringes are appearing on the screen. These are called interference fringes. At the point 'O' on the screen, the waves from S_1 and S_2 travels equal distances and arrive in-phase. Due to constructive interference, bright fringe is formed at point 'O'. This is called central bright fringe.

When one of the slit is covered, then the fringes disappear and there is uniform illumination observed on the screen. This clearly shows that the fringes are due to interference

FIVE MARKS QUESTIONS AND ANSWERS

64. Prove laws of reflection using Huygens principle.

Laws of reflection - Proof:

XY – Reflecting surface,
AB –Incident plane wave front.

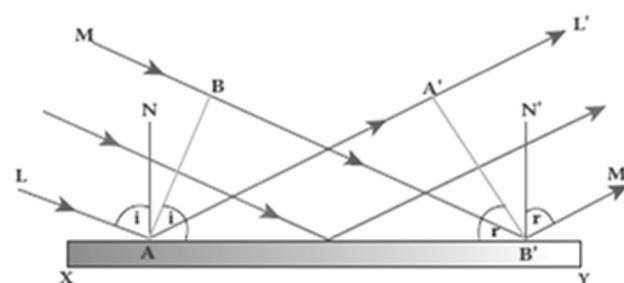
The incident rays from L and M are perpendicular to this incident wave front. Initially the point 'A' reaches reflecting surface.

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, $\angle i = \angle NAL = 90^\circ - \angle NAB = \angle BAB'$

Angle of reflection, $\angle r = \angle N'B'M' = 90^\circ - N'B'A' = \angle A'B'A$

In $\Delta ABB'$ and $\Delta B'A'A$, $\angle B = \angle A' = 90^\circ$; $AA' = BB'$ 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.

65. Prove laws of refraction using Huygens' Principle.

Laws of refraction - Proof:

Let XY be the refracting surface. The incident wave front AB is in rarer medium (1)

The incident rays from L and M are perpendicular to this incident wave front.

Initially the point 'A' reaches refracting surface.

Then the successive points between AB reaches the surface.

Finally, by the time B reaches B', the point A would have reached A' in the other medium.

This is applicable to all the points on the wave front AB. Thus the refracted wave front A'B' emanates as a plane wave front.

The line from L' and M' perpendiculars to A'B' represent refracted rays.

Let v_1 be the speed of light in medium (1) and v_2 be the speed of light in medium (2). Here $v_1 > v_2$. The time taken for the ray to travel from B to B' is same as the time taken for the ray to travel from A reaches A'. So

$$AA' = v_2 t \text{ and } BB' = v_1 t$$

$$\therefore \frac{BB'}{AA'} = \frac{v_1}{v_2} \quad \dots \quad (1)$$

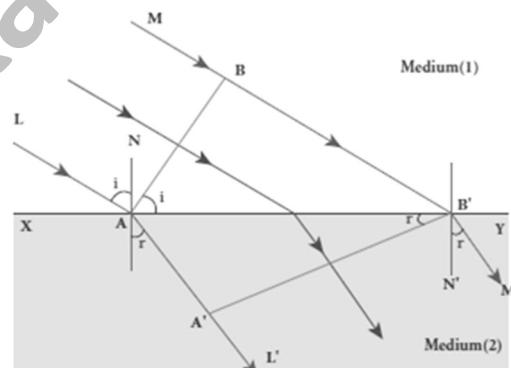
Law (1):

The incident rays, refracted rays and the normal are in the same plane.

Law (2):

Angle of incidence,

$$\angle i = \angle NAL = 90^\circ - \angle NAB = \angle BAB'$$



Angle of refraction,

$$\angle r = \angle N'B'M' = 90^\circ - \angle N'B'A' = \angle A'B'A$$

$$\text{From } \Delta ABB' \text{ and } \Delta B'A'A; \frac{\sin i}{\sin r} = \frac{\left(\frac{BB'}{AB}\right)}{\left(\frac{AA'}{AB}\right)} = \frac{BB'}{AA'} = \frac{v_1}{v_2} = \frac{\left(\frac{c}{n_1}\right)}{\left(\frac{c}{n_2}\right)} = \frac{n_2}{n_1}$$

$$\text{In product form, } n_1 \sin i = n_2 \sin r$$

66. 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,

$$y_1 = a_1 \sin \omega t \quad \dots \dots \quad (1)$$

$$y_2 = a_2 \sin (\omega t + \phi) \quad \dots \dots \quad (2)$$

Where, $\phi \rightarrow$ phase difference between them

Then the resultant displacement,

$$y = y_1 + y_2$$

$$y = a_1 \sin \omega t + a_2 \sin (\omega t + \phi)$$

$$\text{By solving this, we get, } y = A \sin(\omega t + \theta) \quad \dots \dots \quad (3)$$

$$\text{Where, } A = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos \phi} \text{ and } \theta = \tan^{-1} \left[\frac{a_2 \sin \phi}{a_1 + a_2 \cos \phi} \right]$$

(1) When, $\phi = 0, \pm 2\pi, \pm 4\pi, \dots \dots$ the resultant intensity becomes maximum.

$$A_{\max} = \sqrt{(a_1 + a_2)^2}$$

(2) When, $\phi = \pm \pi, \pm 3\pi, \pm 5\pi \dots \dots$ the resultant intensity becomes minimum.

$$A_{\min} = \sqrt{(a_1 - a_2)^2}$$

The intensity of light is directly proportional to the square of the amplitude. $I \propto A^2 ; I \propto a_1^2 + a_2^2 + 2a_1 a_2 \cos \phi$

$$I \propto I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi \quad \dots \dots \quad (4)$$

1) When, $\phi = 0, \pm 2\pi, \pm 4\pi, \dots \dots$ the resultant intensity becomes maximum.

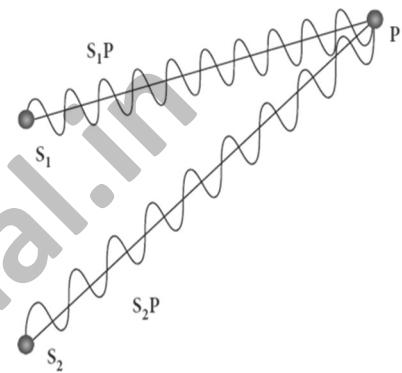
This is called constructive interference. $I_{\max} \propto (a_1 + a_2)^2$

$$I_{\max} \propto I_1 + I_2 + 2\sqrt{I_1 I_2} \quad \dots \dots \quad (5)$$

(2) When, $\phi = \pm \pi, \pm 3\pi, \pm 5\pi \dots \dots$ the resultant intensity becomes minimum.

This is called destructive interference. $I_{\min} \propto (a_1 - a_2)^2$

$$I_{\min} \propto I_1 + I_2 - 2\sqrt{I_1 I_2} \quad \dots \dots \quad (6)$$



Special case:

If $a_1 = a_2 = a$, then resultant amplitude,

$$A = \sqrt{a^2 + a^2 + 2a^2 \cos\phi} ; A = \sqrt{2a^2 + 2a^2 \cos\phi}$$

$$A = \sqrt{2a^2(1 + \cos\phi)} ; A = \sqrt{2a^2 \left[2 \cos^2 \left(\frac{\phi}{2} \right) \right]}$$

$$A = 2a \cos \left(\frac{\phi}{2} \right) \quad \dots \dots \dots \quad (7)$$

If $I_1 = I_2 = I_0$, then the resultant intensity, $I \propto A^2$;

$$I \propto 4a^2 \cos^2 \left(\frac{\phi}{2} \right) ; \quad I = 4 I_0 \cos^2 \left(\frac{\phi}{2} \right) \dots \dots \dots \quad (8)$$

When, $\phi = 0, \pm 2\pi, \pm 4\pi, \dots \dots I_{\max} = 4 I_0$ and

$$\phi = \pm \pi, \pm 3\pi, \pm 5\pi, \dots \dots \dots I_{\min} = 0$$

Thus the phase difference between the two waves decides the intensity of light at the point, where the two waves meet.

- 67. Obtain the equation for Path difference and band width 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 $\delta = S_2 P - S_1 P = s_2 P - M P = S_2 M$

From the figure,

$$\angle OCP = \angle S_2 S_1 M = \theta$$

$$\text{In } \triangle S_2 S_1 M, \sin \theta = \frac{s_2 M}{S_1 S_2} = \frac{\delta}{d} ;$$

$$\therefore \delta = \sin \theta \cdot d$$

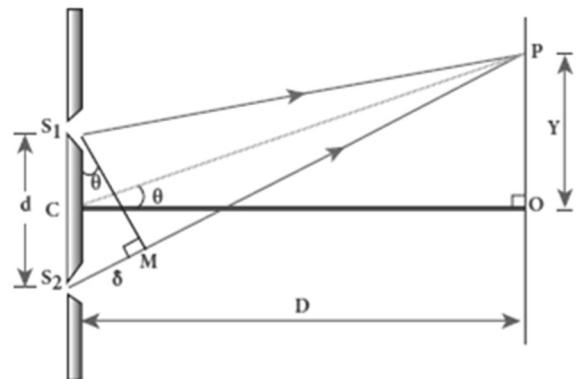
Here θ is small. Hence, $\sin \theta \approx \tan \theta \approx \theta$

$$\delta = \theta \cdot d \dots \dots \dots \quad (1)$$

$$\text{Also, in } \triangle OCP, \theta \approx \tan \theta = \frac{OP}{OC} = \frac{y}{D}$$

$$\text{Put this in equation (1)} \quad \delta = \frac{y}{D} d \quad \dots \dots \dots \quad (2)$$

Point 'P' may appear either bright or dark depending on the path difference.



Condition for bright fringe (maxima):

For constructive interference, the path difference will be,

$$\delta = n\lambda \quad [n = 0, 1, 2, \dots]$$

$$\frac{y}{D} d = n\lambda$$

Thus the distance of the n^{th} bright fringe from "O" is

$$y_n = \frac{D}{d} n\lambda \quad \dots \quad (3)$$

Condition for dark fringe (minima):

For destructive interference, the path difference will be,

$$\delta = (2n - 1) \frac{\lambda}{2} \quad [n = 1, 2, \dots]$$

$$\frac{y}{D} d = (2n - 1) \frac{\lambda}{2}$$

Thus the distance of the n^{th} dark fringe from "O" is $y_n = \frac{D}{d} (2n - 1) \frac{\lambda}{2}$ ---- (4)

Band width (β):

The band width is defined as **the distance between any two consecutive bright or dark fringes**. The distance between $(n+1)^{\text{th}}$ and n^{th} consecutive bright fringes from 'O' is $\beta = y_{n+1} - y_n$

$$\beta = \frac{D}{d} (n + 1)\lambda - \frac{D}{d} n\lambda ; \beta = \frac{D}{d} \lambda \quad \dots \quad (5)$$

Similarly the distance between $(n+1)^{\text{th}}$ and n^{th} consecutive dark fringes from 'O' is $\beta = y_{n+1} - y_n$

$$\beta = \frac{D}{d} [2(n + 1) - 1] \frac{\lambda}{2} - \frac{D}{d} (2n - 1) \frac{\lambda}{2}$$

$$\beta = \frac{D}{d} \lambda \quad \dots \quad (6)$$

Equation (5) and (6) shows that the bright and dark fringes are of same width equally spaced on either side of central bright fringe.

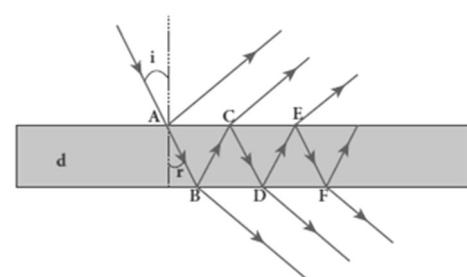
- 68. Obtain the equations for constructive and destructive interference for transmitted and reflected waves in thin films.**

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 into two parts. One part is reflected and other part is refracted.

The refracted part which enters into the film, again gets divided at the lower surface in two parts. One is transmitted and the other is reflected back into the film. Here interference is produced by both the reflected and transmitted light.



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

$$\delta = \mu(BC+CD) = \mu(d+d)$$

$$\delta = 2\mu d \quad \dots \dots \dots (1)$$

(1) The condition for constructive interference in transmitted ray is, $\delta = n\lambda$

$$(or) 2\mu d = n\lambda \quad \dots \dots \dots (2)$$

(2) The condition for destructive interference in transmitted ray is,

$$\delta = (2n - 1)\frac{\lambda}{2} \quad (or) 2\mu d = (2n - 1)\frac{\lambda}{2} \quad \dots \dots \dots (3)$$

Interference due to reflected light:

When light travelling in a rarer medium and getting reflected by a denser medium, undergoes a phase change of π .

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 introduced due to reflection at A, the total path difference, $\delta = 2\mu d + \frac{\lambda}{2} \quad \dots \dots \dots (4)$

1) The condition for constructive interference in reflected ray is $\delta = n\lambda$

$$(or) 2\mu d + \frac{\lambda}{2} = n\lambda \quad (or) 2\mu d = (2n - 1)\frac{\lambda}{2} \quad \dots \dots \dots (5)$$

2) The condition for destructive interference in reflected ray is,

$$\delta = (2n + 1)\frac{\lambda}{2} \quad (or) 2\mu d + \frac{\lambda}{2} = (2n + 1)\frac{\lambda}{2} \quad (or)$$

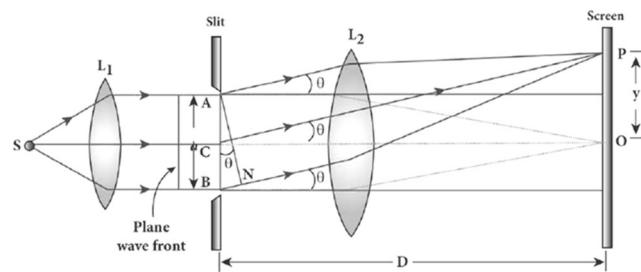
$$2\mu d = n\lambda \quad \dots \dots \dots (6)$$

Equation (5) and (6) shows that the bright and dark fringes are of same width equally spaced on either side of central bright fringe

69. Discuss diffraction at single slit and obtain the condition for n^{th} minimum.

Diffraction at single slit:

Let a parallel beam of light fall normally on a single slit AB. The centre of the slit is C. A straight line through 'C' perpendicular to the plane of slit meets the centre of the screen at 'O'. Let y be the distance of point 'P' from 'O'. The lines joining 'P' to the different points on the slit can be treated as parallel lines, making an angle θ with the normal 'CO'.



All the parallel waves from different points on the slits get interfere at 'P' to give resultant intensity.

Condition for minima:

To explain minimum intensity, divide the slit into even number of parts.

(1) Condition for P to be first minimum:

Let us divide the slit AB into two halves each of width $\frac{a}{2}$

The various points on the slit which are separated by the same width $\left(\frac{a}{2}\right)$ called **Corresponding points**.

The path difference of light waves from different corresponding points meeting at point P. $\delta = \frac{a}{2} \sin\theta$.

The condition for P to be first minimum, $\frac{a}{2} \sin\theta = \frac{\lambda}{2}$ (or) $a \sin\theta = \lambda$

(2) Condition for P to be second minimum

Let us divide the slit AB into four equal parts. Now, the width of each part is $\frac{a}{4}$. Here varies corresponding points on the slit which are separated by the same width $\left(\frac{a}{4}\right)$.

The path difference of light waves from different corresponding points meeting at "P" = $\frac{a}{4} \sin\theta$.

The condition for P to be first minimum, $\frac{a}{4} \sin\theta = \frac{\lambda}{4}$ (or) $a \sin\theta = 2\lambda$

(3) Condition for P to be n^{th} minimum:

Let us divide the slit AB into $2n$ equal parts of width $\frac{a}{2n}$

The condition for P to be n^{th} minimum (or) $a \sin\theta = n\lambda$

Condition for maxima:

To explain maximum intensity, divide the slit in to odd number of parts.

For first maximum, the slit is divided in to three equal parts each of width $\left(\frac{a}{3}\right)$.

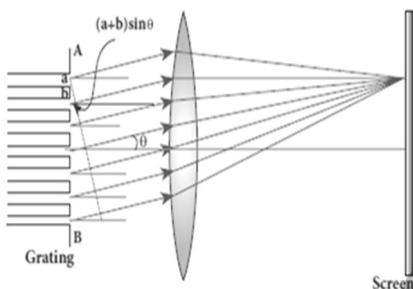
$$\text{Hence } \frac{a}{3} \sin\theta = \frac{\lambda}{2} \text{ (or) } a \sin\theta = 3 \frac{\lambda}{2}$$

For second maximum, the slit is divided in to five equal parts each of width $\left(\frac{a}{5}\right)$. Hence $\frac{a}{5} \sin\theta = \frac{\lambda}{2}$ (or) $a \sin\theta = 5 \frac{\lambda}{2}$

In general, for nth first maximum, the slit is divided in to $(2n+1)$ equal parts each of width $\left(\frac{a}{2n+1}\right)$. Hence $\frac{a}{2n+1} \sin\theta = \frac{\lambda}{2}$ (or) $a \sin\theta = (2n+1) \frac{\lambda}{2}$

- 70. Discuss the diffraction at a grating and obtain the condition for mth maximum.**

Diffraction in grating:



Let 'AB' represent the plane transmission grating.

It has number of slits of equal width (a) and equal number of opaque rulings of equal width (b). Let a plane waveform of monochromatic light of wavelength ' λ ' be incident normally on the grating. As the slit size is comparable to that of wavelength, the incident light diffracts at the grating.

Using convex lens, the diffracted waves are focused on the screen. Consider a point 'P' on the screen, at an angle ' θ ' with the normal drawn from the centre of the grating to the screen. The path difference (δ) between the diffracted waves from one pair of corresponding points is,

$$\delta = (a+b) \sin \theta$$

The point 'P' will be bright, when $\delta = m \lambda$ [$m = 0, 1, 2, 3, \dots$]

$$\text{Hence, } (a+b) \sin \theta = m \lambda \quad \dots \dots \dots (1)$$

Where $m \rightarrow$ order of diffraction

- (1) Condition for zero order maximum:**

When, $(a+b) \sin \theta = 0$, then, $\theta = 0$; $m = 0$ It is zero order diffraction or central maximum

- (2) Condition for first order maximum:**

When, $(a+b) \sin \theta_1 = \lambda$, then, $\theta = \theta_1$; $m = 1$

It is first order diffraction

- (3) Condition for second order maximum:**

When, $(a+b) \sin \theta_2 = 2\lambda$, then, $\theta = \theta_2$; $m = 2$.

It is second order diffraction

(4) Condition for higher order maxima:

$$(a+b) \sin \theta = m \lambda$$

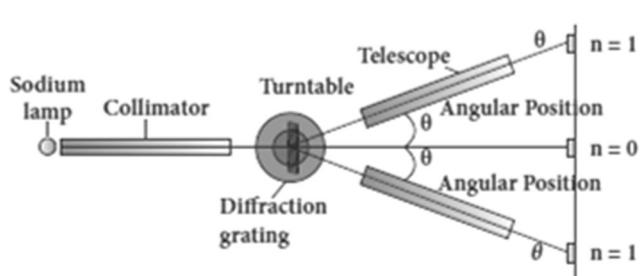
If 'N' be the number of rulings drawn per unit width (1 m), then,

$$Na + Nb = 1 \text{ (or)} \quad N(a+b) = 1 ; a + b = \frac{1}{N}$$

$$\therefore \frac{1}{N} \sin \theta = m \lambda \quad (\text{or}) \quad \sin \theta = N m \lambda \quad \dots \dots \dots (2)$$

- 71. Discuss the experiment to determine the wavelength of monochromatic light using diffraction grating.**

Experiment to determine wavelength of light:



The wavelength of a spectral line can be very accurately determined with help of a diffraction grating and a spectrometer. Let all the preliminary adjustments are made on the spectrometer. The

slit of the spectrometer is illuminated by a monochromatic light, whose wavelength to be determined.

The telescope is brought in line with collimator to view the direct image of the slit. The given transmission grating is then mounted on the prism table with its plane perpendicular to the incident beam of light coming from collimator.

The telescope is turn to one side until the first order diffraction image of the slit coincides with the vertical cross wire of the eye piece.

The reading of the position of the telescope is noted. Similarly, the first order diffraction image on the other side is made to coincide with vertical cross wire and corresponding reading is noted.

The difference between two positions gives 2θ

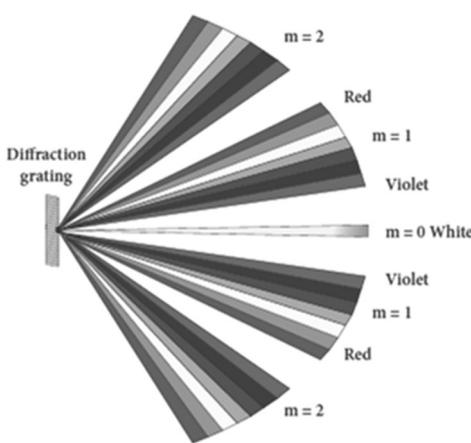
Half of its value gives θ , the diffraction angle for first order maximum.

The wavelength of light is calculated from, $\lambda = \frac{\sin \theta}{N m}$

72. Discuss the experiment to determine the wavelength of different colours using diffraction grating.

Determination of wavelength of different colours :

White light is a composite light which contains all wavelengths from



violet to red in visible region. When white light is used, the diffraction pattern consists of a white central maximum and on both sides continuous coloured diffraction patterns are formed.

The central maximum is white as all the colours meet here constructively with no phase difference. It produces a spectrum of diffraction pattern from violet to red on either side of central maximum.

By measuring the angle (θ) at which these colours appear for various order (m) of diffraction, the wavelength of different colours could be calculated using the formula, $\lambda = \frac{\sin \theta}{N m}$

Where, **N** → number of rulings drawn per unit width of grating

73. Explain about compound microscope and obtain the equation for magnification.

Compound microscope:

The lens near the object is called the objective, forms a real, inverted, magnified image of the object. This serves as the object for the second lens which is the eyepiece. Eye piece serves as a simple microscope that produces finally an enlarged and virtual image.

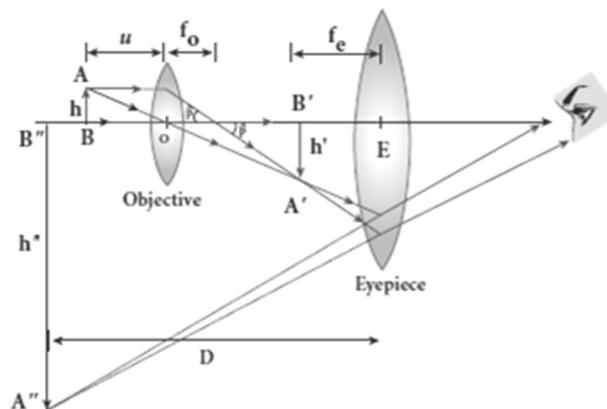
The first inverted image formed by the objective is to be adjusted close to, but within the focal plane of the eyepiece, so that the final image is formed nearly at infinity or at the near point.

The final image is inverted with respect to the original object.

Magnification (m) :

From the ray diagram, the linear magnification due to the objective is,

$$m_0 = \frac{h'}{h} = \frac{L}{f_0} \quad \dots \dots \dots \quad (1)$$



Here 'L' is the distance between the first focal point of the eye piece to the second focal point of the objective. This is called the tube length.

$$\text{The magnification of the eyepiece, } m_e = 1 + \frac{D}{f_e} \dots\dots\dots (2)$$

The total magnification 'm' in near point focusing,

$$m = m_0 m_e = \left[\frac{L}{f_0} \right] \left[1 + \frac{D}{f_e} \right]$$

If the final image is formed at infinity (normal focusing), the magnification if eye piece is, $m_e = \frac{D}{f_e} \dots\dots\dots (3)$

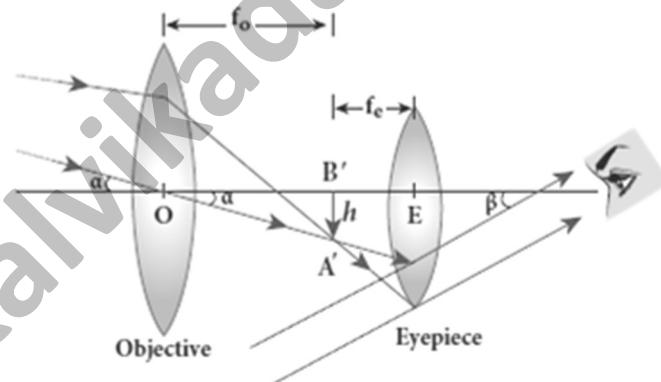
The total magnification 'm' in normal focusing is,

$$m = m_0 m_e = \left[\frac{L}{f_0} \right] \left[\frac{D}{f_e} \right]$$

74. 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. $m = \frac{\beta}{\alpha}$

$$\text{From figure, } m = \frac{\left[\frac{h}{f_e} \right]}{\left[\frac{h}{f_0} \right]} ; \quad m = \frac{f_0}{f_e}$$

The length of the telescope is approximately, $L = f_0 + f_e$

- 75. Explain the experimental determination of material of the prism using spectrometer.**

Determination of refractive index:

The preliminary adjustments of the telescope, collimator and the prism table of the spectrometer are made. The refractive index (μ) of the prism is determined by knowing the angle of the prism (A) and the angle of minimum deviation (D)

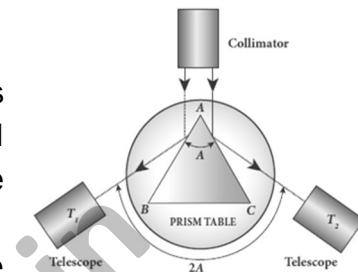
(1) Angle of the prism (A):

The prism is placed on the prism table with its refracting edge facing the collimator. The slit is illuminated by sodium light. The parallel rays coming from the collimator fall on the two faces AB and AC.

The telescope is rotated to the position T_1 until the image of the slit formed by the reflection at the face AB coincides with the vertical cross wire of the telescope. The corresponding vernier readings are noted.

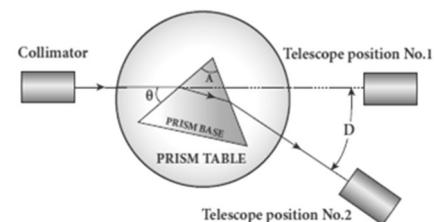
The telescope is then rotated to the position T_2 where the image of the slit formed by the reflection at the face AC coincides with the vertical cross wire of the telescope.

The corresponding vernier readings are again noted. The difference between these two readings gives the angle rotated by the telescope, which is twice the angle of the prism. Half of this value gives the angle of the prism (A)



(2) Angle of minimum deviation (D):

The prism is placed on the prism table, so that the light from the collimator falls on a refracting face and the refracted image is observed through the telescope.



The prism table is now rotated, so that the angle of deviation decreases. A stage comes when the image stops for a moment and if we rotate the prism table further in the same direction, the image is seen to recede and the angle of deviation increases.

The vertical cross wire of telescope is made to coincide with the image of the slit, where it turns back. This gives the minimum deviation position.

The vernier readings corresponding to this position is noted. Now the prism is removed and the telescope is turned to receive the direct ray and the vernier readings are again noted.

The difference between the two readings gives the angle of minimum deviation (D)

Refractive index (μ) of the prism:

The refractive index of the material of the prism is calculated using the formula, $\mu = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

UNIT - VIII (DUAL NATURE OF RADIATION AND MATTER)

TWO MARKS AND THREE MARKS QUESTIONS AND ANSWERS

1. Why do metals have a large number of free electrons?

In metals, the electrons in the outer most shells are loosely bound to the nucleus. Even at room temperature, due to thermal agitation the loosely bounded electrons are detached from their orbit and free to move inside the metal in a random manner. This is the reason for large number of free electrons in the metal.

2. Define surface barrier.

The potential barrier which **prevents free electrons from leaving the metallic surface** is called surface barrier. It is created by the positive nuclei of the metal.

3. Define electron emission.

The **liberation of electrons from any surface of a substance** is called electron emission. The material with small work function is more effective in electron emission.

4. Define work function of a metal. Give its unit.

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)**.

5. Define electron volt (eV)

One electron volt is defined as **the kinetic energy gained by a electron when accelerated by a potential difference of 1 volt**.

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$

6. What is photo electric effect?

The **ejection of electrons from a metal plate when illuminated by light or any other electromagnetic radiation of suitable wavelength or frequency** is called photo electric effect. The ejected electrons are called as photo electrons and the corresponding current is called photo electric current.

7. What are called photo sensitive materials?

The **materials which eject photoelectrons upon irradiation of electromagnetic wave of suitable wavelength** are called photosensitive materials. (e.g.) **Metals like cadmium, zinc, magnesium etc and Alkali metals like lithium, sodium, cesium**

8. How does photo electric current vary with the intensity of the incident light?

Variation of photo current with intensity:

Keeping the frequency (v) and acceleration potential (V) as constant, the intensity of incident light is varied and the corresponding photo electric current is measured. A graph is drawn between intensity along X-axis and the photo current along Y-axis.

From the graph, the photo current (i.e) the number of electrons emitted per second is directly proportional to the intensity of incident light.

9. 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.

10. Define threshold frequency.

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 threshold frequency.

11. State the laws of photo electric effect.

Laws of photo electric 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 photoelectrons 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.

12. Explain why? photoelectric effect cannot be explained on the basis of wave nature of light.

Failures of classical wave theory:

According to wave theory, light of **greater intensity should impart greater kinetic energy to the liberated electrons**. But the experiments show that maximum kinetic energy of the photoelectrons does not depend on the intensity of the incident light.

According to wave theory, if a sufficiently intense beam of light is incident on the surface, electrons will be liberated from the surface of the target, however low the frequency of the radiation is.

But **photoelectric emission is not possible below a certain minimum frequency** called threshold frequency. Since the energy of light is spread across the wave front, each electron needs considerable amount of time (a few hours) to get energy sufficient to overcome the work function and to get liberated from the surface. But experiments show that photoelectric emission is almost instantaneous process.

13. Explain the concept of quantization of energy.

Quantization of energy:

Max Planck proposed quantum concept in 1900 in order **to explain the black body radiations**. According to Planck, matter is composed of a large number of oscillating particles (atoms) which vibrate with different frequencies. Each atomic oscillator which vibrates with its characteristic frequency emits or absorbs electromagnetic radiation of the same frequency.

- (i) If an oscillator vibrates with frequency ν , its energy can have only certain discrete values,

$$E_n = n h \nu \quad [n = 1, 2, 3, \dots]$$

where $h \rightarrow$ Planck's constant.

- (ii) The oscillators emit or absorb energy in small packets or quanta and the energy of each quantum is $E = h \nu$

This implies that the energy of the oscillator is quantized and not continuous this is called quantization of energy.

14. Explain Einstein's explanation for the particle nature (quanta) of light.

Particle nature of light - Einstein's explanation:

According to Einstein, **the energy in light is not spread out over wave fronts but is concentrated in small packets or energy quanta**. Therefore, light of frequency ν from any source can be considered as a stream of quanta

The energy of each light quantum; $E = h \nu$

The linear momentum of quanta is ; $p = \frac{h\nu}{c}$

The individual light quantum of definite energy and momentum can be associated with a particle. **The light quantum can behave as a particle and this is called photon.**

15. Define intensity of light according to the quantum concept.

According to quantum concept, the intensity of light of given wavelength is defined as the number of energy quanta or photons incident per unit area per unit time with photon having same energy. The **unit is Wm⁻²**

16. What is the nature of light?

The light possesses dual nature that of both wave and particle. Light behaves as a wave during its propagation and behaves as a particle during its interaction with matter.

17. What is photo electric cell? Give its type.

The device which **converts light energy into electrical energy** is called photo electric cell or simply photo cell.

It works on the principle of photo electric cell

Photo cells are classified in to three types.

(1) Photo emissive cell (2) Photo voltaic cell (3) Photo conductive cell

18. What is De Broglie hypothesis?

Due to the symmetry in nature, de Broglie suggested that if radiation like light can act as particles at times, then matter particles like electrons should also act as waves at times. According to de Broglie hypothesis, all matter particles like electrons, protons, neutrons in motion are associated with waves. These waves are called de Broglie waves or matter waves.

19. What is called matter waves or de Broglie waves?

The **waves associated with matter particles like electrons in motion** is called matter waves or de Broglie waves.

20. Derive the expression of de Broglie wavelength.

De Broglie wavelength:

The momentum of photon of frequency ' ν ' is, $p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$ [c = $\lambda\nu$]

According to de Broglie, this equation is applicable to matter particle also. Let 'm' be the mass and ' v ' be the velocity of the particle, then the wavelength. $\lambda = \frac{h}{mv} = \frac{h}{p}$

This wavelength of the matter waves is known as de Broglie wavelength.

21. Write the expression for the de Broglie wavelength associated with a charged particle of charge 'q' and mass 'm', when it is accelerated through a potential V.

De Broglie wavelength in terms of potential 'V', $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2m qV}}$

22. Why we do not see the wave properties of a baseball?

The de Broglie wavelength of matter is ; $\lambda = \frac{h}{mv}$

Thus the **de Broglie wavelength is inversely proportional to the mass**

Since the mass of baseball is too large as compared with the electron, the de Broglie wavelength of baseball is negligibly small. So we do not see the wave property of the baseball.

23. A proton and an electron have same kinetic energy. Which one has greater de Broglie wavelength. Justify.

De Broglie wavelength of proton ; $\lambda_p = \frac{h}{\sqrt{2 m_p K}}$

De Broglie wavelength of electron; $\lambda_e = \frac{h}{\sqrt{2 m_e K}}$

Here the mass of the proton is greater than the mass of the electron

$$(m_p > m_e)$$

Hence the de Broglie wavelength of electron is greater than that of proton

$$(\lambda_e > \lambda_p)$$

24. Write the relationship of de Broglie wavelength λ associated with a particle of mass m in terms of its kinetic energy K .

De Broglie wavelength in terms of potential 'V' , $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2 m qV}}$

Since, $q V = K$ (kinetic energy), we have $\lambda = \frac{h}{\sqrt{2 m K}}$

25. Name an experiment which shows wave nature of the electron. Which phenomenon was observed in this experiment using an electron beam?

The wave nature of electron (i.e) de Broglie hypothesis of matter waves was experimentally confirmed by Davisson and Germer experiment.

Diffraction is the important property of waves. So in this experiment, diffraction of electron beam was observed when they fall on crystalline solids.

26. An electron and an alpha particle have same kinetic energy. How are the de-Broglie wavelengths associated with them related?

De- Broglie wavelength of electron beam, $\lambda_e = \frac{h}{\sqrt{2 m_e K}}$

De- Broglie wavelength of alpha particle, $\lambda_\alpha = \frac{h}{\sqrt{2 m_\alpha K}}$

$$\therefore \frac{\lambda_e}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_e}}$$

27. What are called X - rays? Why are they so called?

X - rays are invisible, electromagnetic waves of **very short wavelength ranging from 0.1 \AA to 100 \AA**

When a **fast moving electrons strike a metal target** of high atomic weight, X - rays are produced.

At the time of discovery, the origin of this **highly penetrating ray were not known**. So they were called as X - rays.

28. List the properties of X - rays.

Properties of X - rays:

1. They **travel in straight line** with the velocity of light
2. They are **not deflected both by electric and magnetic field**
3. X - ray photons are **highly energetic**
4. They **pass through materials** which are opaque to visible light.

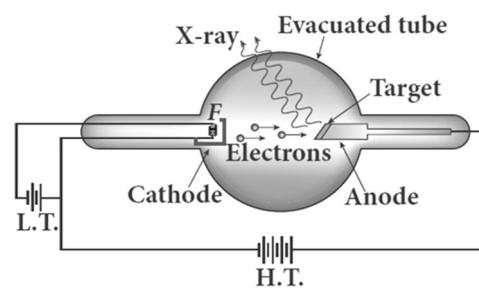
29. What factor does the quality and intensity of X - rays depends?

The quality of X - rays is measured in terms of its penetrating power which depends on the velocity of the striking electron and the atomic number of target material. The intensity of X - rays is depends on the number of electrons striking the target.

30. Write a note on the production of X - rays.

Production of X - rays:

X - Rays are produced in a Coolidge tube which is a discharge tube. Here a **tungsten filament 'F'** is heated by L.T, so that electrons are emitted from it by **thermionic emission**. These electrons are accelerated to very high speeds by H.T. The target material like tungsten is embedded in the face of solid copper anode.



When high speed electrons strike the target, they are decelerated suddenly and lose their kinetic energy. As a result, X-ray photons are produced.

The face of target is inclined at particular angle, so that the X - rays can leave the tube through its side. **Since most of the kinetic energy of electrons get converted in to heat**, the target made of high melting point and a cooling system are usually employed.

31. What is X-ray spectra? Give its types.

The intensity of the X-rays when plotted against its wavelength gives a curve called X-ray spectrum.

X-ray spectrum consists of two parts, namely

- (1) Continuous X-ray spectrum
- (2) Characteristic X-ray spectrum

32. Write a note on continuous X-ray spectrum.

Continuous X-ray spectrum:

When a fast-moving electron penetrates and approaches a target nucleus, it gets accelerates or decelerates

It may result in a change of path of the electron.

The radiation produced from such decelerating electron is called Brims strolling or braking radiation.

The energy of the emitted photon (radiation) is equal to the loss of kinetic energy of the electron. So the photons are emitted with all possible energies or frequencies.

The continuous X-ray spectrum is due to such radiations. When an electron gives up all its energy, then the photon is emitted with highest frequency (ν_0) or lowest wavelength (λ_0)

The initial kinetic energy of an electron = eV where, V → accelerating voltage. Thus $e\nu = h\nu_0 = h\frac{c}{\lambda_0}$ (or)

$$\lambda_0 = \frac{hc}{eV} = \frac{12400}{V} \text{ Å}$$

This relation is known as Duane - Hunt formula.

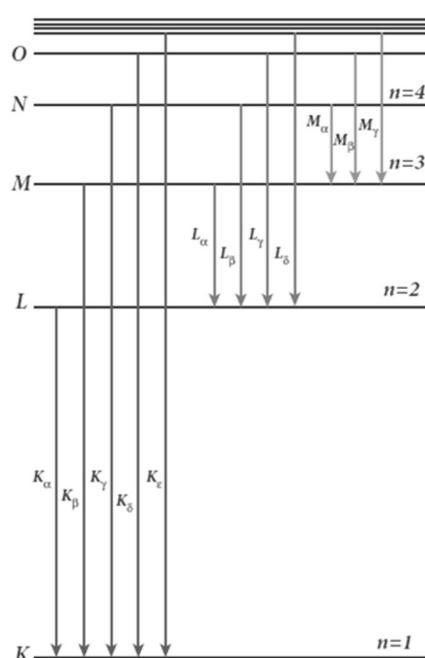
33. Write a note on characteristic X-ray spectra.

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 into the target atom and removes the electrons in K-shell and creates a vacancy in it.

So the electrons from outer orbits jump to fill up the vacancy in K-shell.



During the downward transition, the energy difference between the levels is given out in the form of X - ray photon of definite wavelength.

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.

34. 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-ray's 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.

FIVE MARKS QUESTIONS AND ANSWERS

35. What do you mean by electron emission? Explain briefly various methods of electron emission.

Electron emission:

The **liberation of electrons from any surface of a substance** is called electron emission. The **minimum energy needed to liberate the electrons** from the metal surface is called **work function** of that metal. Depending upon the energy source, the electron emission is classified as four types which are explained below.

(1) Thermionic emission:

When a metal is **heated to a high temperature, the free electrons on the surface get sufficient energy in the form of heat**, so that they are emitted from the metallic surface. This type of emission is known as thermionic emission. The intensity of the thermionic emission depends on the metal used and its temperature. (e.g.) **electron microscopes, X-ray tubes.**

(2) Field emission:

When a **very strong electric field is applied across the metal**, this strong field pulls the free electrons and helps to overcome the surface barrier of the metal. This type of emission of electron is called field emission. (e.g.) **Field emission display**

(3) Photo electric emission:

When an **electromagnetic radiation of suitable frequency is incident on the surface of the metal**, the energy is transferred from the radiation to free electrons. Hence the free electrons get sufficient energy to cross the surface barrier and this type is called photo electric emission.

(e.g.) **photo electric cells, photo diodes**

(4) Secondary emission:

When a beam of **fast-moving electrons strikes the surface of the metal**, the kinetic energy is transferred to the free electrons on the metal surface called secondary emission. (e.g.) **Photo multiplier tube.**

36. Briefly discuss the observations of Hertz, Hallwachs and Lenard.

Hertz experiment:

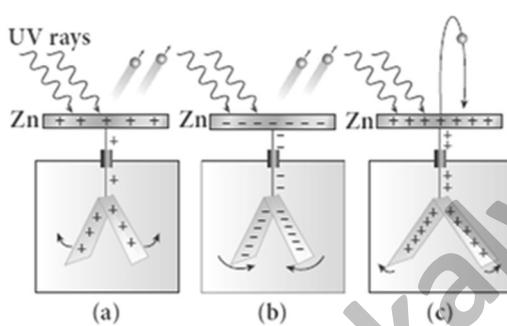
Heinrich Hertz successfully **generating and detecting the existence of electromagnetic waves**. He used high voltage induction coil to cause a spark discharge between two metallic spheres. When spark is formed, the charges will oscillate back and forth rapidly and the electromagnetic waves are produced.

To detect this electromagnetic waves, a copper wire bent in the shape of a circle is used as detector.

Hallwachs's experiment:

In Hertz experiment, in order to improve the visibility of the spark, it is exposed to ultra violet rays which make the spark as more vigorous.

Wilhelm Hallwachs confirmed that the strange behaviour of the spark is due to the photo electric emission under the action of ultra violet light.

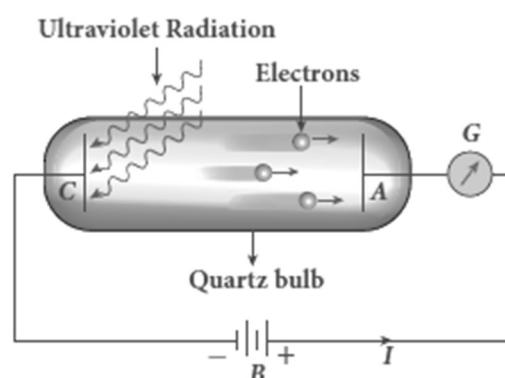


If negatively charged zinc plate is exposed to ultraviolet light, the leaves will close as the charges leaked away quickly as shown in figure (b)

If positively charged plate is exposed to uv-light, it becomes more positive and the leaves are open further as shown in figure (c) from these observations, it was concluded that negatively charged electrons were emitted from the zinc plate under the action of UV - light.

Lenard experiment:

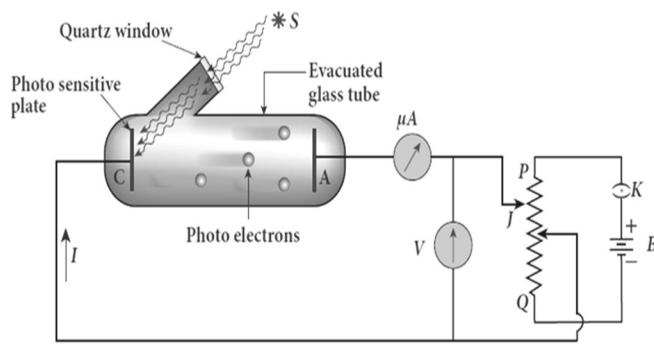
A and C are two metallic plates placed in an evacuated quartz bulb. Galvanometer G and battery B are connected in the circuit. When UV - light is incident on plate C, and electric current flows in a circuit which is indicated by the deflection in the galvanometer. But if the plate A is irradiated by UV - light, no current is observed in the circuit.



From these observations, it is concluded that when uv- light falls on the negative plate C, electrons are ejected from it, which are attracted by the positive plate A. Hence the circuit is completed and the current flows in it. Thus the UV - light falling on the negative plate causes the electron emission from the surface of the plate.

37. Explain the experimental set up for study of photo electric effect.

Experiment for study of photo electric effect:



S is the source of electromagnetic wave of frequency ' ν ' and intensity 'I'. C is the cathode made up of photo sensitive material and is used to emit electrons. A is the anode which collects the emitted electrons. A and C are placed in an evacuated glass envelope with a quartz window that permits UV -light and visible light. PQ is a potential divider arrangement which is connected through a key K and battery B.

The voltmeter 'V' and micro ammeter ' μA ' also included in this circuit. If there is no light incident on the cathode C, no photoelectrons are emitted and the micro ammeter reads zero. When UV - light or visible light is allowed to fall on C, the photo electrons are emitted and are attracted towards anode. As a result, the photo electric current is set up in the circuit which is measured using micro ammeter.

The **photo electric current depends** following quantities,

- (1) The intensity of incident light
- (2) The potential difference between the electrodes
- (3) The nature of the material
- (4) Frequency of incident light

38. Explain the effect of potential difference on photo electric current.

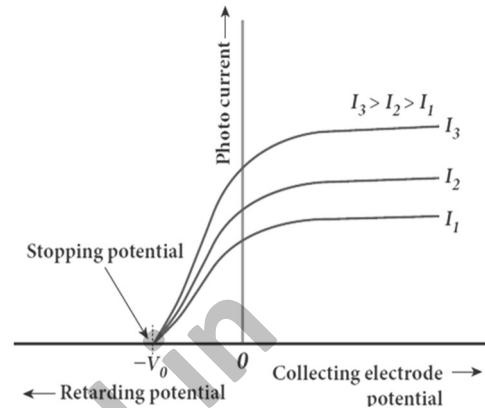
Effect of potential difference on photoelectric current:

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.) $ev_0 = \frac{1}{2}mv_{max}^2$

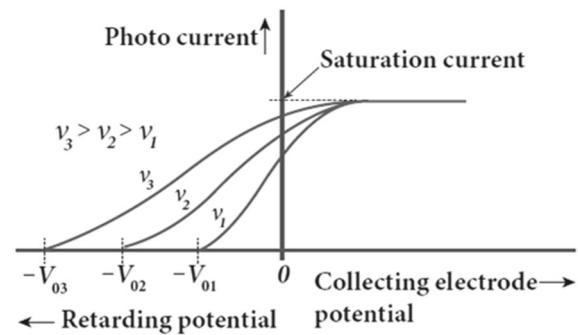
$$(\text{or}) v_{max} = \sqrt{\frac{2e v_0}{m}}; v_{max} = 5.93 \times 10^5 \sqrt{v_0}$$



39. Explain how frequency of incident light varies with stopping potential.

Effect of frequency on photoelectric current:

Let the intensity of incident light is kept constant. The variation of photo current with the Anode potential is studied for different incident frequencies. A graph is plotted by taking anode potential along x - axis and photo current along y - axis.



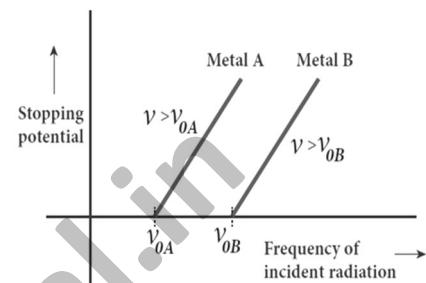
From the graph,

- (1) Stopping potential vary over different frequencies of incident light.
(i.e) **Greater the frequency, larger the stopping potential**
- (2) Thus as the frequency is increased, the photoelectrons are emitted with greater kinetic energies so that the retarding potential needed to stop the photoelectrons is also greater.

Variation of stopping potential with frequency:

From the graph,

- (1) The stopping potential **varies linearly with frequency.**
- (2) Below a particular frequency called threshold frequency (v_0), no electrons are emitted.
- (3) Hence at threshold frequency stopping potential is zero for that reason.



40. List out the laws of photoelectric effect.

Laws of photoelectric effect:

- 1) 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.**
- 2) 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.**
- 3) 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**

41. Explain the particle nature of light. List the characteristics of photons.

Particle nature of light:

According to Einstein, the energy in light is not spread out over wave fronts, but is concentrated in small packets or energy quanta.

The energy of each light quantum is ; $E = h\nu$

The individual light quantum of definite energy and momentum can be associated with a particle and this is called photon.

Characteristics of photons:

- 1) Each **photon will have energy** given by $E = h\nu = \frac{hc}{\lambda}$
- 2) The energy of a photon is determined by the frequency of the radiation and not by its intensity. The photons travel with the velocity of light and its momentum is given by, $p = \frac{h}{\lambda} = \frac{hc}{\lambda}$
- 3) Photons are electrically neutral, and hence they are not deflected **knee electric and magnetic fields**. When photon interacts with matter, the total energy, total linear momentum and angular momentum are conserved.

42. Obtain Einstein's photoelectric equation with necessary explanation.

Einstein's explanation of photoelectric equation:

When a photon of energy ' $h\nu$ ' 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**, $h\nu = \phi_0 + K$ (or)

$$h\nu = \phi_0 + \frac{1}{2}mv^2 \quad \dots \dots \dots (1)$$

Where $m \rightarrow$ mass of the electron and $v \rightarrow$ 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

$$h\nu_0 = \phi_0 \quad \dots \dots \dots (2)$$

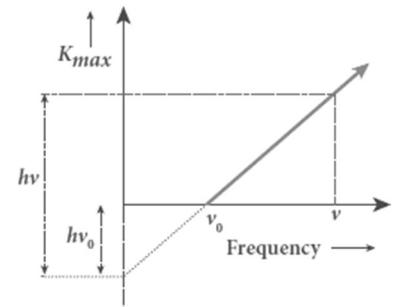
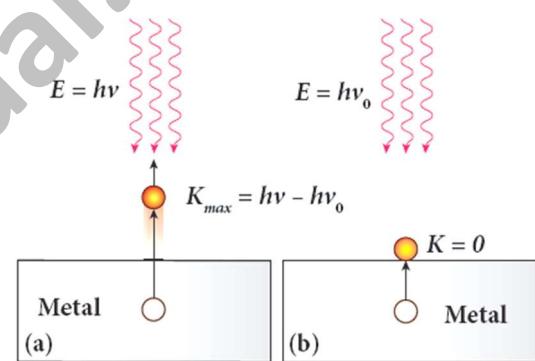
$$\text{Put equation (2) in (1)} \quad h\nu = h\nu_0 + \frac{1}{2}mv^2 \quad \dots \dots \dots (3)$$

The equation (3) is known as **Einstein's photoelectric equation**.

If the electron does not lose energy by internal collisions, then it is emitted with maximum kinetic energy K_{max} . Then $h\nu = h\nu_0 + \left[\frac{1}{2}mv^2 \right]_{max}$

$$(\text{or}) \frac{1}{2}mv_{max}^2 = h\nu - h\nu_0 \quad (\text{or}) \quad K_{max} = h\nu - \phi_0 \quad \dots \dots \dots (4)$$

A graph between maximum kinetic energy K_{max} of the photoelectron and frequency v of the incident light is a straight line.



- 43. Explain experimentally observed facts of photoelectric effect with the help Einstein's explanation.**

Explanation for photo electric effect:

As each photon liberates one electron, then the increase of intensity of the light increases the number of electrons emitted thereby increasing the photo current.

From $K_{\max} = h\nu - \Phi_0$, it is evident that K_{\max} is proportional to the frequency of the light and is independent of intensity of the light.

From, $h\nu = h\nu_0 + \frac{1}{2}mv^2$, there must be minimum energy (equal to the work function of the metal) for incident photons to liberate electrons from the metal surface.

Below which, emission of electrons is not possible. Correspondingly, there exists minimum frequency called **threshold frequency** below which there is no photoelectric emission.

According to quantum concept, the transfer of photon energy to the electrons is **instantaneous** so that there is no time lag between incidence of photons and ejection of electrons.

- 44. Explain photo electric cells and its types.**

Photo electric cell:

Photo electric cell or photo cell is a device which **converts light energy into electrical energy. It works on the principle of photo electric effect**. When light is incident on the photosensitive materials, their electric properties will get affected, based on which photo cells are classified into three types.

They are

- (1) Photo emissive cell
- (2) Photo voltaic cell
- (3) Photo conductive cell

(1) Photo emissive cell:

Its working depends on the electron emission from a metal cathode due to irradiation of light or other radiations.

(2) Photo voltaic cell:

Here sensitive element made of semiconductor is used which **generates voltage proportional to the intensity of light** or other radiations.

(3) Photo conductive cell:

In this, the resistance of the semiconductor changes in accordance with the radiant energy incident on it.

45. Give the construction and working of photo emissive cell.

Photo emissive cell:

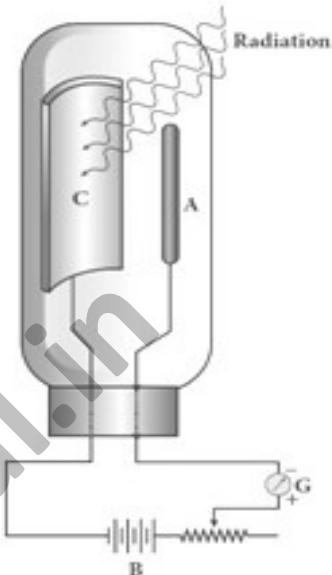
It consists of an evacuated glass or quartz bulb in which two metallic electrodes a cathode and an anode are fixed. The **cathode C is semi-cylindrical in shape and is coated with a photo sensitive material.** The anode A is a thin rod or wire kept along the axis of the semi-cylindrical cathode.

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.**



46. Give the application of photo cells.

Applications of photo cells:

- 1) Photo cells have many applications especially as **switches and sensors.**
- 2) **Automatic lights that turn on when it gets dark use photocells**, as well as street lights that switch on and off according to whether it is night or day.
- 3) Photo cells are used for **reproduction of sound in motion pictures.**
- 4) They are used as timers to **measure the speeds of athletes** during a race.
- 5) Photo cells of exposure meters in **photography are used to measure the intensity** of the given light and to calculate the exact time of exposure.

- 47. 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 $\frac{1}{2}mv^2 = ev$

$$\text{Hence the speed of the electron is, } v^2 = \frac{2eV}{m}; v = \sqrt{\frac{2eV}{m}} \dots\dots\dots(1)$$

$$\text{The de Broglie wavelength of electron is } \lambda = \frac{h}{mv} = \frac{h}{m\sqrt{\frac{2eV}{m}}}$$

$$\lambda = \frac{h}{\sqrt{2m e V}} \dots\dots\dots(2)$$

Where, $h = 6.626 \times 10^{-34} \text{ Js}$. $e = 1.6 \times 10^{-19} \text{ C}$. $m = 9.11 \times 10^{-31} \text{ kg}$

$$\therefore \lambda = \frac{12.27 \times 10^{-10}}{\sqrt{V}} = \frac{12.27}{\sqrt{V}} \text{ Å}$$

- 48. Describe briefly Davisson - Germer experiment which demonstrated the wave nature of electrons.**

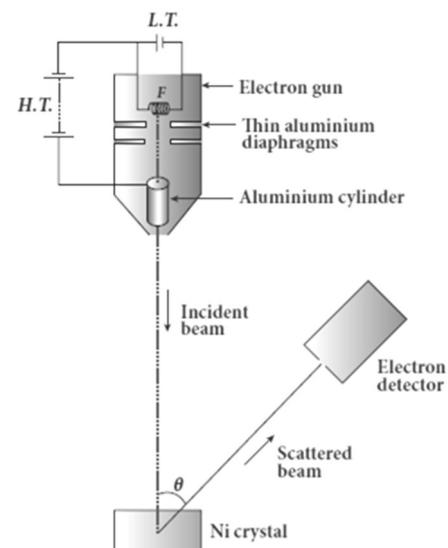
Davisson - Germer experiment:

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** .

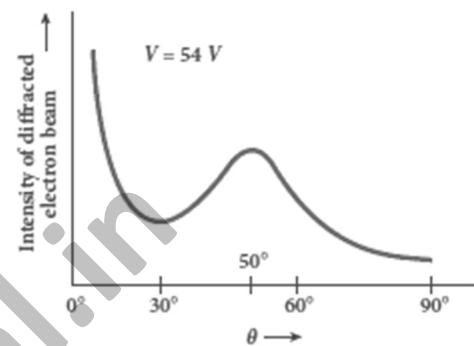


The graph shows the variation of intensity of the scattered electrons with the angle θ for the **accelerating voltage of 54V**. For a given accelerating voltage V, the scattered wave shows a peak or **maximum at an angle of 50°** to the incident electron beam. This peak in intensity is attributed to 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 **1.65 Å**. The wavelength can also be calculated from de Broglie relation for $V = 54$ V as $\lambda = \frac{12.27}{\sqrt{V}} \text{ Å} = \frac{12.27}{\sqrt{54}} \text{ Å}$

$$\lambda = 1.67 \text{ Å}$$

This value agrees well with the experimentally observed wavelength of **1.65 Å**. Thus this experiment directly verifies de Broglie's hypothesis of the wave nature of moving particles.



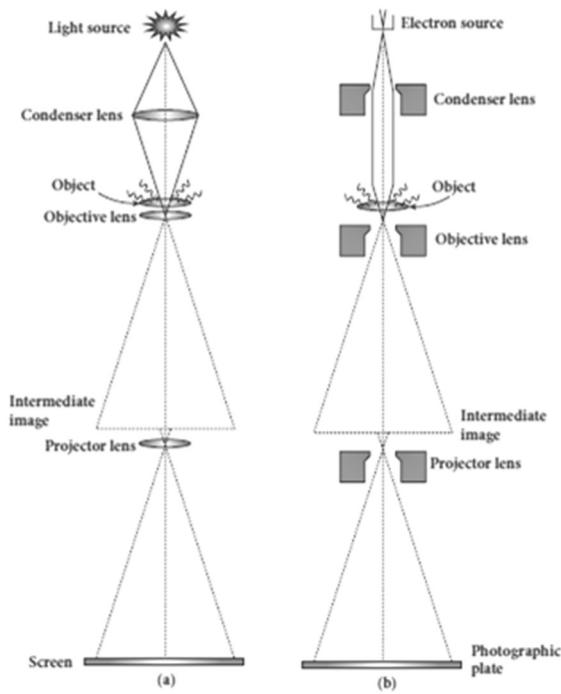
49. Briefly explain the principle and working of electron microscope.

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.

UNIT - IX (ATOMIC AND NUCLEAR PHYSICS)

TWO MARKS AND THREE MARKS QUESTIONS AND ANSWERS

1. What are called cathode rays?

When the **pressure is about 0.01 mm of Hg, positive column** disappears and a dark space is formed between anode and cathode which is called **Crooke's dark space**. At this time the walls of the tube appear with green colour and some invisible rays emanate from cathode called cathode rays, which are later found be a **beam of electrons**.

2. 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 10^7 m 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 $\left(\frac{1}{10}\right)^{\text{th}}$ of the speed of light.

3. Define specific charge.

Charge per unit mass is called specific charge (or) mass-normalized charge. Its unit is **C Kg⁻¹**.

4. Write a note on Thomson's atom model.

Thomson's atom model:

According to J. J. Thomson's atom model, the atoms are considered as homogeneous spheres which contain **uniform distribution of positively charged particles**. The negatively charged electrons are embedded in it like seeds in water melon fruit.

The atoms are electrically neutral; this implies that **the total positive charge in an atom is equal to the total negative charge**. This model could not explain stability of atom and further, it fails to explain the origin of spectral lines observed in the spectrum of hydrogen atom and other atoms.

5. Give the results of Rutherford alpha scattering experiment.

Results of alpha scattering experiment:

Most of the alpha particles are un-deflected through the gold foil and went straight. Some of the alpha particles are deflected through a small angle. **A few alpha particles (one in thousands) are deflected through the angle more than 90°. Very few alpha particles returned back (back scattered)—that is, deflected back by 180°.**

6. What are the conclusions made by Rutherford from the results of alpha scattering experiments?

Conclusion made in alpha scattering experiment: (Rutherford atom model):

Rutherford proposed that an atom has a lot of empty space and contains a tiny matter known as **nucleus whose size is of the order of 10⁻¹⁴ m**. The nucleus is positively charged and most of the mass of the atom is concentrated in nucleus. The nucleus is surrounded by negatively charged electrons.

Since **static charge distribution cannot be in a stable equilibrium**, he suggested that the electrons are not at rest and they revolve around the nucleus in circular orbits like planets revolving around the sun.

7. What is distance of closest approach? Obtain expression for it.

Definition:

The minimum distance between the centre of the nucleus and the alpha particle just before it gets reflected back through 180° is defined as **the distance of closest approach (or) contact distance r_0** .

Expression:

At this closest distance, all the kinetic energy of the alpha particle will be converted into electrostatic potential energy $\frac{1}{2}mv_0^2 = \frac{1}{4\pi\epsilon_0} \frac{(2e)(Ze)}{r_0}$

$$r_0 = \frac{1}{4\pi\epsilon_0} \frac{2Ze^2}{(\frac{1}{2}mv_0^2)}; r_0 = \frac{1}{4\pi\epsilon_0} \frac{2Ze^2}{E_k} \dots \dots \dots (1)$$

Where $E_k \rightarrow$ Kinetic energy of alpha particle.

8. 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.

9. What are the drawbacks of Rutherford atom model?

(1) Stability of atom cannot be explained:

According to classical electrodynamics, any accelerated charge emits electromagnetic radiations which as a result loses in its energy.

Hence, it can no longer sustain the circular motion and the radius of the orbit becomes smaller and smaller (undergoes spiral motion) and finally the electron should fall into the nucleus and hence the atoms should disintegrate. But this does not happen. Hence, Rutherford model could not account for the stability of atoms.

(2) Line spectrum of atom could not explain:

According to this model, emission of radiation must be continuous and must give continuous emission spectrum. But experimentally we observe only **line (discrete) emission spectrum for atoms.**

10. State the 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 $\frac{h}{2\pi}$** ; $l = n \frac{h}{2\pi} = n\hbar$

Where $n \rightarrow$ 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.

$$\Delta E = E_f - E_i = h\nu = h\frac{c}{\lambda}; \text{ Where } c \rightarrow \text{speed of light}$$

$\lambda \rightarrow$ wavelength of the radiation used and $\nu \rightarrow$ frequency of the radiation

11. Define excitation energy.

The energy required to excite an **electron from lower energy state to any higher energy state** is known as excitation energy.

Its unit is **electron volt (eV)**

12. Define excitation potential.

Excitation potential is defined as **excitation energy per unit charge**.

Its unit is **volt (V)**

13. Define ionization energy.

The **minimum energy required to remove an electron from an atom in the ground state** is known as binding energy or ionization energy. Ionization energy of hydrogen atom is **E_{Ionization} = 13.6 eV**

14. Define ionization potential.

Ionization potential is defined as ionization energy per unit charge.

The ionization potential of hydrogen atom is, **V_{Ionization} = 13.6 eV**

15. What are the drawbacks in Bohr atom model?

Drawbacks of Bohr atom model:

Bohr atom model is valid only for hydrogen atom or hydrogen like-atoms but not for complex atoms. **When the spectral lines are closely examined, individual lines of hydrogen spectrum** is accompanied by a number of faint lines. These closed packed lines are called **fine structure**.

This is not explained by Bohr atom model. Bohr atom model fails to explain the intensity variations in the spectral lines. The distribution of electrons in atoms is not completely explained by Bohr atom model.

16. Define atomic number and mass number.

The **number of protons** in the nucleus is called the atomic number (Z)

The **number of neutrons** in the nucleus is called neutron number (N).

The **total number of neutrons and protons** in the nucleus is called the mass number(A) [A = Z+N]

17. Write a general notation of nucleus of element X. What each term denotes?

The general notation of nucleus is ; ${}^A_Z X$

Where X is the chemical symbol of the element,

A is the mass number and Z is the atomic number. (e.g.) Nitrogen nucleus is represented by ${}^{15}_7 N$

18. What is the charge of nucleus?

The nucleus is made up of positively charged protons and electrically neutral neutrons. So the net charge of the nucleus is positive and it has the value = + Ze

19. What is isotope? Give an example.

The **atoms of the same element having same atomic number Z, but different mass number A** are called isotopes. The isotopes of any element have same electronic structure and same chemical properties.

(e.g) Hydrogen isotopes: ${}^1_1 H$, ${}^2_1 H$, ${}^3_1 H$

20. What is an isobar? Give an example.

The **atoms of different elements having the same mass number A, but different atomic number Z** are called isobars. They have different physical and chemical properties. (e.g) ${}^{40}_{16} S$, ${}^{40}_{17} Cl$, ${}^{40}_{18} Ar$, ${}^{40}_{19} K$ and ${}^{40}_{20} Ca$

21. What is isotones? Give an example.

The **atoms of different elements having same number of neutrons** are called isotones. (e.g.) ${}^{12}_{5} B$ and ${}^{13}_{6} C$.

22. Define atomic mass unit.

One atomic mass unit (u) is defined as the **1/12th of the mass of the isotope of carbon. (${}^{12}_{6} C$)** $1u = 1.66 \times 10^{-27} \text{ kg}$.

23. Give the empirical formula for nuclear radius.

The nuclear radius is given by, $R = R_0 A^{\frac{1}{3}}$. Where $R_0 = 1.2F$ [1F = 10^{-15}m]

24. Define nuclear density.

Nuclear density is defined as **the ratio of mass of the nucleus to its volume**. $\rho = \frac{m}{\frac{4}{3}\pi R_0^3} = 2.3 \times 10^{17} \text{ kg m}^{-3}$

25. What is mass defect?

The experimental mass of a nucleus is less than the total mass of its individual constituents. The **mass difference between total mass of the nucleons and the real mass of the nucleus** is called mass defect (Δ_m)

$$\Delta_m (Z m_p + N m_n) - M$$

26. Define binding energy.

When Z protons and N neutrons are combine to form a nucleus, the **mass disappear equivalent to mass defect (Δm) is converted in to energy which is used to bind the nucleons** in the nucleus. This is known as binding energy (BE). $BE = \Delta mc^2 = [(Z m_p + N m_n) - M] c^2$

27. Calculate the energy equivalent to one atomic mass unit (1 u).

Give the answer in eV unit.

According to Einstein's mass - energy relation

$$E = mc^2 = (1) \times (3 \times 10^8)^2$$

$$E = 1.66 \times 10^{-27} \times 9 \times 10^{16}$$

$$E = 14.94 \times 10^{-11} \text{ J}$$

$$\text{But we have, } 1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$

$$\therefore E = 931 \text{ MeV}$$

28. Define average binding energy per nucleon?

The average binding energy per nucleon is the energy required to **separate single nucleon from the particular nucleus**. (\bar{BE}). It measures the stability of the nucleus.

29. What is nuclear force?

It was concluded that there **must be a strong attractive force between protons to overcome the repulsive Coulomb's force**. This strong attractive force which holds the nucleus together is called nuclear force.

30. 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.

31. 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.

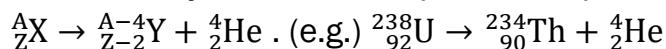
- 32. Give the symbolic representation of alpha decay, beta decay and gamma decay.**

(1) Alpha decay:

When unstable nuclei decay by emitting an α -particle (${}^4_2\text{He}$), its

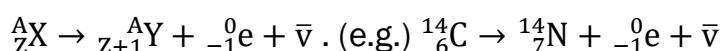
Atomic number (Z) decreases by 2, the mass number (A)

decreases by 4. The α - decay process symbolically written as

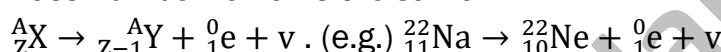


(2) Beta decay:

In β^- - decay, the **atomic number of the nucleus increases by one but mass number remains the same.**



In β^+ - decay, the atomic number of the nucleus decreases by one but mass number remains the same.



(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.** ${}^A_Z\text{X}^* \rightarrow {}^A_Z\text{X} + \text{gamma rays } (\gamma)$



- 33. Define disintegration energy.**

In decay process, the total mass of the daughter nucleus and product nucleus is always less than that of the parent nucleus. The difference in mass (Δm) is released as energy called disintegration energy Q . If $Q > 0$, the decay is spontaneous (natural radioactivity) If $Q < 0$, the decay process cannot occur spontaneously and energy must be supplied to induce the decay.

- 34. In alpha decay, why the unstable nucleus emits ${}^4\text{He}$ nucleus?**

Why it does not emit four separate nucleons?

For example, if ${}^{238}_{92}\text{U}$ nucleus decays into ${}^{234}_{90}\text{Th}$ by emitting four separate nucleons (two protons and two neutrons), then the disintegration energy Q for this process turns out to be negative. It implies that the total mass of products is greater than that of parent (${}^{238}_{92}\text{U}$) nucleus.

This kind of process cannot occur in nature because it would violate conservation of energy.

35. Write a note on positron?

The positron is an anti-particle of an electron whose mass is same as that of electron and charge is opposite to that of electron (i.e.) +e.

36. 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.

37. State the law of radioactive decay.

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.**

38. Define activity. 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)

39. Define one Becquerel.

One Becquerel (Bq) is equal to one decay per second.

1 Bq = 1 decay / Second

40. Define one curie.

One curie was defined as **number of decays per second in 1 g of radium**

$1 \text{ Ci} = 3.7 \times 10^{10} \text{ decay / Second}$

41. What is half-life of nucleus? Give the expression.

The half life $\left(T_{\frac{1}{2}}\right)$ is the time required for the number of atoms initially present to reduce to one half of the initial amount. $T_{\frac{1}{2}} = \frac{0.6931}{\lambda}$

42. What is mean life of nucleus? Give the expression.

The mean life time (τ) of the nucleus is **the ratio of sum or integration of life times of all nuclei to the total number nuclei present initially.** $\tau = \frac{1}{\lambda}$

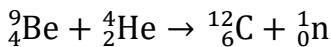
43. Write a note on the discovery of neutron.

Discovery of neutron:

In 1930, **Bothe** and **Becker** found that when beryllium was bombarded with α particle, highly penetrating radiation was emitted. This radiation was capable of penetrating the thick layer of lead and was unaffected by the

electric and magnetic fields. Initially, it was thought wrongly as γ - radiation.

But in 1932, **James Chadwick** discovered that those radiations are particles of mass little greater than the mass of the proton and had no charge. He called them as **neutrons (${}^1_0 n$)**. The above reaction was written as



44. List the properties of neutrons.

Properties of neutrons:

- 1) **Mass of the neutron is little greater than the mass of the proton and had no charge.**
- 2) **Neutrons are stable inside the nucleus.** But free neutron has **half-life of 13 minutes**.
- 3) Then it decays with emission of proton, electron and anti-neutrino. Neutrons are classified according to their kinetic energy as
 - (1) **Slow neutrons (0 to 1000 eV)**
 - (2) **Fast neutrons (0.5 MeV to 10 MeV).**
- 4) The **neutrons with average energy of about 0.025 eV in thermal equilibrium** are called **thermal neutron**.

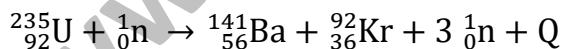
45. What is meant by nuclear fission?

The process of breaking up of the nucleus of a heavier atom into two smaller nuclei with the release of a large amount of energy is called nuclear fission.

46. Calculate the energy released per fission.

Energy released in one fission:

Consider the following fission reaction.



Total mass before fission;

$$\begin{aligned}\text{Mass of } {}^{235}_{92} \text{U} &= 235.045733 \text{ u} \\ \text{Mass of } {}^1_0 \text{n} &= 1.008665 \text{ u} \\ &= \underline{\underline{236.054398 \text{ u}}}\end{aligned}$$

Total mass after fission;

$$\begin{aligned}\text{Mass of } {}^{141}_{56} \text{Ba} &= 140.9177 \text{ u} \\ \text{Mass of } {}^{92}_{36} \text{Kr} &= 91.8854 \text{ u} \\ \text{Mass of } 3 {}^1_0 \text{n} &= 3.025995 \text{ u} \\ &= \underline{\underline{235.829095 \text{ u}}}\end{aligned}$$

$$\begin{aligned}\text{Mass defect; } \Delta_m &= 236.054398 \text{ u} \\ (-) &= \underline{\underline{235.829095 \text{ u}}} \\ \Delta_m &= \underline{\underline{0.225303 \text{ u}}}\end{aligned}$$

Then energy released during this fission reaction,

$$Q = \Delta m \times 931 \text{ MeV}$$

$$Q = 0.225303 \times 931 \text{ MeV}$$

$$\mathbf{Q = 200 \text{ MeV}}$$

47. What is called chain reaction. Give its types.

During every fission reaction, **three neutrons are released along with products. These three neutrons cause further fission produces nine neutrons and this process goes on**. Thus the number of neutrons goes on increasing almost in geometric progression and this is called a chain reaction. There are two kinds of chain reactions:

- (1) Uncontrolled chain reaction
- (2) Controlled chain reaction.

48. What is called nuclear reactor?

Nuclear reactor is a system in which the nuclear fission takes place in a self-sustained controlled manner. The energy produced is used either for research purpose or for power generation. The first nuclear reactor was built in the year 1942 at Chicago, USA.

49. What is nuclear fusion?

When two or more light nuclei ($A < 20$) combine to form a heavier nucleus, then it is called nuclear fusion.

50. What is mean by thermo nuclear reactions?

When two light nuclei come closer to combine, it is strongly repelled by the coulomb repulsive force. To overcome this repulsion, the two light nuclei must have enough kinetic energy to move closer to each other such that the nuclear force becomes effective.

This can be achieved if the **temperature is very much greater than the value 10^7 K . When the surrounding temperature reaches around 10^7 K** , lighter nuclei start fusing to form heavier nuclei and this resulting reaction is called thermonuclear fusion reaction.

51. What is the source of stellar energy?

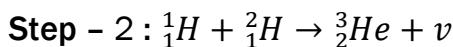
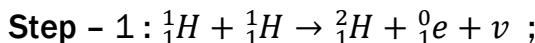
The energy generation in every star is **only through thermonuclear fusion because its temperature is of the order of 10^7 K** . Most of the stars including our Sun fuse hydrogen into helium and some stars even fuse helium into heavier elements.

52. Write a note on proton - proton cycle.

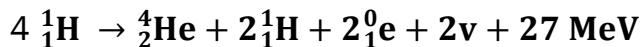
The sun's interior temperature is around 1.5×10^7 K

At this temperature, fusion reaction takes place and the sun is converting 6×10^{11} kg hydrogen, into helium every second. According to Hans Bethe, the sun is powered by proton-proton cycle of fusion reaction.

This cycle consists of three steps:



In general, the above three steps can be written as.



53. 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 $\left(-\frac{1}{3}e\right)$

54. What is radio carbon dating?

Radioactive dating or carbon dating is the **technique to estimate the age of ancient object by using radio carbon isotope (^{14}C)**

55. Write a note on smoke detector.

Smoke detector:

An important application of alpha decay is smoke detector which prevents us from any hazardous fire. It uses around 0.2 mg of man-made weak radioactive isotope called americium (${}_{95}^{241}\text{Am}$)

This radioactive source is placed between two oppositely charged metal plates and α radiation from ${}_{95}^{241}\text{Am}$ continuously ionize the nitrogen, Oxygen molecules in the air space between the plates.

As a result, there will be a continuous flow of small steady current in the circuit. If smoke enters, the radiation is being absorbed by the smoke particles rather than air molecules. As a result, the ionization and along with it the current is reduced. This drop in current is detected by the circuit and alarm starts. The radiation dosage emitted by americium is very much less than safe level, so it can be considered harmless.

FIVE MARKS QUESTIONS AND ANSWERS

56. 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;

$$F_E = e E$$

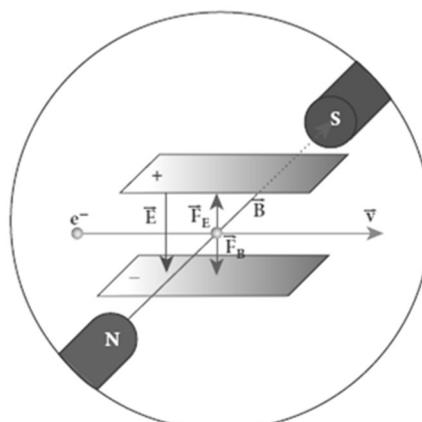
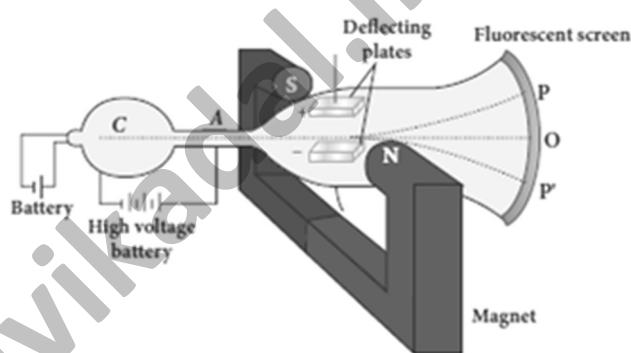
The downward force acting on cathode rays due to magnetic field is ;

$$F_B = e B v$$

In un-deflected equilibrium position,

$$F_E = F_B; eE = eBv$$

$$v = \frac{E}{B} \dots \dots \dots (1)$$



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,

$$eV = \frac{1}{2}mv^2 ; \therefore \frac{e}{m} = \frac{1}{2}\frac{v^2}{V} = \frac{1}{2}\frac{E^2}{VB^2}$$

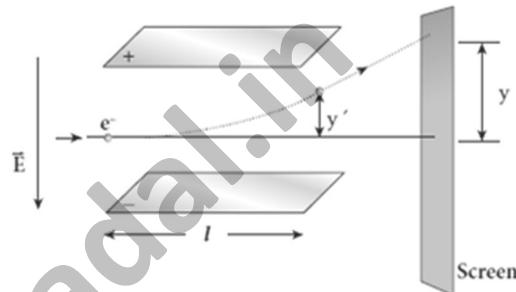
The value of specific charge is, $\frac{e}{m} = 1.7 \times 10^{11} \text{ Ckg}^{-1}\text{m}$

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; $u = 0$



Let 'l' be the length of the deflecting plate, then time taken to travel in electric field is, $t = \frac{l}{v}$

$$\text{Hence the deflection at the end of the electric field } y' = ut + \frac{1}{2}a_E t^2$$

$$= 0 + \frac{1}{2}a_E t^2 ; y' = \frac{1}{2}\frac{eE}{m}\left(\frac{l}{v}\right)^2 ; y' = \frac{1}{2}\frac{eE}{m}\frac{l^2}{v^2} ; y' = \frac{1}{2}\frac{eE}{m}\frac{l^2 B^2}{E^2}$$

$$y' = \frac{1}{2}\frac{e}{m}\frac{l^2 B^2}{E^2} \dots\dots\dots (2)$$

Then the deflection on the screen, $y \propto y'$ (or) $y = Cy'$

C → Proportionality constant.

$$\text{Using equation (2), } y = C \frac{1}{2}\frac{e}{m}\frac{l^2 B^2}{E^2} ; \frac{e}{m} = \frac{2yE}{Cl^2 B^2} \dots\dots\dots (3)$$

By substituting the known values, we get $\frac{e}{m} = 1.7 \times 10^{11} \text{ Ckg}^{-1}\text{m}$

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, $e v B = \frac{mv^2}{R}$

$$e B = \frac{mv}{R} ; e B = \frac{m\left(\frac{E}{B}\right)}{R} ; \frac{m}{B R}$$

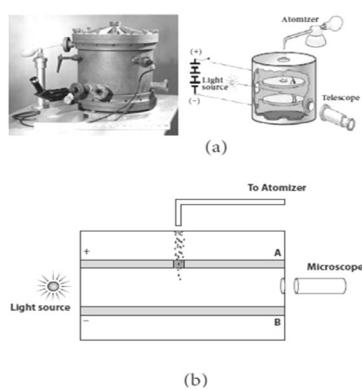
$$\frac{e}{m} = \frac{E}{B^2 R} \dots\dots\dots (4)$$

The specific charge is independent of (1) **Gas used**

(2) Nature of the electrodes

- 57. Discuss the Millikan's oil drop experiment to determine the charge of an electron.**

Millikan's oil drop method:



It consists of two horizontal circular metal **plates A and B each with diameter around 20 cm and are separated by a small distance 1.5 cm.**

These two parallel plates are enclosed in a chamber with glass walls.

A high potential difference around 10 kV applied across the metal plates, such that electric field acts vertically downward.

A small hole is made at the centre of the upper plate A and atomizer is kept exactly above the hole to spray the liquid. When a fine droplet of highly viscous liquid (like glycerin) is sprayed using atomizer, it falls freely downward through the hole of the top plate only under the influence of gravity.

Few oil drops in the chamber can acquire electric charge (negative charge) because of friction with air or passage of x-rays in between the parallel plates. Further the chamber is illuminated by light which is passed horizontally and oil drops can be seen clearly using microscope placed perpendicular to the light beam. These drops can move either upwards or downwards.

Radius of oil drop:

When the electric field is switched off, the oil drop accelerates downwards. Due to the presence of air drag forces, the oil drops easily attain its terminal velocity and moves with constant velocity. Let it be ' v '

Radius of the oil drop = r ; Density of the Oil = ρ

Density of the air = σ

The downward gravitational force acting on the oil drop is.

$$F_g = mg = \rho V g = \rho \left[\frac{4}{3} \pi r^3 \right] g$$

The up-thrust force experienced by the oil drop due to displaced air is

$$F_b = m'g = \sigma V g = \sigma \left[\frac{4}{3} \pi r^3 \right] g$$

Once the oil drop attains a terminal velocity v , the net downward force acting on the oil drop is equal to the viscous force acting opposite to the direction of motion of the oil drop.

From Stokes law, the viscous force on the oil drop is ; $F_v = 6 \pi r \eta v$
 From the free body diagram, $F_g = F_b + F_v$

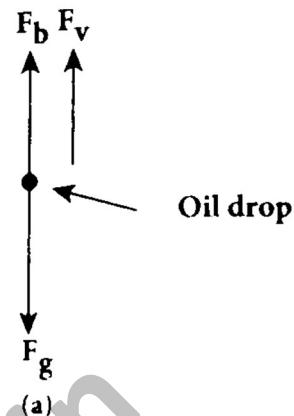
$$\rho \left[\frac{4}{3} \pi r^3 \right] g = \sigma \left[\frac{4}{3} \pi r^3 \right] g + 6 \pi r \eta v$$

$$\rho \left[\frac{4}{3} \pi r^3 \right] g - \sigma \left[\frac{4}{3} \pi r^3 \right] g = 6 \pi r \eta v$$

$$\frac{4}{3} \pi r^3 (\rho - \sigma) g = 6 \pi r \eta v$$

$$\frac{r^3}{r} = \frac{18}{4} \frac{\pi \eta v}{\pi(\rho - \sigma) g}; r^2 = \frac{9 \eta v}{2(\rho - \sigma) g};$$

$$r = \left[\frac{9 \eta v}{2(\rho - \sigma) g} \right]^{\frac{1}{2}} \dots\dots\dots (1)$$



(2) Determination of electric charge:

When the electric field is switched on, charged oil drops experience an upward electric force (qE). Strength of the electric field is adjusted to make that particular drop to be stationary. Under these circumstances, there will be no viscous force acting on the oil drop.

From the free body diagram, $F_g = F_b + F_v$

$$\rho \left[\frac{4}{3} \pi r^3 \right] g = \sigma \left[\frac{4}{3} \pi r^3 \right] g + q E \text{ (or)}$$

$$q E = \rho \left[\frac{4}{3} \pi r^3 \right] g - \sigma \left[\frac{4}{3} \pi r^3 \right] g; q$$

$$E = \frac{4}{3} \pi r^3 (\rho - \sigma) g$$

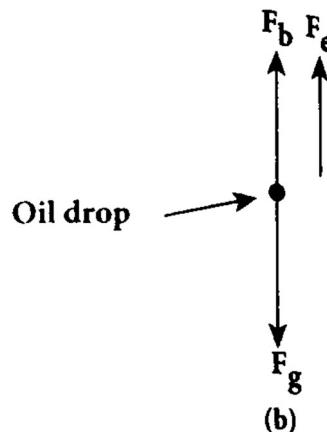
$$q = \frac{4}{3E} \pi r^3 (\rho - \sigma) g$$

Put equation (1), we get

$$q = \frac{4}{3E} \pi \left[\frac{9 \eta v}{2(\rho - \sigma) g} \right] \left[\frac{9 \eta v}{2(\rho - \sigma) g} \right]^{\frac{1}{2}} (\rho - \sigma) g$$

$$q = \frac{18}{E} \pi [\eta v] \left[\frac{\eta v}{2(\rho - \sigma) g} \right]^{\frac{1}{2}} (\rho - \sigma) g;$$

$$q = \frac{18}{E} \pi \left[\frac{\eta^3 v^3}{2(\rho - \sigma) g} \right]^{\frac{1}{2}} \dots\dots\dots (2)$$



Millikan repeated this experiment several times and computed the charges on oil drops. He found that the charge of any oil drop can be written as integral multiple of a basic value, (-1.6×10^{-19} C), which is nothing but the charge of an electron. Hence, $e = -1.6 \times 10^{-19}$ C,

- 58. Derive the expression for radius and energy of the nth orbit of 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.

$$\vec{F}_{Centripetal} = -\frac{mv_n^2}{r_n} \hat{r};$$

$$\text{At equilibrium, } \vec{F}_{Coulomb} = \vec{F}_{Centripetal}$$

$$-\frac{1}{4\pi\epsilon_0} \frac{Ze^2}{r_n^2} \hat{r} = -\frac{mv_n^2}{r_n} \hat{r}; \frac{1}{4\pi\epsilon_0} \frac{Ze^2}{r_n^2} = \frac{mv_n^2}{r_n} \dots\dots\dots (1)$$

$$r_n = \frac{(4\pi\epsilon_0) m v_n^2 r_n^2}{Z e^2}; r_n = \frac{(4\pi\epsilon_0) m^2 v_n^2 r_n^2}{Z e^2 m}; r_n = \frac{(4\pi\epsilon_0) [m v_n r_n]^2}{Z e^2 m}$$

$$\text{From Bohr's Postulate, } l_n = mv_n r_n = n \frac{\hbar}{2\pi} = n\hbar$$

$$\text{Hence, } r_n = \frac{(4\pi\epsilon_0) [l_n]^2}{Z e^2 m}; r_n = \frac{(4\pi\epsilon_0) \left[\frac{n\hbar}{2\pi}\right]^2}{Z e^2 m}$$

$$r_n = \frac{(4\pi\epsilon_0) n^2 \hbar^2}{Z e^2 m \times 4\pi^2}; r_n = \left[\frac{\hbar^2 \epsilon_0}{\pi m e^2} \right] \frac{n^2}{Z} \dots\dots\dots (2)$$

$$r_n = a_0 \frac{n^2}{Z} \dots\dots\dots (3) \text{ Where, } a_0 \rightarrow \frac{\hbar^2 \epsilon_0}{\pi m e^2} = 0.529 \text{\AA} \rightarrow \text{Bohr Radius}$$

$$\text{For hydrogen, (Z = 1), So radius of nth orbit, } r_n = a_0 n^2 \dots\dots\dots (4)$$

$$\text{For first orbit, } n = 1, \text{ (ground level) } r_1 = a_0 = 0.529 \text{\AA}$$

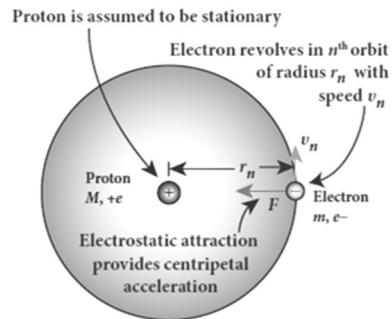
$$\text{For second orbit, } n = 2, \text{ (first excited level)}$$

$$r_2 = 4a_0 = 4 \times 0.529 \text{\AA} = 2.116 \text{\AA}$$

$$\text{For third orbit, } n = 3, \text{ (second excited level)}$$

$$r_3 = 9a_0 = 9 \times 0.529 \text{\AA} = 4.761 \text{\AA}$$

Thus, **radius of the orbit, $r_n \propto n^2$**



Velocity of electron in n^{th} orbit:

According to Bohr's quantization condition,

$$m v_n r_n = n \frac{h}{2\pi} ; m v_n a_0 \frac{n^2}{Z} = n \frac{h}{2\pi}$$

$$v_n = \frac{h}{2\pi m a_0} \frac{Z}{n} \dots\dots\dots(5)$$

Hence, $v_n \propto \frac{1}{n}$ (i.e.) the velocity of the electron decreases as the principal quantum number increases.

Total Energy of electron in n^{th} orbit:

Electrostatic force is a conservative force. So potential energy of the electron in n^{th} orbit, $U_n = \frac{1}{4\pi\epsilon_0} \frac{(+Ze)(-e)}{r_n} = -\frac{1}{4\pi\epsilon_0} \frac{Ze^2}{r_n}$

Kinetic energy of the electron in n^{th} orbit,

$$KE_n = \frac{1}{2} mv_n^2 = \frac{1}{2} \left[\frac{1}{4\pi\epsilon_0} \left[\frac{Ze^2}{r_n} \right] \right] \text{ [By equation (1)]}$$

Thus, $U_n = -2KE_n$

Therefore, total energy of the electron in n^{th} orbit,

$$\begin{aligned} E_n &= U_n + KE_n = -2KE_n + KE_n = -KE_n \\ E_n &= -\frac{1}{8\pi\epsilon_0} \frac{Ze^2}{r_n}. \end{aligned}$$

From equation (2), $r_n = \left[\frac{h^2\epsilon_0}{\pi m e^2} \right] \frac{n^2}{Z}$. Hence

$$E_n = -\frac{1}{8\pi\epsilon_0} \frac{Ze^2}{\left[\frac{h^2\epsilon_0}{\pi m e^2} \right] \frac{n^2}{Z}} ; E_n = -\frac{m e^4}{8\epsilon_0^2 h^2} \frac{Z^2}{n^2} \dots\dots\dots(6)$$

$$\text{For hydrogen, (Z=1), then } E_n = -\frac{m e^4}{8\epsilon_0^2 h^2} \frac{1}{n^2} \dots\dots\dots(7)$$

The negative sign in equation (7) indicates that the electron is bound to the nucleus. Put the values of ϵ_0 , h , m , e and using "eV" unit we have,

$$E_n = -\frac{13.6}{n^2} \text{ eV}$$

When, $n = 1$, $E_1 = -13.6 \text{ eV}$; When, $n = 2$, $E_2 = -3.4 \text{ eV}$

When, $n = 3$, $E_3 = -1.51 \text{ eV}$

Thus, as 'n' increases, energy also increases. (i.e.) the orbit which is closest to the nucleus has lowest energy. So it is often called ground state. The ground state energy of hydrogen (-13.6 eV) is used as a unit of energy called **Rydberg**. **1 Rydberg = -13.6 eV**

59. Explain the spectral series of hydrogen atom.

Spectral series of hydrogen atom:

When an electron jumps from n^{th} orbit to n^{th} orbit, a spectral line was obtained whose wave number (i.e.) reciprocal of wave length is,

$$\bar{\nu} = \frac{1}{\lambda} = R \left[\frac{1}{n^2} - \frac{1}{m^2} \right]. \text{ Here, } R \rightarrow \text{Rydberg Constant}$$

$(R = 1.097 \times 10^7 \text{ m}^{-1})$

From $m > n$, various spectral series are obtained.

(1) Lyman Series:

$n = 1$ and $m = 2, 3, 4, \dots$

$$\text{Hence the wave number, } \bar{\nu} = \frac{1}{\lambda} = R \left[\frac{1}{1^2} - \frac{1}{m^2} \right]$$

They lie in **ultra violet** region.

(2) Balmer Series:

$n = 2$ and $m = 3, 4, 5, \dots$

$$\text{Hence the wave number, } \bar{\nu} = \frac{1}{\lambda} = R \left[\frac{1}{2^2} - \frac{1}{m^2} \right]$$

They lie in **visible** region.

(3) Paschen Series:

$n = 3$ and $m = 4, 5, 6, \dots$

$$\text{Hence the wave number, } \bar{\nu} = \frac{1}{\lambda} = R \left[\frac{1}{3^2} - \frac{1}{m^2} \right]$$

They lie in **infra-red** region.

(4) Brackett Series:

$n = 4$ and $m = 5, 6, 7, \dots$

$$\text{Hence the wave number, } \bar{\nu} = \frac{1}{\lambda} = R \left[\frac{1}{4^2} - \frac{1}{m^2} \right]$$

They lie in **middle infra-red** region.

(5) Pfund Series:

$n = 5$ and $m = 6, 7, 8, \dots$

$$\text{Hence the wave number, } \bar{\nu} = \frac{1}{\lambda} = R \left[\frac{1}{5^2} - \frac{1}{m^2} \right]$$

They lie in **far infra-red** region.

- 60. Explain the variation of average binding energy with the mass number by graph and discuss its features.**

Binding energy curve:

The average binding energy per nucleon (\overline{BE}) is the energy required to separate single nucleon from the particular nucleus.

$$\overline{BE} = \frac{BE}{A} = \frac{[(Z m_p + N m_n) - M_A]C^2}{A}$$

\overline{BE} is plotted against A of all known nuclei and the graph obtained is called binding energy curve. From the graph,

- (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**.

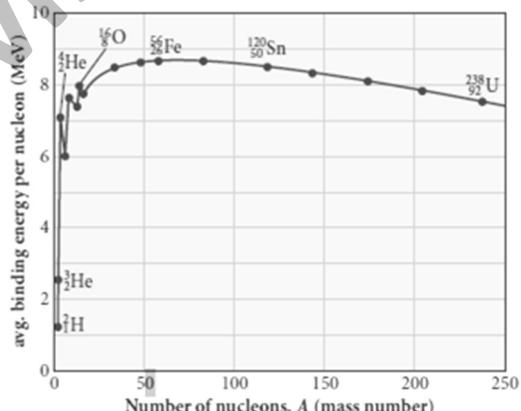
(3) For higher mass numbers, the curve reduces slowly and for **uranium is about 7.6 MeV**.

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.



61. 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,

$$\text{rate of decay} = \frac{dN}{dt}$$

From law of radioactivity, $\frac{dN}{dt} \propto N$

$$(\text{or}) \frac{dN}{dt} = -\lambda N \quad \dots \dots \dots (1)$$

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 $\frac{dN}{N} = -\lambda dt$

$$\text{Integrating on both sides, } \int_{N_0}^N \frac{dN}{N} = -\lambda \int_0^t dt ;$$

$$[\ln N]_{N_0}^N = -\lambda t$$

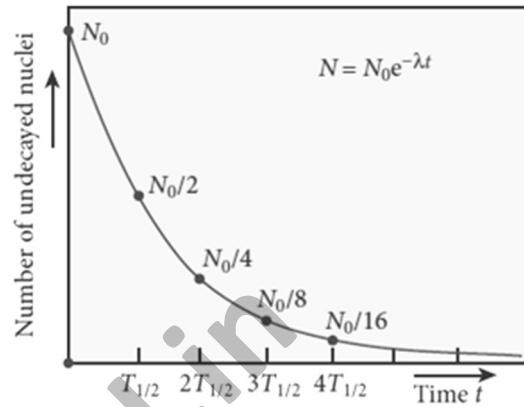
$$[\ln N - \ln N_0] = -\lambda t ; \ln \left[\frac{N}{N_0} \right] = -\lambda t$$

$$\text{Taking exponential on both sides, } \frac{N}{N_0} = e^{-\lambda t}$$

$$N = N_0 e^{-\lambda t} \quad \dots \dots \dots (2)$$

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.**



62. Obtain an expression for half life time and mean life time.

Half life time ($T_{1/2}$)

Half-life $T_{1/2}$ is the time required for the number of atoms initially present to reduce to one half of the initial amount.

From the law of radioactive decay, $N = N_0 e^{-\lambda t}$

$$\text{If } t = T_{1/2} \text{ then, } N = \frac{N_0}{2} \text{ Hence, } \frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}} ; \frac{1}{2} = e^{-\lambda T_{1/2}} \text{ (or)}$$

$$e^{-\lambda T_{1/2}} = 2$$

Taking log on both sides,

$$\lambda T_{1/2} = \ln 2 ; T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.6931}{\lambda}$$

If the number of atoms present at $t = 0$ is N_0 , then

- (1) Number of atoms remains un-decayed after 1st half-life = $\frac{N_0}{2}$
- (2) Number of atoms remains un-decayed after 2nd half-life = $\frac{N_0}{4}$
- (3) Number of atoms remains un-decayed after 3rd half-life = $\frac{N_0}{8}$

In general, after n half-lives, the number of nuclei remaining un-decayed is given by $N = \frac{N_0}{2^n}$

Mean life time (τ):

The mean life time of the nucleus is the ratio of sum or integration of life times of all nuclei to the total number nuclei present initially.

Let λ be the decay constant of the radioactive substance, then $\tau = \frac{1}{\lambda}$

Thus mean life and decay constant is inversely proportional to each other.

Half-life and mean life - Relation:

Half life time is given by, $T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.6931}{\lambda}$

Mean life period is given by, $\tau = \frac{1}{\lambda}$

From the above two equations, $T_{1/2} = \tau \ln 2 = 0.6931\tau$

63. Explain radio carbon dating.

Radio carbon dating:

The important application of beta decay is radioactive dating or carbon dating. Using this technique, the age of an ancient object can be calculated.

All living organisms absorb carbon dioxide (CO_2) from air to synthesize organic molecules. In this absorbed CO_2 , the major part is ^{12}C

and very small fraction $^{14}_6C$ whose **half-life is 5730 years.**

Carbon-14 in the atmosphere is always decaying but at the same time, cosmic rays from outer space are continuously bombarding the atoms in the atmosphere which produces $^{14}_6\text{C}$

So the continuous production and decay of $^{14}_6\text{C}$ in the atmosphere keep the ratio of $^{14}_6\text{C}$ to $^{12}_6\text{C}$ always constant. Since our **human body, tree or any living organisms continuously absorb CO₂ from the atmosphere**, the ratio of $^{14}_6\text{C}$ to $^{12}_6\text{C}$ in the living organism is also nearly constant. But when the organism dies, it stops absorbing CO₂. Since starts to decay, the ratio of $^{14}_6\text{C}$ to $^{12}_6\text{C}$ in a dead organism or specimen decreases over the years. Suppose the ratio of $^{14}_6\text{C}$ to $^{12}_6\text{C}$ in the ancient tree pieces excavated is known, and then the age of the tree pieces can be calculated.

64. Describe the working of nuclear reactor with a block diagram.

Nuclear reactor:

Nuclear reactor is a system in which the **nuclear fission** takes place in a self-sustained controlled manner. The energy produced is used either for research purpose or for power generation. The first nuclear reactor was built in the year 1942 at Chicago.

Main parts of Nuclear reactor:

(1) Fuel:

The commonly used fuels are $^{235}_{92}\text{U}$ and $^{239}_{94}\text{Pu}$

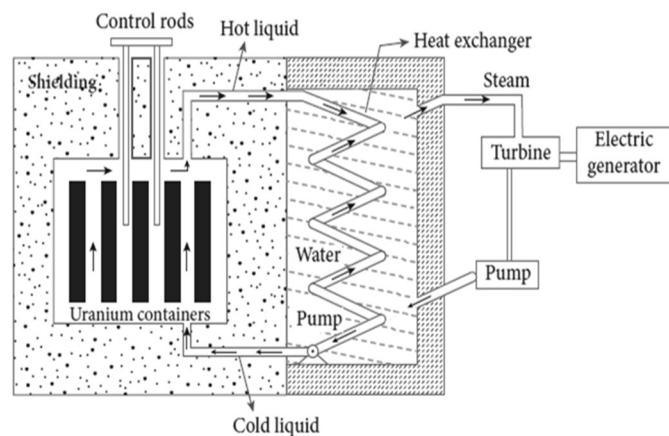
Naturally occurring uranium contains only 0.7% of $^{235}_{92}\text{U}$ and 99.3% are only $^{238}_{92}\text{U}$. So the $^{238}_{92}\text{U}$ must be enriched such that it 92 contains at least 2 to 4% of $^{235}_{92}\text{U}$.

(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.

(6) Shielding:

For a protection against harmful radiations, the nuclear reactor is surrounded by a concrete **wall of thickness of about 2 to 2.5 m**.

65. Briefly explain the elementary particles of nature.

Elementary particles:

An atom has a nucleus surrounded by electrons and nuclei are made up of protons and neutrons. Initially, protons, neutrons and electrons are considered as fundamental building blocks of matter.

But in 1964, **Murray Gellman and George Zweig** theoretically proposed that **protons and neutrons are not fundamental particles**, but they are **made up of quarks**. These quarks are now considered elementary particles of nature. Electrons are fundamental or elementary particles because they are not made up of anything. In the year 1968, the quarks were discovered experimentally by Stanford.

There are **six quarks namely**,

- | | | |
|-------------------|-------------------|------------------|
| (1) Up quark | (2) Down quark | (3) Charm quark |
| (4) Strange quark | (5) Top quark and | (6) Bottom quark |

There exist their anti-particles also. All these quarks have fractional charges.

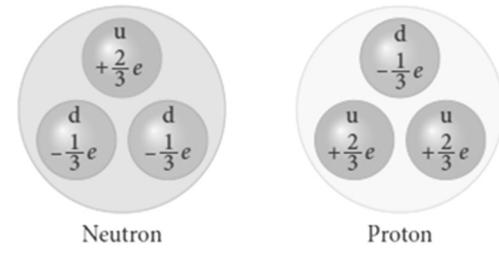
For example,

Charge of up quark is $= +\frac{2}{3}e$;

Charge of down quark is $= -\frac{1}{3}e$

According to quark model,

- (1) Proton is made up of two up quarks and one down quark
- (2) Neutron is made up of one up quark and two down quarks



66. Explain in detail the four fundamental forces.

Fundamental forces in nature:

Gravitational, electromagnetic, strong and weak forces are called fundamental forces of nature.

(1) Gravitational forces:

The **attractive force between two masses** is called gravitational force and it is universal in nature. Our planets are bound to the sun through gravitational force of the sun. We are in the Earth because of Earth's gravitational attraction on our body.

(2) Electromagnetic force:

Between **two charges there exists electromagnetic force** and it plays major role in most of our day-to-day events. We are standing on the surface of the earth because of the electromagnetic force between atoms of the surface of the earth with atoms in our foot. It is stronger than gravitational force.

(3) Strong Nuclear force:

Between two nucleons, there exists a strong nuclear force and this force is responsible for stability of the nucleus. The atoms in our body are stable because of strong nuclear force.

(4) Weak Nuclear force:

In addition to these three forces, there exists another fundamental force of nature called the weak force. This weak force is even shorter in range than nuclear force. This force plays an important role in beta decay and energy production of stars. During the fusion of hydrogen into helium in sun, neutrinos and enormous radiations are produced through weak force.

The lives of species in the earth depend on the solar energy from the sun and it is due to weak force which plays vital role during nuclear fusion reactions going on in the core of the sun.

UNIT – X (ELECTRONICS AND COMMUNICATION)

TWO MARKS AND THREE MARKS QUESTIONS AND ANSWERS

1. What is called electronics?

Electronics is the branch of physics incorporated with technology towards the design of circuits using transistors and microchips. It depicts the behaviour and movement of electrons in a semiconductor, vacuum, or gas.

2. What are passive components and active components?

Components that cannot generate power in a circuit are called passive components. (e.g.) **Resistors, inductors, capacitors**

Components that can generate power in a circuit are called active components. (e.g.) **transistors**

3. What is energy band?

When millions of atoms are brought close to each other, the valence orbital's and the unoccupied orbital's are split according to the number of atoms. Their energy levels will be closely spaced and will be difficult to differentiate the orbital's of one atom from the other and they look like a band. This band of very large number of closely spaced energy levels in a very small energy range is known as energy band.

4. What is valance band, conduction band and forbidden energy gap?

The energy band formed due to the valence orbitals is called **valence band**. The energy band that formed due to the unoccupied orbitals is called the **conduction band**. The energy gap between the valence band and the conduction band is called forbidden energy gap.

5. What is called intrinsic semiconductor?

A semiconductor in its **pure form without impurity** is called an intrinsic semiconductor. Its conduction is low. (e.g.) **Silicon, Germanium**.

6. Define Doping.

The process of **adding impurities to the intrinsic semiconductor** is called doping. It increases the concentration of charge carriers (electrons and holes) in the semiconductor and in turn, its electrical conductivity.

The impurity atoms are called doping.

7. 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.

8. Define hole.

When an **electron is excited, covalent bond is broken**. Now octet rule will not be satisfied. Thus each excited electron leaves a vacancy to complete bonding. This ‘deficiency’ of electron is termed as a ‘hole’

9. What is called P-type semiconductor?

A P - type semiconductor is obtained by **doping a pure Germanium (or Silicon) crystal with a doping of trivalent elements (acceptor impurity)** like Boron, Aluminium, Gallium and Indium. In P-type semiconductors, **Holes are majority charge carriers Electrons are minority charge carriers**

10. What is N-type semiconductor?

A N - type semiconductor is obtained by doping a pure Germanium (or Silicon) crystal with a doping of pentavalent elements (donor impurity) like Phosphorus, Arsenic and Antimony. In N-type semiconductors, **Electrons are majority charge carriers Holes are minority charge carriers**

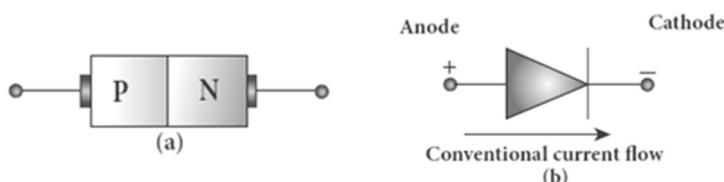
11. Define junction potential or barrier potential.

When P - type and N - type semiconductors combine to form PN junction, due to diffusion of majority charge carriers a depletion region is formed near the junction. It prevents the charge carriers to further diffusion across the junction.

Because a potential difference is set up by the immobile ions in this depletion region. This difference in potential across the depletion layer is called the barrier potential or junction potential. **This barrier potential approximately equals 0.7 V for Silicon and 0.3 V for Germanium.**

12. What is P-N junction diode? Give its symbol.

A P-N junction diode is formed when a P - type semiconductor is fused with a N-type semiconductor. It is a device with single P-N junction. The Schematic representation and circuit symbol is given below.



13. What is called biasing? Give its types.

Biassing is **the process of giving external energy to charge carriers to overcome the barrier potential and make them move in a particular direction.**

The external voltage applied to the p-n junction is called bias voltage.

Depending on the polarity of the external source to the P-N junction we have two types of biasing (1) Forward bias (2) Reverse bias

14. Differentiate forward bias and reverse bias.

Forward bias:

If the **positive terminal of the external voltage** source is connected to the **P-side** and the **negative terminal** to the **N-side**, it is called **forward biased**. It reduces width of the depletion region.

Reverse bias:

If the positive terminal of the battery is connected to the N-side and the negative potential to the P- side, the junction is said to be reverse biased. It increases width of the depletion region.

15. Define reverse saturation current.

Under reverse bias, a small current flows across the junction due to the minority charge carriers in both regions. Because the reverse bias for majority charge carriers serves as the forward bias for minority charge carriers. The current that flows under a reverse bias is called the reverse saturation current or leakage current (IS). **It depends on temperature.**

16. What is meant by 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.

17. What is mean by break down voltage?

The reverse saturation current due to the minority charge carriers is small. If the reverse bias applied to a P-N junction is increased beyond a point, the junction breaks down and the reverse current rises sharply.

The **voltage at which this breakdown happens** is called the breakdown voltage. It depends on the width of the depletion region, which in turn depends on the doping level.

18. Write a note on Zener breakdown.

Zener breakdown:

It will occur in heavily doped P-N junctions which have narrow depletion layers ($<10^{-6}$ m). When a reverse voltage across this junction is increased to the breakdown limit, a very strong electric field of strength $3 \times 10^7 \text{ V m}^{-1}$ is set up across the narrow layer. This **electric field is strong enough to break or rupture the covalent bonds in the lattice and thereby generating electron-hole pairs**. This effect is called **Zener effect**.

Even a small further increase in reverse voltage produces a large number of charge carriers. Hence the junction has very low resistance in the breakdown region.

This process of emission of electrons due to the rupture of bands in from the lattice due to strong electric field is known as internal field emission or field ionization. The electric field required for this is of the order of 10^6 V m^{-1}

19. Write a note on avalanche break down.

Avalanche breakdown:

It will occur in lightly doped junctions which have wide depletion layers. Here the electric field is not strong enough to produce breakdown.

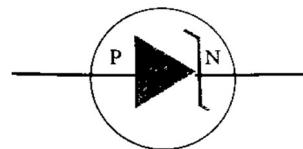
But the minority charge carriers accelerated by the electric field gains sufficient kinetic energy, collide with the semiconductor atoms while passing through the depletion region. This leads to the breaking of covalent bonds and in turn generates electron-hole pairs.

The newly generated charge carriers are also accelerated by the electric field resulting in more collisions and further production of charge carriers.

This cumulative process leads to an avalanche of charge carriers across the junction and consequently reduces the reverse resistance. This is known as avalanche breakdown. Here the diode current increases sharply.

20. 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 below.



21. 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.

22. What is an optoelectronic device?

The devices which convert **electrical energy into light and light into electrical energy through semiconductors** are called optoelectronic devices.

Optoelectronic device is an electronic device which **utilizes light for useful applications. (e.g.) LEDs, photo diodes and solar cells.**

23. What is light emitting diode (LED)?

LED is a P-N junction diode which emits visible or invisible light when it is forward biased. Here **electrical energy is converted into light energy**; this process is also called **electroluminescence**. The circuit symbol of LED is given below.



24. Give the applications of LEDs.

Indicator lamps on the front panel of the scientific and laboratory equipment's, Seven-segment displays **Traffic signals, exit signs, emergency, vehicle lighting etc. Industrial process control**, position encoders, bar graph readers.

25. What is photo diode? Give its circuit symbol.

A P-N junction diode which converts an optical signal into electric current is known as photodiode. Its operation exactly opposite to that of an LED. Photo diode works in reverse bias. The circuit symbol of photo diode is given below.



26. Give the applications of photo diode.

Alarm system, Count items on a conveyer belt, Photoconductors Compact disc players, smoke detectors, Medical applications such as detectors for computed tomography etc..

27. What are called solar cells?

A solar cell, also known as **photovoltaic cell, converts light energy directly into electricity or electric potential difference** by photovoltaic effect. It is basically a P-N junction which generates emf when solar radiation falls on the P-N junction.

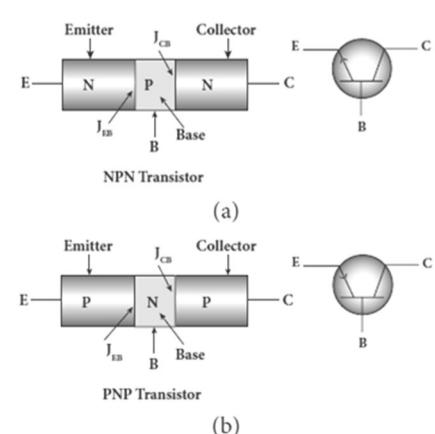
28. Give the applications of solar cells.

Solar cells are widely used in calculators, watches, toys, portable power supplies, etc. Solar cells are used in satellites and space applications. Solar panels are used to generate electricity.

29. Write a note on 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)**. The schematic symbol and circuit symbol of PNP and NPN transistors are given below.



30. Discuss the different modes of transistor biasing.

(1) Forward Active:

In this bias the emitter-base junction (J_{EB}) is forward biased and the collector-base junction (J_{CB}) is reverse biased. The transistor is in the active mode and in this mode, the transistor functions as an amplifier.

(2) Saturation:

Here, both the emitter-base junction (J_{EB}) and collector-base junction (J_{CB}) are forward biased. The transistor has a very large flow of currents across the junctions and in this mode; transistor is used as a closed switch.

(3) Cut-off:

In this bias, both the emitter-base junction (J_{EB}) and collector-base junction (J_{CB}) are reverse biased. Transistor in this mode is an open switch.

31. Draw the circuit diagram of common base configurations of NPN transistor.

Common base configuration:

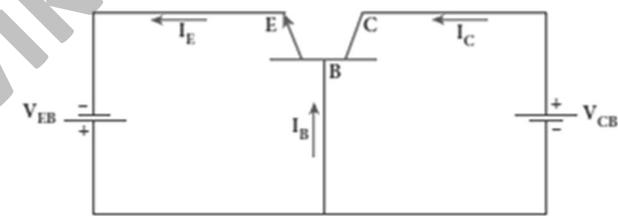
Input terminal – Emitter,

Output terminal – Collector,

Common terminal - Base,

Input current = I_E ; Output current = I_C

The input signal (V_{BE}) is applied across emitter - base junction. The output signal (V_{CB}) is measured across collector - base junction.



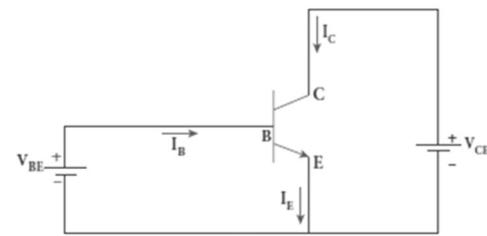
32. Draw the circuit diagram of common emitter configurations of NPN transistor.

Common emitter configuration:

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.

- 33. Draw the circuit diagram of common collector configurations of NPN transistor.**

Common collector configuration:

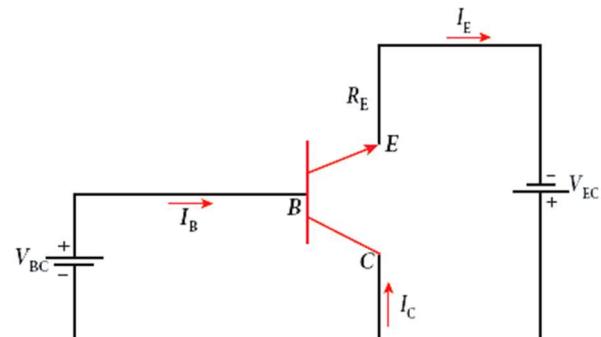
Input terminal – Base,

Output terminal- Emitter,

Common terminal - Collector, Input

current = I_B ; Output current= I_E

The input signal (V_{BC}) is applied across base - collector junction. The output signal (V_{EC}) is measured across emitter - collector junction.



- 34. Define input resistance of transistor.**

The ratio of the change in base-emitter voltage (ΔV_{BE}) to the change in base current (ΔI_B) at a constant collector-emitter voltage (V_{CE}) is called the input resistance (r_i). $r_i = \left[\frac{\Delta V_{BE}}{\Delta I_B} \right]_{V_{CE}}$

The **input resistance is high for a transistor** in common emitter configuration.

- 35. Define output resistance of transistor.**

The ratio of the change in collector-emitter voltage (ΔV_{CE}) to the change in collector current (ΔI_C) at a constant base current (I_B) is called the output resistance (r_o). $r_o = \left[\frac{\Delta V_{CE}}{\Delta I_C} \right]_{I_B}$

The **output resistance is very low for a transistor** in common emitter configuration.

- 36. Define forward current gain.**

The ratio of the change in collector current (ΔI_C) to the change in base current (ΔI_B) at constant collector-emitter voltage (V_{CE}) is called forward current gain (β). $\beta = \left[\frac{\Delta I_C}{\Delta I_B} \right]_{V_{CE}}$

Its value is very high and it generally ranges from 50 to 200.

- 37. 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

$$\alpha = \frac{\beta}{1+\beta} \quad (\text{or}) \quad \beta = \frac{\alpha}{1-\alpha}$$

38. What is called transistor amplifier?

A transistor operating in the active region has the capability to amplify weak signals. Amplification is the process of increasing the signal strength (increase in the amplitude).

39. What is called transistor oscillator?

An electronic oscillator basically **converts DC energy into AC energy of high frequency ranging from a few Hz to several MHz**. Hence, it is a source of alternating current or voltage. Unlike an amplifier, oscillator does not require any external signal source.

40. Give the types of an oscillator.

There are two types of oscillators:

- (1) Sinusoidal and, (2) Non-sinusoidal

Sinusoidal oscillators generate oscillations in the form of sine waves at constant amplitude and frequency,

Non-sinusoidal oscillators generate complex **non-sinusoidal waveforms** like **square wave, triangular wave or saw-toothed wave**.

41. Draw the block diagram of an oscillator Block diagram of oscillator:

Oscillator essentially consists three main parts,

(1) Tank circuit:

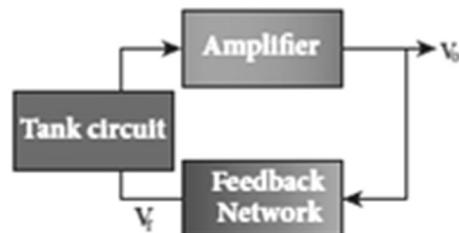
The tank circuit generates electrical oscillations and acts as the AC input source to the transistor amplifier.

(2) Amplifier:

Amplifier amplifies the input ac signal.

(3) Feedback network:

The feedback circuit provides a portion of the output to the tank circuit to sustain the oscillations without energy loss. Hence, an oscillator does not require an external input signal. The output is said to be self-sustained.



42. Give the Barkhausen conditions for sustained oscillations.

The loop phase shift must be 0° or integral multiples of 2π .

The loop gain must be unity. $|A\beta| = 1$

Here, A → Voltage gain of the amplifier, $\beta \rightarrow$ Feedback ratio

43. Give the applications of oscillator.

To generate a **periodic sinusoidal or non-sinusoidal wave forms**.

To generate **RF carriers**, to generate **audio tones**

To generate **clock signal in digital circuits**, as **sweep circuits in TV sets** and CRO.

44. Distinguish between analog and digital signal.

Analog Signal	Digital Signal
It is continuously varying voltage or current with respect to time	It contains only two discrete values of voltages (i.e.) low (OFF) and high (ON)
These signals are employed in rectifying circuits and transistor Amplifier circuits	These signals are employed in signal processing, communication etc.,

45. Distinguish between positive and negative logic.

Positive logic	Negative logic
Binary 1 stands for +5 V	Binary 1 stands for 0V
Binary 0 stands for 0 V	Binary 0 stands for +5 V

46. Why digital signals are preferred than analog signals?

Because of their better performance, accuracy, speed, flexibility and immunity to noise.

47. What are called logic gates?

A logic gate is an electronic circuit which functions based on digital signals. They are considered as the basic building blocks of most of the digital systems. It has one output with one or more inputs.

48. Give the circuit symbol, Boolean expression, logical operation and truth table of AND gate AND gate - circuit symbol:

Boolean expression:

Let A and B are the inputs and Y be the output, then, $Y = A \cdot B$

Logical operation:

The output of AND gate is high (1) only when all the inputs are high (1). The rest of the cases the output is low (0)



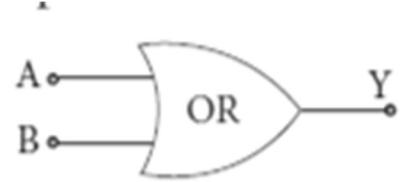
Truth table:

Inputs		Output
A	B	$Y = A \cdot B$
0	0	0
0	1	0
1	0	0
1	1	1

- 49.** Give the circuit symbol, Boolean expression, logical operation and truth table of OR gate, OR gate - circuit symbol:

Boolean expression:

Let A and B are the inputs and Y be the output, then $Y = A + B$



Logical operation:

The output of OR gate is high (1) when either of the inputs or both are high (1)

Truth table:

Inputs		Output
A	B	$Y = A + B$
0	0	0
0	1	1
1	0	1
1	1	1

- 50.** Give the circuit symbol, Boolean expression, logical operation and truth table of NOT gate, NOT gate - circuit symbol:

Boolean expression:

If A be the input and Y be the output, then $Y = \bar{A}$



Logical operation:

The output is the complement of the input. It is represented with an over bar. It is also called as inverter.

The output Y is high (1), when input is low (0) and vice versa.

Truth table:

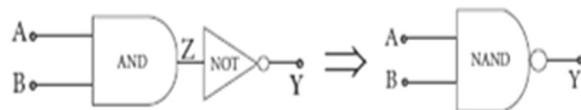
Inputs		Output
A	$Y = \bar{A}$	
0	1	
1	0	

- 51.** Give the circuit symbol, Boolean expression, logical operation and truth table of NAND gate.

Boolean equation: Let A and B are the inputs and Y be the output, then

$$Y = \overline{A \cdot B}$$

Logic operation:



The output Y equals the complement of AND operation. The circuit is an AND gate followed by a NOT gate. Therefore, it is summarized as NAND. The output is at logic zero only when all the inputs are high. The rest of the cases, the output is high (Logic 1 state).

Truth table:

Inputs		Output (AND)	Output (NAND)
A	B	$Z = A \cdot B$	$Y = \overline{A \cdot B}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

- 52. Give the circuit symbol, Boolean expression, logical operation and truth table of NOR gate.**

NOR gate - circuit symbol:



Boolean expression:

Let A and B are the inputs and Y be the output, then $Y = \overline{A + B}$

Logical operation:

The output Y equals the complement of OR operation

The circuit is an OR gate followed by a NOT gate and is summarized as NOR. The output is high (1) when all the inputs are low (0). The output is low (0) for all other combinations of inputs.

Inputs		Output (OR)	Output (NOR)
A	B	$Z = A + B$	$Y = \overline{A + B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

- 53. Give the circuit symbol, Boolean expression, logical operation and truth table of EX-OR gate.**

EX-OR gate - circuit symbol:



Boolean expression:

Let A and B are the inputs and Y be the output, then $Y = A \cdot B + \bar{A} \cdot \bar{B}$

$$Y = A \oplus B$$

Logical operation:

The output Y is high (1) only when either of the two inputs is high (1).

In the case of an Ex-OR gate with more than two inputs, the output will be high (1) when odd number of inputs are high (1)

Truth table:

Inputs		Output
A	B	$Y = A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

- 54. State De-Morgan's theorems.**

Theorem - 1 :

The complement of the **sum of two logical inputs** is equal to the **product of its complements**. $\overline{A + B} = \bar{A} \cdot \bar{B}$

Theorem - 2 :

The complement of the **product of two logical inputs** is equal to the **sum of its complements**. $\overline{A \cdot B} = \bar{A} + \bar{B}$

- 55. What is an integrated circuit?**

An integrated circuit (IC) or a chip or a microchip is an electronic circuit, which **consists of thousands to millions of transistors**, resistors, capacitors, etc. integrated on a small flat piece of Silicon.

- 56. What are the applications of integrated circuits (ICs?)**

Low cost, great performance, Very small in size, High reliability

They can function as an amplifier, oscillator, timer, and microprocessor and computer memory.

57. Distinguish between digital IC and analog IC

Digital IC:

Digital ICs uses digital signals (logical 0 and 1). They usually find their applications in **computers, networking equipment, and most consumer electronics.**

Analog IC:

Analog (or) linear ICs work with continuous values. Linear ICs are typically used in **audio and radio frequency amplification.**

58. How electron-hole pairs are created in a semiconductor material?

A small increase in temperature is sufficient enough to break some of the covalent bonds and release the electrons free from the lattice. Hence a vacant site is created in the valance band and these vacancies are called holes which are treated to possess positive charges. Thus electrons and holes are the two charge carriers in semiconductors.

59. A diode is called as a unidirectional device. Explain

An ideal diode behaves as conductor when it is forward biased and behaves as an insulator when it is reverse biased. Thus diode conducts current only from P -type to N -type through the junction when it is forward biased. Hence Diode is a unidirectional device.

60. 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)

61. What is the necessity of modulation?

When the information signal of low frequency is transmitted over a long distance, there will be information loss occurs. As the frequency of the carrier signal is very high, it can be transmitted to long distances with less attenuation. Thus in the modulation process, carrier signal of very high frequency signal (radio signal) is used to carry the baseband signal (information)

62. Define 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 (AM)

63. Give the advantages and limitations of amplitude modulation (AM)

Advantages of AM:

Easy transmission and reception, lesser bandwidth requirements
Low cost

Limitations of AM:

Noise level is high, Low efficiency, Small operating range

64 Define frequency modulation (FM)

If the frequency of the carrier signal is modified according to the **instantaneous amplitude of the baseband signal**, then it is called frequency modulation (FM)

65. Give the advantages and limitations of frequency modulation (FM)

Advantages of FM:

Large decrease in noise. This leads to an increase in signal-noise ratio.
The operating range is quite large. The transmission efficiency is very high as all the transmitted power is useful. FM bandwidth covers the entire frequency range which humans can hear. Due to this, FM radio has better quality compared to AM radio.

Limitations of 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.

66 Define phase modulation (PM)

The instantaneous amplitude of the baseband signal modifies the **phase of the carrier signal keeping the amplitude and frequency constant** is called phase modulation.

67. What is called centre frequency or resting frequency?

When the frequency of the baseband signal is zero (no input signal), there is no change in the frequency of the carrier wave. It is at its normal frequency and is called as centre frequency or resting frequency.

Practically **75 kHz is the allotted frequency of the FM transmitter.**

68. Give the advantages of phase modulation (PM)

Advantages of PM:

FM signal produced from PM signal is very stable.

The centre frequency called resting frequency is extremely stable.

69. Compare FM and PM?

Comparison between FM and PM:

PM wave is similar to FM wave. PM generally uses a smaller bandwidth than FM. In other words, in PM, more information can be sent in a given bandwidth. Hence, phase modulation provides high transmission speed on a given bandwidth.

70. What is called base band signals?

Information can be in the form of a sound signal like speech, music, pictures, or computer data. The electrical equivalent of the original information is called the baseband signal.

71. Define band width.

The frequency ranges over which the baseband signals or the information signals such as voice, music, picture, etc. is transmitted is known as bandwidth. Bandwidth gives the difference between the upper and lower frequency limits of the signal. If **V₁ and V₂ are the lower and upper-frequency limits of a signal, then the bandwidth, BW = V₂ - V₁**

72. Define the size of the antenna.

Antenna is used at both transmitter and receiver end. Antenna height is an important parameter to be discussed. The height of the antenna must be a multiple of $\frac{\lambda}{4}$. (i.e.) $h = \frac{\lambda}{4} = \frac{c}{4\nu}$

73. What are the three modes of propagation of electromagnetic waves through space.

Ground wave propagation (or) surface wave propagation
(nearly 2 kHz to 2 MHz).

Sky wave propagation (or) ionospheric propagation
(nearly 3 MHz to 30 MHz)

Space wave propagation **(nearly 30 MHz to 400 GHz)**

74. Write a note on ground wave propagation.

If the electromagnetic waves transmitted by the transmitter glide over the **surface of the earth to reach the receiver, then the propagation** is called ground wave propagation. The corresponding waves are called ground waves or surface waves. It is mainly used in local broadcasting, radio navigation, for ship-to-ship, ship to-shore communication and mobile communication.

75. Give the factors that are responsible for transmission impairments.

Increasing distance:

The attenuation of the signal depends on

- (1) Power of the transmitter
- (2) Frequency of the transmitter, and
- (3) Condition of the earth surface.

Absorption of energy by the Earth:

When the transmitted signal in the form of EM wave is in contact with the Earth, it induces charges in the Earth and constitutes a current.

Due to this, the earth behaves like a leaky capacitor which leads to the attenuation of the wave. Tilting of the wave: As the wave:

As the wave progresses, the wave-front starts gradually tilting according to the curvature of the Earth. This increase in the tilt decreases the electric field strength of the wave. Finally, at some distance, the surface wave dies out due to energy loss.

76. Define sky wave propagation.

The mode of **propagation in which the electromagnetic waves radiated from an antenna, directed upwards at large angles gets reflected** by the ionosphere back to earth is called sky wave propagation or ionospheric propagation. The corresponding waves are called sky waves.

77. Define skip distance.

The shortest **distance between the transmitter and the point of reception** of the sky wave along the surface is called as the skip distance.

78. Define skip zone.

There is a zone in **between where there is no reception of electromagnetic waves** neither ground nor sky, called as skip zone or skip area.

79. What is space wave propagation?

The process of sending and receiving information signal through space is called space wave communication. **The electromagnetic waves of very high frequencies above 30 MHz are called as space waves.**

80. Define fibre optical communication.

The method of **transmitting information from one place to another in terms of light pulses through an optical fiber** is called fiber optic communication. It works on the **principle of total internal reflection**.

81. What is mean by RADAR?

Radar basically stands for **RA**dio **D**etection **A**nd **R**anging **S**ystem. It is one of the important applications of communication systems and is mainly **used to sense, detect, and locate distant objects like aircraft, ships, spacecraft, etc.**

82. Write a note on mobile communication and give its applications.

Mobile communication is used **to communicate with others in different locations without the use of any physical connection like wires or cables.**

It enables the people to communicate with each other regardless of a particular location like office, house, etc. It also provides communication access to remote areas.

Applications:

It is used for personal communication and **cellular phones offer voice and data connectivity with high speed.** Transmission of news across the globe is done within a few seconds. Using **Internet of Things (IoT)**, it is made possible to control various devices from a single device.

Example: home automation using a mobile phone.

It enables **smart classrooms, online availability of notes, monitoring student activities etc. in the field of education.**

83. Write a note on internet and give its applications.

Internet is a fast growing technology in the field of communication system with multifaceted tools. Internet is the largest computer network recognized globally that connects millions of people through computers. It finds extensive applications in all walks of life.

Applications:

Search engine:

The search engine is basically **a web-based service tool used to search for information on World Wide Web.**

Communication:

It helps **millions of people to connect with the use of social networking:** emails, instant messaging services and social networking tools.

E-Commerce:

Buying and selling of goods and services, transfer of funds are done over an electronic network.

84. Write a note on Global positioning system.

Global positioning system:

GPS stands for **Global Positioning System**. It is a global navigation satellite system that offers geo location and time information to a GPS receiver anywhere on or near the Earth. **GPS system works with the assistance of a satellite network. Each of these satellites broadcasts a precise signal like an ordinary radio signal.**

These signals that **convey the location data are received by a low-cost aerial** which is then translated by the GPS software.

The software is able **to recognize the satellite**, its location, and the time taken by the signals to travel from each satellite. The software then processes the data it accepts from each satellite **to estimate the location of the receiver.**

Applications:

Global positioning system is highly useful many fields such as

- (1) **Fleet vehicle management** (for tracking cars, trucks and buses),
- (2) **Wildlife management** (for counting of wild animals) and
- (3) **Engineering** (for making tunnels, bridges etc).

85. What do you mean by Internet of Things?

Using Internet of Things (IOT), it is made possible to control various devices from a single device. (e.g.) **Home automation using a mobile phone.**

86. Distinguish between wire-line and wireless communication?

Wire line communication:

Specify the range of electromagnetic waves in which it is used. Wire line communication. It is a (point-point communication) uses mediums like wires, cables and optical fibers. These systems **cannot be used for long distance transmission** as they are connected physically. Examples are **telephone, intercom and cable TV.**

Wireless communication

It **uses free space as a communication medium**. The signals are transmitted in the form of electromagnetic waves with the help of a transmitting antenna. Hence **wireless communication is used for long distance transmission**. Examples are **mobile, radio or TV broadcasting, and satellite communication.**

87. What are called noises?

It is the **undesirable electrical signal** that interfaces with the transmitted signal. Noise attenuates or **reduces the quality of the transmitted signal**. It may be **man-made** (automobiles, welding machines, electric motors etc.) or **natural** (lightning, radiation from sun and stars and environmental effects).

88. What are repeaters?

Repeaters are used **to increase the range or distance through which the signals are sent**. It is a combination of transmitter and receiver. The signals are received, amplified, and retransmitted with a carrier signal of different frequency to the destination. The best example is the **communication satellite in space**.

89. Define attenuation.

The **loss of strength of a signal while propagating through a medium** is known as attenuation.

90. Define Range.

It is the **maximum distance between the source and the destination** up to which the signal is received with sufficient strength.

FIVE MARKS QUESTIONS AND ANSWERS

91. Explain the classification of solids on the basis of energy band theory.

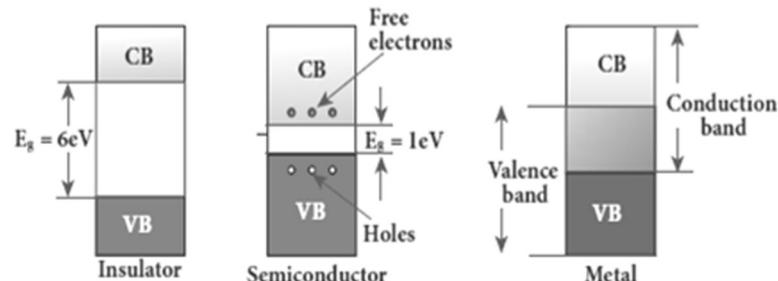
Classification of solids:

Based on the energy band theory, solids are classified in to three types, namely

- (1) Insulators, (2) Metals (Conductors), (3) Semiconductors

Insulators:

In insulator the valence band (VB) and the conduction band (CB) are separated by a large energy gap. The **forbidden energy gap** (E_g) is approximately 6 eV in insulators. The gap is very large that electrons from valence band cannot move into conduction band even on the application of strong external electric field or the increase in temperature.



Therefore, the electrical conduction is not possible as the free electrons are almost nil and hence these materials are called insulators.

Its resistivity is in the range of $10^{11} - 10^{19} \Omega\text{m}$

Metals (Conductors):

In metals, the valence band and conduction band overlap. Hence, electrons can move freely into the conduction band which results in a large number of free electrons in the conduction band.

Therefore, conduction becomes possible even at low temperatures. The application of electric field provides sufficient energy to the electrons to drift in a particular direction to constitute a current. **For metals, the resistivity value lies between 10^{-2} – $10^{-8} \Omega\text{m}$**

Semiconductors:

In semiconductors, there exists a narrow-forbidden energy gap ($E_g < 3\text{eV}$) between the valence band and the conduction band. At a finite temperature, thermal agitations in the solid can break the covalent bond between the atoms. This releases some electrons from valence band to conduction band.

Since free electrons are small in number, the conductivity of the semiconductors is not as high as that of the conductors. **The resistivity value of semiconductors is from 10^{-5} – $10^6 \Omega\text{m}$.** When the temperature is increased further, more number of electrons is promoted to the conduction band and increases the conduction.

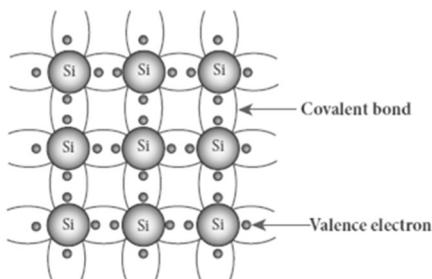
Thus, the electrical conduction increases with the increase in temperature. (i.e.) resistance decreases with increase in temperature. Hence, semiconductors are said to have negative temperature coefficient of resistance. The most important elemental semiconductor materials are **Silicon (Si) and Germanium (Ge)**.

At room temperature, forbidden energy gap for Si ; $E_g = 1.1\text{eV}$ and forbidden energy gap for Ge ; $E_g = 0.7\text{eV}$

92. Explain in detail the intrinsic semiconductor.

Intrinsic semiconductor:

A semiconductor in its pure form without impurity is called an intrinsic semiconductor. (e.g) silicon, germanium



Consider Silicon lattice. Each Silicon atom is covalently bonded with the neighbouring four atoms to form the lattice. At absolute zero (OK), this will behave as insulator, because there is no free charges.

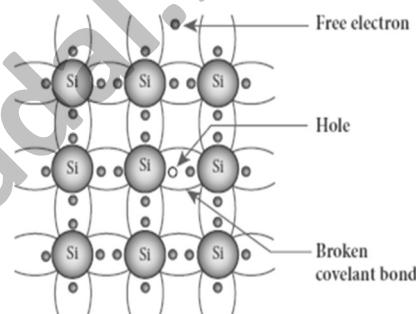
But at room temperature, some of the covalent bonds are broken and releases the electrons free from the lattice. As a result,

some states in the valence band become empty and the same number of states in the conduction band will be occupied.

The vacancies produced in the valence band are called holes which are treated as positive charges. Hence, electrons and holes are the two charge carriers in semiconductors. In intrinsic semiconductors, the number of electrons in the conduction band is equal to the number of holes in the valence band.

The conduction is due to the electrons in the conduction band and holes in the valence band. The total current (I) is always the sum of the electron current (I_e) and the hole current (I_h) ; $I = I_e + I_h$

The increase in temperature increases the number of charge carriers (electrons and holes).



93. Elucidate the formation of a N-type and P-type semiconductors.

N - type semiconductor:

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.**

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

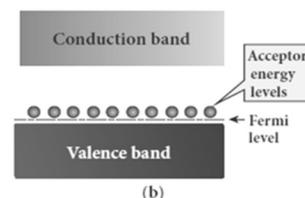
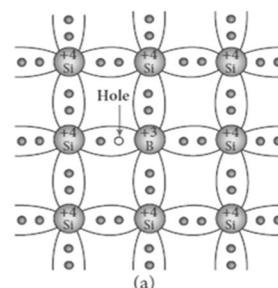
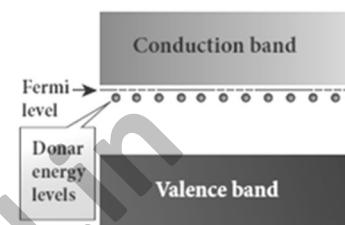
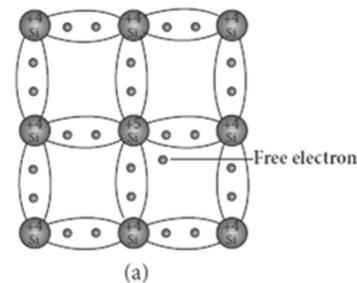
P - type semiconductor:

A n-type semiconductor is obtained by doping a pure Silicon (or Germanium) crystal with a doping from trivalent elements like Boron, Aluminium, Gallium and Indium.

The doping has three valence electrons while the Silicon atom has four valence electrons. During the process of doping, the doping with three valence electrons are bound with the neighbouring three Silicon atoms. As Silicon atom has four valence electrons, one electron position of the doping in the crystal lattice will remain vacant.

The missing electron position in the covalent bond is denoted as a hole. To make complete covalent, the doping is in need of one more electron.

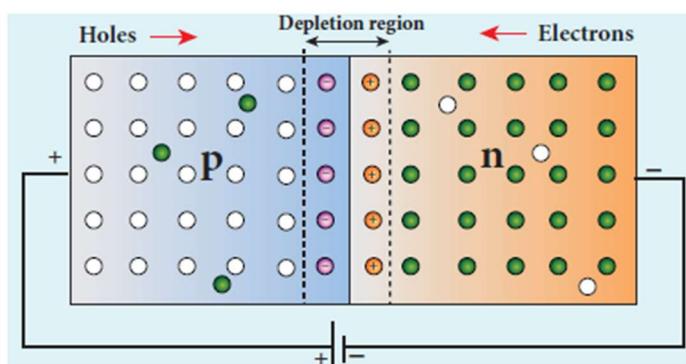
These doping can accept electrons from the neighbouring atoms. Therefore, this impurity is called an **acceptor impurity**. The energy level of the hole created by each impurity atom is just above the valence band and is called the **acceptor energy level**. For each acceptor atom, there will be a hole in the valence band in addition to the thermally generated holes. Hence, in an P-type semiconductor, the majority carriers - Holes minority carriers - Electrons



94. Explain the formation of PN junction diode. Discuss its V-I characteristics.

Formation of PN junction diode:

A P-N junction is formed by joining N-type and P-type semiconductor materials. Here the N-region has a high electron concentration and the P-region a high hole concentration. So the electrons diffuse from the N-side to the P-side. Similarly holes also diffuse from P-side to the N-side. This causes **diffusion current**.



charges on doping atom sites, which are fixed in the crystal lattice and are unable to move.

In a P-N junction, when the electrons and holes move to the other side of the junction, they leave behind exposed

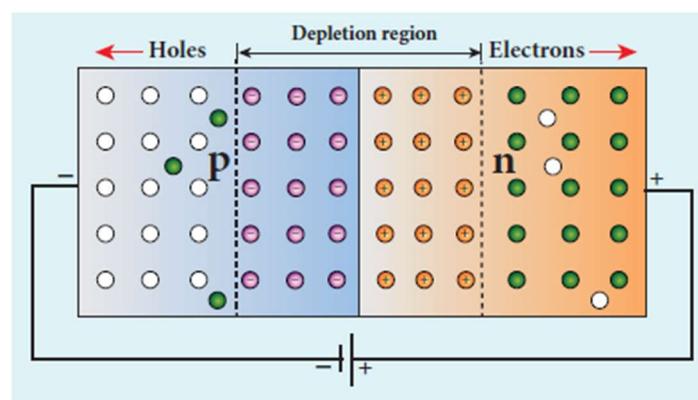
On the n-side, positive ion cores are exposed and on the p-side, negative ion cores are exposed. An electric field E forms between the positive ion cores in the n-type material and negative ion cores in the p-type material.

The electric field sweeps free carriers out of this region and hence it is called **depletion region** as it is depleted of free carriers. A **barrier potential** (V_b) due to the electric field E is formed at the junction.

As this diffusion of charge carriers from both sides continues, the negative ions form a layer of negative space charge region along the p-side. Similarly, a positive space charge region is formed by positive ions on the n-side.

The positive space charge region attracts electrons from P-side to n-side and the negative space charge region attracts holes from N-side to P-side.

This moment of carriers happens in this region due to the formed electric field and it constitutes a current called **drift current**. The diffusion current and drift current flow in the opposite direction and at one instant they both become equal. Thus, a P-N junction is formed.



V - I characteristics:

It is the study of the variation in current through the diode with respect to the applied voltage across the diode when it is forward or reverse biased.

Forward bias characteristics:

If the positive terminal of the external voltage source is connected to the P-side and the negative terminal to the N-side, it is called forward biased.

A graph is plotted by taking the forward bias voltage (V) along the x-axis and the current (I) through the diode along the y-axis. This graph is called the **forward V-I characteristics**.

From the graph,

- (1) At room temperature, a potential difference equal to the barrier potential is required before a reasonable forward current starts flowing across the diode. This voltage is known as **threshold voltage or cut-in voltage or knee voltage (V_{knee})**.
For Silicon $V_{knee} = 0.7 \text{ V}$; For Germanium; $V_{knee} = 0.3 \text{ V}$
- (2) The graph clearly infers that the current flow is not linear and is exponential. Hence it does not obey Ohm's law.
- (3) The forward resistance (r_f) of the diode is the ratio of the small change in voltage (ΔV) to the small change in current (ΔI), $r_f = \frac{\Delta V}{\Delta I}$
- (4) Thus, the diode behaves as a conductor when it is forward biased.

Reverse bias characteristics:

If the positive terminal of the battery is connected to the n-side and the negative potential to the p- side, the junction is said to be reverse biased.

A graph is drawn between the reverse bias voltage and the current across the junction, which is called the **reverse V - I characteristics**.

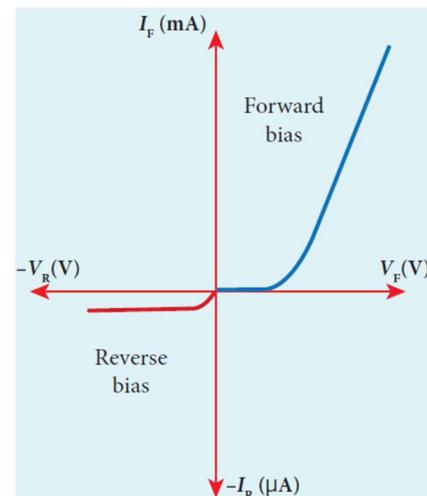
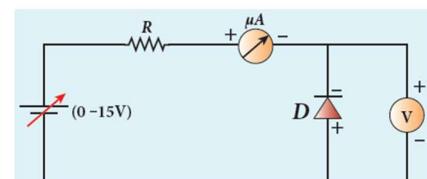
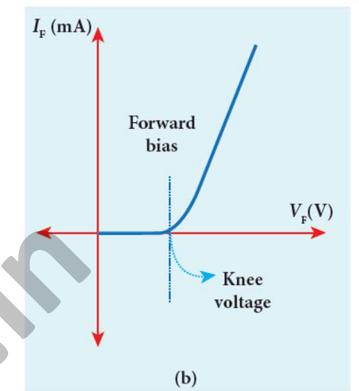
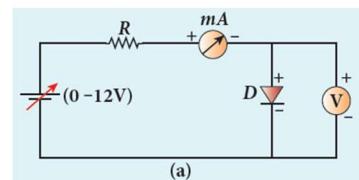
Under this bias, a very small current in μA , flows across the junction. This is due to the flow of the minority charge carriers called the **leakage current or reverse saturation current**.

For Silicon ; $I_{leakage} = 20\mu\text{A}$;

For Germanium; $I_{leakage} = 50\mu\text{A}$;

Besides, the current is almost independent of the voltage.

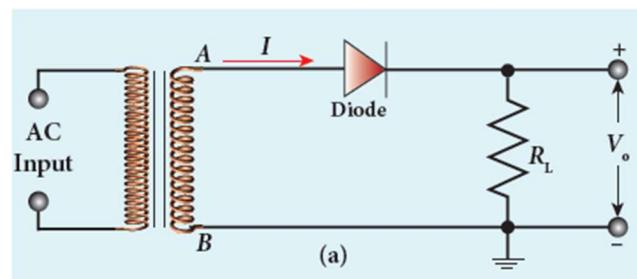
The reverse bias voltage can be increased only up to the rated value otherwise the diode will enter into the breakdown region.



95. Draw the circuit diagram of a half wave rectifier and explain its working.

Half wave rectifier:

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.

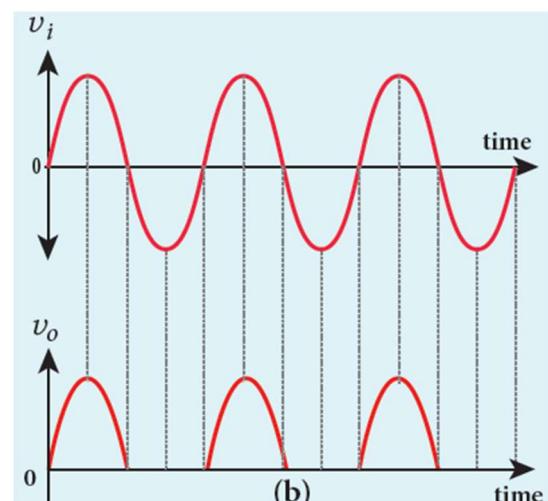
During positive half cycle of input AC	During negative half cycle of input AC
Terminal A becomes positive with respect to terminal B	Terminal B becomes positive with respect to terminal A.
The diode is forward biased and hence it conducts	The diode is reverse biased and hence it does not conduct
The current flows through the load resistor R_L and AC voltage developed across R_L constitutes the output voltage v_o	No current passes through R_L and there is no voltage 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 %**



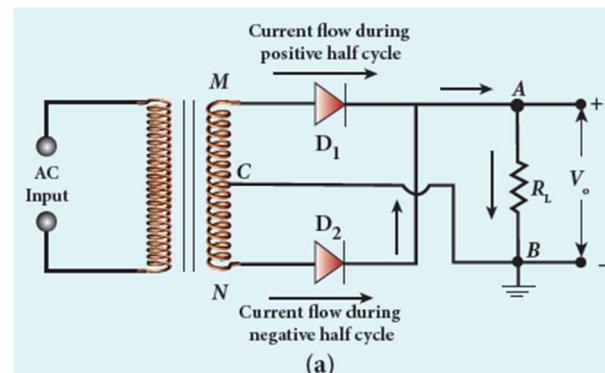
96. Explain the construction and working of a full wave rectifier.

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).

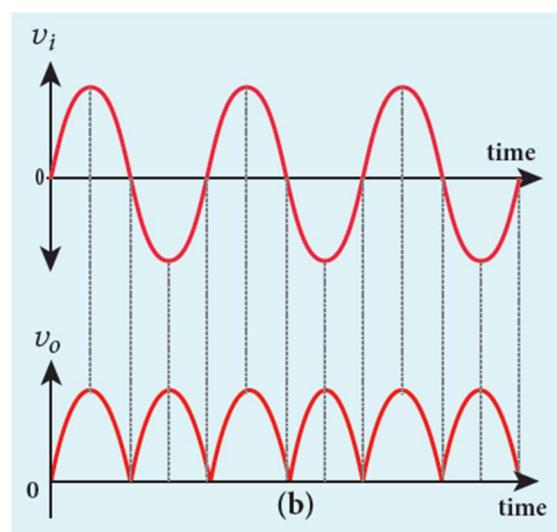
The centre (C) is usually taken as the ground or zero voltage reference point. Due to the centre tap transformer, the output voltage rectified by each diode is only one half of the total secondary voltage.



During positive half cycle of input AC	During negative half cycle of input AC
Terminal M is positive, C is at zero potential and N is at negative potential.	Terminal M is negative, C is at zero potential and N is at positive potential.
Diode D₁ is forward biased. Diode D₂ is reverse biased.	Diode D₁ is reverse biased. Diode D₂ is forward biased.
D ₁ conducts and current flows along the path MD₁ABC	D ₂ conducts and current flows along the path ND₂ABC

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 below.

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 %.**



97. Write a note on Zener diode. Explain the V - I characteristics of Zener diode.

Zener diode:

Zener diode is a reverse biased heavily doped Silicon diode, designed to be operated in the breakdown region. Zener breakdown occurs due to the breaking of covalent bonds by the strong electric field set up in the depletion region by the reverse voltage. **It produces an extremely large number of electrons and holes which constitute the reverse saturation current.**

V-I Characteristics of Zener diode:

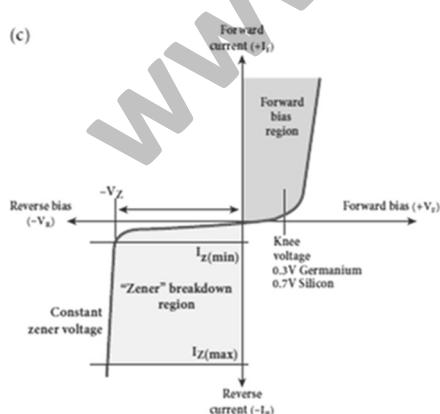
The circuit to study the forward and reverse characteristic s of a Zener diode is shown below. The V-I characteristics of a Zener diode is shown below. The forward characteristic of a Zener diode is similar to that of an ordinary P-N junction diode.

It starts conducting approximately around 0.7 V.

However, the reverse characteristics are highly significant in Zener diode. The increase in reverse voltage normally generates very small reverse current. While in Zener diode, when the reverse voltage is increased to the breakdown voltage (V_Z), the increase in current is very sharp. The voltage remains almost constant throughout the breakdown region.

Here, $I_Z(\max)$ represents the maximum reverse current. If the reverse current is increased further, the diode will be damaged.

The important parameters on the reverse characteristics are



$V_Z \rightarrow$ Zener breakdown voltage
 $I_Z(\min) \rightarrow$ minimum current to sustain breakdown
 $I_Z(\max) \rightarrow$ maximum current limited by maximum power dissipation.
 The Zener diode is operated in the reverse bias having the voltage greater than V_Z and current less than $I_Z(\max)$. 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,

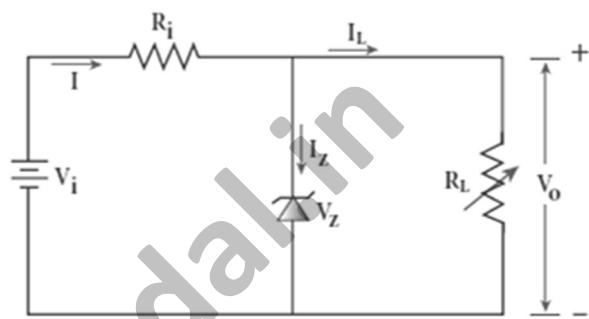
The reverse characteristic is not exactly vertical which means that the diode possesses some small resistance called Zener dynamic impedance.

Zener resistance is the inverse of the slope in the breakdown region. It means an increase in the Zener current produces only a very small increase in the reverse voltage which can be neglected. Thus the voltage of an ideal Zener diode does not change once it goes into breakdown. It means that V_Z remains almost constant even when I_Z increases considerably.

98. Explain the working of Zener diode as a voltage regulator.

Zener diode as a voltage regulator:

A Zener diode working in the breakdown region can serve as a voltage regulator. It maintains a constant output voltage even when input voltage (V_i) or load current (I_L) varies. Here, in this circuit the input voltage V_i is regulated at a constant voltage V_z (Zener voltage) at the output represented as V_o using a Zener diode.



The output voltage is maintained constant as long as the input voltage does not fall below V_z . When the potential developed across the diode is greater than V_z , the diode moves into the Zener breakdown region. It conducts and draws relatively large current through the series resistance. The total current I passing through R_s equals the sum of diode current I_z and load current I_L .

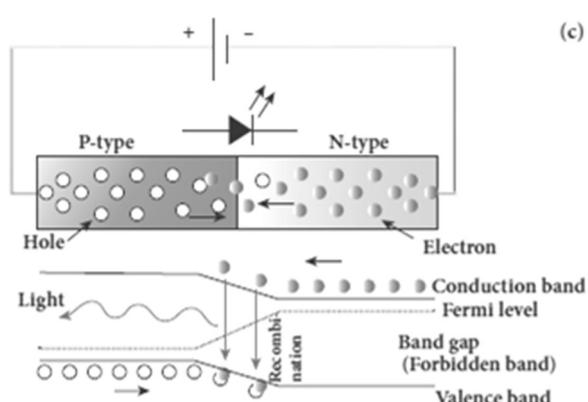
$$(\text{i.e.}) I = I_z + I_L$$

It is to be noted that the total current is always less than the maximum Zener diode current. Under all conditions $V_o = V_z$. Thus, output voltage is regulated.

99. What is meant by light emitting diode? Explain its working principle with diagram.

Light Emitting Diode (LED):

LED is a p-n junction diode which emits visible or invisible light when it is forward biased. Since, **electrical energy is converted into light energy**, this process is also called electro luminescence. It consists of a P-layer, **N-layer and a substrate**. A transparent window is used to allow light to travel in the desired direction. In addition, it has two leads; anode and cathode.



When the P-N junction is forward biased, the conduction band electrons on N-side and valence band holes on P-side diffuse across the junction. When they cross the junction, they become excess minority carriers (electrons in P-side and holes in N-side). These excess minority carriers recombine with oppositely charged majority carriers in the respective regions, i.e. the electrons in the conduction band recombine with holes in the valence band.

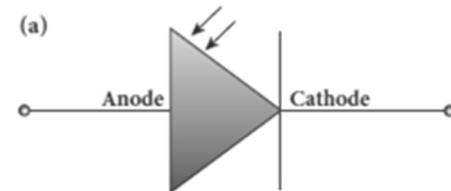
During recombination process, energy is released in the form of light (radioactive) or heat (non-radioactive). For radioactive recombination, a photon of energy $h\nu$ is emitted. For non-radioactive recombination, energy is liberated in the form of heat.

The colour of the light is determined by the energy band gap of the material. Therefore, **LEDs are available in a wide range of colours such as blue (SiC), green (AlGaP) and red (GaAsP). Now a day, LED which emits white light (GaN) is also available.**

100. Explain in detail about the photo diode.

Photo diode:

A P-N junction diode which converts an optical signal into electric current is known as photodiode. Thus, the operation of photodiode is exactly opposite to that of an LED. Photo diode works in reverse bias. Its circuit symbol below. The direction of arrows indicates that the light is incident on the photo diode. The device consists of a P-N junction semiconductor made of photosensitive material kept safely inside a plastic case.



It has a small transparent window that allows light to be incident on the P-N junction. Photodiodes can generate current when the P-N junction is exposed to light and hence are called as **light sensors**. When a photon of sufficient energy ($h\nu$) strikes the depletion region of the diode, some of the valence band electrons are elevated into conduction band, in turn holes are developed in the valence band.

This creates electron-hole pairs. The amount of electron hole pairs generated depends on the intensity of light incident on the P-N junction. These electrons and holes are swept across the P-N junction by the electric field created by reverse voltage before recombination takes place.

Thus, holes move towards the N-side and electrons towards the P-side. When the external circuit is made, the electrons flow through the external circuit and constitute the **photocurrent**. When the incident light is zero, there exists a reverse current which is negligible. This reverse current in the absence of any incident light is called **dark current** and is due to the thermally generated minority carriers.

101. Explain the working principle of Solar cell. Mention its applications.

Solar cell:

A solar cell, also known as **photovoltaic cell**, converts light energy directly into electricity or electric potential difference by photovoltaic effect.

It is basically a P-N junction which generates emf when solar radiation falls on the P-N junction.

A solar cell is of two types: P-type and N-type.

Both types use a combination of P-type and N-type Silicon which together forms the P-N junction of the solar cell.

The difference is that P-type solar cells use P-type Silicon as the base with an ultra-thin layer of N-type Silicon, while N-type solar cell uses the opposite combination. The other side of the P-Silicon is coated with metal which forms the back electrical contact.

On top of the N-type Silicon, metal grid is deposited which acts as the front electrical contact.

The top of the solar cell is coated with anti-reflection coating and toughened glass. In a solar cell, **electron-hole pairs** are generated due to the absorption of light near the junction.

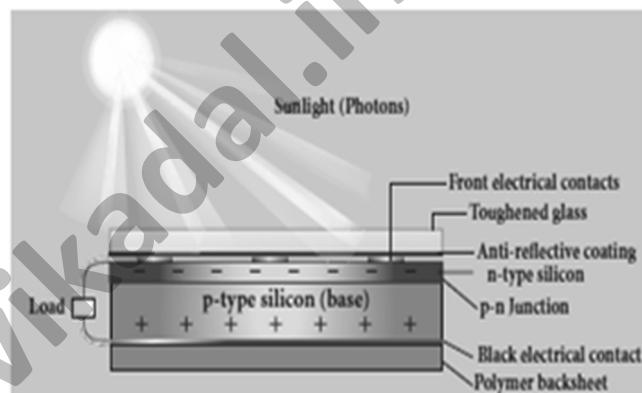
Then the charge carriers are separated due to the electric field of the depletion region. Electrons move towards N-type Silicon and holes move towards P-type Silicon layer.

The electrons reaching the N-side are collected by the front contact and holes reaching P-side are collected by the back electrical contact. Thus a potential difference is developed across solar cell.

When an external load is connected to the solar cell, photocurrent flows through the load. Many solar cells are connected together either in series or in parallel combination to form solar panel or module. Many solar panels are connected with each other to form solar arrays. For high power applications, solar panels and solar arrays are used.

Applications:

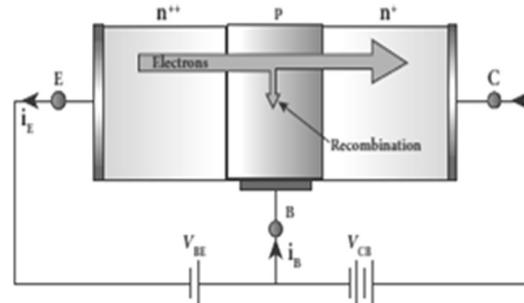
- (1) Solar cells are widely used in calculators, watches, toys, portable power supplies, etc.
- (2) Solar cells are used in satellites and space applications
- (3) Solar panels are used to generate electricity.



102. Explain transistor action in common base configuration.

Working of NPN transistor in CB mode:

Basically, a BJT can be considered as two P-N junction diodes connected back to back. In the forward active bias of the transistor, the emitter-base junction is forward biased by V_{EB} and the collector-base junction is reverse biased by V_{CB} . The forward bias decreases the depletion region across the emitter-base junction and the reverse bias increases the depletion region across the collector-base junction. Hence, the barrier potential across the emitter-base junction is decreased and the collector-base junction is increased.



In an NPN transistor, the majority charge carriers in the emitter are electrons. As it is heavily doped, it has a large number of electrons. The forward bias across the emitter-base junction causes the electrons in the emitter region to flow towards the base region and constitutes the emitter current (I_E).

The electrons after reaching the base region recombine with the holes in the base region. Since the base region is very narrow and lightly doped, all the electrons will not have sufficient holes to recombine and hence most of the electrons reach the collector region.

Eventually, the electrons that reach the collector region will be attracted by the collector terminal as it has positive potential and flows through the external circuit. This constitutes the collector current (I_C).

The holes that are lost due to recombination in the base region are replaced by the positive potential of the bias voltage V_{EB} and constitute the base current (I_B).

The magnitude of the base current will be in microamperes as against mill amperes for emitter and collector currents. It is to be noted that if the emitter current is zero, then the collector current is almost zero. It is therefore imperative that a BJT is called a current controlled device.

Applying Kirchhoff's law, we can write the emitter current as the sum of the collector current and the base current.

$$I_E = I_B + I_C$$

Since the base current is very small, we can write,

$$I_E \approx I_C$$

There is another component of collector current due to the thermally generated electrons called reverse saturation current, denoted as I_{CO} .

This factor is temperature sensitive. The ratio of the collector current to the emitter current is called the forward current gain (β) of a transistor.

The α of a transistor is a measure of the quality of a transistor. Higher the value of α better is the transistor. **The value of α is less than unity and ranges from 0.95 to 0.99.**

- 103. Sketch the static characteristics of a common emitter transistor and bring out the essence of input and output characteristics.**

Static characteristics of NPN transistor in CE mode:

V_{BE} – Base - emitter voltage

V_{CE} – Collector-emitter voltage

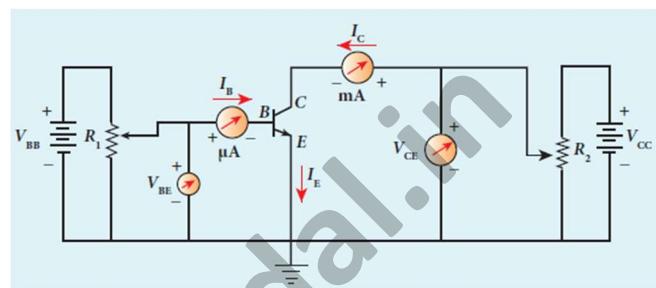
I_B – Base current

I_C – Collector current

V_{BB} & V_{CC} – Biasing voltages

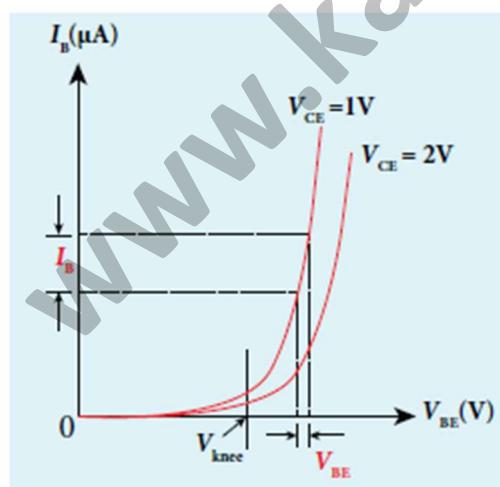
R_1 & R_2 – Variable resistors

(1) Input characteristics:



Input Characteristics curves give the **relationship between the base current (I_B) and base to emitter voltage (V_{BE}) at constant collector to emitter voltage (V_{CE})**. The curve looks like the forward characteristics of an ordinary P-N junction diode. There exists a threshold voltage or knee voltage (V_k) below which the base current is very small. Beyond the knee voltage, **the base current increases with the increase in base-emitter voltage**. It is also noted that the **increase in the collector-emitter voltage decreases the base current**.

This shifts the curve outward. This is because the increase in collector-emitter voltage increases the width of the depletion region in turn, reduces the effective base width and thereby the base current. The ratio of the change in base-emitter voltage (ΔV_{BE}) to the change in base current (ΔI_B) at a constant collector-emitter voltage (V_{CE}) is called the input resistance (r_i).



ratio of the change in base-emitter voltage (ΔV_{BE}) to the change in base current (ΔI_B) at a constant collector-emitter voltage (V_{CE}) is called the input resistance (r_i).

$$r_i = \left[\frac{\Delta V_{BE}}{\Delta I_B} \right]_{V_{CE}}$$

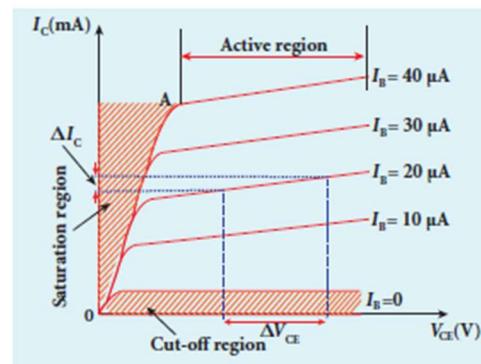
The **input resistance is high for a transistor in common emitter configuration.**

(2) Output characteristics:

The output characteristics give the relationship between the variation in the collector current (ΔI_C) with respect to the variation in collector-emitter voltage (ΔV_{CE}) at constant input current (I_B).

There are four important regions in the curve

- (i) Saturation region
- (ii) Cut-off region
- (iii) Active region
- (iv) Break down region



The ratio of the change in the collector emitter voltage (ΔV_{CE}) to the corresponding change in the collector current (ΔI_C) at constant base current (I_B) is called output resistance r_o .

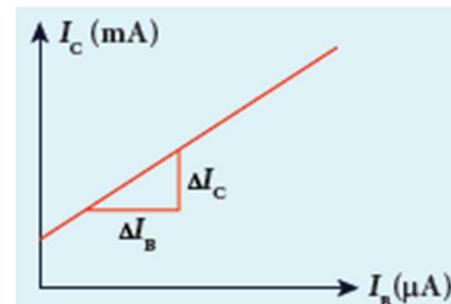
$$r_o = \left[\frac{\Delta V_{CE}}{\Delta I_C} \right]_{I_B}$$

The **output resistance for transistor in common emitter configuration is very low.**

(3) Current transfer characteristics:

This gives the variation of collector current (I_C) with changes in base current (I_B) at constant collector-emitter voltage (V_{CE}).

It is seen that a small I_C flows even when I_B is zero. This current is called the common emitter leakage current (I_{CEO}), which is due to the flow of minority charge carriers.



The ratio of the change in collector current (ΔI_C) to the change in base current (ΔI_B) at constant collector-emitter voltage (V_{CE}) is called forward current gain (β). $\beta = \left[\frac{\Delta I_C}{\Delta I_B} \right]_{V_{CE}}$. Its value is very high and it generally ranges from 50 to 200.

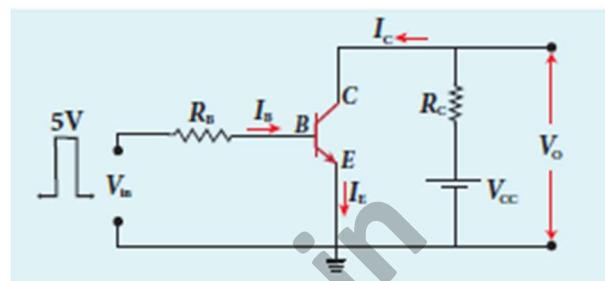
104. Transistor functions as a switch. Explain.

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):

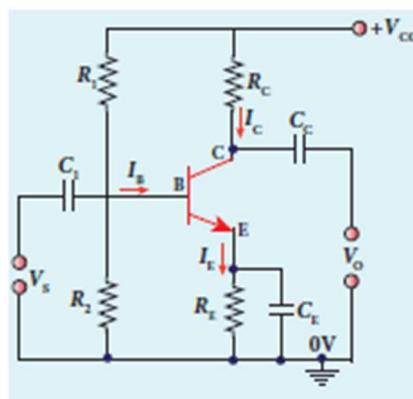
A low input voltage ($V_{in} = 0$ V), decreases the base current (I_B) and in turn decreases the collector current (I_C). The transistor will move into the cut-off region (turned OFF). The decrease in collector current (I_C) decreases the drop across RC , thereby increasing the output voltage, close 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.

105. Describe the function of a transistor as an amplifier with the neat circuit diagram. Sketch the input and output wave form.

Transistor as an amplifier:

Amplification is the process of increasing the signal strength (increase in the amplitude). If a large amplification is required, multistage amplifier is used. Here, the amplification of an electrical signal is explained with a single stage transistor amplifier.



Single stage indicates that the circuit consists of one transistor with the allied components. An NPN transistor is connected in the common emitter configuration. A load resistance, R_L is connected in series with the collector circuit to measure the output voltage.

The capacitor C_1 allows only the ac signal to pass through. The emitter bypass capacitor C_E provides a low reactance path to the amplified ac signal.

The coupling capacitor C_C is used to couple one stage of the amplifier with the next stage while constructing multistage amplifiers. V_s is the sinusoidal input signal source applied across the base-emitter. The output is taken across the collector-emitter. $I_c = \beta I_B$

Applying Kirchhoff's voltage law in the output loop, the collector-emitter voltage is $V_{CE} = V_{CC} - I_c R_C$

Working of the amplifier:

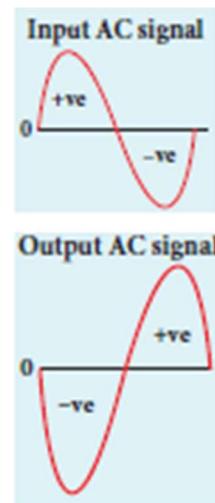
(1) During the positive half cycle:

Input signal (V_s) increases the forward voltage across the emitter-base. As a result, the base current (I_B) increases. Consequently, the collector current (I_c) increases β times. This **increases the voltage drop across R_C which in turn decreases the collector-emitter voltage (V_{CE})**. Therefore, the input signal in the positive direction produces an **amplified signal in the negative direction at the output**. Hence, the output signal is reversed by 180° .

(2) During the negative half cycle:

Input signal (V_s) decreases the forward voltage across the emitter-base. As a result, base current (I_B) decreases and in turn increases the collector current (I_c). The increase in collector current (I_c) decreases the potential drop across R_C and increases the collector-emitter voltage (V_{CE}).

Thus, the input signal in the negative direction produces an amplified signal in the positive direction at the output. Therefore, **180° phase reversal is observed during the negative half cycle of the input signal**



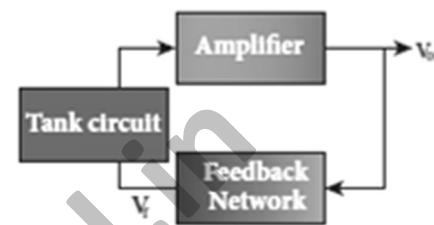
106. Explain the action transistor as an oscillator.

Transistor as an oscillator:

An electronic oscillator basically converts dc energy into ac energy of **high frequency ranging from a few Hz to several MHz. Hence, it is a source of alternating current or voltage.** Unlike an amplifier, oscillator does not require any external signal source. Basically, there are two types of oscillators: **Sinusoidal and non-sinusoidal.** An oscillator circuit consists of a tank circuit, an amplifier and a feedback circuit as shown

Amplifier:

Amplification is the process of increasing amplitude of weak signals (i.e) Amplifier amplifies the input ac signal

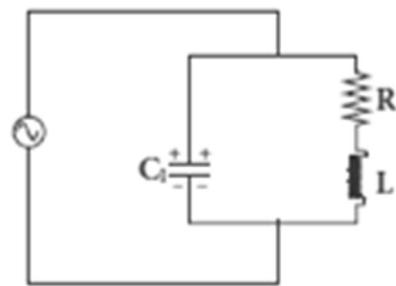


Feedback network:

The circuit used to feedback a portion of the output to the input is called the feedback network. If the portion of the output fed to the input is in phase with the input, then the magnitude of the input signal increases. It is necessary for sustained oscillations.

Tank circuit:

The LC tank circuit consists of an inductance and a capacitor connected in parallel. Whenever energy is supplied to the tank circuit from a DC source, the energy is stored in inductor and capacitor alternatively.



This produces electrical oscillations of definite frequency. But in practical oscillator circuits there will be loss of energy across resistors, inductor coils and capacitors. Due to this, **the amplitude of the oscillations decreases gradually. Hence, the tank circuit produces damped electrical oscillations.**

Therefore, in order to produce undamped oscillations, a positive feedback is provided from the output circuit to the input circuit. The frequency of oscillations is determined by the values of L and C using the equation.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

107. 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. $\overline{A + B} = \bar{A} \cdot \bar{B}$

Proof:

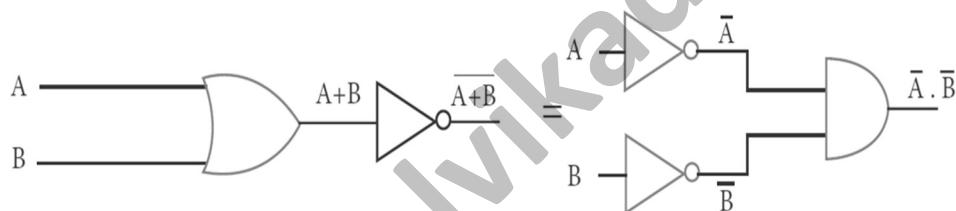
The Boolean equation for NOR gate is $Y = \overline{A + B}$

The Boolean equation for a bubbled AND gate is $Y = \bar{A} \cdot \bar{B}$

A	B	A+B	$\overline{A + B}$	\bar{A}	\bar{B}	$\bar{A} \cdot \bar{B}$
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. $\overline{A \cdot B} = \bar{A} + \bar{B}$

Proof:

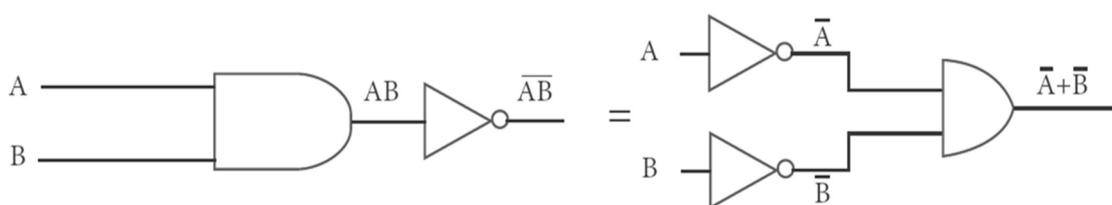
The Boolean equation for NAND gate is $Y = \overline{A \cdot B}$

The Boolean equation for a bubbled OR gate is $Y = \bar{A} + \bar{B}$

A	B	A.B	$\overline{A \cdot B}$	\bar{A}	\bar{B}	$\bar{A} + \bar{B}$
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



- 108. State Boolean laws. Elucidate how they are used to simplify Boolean expressions with suitable example.**

Boolean laws:

(1) Complement law:

$$(i) \bar{\bar{A}} = A$$

(2) OR Laws:

$$(i) A+0 = A, (ii) A + 1 = 1, (iii) A + A = A, (iv) A + \bar{A} = 1$$

(3) AND Laws:

$$(i) A.0=0, (ii) A.1 = A, (iii) A. A = A, (iv) A. \bar{A} = 0$$

(4) Commutative Laws:

$$i) A + B = B + A, (ii) A . B = B . A$$

(5) Associative Laws:

$$(i) A + (B + C) = (A + B) + C, (ii) A . (B . C) = (A . B) . C$$

(6) Distributive Laws:

$$(i) A(B + C) = AB + AC, (ii) A + (BC) = (A + B)(A + C)$$

Example:

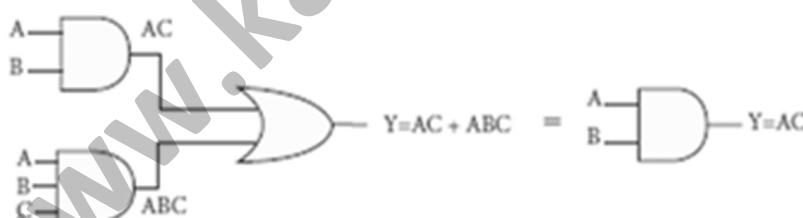
Simplify the following Boolean expression. $AC + ABC$

Solution:

$$AC + ABC = AC(1+B)$$

$$AC + ABC = AC.1 \quad [\text{OR - Law (2)}]$$

$$AC + ABC = AC \quad [\text{AND - Law (2)}]$$



- 109. What is called modulation? Explain the types of 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.

Types of modulation:

- (1) Amplitude modulation (AM)
- (2) Frequency modulation (FM)
- (3) Phase modulation (PM)

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.

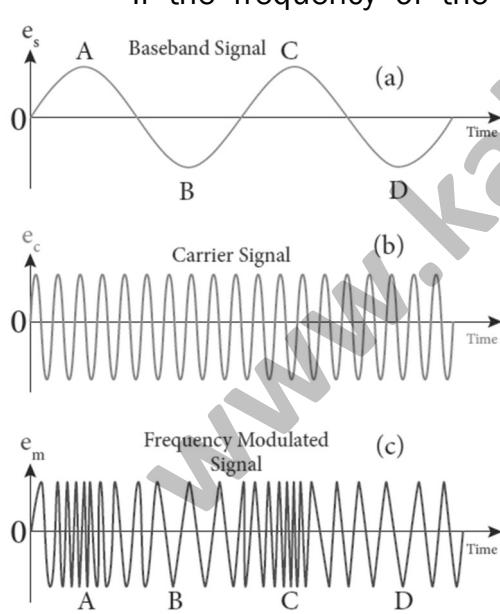
Advantages of AM:

Easy transmission and reception, lesser bandwidth requirements, Low cost

Limitations of AM:

Noise level is high, Low efficiency, Small operating range

Frequency modulation (FM) :

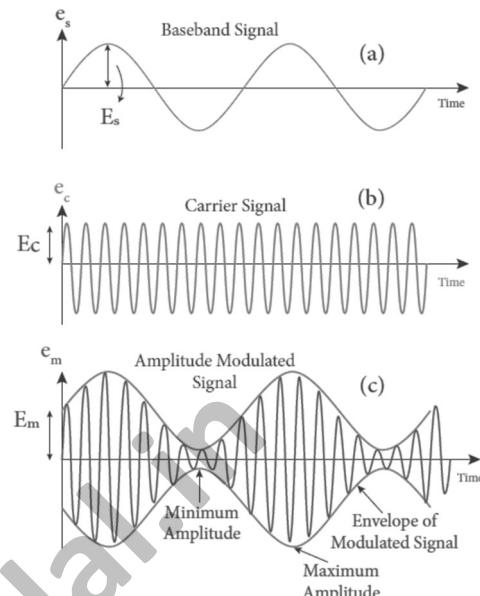


If the frequency of the carrier signal is modified according to the instantaneous amplitude of the baseband signal, then it is called frequency modulation. Here the amplitude and the phase of the carrier signal remain constant.

When the amplitude of the baseband signal is zero, the frequency of the modulated signal is the same as the carrier signal.

The frequency of the modulated wave increases when the amplitude of the baseband signal increases in the positive direction (A, C). The increase in amplitude in the negative half cycle (B, D) reduces the frequency of the modulated wave.

When the frequency of the **baseband signal is zero (no input signal)**, there is no change in the frequency of the carrier wave. It is at its normal frequency and is called as centre frequency or resting frequency. **Practically 75 kHz is the allotted frequency of the FM transmitter.**



Advantages of FM:

Large decrease in noise. This leads to an increase in signal-noise ratio.

The operating range is quite large.

The **transmission efficiency is very high** as all the transmitted power is useful. FM bandwidth covers the entire frequency range which humans can hear. Due to this, **FM radio has better quality** compared to AM radio.

Limitations of 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.

Phase modulation (PM):

The instantaneous amplitude of the baseband signal modifies the phase of the carrier signal keeping the amplitude and frequency constant is called phase modulation. This modulation is used to generate frequency modulated signals.

When the modulating signal goes positive, the amount of phase lead increases with the amplitude of the modulating signal. Due to this, the carrier signal is compressed or its frequency is increased.

On the other hand, the negative half cycle of the baseband signal produces a phase lag in the carrier signal. Hence similar to frequency modulated wave, phase modulated wave also comprises of compressions and rarefactions.

When the signal voltage is zero (A, C and E) the carrier frequency is unchanged. The frequency shifts in carrier wave frequency exists in phase modulation as well.

The **frequency shift depends on**

- (i) Amplitude of the modulating signal and
- (ii) The frequency of the signal.

Advantages of PM:

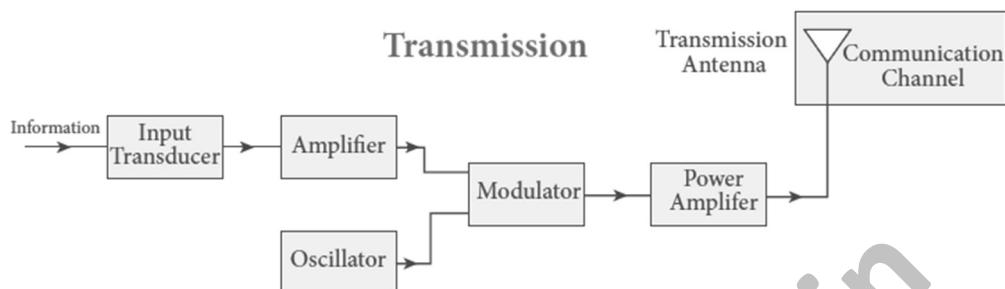
FM signal produced from PM signal is very stable.

The centre frequency called resting frequency is extremely stable.

- 110. Elaborate on the basic elements of communication system with the necessary block diagram.**

Communication system:

Electronic communication is nothing but the transmission of sound, text, pictures, or data through a medium.



Basic elements of communication system:

(1) Input transducer:

A transducer is a device that **converts variations in a physical quantity (pressure, temperature, sound) into an equivalent electrical signal or vice versa**. In communication system, the **transducer converts the information which is in the form of sound, music, pictures or computer data into corresponding electrical signals**.

The electrical equivalent of the original information is called the **baseband signal**. (e.g.) microphone

(2) Transmitter:

It feeds the **electrical signal from the transducer to the communication channel**. The transmitter is located at the broadcasting station. It consists,

- (i) **Amplifier:** The transducer output is **very weak** and is amplified by the amplifier.
- (ii) **Oscillator:** It **generates high-frequency carrier wave** (a sinusoidal wave) for long distance transmission into space.
- (iii) **Modulator:** It **superimposes the baseband signal** onto the carrier signal and generates the modulated signal.
- (iv) **Power amplifier:** It **increases the power level of the electrical signal** in order to cover a large distance.

(3) Transmitting antenna:

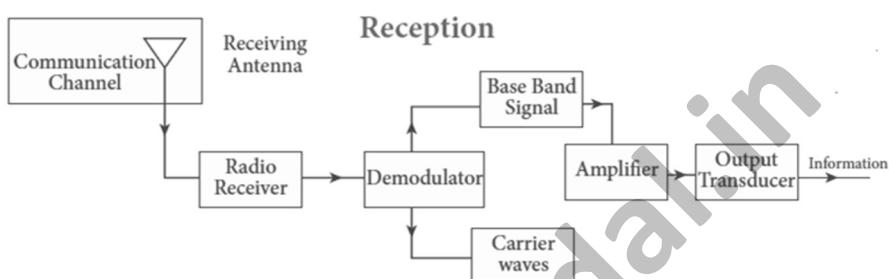
It radiates **the radio signal into space in all directions**. It travels in the form of electromagnetic waves with the velocity of light ($3 \times 10^8 \text{ m s}^{-1}$)

(4) Communication channel:

Communication channel is used **to carry the electrical signal from transmitter to receiver with less noise or distortion**. The communication medium is basically of two types: **wireline communication and wireless communication**.

(5) Receiver:

The **signals that are transmitted through the communication medium are received** with the **help of a receiving antenna** and are fed into the receiver.



The receiver consists of **electronic circuits like demodulator, amplifier, detector etc.**

The demodulator extracts the baseband signal from the carrier signal. Then the baseband signal is detected and amplified using amplifiers. Finally, it is fed to the output transducer.

(6) Output transducer:

It **converts the electrical signal back to its original form** such as sound, music, pictures or data. (e.g.) **loudspeakers, picture tubes, computer monitor, etc.**

111. Explain the three modes of propagation of electromagnetic waves through space.

Modes of propagation of electromagnetic waves:

The electromagnetic wave transmitted by:

- (1) Ground wave propagation (or) surface wave propagation
(2 kHz to 2 MHz)
- (2) Sky wave propagation (or) ionospheric propagation
(3 MHz to 30 MHz)
- (3) Space wave propagation **(30 MHz to 400 GHz)**

Ground wave propagation:

If the electromagnetic waves transmitted by the transmitter glide over the surface of the earth to reach the receiver, then the propagation is called ground wave propagation. The corresponding waves are called **ground waves or surface waves**. Both transmitting and receiving antennas must be close to the earth.

The size of the antenna plays a major role in deciding the efficiency of the radiation of signals. During transmission, the electrical signals are attenuated over a distance. Some **reasons for attenuation** are as follows:

Increasing distance, Absorption of energy by the Earth, tilting of the wave It is mainly used in local broadcasting, radio navigation, for **ship-to-ship**, **ship-to-shore communication** and mobile communication.

Sky wave propagation:

The mode of propagation in which the electromagnetic waves radiated from an antenna, directed upwards at large angles gets reflected by the ionosphere back to earth is called sky wave propagation or ionospheric propagation. **Extremely long distance communication is possible as the radio waves can undergo multiple reflections between the earth and the ionosphere.**

The phenomenon of bending the radio waves back to earth is due to the total internal reflection. This is the reason why the EM waves are transmitted at a critical angle to ensure that the waves undergo total reflection and reaches the ground without escaping into space.

The **shortest distance between the transmitter** and the point of **reception** of the sky wave along the surface is called as the **skip distance**. There is a **zone in between where there is no reception of electromagnetic waves neither ground nor sky, called as skip zone or skip area.**

Space wave propagation:

The process of sending and receiving information signal through space is called space wave communication. **The electromagnetic waves of very high frequencies above 30 MHz are called as space waves.**

These waves travel in a straight line from the transmitter to the receiver. Hence, it is used for a line of sight communication (LOS). For high frequencies, the transmission towers must be high enough so that the transmitted and received signals (direct waves) will not encounter the curvature of the earth and hence travel with less attenuation and loss of signal strength.

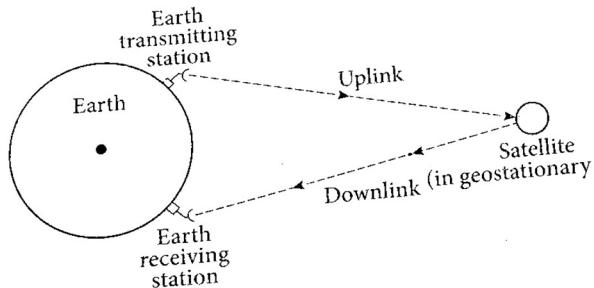
Certain waves reach the receiver after getting reflected from the ground. The communication systems like television broadcast, satellite communication, and RADAR are based on space wave propagation.

The range or distance (d) of coverage of the propagation depends on the height (h) of the antenna given by the equation, $h = \sqrt{2 R h}$ where, R → Radius of earth (6400 km)

112. Explain satellite communication.

Satellite communication:

The satellite communication is a mode of communication of signal between transmitter and receiver via satellite. The message signal from the Earth station is transmitted to the satellite on board via an uplink (**frequency band 6 GHz**), amplified by a transponder and then retransmitted to another earth station via a downlink (**frequency band 4 GHz**).



The **high-frequency radio wave signals travel in a straight line** (line of sight) may come across tall buildings or mountains or even encounter the curvature of the earth.

A communication satellite relays and amplifies such radio signals via transponder to reach distant and far off places using uplinks and downlinks. It is also called as a radio repeater in sky.

Applications:

(1) Weather Satellites:

They are used to **monitor the weather and climate of Earth**.

By measuring **cloud mass**, these satellites enable us to predict rain and dangerous storms like hurricanes, cyclones etc.

(2) Communication satellites:

They are used to **transmit television, radio, internet signals** etc.

Multiple satellites are used for long distances.

(3) Navigation satellites:

These are employed to **determine the geographic location of ships, aircrafts or any other object**.

113. Explain the function of RADAR. Give its applications.

RADAR:

Radar basically stands for **RA**dio **D**etection **A**nd **R**anging **S**ystem. It is one of the important applications of communication systems and is **mainly used to sense, detect, and locate distant objects like aircraft, ships, spacecraft, etc.**

The angle, range, or velocity of the objects that are invisible to the human eye can be determined. Radar uses electromagnetic waves for communication. The electromagnetic signal is initially radiated into space by an antenna in all directions.

When this signal strikes the targeted object, it gets reflected or reradiated in many directions. This reflected (echo) signal is received by the radar antenna which in turn is delivered to the receiver.

Then, it is processed and amplified to determine the geographical statistics of the object. The range is determined by calculating the time taken by the signal to travel from RADAR to the target and back.

Applications:

In **military**, it is used **for locating and detecting the targets**.

It is used in **navigation systems** such as **ship borne surface search**, air search and weapons guidance systems. To measure precipitation rate and wind speed in meteorological observations, Radars are used.

It is employed **to locate and rescue people in emergency situations**.

114. Give the applications of ICT in fisheries, mining and agriculture sectors.

Agriculture:

ICT is widely used in increasing food productivity and farm management. **It helps to optimize the use of water, seeds and fertilizers etc. Sophisticated technologies that include robots, temperature and moisture sensors, aerial images, and GPS technology can be used.**

Geographic information systems are extensively used in farming to decide the suitable place for the species to be planted.

Fisheries:

Satellite vessel monitoring system **helps to identify fishing zones**.

Use of barcodes helps to identify time and date of catch, species name, quality of fish.

Mining:

ICT in mining improves **operational efficiency, remote monitoring and disaster locating system. Information and communication technology** provides audio-visual warning to the trapped underground miners.

It helps to connect remote sites.

- 115. Fiber optic communication is gaining popularity among the various transmission media -justify.**

Fiber optic communication:

The method of **transmitting information from one place to another in terms of light pulses through an optical fiber** is called fiber optic communication. It is in the process of replacing wire transmission in communication systems. **Light has very high frequency** (400THz –790 THz) than microwave radio systems.

The fibers are **made up of silica glass or silicon dioxide which is highly abundant on Earth**. Now it has been replaced with materials such as chalcogenide glasses, **fluoroaluminate crystalline materials** because they provide larger infrared wavelength and better transmission capability.

As fibers are **not electrically conductive**, it is preferred in places where multiple channels are to be laid and isolation is required from electrical and electromagnetic interference.

Applications:

Optical fiber system has a number of applications namely, international communication, **inter-city communication, data links, plant and traffic control and defense applications.**

Merits:

Fiber cables are **very thin and weigh lesser than copper cables**.

This system has much larger band width. This means that its **information carrying capacity is larger**. Fiber optic system is immune to electrical interferences. Fiber optic cables are cheaper than copper cables.

Demerits:

Fiber optic cables are more fragile when compared to copper wires.

It is an expensive technology.

Importance:

Fiber optic cables provide the fastest transmission rate compared to any other form of transmission. It can **provide data speed of 1 GBps for homes and business.**

Multimode fibers operate at the speed of 10 MBps. Recent developments in optical communication provide the **data speed at the rate of 25 GBps**

116. Modulation helps to reduce the antenna size in wireless communication – Explain.

Antenna:

Antenna is used at **both transmitter and receiver end**. **Antenna height is an important parameter to be discussed**. The height of the antenna must be a multiple of $\frac{\lambda}{4}$.

Where $\lambda \rightarrow$ Wavelength [$\lambda = c/v$]

$c \rightarrow$ Velocity of light and $v \rightarrow$ frequency of the signal.

Let us consider two baseband signals. One signal is modulated and the other is not modulated. The frequency of the original baseband signal (un-modulated) is taken as $v = 10$ kHz while the modulated signal is $v = 1\text{MHz}$. The height of the antenna required to transmit the original baseband signal of frequency $v = 10$ kHz is

$$h_1 = \frac{\lambda}{4} = \frac{c}{4v} = \frac{3 \times 10^8}{4 \times 10 \times 10^3} = 7500 \text{ m}$$

The **height of the antenna required to transmit the modulated signal of frequency $v = 1$ MHz is**

$$h_2 = \frac{\lambda}{4} = \frac{c}{4v} = \frac{3 \times 10^8}{4 \times 1 \times 10^3} = 75 \text{ m}$$

We can infer that it is practically feasible to construct an antenna of height 75 m while the one with 7.5 km is not possible. It clearly manifests that modulated signals reduce the antenna height and are required for long distance transmission.

UNIT – XI (RECENT DEVELOPMENTS IN PHYSICS)

TWO MARKS AND THREE MARKS QUESTIONS AND ANSWERS

1. Distinguish between Nano science and Nanotechnology.

Nano science:

It is the science of objects with typical size 1 - 100 nm

Nano means one - billionth of a metre. (i.e) $10^{-9} m$

Nanotechnology:

It is a technology **involving the design, production**, characterization and application of nano structured materials

2. What is the difference between Nano materials and Bulk materials?

If the particle of a solid is of size less than 100 nm, it is said to be a 'nano solid'. When the particle size exceeds 100 nm, it is a 'bulk solid'

Though nano and bulk solids have same chemical composition, nano form of the material shows strikingly different properties when compared to its bulk counterpart.

3. Give the interdisciplinary nature of nano technology.

Nano science and technology is **the interdisciplinary area covering its applications in various fields**. They are,

- (1) Physics, (2) Chemistry, (3) Electrical & Mechanical Engineering
- (4) Material science, (5) Molecular Biology,
- (6) Applied Mathematics & Computer science

4. 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

5. 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

6. What is robotics?

Robotics is an **integrated study of mechanical engineering**, electronic engineering, computer engineering and science. **Robot is a mechanical device designed with electronic circuitry and programmed to perform a specific task.**

7. What are the components of robotics?

The robotic system mainly consists of (1) Sensors, (2) Power supplies, (3) Control systems, (4) Manipulators, (5) Necessary software

8. Give the types of robots.

(1) Human robot:

Certain robots are made to resemble humans in appearance and replicate the human activities like walking, lifting and sensing etc..

(2) Industrial robots:

Six main types of industrial robots are **Cartesian, SCARA, Cylindrical, Delta, Polar and vertically articulated**. They are ideal for Arc welding, Spot welding, Material handling, machine tending and other applications.

9. 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**

10. 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.

11. Write a note on nano robots.

Nano robots:

The size of the nano robots is reduced to microscopic level to perform a task in very small spaces. In future nano robots are used in **the medical fields. Nano robots in blood stream to perform small surgical procedures, to fight against bacteria, repairing individual cell in the body.** It can travel into the body and once after the job is performed it can find its way out.

12. Why steels are preferred to make robots?

For robots, aluminum and steel are the most common metals.

Aluminum is a softer metal and is therefore easier to work with it. But steel is several times stronger and because of the inherent strength of steel, robot bodies are made using sheet, bar, rod, channel and other shapes.

13. 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 .,

14. Write a note on Cosmology.

Cosmology is the branch that involves **the origin and evolution of the universe. It deals with the formation of stars, galaxy etc.**

15. 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.

16. Write a note on black holes.

Black holes:

Black holes are end stage of stars which are highly dense massive object. Its mass ranges 20 times mass of the sun to 1 million times mass of the sun. It has very strong gravitational force such that no particle or even light can escape from it. The existence of black hole is studied when the stars orbiting the black hole behave differently from the other stars. Every galaxy has black hole at its centre. Sagittarius A* is the black hole at the centre of the Milky Way galaxy.

FIVE MARKS QUESTIONS AND ANSWERS

17. Explain Nano structure in nature with examples.

Nano in nature:

(1) Single strand DNA:

It is the basic building block of all living things.

It is about 3 nm wide

(2) Morpho butterfly:

The scales of the wings of this butterfly contains nano structures. When light wave interacts with this giving the wings brilliant metallic blue and green hues.

(3) Peacock feathers:

They get their iridescent coloration from light interacting with 2 dimensional photonic crystal structures just tens of nanometers thick. Similar nano structures are made in lab to glow in different colors

(4) Parrot fish:

It crunches up coral all day. The source of powerful bite is the interwoven fibre nanostructure. Crystals of a mineral called fluorapatite are woven together in a chain mail-like arrangement.

This structure gives parrot fish teeth incredible durability. It provides a blue print for creating ultra - durable synthetic materials that could be useful for mechanical components in electronics and in other devices that undergo repetitive movement, abrasion and contact stress.

(5) Lotus Leaf surface:

Scanning electron micrograph (SEM) gives the nano structures on the surface of a leaf from a lotus plant. This is the reason for self-cleaning process on lotus leaf.

18. Discuss the applications of Nano-materials in various fields.

Automotive industry:

Lightweight construction, Painting (fillers, base coat, clear coat)
Catalysts, Tires (fillers), Sensors, Coatings for windscreen and car bodies

Chemical industry:

Fillers for paint systems, Coating systems based on nano composites
Impregnation of papers, Switchable adhesives, Magnetic fluids

Engineering:

Wear protection for tools and machines, Lubricant-free bearings

Electronic industry:

Data memory, Displays, Laser diodes, Glass fibres, Optical switches
Filters (IR-blocking), Conductive, antistatic coatings

Construction:

Construction materials, Thermal insulation, Flame retardants
Surface-functionalized building materials for wood, floors, stone, facades, tiles, roof tiles, etc. Facade coatings, Groove mortar

Medicine:

Drug delivery systems, Active agents, Contrast medium, Medical rapid tests, Prostheses and implants, Antimicrobial agents and coatings
Agents in cancer therapy

Food and drinks:

Package materials, Storage life sensors, Additives, Clarification of fruit juices

Energy:

Fuel cells, Solar cells, Batteries, Capacitors

Textile / fabrics / non-woven:

Surface-processed textiles, Smart clothes

Household:

Ceramic coatings for irons, Odors catalyst, Cleaner for glass, ceramic, floor, windows.

Cosmetics:

Sun protection, Lipsticks, Skin creams, Tooth paste

Sports / outdoor:

Ski wax, Antifogging of glasses / goggles, Antifouling coatings for ships / boats, Reinforced tennis rackets and balls.

19. What are the possible harmful effects of usage of Nano particles? Why?

Possible harmful effects of nano particles:

The major concern here is that the nano particles have the dimensions same as that of the biological molecules such as proteins. They may easily get absorbed on to the surface of living organisms and they might enter the tissues and fluids of the body.

The adsorbing nature depends on the surface of the nano particle. Indeed, it is possible to deliver a drug directly to a specific cell in the body by designing the surface of a nano particle so that it adsorbs specifically on to the surface of the target cell.

The interaction with living systems is also affected by the dimensions of the nano particles. Nano particles can also cross cell membranes. It is also possible for the inhaled nano particles to reach the blood, to reach other sites such as the liver, heart or blood cells. Researchers are trying to understand the response of living organisms to the presence of nano particles of varying size, shape, chemical composition and surface characteristics.

20. 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.

21. Comment on the recent advancement in medical diagnosis and therapy.

(1) Virtual reality:

Medical virtual reality is effectively used to stop the brain from processing pain and cure soreness in the hospitalized patients. It helps in the treatment of Autism, Memory loss, and Mental illness.

(2) Precision medicine:

Precision medicine is an emerging approach for disease treatment and prevention that takes into account individual variability in genes, environment, and lifestyle for each person.

(3) Health wearable's:

A health wearable is a device used for tracking a wearer's vital signs or health and fitness related data, location, etc. Medical wearables with artificial intelligence and big data provide an added value to healthcare with a focus on diagnosis, treatment, patient monitoring and prevention.

(4) Artificial organs:

An artificial organ is an engineered device or tissue that is implanted or integrated into a human. It is possible to interface it with living tissue or to replace a natural organ. It duplicates or augments a specific function or functions of human organs so that the patient may return to a normal life as soon as possible.

(5) 3D printing:

Advanced 3D printer systems and materials assist physicians in a range of operations in the medical field from audiology, dentistry, orthopedics and other applications.

(6) Wireless brain sensors:

Wireless brain sensors monitor intracranial pressure and temperature and then are absorbed by the body. Hence there is no need for surgery to remove these devices.

(7) Robotic surgery:

Robotic surgery is a type of surgical procedure that is done using robotic systems. Robotically-assisted surgery helps to overcome the limitations of pre-existing minimally-invasive surgical procedures and to enhance the capabilities of surgeons performing open surgery.

(8) Smart inhalers:

Inhalers are the main treatment option for asthma. Smart inhalers are designed with health systems and patients in mind so that they can offer maximum benefit. Smart inhalers use Bluetooth technology to detect inhaler use, remind patients when to take their medication and gather data to help guide care.

22. Discuss the functions of key components in Robots?

Functions of key components of Robots: Most robots are composed of 3 main parts: (1) Controller, (2) Mechanical parts, (3) Sensors

Controller:

It is also known as the "brain" which is run by a computer program.

It gives commands for the moving parts to perform the job.

Mechanical parts:

It consists motors, pistons, grippers, wheels, and gears that make the robot move, grab, turn, and lift.

Sensors:

It tells the robot about its surroundings. It helps to determine the sizes and shapes of the objects around, distance between the objects, and directions as well.

23. 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. They contract almost 40% when the air is sucked inside them.

Muscle wires:

They are thin strands of wire made of shape memory alloys. They 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

UNIT - I (ELECTROSTATICS)

- 1. Calculate the number of electrons in one coulomb of negative charge.**

Solution:

According to the quantization of charge $q = ne$

Here $q = 1C$. So the number of electrons in 1 coulomb of charge is

$$n = \frac{q}{e} = \frac{1 \text{ C}}{1.6 \times 10^{-19} \text{ C}} \quad n = 6.25 \times 10^{18} \text{ electrons}$$

No.	Log
10^{19}	19.0000
1.6	0.2041
(-)	18.7959
Antilog	6.25×10^{18}

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

Solution:

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

$$\tau_{max} = pE \sin 90^\circ ; = 3.4 \times 10^{-30} \times 3 \times 10^4 \text{ N m}$$

$$\tau_{max} = 10.2 \times 10^{-26} \text{ N m}$$

- 3. Calculate the electrostatic force and gravitational force between the proton and the electron in a hydrogen atom. They are separated by a distance of $5.3 \times 10^{-11} \text{ m}$. The magnitude of charges on the electron and proton are $1.6 \times 10^{-19} \text{ C}$. Mass of the electron is $m_e = 9.1 \times 10^{-31} \text{ kg}$ and mass of proton is $m_p = 1.6 \times 10^{-27} \text{ kg}$.**

Solution:

The magnitude of the electrostatic force between these two particles is given by $F_e = \frac{ke^2}{r^2} ; = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{(5.3 \times 10^{-11})^2} ; \frac{9 \times 2.56}{28.09} \times 10^{-7} ;$

$$F_e = 8.2 \times 10^{-8} \text{ N}$$

The magnitude of the gravitational force between these two particles is given by $F_G = \frac{Gm_e m_p}{r^2} ; = \frac{6.67 \times 10^{-11} \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-27}}{(5.3 \times 10^{-11})^2} ; \frac{97.11}{28.09} \times 10^{-47} ;$

$$F_G = 3.4 \times 10^{-47} \text{ N}$$

$$\text{The ratio of the two forces } \frac{F_e}{F_G} = \frac{8.2 \times 10^{-8}}{3.4 \times 10^{-47}} ; \frac{F_e}{F_G} = 2.41 \times 10^{39} \text{ N}$$

Note that $F_e \approx 10^{39} F_G$

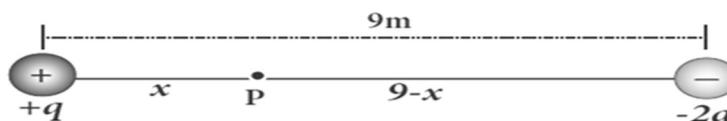
The electrostatic force between a proton and an electron is enormously greater than the gravitational force between them. Thus the gravitational force is negligible when compared with the electrostatic force in many situations such as for small size objects and in the atomic domain. This is the reason why a charged comb attracts an uncharged piece of paper with greater force even though the piece of paper is attracted downward by the Earth.

- 4.** Consider a point charge $+q$ placed at the origin and another point charge $-2q$ placed at a distance of 9 m from the charge $+q$. Determine the point between the two charges at which electric potential is zero.

Solution:

According to the superposition principle, the total electric potential at a point is equal to the sum of the potentials due to each charge at that point.

Consider the point at which the total potential zero is located at a distance x from the charge $+q$ as shown in the figure.



$$\text{The total electric potential at P is zero. } V_{tot} = \frac{1}{4\pi\epsilon_0} \left(\frac{q}{x} - \frac{2q}{(9-x)} \right) = 0$$

$$\text{Which gives, } \frac{q}{x} = \frac{2}{(9-x)} \text{ (or) } \frac{1}{x} = \frac{2}{(9-x)} \text{ Hence, } x = 3\text{m}$$

- 5.** Calculate the electric flux through the rectangle of sides 5 cm and 10 cm kept in the region of a uniform electric field 100 NC⁻¹. The angle θ is 60°. Suppose θ becomes zero, what is the electric flux?

Solution: The electric flux $\Phi_E = \vec{E} \cdot \vec{A} = EA \cos\theta = 100 \times 5 \times 10 \times 10^{-4} \times \cos 60^\circ$
 $\Rightarrow \Phi_E = 0.25 \text{ Nm}^2\text{C}^{-1}$.

$$\text{For } \theta = 0^\circ, \Phi_E = \vec{E} \cdot \vec{A} = EA \cos\theta = 100 \times 5 \times 10 \times 10^{-4}; = 0.5 \text{ Nm}^2\text{C}^{-1}$$

- 6.** A parallel plate capacitor has square plates of side 5 cm and separated by a distance of 1 mm. (a) Calculate the capacitance of this capacitor. (b) If a 10 V battery is connected to the capacitor, what is the charge stored in any one of the plates? (The value of $\epsilon_0 = 8.85 \times 10^{-12} \text{ Nm}^2 \text{ C}^{-2}$)

Solution:

$$(a) \text{ The capacitance of the capacitor is } C = \frac{\epsilon_0 A}{d};$$

$$= \frac{8.854 \times 10^{-12} \times 25 \times 10^{-4}}{1 \times 10^{-3}} \\ = 221.2 \times 10^{-13} \text{ F};$$

$$C = 22.12 \times 10^{-12} \text{ F}; \quad \mathbf{C = 22.12 \text{ pF}}$$

- (b) The charge stored in any one of the plates is $Q = CV$, Then

$$Q = 22.12 \times 10^{-12} \times 10 = 221.2 \times 10^{-12} \text{ C}$$

$$\mathbf{Q = 221.2 \text{ pC}}$$

- 7.** A parallel plate capacitor filled with mica having $\epsilon_r = 5$ is connected to a 10 V battery. The area of the parallel plate is 6 m^2 and separation distance is 6 mm. (a) Find the capacitance and stored charge.
 (b) After the capacitor is fully charged, the battery is disconnected and the dielectric is removed carefully. Calculate the new values of capacitance, stored energy and charge.

Solution:

The capacitance of the capacitor in the presence of dielectric is

$$C = \frac{\epsilon_r \epsilon_0 A}{d} = \frac{5 \times 8.854 \times 10^{-12} \times 6}{6 \times 10^{-3}} ; \\ = 44.25 \times 10^{-9} \text{ F} = 44.25 \text{ nF}$$

The stored charge is $Q = CV$

$$= 44.25 \times 10^{-9} \times 10 \\ = 442.5 \times 10^{-9} ; C = 442.5 \text{nC}$$

$$\text{The stored energy is } U = \frac{1}{2} CV^2 = \frac{1}{2} \times 44.25 \times 10^{-9} \times 10^0 \\ = 2.21 \times 10^{-6} \text{ J} ; U = 2.21 \mu\text{J}$$

- (b) After the removal of the dielectric, since the battery is already disconnected the total charge will not change. But the potential difference between the plates increases. As a result, the capacitance is decreased.

$$\text{New capacitance is } C_0 = \frac{C}{\epsilon_r} = \frac{44.25 \times 10^{-9}}{5} ; \\ = 8.85 \times 10^{-9} \text{ F} ; C_0 = 8.85 \text{nF}$$

The stored charge remains same and 442.5 nC.

$$\text{Hence newly stored energy is } U_0 = \frac{Q^2}{2C_0} ; = \frac{Q^2 \epsilon_r}{2C} = \epsilon_r U \\ = 5 \times 2.21 \mu\text{J} ; U_0 = 11.05 \mu\text{J}$$

The increased energy is $\Delta U = 11.05 \mu\text{J} - 2.21 \mu\text{J} = 8.84 \mu\text{J}$

When the dielectric is removed, it experiences an inward pulling force due to the plates. To remove the dielectric, an external agency has to do work on the dielectric which is stored as additional energy. This is the source for the extra energy $8.84 \mu\text{J}$.

- 8.** Dielectric strength of air is $3 \times 10^6 \text{ V m}^{-1}$. Suppose the radius of a hollow sphere in the Van de Graaff generator is $R = 0.5 \text{ m}$, calculate the maximum potential difference created by this Van de Graaff generator.

Solution:

The electric field on the surface of the sphere (by Gauss law) is given by

$$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{R^2}$$

The potential on the surface of the hollow metallic sphere is given by

$$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{R} = ER$$

With $V_{\max} = E_{\max} R$

Here $E_{\max} = 3 \times 10^6 \frac{\text{V}}{\text{m}}$. So, the maximum potential difference created is given by $V_{\max} = 3 \times 10^6 \times 0.5 ; V_{\max} = 1.5 \times 10^6 \text{ V (or) } 1.5 \text{ million volt}$

- 9.** A water molecule has an electric dipole moment of $6.3 \times 10^{-30} \text{ Cm}$. A sample contains 10^{22} water molecules, with all the dipole moments aligned parallel to the external electric field of magnitude $3 \times 10^5 \text{ N C}^{-1}$. How much work is required to rotate all the water molecules from $\theta = 0^\circ$ to 90° ?

Solution:

$$\theta_i = 0^\circ; \theta_f = 90^\circ ; E = 3 \times 10^5 \text{ NC}^{-1}; p = 6.3 \times 10^{-30} \text{ Cm}; n = 10^{22}$$

When the water molecules are aligned in the direction of the electric field, it has minimum potential energy.

The work done to rotate the dipole from $\theta = 0^\circ$ to 90° is equal to the potential energy difference between these two configurations

$$W = U(\theta_f) - U(\theta_i)$$

$$W = -pE \cos\theta_f + pE \cos\theta_i ;$$

$$= pE \cos(\theta_i - \theta_f) ; = pE \cos(0^\circ - 90^\circ)$$

$$= pE \cos(1 - 0) ;$$

$$W = pE ; = 6.3 \times 10^{-30} \times 3 \times 10^5 ; = 18.9 \times 10^{-25} \text{ J}$$

Hence for 10^{22} water molecules, the total work done is

$$W_{\text{tot}} = 10^{22} \times 18.9 \times 10^{-25} ;$$

$$W_{\text{tot}} = 18.9 \times 10^{-3} \text{ J}$$

EXERCISE PROBLEM

- 10.** When two objects are rubbed with each other, approximately a charge of 50 nC can be produced in each object. Calculate the number of electrons that must be transferred to produce this charge.

Solution:

Charge produced in each object $q = 50 \text{ nc}$ (or) $q = 50 \times 10^{-9} \text{ C}$

Charge of electron (e) = $1.6 \times 10^{-19} \text{ C}$

$$\text{Number of electron transferred, } n = \frac{q}{e} = \frac{50 \times 10^{-9}}{1.6 \times 10^{-19}}$$

$$= 31.25 \times 10^9 \times 10^{19}$$

$N = 31.25 \times 10^{10} \text{ electrons.}$

No.	Log
50	1.6990
1.6	0.2041
(-)	1.4949
Antilog	3.125×10^1

- 11.** The total number of electrons in the human body is typically in the order of 10^{28} . Suppose, due to some reason, you and your friend lost 1% of this number of electrons. Calculate the electrostatic force between you and your friend separated at a distance of 1m. Compare this with your weight. Assume mass of each person is 60 kg and use point charge approximation.

Solution:

Number of electrons in the human body = 10^{28}

Number of electrons in me and my friend after lost of 1 % = $10^{28} \times 1\%$

$$= 10^{28} \times \frac{1}{100} \quad n = 10^{26} \text{ electrons.}$$

Separate distance $d = 1\text{m}$,

Charge of each person $q = 10^{26} \times 1.6 \times 10^{-19}$;
 $q = 1.6 \times 10^7 \text{ C}$

$$\text{Electrostatic force, } F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} ;$$

$$\frac{9 \times 10^9 \times 1.6 \times 10^7 \times 1.6 \times 10^7}{1}$$

$F = 2.304 \times 10^{24} \text{ N}$

Mass of the person, $M = 60 \text{ kg}$,

Acceleration due to gravity, $g = 9.8 \text{ ms}^{-2}$; Wight (W) = mg
 $= 60 \times 9.8 \text{ W} = 588 \text{ N}$

Comparison: Electrostatic force is equal to 3.92×10^{21} times of weight of the person.

No.	Log
23.04	1.3625
588	2.7694
(-)	2.5931
Antilog	3.918×10^{-2}

- 12.** A spark plug in a bike or a car is used to ignite the air-fuel mixture in the engine. It consists of two electrodes separated by a gap of around 0.6 mm gap. To create the spark, an electric field of magnitude $3 \times 10^6 \text{ Vm}^{-1}$ is required. (a) What potential difference must be applied to produce the spark? (b) If the gap is increased, does the potential difference increase, decrease or remains the same? (c) find the potential difference if the gap is 1 mm.

Solution:

Separation gap between two electrodes, $d = 0.6 \text{ mm}$ (or) $d = 0.6 \times 10^{-3} \text{ m}$

$$\text{Magnitude of electric field } E = 3 \times 10^6 \text{ Vm}^{-1}; \quad \text{Electric field } E = \frac{V}{d}$$

a) Applied potential difference, $V = E.d$

$$= 3 \times 10^6 \times 0.6 \times 10^{-3} : = 1.8 \times 10^3 ; \mathbf{V = 1800V}$$

b) From equation, $V = E.d$ (If the gap (distance) between the electrodes increases, the potential difference also increases.

c) Gap between the electrodes, $d = 1\text{mm} = 1 \times 10^{-3} \text{ m}$

Potential difference, $V = E . d$

$$= 3 \times 10^6 \times 1 \times 10^{-3} ; 3 \times 10^3 ; \mathbf{V = 3000 V}$$

- 13.** For the given capacitor configuration (a) Find the charges on each capacitor (b) potential difference across them (c) energy stored in each capacitor

Solution:

Capacitor b and c in parallel combination

$$C_p = C_b + C_c = (6 + 2) \mu\text{F} = 8 \mu\text{F}$$

Capacitor, a, C_p and d are in series combination, so the resultant capacitance.

$$\frac{1}{C_s} = \frac{1}{C_a} + \frac{1}{C_p} + \frac{1}{C_d} ; = \frac{1}{8} + \frac{1}{8} + \frac{1}{8} = \frac{3}{8}$$

a) Charge on capacitor a, $Q_a = C_s V = \frac{8}{3} \times 9 ; Q_a = 24 \mu\text{C}$

Charge on capacitor d, $Q_d = C_s V = \frac{8}{3} \times 9 ; Q_d = 24 \mu\text{C}$

Capacitor b and c in parallel

Charge on capacitor b, $Q_b = C_s V = \frac{6}{3} \times 9 ; Q_b = 18 \mu\text{C}$

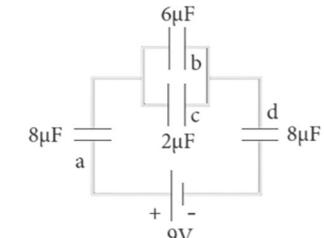
Charge on capacitor c, $Q_c = C_s V = \frac{2}{3} \times 9 ; Q_c = 6 \mu\text{C}$

b) Potential difference across each capacitor, $V = \frac{q}{C}$

Capacitor C_a , $V_a = \frac{q_a}{C_a} = \frac{24 \times 10^{-6}}{8 \times 10^{-6}} ; V_a = 3\text{V}$

Capacitor C_b , $V_b = \frac{q_b}{C_b} = \frac{18 \times 10^{-6}}{6 \times 10^{-6}} ; V_b = 3\text{V}$

Capacitor C_c , $V_c = \frac{q_c}{C_c} = \frac{6 \times 10^{-6}}{2 \times 10^{-6}} ; V_c = 3\text{V}$



$$\text{Capacitor } C_d, V_d = \frac{q_d}{C_d} = \frac{24 \times 10^{-6}}{8 \times 10^{-6}} ; V_d = 3V$$

- c) Energy stores in a capacitor, $U = \frac{1}{2} CV^2$

$$\text{Energy in capacitor } C_a, U_a = \frac{1}{2} C_a V_a^2 = \frac{1}{2} \times 8 \times 10^{-6} \times (3)^2; U_a = 36\mu J$$

$$\text{Energy in capacitor } C_b, U_b = \frac{1}{2} C_b V_b^2 = \frac{1}{2} \times 6 \times 10^{-6} \times (3)^2; U_b = 27\mu J$$

$$\text{Energy in capacitor } C_c, U_c = \frac{1}{2} C_c V_c^2 = \frac{1}{2} \times 2 \times 10^{-6} \times (3)^2; U_b = 9\mu J$$

$$\text{Energy in capacitor } C_d, U_d = \frac{1}{2} C_d V_d^2 = \frac{1}{2} \times 8 \times 10^{-6} \times (3)^2; U_b = 36\mu J$$

UNIT - II (CURRENT ELECTRICITY)

- 14. Compute the current in the wire if a charge of 120 C is flowing through a copper wire in 1 minute.**

Solution:

$$\text{The current (rate of flow of charge) in the wire is } I = \frac{Q}{t} = \frac{120}{60}; I = 2A$$

- 15. If an electric field of magnitude 570 N C⁻¹, is applied in the copper wire, find the acceleration experienced by the electron.**

Solution:

$$E = 570 \text{ N C}^{-1}, e = 1.6 \times 10^{-19} \text{ C}, m = 9.11 \times 10^{-31} \text{ kg and } a = ?$$

$$\begin{aligned} F &= ma = eE; a = \frac{e E}{m} = \frac{570 \times 1.6 \times 10^{-19}}{9.11 \times 10^{-31}}; \\ &= \frac{912 \times 10^{-1} \times 10^{31}}{9.11} \\ a &= 1.001 \times 10^{14} \text{ ms}^{-2} \end{aligned}$$

- 16. A copper wire of cross-sectional area 0.5 mm² carries a current of 0.2 A. If the free electron density of copper is $8.4 \times 10^{28} \text{ m}^{-3}$ then compute the drift velocity of free electrons.**

Solution:

The relation between drift velocity of electrons and current in a wire of

$$\text{cross- sectional area } A \text{ is } V_d = \frac{I}{neA};$$

$$= \frac{0.2}{8.4 \times 10^{28} \times 1.6 \times 10^{-19} \times 0.5 \times 10^{-6}}$$

$$= \frac{2 \times 10^{-3}}{6.72}$$

$$V_d = 0.03 \times 10^{-3} \text{ ms}^{-1}$$

- 17.** Determine the number of electrons flowing per second through a conductor, when a current of 32 A flows through it.

Solution:

$I = 32 \text{ A}$, $t = 1 \text{ s}$ Charge of an electron, $e = 1.6 \times 10^{-19} \text{ C}$ The number of electrons flowing per second, $n = ?$

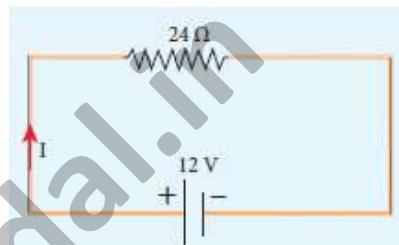
$$I = \frac{q}{t} = \frac{ne}{t}; n = \frac{It}{e}; n = \frac{32 \times 1}{1.6 \times 10^{-19} \text{ C}}$$

$$n = 20 \times 10^{19}, n = 2 \times 10^{20} \text{ electrons}$$

- 18.** A potential difference across 24Ω resistor is 12 V. What is the current through the resistor?

Solution:

$$\text{From Ohm's law, } I = \frac{V}{R}; I = \frac{12}{24}; I = 0.5 \text{ A}$$



- 19.** The resistance of a wire is 20Ω . What will be new resistance, if it is stretched uniformly 8 times its original length?

Solution:

$R_1 = 20 \Omega, R_2 = ?$; Let the original length (l_1) be l

The new length, $l_2 = 8l_1$ (i.e.), $l_2 = 8l$

$$\text{The original resistance, } R_1 = \rho \frac{l_1}{A_2}$$

$$\text{The new resistance } R_2 = \rho \frac{l_2}{A_2} = \frac{\rho (8l)}{A_2}$$

Though the wire is stretched, its volume is unchanged.

Initial volume = Final volume

$$A_1 l_1 = A_2 l_2; A_1 l = A_2 8l; \frac{A_1}{A_2} = \frac{8l}{l} = 8$$

$$\text{By dividing equation } R_2 \text{ by equation } R_1, \text{ we get } \frac{R_2}{R_1} = \frac{\rho (8l)}{A_2} \times \frac{A_1}{\rho_1}$$

$$\frac{R_2}{R_1} = \frac{A_1}{A_2} \times 8$$

$$\text{Substituting the value of } \frac{A_1}{A_2}, \text{ we get } \frac{R_2}{R_1} = 8 \times 8 = 64$$

$$R_2 = 64 \times 20; R_2 = 1280 \Omega$$

Hence, stretching the length of the wire has increased its resistance.

20. Calculate the equivalent resistance for the circuit which is connected to 24 V batteries and also find the potential difference across $4\ \Omega$ and $6\ \Omega$ resistors in the circuit.

Solution:

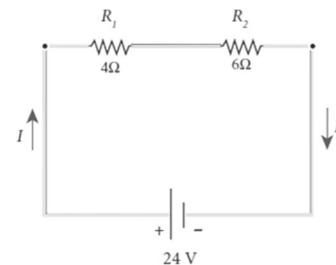
Since the resistors are connected in series, the effective resistance in the circuit = $4 \Omega + 6 \Omega = 10 \Omega$

$$\text{The Current } I \text{ in the circuit} = \frac{V}{R_{\text{eq}}} = \frac{24}{10} = 2.4 \text{ A}$$

Voltage across 4Ω resistor

$$V_1 = IR_1 = 2.4A \times 4\Omega = 9.6V$$

Voltage across $6\ \Omega$ resistors ; $V_2 = IR_1 = 2.4A \times 6\ \Omega = 14.4\text{ V}$



- 21.** Calculate the equivalent resistance in the following circuit and also find the current I , I_1 and I_2 in the given circuit.

Solution:

Since the resistances are connected in parallel, therefore, the equivalent resistance in the circuit is

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{4} + \frac{1}{6}; \frac{1}{R_P} = \frac{5}{12} \Omega \text{ (or) } R_P = \frac{12}{5} \Omega$$

The resistors are connected in parallel; the potential (voltage) across each resistor is the same.

$$I_1 = \frac{V}{R_1} = \frac{24 \text{ V}}{4 \Omega} = 6 \text{ A} \quad ; \quad I_2 = \frac{V}{R_2} = \frac{24 \text{ V}}{6 \Omega} = 4 \text{ A}$$

The current I is the total of the currents in the two branches. Then,

$$I = I_1 + I_2 = 6A + 4A = 10A$$

- 22.** When two resistances connected in series and parallel their equivalent resistances are $15\ \Omega$ and $\frac{56}{15}\ \Omega$ respectively. Find the individual resistances.

Solution:

$$R_s = R_1 + R_2 = 15 \Omega \quad \dots \quad (1)$$

$$R_p = \frac{R_1 R_2}{R_1 + R_2} = \frac{56}{15} \Omega \quad \dots \dots \dots \quad (2)$$

From equation (1) substituting for $R_1 + R_2$ in equation (2)

$$\frac{R_1 R_2}{15} = \frac{56}{15} \Omega ; \therefore R_1 R_2 = 56$$

$$R_2 = \frac{56}{15} \Omega \quad \dots \dots \dots \quad (3)$$

Substituting for R_2 in equation (1) from equation (3)

$$R_1 + \frac{56}{R_1} = 15 ; \text{ Then, } \frac{R_1^2 + 56}{R_1} = 15 ; R_1^2 + 56 = 15 R_1$$

$$R_1^2 - 15 R_1 + 56 = 0$$

The above equation can be solved using factorization.

$$R_1^2 - 8 R_1 - 7 R_1 + 56 = 0 \quad ; \quad R_1(R_1 - 8) - 7(R_1 - 8) = 0$$

$$(R_1 - 8)(R_1 - 7) = 0 ; \text{ If } (R_1 = 8 \Omega)$$

Using in equation (1)

$$8 + R_2 = 15 ; R_2 = 15 - 8 = 7 \Omega ,$$

$$R_2 = 7 \Omega \text{ i.e., (when } R_1 = 8 \Omega ; R_2 = 7 \Omega \text{) ; If } (R_1 = 7 \Omega)$$

Substituting in equation (1) $7 + R_2 = 15$

$$R_2 = 8 \Omega , \text{ i.e., (when } R_1 = 8 \Omega ; R_2 = 7 \Omega \text{) }$$

- 23. If the resistance of coil is 3Ω at 20°C and $\alpha = 0.004/\text{ }^\circ\text{C}$ then determine its resistance at 100°C .**

Solution:

$$R_0 = 3 \Omega, T = 100^\circ\text{C}, T_0 = 20^\circ\text{C}$$

$$\alpha = 0.004/\text{ }^\circ\text{C}, R_T = ?$$

$$R_T = R_0(1 + \alpha(T - T_0))$$

$$R_{100} = 3(1 + 0.004 \times 80); R_{100} = 3(1 + 0.32)$$

$$R_{100} = 3(1.32); \mathbf{R_{100} = 3.96 \Omega}$$

- 24. Resistance of a material at 20°C and 40°C are 45Ω and 85Ω respectively. Find its temperature co-efficient of resistance.**

Solution:

$$T_0 = 20^\circ\text{C}, T = 40^\circ\text{C}, R_0 = 45 \Omega, R = 85 \Omega$$

$$\alpha = \frac{1}{R_0} \frac{\Delta R}{\Delta T}; \alpha = \frac{1}{45} \left(\frac{85 - 45}{40 - 20} \right); = \frac{1}{45} \left(\frac{40}{20} \right)$$

$$\alpha = \mathbf{0.044 / }^\circ\text{C}$$

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

Solution:

- a) The terminal voltage of the battery is equal to voltage drop across the resistor $V = IR = 3.93 \times 3; \mathbf{V = 11.79 V}$

The internal resistance of the battery,

$$r = \left[\frac{\xi - V}{V} \right]; \left[\frac{12 - 11.79}{11.79} \right] \times 3; r = \mathbf{0.05341 \Omega}$$

- b) The power delivered by the battery $P = I\xi = 3.93 \times 12; \mathbf{P = 47.1 W}$

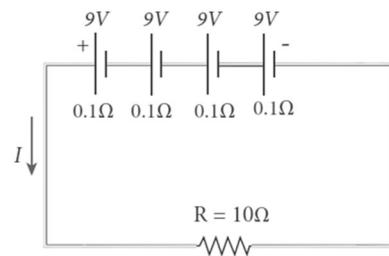
The power delivered to the resistor $= I^2R = 46.3 \text{ W}$

The remaining power $\mathbf{P = (47.1 - 46.3) = 0.8 \text{ W}}$ is delivered to the internal resistance and cannot be used to do useful work. (It is equal to I^2r).

26. From the given circuit,

Find

- Equivalent emf of the combination**
- Equivalent internal resistance**
- Total current**
- Potential difference across external resistance**
- Potential difference across each cell**



Solution:

- Equivalent emf of the combination $\xi_{eq} = n\xi = 4 \times 9 = 36 \text{ V}$
- Equivalent internal resistance $r_{eq} = nr = 4 \times 0.1 = 0.4 \Omega$
- Total current $I = \frac{n\xi}{R+nr} ; = \frac{4 \times 9}{10 + (4 \times 0.1)} ; = \frac{4 \times 9}{10 + 0.4} ; = \frac{36}{10.4} \text{ A}$
 $I = 3.46 \text{ A}$
- Potential difference across external resistance
 $V = IR = 3.46 \times 10 = 34.6 \text{ V}$. The remaining 1.4 V is dropped across the internal resistance of cells.
- Potential difference across each cell $\frac{V}{n} = \frac{34.6}{4} = 8.65 \text{ V}$

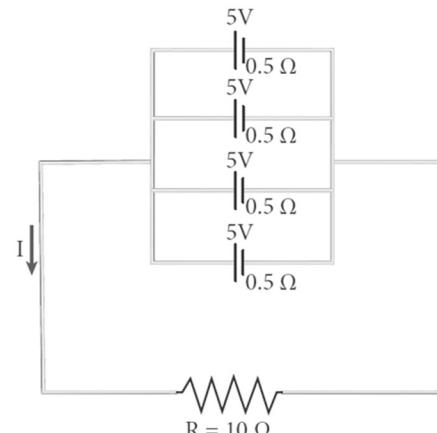
27. From the given circuit

Find

- Equivalent emf**
- Equivalent internal resistance**
- Total current (I)**
- Potential difference across each cell**
- Current from each cell**

Solution:

- Equivalent emf $\xi_{eq} = 5 \text{ V}$
- Equivalent internal resistance, $R_{eq} = \frac{r}{n}$
 $= \frac{0.5}{4} = 0.125 \Omega$
- Total Current, $I = \frac{\xi}{R+ \frac{r}{n}} ; I = \frac{5}{10 + 0.125} = \frac{5}{10.125} \text{ A} \approx 0.5 \text{ A}$
- Potential difference across each cell $V = IR = 0.5 \times 10 = 5 \text{ V}$
- Current from each cell, $I' = \frac{I}{n} ; I' = \frac{0.5}{4} ; I' = 0.125 \text{ A}$



- 28. Calculate the current that flows in the $1\ \Omega$ resistor in the following circuit.**

Solution:

We can denote the current that flows from 9V battery as I_1 and it splits into I_2 and $I_1 - I_2$ in the junction according Kirchhoff's current rule (KCR). It is shown below.

Now consider the loop EFCBE and apply KVR, we get

$$1I_2 + 3I_1 + 2I_1 = 9$$

$$5I_1 + I_2 = 9 \dots\dots\dots(1)$$

Applying KVR to the loop EADFE, we get

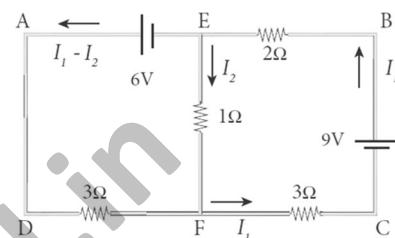
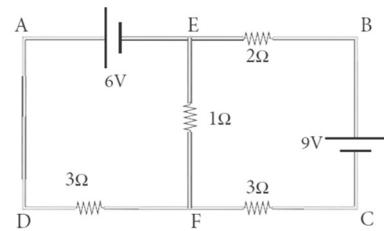
$$3(I_1 - I_2) - 1I_2 = 6$$

$$3I_1 - 4I_2 = 6 \dots\dots\dots(2)$$

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

$$I_1 = 1.83\ A \text{ and } I_2 = -0.13\ A$$

It implies that the current in the 1-ohm resistor flows from F to E.



- 29. In a Wheatstone's Bridge $P = 100\ \Omega$, $Q = 1000\ \Omega$ and $R = 40\ \Omega$. If the galvanometer shows zero deflection, determine the value of S .**

Solution:

$$\frac{P}{Q} = \frac{R}{S};$$

$$S = \frac{Q}{P} \times R;$$

$$S = \frac{1000}{100} \times 40; S = 400\ \Omega$$

- 30. What is the value of x when the Wheatstone's network is balanced?**

$$P = 500\ \Omega, Q = 800\ \Omega, R = x + 400,$$

$$S = 1000\ \Omega$$

Solution:

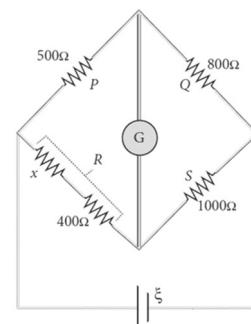
$$\frac{P}{Q} = \frac{R}{S}; \frac{500}{800} = \frac{x+400}{1000}; \frac{x+400}{1000} = \frac{500}{800}$$

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

$$x + 400 = 0.625 \times 1000$$

$$x + 400 = 625; x = 625 - 400$$

$$x = 225\ \Omega$$



- 31.** In a meter bridge, the value of resistance in the resistance box is 10Ω . The balancing length is $l_1 = 55$ cm. Find the value of unknown resistance.

Solution:

$$Q = 10 \Omega \quad \frac{P}{Q} = \frac{l_1}{100 - l_1} = \frac{l_1}{l_2}; \quad P = Q \times \frac{l_1}{100 - l_1} \quad P = \frac{10 \times 55}{100 - 55}$$

$$P = \frac{550}{45}; \quad P = 12.2 \Omega$$

- 32.** Find the heat energy produced in a resistance of 10Ω when 5 A current flow through it for 5 minutes.

Solution:

$$R = 10 \Omega, I = 5 \text{ A}, t = 5 \text{ minutes} = 5 \times 60 \text{ s}$$

$$H = I^2 R t$$

$$= 5^2 \times 10 \times 5 \times 60; = 25 \times 10 \times 300$$

$$= 25 \times 3000; \quad R = 75000 \text{ J (or) } 75 \text{ kJ}$$

EXERCISE PROBLEM

- 33.** A copper wire of 10^{-6} m^2 area of cross section, carries a current of 2 A . If the number of electrons per cubic meter is 8×10^{28} , calculate the current density and average drift velocity.

Solution:

Cross – sections area of copper wire, $A = 10^{-6} \text{ m}^2, I = 2 \text{ A}$

Number of electron, $n = 8 \times 10^{28}$

Current density, $J = \frac{I}{A} = \frac{2}{10^{-6}}; J = 2 \times 10^6 \text{ Am}^{-2}$

Average drift velocity, $V_d = \frac{I}{neA}$

e is the charge of electron = $1.6 \times 10^{-19} \text{ C}$

$$V_d = \frac{2}{8 \times 10^{28} \times 1.6 \times 10^{-19} \times 10^{-6}} = \frac{1}{64 \times 10^3}$$

$$V_d = 0.15625 \times 10^{-3}; V_d = 15.625 \times 10^{-3} \text{ ms}^{-1}$$

No.	Log
1	0.0000
6.490	0.8062
(–)	1.1938
Antilog	1.562×10^{-1}

- 34.** The resistance of a nichrome wire at 20°C is 10Ω . If its temperature coefficient of resistance is $0.004/\text{°C}$, find its resistance at boiling point of water. Comment on the result.

Solution:

Temperature of boiling point of water, $R_T = R_0 [1 + \alpha (T - T_0)]$

$$= 10 [(1 + 0.004 (100 - 20))]$$

$$= 10 [1 + 0.004 \times 80]$$

$$= 10 [1 + 0.32]; = 10 \times 1.32$$

$$R_T = 13.2 \Omega$$

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

- 35. The rod given in the figure is made up of two different materials**



Both have square cross sections of 3 mm side. The resistivity of the first material is $4 \times 10^{-3} \Omega\text{m}$ and that of second material has resistivity of $5 \times 10^{-3} \Omega\text{m}$. What is the resistance of rod between its ends?

Solution:

$$A = 3\text{mm} \times 3\text{mm} = 9\text{mm}^2 = 9 \times 10^{-6} \text{m}^2; l_1 = 25 \text{cm} = 25 \times 10^{-2} \text{m},$$

$$l_2 = 70 \text{ cm} = 70 \times 10^{-2} \text{ m}; \rho_1 = 4 \times 10^{-3}; \rho_2 = 5 \times 10^{-3};$$

$$\text{Resistance of first material } R_1 = \frac{\rho_1 l_1}{A} ; = \frac{4 \times 10^{-3} \times 25 \times 10^{-2}}{9 \times 10^{-6}} ; = \frac{1000}{9} \Omega$$

$$\text{Resistance of second material } R_2 = \frac{\rho_2 l_2}{A} ; = \frac{5 \times 10^{-3} \times 70 \times 10^{-2}}{9 \times 10^{-6}} ; \frac{3500}{9} \Omega$$

The two materials are in series, their effective resistance

$$R_{\text{tot}} = R_1 + R_2 ;$$

$$= \frac{1000}{9} + \frac{3500}{9}; = \frac{4500}{9}; \quad R_{\text{tot}} = 500 \Omega$$

- 36.** An electronics hobbyist is building a radio which requires $150\ \Omega$ in her circuit, but she has only $220\ \Omega$, $79\ \Omega$ and $92\ \Omega$ resistors available. How can she connect the available resistors to get desired value of resistance?

Solution:

Required effective resistance = $150\ \Omega$

Resistors of resistance, $R_1 = 220\Omega$, $R_2 = 79\Omega$, $R_3 = 92\Omega$

Parallel combination of R_1 and R_2

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{220} + \frac{1}{79}; \frac{79+220}{220 \times 79} \quad R_p = 58 \Omega$$

Parallel combination of R_P and R_3

$$R_s = R_p + R_3; = 58 + 92 \quad \mathbf{Rs = 150 \Omega}$$

No.	Log
17380	4.2400
299	2.4757
(-)	1.7643
Antilog	5.811×10^1

37. A cell supplies a current of 0.9 A through a $2\ \Omega$ resistor and a current of 0.3 A through a $7\ \Omega$ resistor. Calculate the internal resistance of the cell.

Solution:

The internal resistance of the cell $I_1 = \frac{\varepsilon}{R_1+r}$; $\varepsilon = I_1 (R_1 + r)$ 1

The internal resistance of the cell $I_2 = \frac{\varepsilon}{R_2+r}$; $\varepsilon = I_2 (R_2 + r)$ 1

From equation 1 and 2

$$I_1(R_1 + r) = I_2(R_2 + r)$$

$$r = \frac{I_1 R_1 - I_2 R_2}{I_2 - I_1} ; = \frac{(0.9 \times 2) - (0.3 \times 7)}{0.3 - 0.9} ; = \frac{1.8 - 2.1}{-0.6} ; = \frac{0.3}{0.6} ; = \frac{1}{2} \quad r = 0.5\Omega$$

- 38.** A potentiometer wire has a length of 4 m and resistance of 20Ω . It is connected in series with resistance of 2980Ω and a cell of emf 4 V. Calculate the potential along the wire.

Solution:

Resistance of the wire, $r = 20 \Omega$

Length of the potential wire, $l = 4\text{m}$

Resistance connected series with potentiometer wire, $R = 2980 \Omega$

Emf of the cell, $\xi = 4\text{V}$

Effective resistance, $R = r + R = 20 + 2980 = 3000 \Omega$

Current flowing through the wire, $I = \frac{\xi}{R_s} = \frac{4}{3000}$

$$I = 1.33 \times 10^{-3} \text{ A}$$

Potential difference across the Potentiometer wire

$$V = IR ; = 1.33 \times 10^{-3} \times 20 ; V = 26.6 \times 10^{-3} \text{ V}$$

Then the Potential gradient along the wire

$$V = Ir ; = 1.33 \times 10^{-3} \times 5 ; V = 6.65 \times 10^{-3} \text{ Vm}^{-1}$$

- 39.** Two cells each of 5V are connected in series across a 8Ω resistor and three parallel resistors of 4Ω , 6Ω and 12Ω . Draw a circuit diagram for the above arrangement. Calculate i) the current drawn from the cell (ii) current through each resistor.

Solution:

$$V_1 = 5\text{V} ; V_2 = 5\text{V}$$

$$R_1 = 8 \Omega , R_2 = 4 \Omega , R_3 = 6 \Omega , R_4 = 12 \Omega$$

Three resistors R_2 , R_3 and R_4 are connected parallel combination

$$\begin{aligned} \frac{1}{R_p} &= \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} ; = \frac{1}{4} + \frac{1}{6} + \frac{1}{12} ; \\ &= \frac{3}{12} + \frac{2}{12} + \frac{1}{12} ; = \frac{6}{12} ; R_p = 2 \Omega \end{aligned}$$

Resistors R_1 , and R_p are connected in series combination

$$R_s = R_1 + R_p ; = 8 + 2 = 10$$

$$\text{Total voltage connected series to the circuit } V = V_1 + V_2$$

$$= 5 + 5 = 10 ; V = 10 \text{ V}$$

$$\text{i) Current through the circuit, } I = \frac{V}{R_s} = \frac{10}{10} ; I = 1\text{A}$$

Potential drop across the parallel combination, $V' = IR_p = 1 \times 2 ; V' = 2\text{V}$

$$\text{ii) Current in } 4\Omega \text{ resistor, } I = \frac{V'}{R_2} = \frac{2}{4} = 0.5 \text{ A}$$

$$\text{Current in } 6\Omega \text{ resistor, } I = \frac{V'}{R_3} = \frac{2}{6} = 0.33 \text{ A}$$

$$\text{Current in } 12\Omega \text{ resistor, } I = \frac{V'}{R_4} = \frac{2}{12} = 0.17 \text{ A}$$

- 40.** In a potentiometer arrangement, a cell of emf 1.25 V gives a balance point at 35 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 63 cm, what is the emf of the second cell?

Solution:

$$\text{Emf of the cell}_1, \xi_1 = 1.25\text{V}$$

$$\text{Balancing length of the cell, } l_1 = 35 \text{ cm} = 35 \times 10^{-2} \text{ m}$$

$$\text{Balancing length after interchanged, } l_2 = 63 \text{ cm} = 63 \times 10^{-2} \text{ m}$$

$$\text{Emf of the cell}_2, \xi_2 ?$$

$$\text{The ratio of emf's } \frac{\xi_1}{\xi_2} = \frac{l_1}{l_2}$$

$$\text{The ratio of emf's } \xi_2 = \xi_1 \left(\frac{l_1}{l_2} \right)$$

$$= 1.25 \times \left(\frac{63 \times 10^{-2}}{35 \times 10^{-2}} \right)$$

$$= 1.25 \times 1.8$$

$$\xi_2 = 2.25\text{V}$$

UNIT - III (MAGNETISM AND MAGNETIC EFFECTS OF ELECTRIC CURRENT)

- 41.** The horizontal component and vertical component of Earth's magnetic field at a place are 0.15 G and 0.26 G respectively. Calculate the angle of dip and resultant magnetic field. (G-gauss, cgs unit for magnetic field $1\text{G} = 10^{-4} \text{ T}$)

Solution:

$$B_H = 0.15 \text{ G} \text{ and } B_V = 0.26 \text{ G}$$

$$\text{Angle of dip } I \text{ is } \tan I = \frac{B_V}{B_H}; = \frac{0.26}{0.15}; = \frac{26}{15} = 1.733; I = \tan^{-1}(1.733) = 60^\circ$$

$$\begin{aligned} \text{Resultant magnetic field. } B &= \sqrt{B_H^2 + B_V^2}; = \sqrt{0.15^2 + 0.26^2} \\ &= \sqrt{0.0225 + 0.0676}; = \sqrt{0.0901}; B = 0.3\text{G} \end{aligned}$$

- 42.** Compute the magnetic length of a uniform bar magnet if the geometrical length of the magnet is 12 cm. Mark the positions of magnetic pole points.

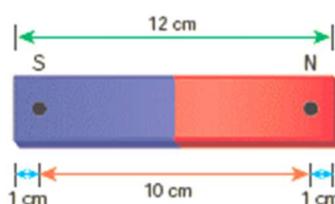
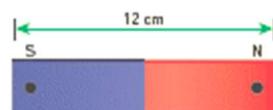
Solution:

Geometrical length of the bar magnet is 12 cm

$$\text{Magnetic Length} = \frac{5}{6} \times (\text{Geometrical Length}) ; = \frac{5}{6} \times 12$$

$$\text{Magnetic Length} = 10 \text{ cm}$$

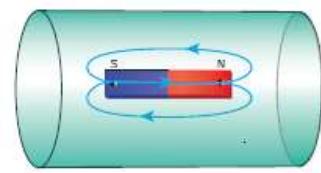
In this figure, the dot implies the pole points.



- 43. Calculate the magnetic flux coming out from closed surface containing magnetic dipole (say, a bar magnet) as shown in figure.**

Solution:

The total flux emanating from the closed surface S enclosing the dipole is zero. So, $\oint \vec{B} \cdot d\vec{A} = 0$



Here the integral is taken over closed surface. Since no isolated magnetic pole (called magnetic monopole) exists, this integral is always zero, $\oint \vec{B} \cdot d\vec{A} = 0$ This is similar to Gauss's law in electrostatics.

- 44. 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.**

Solution:

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 = 10×10^{-2} m

Therefore, $9 \times 10^{-3} = 10^{-7} \times \frac{q_m^2}{(10 \times 10^{-2})^2} \Rightarrow q_m^2 = 900 ; q_m = 30 \text{ NT}^{-1}$

- 45. Compute the intensity of magnetisation of the bar magnet whose mass, magnetic moment and density are 200 g, 2 A m^2 and 8 g cm^{-3} , respectively.**

Solution:

Density of the magnet is, Density = $\frac{\text{Mass}}{\text{Volume}} \Rightarrow \text{Volume} = \frac{\text{Mass}}{\text{Density}}$

Volume = $\frac{200 \times 10^{-3} \text{ kg}}{(8 \times 10^{-3}) \times 10^6 \text{ m}^{-3}}$ **Volume = $25 \times 10^{-6} \text{ m}^3$**

Magnitude of magnetic moment $p_m = 2 \text{ Am}^2$

Intensity of magnetization, $I = \frac{\text{Magnetic moment}}{\text{Volume}} ; = \frac{2}{25 \times 10^{-6}}$

$I = 0.8 \times 10^5 \text{ Am}^{-1}$

- 46. Two materials X and Y are magnetized, whose intensity of magnetization are 500 Am^{-1} and 2000 Am^{-1} , respectively. If the magnetizing field is 1000 Am^{-1} , then which one among these materials can be easily magnetized?**

Solution:

The susceptibility of material X is $\chi_m X = \frac{|\vec{M}|}{|\vec{H}|} = \frac{500}{100} = 0.5$

The susceptibility of material Y is $\chi_m Y = \frac{|\vec{M}|}{|\vec{H}|} = \frac{2000}{1000} = 2$

Since, susceptibility of material Y is greater than that of material X, material Y can be easily magnetized than X.

- 47. A coil of a tangent galvanometer of diameter 0.24 m has 100 turns. If the horizontal component of Earth's magnetic field is 25×10^{-6} T then, calculate the current which gives a deflection of 60° .**

Solution:

The diameter of the coil is 0.24 m.

Therefore, radius of the coil is 0.12 m.

Number of turns is 100 turns.

Earth's magnetic field is 25×10^{-6} T

Deflection is $\theta = 60^\circ \Rightarrow \tan 60^\circ = \sqrt{3} = 1.732$

$$I = \frac{2RB_H}{\mu_0 N} \tan\theta ; \quad = \frac{2 \times 0.12 \times 25 \times 10^{-6}}{4 \times 10^{-7} \times 3.14 \times 100} \times 1.732$$

$$\mathbf{I = 0.82 \times 10^{-1} A (or) \quad I = 0.082 A.}$$

No.	Log
6	0.7782
1.732	0.2385
(+)	1.0167
12.56	1.0990
(-)	1.9177
Antilog	8.274×10^{-1}

- 48. Compute the magnitude of the magnetic field of a long, straight wire carrying a current of 1 A at distance of 1m from it. Compare it with Earth's magnetic field.**

Solution:

Given that $I = 1$ A and radius $r = 1$ m

$$B_{\text{straight wire}} = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 1}{2\pi \times 1} = 2 \times 10^{-7} \text{ T}$$

But the Earth's magnetic field is $B_{\text{Earth}} \sim 10^{-5}$ T

So, $B_{\text{straight wire}}$ is one hundred times smaller B_{Earth}

- 49. An electron moving perpendicular to a uniform magnetic field 0.500 T undergoes circular motion of radius 2.50 mm. What is the speed of electron?**

Solution:

Charge of an electron $q = -1.60 \times 10^{-19}$ C $\Rightarrow |q| = 1.60 \times 10^{-19}$ C

Magnitude of magnetic field $B = 0.500$ T

Mass of the electron, $m = 9.11 \times 10^{-31}$ kg

Radius of the orbit, $r = 2.50$ mm $= 2.50 \times 10^{-3}$ m

$$\text{Velocity of the electron, } v = |q| \frac{rB}{m}$$

$$v = 1.60 \times 10^{-19} \times \frac{2.50 \times 10^{-3} \times 0.500}{9.11 \times 10^{-31}} ;$$

$$\mathbf{v = 2.195 \times 10^8 \text{ ms}^{-1}}$$

- 50.** Suppose a cyclotron is operated to accelerate protons with a magnetic field of strength 1 T. Calculate the frequency in which the electric field between two Dees could be reversed.

Solution:

$$\text{Magnetic field } B = 1 \text{ T}$$

$$\text{Mass of the proton, } m_p = 1.67 \times 10^{-27} \text{ kg}$$

$$\text{Charge of the proton, } q = 1.6 \times 10^{-19} \text{ C}$$

$$f = \frac{qB}{2\pi m_p} = \frac{1.6 \times 10^{-19} \times 1}{2 \times 3.14 \times 1.67 \times 10^{-27}} \\ = 15.3 \times 10^6 \text{ Hz; } f = 15.3 \text{ MHz}$$

- 51.** The coil of a moving coil galvanometer has 5 turns and each turn has an effective area of $2 \times 10^{-2} \text{ m}^2$. It is suspended in a magnetic field whose strength is $4 \times 10^{-2} \text{ Wb m}^{-2}$. If the torsional constant K of the suspension fibre is $4 \times 10^{-9} \text{ N m deg}^{-1}$

- (a) Find its current sensitivity in division per micro - ampere.
- (b) Calculate the voltage sensitivity of the galvanometer for it to have full scale deflection of 50 divisions for 25 mV.
- (c) Compute the resistance of the galvanometer

Solution:

(a) Current Sensitivity

$$I_s = \frac{NAB}{K} ; = \frac{5 \times 2 \times 10^{-2} \times 4 \times 10^{-2}}{4 \times 10^{-9}} = 10^6 \text{ divisions per ampere}$$

$$1\mu\text{A} = 1 \text{ microampere} = 10^{-6} \text{ ampere}$$

$$\text{Therefore, } I_s = 10^6 \frac{\text{div}}{A} ; = 1 \frac{\text{div}}{10^{-6} A} ; = 1 \frac{\text{div}}{\mu\text{A}}$$

$$I_s = 1 \text{ div } (\mu\text{A})^{-1}$$

(b) Voltage Sensitivity

$$V_s = \frac{\theta}{V} ; = \frac{50 \text{ div}}{25 \text{ mV}} ; V_s = 2 \times 10^3 \text{ div V}^{-1}$$

(c) The resistance of the galvanometer is

$$R_g = \frac{I_s}{V_s} ; = \frac{10^6 \frac{\text{div}}{\mu\text{A}}}{2 \times 10^3 \frac{\text{div}}{\text{V}}} ; = 0.5 \times 10^3 \frac{\text{V}}{\mu\text{A}} ; R_g = 0.5 \text{ k}\Omega$$

52. The resistance of a moving coil galvanometer is made twice its original value in order to increase current sensitivity by 50%. Will the voltage sensitivity change? If so, by how much?

Solution:

Yes, voltage sensitivity will change. ; Voltage sensitivity is $V_s = \frac{I_s}{R}$

When the resistance is doubled, then new resistance is $R' = 2R$

Increase in current sensitivity is $I'_s = \left(1 + \frac{50}{100}\right) I_s = \frac{3}{2} I_s$

The new voltage sensitivity is $V'_s = \frac{\frac{3}{2}I_s}{2R} = \frac{3}{4}V_s$

Hence the voltage sensitivity decreases. The percentage decrease in

$$\text{voltage sensitivity is } \frac{V_s - V'_s}{V_s} \times 100\% = 25\%$$

EXERCISE PROBLEM

Solution:

Cross sectional area of coil, $A = 0.1 \text{ cm}^2$; $A = 0.1 \times 10^{-4} \text{ m}^2$

Uniform magnetic field of strength, $B = 0.2\text{T}$

Current passing in the coil, $I = 3A$

Angle between the magnetic field and normal to the coil, $\theta = 0^\circ$

a) Total torque on the coil.

$$\tau = \text{ABI} \sin \theta = 0.1 \times 10^{-4} \times 0.2 \times 3 \sin 0^\circ \sin 0^\circ = 0$$

τ = 0

b) Total force on the coil $F = BIl \sin \theta = 0.2 \times 3 \times l \times \sin 0^\circ$

$$F = 0$$

c) Average force: $F = qV_dB$ $[\because q = e]$

$$\text{Drift velocity, } V_d = \frac{I}{neA} ; F = e \left(\frac{I}{neA} \right) B \quad [\because n = 10^{28} \text{ m}^{-3}]$$

$$= \frac{IB}{nA} = \frac{3 \times 0.2}{10^{28} \times 0.1 \times 10^{-4}} = 6 \times 10^{-24}; F_{av} = 0.6 \times 10^{-23} N$$

54. A non - conducting sphere has a mass of 100 g and radius 20 cm. A flat compact coil of wire with turns 5 is wrapped tightly around it with each turns concentric with the sphere. This sphere is placed on an inclined plane such that plane of coil is parallel to the inclined plane. A uniform magnetic field of 0.5 T exists in the region in vertically upward direction. Compute the current I required to rest the sphere in equilibrium.

Solution:

Torque on the sphere due to magnetic field about its centre:

$$\tau_B = \text{NBAI} \sin\theta \quad \dots \quad 1$$

Torque on the sphere due to friction about its centre;

$$\tau_a = mgR \sin\theta \quad \dots \quad 2$$

Under rotational equilibrium (From equation 1 and 2) $\tau_B = \tau_a$

$$NBAI \sin\theta = mgR \sin\theta$$

$$I = \frac{mgR}{NBA} ; I = \frac{0.1 \times 10 \times 0.2}{5 \times 0.5 \times \pi \times 0.2 \times 0.2} ; I = \frac{1}{0.5\pi} ; I = \frac{2}{\pi} A$$

55. Calculate the magnetic field at the center of a square loop which carries a current of 1.5 A. length of each loop is 50 cm.

Solution:

Current through the square loop, $I = 1.5\text{A}$

Length of each loop, $l = 50 \text{ cm} = 50 \times 10^{-2} \text{ m}$

According to Biot - Savart Law.

Magnetic field due to a current carrying straight wire

$$\begin{aligned}
 B &= \frac{\mu_0 I}{4\pi a} (\sin \alpha + \sin \beta) \\
 &= \frac{4\pi \times 10^{-7} \times 1.5}{4\pi \times \left(\frac{1}{2}\right)} (\sin 45^\circ + \sin 45^\circ) \\
 &= \frac{2 \times 1.5 \times 10^{-7}}{1} [2 \sin 45^\circ] = \frac{2 \times 1.5 \times 10^{-7}}{50 \times 10^{-2}} [2 \sin 45^\circ] \\
 &= \frac{1.5 \times 10^{-5}}{25} [2 \sin 45^\circ]; = 0.06 \times 10^{-5} \times 2 \times \frac{1}{\sqrt{2}}; = 6\sqrt{2} \times 10^{-7} T
 \end{aligned}$$

$$B = 4 \times 6\sqrt{2} \times 10^{-7} \text{ T} = 24 \times 1.414 \times 10^{-7} \text{ T} = 33.936 \times 10^{-7} \text{ T}$$

$$= 3.3936 \times 10^{-6} \text{ T}$$

$$B = 3.4 \times 10^{-6} T$$

UNIT - IV (ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENT)

- 56.** A circular antenna of area 3m^2 is installed at a place in Madurai. The plane of the area of antenna is inclined at 47° with the direction of Earth's magnetic field. If the magnitude of Earth's field at that place is 4.1×10^{-5} T. find the magnetic flux linked with the antenna.

Solution:

$$B = 4.1 \times 10^{-5} \text{ T}; \theta = 90^\circ - 47^\circ = 43^\circ; A = 3\text{m}^2$$

$$\begin{aligned} \text{We know that } \phi_B &= BA \cos \theta \\ &= 4.1 \times 10^{-5} \times 3 \times \cos 43^\circ \\ &= 4.1 \times 10^{-5} \times 3 \times 0.7314 \\ \phi_B &= 89.96 \mu\text{Wb} \end{aligned}$$

- 57.** A circular loop of area $5 \times 10^{-2}\text{m}^2$ rotates in a uniform magnetic field of 0.2 T. If the loop rotates about its diameter which is perpendicular to the magnetic field as shown in figure. Find the magnetic flux linked with the loop when its plane is (i) normal to the field (ii) inclined 60° to the field and (iii) parallel to the field.

Solution:

$$A = 5 \times 10^{-2} \text{ m}^2; B = 0.2 \text{ T}$$

$$(i) \theta = 0^\circ;$$

$$\phi_B = BA \cos \theta$$

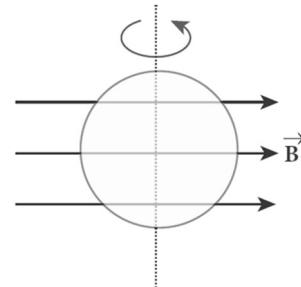
$$= 0.2 \times 5 \times 10^{-2} \times \cos 0^\circ; \phi_B = 1 \times 10^{-2} \text{ Wb.}$$

$$(ii) \theta = 90^\circ - 60^\circ = 30^\circ;$$

$$\phi_B = BA \cos \theta;$$

$$= 0.2 \times 5 \times 10^{-2} \times \cos 30^\circ; \phi_B = 1 \times 10^{-2} \times \frac{\sqrt{3}}{2}; \phi_B = 8.66 \times 10^{-3} \text{ Wb.}$$

$$(iii) \theta = 90^\circ; \phi_B = BA \cos 90^\circ = 0$$



- 58.** A cylindrical bar magnet is kept along the axis of a circular solenoid. If the magnet is rotated about its axis, find out whether an electric current is induced in the coil.

Solution:

The magnetic field of a cylindrical magnet is symmetrical about its axis. As the magnet is rotated along the axis of the solenoid, there is no induced current in the solenoid because the flux linked with the solenoid does not change due to the rotation of the magnet.

- 59.** A closed coil of 40 turns and of area 200 cm^2 , is rotated in a magnetic field of flux density 2 Wb m^{-2} . It rotates from a position where its plane makes an angle of 30° with the field to a position perpendicular to the field in a time 0.2 sec. Find the magnitude of the emf induced in the coil due to its rotation.

Solution:

$$N = 40 \text{ turns}; B = 2 \text{ Wb m}^{-2}; A = 200 \text{ cm}^2 = 200 \times 10^{-4} \text{ m}^2;$$

$$\text{Initial flux, } \phi_i = BA \cos \theta ; = 2 \times 200 \times 10^{-4} \times \cos 60^\circ$$

$$\text{Since } \theta = 90^\circ - 30^\circ = 60^\circ; \phi_i = 2 \times 10^{-2} \text{ Wb}$$

$$\text{Final flux, } \phi_f = BA \cos \theta ; = 2 \times 200 \times 10^{-4} \times \cos 0^\circ$$

$$\text{Since } \theta = 0^\circ; \phi_f = 4 \times 10^{-2} \text{ Wb}$$

$$\text{Magnitude of the induced emf is } \epsilon = N \frac{d\phi_B}{dt}$$

$$= \frac{40 \times (4 \times 10^{-2} - 2 \times 10^{-2})}{0.2} \quad \epsilon = 4V$$

- 60.** A straight conducting wire is dropped horizontally from a certain height with its length along east – west direction. Will an emf be induced in it? Justify your answer.

Solution:

Yes! An emf will be induced in the wire because it moves perpendicular to the horizontal component of Earth's magnetic field.

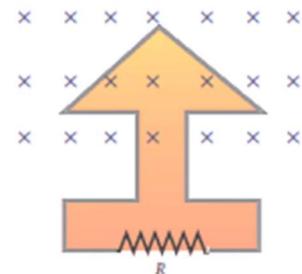
- 61.** The magnetic flux passes perpendicular to the plane of the circuit and is directed into the paper. If the magnetic flux varies with respect to time as per the following relation: $\Phi_B = (2t^3 + 3t^2 + 8t + 5) \text{ mWb}$, what is the magnitude of the induced emf in the loop when $t = 3 \text{ s}$? Find out the direction of current through the circuit.

Solution:

$$\begin{aligned} \epsilon &= \frac{d(N\Phi_B)}{dt} ; = \frac{d}{dt} (2t^3 + 3t^2 + 8t + 5) \times 10^{-3} \\ &= (6t^2 + 6t + 8) \times 10^{-3} \text{ V} \end{aligned}$$

At $t = 3 \text{ s}$,

$$\begin{aligned} \epsilon &= [(6 \times 9) + (6 \times 3) + 8] \times 10^{-3} ; \\ &= 54 + 18 + 8 ; \epsilon = 80 \times 10^{-3} \text{ V} ; \epsilon = 80 \text{ mV} \end{aligned}$$



As time passes, the magnetic flux linked with the loop increases. According to Lenz's law, the direction of the induced current should be in a way so as to oppose the flux increase. So, the induced current flows in such a way to produce a magnetic field opposite to the given field. This magnetic field is perpendicularly outwards. Therefore, the induced current flows in anti-clockwise direction.

- 62.** A conducting rod of length 0.5 m falls freely from the top of a building of height 7.2 m at a place in Chennai where the horizontal component of Earth's magnetic field is 40378.7nT. If the length of the rod is perpendicular to Earth's horizontal magnetic field, find the emf induced across the conductor when the rod is about to touch the ground. [Take $g = 10 \text{ m s}^{-2}$]

Solution:

$$l = 0.5 \text{ m}; h = 7.2 \text{ m}; u = 0 \text{ m s}^{-1}; g = 10 \text{ ms}^{-2}; B_H = 40378.7\text{nT}$$

$$\text{The final velocity of the rod is } v^2 = u^2 + 2gh ; 0 + (2 \times 10 \times 7.2)$$

$$v^2 = 144 ; v = 12 \text{ ms}^{-1}$$

$$\text{Induced emf when the rod is about to touch the ground, } \epsilon = B_H l v$$

$$= 40378.7 \times 10^{-9} \times 0.5 \times 12 ; = 242.27 \times 10^{-6} \text{ V}$$

$$\epsilon = 242.27 \mu\text{F}$$

- 63.** A solenoid of 500 turns is wound on an iron core of relative permeability 800. The length and radius of the solenoid are 40 cm and 3 cm respectively. Calculate the average emf induced in the solenoid if the current in it changes from 0 to 3 A in 0.4 second.

Solution:

$$N = 500 \text{ turns}; \mu_r = 800 ; l = 40 \text{ cm} = 0.4 \text{ m}; r = 3 \text{ cm} = 0.03 \text{ m};$$

$$di = 3 - 0 = 3 \text{ A}; dt = 0.4 \text{ s}$$

$$\text{Self-inductance, } L = \mu n^2 A l$$

$$\begin{aligned} (\therefore \mu = \mu_0 \mu_r; A = \pi r^2; n = \frac{N}{l}) &= \frac{\mu_0 \mu_r N^2 \pi r^2}{l}, \\ &= \frac{4 \times 3.14 \times 10^{-7} \times 800 \times 500^2 \times 3.14 \times (3 \times 10^{-2})^2}{0.4} \end{aligned}$$

$$L = 1.77 \text{ H}$$

$$\text{Magnitude of induced emf, } \epsilon = L \frac{di}{dt}, \frac{1.77 \times 3}{0.4},$$

$$\epsilon = 13.275 \text{ V}$$

No.	Log
3.14	0.4969
3.14	0.4969
1800	3.2553
(-)	4.2491
Antilog	1.775×10^4

- 64.** The self-inductance of an air-core solenoid is 4.8 mH. If its core is replaced by iron core, then its self-inductance becomes 1.8 H. Find out the relative permeability of iron.

Solution:

$$L_{\text{air}} = 4.8 \times 10^{-3} \text{ H}; L_{\text{iron}} = 1.8 \text{ H}; L_{\text{air}} = \mu_0 n^2 A l = 4.8 \times 10^{-3} \text{ H}$$

$$L_{\text{iron}} = \mu n^2 A l ; \mu_0 \mu_r n^2 A l = 1.8 \text{ H}$$

$$\therefore \mu_r = \frac{L_{\text{iron}}}{L_{\text{air}}} = \frac{1.8}{4.8 \times 10^{-3}} \quad \mu_r = 375$$

- 65.** The current flowing in the first coil changes from 2 A to 10 A in 0.4 sec. Find the mutual inductance between two coils if an emf of 60 mV is induced in the second coil. Also determine the induced emf in the second coil if the current in the first coil is changed from 4 A to 16 A in 0.03 sec. Consider only the magnitude of induced emf.

Solution:

$$\text{Case (i): } di_1 = 10 - 2 = 8 \text{ A; } dt = 0.4 \text{ s; } \epsilon_2 = 60 \times 10^{-3} \text{ V}$$

$$\text{Case (ii): } di_1 = 16 - 4 = 12 \text{ A; } dt = 0.03 \text{ s}$$

(i) Mutual inductance of the second coil with respect to the first coil

$$M_{21} = \frac{\epsilon_2}{\frac{di_1}{dt}} = \frac{60 \times 10^{-3} \times 0.4}{8}; M_{21} = 3 \times 10^{-3} \text{ H}$$

(ii) Induced emf in the second coil due to the rate of change of current

$$\text{in the first coil is } \epsilon_2 = M_{21} \frac{di}{dt}; = \frac{3 \times 10^{-3} \times 12}{0.03}; \epsilon_2 = 1.2 \text{ V}$$

- 66.** A circular metal of area 0.03 m² rotates in a uniform magnetic field of 0.4 T. The axis of rotation passes through the centre and perpendicular to its plane and is also parallel to the field. If the disc completes 20 revolutions in one second and the resistance of the disc is 4 Ω, calculate the induced emf between the axis and the rim and induced current flowing in the disc.

Solution:

$$A = 0.03 \text{ m}^2; B = 0.4 \text{ T}; f = 20 \text{ rps; } R = 4 \Omega$$

$$\begin{aligned} \text{Area covered in 1 sec} &= \text{Area of the disc} \times \text{frequency} \\ &= 0.03 \times 20; = 0.6 \text{ m}^2 \end{aligned}$$

Induced emf, ε = Rate of change of flux

$$\epsilon = \frac{d\phi_B}{dt} = \frac{d(BA)}{dt}; \epsilon = \frac{0.4 \times 0.6}{1}; \epsilon = 0.24 \text{ V}$$

$$\text{Induced current, } i = \frac{\epsilon}{R} = \frac{0.24}{4}; i = 0.06 \text{ A}$$

- 67.** A rectangular coil of area 70 cm² having 600 turns rotates about an axis perpendicular to a magnetic field of 0.4 Wb m⁻². If the coil completes 500 revolutions in a minute, calculate the instantaneous emf when the plane of the coil is (i) perpendicular to the field (ii) parallel to the field and (iii) inclined at 60° with the field.

Solution:

$$A = 70 \times 10^{-4} \text{ m}^2; N = 600 \text{ turns, } B = 0.4 \text{ Wb m}^{-2}; f = 500 \text{ rpm}$$

$$\begin{aligned} \text{The instantaneous emf is } \epsilon &= \epsilon_m \sin \omega t \text{ since } \epsilon_m = N\phi_m \omega \\ &= N(BA)(2\pi f) \end{aligned}$$

$$\epsilon = NBA \times 2\pi f \times \sin \omega t$$

$$\text{i) When } \omega t = 0^\circ, \epsilon = \epsilon_m \sin 0^\circ = 0$$

$$\text{ii) When } \omega t = 90^\circ, \epsilon = \epsilon_m \sin 90^\circ = NBA \times 2\pi f \times 1$$

$$= 600 \times 0.4 \times 70 \times 10^{-4} \times 2 \times \frac{22}{7} \times \left(\frac{500}{60} \right)$$

$$\epsilon = 88 \text{ V}$$

$$\text{iii) When } \omega t = 90^\circ - 60^\circ = 30^\circ, \epsilon = \epsilon_m \sin 30^\circ = 88 \times \frac{1}{2}$$

$$\epsilon = 44 \text{ V}$$

- 68. 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.**

Solution:

$$N_p = 460 \text{ turns}; N_s = 40,000 \text{ turns}; V_p = 230 \text{ V}; R_s = 10^4 \Omega$$

$$(i) \text{ Secondary voltage, } V_s = \frac{V_p N_s}{N_p} = \frac{230 \times 40000}{460}; V_s = 20000 \text{ V}$$

$$\text{Secondary voltage per turn, } \frac{V_s}{N_s} = \frac{20000}{40000}; \frac{V_s}{N_s} = 0.5 \text{ V}$$

$$(ii) \text{ Power delivered} = V_s I_s = \frac{V_s^2}{R_s} = \frac{20000 \times 20000}{10^4}; V_s I_s = 40 \text{ kW}$$

- 69. An inverter is common electrical device which we use in our homes. When there is no power in our house, inverter gives AC power to run a few electronic appliances like fan or light. An inverter has inbuilt step-up transformer which converts 12 V AC to 240 V AC. The primary coil has 100 turns and the inverter delivers 50 mA to the external circuit. Find the number of turns in the secondary and the primary current.**

Solution:

$$V_p = 12 \text{ V}; V_s = 240 \text{ V}, I_s = 50 \text{ mA}; N_p = 100 \text{ turns}$$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s} = K; \text{ Transformation ratio, } K = \frac{240}{12} = 20$$

$$\text{The number of turns in the secondary } N_s = N_p \times K = 100 \times 20 = 2000$$

$$\text{Primary current, } I_p = K \times I_s = 20 \times 50 \text{ mA} = 1 \text{ A}$$

- 70. Write down the equation for a sinusoidal voltage of 50 Hz and its peak value is 20 V. Draw the corresponding voltage versus time graph.**

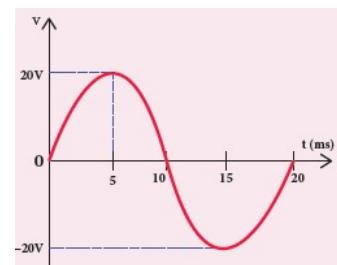
Solution:

$$\text{Instantaneous voltage, } v = v_m \sin \omega t; = v_m \sin 2\pi f t;$$

$$= 20 \sin (2\pi \times 50)t; = 20 \sin (100 \times 3.14)t; v = 20 \sin 314t$$

$$\text{Time for one cycle, } T = \frac{1}{f}; = \frac{1}{50}; T = 0.02 \text{ s}$$

$$= 20 \times 10^{-3} \text{ s} = 20 \text{ ms}$$



- 71.** The equation for an alternating current is given by $i = 77 \sin 314t$. Find the peak value, frequency, time period and instantaneous value at $t = 2 \text{ ms}$.

Solution:

$$i = 77 \sin 314t; t = 2 \text{ ms} = 2 \times 10^{-3} \text{ s}$$

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

On comparison,

(i) Peak value, $I_m = 77 \text{ A}$

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

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

(iv) At $t = 2 \text{ ms}$, Instantaneous value,

$$i = 77 \sin (314 \times 2 \times 10^{-3}) i = 45.24 \text{ A}$$

No.	Log
77	1.8865
0.5878	1.7692
(-)	1.6557
Antilog	4.526×10^1

- 72.** A 400 mH coil of negligible resistance is connected to an AC circuit in which an effective current of 6 mA is flowing. Find out the voltage across the coil if the frequency is 1000 Hz.

Solution:

$$L = 400 \times 10^{-3} \text{ H}; I_{\text{eff}} = 6 \times 10^{-3} \text{ A}; f = 1000 \text{ Hz}$$

$$\text{Inductive reactance, } X_L = L\omega = L \times 2\pi f$$

$$= 2 \times 3.14 \times 1000 \times 0.4; = 2512 \Omega$$

$$\text{Voltage across } L, V = IX_L = 6 \times 10^{-3} \times 2512$$

$$V = 15.072 \text{ V}_{(\text{RMS})}$$

- 73.** A capacitor of capacitance $\frac{10^2}{\pi} \mu\text{F}$ is connected across a 220 V, 50 Hz A.C. mains. Calculate the capacitive reactance, RMS value of current and write down the equations of voltage and current.

Solution:

$$C = \frac{10^2}{\pi} \times 10^{-6} \text{ F}, V_{\text{RMS}} = 220 \text{ V}; f = 50 \text{ Hz}$$

i) Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}; = \frac{1}{2 \times \pi \times 50 \times \frac{10^{-4}}{\pi}}; X_C = 100 \Omega$

ii) RMS value of current, $I_{\text{RMS}} = \frac{V_{\text{RMS}}}{X_C}; = \frac{220}{100}; I_{\text{RMS}} = 2.2 \text{ A}$

iii) $V_m = 220 \times \sqrt{2} = 311 \text{ V}; I_m = 2.2 \times \sqrt{2} = 3.1 \text{ A}$

Therefore, $v = 311 \sin 314t; i = 3.1 \sin \left(314t + \frac{\pi}{2} \right)$

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

Solution:

$$X_L = 184\ \Omega; X_C = 144\ \Omega; R = 30\ \Omega$$

$$\begin{aligned} \text{(i) The impedance is Impedance, } Z &= \sqrt{R^2 + (X_L - X_C)^2} \\ &= \sqrt{30^2 + (184 - 144)^2}; = \sqrt{900 + 1600} \end{aligned}$$

$$\text{Impedance, } Z = 50\ \Omega$$

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

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

- 75.** A $500\ \mu\text{H}$ inductor, $\frac{80}{\pi^2}$ capacitor and a $628\ \Omega$ resistor are connected to form a series RLC circuit. Calculate the resonant frequency and Q-factor of this circuit at resonance.

Solution:

$$L = 500 \times 10^{-6}\ \text{H}; C = \frac{80}{\pi^2} \times 10^{-12}\ \text{F}; R = 628\ \Omega$$

(i) Resonant frequency is

$$\begin{aligned} f_r &= \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{500 \times 10^{-6} \times \frac{80}{\pi^2} \times 10^{-12}}}; = \frac{1}{2\sqrt{40,000 \times 10^{-18}}} \\ &= \frac{10,000 \times 10^3}{4} \quad f_r = 2500\ \text{KHz} \end{aligned}$$

(ii) Q-factor

$$= \frac{\omega_r L}{R}; = \frac{2 \times 3.14 \times 2500 \times 10^3 \times 500 \times 10^{-6}}{628}$$

$$Q = 12.5$$

- 76.** The current in an inductive circuit is given by $0.3 \sin(200t - 40^\circ)$ A. Write the equation for the voltage across it if the inductance is $40\ \text{mH}$.

Solution:

$$L = 40 \times 10^{-3}\ \text{H}; i = 0.1 \sin(200t - 40^\circ)$$

$$X_L = \omega L = 200 \times 40 \times 10^{-3} = 8\ \Omega$$

$$V_m = I_m X_L = 0.3 \times 8 = 2.4\ \text{V}$$

In an inductive circuit, the voltage leads the current by 90° . Therefore,

$$v = V_m \sin(\omega t + 90^\circ); v = 2.4 \sin(200t - 40^\circ + 90^\circ)$$

$$v = 2.4 \sin(200t + 50^\circ)\ \text{V}$$

- 77.** A series RLC circuit which resonates at 400 kHz has 80 μH inductor, 2000 pF capacitor and 50 Ω resistor. Calculate (i) Q-factor of the circuit (ii) the new value of capacitance when the value of inductance is doubled and (iii) the new Q-factor.

Solution:

$$\text{i) Q-factor, } Q_1 = \frac{1}{R} \sqrt{\frac{L}{C}} ; = \frac{1}{50} \sqrt{\frac{80 \times 10^{-6}}{2000 \times 10^{-12}}} ; Q_1 = 4$$

$$\text{ii) When } L_2 = 2L ; 2 \times 80 \times 10^{-6} \text{ H} ; L_2 = 160 \times 10^{-6} \text{ H}$$

$$C_2 = \frac{1}{4\pi^2 f_r^2 L_2} ; = \frac{1}{4 \times 3.14^2 \times (400 \times 10^3)^2 \times 160 \times 10^{-6}} ; \approx 1000 \times 10^{-12} \text{ F}$$

$$C_2 \approx 1000 \text{ pF}$$

$$\text{iii) } Q_2 = \frac{1}{R} \sqrt{\frac{L_2}{C_2}} ; = \frac{1}{50} \sqrt{\frac{160 \times 10^{-6}}{1000 \times 10^{-12}}} ; = \frac{1}{50} \sqrt{\frac{16 \times 10^{-5}}{10^{-9}}} ; = \frac{4 \times 10^2}{50} ; Q_2 = 8$$

EXERCISE PROBLEM

- 78.** A square coil of side 30 cm with 500 turns is kept in a uniform magnetic field of 0.4 T. The plane of the coil is inclined at an angle of 30° to the field. Calculate the magnetic flux through the coil.

Solution:

$$\text{Square coil of side (a)} = 30 \text{ cm} = 30 \times 10^{-2} \text{ m}$$

$$\text{Area of square coil (A)} = a^2 = (30 \times 10^{-2})^2 = 9 \times 10^{-2} \text{ m}^2$$

$$\text{Number of turns (N)} = 500; \text{Magnetic field (B)} = 0.4 \text{ T}$$

$$\text{Angular between the field and coil (\theta)} = 90^\circ - 30^\circ = 60^\circ$$

$$\text{Magnetic flux (\phi)} = NBA \cos\theta = 500 \times 0.4 \times 9 \times 10^{-2} \times \cos 60^\circ$$

$$= 18 \times \frac{1}{2} ; \phi = 9 \text{ Wb}$$

- 79.** A straight metal wire crosses a magnetic field of flux 4 mWb in a time 0.4 s. Find the magnitude of the emf induced in the wire.

Solution:

$$\text{Magnetic flux (\phi)} = 4 \text{ mWb} = 4 \times 10^{-3} \text{ Wb} ; \text{time (t)} = 0.4 \text{ Sec.}$$

$$\text{The magnitude of induced emf (e)} = \frac{d\phi}{dt} = \frac{4 \times 10^{-3}}{0.4} = 10 \times 10^{-3}$$

$$e = 10 \text{ mV}$$

- 80.** An induced current of 2.5 mA flows through a single conductor of resistance 100Ω . Find out the rate at which the magnetic flux is cut by the conductor.

Solution:

Induced Current, $I = 2.5 \text{ mA}$, Resistance of conductor, $R = 100 \Omega$

$$\therefore \text{The rate of change of flux, } \frac{d\phi_B}{dt} = e$$

$$\frac{d\phi_B}{dt} = e = IR = 2.5 \times 10^{-3} \times 100$$

$$= 250 \times 10^{-3} \quad \frac{d\phi_B}{dt} = 250 \text{ mWbs}^{-1}$$

- 81.** A fan of metal blades of length 0.4 m rotates normal to a magnetic field of $4 \times 10^{-3} \text{ T}$. If the induced emf between the centre and edge of the blade is 0.02 V, determine the rate of rotation of the blade.

Solution:

Length of the metal blade, $l = 0.4 \text{ m}$

Magnetic field, $B = 4 \times 10^{-3} \text{ T}$; Induced emf, $e = 0.02 \text{ V}$

Rotational area of the blade, $A = \pi r^2 = 3.14 \times (0.4)^2 = 0.5024 \text{ m}^2$

Induced emf in rotational of the coil, $e = NBA \omega \sin\theta$

$$\omega = \frac{e}{NBA \sin\theta} \quad [N = 1, \theta = 90^\circ, \sin 90^\circ = 1]$$

$$\begin{aligned} \omega &= \frac{0.02}{1 \times 4 \times 10^{-3} \times 0.5024 \times \sin 90^\circ} = \frac{0.02}{2.0096 \times 10^{-3}} \\ &= 9.95222 \times 10^{-3} \times 10^3 \end{aligned}$$

$$= 9.95 \text{ revolutions / second}$$

Rate of rotational of the blade, $\omega = 9.95 \text{ revolutions / second}$

- 82.** A bicycle wheel with metal spokes of 1 m long rotates in Earth's magnetic field. The plane of the wheel is perpendicular to the horizontal component of Earth's field of $4 \times 10^{-5} \text{ T}$. If the emf induced across the spokes is 31.4 mV, calculate the rate of revolution of the wheel.

Solution:

Length of the metal spokes, $l = 1 \text{ m}$

Rotational area of the spokes, $A = \pi r^2 = 3.14 \times (1)^2 = 3.14 \text{ m}^2$

Horizontal area of the Earth's field, $B = 4 \times 10^{-5} \text{ T}$

Induced emf, $e = 3.14 \text{ mV}$

$$\text{The rate of revolution of wheel, } \omega = \frac{e}{NBA \sin\theta} \quad [N = 1, \theta = 90^\circ, \sin 90^\circ = 1]$$

$$\begin{aligned} \omega &= \frac{31.4 \times 10^{-3}}{1 \times 4 \times 10^{-5} \times 3.14 \times \sin 90^\circ} = \frac{31.4 \times 10^{-3}}{12.56 \times 10^{-5}} \\ &= 2.5 \times 10^2 ; \quad \omega = 250 \text{ revolutions / second} \end{aligned}$$

- 83. Determine the self-inductance of 4000 turn air-core solenoid of length 2m and diameter 0.04 m.**

Solution:

Length of the air core solenoid, $l = 2\text{m}$; Diameter, $d = 0.04\text{ m}$;

$$\text{Radius, } r = \frac{d}{2} = 0.02\text{ m}$$

Area of the air core solenoid, $A = \pi r^2 = 3.14 \times (0.02)^2 = 1.256 \times 10^{-3}\text{ m}^2$

Number of turns, $N = 4000$ turns

$$\begin{aligned} \text{Self-inductance, } L &= \mu_0 n^2 A l ; = \mu_0 \frac{N^2}{l^2} A l \quad [n = \frac{N}{l}, \mu_0 = 4\pi \times 10^{-7} \text{ Hm}^{-1}] \\ &= \mu_0 \frac{N^2 A}{l} = \frac{4\pi \times 10^{-7} \times (4000)^2 \times 1.256 \times 10^{-3}}{2} \\ &= \frac{252405760 \times 10^{-10}}{2} ; = 126202880 \times 10^{-10} \\ &= 12.62 \times 10^{-3}; \mathbf{L = 12.62\text{ mH}} \end{aligned}$$

- 84. A coil of 200 turns carries a current of 4 A. If the magnetic flux through the coil is 6×10^{-5} Wb, find the magnetic energy stored in the medium surrounding the coil.**

Solution:

Number of turns of the coil, $N = 200$, Current, $I = 4\text{ A}$

Magnetic flux through the coil, $\phi = 6 \times 10^{-5}\text{ Wb}$

Energy stored in the coil, $U = \frac{1}{2} LI^2$; Self-inductance of the coil, $L = \frac{N\phi}{I}$

$$U = \frac{1}{2} \frac{N\phi}{I} \times I^2 = \frac{1}{2} N\phi I ; = \frac{1}{2} \times 200 \times 6 \times 10^{-5} \times 4$$

$$U = 2400 \times 10^{-5}; \mathbf{U = 0.024\text{ J (or) Joules}}$$

- 85. 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.**

Solution:

Number of turns of the coil, $N = 200$, Current, $I = 0.4\text{ A}$

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

Inductance of the coil, $L = \frac{N\phi}{I}$;

$$= \frac{200 \times 4 \times 10^{-3}}{0.4} ;$$

$$= \frac{800 \times 10^{-3}}{0.4} ;$$

$$\mathbf{L = 2\text{ H}}$$

- 86.** 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.

Solution:

Number of turns of the solenoid, $N_2 = 200$;

Radius of the solenoid, $r = 2 \text{ cm} = 2 \times 10^{-2} \text{ m}$

$$\begin{aligned}\text{Area of the solenoid, } A &= \pi r^2 = 3.14 \times (2 \times 10^{-2})^2 \\ &= 1.256 \times 10^{-3} \text{ m}^2\end{aligned}$$

Turn density of long solenoid per cm, $N_1 = 90 \times 10^2$

$$\begin{aligned}\text{Mutual inductance of the coil, } M &= \frac{\mu_0 N_1 N_2 A}{l} \\ &= \frac{4\pi \times 10^{-7} \times 90 \times 10^2 \times 200 \times 1.256 \times 10^{-3}}{1} \\ &= 283956.48 \times 10^{-8} \Rightarrow M = 2.84 \text{ mH}\end{aligned}$$

No.	Log
3.14	0.4969
3.14	0.4969
288	2.4594
(+)	3.4532
Antilog	2.839×10^3

- 87.** A step-down transformer connected to main supply of 220 V is made to operate 11V, 88 W lamp. Calculate (i) Transformation ratio and (ii) Current in the primary.

Solution:

Voltage in primary coil, $V_p = 220 \text{ V}$; Voltage in secondary coil, $V_s = 11 \text{ V}$

Output power = 88 W

$$\text{i) To find transformation ratio, } k = \frac{V_s}{V_p} = \frac{11}{220} = \frac{1}{20}$$

$$\text{ii) Current in primary, } I_p = \frac{V_s}{V_p} I_s \text{ So, } I_s = ?$$

$$\text{Output power} = V_s I_s \Rightarrow 88 = 11 \times I_s$$

$$I_s = \frac{88}{11} = 8 \text{ A} \text{ Therefore, } I_p = \frac{V_s}{V_p} I_s ; I_p = \frac{11}{220} \times 8 ; I_p = 0.4 \text{ A}$$

- 88.** Calculate the instantaneous value at 60° , average value and RMS value of an alternating current whose peak value is 20 A.

Solution:

Peak value of current, $I_m = 20 \text{ A}$; Angle, $\theta = 60^\circ$

$$\text{i) Instantaneous value of current, } i = I_m \sin \omega t = I_m \sin \theta$$

$$= 20 \sin 60^\circ = 20 \times \frac{\sqrt{3}}{2} = 10\sqrt{3} = 10 \times 1.732$$

$$\mathbf{i = 17.32 \text{ A}}$$

$$\text{ii) Average value of current, } I_{av} = \frac{2I_m}{\pi} = \frac{2 \times 20}{3.14} ; I_{av} = 12.74 \text{ A}$$

$$\text{iii) RMS value of current, } I_{RMS} = 0.707I_m \text{ (or) } \frac{I_m}{\sqrt{2}} = 0.707 \times 20$$

$$\mathbf{I_{RMS} = 14.14 \text{ A}}$$

UNIT - V (ELECTROMAGNETIC WAVES)

- 89.** Consider a parallel plate capacitor which is connected to an 230 V RMS value and 50 Hz frequency. If the separation distance between the plates of the capacitor and area of the plates are 1 mm and 20 cm² respectively. Calculate the displacement current at t = 1 s.

Solution:

Potential difference between the plates of the capacitor, $V = V_{\max} \sin 2\pi ft$

$$= 230 \sqrt{2} \sin (2\pi \times 50t) ; V = 325 \sin 100\pi t$$

$$d = 1\text{mm} = 1 \times 10^{-3} \text{ m}; A = 20\text{cm}^2 = 20 \times 10^{-4} \text{ m}^2$$

$$\text{Displacement Current, } i_d = \epsilon_0 \frac{d\Phi_E}{dt} ; = \epsilon_0 \frac{d(EA)}{dt}$$

$$i_d = \frac{\epsilon_0 A}{d} \left[\frac{dV}{dt} \right] ; \left[E = \frac{V}{d} \right]$$

$$= \frac{\epsilon_0 A}{d} (325) (100\pi) \cos 100\pi t$$

$$= \frac{8.85 \times 10^{-12} \times 20 \times 10^{-4} \times 325 \times 100 \times 3.14 \times \cos(100\pi \times 1)}{1 \times 10^{-3}} \quad \because \cos(100\pi \times 1) = 1$$

$$i_d = 1.81 \times 10^{-6} \text{ A (or) } i_d = 1.81 \mu\text{A}$$

- 90.** The relative magnetic permeability of the medium is 2.5 and the relative electrical permittivity of the medium is 2.25. Compute the refractive index of the medium.

Solution:

Dielectric constant (relative permeability of the medium) is $\epsilon_r = 2.25$

Magnetic permeability is $\mu_r = 2.5$

$$\text{Refractive index of the medium, } n = \sqrt{\epsilon_r \mu_r} ; = \sqrt{2.25 \times 2.5} ; \\ = \sqrt{5.625} ; n = 2.37 \text{ (No unit)}$$

No.	Log
$\sqrt{5.625}$	$0.7501 \times \frac{1}{2}$ 0.3751
Antilog	2.372×10^0

- 91.** Compute the speed of the electromagnetic wave in a medium if the amplitude of electric and magnetic fields are $3 \times 10^4 \text{ N C}^{-1}$ and $2 \times 10^{-4} \text{ T}$, respectively.

Solution:

The amplitude of the electric field, $E_0 = 3 \times 10^4 \text{ N C}^{-1}$

The amplitude of the magnetic field, $B_0 = 2 \times 10^{-4} \text{ T}$.

Therefore, speed of the electromagnetic wave in a medium is

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

$$v = \frac{3 \times 10^4}{2 \times 10^{-4}} ;$$

$$v = 1.5 \times 10^8 \text{ ms}^{-1}$$

- 92. A magnetron in a microwave oven emits electromagnetic waves (em waves) with frequency $f = 2450$ MHz. What magnetic field strength is required for electrons to move in circular paths with this frequency?**

Solution:

Frequency of the electromagnetic waves given is $f = 2450$ MHz

The corresponding angular frequency is

$$\omega = 2\pi f = 2 \times 3.14 \times 2450 \times 10^6$$

$$= 15,386 \times 10^6 \text{ Hz}$$

$$= 1.54 \times 10^{10} \text{ s}^{-1}$$

$$\text{The magnetic field } B = \frac{m_e \omega}{|q|}$$

Mass of the electron, $m_e = 9.11 \times 10^{-31} \text{ kg}$

Charge of the electron $q = -1.60 \times 10^{-19} \text{ C} \Rightarrow |q| = 1.60 \times 10^{-19} \text{ C}$

$$B = \frac{(9.11 \times 10^{-31})(1.54 \times 10^{10})}{(1.60 \times 10^{-19})}; = 8.87425 \times 10^{-2} \text{ T}; \mathbf{B = 0.0887 T}$$

This magnetic field can be easily produced with a permanent magnet. So, electromagnetic waves of frequency 2450 MHz can be used for heating and cooking food because they are strongly absorbed by water molecules.

EXERCISE PROBLEM

- 93. A transmitter consists of LC circuit with an inductance of 1 μH and a capacitance of 1 μF . What is the wavelength of the electromagnetic waves it emits?**

Solution:

Inductance of LC circuit, $L = 1 \mu\text{H} = 1 \times 10^{-6} \text{ H}$

Capacitance of LC circuit, $C = 1 \mu\text{F} = 1 \times 10^{-6} \text{ F}$

$$\text{Wavelength of the electromagnetic wave } \lambda = \frac{c}{f}$$

Velocity of light $c = 3 \times 10^8 \text{ ms}^{-1}$

$$\text{Frequency of electromagnetic wave, } f = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2 \times 3.14 \sqrt{1 \times 10^{-6} \times 10^{-6}}}; = \frac{1}{6.28 \times 10^{-6}} \Rightarrow f = 15.92 \times 10^4 \text{ Hz}$$

$$\text{Wave length } \lambda = \frac{c}{f} = \frac{3 \times 10^8}{15.92 \times 10^4}; 0.1884 \times 10^4$$

$$\lambda = \mathbf{18.84 \times 10^2 \text{ m}}$$

- 94.** 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.

Solution:

Duration of the absorption of light pulse, $t = 10^{-6}$ s

Power of the pulse $P = 60 \times 10^{-3}$ W

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

Velocity of light, $C = 3 \times 10^8$

Energy $U = \text{power} \times \text{time}$

$$\text{Momentum, } P = \frac{60 \times 10^{-3} \times 10^{-6}}{3 \times 10^8};$$

$$P = 20 \times 10^{-17} \text{ kg ms}^{-1}$$

- 95.** 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.

Solution:

Relative permeability of the medium, $\mu_r = 1$

Relative permittivity of the medium, $\epsilon_r = 2.25 \left(\epsilon_r = \frac{\epsilon}{\epsilon_0} \text{ & } \mu_r = \frac{\mu}{\mu_0} \right)$

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

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

$$= \frac{3 \times 10^8}{\sqrt{1 \times 2.25}};$$

$$= \frac{3 \times 10^8}{1.5}$$

$$v = 2 \times 10^8 \text{ ms}^{-1}$$

UNIT – VI (RAY OPTICS)

- 96. An object is placed at a distance of 20.0 cm from a concave mirror of focal length 15.0 cm.**

(a) What distance from the mirror a screen should be placed to get a sharp image? (b) What is the nature of the image?

Solution:

Given, $f = -15 \text{ cm}$, $u = -20 \text{ cm}$

$$\text{(a) Mirror equation, } \frac{1}{v} + \frac{1}{u} = \frac{1}{f}; \text{ Rewriting to find } v, \frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

$$\text{Substituting for } f \text{ and } u, \frac{1}{v} = \frac{1}{-15} - \frac{1}{-20}; \frac{1}{v} = \frac{(-2) - (-15)}{300}$$

$$= \frac{-5}{300} = \frac{-1}{60}; v = -60.0 \text{ cm}$$

As the image is formed at 60.0 cm to the left of the concave mirror, the screen is to be placed at distance 60.0 cm to the left of the concave mirror.

$$\text{(b) Magnification, } m = \frac{h'}{h} = -\frac{v}{u}; m = \frac{h'}{h} = -\frac{(-60)}{(-2)}; = -3$$

As the sign of magnification is negative, the image is inverted.

As the magnitude of magnification is 3, the image is enlarged three times. As the image is formed to the left of the **concave mirror**, the image is real.

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

Solution:

$$n = \frac{c}{v}; v = \frac{c}{n};$$

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

Light travels with a speed of $2 \times 10^8 \text{ ms}^{-1}$ through this glass.

- 98. Pure water has refractive index 1.33. What is the speed of light through it.**

Solution:

$$n = \frac{c}{v}; v = \frac{c}{n};$$

$$v = \frac{3 \times 10^8}{1.33};$$

$$= 2.25 \times 10^8 \text{ ms}^{-1}$$

Light travels with a speed of $2.25 \times 10^8 \text{ ms}^{-1}$ through pure water.

- 99. Light travels from air in to glass slab of thickness 50 cm and refractive index 1.5.**

- (i) **What is the speed of light in glass?**
- (ii) **What is the time taken by the light to travel through the glass slab?**
- (iii) **What is the optical path of the glass slab?**

Solution:

Given, thickness of glass slab, $d = 50 \text{ cm} = 0.5 \text{ m}$, refractive index, $n = 1.5$

$$\text{refractive index, } n = \frac{c}{v}$$

$$\text{Speed of light in glass is, } v = \frac{c}{n} ; = \frac{3 \times 10^8}{1.5} ; = 2 \times 10^8 \text{ ms}^{-1}.$$

Time taken by light to travel through glass slab is,

$$t = \frac{d}{v} ; = \frac{0.5}{2 \times 10^8} = 2.5 \times 10^{-9} \text{ s}$$

$$\text{Optical path, } d' = nd = 1.5 \times 0.5 ; = 0.75 \text{ m} ; = 75 \text{ cm}$$

Light would have travelled 25 cm more (75 cm - 50 cm) in vacuum by the same time had there not been a glass slab.

- 100. Light travelling through transparent oil enters in to glass of refractive index 1.5. If the refractive index of glass with respect to the oil is 1.25, what is the refractive index of the oil?**

Solution:

$$\text{Given, } n_{go} = 1.25 \text{ and } n_g = 1.5;$$

$$\text{Refractive index of glass with respect to oil, } n_{go} = \frac{n_g}{n_o}$$

$$\text{Rewriting for refractive index of oil, } n_o = \frac{n_g}{n_{go}} = \frac{1.5}{1.25} = 1.2$$

The **refractive index of oil is, $n_o = 1.2$**

- 101. What is the radius of the illumination when seen above from inside a swimming pool from a depth of 10 m on a sunny day? What is the total angle of view? [Given, refractive index of water is $\frac{4}{3}$]**

Solution:

$$\text{Given, } n = \frac{4}{3}, \text{ } d = 10 \text{ m, Radius of illumination, } R = \frac{d}{\sqrt{n^2-1}}$$

$$R = \frac{10}{\sqrt{\left(\frac{4}{3}\right)^2-1}} ; = \frac{10 \times 3}{\sqrt{16-9}} ; R = \frac{30}{\sqrt{7}} ; R = 11.32 \text{ m}$$

$$\text{To find the angle of the view of the cone, } i_c = \sin^{-1} \left(\frac{1}{n} \right)$$

$$i_c = \sin^{-1} \left(\frac{1}{\frac{4}{3}} \right) ; = \sin^{-1} \left(\frac{3}{4} \right) ; = 48.6^\circ$$

The total angle of view is, $2i = 2 \times 48.6^\circ = 97.2^\circ$

- 102.** 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° . Find the lateral displacement of the light when it emerges from the other side of the mirror.

Solution:

Given, thickness of the lab, $t = 0.25 \text{ m}$,

Refractive index, $n = 1.5$, angle of incidence, $i = 60^\circ$. Using Snell's law, $1 \times \sin i = n \sin r$;

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

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

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

$$L = (0.25) \times \left(\frac{\sin(60-35.25)}{\cos(35.25)} \right) ; = 0.1282 \text{ m}$$

No.	Log
0.25	1.3979
0.4187	1.6219
(+)	1.0198
0.8166	1.9120
(-)	1.1078
Antilog	1.282×10^{-1}

The lateral displacement is, $L = 12.82 \text{ cm}$

- 103.** Determine the focal length of the lens made up of a material of refractive index 1.52 as shown in the diagram. (Points C_1 and C_2 are the centers of curvature of the first and second surface.)

Solution:

This lens is called convexo-concave lens

Given, $n = 1.52$, $R_1 = 10 \text{ cm}$ and $R_2 = 20 \text{ cm}$

$$\text{Lens makers formula, } \frac{1}{f} = (n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

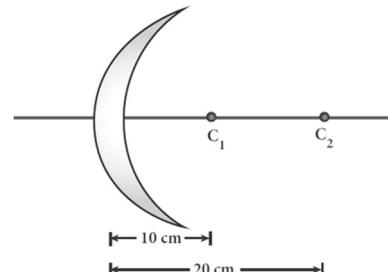
Substituting the values,

$$\frac{1}{f} = (1.52 - 1) \left(\frac{1}{10} - \frac{1}{20} \right)$$

$$\frac{1}{f} = (0.52) \left(\frac{1}{20} \right) ; = (0.52) \left(\frac{1}{20} \right) = \frac{0.52}{20} ;$$

$$f = \frac{20}{0.52} = 38.46 \text{ cm}$$

As the focal length is positive, the lens is a converging lens.



No.	Log
20	1.3010
0.52	1.7160
(-)	1.5850
Antilog	3.846×10^1

- 104. If the focal length is 150 cm for a glass lens, what is the power of the lens?**

Solution:

Given, focal length, $f = 150 \text{ cm}$ (or) $f = 1.5 \text{ m}$

$$\text{Equation for power of lens is, } P = \frac{1}{f}$$

$$\text{Substituting the values, } P = \frac{1}{1.5} = 0.67 \text{ diopter}$$

As the power is positive, it is a converging lens.

- 105.** What is the focal length of the combination if a lens of focal length -70 cm is brought in contact with a lens of focal length 150 cm? What is the power of the combination?

Solution:

Given, focal length of first lens, $f_1 = -70 \text{ cm}$,
focal length of second lens, $f_2 = 150 \text{ cm}$.

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

$$\begin{aligned} \text{Substituting the values, } \frac{1}{F} &= \frac{1}{-70} + \frac{1}{150}; = -\frac{1}{70} + \frac{1}{150} \\ \frac{1}{F} &= \frac{-15}{70 \times 150}; = \frac{-80}{70 \times 150}; \\ &= -\frac{80}{10500}; F = -\frac{1050}{8}; = -131.25 \text{ cm} \end{aligned}$$

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

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

No.	Log
1	0.0000
1.3125	0.1183
(-)	1.8857
Antilog	7.616×10^{-1}

- 106.** A monochromatic light is incident on an equilateral prism at an angle 30° and emerges at an angle of 75° . What is the angle of deviation produced by the prism?

Solution:

Given, as the prism is equilateral,

$$A=60^\circ; i_1 = 30^\circ; i_2 = 75^\circ$$

$$\text{Equation for angle of deviation, } d = i_1 + i_2 - A$$

$$\text{Substituting the values, } d = 30^\circ + 75^\circ - 60^\circ = 45^\circ$$

The angle of deviation produced is, $d = 45^\circ$ (Degree)

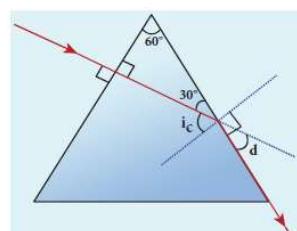
- 107.** Light ray falls at normal incidence on the first face and emerges grazing the second face for an equilateral prism. (a) What is the angle of deviation produced? (b) What is the refractive index of the material of the prism?

Solution:

$$(a) \text{Equation for angle of deviation, } d = i_1 + i_2 - A$$

$$\text{Substituting the values, } d = 0^\circ + 90^\circ - 60^\circ = 30^\circ$$

The angle of deviation produced is, $d = 30^\circ$



(b) The light inside the prism must be falling on the second face at critical angle as it grazes the boundary,

$$i_c = 90^\circ - 30^\circ = 60^\circ$$

$$\text{Equation for critical angle is, } \sin i_c = \frac{1}{n}$$

$$n = \frac{1}{\sin i_c}; n = \frac{1}{\sin 60^\circ}; = \frac{1}{\frac{\sqrt{3}}{2}}; = \frac{2}{\sqrt{3}} \quad n = 1.15 \text{ (No Unit)}$$

The refractive index of the material of the prism is, **$n = 1.15$ (No Unit)**

- 108. The angle of minimum deviation for a prism is 37° . If the angle of prism is 60° , find the refractive index of the material of the prism.**

Solution:

$$\text{Given, } A = 60^{\circ}; D = 37^{\circ}; \text{ Equation for refractive index is, } n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\text{Substituting the values, } n = \frac{\sin\left(\frac{60^{\circ}+37^{\circ}}{2}\right)}{\sin\left(\frac{60^{\circ}}{2}\right)} ; = \frac{\sin(48.5^{\circ})}{\sin(30^{\circ})} ; = \frac{0.75}{0.5} ; = 1.5;$$

The refractive index of the material of the prism is, $n = 1.5$ (No Unit)

- 109. 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.**

Solution:

$$\text{Given, } n_V = 1.632; n_R = 1.613; n_G = 1.620$$

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

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

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

EXERCISE PROBLEM

- 110. An object of 4 cm height is placed at 6 cm in front of a concave mirror of radius of curvature 24 cm. Find the position, height, magnification and nature of the image.**

Solution:

$$H = 4\text{cm}, R = -24\text{cm}, u = -6\text{cm}$$

i) Position of the image

From the relation between focal length(f) and radius of curvature(R)

$$R = 2f \text{ or } f = \frac{R}{2} ; = \frac{-24}{2} ; = -12\text{cm}$$

$$\text{From Mirror Equation } \frac{1}{f} = \frac{1}{v} + \frac{1}{u} ; \frac{1}{v} = \frac{1}{f} - \frac{1}{u} ; = \frac{1}{(-12)} - \frac{1}{(-6)} ; = -\frac{1}{(12)} + \frac{1}{(6)} \\ = \frac{-1+2}{(12)} ; = \frac{1}{12} \text{ V = 12cm}$$

$$\text{ii) Magnification } m = -\frac{v}{u} ; = -\frac{12}{(-6)} ; m = 2$$

Height of the image:

$$\text{Magnification } m = -\frac{h'}{h} ; \text{ Height of the image}$$

$$h' = mh = 2 \times 4 = 8\text{cm}$$

Thus the image is virtual, twice the height of object formed on right side of mirror.

- 111.** An object is placed at a certain distance from a convex lens of focal length 20 cm. Find the distance of the object if the image obtained is magnified 4 times.

Solution:

$$f = -20 \text{ cm} ; v = -4u$$

$$\text{According to lens formula, } \frac{1}{f} = \frac{1}{v} + \frac{1}{u} ; \frac{1}{(-20)} = \frac{1}{(-4u)} + \frac{1}{u}$$

$$\frac{1}{(-20)} = \frac{1}{u} \left[-\frac{1}{4} + 1 \right] ; = \frac{1}{u} \left[\frac{3}{4} \right] ;$$

$$u = \frac{3 \times 20}{4} ; = -15 \text{ cm.}$$

- 112.** Refractive index of material of the prism is 1.541. Find the critical angle.

Solution:

$$n = 1.541$$

Let i_c be the critical angle, then

$$\sin i_c = \frac{1}{n} = \frac{1}{1.541} = 0.6489$$

$$i_c = \sin^{-1}(0.6489) \quad i_c = 42^\circ 27'$$

No.	Log
1	0.0000
1.541	0.1878
(-)	1.8122
Antilog	6.489×10^{-1}

UNIT – VII (WAVE OPTICS)

- 113.** Two light sources with amplitudes 5 units and 3 units respectively interfere with each other. Calculate the ratio of maximum and minimum intensities.

Solution:

$$\text{Amplitudes, } a_1 = 5, a_2 = 3$$

$$\text{Resultant amplitude, } A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2 \cos\phi}$$

Resultant amplitude is, maximum when,

$$\phi = 0, \cos 0 = 1, A_{\max} = \sqrt{a_1^2 + a_2^2 + 2a_1a_2}$$

$$A_{\max} = \sqrt{(a_1 + a_2)^2} ; = \sqrt{(5 + 3)^2} ; = \sqrt{(8)^2} ; = 8 \text{ units}$$

Resultant amplitude is, minimum when,

$$\phi = \pi, \cos \pi = -1, A_{\min} = \sqrt{a_1^2 + a_2^2 - 2a_1a_2}$$

$$A_{\min} = \sqrt{(a_1 - a_2)^2} ; = \sqrt{(5 - 3)^2} ; = \sqrt{(2)^2} ; = 2 \text{ units}$$

$$I \propto A^2 ; \frac{I_{\max}}{I_{\min}} = \frac{(A_{\max})^2}{(A_{\min})^2} ; \text{ Substituting } \frac{I_{\max}}{I_{\min}} = \frac{(8)^2}{(2)^2} ;$$

$$= \frac{64}{4} ; 16 ; I_{\max} : I_{\min} = 16 : 1$$

- 114. Two light sources of equal amplitudes interfere with each other. Calculate the ratio of maximum and minimum intensities.**

Solution:

Let the amplitude be a , The intensity is, $I \propto 4 a^2 \cos^2 \left(\frac{\phi}{2}\right)$ (or) $I = 4 I_0 \cos^2 \left(\frac{\phi}{2}\right)$

Resultant intensity is maximum when, $\phi = 0$, $\cos 0 = 1$, $I_{\max} \propto 4 a^2$

Resultant amplitude is minimum when, $\phi = \pi$, $\cos \left(\frac{\pi}{2}\right) = 0$, $I_{\min} = 0$

$$I_{\max} : I_{\min} = 4a^2 : 0$$

- 115. Two light sources have intensity of light as I_0 . What is the resultant intensity at a point where the two light waves have a phase difference of $\pi/3$?**

Solution:

Let the intensities be I_0 , The resultant intensity is, $I = 4 I_0 \cos^2 \left(\frac{\phi}{2}\right)$

The resultant intensity when, $\phi = \frac{\pi}{3}$, is $I = 4 I_0 \cos^2 \left(\frac{\pi}{6}\right)$; $I = 4 I_0 \left(\frac{\sqrt{3}}{2}\right)^2$; $I = 3 I_0$

- 116. The wavelength of a light is 450 nm. How much phase it will differ for a path of 3 mm?**

Solution:

The wavelength is, $\lambda = 450 \text{ nm} = 450 \times 10^{-9} \text{ m}$

Path difference is, $\delta = 3 \text{ mm} = 3 \times 10^{-3} \text{ m}$

Relation between phase difference and path difference is, $\phi = \frac{2\pi}{\lambda} \times \delta$

Substituting, $\phi = \frac{2\pi}{450 \times 10^{-9}} \times 3 \times 10^{-3} = \frac{\pi}{75} \times 10^6$;

$$\phi = \frac{\pi}{75} \times 10^6 \text{ rad}; \quad \phi = 4.19 \times 10^4 \text{ rad.}$$

- 117. Find the minimum thickness of a film of refractive index 1.25, which will strongly reflect the light of wavelength 589 nm. Also find the minimum thickness of the film to be anti-reflecting.**

Solution:

The least optical path difference introduced by the film should be $\lambda/2$. The optical path difference between the waves reflected from the two surfaces of the film is $2\mu d$. Thus, for strong reflection, $2\mu d = \lambda/2$

$$\text{Rewriting, } d = \frac{\lambda}{4\mu}; \quad d = \frac{589 \times 10^9}{4 \times 1.25}; \quad d = 117.8 \times 10^{-9} \text{ m} = 117.8 \text{ nm}$$

The least optical path difference introduced by the film should be λ . The optical path difference between the waves reflected from the two surfaces of the film is $2\mu d$. For strong reflection, $2\mu d = \lambda$

$$\text{Rewriting, } d = \frac{\lambda}{2\mu}; \quad d = \frac{589 \times 10^9}{2 \times 1.25}; \quad d = 235.6 \times 10^{-9} \text{ m} = 235.6 \text{ nm}$$

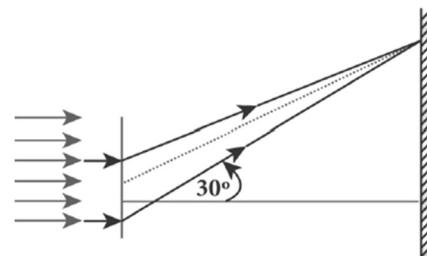
- 118.** A monochromatic light of wavelength 5000 \AA passes through a single slit producing diffraction pattern for the central maximum as shown in the figure. Determine the width of the slit.

Solution:

$$\lambda = 5000 \text{ \AA} = 5000 \times 10^{-10} \text{ m} ;$$

$$\sin 30^\circ = 0.5, n = 1, a = ?$$

Equation for diffraction minimum is,
 $a \sin \theta = n\lambda$



The central maximum is spread up to the first minimum. Hence, $n = 1$

$$\text{Rewriting, } a = \frac{\lambda}{\sin \theta} ;$$

$$\text{substituting, } a = \frac{5000 \times 10^{-10}}{0.5}$$

$$a = 1 \times 10^{-6} \text{ m} = 0.001 \times 10^{-3} \text{ m}$$

$$a = 0.001 \text{ mm}$$

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

Solution:

$$a = 5 \text{ mm} = 5 \times 10^{-3} \text{ m}, \lambda = 500 \text{ nm} = 500 \times 10^{-9} \text{ m} ; z = ?$$

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

$$\text{Substituting, } z = \frac{(5 \times 10^{-3})^2}{2 \times 500 \times 10^{-9}} ;$$

$$= \frac{25 \times 10^{-6}}{1 \times 10^{-6}} ; z = 25 \text{ m}$$

- 120.** A diffraction grating consisting of 4000 slits per centimeter is illuminated with a monochromatic light that produces the second order diffraction at an angle of 30° . What is the wavelength of the light used?

Solution:

$$\text{Number of lines per cm} = 4000; m = 2; \theta = 30^\circ; \lambda = ?$$

$$\text{Number of lines per unit length, } N = \frac{4000}{1 \times 10^{-2}} ; = 4 \times 10^5$$

$$\text{Equation for diffraction maximum in grating is, } \sin \theta = Nm \lambda$$

$$\text{Rewriting, } \lambda = \frac{\sin \theta}{Nm} ;$$

$$\text{Substituting, } \lambda = \frac{\sin 30^\circ}{4 \times 10^5 \times 2} = \frac{0.5}{4 \times 10^5 \times 2} ;$$

$$= \frac{1}{2 \times 10^5 \times 2} ; = \frac{1}{16 \times 10^5}$$

$$\lambda = 6250 \times 10^{-10} \text{ m}$$

$$\lambda = 6250 \text{ \AA}$$

- 121.** A monochromatic light of wavelength of 500 nm strikes a grating and produces fourth order bright line at an angle of 30° . Find the number of slits per centimeter.

Solution:

$$\lambda = 500 \text{ nm} = 500 \times 10^{-9} \text{ m}; m = 4; \theta = 30^\circ,$$

Number of lines per cm = ?

Equation for diffraction maximum in grating is, $\sin \theta = Nm \lambda$

$$\text{Rewriting, } \lambda = \frac{\sin \theta}{Nm};$$

$$\text{Substituting, } N = \frac{0.5}{2 \times 4 \times 500 \times 10^{-9}} \\ = 2.5 \times 10^5 \text{ lines per meter}$$

Number of lines centimeter

$$= 2.5 \times 10^5 \times 10^2 = 2500 \text{ lines per centimeter}$$

- 122.** The optical telescope in the Vainu Bappu observatory at Kavalur has an objective lens of diameter 2.3 m. What is its angular resolution if the wavelength of light used is 589 nm?

Solution:

$$a = 2.3 \text{ m}; \lambda = 589 \text{ nm} = 589 \times 10^{-9} \text{ m}; \theta = ?$$

$$\text{The equation for angular resolution is, } \theta = \frac{1.22 \lambda}{a}$$

$$\text{Substituting, } = \frac{1.22 \times 589 \times 10^{-9}}{2.3}; = 321.4 \times 10^{-9}$$

$$\theta = 3.214 \times 10^{-7} \text{ rad} \approx 0.0011'$$

Note: The angular resolution of human eye is approximately,

$$3 \times 10^{-4} \text{ rad} \approx 1.03'$$

- 123.** Two polaroids are kept with their transmission axes inclined at 30° . Unpolarised light of intensity I falls on the first polaroid. Find out the intensity of light emerging from the second polaroid.

Solution:

As the intensity of the unpolarised light falling on the first polaroid is I, the intensity of polarized light emerging from it will be, $I_0 = \left(\frac{I}{2}\right)$. Let I^I be the intensity of light emerging from the second polaroid.

$$\text{Malus' Law, } I^I = I_0 \cos^2 \theta$$

$$\text{Substituting, } I^I = \left(\frac{I}{2}\right) \cos^2 (30^\circ);$$

$$= \left(\frac{I}{2}\right) \left(\frac{\sqrt{3}}{2}\right)^2;$$

$$= I \frac{3}{8}; I^I = \left(\frac{3}{8}\right) I$$

- 124. Find the polarizing angles for (i) glass of refractive index 1.5 and (ii) Water of refractive index 1.33.**

Solution:

$$\text{Brewster's law, } \tan i_p = n$$

$$\text{For glass, } \tan i_p = 1.5; i_p = \tan^{-1} 1.5; i_p = 56.3^\circ$$

$$\text{For water, } \tan i_p = 1.33; i_p = \tan^{-1} 1.33; i_p = 53.1^\circ$$

- 125. What is the angle at which a glass plate of refractive index 1.65 is to be kept with respect to the horizontal surface so that an unpolarised light travelling horizontal after reflection from the glass plate is found to be plane polarised?**

Solution:

$$\text{Brewster's law, } \tan i_p = n$$

$$\tan i_p = 1.65;$$

$$i_p = \tan^{-1} 1.65;$$

$$i_p = 58.8^\circ$$

The inclination with the horizontal surface is $(90^\circ - 58.8^\circ) = 31.2^\circ$

- 126. 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.**

Solution:

$$f_o = 5\text{cm} = 5 \times 10^{-2} \text{ m}; f_e = 50 \text{ cm} = 50 \times 10^{-2} \text{ m}$$

$$L = 30 \text{ cm} = 30 \times 10^{-2} \text{ m}; D = 25 \text{ cm} = 25 \times 10^{-2} \text{ m}$$

(i) The total magnification m in near point focusing is ,

$$m = m_o m_e = \left(\frac{L}{f_o}\right) \left(1 + \frac{D}{f_e}\right)$$

$$\text{Substituting, } m_o m_e = \left(\frac{30 \times 10^{-2}}{5 \times 10^{-2}}\right) \left(1 + \frac{25 \times 10^{-2}}{50 \times 10^{-2}}\right);$$

$$= (6) (1.5) = 9$$

(ii) The total magnification m in normal focusing is,

$$m = m_o m_e = \left(\frac{L}{f_o}\right) \left(\frac{D}{f_e}\right)$$

$$\text{Substituting, } m_o m_e = \left(\frac{30 \times 10^{-2}}{5 \times 10^{-2}}\right) \left(\frac{25 \times 10^{-2}}{50 \times 10^{-2}}\right);$$

$$m_o m_e = (6) (0.5) = 3$$

- 127.** A small telescope has an objective lens of focal length 125 cm and an eyepiece of focal length 2 cm. What is the magnification of the telescope? What is the separation between the objective and the eyepiece? Two stars separated by 1' will appear at what separation when viewed through the telescope?

Solution:

$$f_o = 125 \text{ cm}; f_e = 2 \text{ cm}; m = ?; L = ?; \theta_i = ?$$

$$\text{Equation for magnification of telescope, } m = \frac{f_o}{f_e}$$

$$\text{Substituting, } m = \frac{125}{2} = 62.5$$

$$\text{Equation for approximate length of telescope, } L = f_o + f_e$$

$$\text{Substituting, } L = 125 + 2 = 127 \text{ cm} = 1.27 \text{ m}$$

$$\text{Equation for angular magnification, } m = \frac{\theta_i}{\theta_0}$$

$$\text{Rewriting, } \theta_i = m \times \theta_0 ;$$

$$\text{Substituting, } \theta_i = 62.5 \times 1' = 62.5' = \frac{62.5}{60} ; = 1.04^\circ ; \theta_i = 1^{\circ}2'30''$$

- 128.** Calculate the power of the lens of the spectacles necessary to rectify the defect of nearsightedness for a person who could see clearly only up to a distance of 1.8 m.

Solution:

The maximum distance the person could see is, $x = 1.8 \text{ m}$.

The lens should have a focal length of, $f = -x \text{ m} = -1.8 \text{ m}$.

It is a concave or diverging lens. The power of the lens is,

$$P = -\frac{1}{1.8 \text{ m}} ; P = -0.56 \text{ D}$$

- 129.** A person has farsightedness with the minimum distance he could see clearly is 75 cm. Calculate the power of the lens of the spectacles necessary to rectify the defect.

Solution:

The minimum distance the person could see clearly is, $y = 75 \text{ cm}$.

$$\text{The lens should have a focal length of, } f = \frac{y \times 25 \text{ cm}}{y - 25 \text{ cm}} ;$$

$$f = \frac{75 \text{ cm} \times 25 \text{ cm}}{75 \text{ cm} - 25 \text{ cm}} ; f = 37.5 \text{ cm}$$

It is a convex or converging lens. The power of the lens is,

$$P = \frac{1}{0.375 \text{ m}} \quad P = 2.67 \text{ D}$$

EXERCISE PROBLEM

- 130. The ratio of maximum and minimum intensities in an interference pattern is 36 : 1. What is the ratio of the amplitudes of the two interfering waves?**

Solution:

$$I_{\max} = I_{\min} = 36 : 1$$

$$\frac{I_{\max}}{I_{\min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} \text{ or } \frac{a_1+a_2}{a_1-a_2} = \sqrt{\frac{I_{\max}}{I_{\min}}} = \sqrt{\frac{36}{1}} = 6$$

$$a_1 + a_2 = 6(a_1 - a_2); a_1 + a_2 = 6a_1 - 6a_2$$

$$a_2 + 6a_2 = 6a_1 - a_1; 7a_2 = 5a_1$$

$$\frac{a_1}{a_2} = \frac{7}{5}; a_1 : a_2 = 7 : 5$$

- 131. 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?**

Solution:

$$\lambda_1 = 5893 \text{ Å}; \lambda_2 = 4359 \text{ Å}, n_1 = 62, n_2 = ?$$

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

$$\text{constant for both wavelengths. } \frac{62 \times 5893 \times 10^{-1} \times D}{d}$$

$$= \frac{n_2 \times 5893 \times 10^{-10} \times D}{d}$$

$$n_2 = \frac{62 \times 5893}{4359} ; = \frac{365366}{4359} ; = 83.8$$

$$n_2 \approx 84$$

No.	Log
62	1.7924
5893	3.7703
(+)	5.5627
4359	3.6394
(-)	1.9233
Antilog	8.3181×10^1

- 132. Light of wavelength 600 nm that falls on a pair of slits producing interference pattern on a screen in which the bright fringes are separated by 7.2 mm. What must be the wavelength of another light which produces bright fringes separated by 8.1 mm with the same apparatus?**

Solution:

$$\lambda_1 = 600 \text{ nm} = 600 \times 10^{-9} \text{ m}; \beta_1 = 7.2 \text{ mm} = 7.2 \times 10^{-3} \text{ m};$$

$$\beta_2 = 8.1 \text{ mm} = 8.1 \times 10^{-3} \text{ m};$$

$$\text{Equation of fringe width } \beta = \frac{\lambda D}{d}; \frac{\beta_1}{\beta_2} = \frac{\lambda_1}{\lambda_2} \text{ or } \lambda_2 = \lambda_1 \frac{\beta_2}{\beta_1}$$

$$\lambda_2 = 600 \times 10^{-9} \times \frac{8.1 \times 10^{-3}}{7.2 \times 10^{-3}} = \frac{4860}{7.2} \times 10^{-9} \text{ m}; 675 \times 10^{-9} \text{ m}; \lambda_2 = 675 \text{ nm}$$

- 133.** 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?

Solution:

$$\text{Equation for diffraction minimum, } a \sin \theta = n \lambda \text{ (or) } a \frac{y}{D} = n \lambda$$

$$\text{Condition for first minimum (n=1) } a \frac{y}{D} = \lambda$$

$$y = \frac{D\lambda}{a} ; = \frac{2 \times 600 \times 10^{-9}}{1 \times 10^{-3}} ;$$

$$1200 \times 10^{-6} \text{ m} ; = 1.2 \times 10^{-3} \text{ m} ; \mathbf{y = 1.2 \text{ mm}}$$

Distance between the first fringe on either side of the central bright fringe $Y = 2y ; 2 \times 1.2 ; \mathbf{Y = 2.4 \text{ mm}}$

- 134.** Light of wavelength of 5000 Å produces diffraction pattern of the single slit of width 2.5 µm. What is the maximum order of diffraction possible?

Solution:

$$a = 2.5 \mu\text{m} = 2.5 \times 10^{-6} \text{ m}, \lambda = 5000 \text{ \AA} = 5000 \times 10^{-10} \text{ m}$$

$$\text{Equation for diffraction minimum } a \sin \theta = n\lambda$$

$$\text{For maximum order } \theta = 90^\circ \text{ or } \sin \theta = 1$$

$$\begin{aligned} n &= \frac{a \sin \theta}{\lambda} \\ &= \frac{2.5 \times 10^{-6} \times 1}{5000 \times 10^{-10}} ; \\ &= 0.5 \times 10^1 \quad \mathbf{n=5} \end{aligned}$$

- 135.** The reflected light is found to be plane polarised when an unpolarized light falls on a denser medium at 60° with the normal. Find the angle of refraction and critical angle of incidence for total internal reflection in the denser to rarer medium reflection.

Solution:

The angle of incidence at which the reflected ray gets completely plane polarized is called angle of polarization (i_p). Hence $i_p = 60^\circ$

$$\text{At polarizing angle, the angle of refraction, } r = 90^\circ - i_p = 90^\circ - 60^\circ = 30^\circ$$

$$\text{From Brewster's law, } n = \tan i_p = \tan 60^\circ = \sqrt{3}$$

$$\text{Let } i_c \text{ be the critical angle, then } \sin i_c = \frac{1}{n} = \frac{1}{\sqrt{3}} = 0.5774$$

$$i_c = \sin^{-1}(0.5774) ; = 35.260 ; \mathbf{i_c = 35^\circ 16'}$$

- 136.** A compound microscope has a magnifying power of 100 when the image is formed at infinity. The objective has a focal length of 0.5 cm. and the tube length is 6.5 cm. What is the focal length of the eyepiece?

Solution:

$$m = 100 ; f_0 = 0.5 \text{ cm} ; L = 6.5 \text{ cm} ; D = 25$$

$$\text{Magnifying Power of Compound Microscope } m = \frac{LD}{f_0 f_e}$$

$$f_e = \frac{LD}{f_0 m} ; = \frac{6.5 \times 25}{0.5 \times 100} ; = \frac{6.5 \times 25}{50} ; = \frac{6.5}{2} ; f_e = 3.25 \text{ cm}$$

The focal length of the eyepiece $f_e = 3.25 \text{ cm}$

UNIT – VIII (DUAL NATURE OF RADIATION AND MATTER)

- 137.** A radiation of wavelength 300 nm is incident on a silver surface. Will photoelectrons be observed?

Solution:

$$\text{Energy of the incident photon is } E = h\nu = \frac{hc}{\lambda} \text{ (in Joules)}$$

$$E = \frac{hc}{\lambda e} \text{ (in eV)} ; \text{ Substituting the known values, we get}$$

$$= \frac{6.634 \times 10^{-34} \times 3 \times 10^8}{300 \times 10^{-9} \times 1.6 \times 10^{-19}} ; = \frac{19.902 \times 10^{-2}}{480 \times 10^{-28}} ; 0.04146 \times 10^2$$

$$\mathbf{E = 4.14 \text{ eV}}$$

The **work function of silver = 4.7 eV**. Since the energy of the incident photon is **less than the work function of silver**, photoelectrons are not observed in this case.

- 138.** The work function of potassium is 2.2 eV. UV light of wavelength 3000 Å and intensity 2 Wm⁻² is incident on the potassium surface.

- i) Determine the maximum kinetic energy of the photo electrons
ii) If 40% of incident photons produce photo electrons, how many electrons are emitted per second if the area of the potassium surface is 2 cm²?

Solution:

i) The energy of the photon is $E = \frac{hc}{\lambda} ; = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3000 \times 10^{-10}}$

$$E = 6.626 \times 10^{-19} \text{ J} = 4.14 \text{ eV}$$

Maximum KE of the photoelectrons is

$$K_{\max} = h\nu - \phi_0 = 4.14 - 2.30 = 1.84 \text{ eV}$$

- ii) The number of photons reaching the surface per second is

$$n_P = \frac{P}{E} \times A ; = \frac{2}{6.626 \times 10^{-19}} \times 2 \times 10^{-4}$$

The rate of emission of photoelectrons is $= (0.40) n_P = 0.4 \times 6.04 \times 10^{14}$
 $= 2.415 \times 10^{14} \text{ photoelectrons / sec}$

- 139.** Calculate the momentum and the de Broglie wavelength in the following cases: i) an electron with kinetic energy 2 eV. ii) a bullet of 50 g fired from rifle with a speed of 200 m/s iii) a 4000 kg car moving along the highways at 50 m/s. Hence show that the wave nature of matter is important at the atomic level but is not really relevant at macroscopic level.

Solution:

i) Momentum of the electron is

$$p = \sqrt{2mK} = \sqrt{2 \times 9.1 \times 10^{-31} \times 2 \times 1.6 \times 10^{-19}} ; \sqrt{58.24 \times 10^{-5}}$$

$$p = 7.63 \times 10^{-25} \text{ kg ms}^{-1}$$

$$\text{Its de Broglie wavelength is } \lambda = \frac{h}{p} = \frac{6.634 \times 10^{-34}}{7.63 \times 10^{-25}} ; = 0.868 \times 10^{-9} \text{ m}$$

$$\lambda = 8.68 \text{ \AA}$$

ii) Momentum of the bullet is $p = mv = 0.050 \times 200 = 10 \text{ kgms}^{-1}$

$$\text{Its de Broglie wavelength is } \lambda = \frac{h}{p} = \frac{6.634 \times 10^{-34}}{10} ; = 6.626 \times 10^{-33} \text{ m}$$

iii) Momentum of the car is $p = mv = 4000 \times 50 = 2 \times 10^5 \text{ kgms}^{-1}$

$$\text{Its de Broglie wavelength is } \lambda = \frac{h}{p} = \frac{6.634 \times 10^{-34}}{2 \times 10^5} ; = 3.313 \times 10^{-39} \text{ m}$$

From these calculations, we notice that electron has significant value of de Broglie wavelength ($\approx 10^{-9} \text{ m}$ which can be measured from diffraction studies) but bullet and car have negligibly small de Broglie wavelengths associated with them ($\approx 10^{-33} \text{ m}$ and 10^{-39} m respectively, which are not measurable by any experiment). This implies that the wave nature of matter is important at the atomic level but it is not really relevant at the macroscopic level.

- 140.** Find the de Broglie wavelength associated with an alpha particle which is accelerated through a potential difference of 400 V. Given that the mass of the proton is $1.67 \times 10^{-27} \text{ kg}$.

Solution:

An alpha particle contains 2 protons and 2 neutrons. Therefore, the mass M of the alpha particle is 4 times that of a proton (m_p) (or a neutron) and its charge q is twice that of a proton ($+e$). The de Broglie wavelength associated with it is $\lambda = \frac{h}{\sqrt{2 M q V}} = \frac{h}{\sqrt{2 \times (4m_p) \times (2e) \times V}}$

$$= \frac{6.634 \times 10^{-34}}{\sqrt{2 \times 4 \times 1.67 \times 10^{-27} \times 2 \times 1.6 \times 10^{-19} \times 400}}$$

$$= \frac{6.634 \times 10^{-34}}{4 \times 20 \times 10^{-23} \sqrt{1.67 \times 1.6}} ; \lambda = 0.00507 \text{ \AA}$$

- 141. Calculate the cut-off wavelength and cutoff frequency of x-rays from an X -ray tube of accelerating potential 20,000 V.**

Solution:

$$\begin{aligned} \text{The cut-off wavelength of the characteristic x-rays is } \lambda_0 &= \frac{12400}{V} \text{ Å} \\ &= \frac{12400}{20000} \text{ Å} ; = 0.62 \text{ Å} \end{aligned}$$

$$\text{The corresponding frequency is } v_0 = \frac{c}{\lambda_0} ; = \frac{3 \times 10^8}{0.62 \times 10^{-10}}$$

$$v_0 = 4.84 \times 10^{18} \text{ Hz}$$

EXERCISE PROBLEM

- 142. How many photons per second emanate from a 50 mW laser of 640 nm?**

Solution:

$$P = 50 \text{ mW}, \lambda = 640 \text{ nm}, h = 6.6 \times 10^{-34} \text{ Js},$$

$$c = 3 \times 10^8 \text{ ms}^{-1}$$

Number of photons emanate per second

$$\begin{aligned} n_p &= \frac{P}{E} = \frac{P\lambda}{hc} ; = \frac{50 \times 10^3 \times 640 \times 10^{-9}}{6.6 \times 10^{-34} \times 3 \times 10^8} ; = \frac{32000 \times 10^{-6}}{19.8 \times 10^{-26}} ; \\ &= 1616.16 \times 10^{20} \quad n_p = 1.6 \times 10^{17} \text{ s}^{-1} \end{aligned}$$

No.	Log
32000	4.5051
19.878	1.2984
(-)	3.2067
Antilog	1.610×10^3

- 143. Calculate the energies of the photons associated with the following radiation:**

(i) Violet light of 413 nm (ii) X-rays of 0.1 nm (iii) radio waves of 10 m.

Solution:

$$h = 6.6 \times 10^{-34} \text{ Js}, c = 3 \times 10^8 \text{ ms}^{-1}$$

$$\text{Energy of photon, } E = h\nu ; E = \frac{hc}{\lambda}$$

$$\begin{aligned} \text{i) Violet light, } \lambda &= 413 \text{ nm} ; E = \frac{6.6 \times 10^{-3} \times 3 \times 10^8}{413 \times 10^{-9}} = 0.04794 \times 10^{-17} \\ &= 4.794 \times 10^{-19} \text{ J} ; = \frac{4.794 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV} ; \mathbf{E = 3 \text{ eV}} \end{aligned}$$

$$\begin{aligned} \text{ii) X -Ray, } \lambda &= 0.1 \text{ nm} ; E = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{0.1 \times 10^{-9}} = 198 \times 10^{-17} \\ &= \frac{198 \times 10^{-1}}{1.6 \times 10^{-1}} ; 123.75 \times 10^2 \end{aligned}$$

$$\mathbf{E = 12375 \text{ eV}}$$

$$\begin{aligned} \text{iii) Radio waves, } \lambda &= 10 \text{ m} ; E = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{10} = 1.98 \times 10^{-26} \text{ J} \\ &= \frac{1.98 \times 10^{-26}}{1.6 \times 10^{-19}} ; 1.2375 \times 10^{-7} \end{aligned}$$

$$\mathbf{E = 1.24 \times 10^{-7} \text{ eV}}$$

- 144. A 150 W lamp emits light of mean wavelength of 5500 Å . If the efficiency is 12%, find out the number of photons emitted by the lamp in one second.**

Solution:

$$P = 150 \text{ W}, \lambda = 5500 \text{ Å}, h = 6.6 \times 10^{-34} \text{ Js}, c = 3 \times 10^8 \text{ ms}^{-1}$$

$$\text{Number of photons emanated per second } n = \frac{P\lambda}{hc}$$

$$\text{If the efficiency is 12\% , } \eta = \frac{12}{100} = 0.12$$

$$\begin{aligned} n &= \frac{P\eta\lambda}{hc} \\ &= \frac{150 \times 0.12 \times 5500 \times 10^{-10}}{6.6 \times 10^{-34} \times 3 \times 10^8}; = \frac{99000 \times 10^{-10}}{19.8 \times 10^{-26}}; \\ &= 5000 \times 10^{16}; \mathbf{n = 5 \times 10^{19}} \end{aligned}$$

No.	Log
825	2.9165
19.878	1.2984
(-)	1.6181
Antilog	4.150×10^1

- 145. How many photons of frequency 10^{14} Hz will make up 19.86 J of energy?**

Solution:

Total energy emitted per second = Power x time

$$19.86 = \text{Power} \times 1 \text{ s}; \therefore \text{Power} = 19.86 \text{ W}$$

$$\begin{aligned} \text{Number of photons, } n &= \frac{P}{E} = \frac{P}{hv}; = \frac{19.86}{6.6 \times 10^{-34} \times 10^{14}} \\ &= 3.009 \times 10^{20} \quad n = 3 \times 10^{20}; \end{aligned}$$

$$n_p = 3 \times 10^{20}$$

No.	Log
19.86	1.2980
6.626	0.8213
(-)	0.4767
Antilog	2.997×10^0

- 146. What should be the velocity of the electron so that its momentum equals that of 4000 Å wavelength photon.**

Solution:

$$\begin{aligned} \lambda &= \frac{h}{P} = \frac{h}{mv}; v = \frac{h}{m\lambda}; = \frac{6.626 \times 10^{-34}}{9.11 \times 10^{-31} \times 4000 \times 10^{10}} \\ &\frac{6.626 \times 10^{-3}}{36.44 \times 10^{-38}}; = 0.1818 \times 10^4; \mathbf{v = 1818 \text{ ms}^{-1}} \end{aligned}$$

- 147. When a light of frequency 9×10^{14} Hz is incident on a metal surface, photoelectrons are emitted with a maximum speed of $8 \times 10^5 \text{ ms}^{-1}$. Determine the threshold frequency of the surface.**

Solution:

$$V = 9 \times 10^{14} \text{ Hz}; V_{\max} = 8 \times 10^5 \text{ ms}^{-1}$$

By Einstein's Photo electric equation, $h\nu = h\nu_0 + \frac{1}{2}mv_{\max}^2$ or

$$h\nu_0 = h\nu - \frac{1}{2}mv_{\max}^2;$$

$$= [6.626 \times 10^{-34} \times 9 \times 10^{14}] - \left[\frac{1}{2} \times 9.11 \times 10^{-31} \times 64 \times 10^{10} \right]$$

$$\begin{aligned}
 &= [59.634 \times 10^{-20}] - [291.2 \times 10^{-2}]; \\
 &= [59.634 - 29.12] \times 10^{-20} \\
 \mathbf{h\nu_0} &= \mathbf{30.514 \times 10^{-20}} \\
 \mathbf{v_0} &= \frac{30.514 \times 10^{-20}}{h} = \frac{30.514 \times 10^{-20}}{6.626 \times 10^{-34}} = \frac{30.514 \times 10^{14}}{6.626}; \\
 \mathbf{v_0} &= 4.603 \times 10^{14} \text{ Hz}
 \end{aligned}$$

No.	Log
6.626	0.8213
30.514	1.4844
(-)	0.6631
Antilog	4.603×10^0

- 148.** At the given point of time, the earth receives energy from sun at $4 \text{ cal cm}^{-2} \text{ min}^{-1}$. Determine the number of photons received on the surface of the Earth per cm^2 per minute.
(Given: Mean wavelength of sun light = 5500 \AA)

Solution:

$$P = 4 \text{ cal cm}^{-2} \text{ min}^{-1} = 4 \times 4.2 = 16.8 \text{ J cm}^{-2} \text{ min}^{-1};$$

$$\lambda = 5500 \text{ \AA} = 5500 \times 10^{-10} \text{ m}$$

The number of photons received on the surface of the

$$\text{Earth per cm}^2 \text{ per minute}, n_p = \frac{P}{E} = \frac{P}{h\nu} = \frac{P}{\left(\frac{hc}{\lambda}\right)} = \frac{P\lambda}{hc};$$

$$= \frac{1.68 \times 5500 \times 10^{-10}}{6.626 \times 10^{-34} \times 3 \times 10^8};$$

$$= \frac{924 \times 10^{-1}}{19.878}; = 4.648 \times 10^1 \times 10^{18}; n_p = 4.648 \times 10^{19}$$

No.	Log
924	2.9657
19.878	1.2984
(-)	1.6673
Antilog	4.648×10^1

- 149.** Calculate the de Broglie wavelength of a proton whose kinetic energy is equal to $81.9 \times 10^{-15} \text{ J}$. (Given: mass of proton is 1836 times that of electron).

Solution:

$$M_p = 1.67 \times 10^{-27} \text{ kg}, KE = 81.9 \times 10^{-15} \text{ J}$$

$$\text{de Broglie wavelength of a proton, } \lambda = \frac{h}{\sqrt{2mK}}$$

$$= \frac{6.6 \times 10^{-3}}{\sqrt{2 \times 1.67 \times 10^{-2} \times 81.9 \times 10^{-15}}};$$

$$= \frac{6.6 \times 10^{-3}}{1.6539 \times 10^{-20}}; = 3.99 \times 10^{-14}; \lambda = 4 \times 10^{-14} \text{ m}$$

- 150.** An electron is accelerated through a potential difference of 81 V . What is the de Broglie wavelength associated with it? To which part of electromagnetic spectrum does this wavelength correspond?

Solution:

$$\text{de - Broglie wavelength of an electron beam accelerated through a potential difference of } V \text{ volts is } \lambda = \frac{h}{\sqrt{2mV}}; = \frac{1.23}{\sqrt{V}} \text{ nm}$$

$$V = 81 \text{ V}, \text{ So } \lambda = \frac{1.23}{\sqrt{81}} \times 10^{-9} \text{ m} = 0.1366 \times 10^{-9} \text{ m}; \lambda = 1.36 \text{ \AA}$$

X -Ray is the part of electromagnetic spectrum does this wavelength corresponds. X - Ray has the wavelengths ranging from about 10^{-8} to 10^{-12} m

UNIT – IX (ATOMIC AND NUCLEAR PHYSICS)

- 151. The radius of the 5th orbit of hydrogen atom is 13.25 Å. Calculate the wavelength of the electron in the 5th orbit.**

Solution:

$$2\pi r = n\lambda ; 2 \times 3.14 \times 13.25 \text{ Å} = 5 \times \lambda ; \therefore \lambda = 16.64 \text{ Å}$$

- 152. Find the (i) angular momentum (ii) velocity of the electron in the 5th orbit of hydrogen atom.**

Solution:

(i) **Angular momentum is given by** = $n\hbar = \frac{nh}{2\pi} ; = \frac{5 \times 6.6 \times 10^{-34}}{2 \times 3.14}$
 $= 5.25 \times 10^{-34} \text{ kgm}^2\text{s}^{-1}$

(ii) **Velocity is given by velocity,** $= \frac{l}{mr} ; = \frac{(5.25 \times 10^{-34} \text{ kg} \cdot \text{m}^2\text{s}^{-1})}{(9.1 \times 10^{-31} \text{ kg})(13.25 \times 10^{-10} \text{ m})}$
 $v = 4.4 \times 10^5 \text{ ms}^{-1}$

- 153. Calculate the average atomic mass of chlorine if no distinction is made between its different isotopes?**

Solution:

The element chlorine is a mixture of 75.77% of ^{35}Cl and 24.23% of ^{37}Cl . So the average atomic mass will be

$$\frac{75.77}{100} \times 34.96885 \text{ u} + \frac{24.23}{100} \times 36.96593 \text{ u} ; = 35.453 \text{ u}$$

In fact, the chemist uses the average atomic mass or simply called chemical atomic weight (35.453u for chlorine) of an element. So it must be remembered that the atomic mass which is mentioned in the periodic table is basically averaged atomic mass.

- 154. Calculate the radius of $^{197}_{79}\text{Au}$ nucleus.**

Solution:

According to the equation ($R = R_0 A^{\frac{1}{3}}$), $R = 1.2 \times 10^{-15} \times (197)^{\frac{1}{3}}$
 $= 6.97 \times 10^{-15} \text{ m}$ (or) $R = 6.97 \text{ F}$

- 155. Compute the binding energy of ${}^4_2\text{He}$ nucleus using the following data:
Atomic mass of Helium atom, $M_A(\text{He}) = 4.00260 \text{ u}$ and that of hydrogen atom, $m_H = 1.00785 \text{ u}$.**

Solution:

$$\text{Binding energy BE} [Zm_H + Nm_n - M_A] c^2$$

$$\text{For helium nucleus, } Z = 2, N = A-Z = 4-2 = 2$$

$$\text{Mass defect } \Delta m = [(2 \times 1.00785 \text{ u}) + (2 \times 1.008665 \text{ u}) - 4.00260 \text{ u}]$$

$$\Delta m = 0.03038 \text{ u}; \text{B.E} = 0.03038 \text{ u} \times c^2$$

$$\text{B.E} = 0.03038 \times 931 \text{ MeV} = 28 \text{ MeV}; [\because 1 \text{ uc}^2 = 931 \text{ MeV}]$$

- 156. Compute the binding energy per nucleon of ${}^4_2\text{He}$**

Solution:

$$Z=2; A = 4$$

$$\text{Mass defect of helium nucleus, } \Delta m = 0.03043 \text{ u}$$

$$\text{Binding energy of helium nucleus,}$$

$$\text{BE} = \Delta m \times 931 \text{ MeV} = 0.03043 \times 931 = 28 \text{ MeV}$$

$$\text{Hence Binding energy per nucleon, } \overline{\text{BE}} = \frac{\text{BE}}{A} = \frac{28}{7}; \overline{\text{BE}} = 7 \text{ MeV}$$

- 157. Calculate the number of nuclei of carbon-14 un-decayed after 22,920 years if the initial number of carbon-14 atoms is 10,000. The half-life of carbon-14 is 5730 years.**

Solution:

$$\text{To get the time interval in terms of half-life, } n = \frac{t}{T_{1/2}} = \frac{22920 \text{ years}}{5730 \text{ years}} = 4$$

The number of nuclei remaining un-decayed after 22,920 years,

$$N = \left(\frac{1}{2}\right)^n N_0 = \left(\frac{1}{2}\right)^4 \times 10000; N = 625$$

- 158. Calculate the amount of energy released when 1 kg of ${}^{235}_{92}\text{U}$ undergoes fission reaction.**

Solution:

235 g of ${}^{235}_{92}\text{U}$ has 6.02×10^{23} atoms. In one gram of ${}^{235}_{92}\text{U}$, the number of atoms is equal to $\frac{6.02 \times 10^{23}}{235} = 2.56 \times 10^{21}$; So the number of atoms present in

$$1 \text{ kg of } {}^{235}_{92}\text{U} = 2.56 \times 10^{21} \times 1000 = 2.56 \times 10^{24}$$

Each ${}^{235}_{92}\text{U}$ nucleus releases 200 Mev of energy during the fission. The total energy released by 1 kg of ${}^{235}_{92}\text{U}$ is

$$Q = 2.56 \times 10^{24} \times 200 \text{ Mev} = 5.12 \times 10^{26} \text{ MeV}$$

$$\text{In terms of joules, } 5.12 \times 10^{26} \times 1.6 \times 10^{-13} \text{ J} = 8.192 \times 10^{13} \text{ J}$$

$$\text{In terms of kilowatt hour, } Q = \frac{8.192 \times 10^{13}}{3.6 \times 10^6} \text{ kWh} \quad Q = 2.27 \times 10^7 \text{ kWh}$$

EXERCISE PROBLEM

- 159. Calculate the mass defect and the binding energy per nucleon of the $^{108}_{47}\text{Ag}$ nucleus. [Atomic mass of Ag = 107.905949]**

Solution:

Mass of proton, $m_p = 1.007825$ amu, Mass of neutron, $m_n = 1.008865$ amu

$$\begin{aligned} \text{Mass defect, } \Delta m &= Zm_p + Zm_n - M_N ; \\ &= 47 \times 1.007825 + 61 \times 1.008865 - 107.905949 \\ &= 108.89634 - 107.905949; \Delta m = 0.990391\text{u} \\ \text{Binding energy per nucleon of the } &^{108}_{47}\text{Ag nucleus} \\ \overline{\text{B.E}} &= \frac{\Delta m \times 931}{A}; = \frac{0.990391 \times 931}{108}; = \frac{922.054021}{108} ; \\ &= 8.539 \quad \overline{\text{B.E}} = 8.5 \frac{\text{MeV}}{\text{A}} \end{aligned}$$

No.	Log
922.1	2.9648
108	2.0334
(-)	0.9314
Antilog	8.539×10^0

- 160. Half lives of two radioactive elements A and B are 20 minutes and 40 minutes respectively. Initially, the samples have equal number of nuclei. Calculate the ratio of decayed numbers of A and B nuclei after 80 minutes.**

Solution:

80 minutes = 4 half-lives of A = 2 half live of B

Let the initial number of nuclei in each sample be N.

$$N_A \text{ after 80 minutes} = \frac{N}{2^4}$$

$$\text{Number of A nuclides decayed} = \frac{15}{16} N$$

$$N_B \text{ after 80 minutes} = \frac{N}{2^4}$$

$$\text{Number of B nuclides decayed} = \frac{3}{4} N$$

$$\text{Required ratio} = \frac{15}{16} \times \frac{4}{3} = \frac{5}{4}; N_A:N_B = 5 : 4$$

- 161. Calculate the time required for 60% of a sample of radon undergo decay. (Given $T_{1/2}$ of radon = 3.8 days.)**

Solution:

Here consider $R_n - 222$ with a half-life of 3.823 days.

From decay equation, Current amount = Initial amount $\times (2)^{-n}$

$$N = N_0 (2)^{-n}; \frac{N}{N_0} = (2)^{-\frac{t}{T_{1/2}}}$$

$$\log \left(\frac{N}{N_0} \right) = \log (2) \times \left(-\frac{t}{T_{1/2}} \right); \frac{\log \left(\frac{N}{N_0} \right)}{\log (2)} = \left(-\frac{t}{T_{1/2}} \right)$$

$$t = \frac{\log(0.4)}{\log(2)} \times (-3.823); \text{time } t = 5.02 \text{ days.}$$

- 162. Assuming that energy released by the fission of a single $^{92}\text{U}^{235}$ nucleus is 200MeV, calculate the number of fissions per second required to produce 1 Watt power.**

Solution:

The fission of a single $^{92}\text{U}^{235}$ nucleus releases 200 Mev of energy

$$\text{Energy released in the fission is given by the formula } E = \frac{Pt}{n} \Rightarrow \frac{n}{t} = \frac{P}{E}$$

$$E = 200 \text{ Mev} = 200 \times 10^6 \times 1.6 \times 10^{-19}$$

$$E = 320 \times 10^{-13}; E = 3.2 \times 10^{-11} \text{ J}$$

$$\frac{n}{t} = \frac{P}{E} = \frac{1}{3.2 \times 10^{-11}}; = 0.3125 \times 10^{11} = 3.125 \times 10^{10}$$

$$\frac{n}{t} = 3.125 \times 10^{10}$$

- 163. Show that the mass of radium ($^{88}\text{Ra}^{226}$) with an activity of 1 curie is almost a gram. (Given $T_{\frac{1}{2}} = 1600$ years.)**

Solution:

The activity of the sample at any time t

$$R = \lambda N; \text{ Here, } \lambda = \frac{0.6931}{T_{1/2}}; R = 1\text{Ci} = 3.7 \times 10^{10} \text{ dis s}^{-1}$$

$$T_{1/2} = 1600 \text{ year} = 1600 \times 3.16 \times 10^7 \text{ dis}$$

$$\therefore \text{The amount of radium, } N = \frac{R}{\lambda} = \frac{RT_{1/2}}{0.6931} \\ = \frac{3.7 \times 10^{10} \times 1600 \times 3.16 \times 10^7}{0.6931}; = \frac{18707.2 \times 10^{17}}{0.6931} \\ = 26990.62 \times 10^{17}; N = 2.7 \times 10^{21} \text{ atoms}$$

As 226g of radiation contains 6.023×10^{23} atoms so the amount of required

$$\text{strength. } = \frac{226 \times 2.7 \times 10^{21}}{6.023 \times 10^{23}}; = 101.311 \times 10^{-2}; = 1.013\text{g} \approx 1\text{g}$$

- 164. 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?**

Solution:

$$R_0 = 100\%, R = 17.5\%, \lambda = \frac{0.6931}{T_{1/2}}, T_{1/2} = 5730 \text{ years}$$

$$\text{According to radioactive law } R = R_0 e^{-\lambda t}; e^{\lambda t} = \frac{R_0}{R}$$

$$\text{Taking log on both sides } t = \frac{1}{\lambda} \ln \left(\frac{R_0}{R} \right)$$

$$\text{Half-life of carbon, } T_{1/2} = 5730 \text{ years}$$

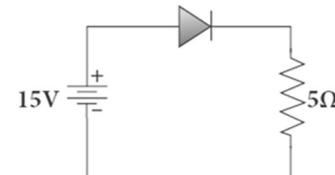
$$T = \frac{T_{1/2}}{0.6931} \ln \left(\frac{1}{0.175} \right); \frac{5730 \text{ years}}{0.6931} \times 1.74297 \\ = 14409.49 \text{ years}; t = 1.44 \times 10^4 \text{ years}$$

UNIT – X (ELECTRONICS AND COMMUNICATION)

- 165.** An ideal diode and a 5Ω resistor are connected in series with a 15 V power supply as shown in figure below. Calculate the current that flows through the diode.

Solution:

The diode is forward biased and it is an ideal one. Hence, it acts like a closed switch with no barrier voltage. Therefore, current that flows through the diode can be



$$\text{calculated using Ohm's law. } V = IR ; I = \frac{V}{R} ; = \frac{15}{5} ; I = 3A$$

- 166.** A silicon diode is connected with $1k\Omega$ resistor as shown. Find the value of current flowing through AB.

Solution:



The potential difference between A and B is given by

$$\begin{aligned} V &= [V_A - V_B] - V_b (\text{Si}) \\ &= [3.3 - (-7.4)] - 0.7 \\ &= 10.7 - 0.7 ; V = 10 \text{ V} \end{aligned}$$

The value of current flowing through AB can be obtained by using Ohm's law,

$$I = \frac{V}{R} ; = \frac{10}{1 \times 10^3} ; = \frac{10}{10^3} ; 10^{-2} \text{ A} = 10 \text{ mA}$$

- 167.** Find the current through the Zener diode when the load resistance is $1 \text{ k}\Omega$. Use diode approximation.

Solution:

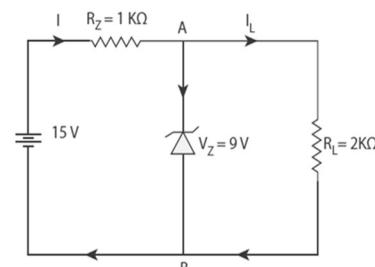
Voltage across AB is $V_{AB} = 9 \text{ V}$

Voltage drop across R = $15 - 9 = 6 \text{ V}$

Therefore, current through the resistor R,

$$I = \frac{6}{1 \times 10^3} = 6 \text{ mA}$$

Voltage across the load resistor = $V_{AB} = 9 \text{ V}$



$$\text{Current through load resistor, } I_L = \frac{V_{AB}}{R_L} = \frac{9}{2 \times 10^3} ; = 4.5 \text{ mA}$$

The current through the Zener diode,

$$I_Z = I - I_L = 6 \text{ mA} - 4.5 \text{ mA} = 1.5 \text{ mA}$$

- 168.** Determine the wavelength of light emitted from LED which is made up of GaAsP semiconductor whose forbidden energy gap is 1.875 eV. Mention the colour of the light emitted (Take $\hbar = 6.6 \times 10^{-34}$ Js).

Solution:

$$E_g = \frac{hc}{\lambda} ; \text{ Therefore, } \lambda = \frac{hc}{E_g} ; = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.875 \times 1.6 \times 10^{-19}} \\ = 660 \text{ nm}$$

The wavelength 660 nm corresponds to red colour light.

- 169.** In a transistor connected in the common base configuration, a $\alpha = 0.95$, $I_E = 1 \text{ mA}$. Calculate the values of I_C and I_B .

Solution:

$$\alpha = \frac{I_C}{I_E} ; I_C = \alpha I_E = 0.95 \times 1 = 0.95 \text{ mA} \\ I_E = I_B + I_C \therefore I_B = I_E - I_C ; = 1 - 0.95 = 0.05 \text{ mA}$$

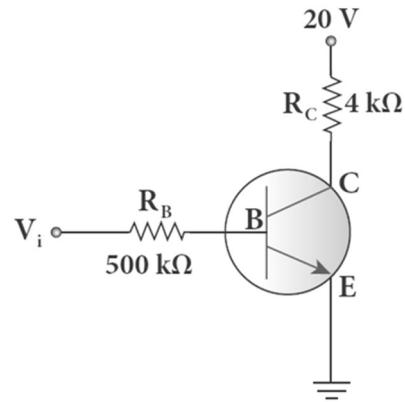
- 170.** In the circuit shown in the figure, the input voltage V_i is 20 V, $V_{BE} = 0 \text{ V}$ and $V_{CE} = 0 \text{ V}$. What are the values of I_B , I_C , β ?

Solution:

$$I_B = \frac{V_i}{R_B} = \frac{20 \text{ V}}{500 \text{ k}\Omega} ; = 40 \mu\text{A} \\ [\because V_{BE} = 0 \text{ V}]$$

$$I_C = \frac{V_{CC}}{R_C} = \frac{20 \text{ V}}{4 \text{ k}\Omega} ; = 5 \text{ mA} \\ [\because V_{CE} = 0 \text{ V}]$$

$$\beta = \frac{I_C}{I_B} = \frac{5 \text{ mA}}{40 \mu\text{A}} ; \beta = 125$$



- 171.** Calculate the range of the variable capacitor that is to be used in a tuned-collector oscillator which has a fixed inductance of 150 μH . The frequency band is from 500 kHz to 1500 kHz.

Solution:

$$\text{Resonant frequency, } f_0 = \frac{1}{2\pi\sqrt{LC}} ; \text{ On simplifying we get } C = \frac{1}{4\pi^2 f_0^2 L}$$

When frequency is equal to 500 kHz

$$C = \frac{1}{4 \times 3.14^2 \times (500 \times 10^3)^2 \times 150 \times 10^{-6}} ; = 676 \text{ pF}$$

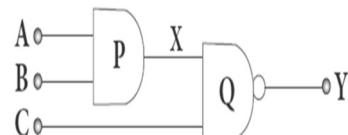
When frequency is equal to 1500 kHz

$$C = \frac{1}{4 \times 3.14^2 \times (1500 \times 10^3)^2 \times 150 \times 10^{-6}} ; = 75 \text{ pF}$$

Therefore, the capacitor range is from 75 to 676 pF

- 172. What is the output Y in the following circuit, when all the three inputs A, B, and C are first 0 and then 1?**

Solution:



A	B	C	X = A.B	Y = $\bar{X} \cdot \bar{C}$
0	0	0	0	1
1	1	1	1	0

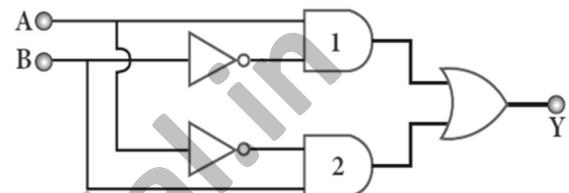
- 173. In the combination of the following gates, write the Boolean equation for output Y in terms of inputs A and B.**

Solution:

The output at the 1st AND gate: $A \bar{B}$

The output at the 2nd AND gate: $\bar{A} B$

The output at the OR gate: $Y = A \cdot \bar{B} + \bar{A} \cdot B$



- 174. Simplify the Boolean identity $AC + ABC = AC$**

Solution:

Step 1: $AC(1 + B) = AC \cdot 1$ [OR law - 2]

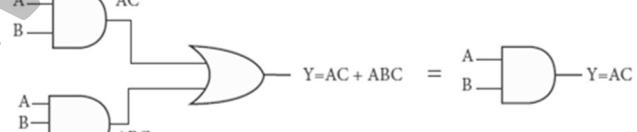
Step 2: $AC \cdot 1 = AC$ [AND law - 2]

Therefore, $AC + ABC = AC$

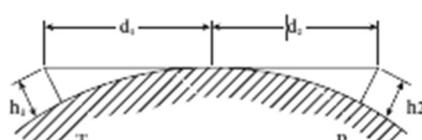
Circuit Description

$$Y = AC + ABC \\ Y = AC$$

Thus the given statement is proved.



- 175. A transmitting antenna has a height of 40 m and the height of the receiving antenna is 30 m. What is the maximum distance between them for line-of-sight communication? The radius of the earth is 6.4×10^6 m.**



Solution:

The total distance d between the transmitting and receiving antennas will be the sum of the individual distances of coverage.

$$\begin{aligned} d &= d_1 + d_2 ; = \sqrt{2Rh_1} + \sqrt{2Rh_2} = \sqrt{2R}(\sqrt{h_1} + \sqrt{h_2}) \\ &= \sqrt{2 \times 6.4 \times 10^6}(\sqrt{40} + \sqrt{30}) ; = \sqrt{2 \times 6.4 \times 10^6} \times \sqrt{10}(\sqrt{4} + \sqrt{3}) \\ &= \sqrt{2 \times 6.4 \times 10^7} (\sqrt{4} + \sqrt{3}) ; = \sqrt{2 \times 64 \times 10^6} (\sqrt{4} + \sqrt{3}) \\ d &= 1.414 \times 8 \times 10^3 (2 + 1.732) ; d = 42.21 \times 10^3 \text{ m}; d = 42.21 \text{ km} \end{aligned}$$

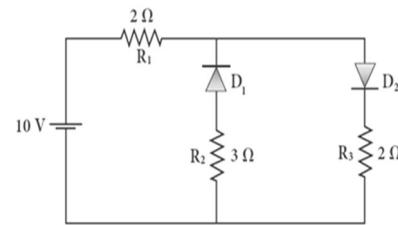
EXERCISE PROBLEM

- 176.** The given circuit has two ideal diodes connected as shown in figure below. Calculate the current flowing through the resistance R_1

Solution:

Diode D_1 is reverse biased so, it will block the current and Diode D_2 is forward biased, so it will pass the current.

$$\text{Current in the circuit is } I = \frac{V}{R} ; = \frac{10}{2+2} = \frac{10}{4} ; \\ I = 2.5\text{A}$$



- 177.** Four silicon diodes and a 10Ω resistor are connected as shown in figure below. Each diode has a resistance of 1Ω . Find the current flows through the 18Ω resistor.

Solution:

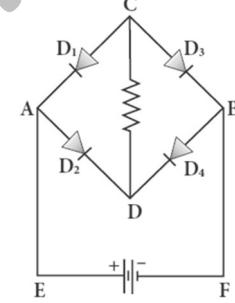
Diode D_2 and D_4 are forward biased while diodes D_1 and D_3 are reverse biased. Only current flowing through the closed loop is EADCBFE. Consider the applied voltage is 4V. For silicon diode, Barrier voltage is 0.7 V.

$$\text{Net circuit voltages} = 4 - (0.7 + 0.7) = 4 - 1.4$$

$$V = 2.6\text{ V}$$

$$\text{Total circuit resistance} = 1 + 18 + 1 R = 20\Omega$$

$$\therefore \text{Circuit Current } I = \frac{V}{R} = \frac{2.6}{20} ; = 0.13\text{ A}$$



- 178.** Assuming $V_{CEsat} = 0.2\text{ V}$ and $\beta = 50$, find the minimum base current (I_B) required to drive the transistor given in the figure to saturation.

Solution:

$$\text{From figure } V_{CC} = I_C R_C + V_{CE} \text{ (or) } I_C R_C = V_{CC} - V_{CE}$$

$$\text{(or) } I_C = \frac{V_{CC} - V_{CE}}{R_C} ; = \frac{3 - 0.2}{1000}$$

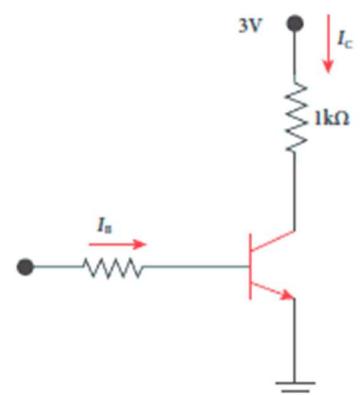
$$I_C = 2.8 \times 10^{-3}\text{ A}$$

$$\text{The Current Gain } \beta = \frac{I_C}{I_B} ; I_B = \frac{I_C}{\beta}$$

$$= \frac{2.8 \times 10^{-3}}{50} ;$$

$$= 0.056 \times 10^{-3}\text{ A} ;$$

$$= 56 \times 10^{-6}\text{ A} ; I_B = 56\text{ }\mu\text{A}$$



- 179. Determine the current flowing through 3Ω and 4Ω resistors of the circuit given below. Assume that diodes D_1 and D_2 are ideal diodes.**

Solution:

Here diode D_1 is forward biased (closed switch) and D_2 is reverse biased (open switch)

So D_1 conducts while D_2 do not conduct the current.

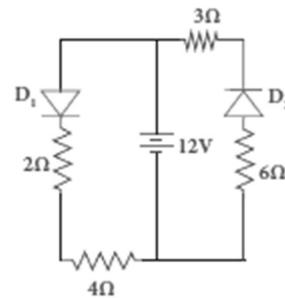
For ideal diode, there is no barrier voltage (i.e.) $V_B = 0$

Let ' I ' be the current through D_1 , then by Ohm's Kirchoff's voltage law,

$$2I + 4I = 12 \text{ (or)} 6I = 12 \text{ or} I = 2A$$

Since D_2 will not conduct, no current flows through diode D_2

Thus current flowing through 3Ω and 4Ω resistors of the circuit are 0 and 2 A Respectively.



- 180. Prove the following Boolean expressions using the laws and theorems of Boolean algebra.**

$$\text{i) } (A + B)(A + \bar{B}) = A \quad \text{ii) } A(\bar{A} + B) = AB \quad \text{iii) } (A + B)(A + C) = A + BC$$

Solution:

$$\text{i) } (A + B)(A + \bar{B}) = A$$

$$= AA + A\bar{B} + BA + B\bar{B} \quad [\text{By AND laws : } AA = A \text{ & } B\bar{B} = 0]$$

$$= A + A(\bar{B} + B) + 0 \quad [\text{By OR laws : } \bar{B} + B = 1 \text{ & } A + 0 = 0]$$

$$= A + A(1) \quad [\text{By AND laws: } A \cdot 1 = A]$$

$$(A + B)(A + \bar{B}) = A \quad [\text{By OR laws : } A + A = A]$$

$$\text{ii) } A(\bar{A} + B) = AB$$

$$[\text{By AND laws : } A\bar{A} = 0]$$

$$= 0 + AB \quad [\text{By OR laws : } 0 + A = A]$$

$$A(\bar{A} + B) = AB$$

$$\text{iii) } (A + B)(A + C) = A + BC$$

$$= AA + AC + BA + BC$$

$$= A + AC + BA + BC$$

$$= A(1 + C + B) + BC \quad [\text{By OR laws : } 1 + A = 1]$$

$$= A(1) + BC$$

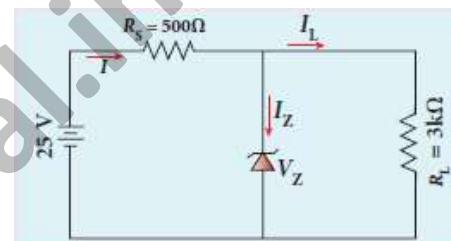
$$(A + B)(A + C) = A + BC$$

- 181.** Verify the given Boolean equation $A + \overline{AB} = A + B$ using truth table.

Solution:

A	B	\overline{A}	\overline{AB}	$A + \overline{AB}$	$A + B$
0	0	1	0	0	0
0	1	1	1	1	1
1	0	0	0	1	1
1	1	0	0	1	1

- 182.** In the given figure of a voltage regulator, a Zener diode of breakdown voltage 15V is employed. Determine the current through the load resistance, the total current and the current through the diode. Use diode approximation.



Solution:

From Ohm's law Current through load resistance R_L ,

$$I_L = \frac{V_0}{R_L} ; = \frac{15}{3 \times 10^3} ; = 5 \times 10^{-3} ; I_L = 5 \text{ mA}$$

$$\text{Current through } R_s = \frac{V_{RS}}{R_s} ; = \frac{10}{500} ; = 2 \times 10^{-2} ; 20 \times 10^{-3} ;$$

$$R_s = 20 \text{ mA}$$

$$\text{Current through Zener Diode, } I_z = I - I_L$$

$$= (20 \times 10^{-3}) - (5 \times 10^{-3}) ; = 10^{-3} (20 - 5) ; 15 \times 10^{-3} ;$$

$$I_z = 15 \text{ mA}$$

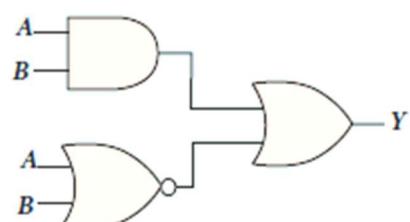
- 183.** Write down Boolean equation for the output Y of the given circuit and give its truth table.

Solution

Output of AND gate = $A \cdot B$

Output of NOR gate = $\overline{A + B}$

The final output of OR gate $Y = (A \cdot B) + (\overline{A + B})$



A	B	$A \cdot B$	$A + B$	$\overline{A + B}$	$Y = A \cdot B + (\overline{A + B})$
0	0	0	0	1	1
0	1	0	1	0	1
1	0	0	1	0	1
1	1	1	1	0	1

PRACTICAL HAND BOOK

HIGHER SECONDARY SECOND YEAR

இயற்பியல் **PHYSICS**

PREPARED BY



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2024 - 2025

INSTRUCTIONS TO STUDENTS

01. Before coming to the laboratory, a student should plan the experiment in advance by consulting with his / her friends and reading this book.

02. As separate observation Note Book must be used and everything regarding the experiment **must be written before coming to the laboratory.**

03. Write the date, experiment number, aim, apparatus required, formula, procedure and result in the right-hand page and diagram (Ray diagrams, and Circuit diagrams), tabulations, observations and calculations, in the **left-hand page of the observation note book / record note book.**

04. After the completion of experiment with all observations in the laboratory, the **student should get the signature of the teacher. Within three days** of the experiment the **student should complete the calculations** and **get the signature of the teacher.**

05. Enter the observed reading with the relevant units (gram, cm, mm...) but the **final calculation must be done with SI units only.** The result must be given with proper SI Unit.

PHYSICS PRACTICAL – SCHEME OF EVALUATION

Internal Assessment	: 15 Marks
External Examination	: 15 Marks
Total Marks	: 30 Marks

Internal Assessment (15)

(Teacher should maintain the Assessment Register and the Head of the Institution should monitor it)

Attendance (Above 80.01%)	:	02 Marks
Test	:	04 Marks
Assignment	:	02 Marks
Performance (while doing the experiment In the laboratory)	:	02 Marks
Record Note Book	:	03 Marks
Co-curricular Activities	:	02 Marks

External Examination (15)

01. Formula : 02 Marks
(mere expression –1, explanation of notations –1)
02. Brief Procedure : 03 Marks
03. Observations : 05 Marks
04. Calculations (Including graphs) : 04 Marks
05. Result : 01 Mark
(Correct Value –½ Mark, Mentioning SI Unit – ½ Mark)

LIST OF EXPERIMENTS

1. Determination of the specific resistance of the material of the given coil using Metre Bridge.
2. Determination of the value of the horizontal component of the Earth's magnetic field using tangent galvanometer.
3. Comparison of emf of two cells using potentiometer
4. Determination of the refractive index of the material of the prism by finding angle of prism and angle of minimum deviation using spectrometer.
5. Determination of the wavelength of a composite light by normal incidence method using diffraction grating and spectrometer (The number of lines per metre length of the grating is given).
6. Investigation of the voltage-current (V-I) characteristics of PN junction diode.
7. Investigation of the voltage-current (V-I) characteristics of Zener diode.
8. Investigation of the static characteristics of a NPN Junction transistor in common emitter configuration.
9. Verification of the truth table of the basic logic gates using integrated circuits.
10. Verification of De Morgan's theorems using integrated circuits.

Ex. No. : 1

Date :

SPECIFIC RESISTANCE OF THE MATERIAL OF THE COIL USING METRE BRIDGE

AIM:

To determine the specific resistance of the material of the given coil using metre bridge.

APPARATUS REQUIRED:

Meter Bridge, Galvanometer, Key, Resistance box, Connecting wires, Lechlanche cell, Jockey and High resistance.

FORMULA:

$$\rho = \frac{X\pi r^2}{L} (\Omega m)$$

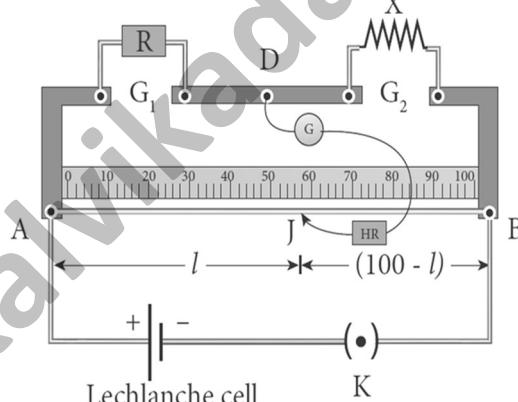
Where, X → Resistance of the given coil (Ω)

R → Known resistance (Ω)

L → Length of the coil (m)

r → Radius of the wire (m)

CIRCUIT DIAGRAM:



PROCEDURE:

A resistance box R is connected in the left gap and the unknown resistance X in the right gap. A Lechlanche cell is connected across the wire of length 1 m through a key. A sensitive galvanometer G is connected between the central strip and the jockey through a high resistance (HR). With a suitable resistance included in the resistance box, the circuit is switched on.

To check the circuit connections, the jockey is pressed near one end of the, say A. The galvanometer will show deflection in one direction. When the jockey is pressed near the other end of the wire B, the galvanometer will show deflection in the opposite directions. This ensures that the circuit connections are correct.

By moving the jockey over the wire, the point on the wire at which the galvanometer shows null deflection i.e., balancing point J is found. The balancing length AJ = l is noted.

The unknown resistance X_1 is found using the formula $X_1 = \frac{R(100-l)}{l}$

The experiment is repeated for different values of R. The same procedure is repeated after interchanging R and X.

The unknown resistance X_2 is found using the formula $X_2 = \frac{Rl}{(100-l)}$

The experiment is repeated for same values of R as before. The resistance of the given coil is found from the mean value of X_1 and X_2 . The radius of the wire r is found using screw gauge. The length of the coil L is measured using meter scale. From the values of X, r and L, the specific resistance of the material of the wire is determined.

OBSERVATION:

Length of the coil **L = 100 cm = 1 m.**

Table 1: To find the resistance of the given coil

S. No.	Resistance (R) (Ω)	Before interchanging		After interchanging		Mean $X = \frac{X_1 + X_2}{2}$ (Ω)	$\rho = \frac{X\pi r^2}{L}$ (Ωm)
		Balancing length l (cm)	$X_1 = \frac{R(100-l)}{l}$ (Ω)	Balancing length l (cm)	$X_2 = \frac{Rl}{(100-l)}$ (Ω)		
1	1	14.3	5.993	85.7	5.993	5.993	1.750
2	2	25.1	5.968	74.9	5.968	5.968	1.742
3	3	33.4	5.982	66.6	5.982	5.982	1.746
4	4	41.3	5.685	58.7	5.685	5.685	1.660
5	5	45.9	5.893	54.1	5.893	5.893	1.720
Mean / Average						5.904	1.723

Table 2: To find the radius of the wire

Zero error = **No Error**; LC = **0.01mm**; Zero correction = **No Correction**

S. No.	PSR (mm)	HSC (Div.)	Total Reading = PSR + (HSC x LC)+ZC (mm)	Corrected Reading = TR + ZC (mm)
1	0	60	60	0.60
2	0	60	60	0.60
3	0	61	61	0.61
4	0	62	62	0.62
5	0	62	62	0.62
Mean / Average (2r) =				0.61 mm
Radius of the wire r =				0.305 mm
r =				0.305 x 10⁻³ m

CALCULATION:

S. No.	$X_1 = \frac{R(100-l)}{l} (\Omega)$	$X_2 = \frac{Rl}{(100-l)} (\Omega)$	$\rho = \frac{\pi r^2}{L} (\Omega m)$
01	$= \frac{1(100-14.3)}{14.3}$ $= \frac{85.7}{14.3}$ $X_1 = 5.993 \Omega$	$= \frac{1(85.7)}{(100-85.7)}$ $= \frac{85.7}{14.3}$ $X_2 = 5.993 \Omega$	$\rho = \frac{5.993 \times 3.14 \times (0.305 \times 10^{-3})^2}{1}$ $= \frac{5.993 \times 3.14 \times 0.0930 \times 10^{-6}}{1}$ $\rho = 1.750 \times 10^{-6} (\Omega m)$
02	$= \frac{2(100-25.1)}{25.1}$ $= \frac{149.8}{25.1}$ $X_1 = 5.968 \Omega$	$= \frac{2(74.9)}{(100-74.9)}$ $= \frac{149.8}{25.1}$ $X_2 = 5.968 \Omega$	$\rho = \frac{5.968 \times 3.14 \times (0.305 \times 10^{-3})^2}{1}$ $= \frac{5.968 \times 3.14 \times 0.0930 \times 10^{-6}}{1}$ $\rho = 1.742 \times 10^{-6} (\Omega m)$
03	$= \frac{3(100-33.4)}{33.4}$ $= \frac{199.8}{33.4}$ $X_1 = 5.982 \Omega$	$= \frac{3(66.6)}{(100-66.6)}$ $= \frac{199.8}{33.4}$ $X_2 = 5.982 \Omega$	$\rho = \frac{5.982 \times 3.14 \times (0.305 \times 10^{-3})^2}{1}$ $= \frac{5.982 \times 3.14 \times 0.0930 \times 10^{-6}}{1}$ $\rho = 1.746 \times 10^{-6} (\Omega m)$
04	$= \frac{4(100-41.3)}{41.3}$ $= \frac{234.8}{41.3}$ $X_1 = 5.685 \Omega$	$= \frac{4(58.7)}{(100-58.7)}$ $= \frac{234.8}{41.3}$ $X_2 = 5.685 \Omega$	$\rho = \frac{5.685 \times 3.14 \times (0.305 \times 10^{-3})^2}{1}$ $= \frac{5.685 \times 3.14 \times 0.0930 \times 10^{-6}}{1}$ $\rho = 1.660 \times 10^{-6} (\Omega m)$
05	$= \frac{5(100-45.9)}{45.9}$ $= \frac{270.5}{45.9}$ $X_1 = 5.893 \Omega$	$= \frac{5(54.1)}{(100-54.1)}$ $= \frac{270.5}{45.9}$ $X_2 = 5.893 \Omega$	$\rho = \frac{5.893 \times 3.14 \times (0.305 \times 10^{-3})^2}{1}$ $= \frac{5.893 \times 3.14 \times 0.0930 \times 10^{-6}}{1}$ $\rho = 1.720 \times 10^{-6} (\Omega m)$

RESULT:

The specific resistance of the material of the given coil $\rho = 1.723 \times 10^{-6} (\Omega m)$

Ex. No. : 2

Date :

HORIZONTAL COMPONENT OF EARTH'S MAGNETIC FIELD USING TANGENT GALVANOMETER

AIM:

To determine the horizontal component of the Earth's magnetic field using tangent galvanometer.

APPARATUS REQUIRED:

Tangent galvanometer (TG), Commutator, Battery, Rheostat, Ammeter, key and Connecting wires.

$$\text{FORMULA: } B_H = \frac{\mu_0 nk}{2r} \text{ (Tesla)}$$

Where, $B_H \rightarrow$ Horizontal component of the Earth's magnetic field (T)

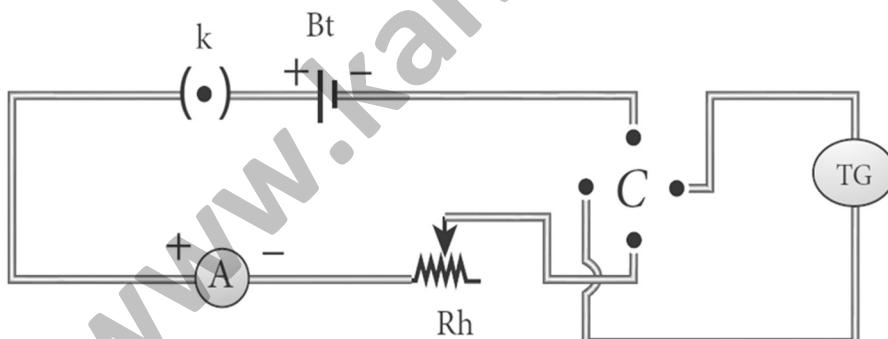
$\mu_0 \rightarrow$ Permeability of free space ($4\pi \times 10^{-7} \text{ Hm}^{-1}$)

n → Number of turns of TG in the circuit (No unit)

k → Reduction factor of TG (A)

r → Radius of the coil (m)

CIRCUIT DIAGRAM:



PROCEDURE:

The preliminary adjustments are carried out as follows. The leveling screws at the base of TG are adjusted so that the circular turn table is horizontal and the plane of the circular coil is vertical.

The circular coil is rotated so that its plane is in the magnetic meridian i.e., along the north-south direction. The compass box alone is rotated till the aluminium pointer reads $0^\circ - 0^\circ$. The connections are made as shown in circuit. The number of turn's n is selected and the circuit is switched on.

The range of current through TG is chosen in such a way that the deflection of the aluminium pointer lies between $30^\circ - 60^\circ$. A suitable current is allowed to pass through the circuit; the deflections θ_1 and θ_2 are noted from two ends of the aluminium pointer. Now the direction of current is reversed

using commutator C, the deflections θ_3 and θ_4 in the opposite direction are noted. The mean value θ of θ_1 , θ_2 , θ_3 and θ_4 is calculated and tabulated.

The reduction factor k is calculated for each case and it is found that k is a constant. The experiment is repeated for various values of current and the readings are noted and tabulated. The radius of the circular coil is found by measuring the circumference of the coil using a thread around the coil. From the values of r , n and k , the horizontal component of Earth's magnetic field is determined.

OBSERVATION:

Number of turns of the coil (n) = 5

Circumference of the coil ($2\pi r$) = 49.5×10^{-2} m

Radius of the coil (r) = $2\pi r = 49.5 \times 10^{-2}$ m

$$\begin{aligned} r &= \frac{49.5 \times 10^{-2}}{2\pi}; \\ &= \frac{49.5 \times 10^{-2} \text{ m}}{2 \times 3.14}; \\ &= \frac{49.5 \times 10^{-2}}{6.28} \\ r &= 7.882 \times 10^{-2} \text{ m} \end{aligned}$$

S. No.	Current I (A)	Deflection of T.G. (Degree)				Mean θ	$\tan \theta$	$k = \frac{I}{\tan \theta}$ (A)	$B_H = \frac{\mu_0 n k}{2r}$ (Tesla)
		θ_1	θ_2	θ_3	θ_4				
1	0.6	32	32	33	33	$32^{\circ} 30'$	0.637	0.941	3.748
2	0.8	39	39	40	40	$39^{\circ} 30'$	0.824	0.970	3.864
3	1.0	45	45	46	46	$45^{\circ} 30'$	1.017	0.983	3.915
4	1.2	50	50	51	51	$50^{\circ} 30'$	1.213	0.989	3.939
Mean / Average								0.970	3.866

CALCULATION: To find horizontal component of the Earth's magnetic field

S. No.	$k = \frac{I}{\tan \theta}$	$B_H = \frac{\mu_0 nk}{2r}$ (Tesla)
01	$k = \frac{0.6}{\tan 32^0 30'} ;$ $= \frac{0.6}{0.637} ;$ $k = 0.941 \text{ A}$	$B_H = \frac{4\pi \times 10^{-7} \times 5 \times 0.941}{49.5 \times 10^{-2} / \pi} ;$ $= \frac{4\pi^2 \times 10^{-7} \times 5 \times 0.941}{49.5 \times 10^{-2}} ;$ $= \frac{4 \times 3.14 \times 3.14 \times 10^{-7} \times 5 \times 0.941}{49.5 \times 10^{-2}} ;$ $= \frac{185.557 \times 10^{-7}}{49.5 \times 10^{-2}} ;$ $B_H = 3.748 \times 10^{-5} \text{ (Tesla)}$
02	$k = \frac{0.8}{\tan 39^0 30'} ;$ $= \frac{0.8}{0.824} ;$ $k = 0.970 \text{ A}$	$B_H = \frac{4\pi \times 10^{-7} \times 5 \times 0.970}{49.5 \times 10^{-2} / \pi} ;$ $= \frac{4\pi^2 \times 10^{-7} \times 5 \times 0.970}{49.5 \times 10^{-2}} ;$ $= \frac{4 \times 3.14 \times 3.14 \times 10^{-7} \times 5 \times 0.970}{49.5 \times 10^{-2}} ;$ $= \frac{191.276 \times 10^{-7}}{49.5 \times 10^{-2}} ;$ $B_H = 3.864 \times 10^{-5} \text{ (Tesla)}$
03	$k = \frac{1.0}{\tan 45^0 30'} ;$ $= \frac{1.0}{1.017} ;$ $k = 0.983 \text{ A}$	$B_H = \frac{4\pi \times 10^{-7} \times 5 \times 0.983}{49.5 \times 10^{-2} / \pi} ;$ $= \frac{4\pi^2 \times 10^{-7} \times 5 \times 0.983}{49.5 \times 10^{-2}} ;$ $= \frac{4 \times 3.14 \times 3.14 \times 10^{-7} \times 5 \times 0.983}{49.5 \times 10^{-2}} ;$ $= \frac{193.839 \times 10^{-7}}{49.5 \times 10^{-2}} ;$ $B_H = 3.915 \times 10^{-5} \text{ (Tesla)}$
04	$k = \frac{1.2}{\tan 50^0 30'} ;$ $= \frac{1.2}{1.213} ;$ $k = 0.989 \text{ A}$	$B_H = \frac{4\pi \times 10^{-7} \times 5 \times 0.989}{49.5 \times 10^{-2} / \pi} ;$ $= \frac{4\pi^2 \times 10^{-7} \times 5 \times 0.989}{49.5 \times 10^{-2}} ;$ $= \frac{4 \times 3.14 \times 3.14 \times 10^{-7} \times 5 \times 0.989}{49.5 \times 10^{-2}} ;$ $= \frac{195.022 \times 10^{-7}}{49.5 \times 10^{-2}} ;$ $B_H = 3.939 \times 10^{-5} \text{ (Tesla)}$

RESULT:

The horizontal component of Earth's magnetic field is found to be

$$\mathbf{B_H = 3.866 \times 10^{-5} \text{ Tesla}}$$

Ex. No. : 3

Date :

COMPARISON OF EMF OF TWO CELLS USING POTENTIOMETER

AIM:

To compare the emf of the given two cells using a potentiometer.

APPARATUS REQUIRED:

Battery eliminator, key, rheostat, DPDT switch, Lechlanche and Daniel cells, galvanometer, high resistance box, pencil jockey and connecting wires.

FORMULA:

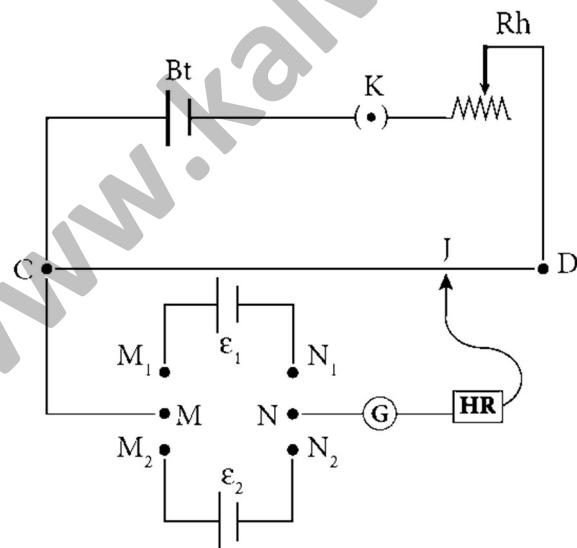
$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2} \text{ (No Unit)}$$

Where,

ε_1 and ε_2 → The emf of Lechlanche and Daniel cells respectively (V)

l_1 and l_2 → The balancing lengths for Lechlanche and Daniel cells respectively (cm)

CIRCUIT DIAGRAM:



PROCEDURE:

The apparatus is arranged as shown in the circuit diagram.

The primary circuit consisting of battery, key and rheostat is connected to the potentiometer in series.

The positive poles of the cells are connected to terminals M_1 & M_2 and the negative poles to terminals N_1 & N_2 of the DPDT switch. The potentiometer is connected to the common terminals M and N as shown in the circuit.

Using the two-way key, Lechlanche cell is included in the circuit. By sliding the jockey on the potentiometer wire, the balancing point is found and the corresponding balancing length is measured.

Similarly, the balancing length is found by including Daniel cell in the circuit. The experiment is repeated for different sets of balancing lengths by adjusting the rheostat. From different values of l_1 and l_2 , the ratio of emf of the two cells is calculated.

OBSERVATION:

To find the ratio of emf of two cells;

S. No.	Balancing length for Lechlanche cell, l_1 (cm)	Balancing length for Daniel cell, l_2 (cm)	$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$ (No Unit)
1	625	458	1.364
2	636	459	1.385
3	647	473	1.367
4	658	478	1.376
5	668	481	1.388
6	680	497	1.368
Mean $\frac{\varepsilon_1}{\varepsilon_2} =$			1.374 (NO Unit)

CALCULATION:

S. No.	$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$ (No Unit)
1	$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2} = \frac{625}{458} = 1.364$ (No Unit)
2	$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2} = \frac{636}{459} = 1.385$ (No Unit)
3	$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2} = \frac{647}{473} = 1.367$ (No Unit)
4	$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2} = \frac{658}{478} = 1.376$ (No Unit)
5	$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2} = \frac{668}{481} = 1.388$ (No Unit)
6	$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2} = \frac{680}{497} = 1.368$ (No Unit)

Mean :

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{1.364 + 1.385 + 1.367 + 1.376 + 1.388 + 1.368}{6}$$

$$\frac{\varepsilon_1}{\varepsilon_2} = 1.374 \text{ (No unit)}$$

RESULT:

Ratio of emf of the given two cells = 1.374 (No unit)

Ex. No. : 4

Date :

REFRACTIVE INDEX OF THE MATERIAL OF THE PRISM

AIM:

To determine the refractive index of the material of a prism using spectrometer.

APPARATUS REQUIRED:

Spectrometer, prism, prism clamp, sodium vapour lamp, spirit level.

FORMULA:

$$\mu = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)} \text{ (No unit)}$$

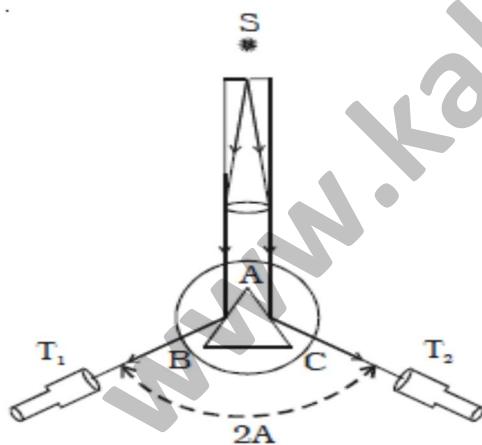
Where, $\mu \rightarrow$ Refractive index of the material of the prism (No unit)

$A \rightarrow$ Angle of the prism (degree)

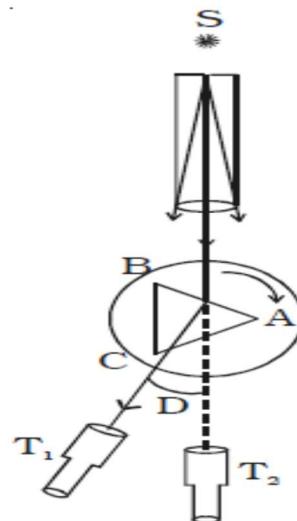
$D \rightarrow$ Angle of minimum deviation (degree)

DIAGRAMS:

To find the Angle of Prism:



To find the Angle of Minimum Deviation:



PROCEDURE:

1) Initial adjustments of the spectrometer:

Eye-piece:

The eye-piece of the telescope is adjusted so that the cross-wires are seen clearly.

Slit:

The slit of the collimator is adjusted such that it is very thin and vertical.

Base of the spectrometer:

The base of the spectrometer is adjusted to be horizontal using leveling screws.

Telescope:

The telescope is turned towards a distant object and is adjusted till the clear inverted image of the distant object is seen. Now the telescope is adjusted to receive parallel rays.

Collimator:

The telescope is brought in line with the collimator. Collimator is adjusted until a clear image of the slit is seen in the telescope. Now the collimator gives parallel rays.

Prism table:

Using a spirit level, the prism table is adjusted to be horizontal with the three leveling screws provided in the prism table.

2) Determination of angle of the prism (A):

The slit is illuminated by yellow light from sodium vapour lamp. The given equilateral prism is placed on the prism table in such a way that refracting edge of the prism is facing the collimator. The light emerging from the collimator is incident on both reflecting faces of the prism and is reflected. Telescope is rotated towards left to obtain reflected image of the slit from face 1 of the prism and is fixed. Using tangential screws, the telescope is adjusted until the vertical cross-wire coincides with the reflected image of the slit. The main scale reading and vernier coincidence are noted from both vernier scales. The telescope is now rotated towards right to obtain the reflected image from face 2 of the prism. As before, the readings are taken. The difference between the two readings gives $2A$ from which the angle of the prism A is calculated.

3) Determination of angle of minimum deviation (D):

The prism table is rotated such that the light emerging from the collimator is incident on one of the refracting faces of the prism, gets refracted and emerges out from the other refracting face. The telescope is turned to view the refracted image. Looking through the telescope, the prism table is rotated in such a direction that the image moves towards the direct ray. One particular position, the refracted ray begins to retrace its path. The position where the refracted image returns is the position of minimum deviation. The telescope is fixed in this position and is adjusted until the vertical cross-wire coincides with the refracted image of the slit. The readings are taken from both vernier scales. The prism is now removed and the telescope is rotated to obtain the direct ray image and the readings are taken. The readings are tabulated and the difference between these two readings gives the angle of minimum deviation D . From the values of A and D , the refractive index of the material of the glass prism is determined.

OBSERVATION:

Table 1: To find the angle of the prism (A)

RAY	VERNIER A (Degree)			VERNIER B (Degree)		
	MSR	VC	TR = MSR+ (VC×LC)	MSR	VC	TR = MSR+ (VC×LC)
Reflected image from face 1	60°	7	60° 7'	240°	7	240° 7'
Reflected image from face 2	299°	3	299° 3'	119°	3	119° 3'
Difference 2A	2A= R₁ ~R₂		121° 4'	2A= R₁ ~R₂		121° 4'
Mean / Average 2A =					121° 4'	
Mean / Average A =					60° 32'	

Table 2: To find the angle of minimum deviation (D)

Image	VERNIER A (Degree)			VERNIER B (Degree)		
	MSR	VC	TR = MSR+ (VC×LC)	MSR	VC	TR = MSR+ (VC×LC)
Reflected image (R3)	319°	14	319° 14'	139°	14	139° 14'
Direct image (R4)	0°	0	0° 0'	180°	0	180° 0'
Difference D	D = R₃ ~R₄		40° 46'	D = R₃ ~R₄		40° 46'
Mean / Average 2D =					81° 32'	
Mean / Average D =					40° 46'	

CALCULATION:

To find “A” (Vernier – A)

$$2A = R_1 \sim R_2 = 299^{\circ} 3' - 60^{\circ} 7' = 238^{\circ} 56'$$

This value is larger Obtuse angle, so, it must be subtracted from 360°

$$2A = 360^{\circ} - 238^{\circ} 56' = 121^{\circ} 4'$$

To find “A” (Vernier – B)

$$2A = R_1 \sim R_2 = 240^{\circ} 7' - 119^{\circ} 3' = 121^{\circ} 4'$$

$$\begin{aligned} \text{Average } 2A &= \frac{121^{\circ} 4' + 121^{\circ} 4'}{2}; = \frac{242^{\circ} 8'}{2} = 121^{\circ} 4' \\ &= \frac{121^{\circ} 4'}{2}; \mathbf{A = 60^{\circ} 32' (Degree)} \end{aligned}$$

To find “D” (Vernier – A)

$$D = R_3 \sim R_4 = 319^{\circ} 14' - 0^{\circ} 0' = 319^{\circ} 14'$$

$$\mathbf{D = 360^{\circ} - 319^{\circ} 14' = 40^{\circ} 46'}$$

To find “D” (Vernier – B)

$$D = R_3 \sim R_4 = 180^{\circ} 0' - 139^{\circ} 14' = 40^{\circ} 46'$$

$$\begin{aligned} \text{Average } D &= \frac{40^{\circ} 46' + 40^{\circ} 46'}{2}; \\ &= \frac{81^{\circ} 32'}{2}; \mathbf{D = 40^{\circ} 46' (Degree)} \end{aligned}$$

To find “μ” :

$$\mu = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)} \text{ (No unit)}$$

$$= \frac{\sin\left(\frac{60^{\circ} 32' + 40^{\circ} 46'}{2}\right)}{\sin\left(\frac{60^{\circ} 32'}{2}\right)}; = \frac{\sin\left(\frac{101^{\circ} 18'}{2}\right)}{\sin\left(\frac{60^{\circ} 32'}{2}\right)};$$

$$= \frac{\sin(50^{\circ} 39')}{\sin(30^{\circ} 16')}$$

$$= \frac{0.7732}{0.5040}$$

$$\mathbf{\mu = 1.534 (No Unit)}$$

RESULT:

1. Angle of the Prism **A = 60° 32' (Degree)**
2. Angle of the minimum deviation of the prism **D = 40° 46' (Degree)**
3. Refractive index of the material of the Prism **μ = 1.534 (No Unit)**

Ex. No. : 5

Date :

WAVELENGTH OF THE CONSTITUENT COLOURS OF A COMPOSITE LIGHT USING DIFFRACTION GRATING AND SPECTROMETER

AIM:

To find the wavelength of the constituent colours of a composite light using diffraction grating and spectrometer.

APPARATUS REQUIRED:

Spectrometer, mercury vapour lamp, diffraction grating, grating table, and spirit level.

FORMULA:

$$\lambda = \frac{\sin \theta}{nN} \text{ Å}$$

Where, $\lambda \rightarrow$ Wavelength of the constituent colours of a composite light (Å)

$N \rightarrow$ Number of lines per metre length of the given grating (No unit)

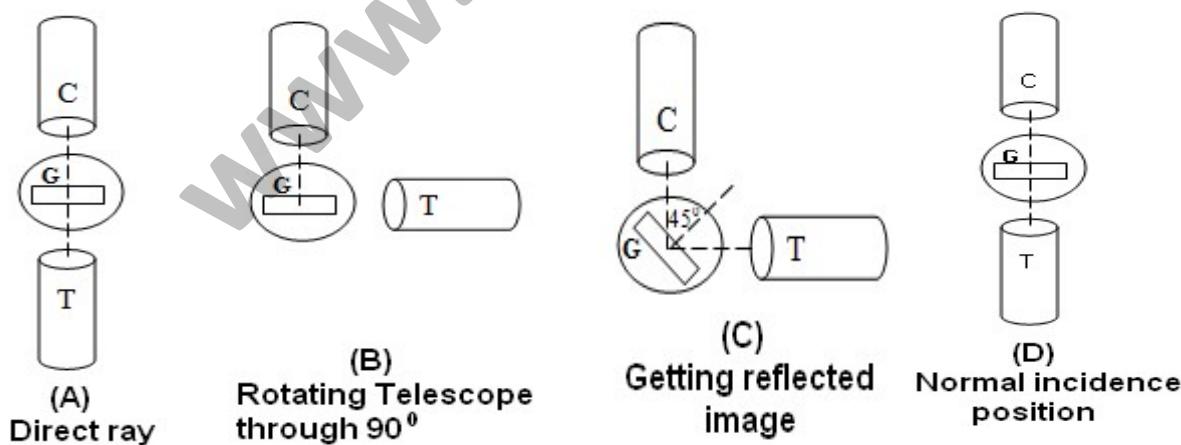
(The value of N for the grating is given)

$n \rightarrow$ Order of the diffraction (No unit)

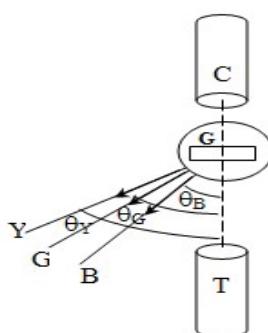
$\theta \rightarrow$ Angle of diffraction (degree)

DIAGRAMS:

ADJUSTING THE GRATING FOR NORMAL INCIDENCE: (NOT FOR EXAMINATION)



DETERMINATION OF ANGLE OF DIFFRACTION: (NOT FOR EXAMINATION)



PROCEDURE:

1) Initial adjustments of the spectrometer

Eye-piece:

The eye-piece of the telescope is adjusted so that the cross-wires are seen clearly.

Slit:

The slit of the collimator is adjusted such that it is very thin and vertical.

Base of the spectrometer:

The base of the spectrometer is adjusted to be horizontal using leveling screws.

Telescope:

The telescope is turned towards a distant object and is adjusted till the clear image of the distant object is seen. Now the telescope is adjusted to receive parallel rays.

Collimator:

The telescope is brought in line with the collimator. Collimator is adjusted until a clear image of the slit is seen in the telescope. Now the collimator gives parallel rays.

Grating table:

Using a spirit level, the grating table is adjusted to be horizontal with the three leveling screws provided in the grating table.

2) Adjustment of the grating for normal incidence:

The slit is illuminated with a composite light (white light) from mercury vapour lamp. The telescope is brought in line with the collimator. The vertical cross-wire is made to coincide with the image of the slit (Figure (a)).

The vernier disc alone is rotated till the vernier scale reads $0^\circ - 180^\circ$ and is fixed. This is the reading for the direct ray. The telescope is then rotated (anti-clockwise) through an angle of 90° and fixed (Figure (b)).

Now the plane transmission grating is mounted on the grating table.

The grating table alone is rotated so that the light reflected from the grating coincides with vertical cross-wire of the telescope.

The reflected image is white in colour (Figure (c)). Now the vernier disc is released. The vernier disc along with grating table is rotated through an angle of 45° in the appropriate direction such that the light from the collimator is incident normally on the grating (Figure (d)).

3) Determination of wave length of the constituent colours of the mercury spectrum:

The telescope is released and is brought in line with the collimator to receive central direct image. This un-dispersed image is white in colour. The diffracted images of the slit are observed on either side of the direct image.

The diffracted image consists of the prominent colours of mercury spectrum in increasing order of wavelength. The telescope is turned to any one side (say left) of direct image to observe first order diffracted image. The vertical cross-wire is made to coincide with the prominent spectral lines (Violet, Blue, Yellow and Red) and the readings of both vernier scales for each case are noted.

Now the telescope is rotated to the right side of the direct image and the first order image is observed. The vertical cross-wire is made to coincide with the same prominent spectral lines and the readings of both vernier scales for each case are again noted. The readings are tabulated.

The difference between these two readings gives the value of 2θ for the particular spectral line. The number of lines per metre length of the given grating N is noted from the grating. From the values of N, n and θ , the wave length of the prominent colours of the mercury light is determined using the given formula.

OBSERVATION:

To find the wave length of prominent colours of the mercury spectrum:

Red	Yellow	Green	Blue	Colour of Light	Diffracted Ray Reading (Degree)								Difference 2θ (Degree)	θ (Degree)		
					Left				Right							
					VERNIER A	VERNIER B	VERNIER A	VERNIER B	VERNIER A	VERNIER B	VERNIER A	VERNIER B				
296° 0'	298° 0'	299° 0'	302° 0'	MSR	0	0	TR	TR	122° 0'	122° 0'	302° 0'	302° 0'	25° 0'	25° 0'	12° 0'	
0	0	0	0	VSC	116° 0'	118° 0'	119° 0'	119° 0'	327° 0'	327° 0'	320° 0'	320° 0'	31° 30'	31° 30'	15° 30'	
296° 0'	298° 0'	299° 0'	302° 0'	MSR	0	0	TR	TR	147° 0'	147° 0'	150° 0'	150° 0'	33° 30'	33° 30'	16° 45'	
116° 0'	118° 0'	119° 0'	122° 0'	VSC	0	0	0	0	0	0	0	0	37° 30'	37° 30'	18° 45'	
116° 0'	118° 0'	119° 0'	122° 0'	MSR	333° 30'	331° 30'	330° 30'	330° 30'	327° 0'	327° 0'	320° 0'	320° 0'	31° 30'	31° 30'	15° 45'	
0	0	0	0	VSC	333° 30'	331° 30'	330° 30'	330° 30'	327° 0'	327° 0'	320° 0'	320° 0'	31° 30'	31° 30'	15° 45'	
296° 0'	298° 0'	299° 0'	302° 0'	MSR	153° 30'	151° 30'	150° 30'	150° 30'	147° 0'	147° 0'	150° 30'	150° 30'	33° 30'	33° 30'	16° 45'	
0	0	0	0	VSC	153° 30'	151° 30'	150° 30'	150° 30'	147° 0'	147° 0'	150° 30'	150° 30'	37° 30'	37° 30'	18° 45'	

CALCULATION:

S. No.	Colour	$\lambda = \frac{\sin \theta}{nN} \text{ Å}$
01	Blue	$= \frac{\sin 12^0 30^0}{1 \times 5 \times 10^5}; = \frac{0.2164}{5 \times 10^5};$ $= 0.04328 \times 10^{-5}$ $\lambda = 4328 \times 10^{-10} \text{ m (or) } \lambda = 4328 \text{ Å}$
02	Green	$= \frac{\sin 15^0 45^0}{1 \times 5 \times 10^5}; = \frac{0.2714}{5 \times 10^5};$ $= 0.05428 \times 10^{-5}$ $\lambda = 5428 \times 10^{-10} \text{ m (or) } \lambda = 5428 \text{ Å}$
03	Yellow	$= \frac{\sin 16^0 45^0}{1 \times 5 \times 10^5}; = \frac{0.2881}{5 \times 10^5};$ $= 0.05763 \times 10^{-5}$ $\lambda = 5763 \times 10^{-10} \text{ m (or) } \lambda = 5763 \text{ Å}$
04	Red	$= \frac{\sin 18^0 45^0}{1 \times 5 \times 10^5}; = \frac{0.3214}{5 \times 10^5};$ $= 0.06428 \times 10^{-5}$ $\lambda = 6428 \times 10^{-10} \text{ m (or) } \lambda = 6428 \text{ Å}$

RESULT:

1. The wavelength of blue line $\lambda = 4328 \times 10^{-10} \text{ m (or) } \lambda = 4328 \text{ Å}$
2. The wavelength of green line $\lambda = 5428 \times 10^{-10} \text{ m (or) } \lambda = 5428 \text{ Å}$
3. The wavelength of yellow line $\lambda = 5763 \times 10^{-10} \text{ m (or) } \lambda = 5763 \text{ Å}$
4. The wavelength of red line $\lambda = 6428 \times 10^{-10} \text{ m (or) } \lambda = 6428 \text{ Å}$

Ex. No. : 6

Date :

VOLTAGE - CURRENT CHARACTERISTICS OF A PN JUNCTION DIODE

AIM:

To draw the voltage-current (V- I) characteristics of the PN junction diode and to determine its knee voltage and forward resistance.

APPARATUS REQUIRED:

PN junction diode (IN4007), variable DC power supply, milli-ammeter, micro-ammeter, voltmeter, resistance and connecting wires.

FORMULA:

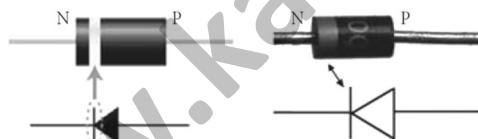
$$R_F = \frac{\Delta V_F}{\Delta I_F} (\Omega)$$

Where, $R_F \rightarrow$ Forward resistance of the diode (Ω)

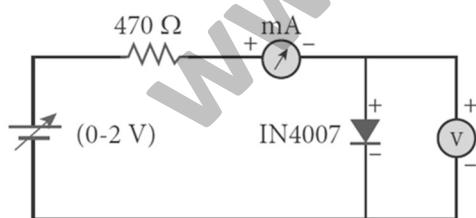
$\Delta V_F \rightarrow$ The change in forward voltage (volt)

$\Delta I_F \rightarrow$ The change in forward current (mA)

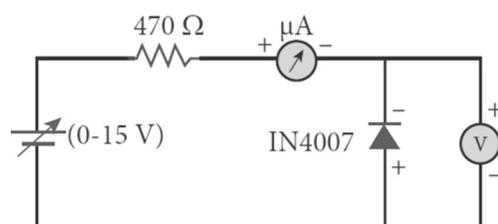
CIRCUIT DIAGRAM:



(PN Junction diode and its symbol (Silver ring denotes the negative terminal of the diode))



(PN Junction diode in forward bias)



(PN Junction diode in reverse bias)

PROCEDURE:

i) Forward bias characteristics:

In the forward bias, the P- region of the diode is connected to the positive terminal and N-region to the negative terminal of the DC power supply. The connections are given as per the circuit diagram. The voltage across the diode can be varied with the help of the variable DC power supply.

The forward voltage (V_F) across the diode is increased from 0.1 V in steps of 0.1 V up to 0.8 V and the forward current (I_F) through the diode is noted from the milliammeter. The readings are tabulated.

The forward voltage V_F and the forward current I_F are taken as positive. A

graph is drawn taking the forward voltage (V_F) along the x-axis and the forward current (I_F) along the y-axis.

The voltage corresponding to the dotted line in the forward characteristics gives the knee voltage or threshold voltage or turn-on voltage of the diode. The slope in the linear portion of the forward characteristics is calculated. The reciprocal of the slope gives the forward resistance of the diode.

ii) Reverse bias characteristics:

In the reverse bias, the polarity of the DC power supply is reversed so that the P-region of the diode is connected to the negative terminal and N-region to the positive terminal of the DC power supply. The connections are made as given in the circuit diagram. The voltage across the diode can be varied with the help of the variable DC power supply.

The reverse voltage (V_R) across the diode is increased from 1 V in steps of 1 V up to 5 V and the reverse current (I_R) through the diode is noted from the micro-ammeter. The readings are tabulated. The reverse voltage V_R and reverse current I_R are taken as negative. A graph is drawn taking the reverse bias voltage (V_R) along negative x-axis and the reverse bias current (I_R) along negative y-axis.

OBSERVATION:

Table 1

Forward bias characteristic curve

S. No.	Forward Bias Voltage V_F (V)	Forward Bias Current I_F (mA)
1	0.1	0
2	0.2	0
3	0.3	0
4	0.4	0
5	0.5	0
6	0.6	3.5
7	0.7	17.5

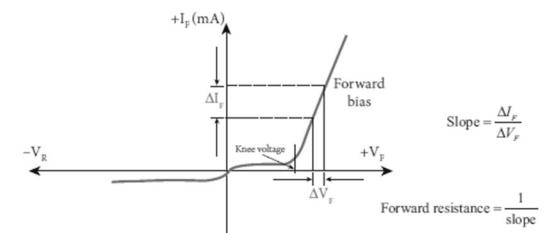


Table 2

Reverse bias characteristic curve

S. No.	Reverse Bias Voltage V_R (V)	Reverse Bias Current I_R (μA)
1	1	50
2	2	70
3	3	90
4	4	100
5	5	110
6	6	120
7	7	130

Voltage - Current characteristics DATE

-PN Junction Diode.

Forward Resistance: R_F

$$R_F = \frac{\Delta V_F}{\Delta I_F} \Omega$$

$$= \frac{0.1 \text{ V}}{14 \times 10^{-9} \text{ A}}$$

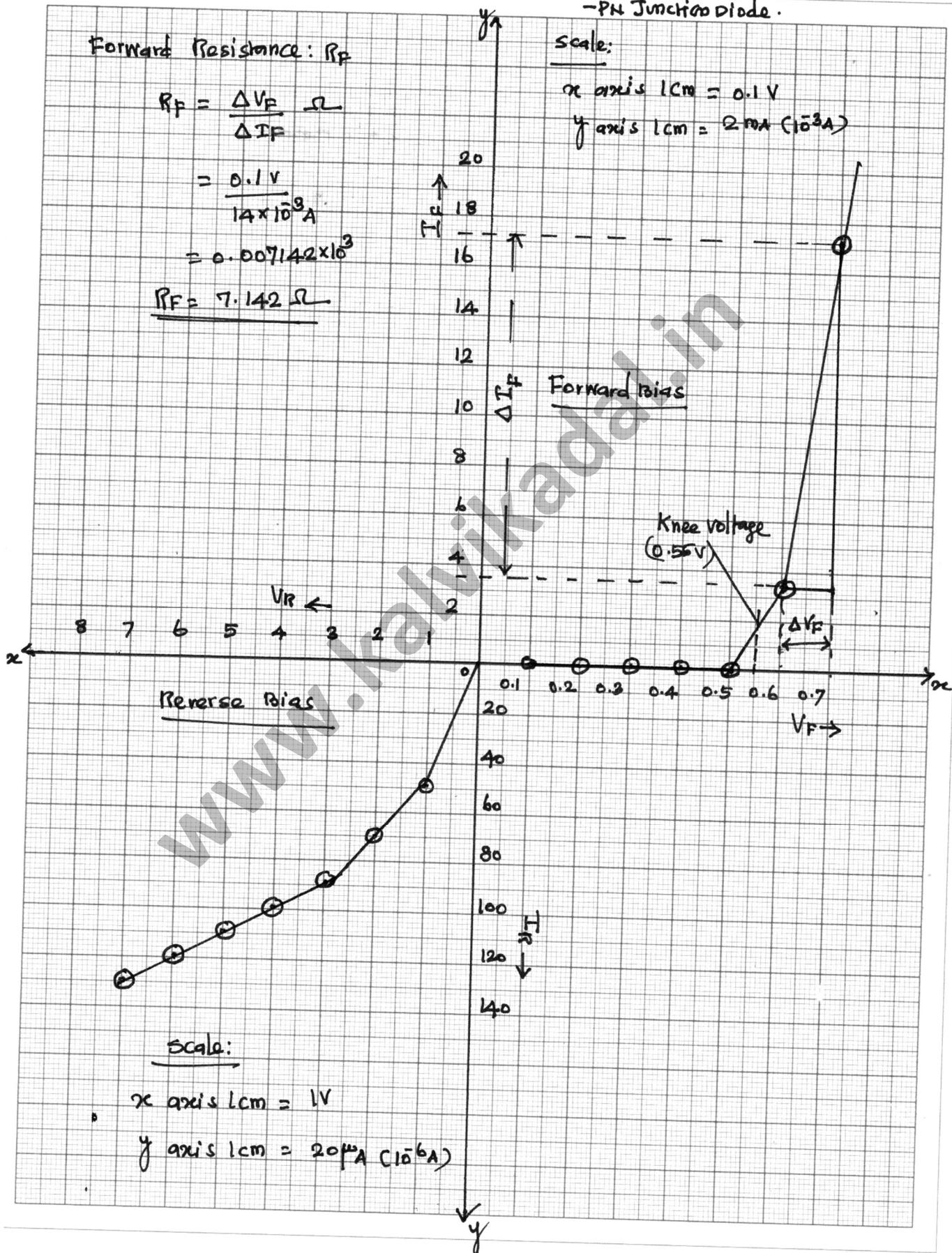
$$= 0.007142 \times 10^3$$

$$\underline{R_F = 7.142 \Omega}$$

Scale:

x axis 1cm = 0.1 V

y axis 1cm = 2 mA ($2 \times 10^{-3} \text{ A}$)



CALCULATION:

(i) Forward resistance $R_F = \frac{\Delta V_F}{\Delta I_F} \Omega$

$$= \frac{0.1 \text{ V}}{14 \times 10^{-3} \text{ A}}$$

$$= 0.007142 \times 10^3$$

$$R_F = 7.142 \Omega$$

(ii) Knee voltage = **0.55 V (From Graph)**

RESULT:

The V-I characteristics of the PN junction diode are studied.

- i) Knee voltage of the PN junction diode = **0.55 V (From Graph)**
- ii) Forward resistance of the diode **$R_F = 7.142 \Omega$**

Ex. No. : 7

Date :

VOLTAGE - CURRENT CHARACTERISTICS OF A ZENER DIODE

AIM:

To draw the voltage-current (V-I) characteristic curves of a Zener diode and to determine its knee voltage, forward resistance and reverse breakdown voltage.

APPARATUS REQUIRED:

Zener diode IZ5.6V, variable dc power supply (0 – 15V), milli ammeter, volt meter, $470\ \Omega$ resistance, and connecting wires.

FORMULA:

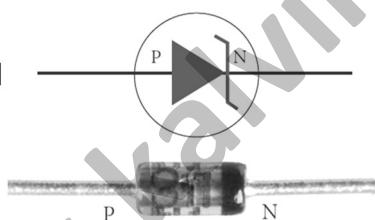
$$R_F = \frac{\Delta V_F}{\Delta I_F} \ (\Omega)$$

Where, $R_F \rightarrow$ Forward resistance of the diode (Ω)

$\Delta V_F \rightarrow$ The change in forward voltage (volt)

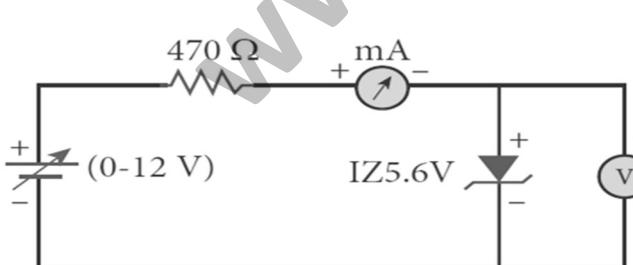
$\Delta I_F \rightarrow$ The change in forward current (mA)

CIRCUIT DIAGRAM

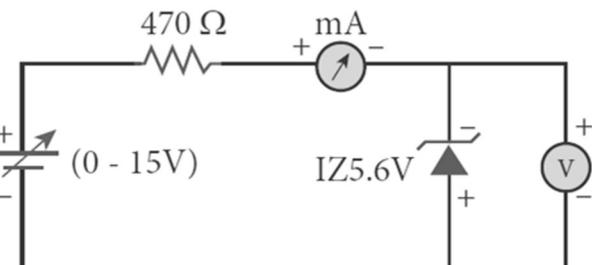


Zener diode and its symbol

(The black colour ring denotes the negative terminal of the Zener diode)



Zener diode in forward bias



Zener diode in reverse bias

PROCEDURE:

i) Forward bias characteristics:

In the forward bias, the P- region of the diode is connected to the positive terminal and N-region to the negative terminal of the DC power supply. The connections are given as per the circuit diagram. The voltage across the diode can be varied with the help of the variable DC power supply.

The forward voltage (V_F) across the diode is increased from 0.1V in steps of 0.1V up to 0.8V and the forward current (I_F) through the diode is noted from the milli-ammeter. The readings are tabulated. The forward voltage and the forward current are taken as positive.

A graph is drawn taking the forward voltage along the x-axis and the forward current along the y-axis. The voltage corresponding to the dotted line in the forward characteristics gives the knee voltage or threshold voltage or turn-on voltage of the diode.

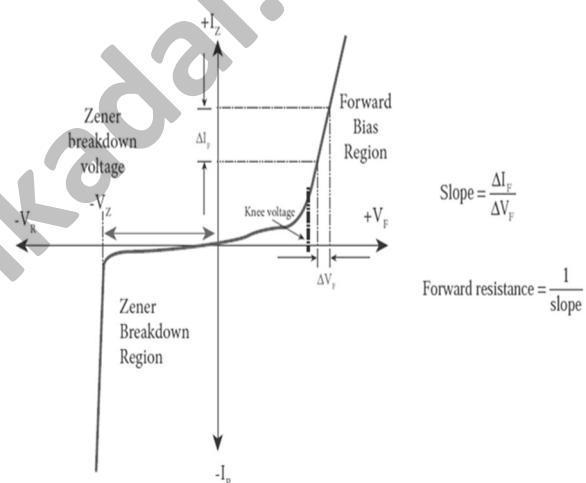
The slope in the linear portion of the forward characteristics is calculated. The reciprocal of the slope gives the forward resistance of the diode.

ii) Reverse bias characteristics:

In the reverse bias, the polarity of the DC power supply is reversed so that the P- region of the diode is connected to the negative terminal and N-region to the positive terminal of the DC power supply. The connections are made as given in the circuit diagram. The voltage across the diode can be varied with the help of the variable DC power supply.

The reverse voltage (V_R) across the diode is increased from 0.5V in steps of 0.5V up to 6V and the reverse current (I_R) through the diode is noted from the milli-ammeter. The readings are tabulated. Initially, the voltage is increased in steps of 0.5V. When the breakdown region is approximately reached, then the input voltage may be raised in steps of, say 0.1V to find the breakdown voltage.

The reverse voltage and reverse current are taken as negative. A graph is drawn taking the reverse bias voltage along negative x-axis and the reverse bias current along negative y-axis. In the reverse bias, Zener breakdown occurs at a particular voltage called Zener voltage V_Z (~5.6 to 5.8V) and a large amount of current flows through the diode which is the characteristics of a Zener diode. The breakdown voltage of the Zener diode is determined from the graph as shown.



OBSERVATION:

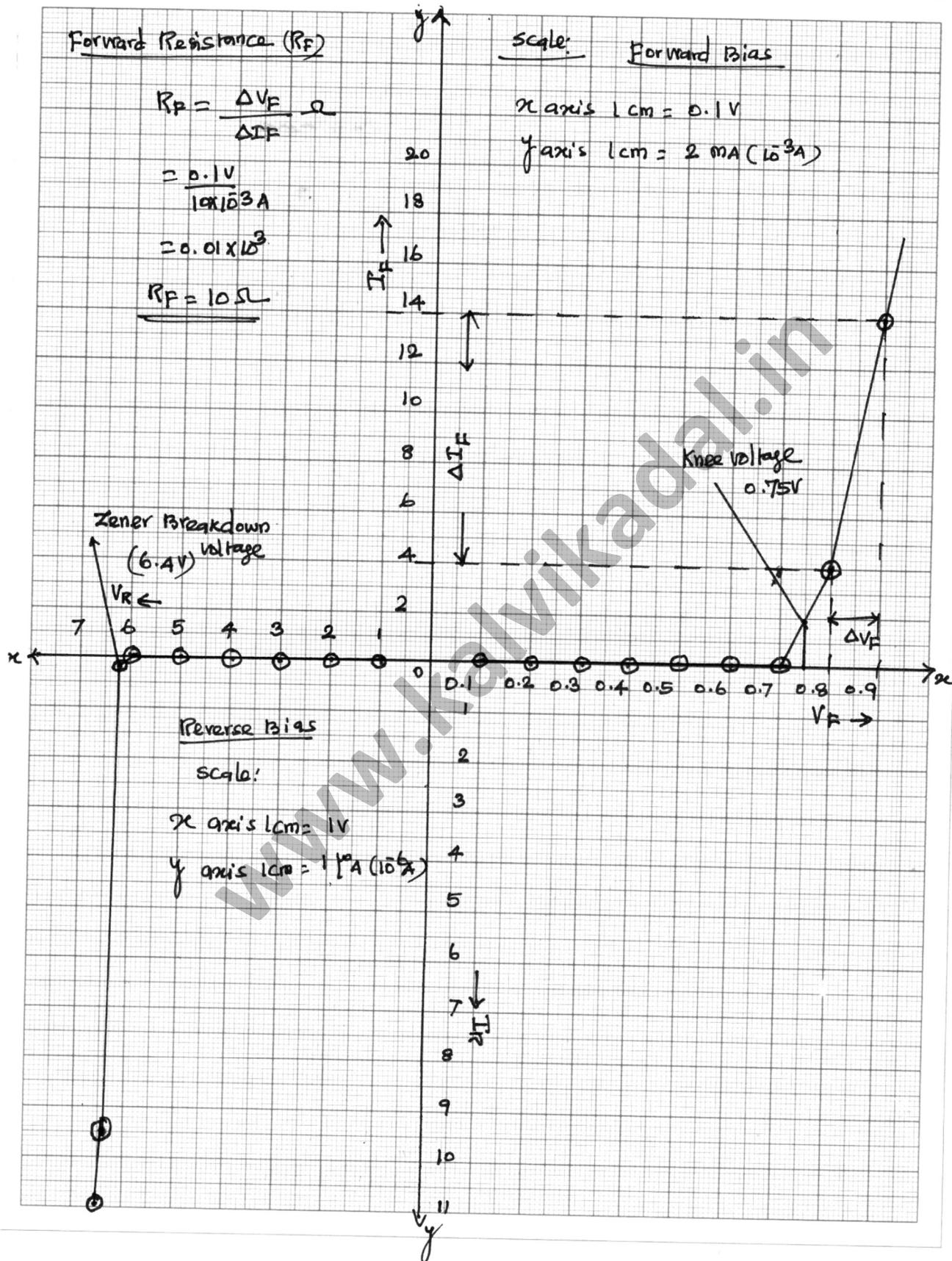
Table 1
Forward bias characteristic curve

S. No.	Forward Bias Voltage V_F (V)	Forward Bias Current I_F (mA)
1	0.1	0
2	0.2	0
3	0.3	0
4	0.4	0
5	0.5	0
6	0.6	0
7	0.7	0
8	0.8	4
9	0.9	14

Table 2
Reverse bias characteristic curve

S. No.	Reverse Bias Voltage V_F (V)	Reverse Bias Current I_R (μ A)
1	1	0
2	2	0
3	3	0
4	4	0
5	5	0
6	6	0
7	6.2	0.2
8	6.4	10
9	6.5	11

Voltage - Current characteristics - Zener diode. DATE



CALCULATION:

(i) Forward resistance $R_F = \frac{\Delta V_F}{\Delta I_F} \Omega$

$$= \frac{0.1 \text{ V}}{10 \times 10^{-3} \text{ A}} ; = 0.01 \times 10^3$$
$$R_F = 10 \Omega$$

(ii) Knee voltage = **0.75 V (From Graph)**

(iii) The breakdown voltage of the Zener diode **V_Z = 6.4 V (From Graph)**

RESULT:

The V-I characteristics of the Zener diode are studied.

- (i) Forward resistance **R_F = 10 Ω**
- (ii) Knee voltage = **0.75 V (From Graph)**
- (iii) The breakdown voltage of the Zener diode **V_Z = 6.4 V (From Graph)**

Ex. No. : 8

Date :

CHARACTERISTICS OF A NPN-JUNCTION TRANSISTOR IN COMMON Emitter CONFIGURATION

AIM:

To study the characteristics and to determine the current gain of a NPN junction transistor in common emitter configuration.

APPARATUS REQUIRED:

Transistor - BC 548/BC107, bread board, micro ammeter, milli ammeter, voltmeters, variable DC power supply and connecting wires.

FORMULA :

$$r_i = \left[\frac{\Delta V_{BE}}{\Delta I_B} \right]_{V_{CE}}, \quad r_o = \left[\frac{\Delta V_{CE}}{\Delta I_C} \right]_{I_B}, \quad \beta = \left[\frac{\Delta I_C}{\Delta I_B} \right]_{V_{CE}} \text{ (No unit)}$$

Where, $r_i \rightarrow$ Input impedance (Ω)

ΔV_{BE} → The change in base-emitter voltage (volt)

$\Delta I_B \rightarrow$ The change in base current (μA)

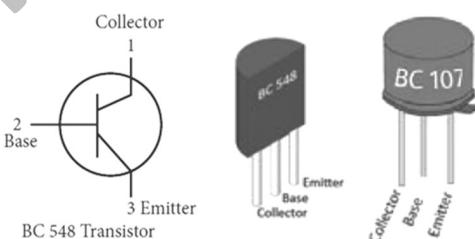
$r_o \rightarrow$ Output impedance (Ω)

ΔV_{CE} → The change in collector-emitter voltage (volt)

$\Delta I_C \rightarrow$ The change in collector current (mA)

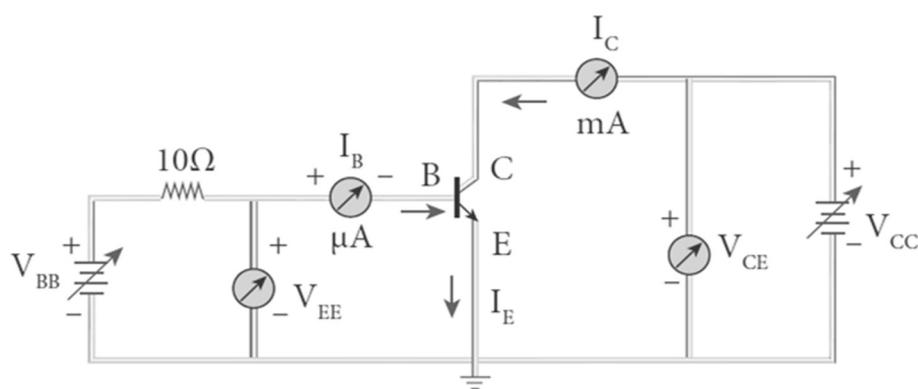
$\beta \rightarrow$ Current gain of the transistor (No unit)

CIRCUIT DIAGRAM



NPN - Junction transistor and its symbol

(Transistor is held with the flat surface facing us)



NPN junction transistor in CE configuration

PROCEDURE:

The connections are given as shown in the diagram. The current and voltage at the input and output regions can be varied by adjusting the DC power supply.

(i) Input characteristic curve: V_{BE} vs I_B (V_{CE} constant):

The collector-emitter voltage V_{CE} is kept constant. The base-emitter voltage V_{BE} is varied in steps of 0.1V and the corresponding base current (I_B) is noted. The readings are taken till V_{CE} reaches a constant value. The same procedure is repeated for different values of V_{CE} . The readings are tabulated.

A graph is plotted by taking V_{BE} along x-axis and I_B along y-axis for both the values of V_{CE} . The curves thus obtained are called the input characteristics of a transistor. The reciprocal of the slope of these curves gives the input impedance of the transistor.

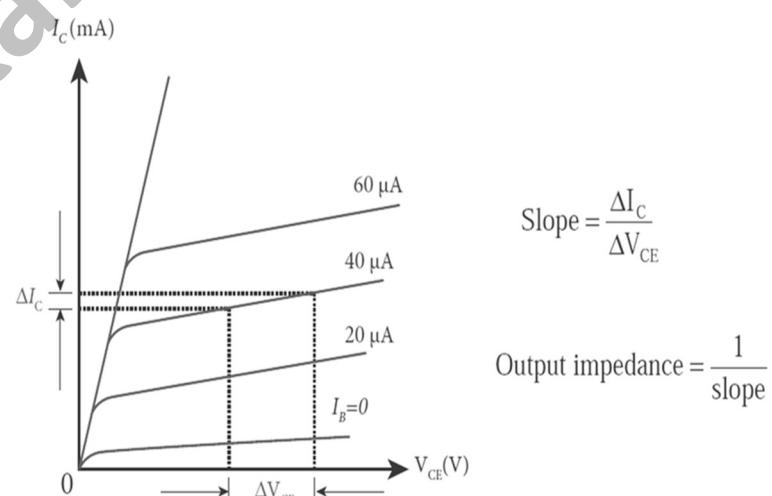
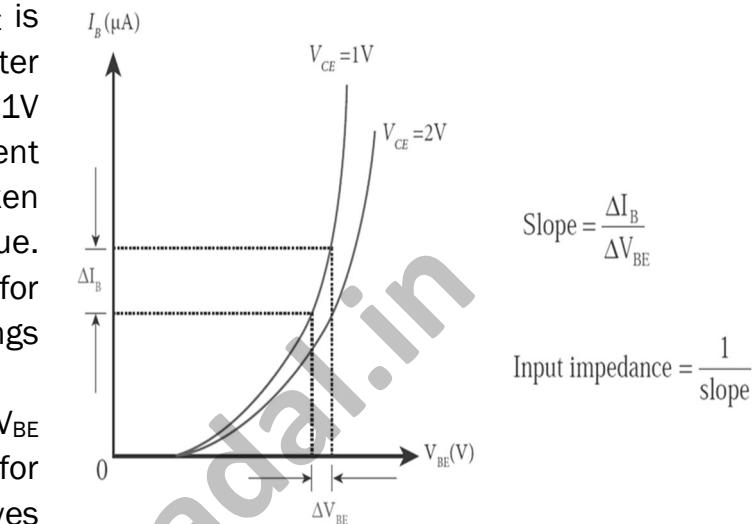
(ii) Output characteristic curve: V_{CE} vs I_C (I_B constant):

The base current I_B is steps of 1V and the corresponding collector current I_C is noted. The readings are taken till the collector current becomes almost constant.

Initially I_B is kept at 0 mA and the corresponding collector current is noted. This current is the reverse saturation current I_c . The experiment is repeated for various values of I_B .

The readings are tabulated. A graph is drawn by taking V_{CE} along x-axis and I_C along y-axis for various values of I_B .

The set of curves thus obtained is called the output characteristics of a transistor. The reciprocal of the slope of the curve gives output impedance of the transistor.



(iii) Transfer characteristic curve: I_B vs I_C (V_{CE} constant):

The collector-emitter voltage V_{CE} is kept constant. The base current I_B is varied in steps of $10 \mu\text{A}$ and the corresponding collector current I_C is noted.

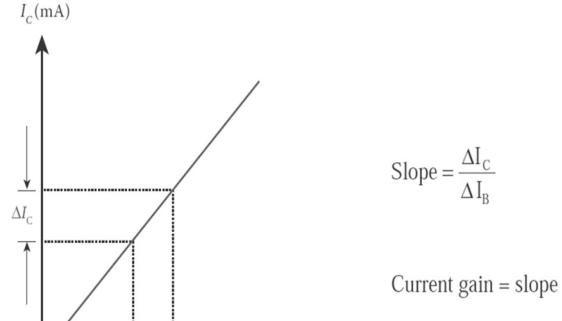
This is repeated by changing the value of V_{CE} . The readings are tabulated.

The transfer characteristics is a plot between the input current I_B along x-axis and the output current I_C along y-axis keeping V_{CE} constant. The slope of the transfer characteristics plot gives the current gain β can be calculated.

OBSERVATION:

(i) Input characteristic curve: V_{BE} vs I_B (V_{CE} constant):

S. No.	$V_{CE} = 2 \text{ V}$		$V_{CE} = 5 \text{ V}$	
	$V_{BE} (\text{V})$	$I_B (\mu\text{A})$	$V_{BE} (\text{V})$	$I_B (\mu\text{A})$
1	0	0	0.1	0
2	0.1	0	0.2	0
3	0.2	0	0.3	0
4	0.3	0	0.4	0
5	0.4	0	0.5	0
6	0.5	25	0.6	12
7	0.55	80	0.7	48
8	0.6	140	0.8	86
9	0.9	-	0.9	148
10	1.0	-	1.0	200



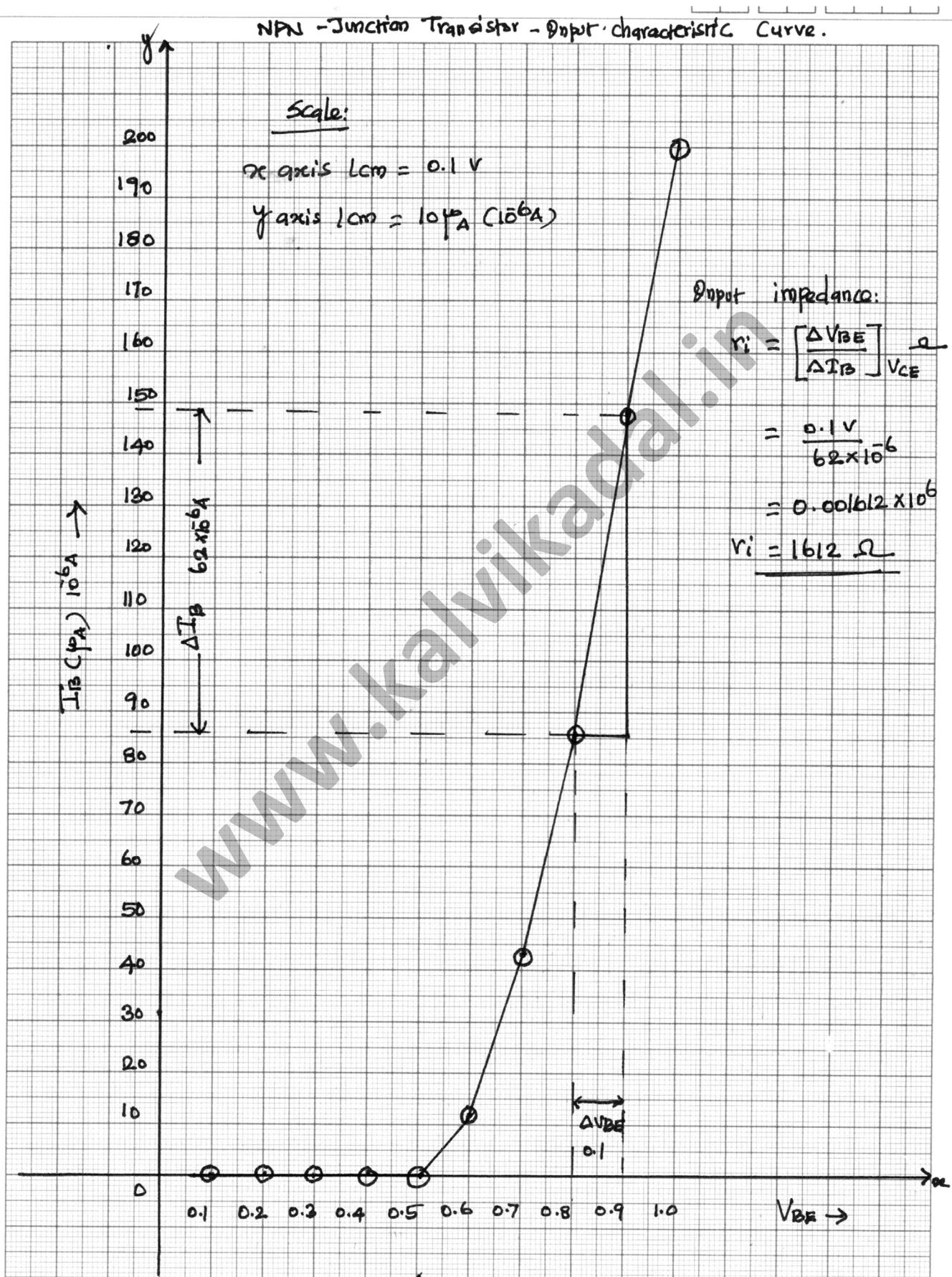
(ii) Output characteristic curve: V_{CE} vs I_c (I_B constant):

S. No.	$I_B = 20 \mu A$		$I_B = 40 \mu A$	
	V_{CE} (V)	I_c (mA)	V_{CE} (V)	I_c (mA)
1	0	0	0	0
2	0.2	5.5	0.2	8
3	0.4	7	0.4	9.5
4	0.6	8	0.6	10.5
5	0.8	8.5	0.8	11
6	1.0	9	1.0	11
7	2.0	9	2.0	11
8	3.0	9	3.0	11

(iii) Transfer characteristic curve: I_B vs I_c (V_{CE} constant):

S. No.	$V_{CE} = 5 V$		S. No.	$V_{CE} = 5 V$	
	I_B (μA)	I_c (mA)		I_B (μA)	I_c (mA)
1	0	0	5	40	5
2	10	1.25	6	50	6.25
3	20	2.5	7	60	7.5
4	30	3.75	8	70	8.75

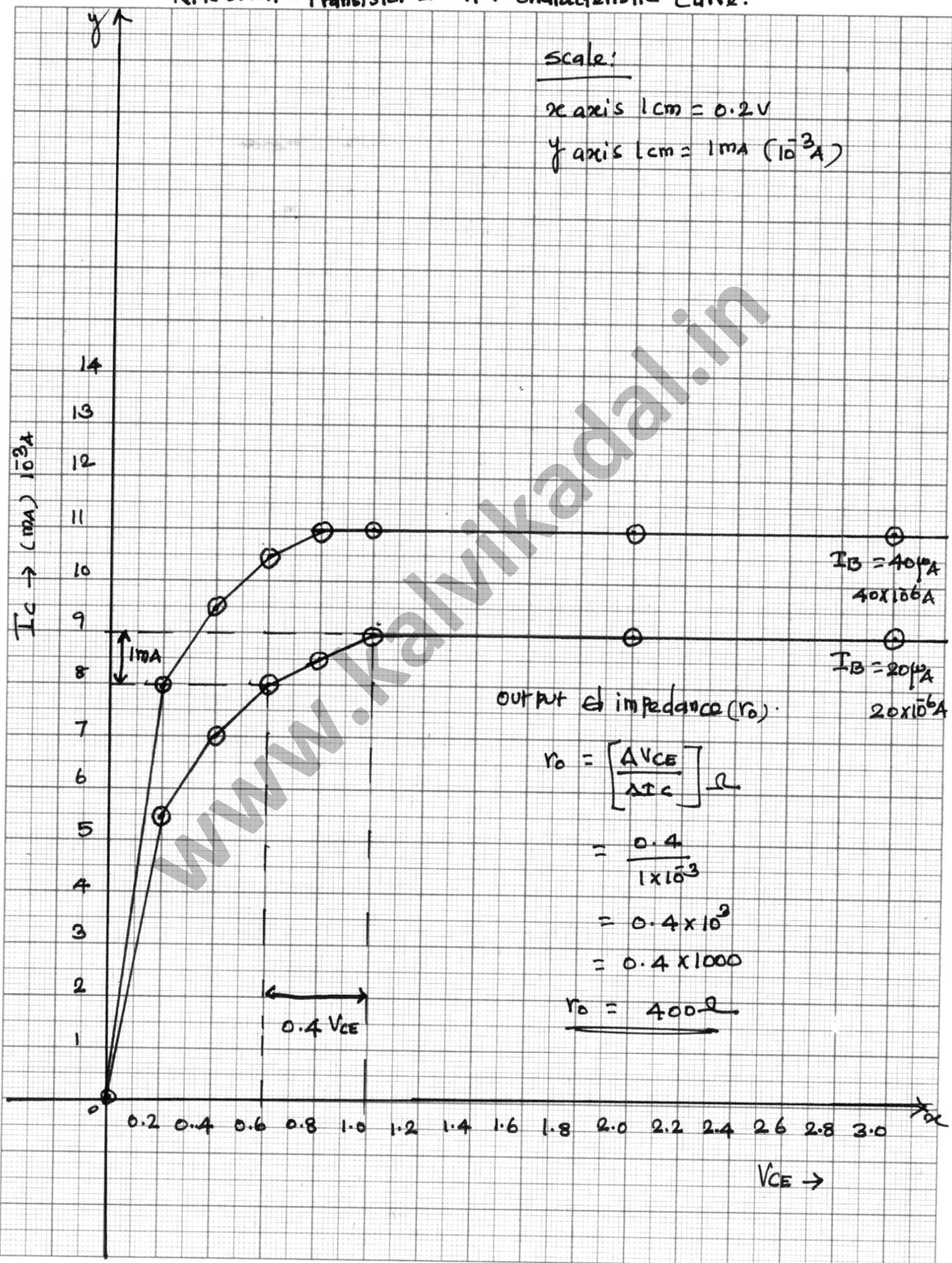
(i) Input characteristic curve: V_{BE} vs I_B (V_{CE} constant):



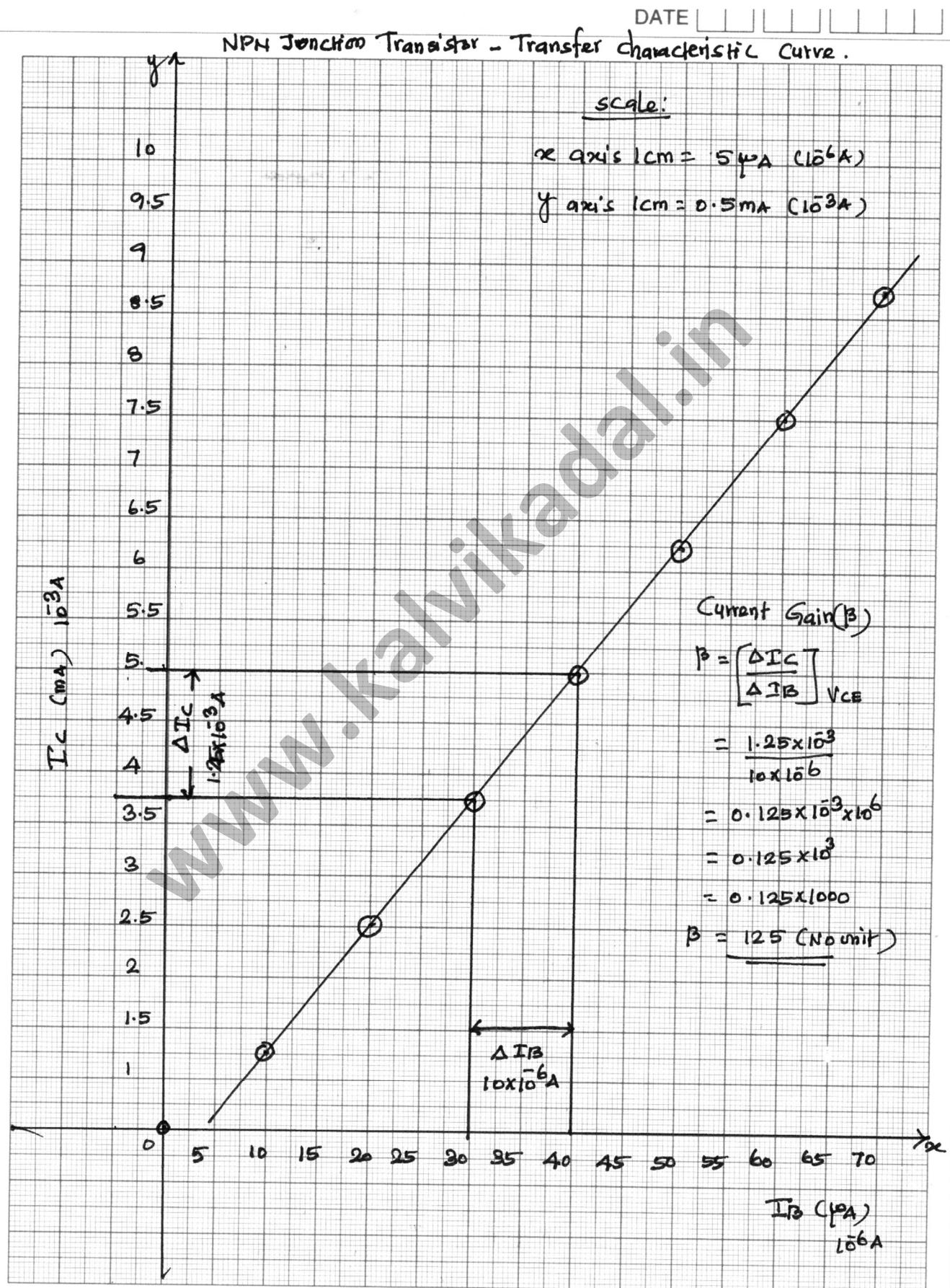
(ii) Output characteristic curve: V_{CE} vs I_C (I_B constant):

DATE _____

NPN Junction transistor - output characteristic Curve.



(iii) Transfer characteristic curve: I_B vs I_C (V_{CE} constant):



CALCULATION:

i) **Input impedance (r_i) :** $r_i = \left[\frac{\Delta V_{BE}}{\Delta I_B} \right]_{V_{CE}} (\Omega)$

$$\Delta V_{BE} - 0.9 - 0.8 = 0.1 \text{ V} ; \Delta I_B - 148 - 86 = 62 \mu\text{A}$$

$$\begin{aligned} r_i &= \frac{0.1}{62 \times 10^{-6}} ; \\ &= 0.001612 \times 10^6 \\ &= 1612 \end{aligned}$$

$r_i = 1612 \Omega$

ii) **Output impedance (r_0) :** $r_0 = \left[\frac{\Delta V_{CE}}{\Delta I_C} \right]_B (\Omega)$

$$\Delta V_{CE} - 1.0 - 0.6 = 0.4 \text{ V} ; \Delta I_C - 9 - 8 = 1 \text{ mA}$$

$$\begin{aligned} r_0 &= \frac{0.4}{1 \times 10^{-3}} ; \\ &= 0.4 \times 10^3 \\ &= 0.4 \times 1000 \end{aligned}$$

$r_0 = 400 \Omega$

iii) **Current Gain (β) :** $\beta = \left[\frac{\Delta I_C}{\Delta I_B} \right]_{V_{CE}} (\text{No unit})$

$$\Delta I_B - 40 - 30 = 10 \mu\text{A} ; \Delta I_C - 5 - 3.75 = 1.25 \text{ mA}$$

$$\begin{aligned} \beta &= \frac{1.25 \times 10^{-3}}{10 \times 10^{-6}} ; \\ &= 0.125 \times 10^{-3} \times 10^6 \\ &= 0.125 \times 10^3 \\ &= 0.125 \times 1000 \end{aligned}$$

$\beta = 125 \text{ (No Unit)}$

RESULT:

- i) The input, output and transfer characteristics of the NPN junction in common emitter mode are drawn.
- ii) (a) Input impedance **$r_i = 1612 \Omega$**
- (b) Output impedance **$r_0 = 400 \Omega$**
- (c) Current gain **$\beta = 125 \text{ (No Unit)}$**

Ex. No. : 9

Date :

VERIFICATION OF TRUTH TABLES OF LOGIC GATES USING INTEGRATED CIRCUITS

AIM:

To verify the truth tables of AND, OR, NOT, EX-OR, NAND and NOR gates using integrated circuits

COMPONENTS REQUIRED:

AND gate (IC 7408), NOT gate (IC 7404), OR gate (IC 7432), NAND gate (IC 7400), NOR gate (IC 7402), X-OR gate (IC 7486), Power supply, Digital IC trainer kit, connecting wires.

BOOLEAN EXPRESSIONS:

Logic 1 represents TRUE or high voltage 5V or LED ON

Logic 0 represents FALSE or low voltage 0V or LED OFF

OR Function, when any one input or all inputs are true, output is true $Y = A + B$

AND Function, only when all inputs are true, output is true $Y = AB$

NOT Function, Output is the complement of input $Y = \bar{A}$

NOR Function, Only when all inputs are false, output is true $Y = \overline{A + B}$

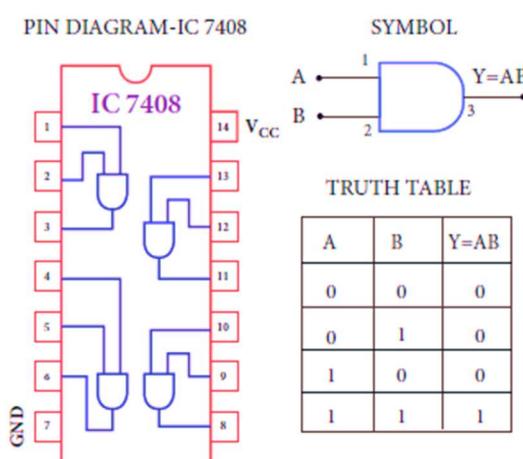
NAND Function, When any one of the inputs is false, output is true $Y = \overline{A \cdot B}$

EXOR Function, Only when the inputs are different, output is true

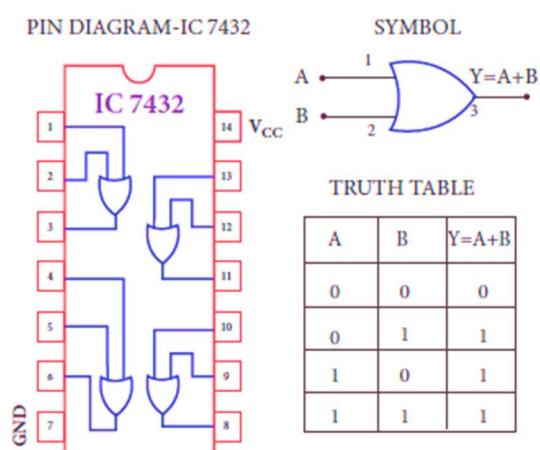
$$Y = A \oplus B = A\bar{B} + \bar{A}B$$

CIRCUIT DIAGRAM:

AND Gate:

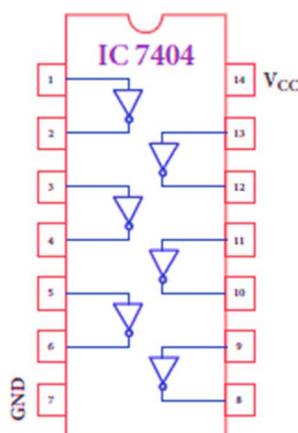


OR Gate:

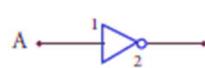


NOT Gate:

PIN DIAGRAM-IC 7404



SYMBOL

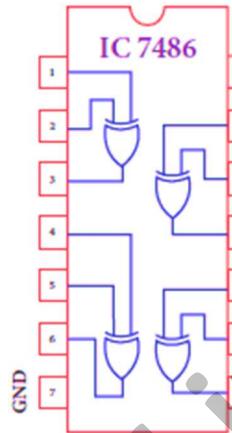


TRUTH TABLE

A	$Y = \bar{A}$
0	1
1	0

X-OR Gate :

PIN DIAGRAM-IC 7486



SYMBOL

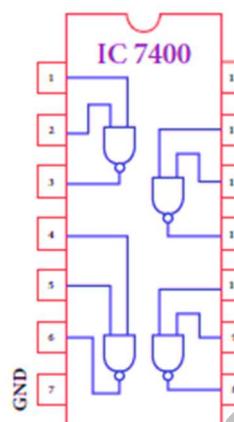


TRUTH TABLE

A	B	$Y = \bar{A}B + A\bar{B}$
0	0	0
0	1	1
1	0	1
1	1	0

NAND Gate:

PIN DIAGRAM-IC 7400



SYMBOL

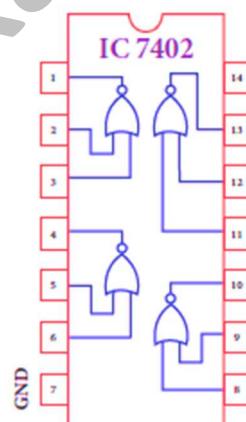


TRUTH TABLE

A	B	$Y = \bar{A}\bar{B}$
0	0	1
0	1	1
1	0	1
1	1	0

NOR Gate:

PIN DIAGRAM-IC 7402



SYMBOL



TRUTH TABLE

A	B	$Y = \bar{A} + \bar{B}$
0	0	1
0	1	0
1	0	0
1	1	0

PROCEDURE:

To verify the truth table of a logic gate, the suitable IC is taken and the connections are given using the circuit diagram.

NAND Gate:

Power supply +5V is connected to pin 14 and ground to pin 7 of the IC. Inputs A & B are connected to pins 1 & 2 of the IC. Output pin 3 of the IC is connected to logic level indicator. Both inputs A & B are kept at logic 0 and output LED is observed, Then the inputs are changed as logic 0 & logic 1, logic 1 & logic 0 and logic 1 & logic 1 and the outputs are observed each time. The inputs and outputs are tabulated in the truth table.

AND, OR and EX-OR Gates:

ICs 7408 (AND), 7432 (OR) and 7486 (EXOR) are placed on the board and the same procedure is followed as for NAND gate and outputs are tabulated in the truth table.

NOR Gate:

IC 7402 is placed on the board. Power supply and ground are connected as before. The inputs are connected to pins 2 & 3 and the output to pin 1 of IC. Then the same procedure is repeated and tabulation is done in the truth table.

NOT Gate:

IC 7404 is placed on the board. One input A is connected to pin 1 and the output to pin 2 of IC. Input is kept at logic 1 and then at logic 0 and the outputs are found and tabulated in the truth table.

In this way, the truth table of a logic gate is verified.

OBSERVATION:

INPUT		AND Gate	OR Gate	NOT Gate	EX - OR Gate	NAND Gate	NOR Gate
A	B	$Y = A \cdot B$	$Y = A + B$	$Y = \bar{A}$	$Y = A \cdot \bar{B} + \bar{A} \cdot B$	$Y = \bar{A} \cdot \bar{B}$	$Y = \bar{A} + \bar{B}$
0	0	0	0	1	0	1	1
0	1	0	1	1	1	1	0
1	0	0	1	0	1	1	0
1	1	1	1	0	0	0	0

CALCULATION:

AND Gate:

- 1) A = 0 , B = 0 ; Y = A . B = 0 . 0 = 0
- 2) A = 0 , B = 1 ; Y = A . B = 0 . 1 = 0
- 3) A = 1 , B = 0 ; Y = A . B = 1 . 0 = 0
- 4) A = 1 , B = 1 ; Y = A . B = 1 . 1 = 1

OR Gate:

- 1) A = 0 , B = 0 ; Y = A + B = 0 + 0 = 0
- 2) A = 0 , B = 1 ; Y = A + B = 0 + 1 = 1
- 3) A = 1 , B = 0 ; Y = A + B = 1 + 0 = 1
- 4) A = 1 , B = 1 ; Y = A + B = 1 + 1 = 1

NOT Gate:

- 1) A = 0 , Y = \bar{A} = $\bar{0} = 1$
- 2) A = 1 , Y = \bar{A} = $\bar{1} = 0$

EX - OR Gate:

- 1) A = 0 , B = 0 ; Y = $\bar{A} B + A\bar{B} = \bar{0} 0 + 0\bar{0} = 1.0 + 0.1 = 0+0 = 0$
- 2) A = 0 , B = 1 ; Y = $\bar{A} B + A\bar{B} = \bar{0} 1 + 0\bar{1} = 1.1 + 0.0 = 1+0 = 1$
- 3) A = 1 , B = 0 ; Y = $\bar{A} B + A\bar{B} = \bar{1} 0 + 1\bar{0} = 0.0 + 1.1 = 0+1 = 1$
- 4) A = 1 , B = 1 ; Y = $\bar{A} B + A\bar{B} = \bar{1} 1 + 1\bar{1} = 0.1 + 1.0 = 0+0 = 0$

NAND Gate:

- 1) A = 0 , B = 0 ; Y = $\overline{A \cdot B} = \overline{0 \cdot 0} = \bar{0} = 1$
- 2) A = 0 , B = 1 ; Y = $\overline{A \cdot B} = \overline{0 \cdot 1} = \bar{0} = 1$
- 3) A = 1 , B = 0 ; Y = $\overline{A \cdot B} = \overline{1 \cdot 0} = \bar{0} = 1$
- 4) A = 1 , B = 1 ; Y = $\overline{A \cdot B} = \overline{1 \cdot 1} = \bar{1} = 0$

NOR Gate:

- 1) A = 0 , B = 0 ; Y = $\overline{A + B} = \overline{0 + 0} = \bar{0} = 1$
- 2) A = 0 , B = 1 ; Y = $\overline{A + B} = \overline{0 + 1} = \bar{1} = 0$
- 3) A = 1 , B = 0 ; Y = $\overline{A + B} = \overline{1 + 0} = \bar{1} = 0$
- 4) A = 1 , B = 1 ; Y = $\overline{A + B} = \overline{1 + 1} = \bar{1} = 0$

RESULT:

The truth table of logic gates AND, OR, NOT, Ex-OR, NAND and NOR using integrated circuits is verified.

Ex. No. : 10

Date :

VERIFICATION OF DE MORGAN'S THEOREMS

AIM:

To verify De Morgan's first and second theorems.

COMPONENTS REQUIRED:

Power Supply (0 – 5V), IC 7400, 7408, 7432, 7404, and 7402,
Digital IC trainer kit, connecting wires.

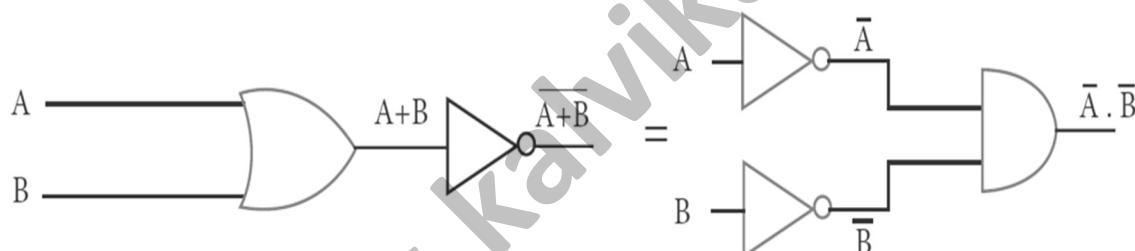
FORMULA:

De Morgan's first theorem $\overline{A + B} = \overline{A} \cdot \overline{B}$

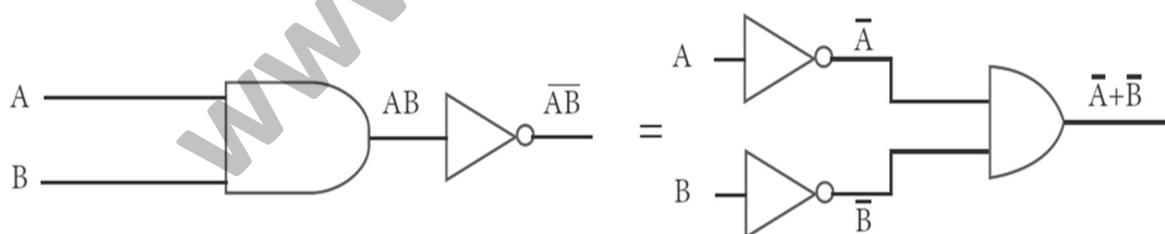
De Morgan's second theorem $\overline{A \cdot B} = \overline{A} + \overline{B}$

CIRCUIT DIAGRAM:

De Morgan's First Theorem:



De Morgan's Second theorem:



PROCEDURE:

i) Verification of De Morgan's first theorem

The connections are made for LHS $[A + B]$ of the theorem as shown in the circuit diagram using appropriate ICs. The output is noted and tabulated for all combinations of logical inputs of the truth table. The same procedure is repeated for RHS $[\bar{A} \cdot \bar{B}]$ of the theorem.

From the truth table, it can be shown that $\overline{A + B} = \bar{A} \cdot \bar{B}$

ii) Verification of De Morgan's second theorem

The connections are made for LHS $[A \cdot B]$ of the theorem as shown in the circuit diagram using appropriate ICs. The output is noted and tabulated for all combinations of logical inputs of the truth table. The same procedure is repeated for RHS $[\bar{A} + \bar{B}]$ of the theorem.

From the truth table, it can be shown that $\overline{A \cdot B} = \bar{A} + \bar{B}$

OBSERVATION:

De Morgan's First Theorem: Truth Table

A	B	A+B	$\overline{A + B}$	\bar{A}	\bar{B}	$\bar{A} \cdot \bar{B}$
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

De Morgan's Second Theorem: Truth Table

A	B	A.B	$\overline{A \cdot B}$	\bar{A}	\bar{B}	$\bar{A} + \bar{B}$
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

CALCULATION:

De Morgan's First Theorem:

$$\overline{A + B} = \overline{A} \cdot \overline{B}$$

- | | | |
|------------------|--|---|
| 1) A = 0 , B = 0 | $\overline{A + B} = \overline{0 + 0} = \overline{0} = 1$ | $\overline{A} \cdot \overline{B} = \overline{0} \cdot \overline{0} = 1 \cdot 1 = 1$ |
| 2) A = 0 , B = 1 | $\overline{A + B} = \overline{0 + 1} = \overline{1} = 0$ | $\overline{A} \cdot \overline{B} = \overline{0} \cdot \overline{1} = 1 \cdot 0 = 0$ |
| 3) A = 1 , B = 0 | $\overline{A + B} = \overline{1 + 0} = \overline{1} = 0$ | $\overline{A} \cdot \overline{B} = \overline{1} \cdot \overline{0} = 0 \cdot 1 = 0$ |
| 4) A = 1 , B = 1 | $\overline{A + B} = \overline{1 + 1} = \overline{1} = 0$ | $\overline{A} \cdot \overline{B} = \overline{1} \cdot \overline{1} = 0 \cdot 0 = 0$ |

De Morgan's Second Theorem:

$$\overline{A \cdot B} = \overline{A} + \overline{B}$$

- | | | |
|------------------|--|---|
| 1) A = 0 , B = 0 | $\overline{A \cdot B} = \overline{0 \cdot 0} = \overline{0} = 1$ | $\overline{A} + \overline{B} = \overline{0} + \overline{0} = 1 + 1 = 1$ |
| 2) A = 0 , B = 1 | $\overline{A \cdot B} = \overline{0 \cdot 1} = \overline{0} = 1$ | $\overline{A} + \overline{B} = \overline{0} + \overline{1} = 1 + 0 = 1$ |
| 3) A = 1 , B = 0 | $\overline{A \cdot B} = \overline{1 \cdot 0} = \overline{0} = 1$ | $\overline{A} + \overline{B} = \overline{1} + \overline{0} = 0 + 1 = 1$ |
| 4) A = 1 , B = 1 | $\overline{A \cdot B} = \overline{1 \cdot 1} = \overline{1} = 0$ | $\overline{A} + \overline{B} = \overline{1} + \overline{1} = 0 + 0 = 0$ |

RESULT:

De Morgan's first and second theorems are verified.

SUGGESTED QUESTIONS FOR THE PRACTICAL EXAMINATION

1. Determine the resistance of a given wire using metre bridge. Also find the radius of the wire using screw gauge and hence determine the specific resistance of the material of the wire. Take at least 4 readings.
2. Determine the value of the horizontal component of the Earth's magnetic field, using tangent galvanometer. Take at least 4 readings.
3. Compare the emf of two cells using potentiometer.
4. Using the spectrometer, measure the angle of the given prism and angle of minimum deviation. Hence calculate the refractive index of the material of the prism.
5. Adjust the grating for normal incidence using the spectrometer. Determine the wavelength of green, blue, yellow and red lines of mercury spectrum (The number of lines per metre length of the grating can be noted from the grating).
6. Draw the V-I characteristics of PN junction diode and determine its forward resistance and knee voltage from forward characteristics.
7. Draw the V-I characteristics of Zener diode and determine its forward resistance and knee voltage from forward characteristics. Also find break down voltage of the Zener diode from reverse characteristics.
8. Draw the input and transfer characteristic curves of the given NPN junction transistor in CE mode. Find the input impedance from input characteristics and current gain from transfer characteristics.
9. Draw the output and transfer characteristic curves of the given NPN junction transistor in CE mode. Find the output impedance from output characteristics and current gain from transfer characteristics.
10. Verify the truth table of logic gates AND, NOT, Ex-OR and NOR gates using integrated circuits.
11. Verify the truth table of logic gates OR, NOT, Ex-OR and NOR gates using integrated circuits.
12. Verify De Morgan's first and second theorems.

**“நேர்மையான முயற்சியில் கிடைத்த
வெற்றியின் மூலமாகக் கிடைக்கும் மகிழ்ச்சியின்
சிகரத்தை யாரும் அளக்கவே முடியாது.”**

QR CODE & ICT CORNER

Unit	Topic	QR Code
1	Gravitational force	
1	Van-de Graff Generator	
2	Electric Current	
2	ICT CORNER	
3	Helical Magnetic Field	
4	AC Generator	

Unit	Topic	QR Code
1	Electrostatic Shielding	
1	ICT CORNER	
2	Bulb Glows	
3	Uniform Magnetic Field	
3	ICT CORNER	
4	Eddy Current	

Unit	Topic	QR Code
4	ICT CORNER	
5	Absorption Spectra	
6	Optics	
6	ICT CORNER	
7	Polarization	
7	Resolution	

Unit	Topic	QR Code
5	Electromagnetic Waves	
5	ICT CORNER	
6	Optics fibre	
7	Scattering of Light	
7	Resolution	
7	ICT CORNER	

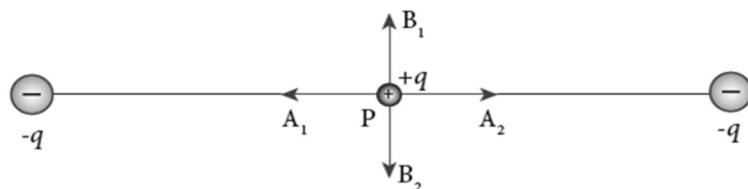
Unit	Topic	QR Code	Unit	Topic	QR Code
8	Dual Nature of Radiation		8	Photo Electric Cells	
8	ICT CORNER		9	Bohr Atom Model	
9	Rutherford Atom Model		9	Nuclear Reactor	
9	ICT CORNER		10	Semiconductor	
10	LED		10	Reverse Bias	
10	Communication System		10	Electronic Communication System	

Unit	Topic	QR Code
10	Amplitude Modulation	
11	Recent Development of Physics	
11	Types of Robotics	

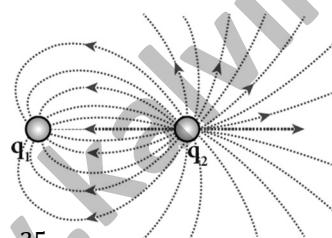
Unit	Topic	QR Code
10	ICT CORNER	
11	Applications of Nano technology	
11	ICT CORNER	

ONE MARK QUESTIONS
UNIT – I : ELECTROSTATICS

1. Two identical point charges of magnitude $-q$ are fixed as shown in the figure below. A third charge $+q$ is placed midway between the two charges at the point P. Suppose this charge $+q$ is displaced a small distance from the point P in the directions indicated by the arrows, in which direction(s) will $+q$ be stable with respect to the displacement?

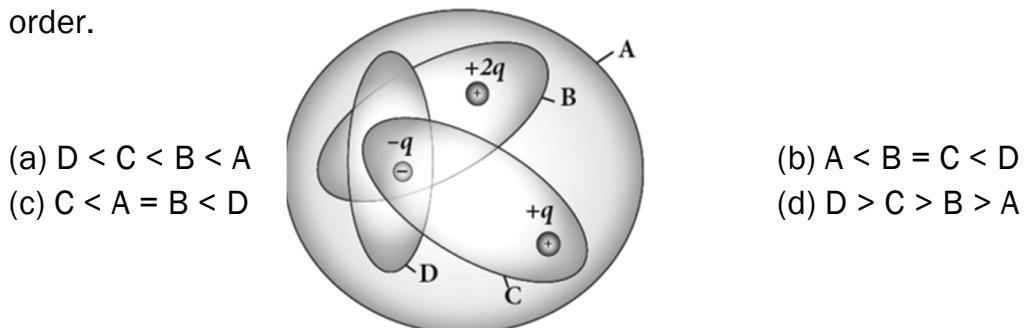


- (a) A_1 and A_2 (b) B_1 and B_2 (c) both directions (d) No stable
2. Which charge configuration produces a uniform electric field?
 (a) point charge (b) uniformly charged infinite line
 (c) uniformly charged infinite plane (d) uniformly charged spherical shell
3. What is the ratio of the charges $\left| \frac{q_1}{q_2} \right|$ for the following electric field line pattern?



- (a) $\frac{1}{5}$ (b) $\frac{25}{11}$ (c) 5 (d) $\frac{11}{25}$
4. An electric dipole is placed at an alignment angle of 30° with an electric field of $2 \times 10^5 \text{ N C}^{-1}$. It experiences a torque equal to 8 N m . The charge on the dipole if the dipole length is 1 cm is
 (a) 4 mC (b) 8 mC (c) 5 mC (d) 7 mC

5. Four Gaussian surfaces are given below with charges inside each Gaussian surface. Rank the electric flux through each Gaussian surface in increasing order.



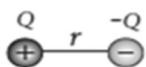
6. The total electric flux for the following closed surface which is kept inside water



- (a) $\frac{80q}{\epsilon_0}$ (b) $\frac{q}{40\epsilon_0}$ (c) $\frac{q}{80\epsilon_0}$ (d) $\frac{q}{160\epsilon_0}$

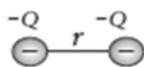
7. Two identical conducting balls having positive charges q_1 and q_2 are separated by a centre to centre distance r . If they are made to touch each other and then separated to the same distance, the force between them will be
 (a) less than before (b) same as before (c) more than before (d) zero

8. Rank the electrostatic potential energies for the given system of charges in increasing order.



(a)

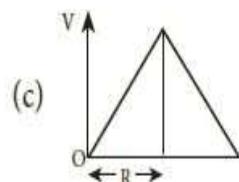
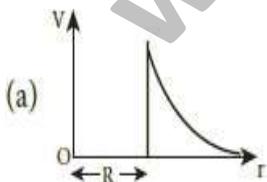
- (a) $1 = 4 < 2 < 3$ (b) $2 = 4 < 3 < 1$
(c) $2 = 3 < 1 < 4$ (d) $3 < 1 < 2 < 4$



(b)

9. An electric field $\vec{E} = 10x\hat{i}$ exists in a certain region of space. Then the potential difference $V = V_0 - V_A$, where V_0 is the potential at the origin and V_A is the potential at $x = 2 \text{ m}$ is :
 (a) 10V (b) -20 V (c) +20 V (d) -10 V

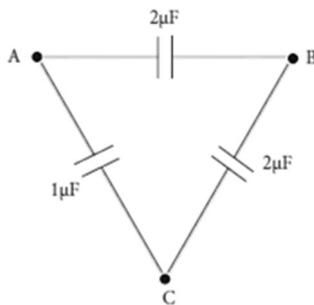
10. A thin conducting spherical shell of radius R has a charge Q which is uniformly distributed on its surface. The correct plot for electrostatic potential due to this spherical shell is



11. Two points A and B are maintained at a potential of 7 V and -4 V respectively. The work done in moving 50 electrons from A to B is
(a) 8.80×10^{-17} J (b) -8.80×10^{-17} J (c) 4.40×10^{-17} J (d) 5.80×10^{-17} J

12. If voltage applied on a capacitor is increased from V to 2V, choose the correct conclusion.
(a) Q remains the same, C is doubled (b) Q is doubled, C doubled
(c) C remains same, Q doubled (d) Both Q and C remain same

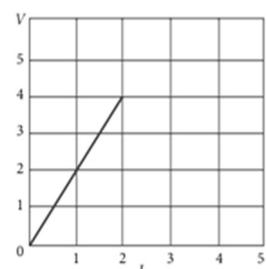
13. Parallel plate capacitor stores a charge Q at a voltage V. Suppose the area of the Parallel plate capacitor and the distance between the plates are each doubled then which is the quantity that will change?
- (a) Capacitance (b) Charge (c) Voltage (d) Energy density
14. Three capacitors are connected in triangle as shown in the figure. The equivalent capacitance between the points A and C is



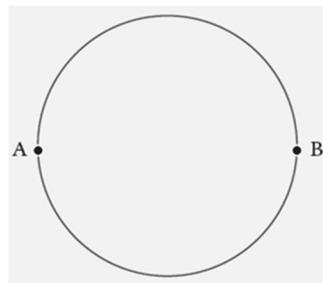
- (a) $1\mu F$ (b) $2\mu F$ (c) $3\mu F$ (d) $\frac{1}{4}\mu F$
15. Two metallic spheres of radii 1 cm and 3 cm are given charges of $-1 \times 10^{-2} C$ and $5 \times 10^{-2} C$ respectively. If these are connected by a conducting wire, the final charge on the bigger sphere is
- (a) $3 \times 10^{-2} C$ (b) $4 \times 10^{-2} C$ (c) $1 \times 10^{-2} C$ (d) $2 \times 10^{-2} C$

UNIT – 2 : CURRENT ELECTRICITY

16. The following graph shows current versus voltage values of some unknown conductor. What is the resistance of this conductor?



- (a) 2 ohm (b) 4 ohm (c) 8 ohm (d) 1 ohm
17. A wire of resistance 2 ohms per meter is bent to form a circle of radius 1m. The equivalent resistance between its two diametrically opposite points, A and B as shown in the figure is



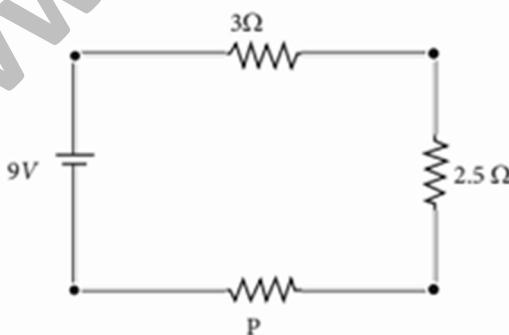
- (a) $\pi \Omega$ (c) $\frac{\pi}{2} \Omega$ (c) $2\pi \Omega$ (d) $\frac{\pi}{4} \Omega$
18. A toaster operating at 240V has a resistance of 120Ω . The power is
- (a) 240W (b) 400W (c) 2W (d) 480W

19. A carbon resistor of $(47 \pm 4.7) \text{ k}\Omega$ to be marked with rings of different colours for its identification. The colour code sequence will be.....
 (a) Yellow – Green – Violet – Gold (b) Yellow – Violet – Orange – Silver
 (c) Violet – Yellow – Orange – Silver (d) Green – Orange – Violet - Gold

20. What is the value of resistance of the following resistor?

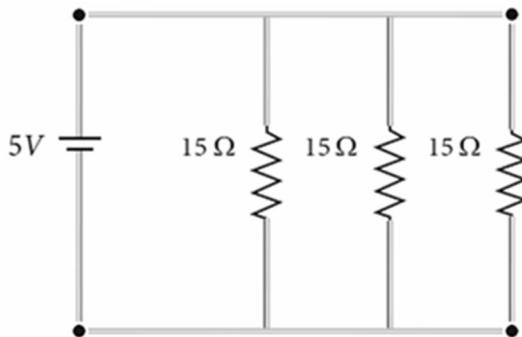


- (a) $100 \text{ k}\Omega$ (b) $10 \text{ k}\Omega$ (c) $1\text{k}\Omega$ (d) $1000 \text{ k}\Omega$
21. Two wires of A and B with circular cross section are made up of the same material with equal lengths. Suppose $R_A = 3 R_B$, then what is the ratio of radius of wire A to that of B?
 (a) 3 (b) $\sqrt{3}$ (c) $\frac{1}{\sqrt{3}}$ (d) $\frac{1}{3}$
22. A wire connected to a power supply of 230 V has power dissipation P_1 . Suppose the wire is cut into two equal pieces and connected parallel to the same power supply. In this case power dissipation is P_2 . The ratio $\frac{P_2}{P_1}$ is
 (a) 1 (b) 2 (c) 3 (d) 4
23. In India electricity is supplied for domestic use at 220 V. It is supplied at 110 V in USA. If the resistance of a 60W bulb for use in India is R, the resistance of a 60W bulb for use in USA will be
 (a) R (b) $\frac{R}{4}$ (c) $2R$ (d) $\frac{R}{2}$
24. In a large building, there are 15 bulbs of 40W, 5 bulbs of 100W, 5 fans of 80W and 1 heater of 1kW are connected. The voltage of electric mains is 220V. The minimum capacity of the main fuse of the building will be
 (a) 14 A (b) 8 A (c) 10 A (d) 12 A
25. There is a current of 1.0 A in the circuit shown below. What is the resistance of P ?



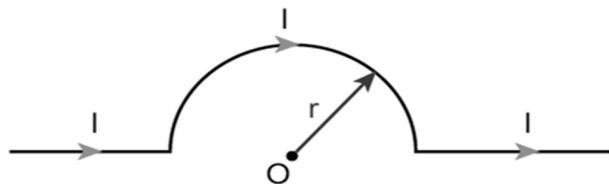
- (a) 1.5Ω (b) 2.5Ω (c) 3.5Ω (d) 4.5Ω

26. What is the current drawn out from the battery?



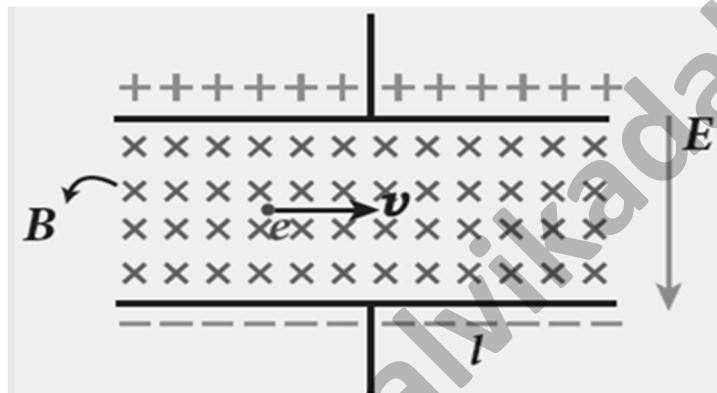
UNIT – 3 : MAGNETISM AND MAGNETIC EFFECTS OF ELECTRIC CURRENT

31. The magnetic field at the centre O of the following current loop is



(a) $\frac{\mu_0 I}{4r} \otimes$ (b) $\frac{\mu_0 I}{4r} \odot$ (c) $\frac{\mu_0 I}{2r} \otimes$ (d) $\frac{\mu_0 I}{2r} \odot$

32. An electron moves in a straight line inside a charged parallel plate capacitor of uniform charge density σ . The time taken by the electron to cross the parallel plate capacitor un-deflected when the plates of the capacitor are kept under constant magnetic field of induction \vec{B} is



(a) $\varepsilon_0 \frac{elB}{\sigma}$ (b) $\varepsilon_0 \frac{lB}{\sigma l}$ (c) $\varepsilon_0 \frac{lB}{e\sigma}$ (d) $\varepsilon_0 \frac{lB}{\sigma}$

33. The force experienced by a particle having mass m and charge q accelerated through a potential difference V when it is kept under perpendicular magnetic field \vec{B} is

(a) $\sqrt{\frac{2q^3BV}{m}}$ (b) $\sqrt{\frac{q^3B^2V}{2m}}$ (c) $\sqrt{\frac{2q^3B^2V}{m}}$ (d) $\sqrt{\frac{2q^3BV}{m^3}}$

34. A circular coil of radius 5 cm and 50 turns carries a current of 3 ampere. The magnetic dipole moment of the coil is

(a) 1.0 amp – m² (b) 1.2 amp – m² (c) 0.5 amp – m² (d) 0.8 amp – m²

35. A thin insulated wire forms a plane spiral of $N = 100$ tight turns carrying a current $I=8$ m A (milli ampere). The radii of inside and outside turns are $a=50$ mm and $b=100$ mm respectively. The magnetic induction at the centre of the spiral is

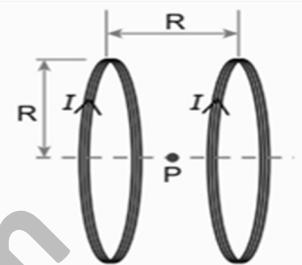
(a) 5 μ T (b) 7 μ T (c) 8 μ T (d) 10 μ T

36. Three wires of equal lengths are bent in the form of loops. One of the loops is circle, another is a semi-circle and the third one is a square. They are placed in a uniform magnetic field and same electric current is passed through them. Which of the following loop configuration will experience greater torque?

(a) circle (b) semi-circle (c) square (d) all of them

37. Two identical coils, each with N turns and radius R are placed coaxially at a distance R as shown in the figure. If I is the current passing through the loops in the same direction, then the magnetic field at a point P at a distance of $R/2$ from the centre of each coil is

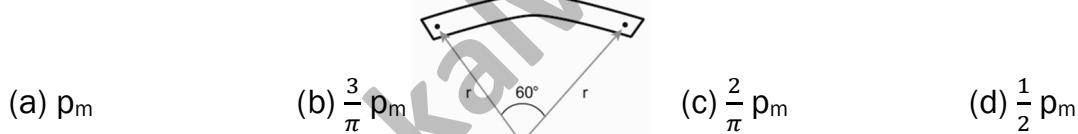
$$(a) \frac{8N\mu_0 I}{\sqrt{5}R} \quad (b) \frac{8N\mu_0 I}{5^2 R} \quad (c) \frac{8N\mu_0 I}{5R} \quad (d) \frac{4N\mu_0 I}{\sqrt{5}R}$$



38. A wire of length l carries a current I along the Y direction and magnetic field is given by $\vec{B} = \frac{\beta}{\sqrt{3}}(\vec{i} + \vec{j} + \vec{k})T$. The magnitude of Lorentz force acting on the wire is

$$(a) \sqrt{\frac{2}{\sqrt{3}}} \beta Il \quad (b) \sqrt{\frac{1}{\sqrt{3}}} \beta Il \quad (c) \sqrt{2} \beta Il \quad (d) \sqrt{\frac{1}{\sqrt{2}}} \beta Il$$

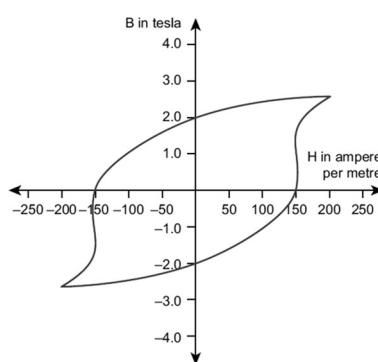
39. A bar magnet of length l and magnetic moment p_m is bent in the form of an arc as shown in figure. The new magnetic dipole moment will be



40. A non-conducting charged ring carrying a charge of q , mass m and radius r is rotated about its axis with constant angular speed ω . Find the ratio of its magnetic moment with angular momentum is

$$(a) \frac{q}{m} \quad (b) \frac{q}{2m} \quad (c) \frac{2q}{m} \quad (d) \frac{q}{4m}$$

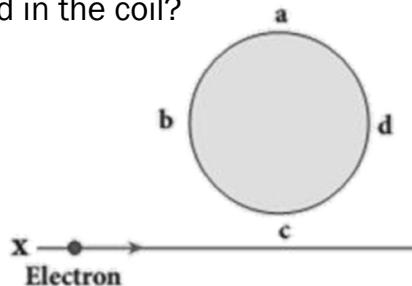
41. The BH curve for a ferromagnetic material is shown in the figure. The material is placed inside a long solenoid which contains 1000 turns/cm. The current that should be passed in the solenoid to demagnetize the ferromagnet completely is



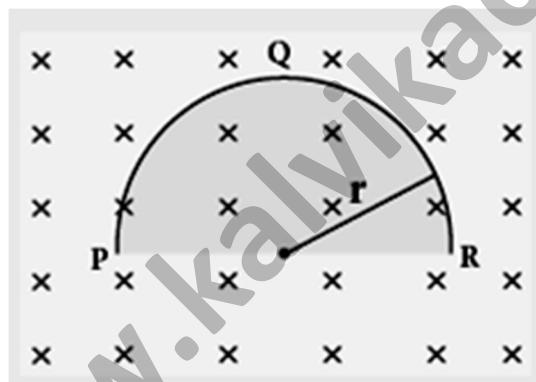
(a) 1.00 m A (b) 1.25 mA (c) 1.50 mA (d) 1.75 mA

UNIT – IV : ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENT

46. An electron moves on a straight line path XY as shown in the figure. The coil abcd is adjacent to the path of the electron. What will be the direction of current, if any, induced in the coil?



- (a) The current will reverse its direction as the electron goes past the coil
 - (b) No current will be induced
 - (c) abcd
 - (d) adcb
47. A thin semi-circular conducting ring (PQR) of radius r is falling with its plane vertical in a horizontal magnetic field B , as shown in the figure.

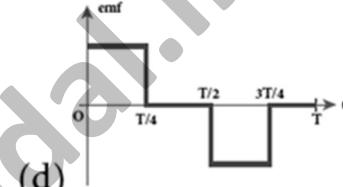
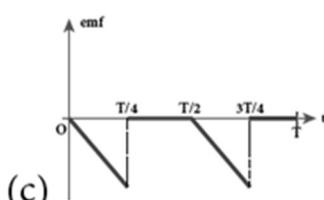
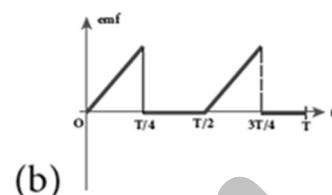
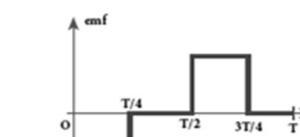
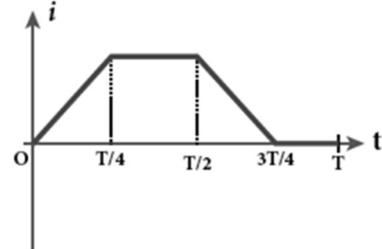


The potential difference developed across the ring when its speed v , is

- (a) Zero
- (b) $\frac{Bv\pi r^2}{2}$ and P is at higher potential
- (c) πrBv and R is at higher potential
- (d) $2rBv$ and R is at higher potential

48. The flux linked with a coil at any instant t is given by $\Phi_B = 10t^2 - 50t + 250$.
The induced emf at $t = 3\text{s}$ is
- (a) -190 V
 - (b) -10 V
 - (c) 10 V
 - (d) 190 V
49. When the current changes from $+2\text{A}$ to -2A in 0.05s , an emf of 8 V is induced in a coil. The co-efficient of self-induction of the coil is
- (a) 0.2 H
 - (b) 0.4 H
 - (c) 0.8 H
 - (d) 0.1 H

50. The current i flowing in a coil varies with time as shown in the figure. The variation of induced emf with time would be



51. A circular coil with a cross-sectional area of 4 cm^2 has 10 turns. It is placed at the centre of a long solenoid that has 15 turns/cm and a cross-sectional area of 10 cm^2 . The axis of the coil coincides with the axis of the solenoid. What is their mutual inductance?

(a) $7.54 \mu\text{H}$ (b) $8.54 \mu\text{H}$ (c) $9.54 \mu\text{H}$ (d) $10.54 \mu\text{H}$

52. In a transformer, the number of turns in the primary and the secondary are 410 and 1230 respectively. If the current in primary is 6A, then that in the secondary coil is

(a) 2 A (b) 18 A (c) 12 A (d) 1 A

53. A step-down transformer reduces the supply voltage from 220 V to 11 V and increase the current from 6 A to 100 A. Then its efficiency is

(a) 1.2 (b) 0.83 (c) 0.12 (d) 0.9

54. In an electrical circuit, RLC and AC voltage source are all connected in series. When L is removed from the circuit, the phase difference between the voltage and current in the circuit is $\frac{\pi}{3}$. Instead, if C is removed from the circuit, the phase difference is again $\frac{\pi}{3}$. The power factor of the circuit is

(a) $\frac{1}{2}$ (b) $\frac{1}{\sqrt{2}}$ (c) 1 (d) $\frac{\sqrt{3}}{2}$

55. In a series RL circuit, the resistance and inductive reactance are the same. Then the phase difference between the voltage and current in the circuit is

(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{2}$ (c) $\frac{\pi}{6}$ (d) zero

56. In a series resonant RLC circuit, the voltage across $100\ \Omega$ resistor is 40 V. The resonant frequency ω is 250 rad/s. If the value of C is $4\ \mu\text{F}$, then the voltage across L is
 (a) 600 V (b) 4000 V (c) 400V (d) 1 V
57. An inductor $20\ \text{mH}$, a capacitor $50\ \mu\text{F}$ and a resistor $40\ \Omega$ are connected in series across a source of emf $v = 10 \sin 340 t$. The power loss in AC circuit is
 (a) $0.76\ \text{W}$ (b) $0.89\ \text{W}$ (c) $0.46\ \text{W}$ (d) $0.67\ \text{W}$
58. The instantaneous values of alternating current and voltage in a circuit are $i = \frac{1}{\sqrt{2}} \sin(100 \pi t)$ A and $v = \frac{1}{\sqrt{2}} \sin(100 \pi t + \frac{\pi}{3})$ V. The average power in watts consumed in the circuit is
 (a) $\frac{1}{4}$ (b) $\frac{\sqrt{3}}{4}$ (c) $\frac{1}{2}$ (d) $\frac{1}{8}$
59. In an oscillating LC circuit, the maximum charge on the capacitor is Q. The charge on the capacitor when the energy is stored equally between the electric and magnetic fields is
 (a) $\frac{Q}{2}$ (b) $\frac{Q}{\sqrt{3}}$ (c) $\frac{Q}{\sqrt{2}}$ (d) Q
60. $\frac{20}{\pi^2}\ \text{H}$ inductor is connected to a capacitor of capacitance C. The value of C in order to impart maximum power at 50 Hz is
 (a) $50\ \mu\text{F}$ (b) $0.5\ \mu\text{F}$ (c) $500\ \mu\text{F}$ (d) $5\ \mu\text{F}$

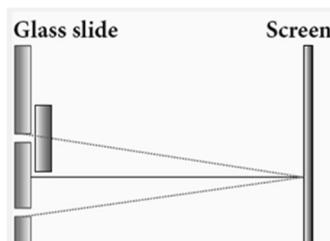
UNIT – V : ELECTROMAGNETIC WAVES

61. The dimension of $\frac{1}{\mu_0 \epsilon_0}$ is
 (a) $[\text{L T}^{-1}]$ (b) $[\text{L}^2 \text{T}^{-2}]$ (c) $[\text{L}^{-1} \text{T}]$ (d) $[\text{L}^{-2} \text{T}^2]$
62. If the amplitude of the magnetic field is $3 \times 10^{-6}\ \text{T}$, then amplitude of the electric field for electromagnetic waves is
 (a) $100\ \text{Vm}^{-1}$ (b) $300\ \text{Vm}^{-1}$ (c) $600\ \text{Vm}^{-1}$ (d) $900\ \text{Vm}^{-1}$
63. Which of the following electromagnetic radiation is used for viewing objects through fog
 (a) microwave (b) gamma rays (c) X- rays (d) infrared
64. Which of the following are false for electromagnetic waves
 (a) transverse (b) mechanical waves
 (c) longitudinal (d) produced by accelerating charges
65. Consider an oscillator which has a charged particle oscillating about its mean position with a frequency of 300 MHz. The wavelength of electromagnetic waves produced by this oscillator is
 (a) 1 m (b) 10 m (c) 100 m (d) 1000 m
66. The electric and the magnetic field, associated with an electromagnetic wave, propagating along X axis can be represented by
 (a) $\vec{E} = E_0 \vec{j}$ and $\vec{B} = B_0 \vec{k}$ (b) $\vec{E} = E_0 \vec{k}$ and $\vec{B} = B_0 \vec{j}$
 (c) $\vec{E} = E_0 \vec{i}$ and $\vec{B} = B_0 \vec{j}$ (d) $\vec{E} = E_0 \vec{j}$ and $\vec{B} = B_0 \vec{i}$

UNIT – VI : RAY OPTICS

76. The speed of light in an isotropic medium depends on,
- (a) its intensity
 - (b) its wavelength
 - (c) the nature of propagation
 - (d) the motion of the source w.r.t medium
77. A rod of length 10 cm lies along the principal axis of a concave mirror of focal length 10 cm in such a way that its end closer to the pole is 20 cm away from the mirror. The length of the image is,
- (a) 2.5 cm
 - (b) 5cm
 - (c) 10 cm
 - (d) 15cm
78. An object is placed in front of a convex mirror of focal length of f and the maximum and minimum distance of an object from the mirror such that the image formed is real and magnified.
- (a) $2f$ and c
 - (b) c and ∞
 - (c) f and 0
 - (d) None of these
79. For light incident from air on a slab of refractive index 2, the maximum possible angle of refraction is,
- (a) 30°
 - (b) 45°
 - (c) 60°
 - (d) 90°
80. If the velocity and wavelength of light in air is V_a and λ_a and that in water is V_w and λ_w , then the refractive index of water is,
- (a) $\frac{V_w}{V_a}$
 - (b) $\frac{V_a}{V_w}$
 - (c) $\frac{\lambda_w}{\lambda_a}$
 - (d) $\frac{V_a \lambda_a}{V_w \lambda_w}$
81. Stars twinkle due to,
- (a) reflection
 - (b) total internal reflection
 - (c) refraction
 - (d) polarisation
82. When a biconvex lens of glass having refractive index 1.47 is dipped in a liquid, it acts as a plane sheet of glass. This implies that the liquid must have refractive index,
- (a) less than one
 - (b) less than that of glass
 - (c) greater than that of glass
 - (d) equal to that of glass
83. The radius of curvature of curved surface at a thin planoconvex lens is 10 cm and the refractive index is 1.5. If the plane surface is silvered, then the focal length will be,
- (a) 5 cm
 - (b) 10 cm
 - (c) 15 cm
 - (d) 20 cm
84. An air bubble in glass slab of refractive index 1.5 (near normal incidence) is 5 cm deep when viewed from one surface and 3 cm deep when viewed from the opposite face. The thickness of the slab is,
- (a) 8 cm
 - (b) 10 cm
 - (c) 12 cm
 - (d) 16 cm
85. A ray of light travelling in a transparent medium of refractive index n falls, on a surface separating the medium from air at an angle of incidents of 45° . The ray can undergo total internal reflection for the following n ,
- (a) $n = 1.25$
 - (b) $n = 1.33$
 - (c) $n = 1.4$
 - (d) $n = 1.5$

UNIT – 7 : WAVE OPTICS



95. The transverse nature of light is shown in,
 (a) interference (b) diffraction (c) scattering (d) polarization

UNIT – 8 : DUAL NATURE OF RADIATION AND MATTER

96. The wavelength λ_e of an electron and λ_p of a photon of same energy E are related by
 (a) $\lambda_p \propto \lambda_e$ (b) $\lambda_p \propto \sqrt{\lambda_e}$ (c) $\lambda_p \propto \frac{1}{\sqrt{\lambda_e}}$ (d) $\lambda_p \propto \lambda_e^2$
97. In an electron microscope, the electrons are accelerated by a voltage of 14 kV. If the voltage is changed to 224 kV, then the de Broglie wavelength associated with the electrons would
 (a) increase by 2 times (b) decrease by 2 times
 (c) decrease by 4 times (d) increase by 4 times
98. The wave associated with a moving particle of mass 3×10^{-6} g has the same wavelength as an electron moving with a velocity 6×10^6 ms⁻¹. The velocity of the particle is
 (a) 1.82×10^{-18} ms⁻¹ (b) 9×10^{-2} ms⁻¹
 (c) 3×10^{-31} ms⁻¹ (d) 1.82×10^{-15} ms⁻¹
99. When a metallic surface is illuminated with radiation of wavelength λ , the stopping potential is V. If the same surface is illuminated with radiation of wavelength 2λ , the stopping potential is $\frac{V}{4}$. The threshold wavelength for the metallic surface is
 (a) 4λ (b) 5λ (c) $\frac{5}{2}\lambda$ (d) 3λ
100. If a light of wavelength 330 nm is incident on a metal with work function 3.55 eV, the electrons are emitted. Then the wavelength of the wave associated with the emitted electron is (Take $h = 6.6 \times 10^{-34}$ Js)
 (a) $< 2.75 \times 10^{-9}$ m (b) $\geq 2.75 \times 10^{-9}$ m
 (c) $\leq 2.75 \times 10^{-12}$ m (d) $< 2.75 \times 10^{-10}$ m
101. A photoelectric surface is illuminated successively by monochromatic light of wavelength λ and $\frac{\lambda}{2}$. If the maximum kinetic energy of the emitted photoelectrons in the second case is 3 times that in the first case, the work function of the material is
 (a) $\frac{hc}{\lambda}$ (b) $\frac{2hc}{\lambda}$ (c) $\frac{hc}{3\lambda}$ (d) $\frac{hc}{2\lambda}$
102. In photoelectric emission, a radiation whose frequency is 4 times threshold frequency of a certain metal is incident on the metal. Then the maximum possible velocity of the emitted electron will be
 (a) $\sqrt{\frac{h\nu_0}{m}}$ (b) $\sqrt{\frac{6h\nu_0}{m}}$ (c) $2\sqrt{\frac{h\nu_0}{m}}$ (d) $\sqrt{\frac{h\nu_0}{2m}}$

UNIT – 9 : ATOMIC AND NUCLEAR PHYSICS

111. Suppose an alpha particle accelerated by a potential of V volt is allowed to collide with a nucleus of atomic number Z , then the distance of closest approach of alpha particle to the nucleus is
 (a) $14.4 \frac{Z}{V} \text{ \AA}$ (b) $14.4 \frac{V}{Z} \text{ \AA}$ (c) $1.44 \frac{Z}{V} \text{ \AA}$ (d) $1.44 \frac{V}{Z} \text{ \AA}$
112. In a hydrogen atom, the electron revolving in the fourth orbit, has angular momentum equal to
 (a) h (b) $\frac{h}{\pi}$ (c) $\frac{3h}{\pi}$ (d) $\frac{2h}{\pi}$
113. Atomic number of H – like atom with ionization potential 122.4 V for $n = 1$ is
 (a) 1 (b) 2 (c) 3 (d) 4
114. The ratio between the first three orbits of hydrogen atom is
 (a) 1:2:3 (b) 2:4:6 (c) 1:4:9 (d) 1:3:5
115. The charge of cathode ray's particle is
 (a) positive (b) negative (c) neutral (d) not defined
116. In J.J.Thomson e/m experiment, electrons are accelerated through 2.6 kV enter the region of crosses electric filled and magnetic field of strength $3.0 \times 10^4 \text{ Vm}$ and $1.0 \times 10^{-3} \text{ T}$, respectively, and pass through it and un-deflected, then the specific charge is
 (a) $1.6 \times 10^{10} \text{ Ckg}^{-1}$ (b) $1.7 \times 10^{11} \text{ Ckg}^{-1}$ (c) $1.5 \times 10^{11} \text{ Ckg}^{-1}$ (d) $1.8 \times 10^{11} \text{ Ckg}^{-1}$
117. The ratio of the wavelengths radiation emitted for the transition from $n = 2$ to $n = 1$ in Li^{++} , He^+ and H is
 (a) 1: 2: 3 (b) 1: 4: 9 (c) 3:2:1 (d) 4:9:36
118. The electric potential between a proton and an electron is given by $V = V_0 \ln \left(\frac{r}{r_0} \right)$, where r_0 is a constant. Assume that Bohr atom model is applicable to potential, then variation of radius of n^{th} orbit r_n with the principal quantum number n is
 (a) $r_n \propto \frac{1}{n}$ (b) $r_n \propto n$ (c) $r_n \propto \frac{1}{n^2}$ (d) $r_n \propto n^2$
119. If the nuclear radius of ${}^{27}\text{Al}$ is 3.6 fermi, the approximate nuclear radius of ${}^{64}\text{Cu}$ in fermi is
 (a) 2.4 (b) 1.2 (c) 4.8 (d) 3.6
120. The nucleus is approximately spherical in shape. Then the surface area of nucleus having mass number A varies as
 (a) $A^{\frac{2}{3}}$ (b) $A^{\frac{4}{3}}$ (c) $A^{\frac{1}{3}}$ (d) $A^{\frac{5}{3}}$
121. The mass of a ${}^7\text{Li}_3$ nucleus is 0.042 u less than the sum of the masses of all its nucleons. The average binding energy per nucleon of ${}^7\text{Li}_3$ nucleus is nearly
 (a) 46 MeV (b) 5.6 MeV (c) 3.9 MeV (d) 23 MeV

122. M_p denotes the mass of the proton and M_n denotes mass of a neutron. A given nucleus of binding energy B , contains Z protons and N neutrons. The mass $M(N,Z)$ of the nucleus is given by (where c is the speed of light)
- (a) $M(N,Z) = NM_n + ZM_p - BC^2$ (b) $M(N,Z) = NM_n + ZM_p + BC^2$
 (c) $M(N,Z) = NM_n + ZM_p - B/C^2$ (d) $M(N,Z) = NM_n + ZM_p + B/C^2$
123. A radioactive nucleus (initial mass number A and atomic number Z) emits two α -particles and 2 positrons. The ratio of number of neutrons to that of proton in the final nucleus will be
- (a) $\frac{A-Z-4}{Z-2}$ (b) $\frac{A-Z-2}{Z-6}$ (c) $\frac{A-Z-4}{Z-6}$ (d) $\frac{A-Z-12}{Z-4}$
124. The half-life period of a radioactive element A is same as the mean life time of another radioactive element B. Initially both have the same number of atoms. Then
- (a) A and B have the same decay rate initially
 (b) A and B decay at the same rate always
 (c) B will decay at faster rate than A (d) A will decay at faster rate than B.
125. A radiative element has N_0 number of nuclei at $t=0$. The number of nuclei remaining after half of a half-life (that is, at time $t = \frac{1}{2} T_{1/2}$)
- (a) $\frac{N_0}{2}$ (b) $\frac{N_0}{\sqrt{2}}$ (c) $\frac{N_0}{4}$ (d) $\frac{N_0}{8}$

UNIT – 10 : ELECTRONICS AND COMMUNICATION

126. The barrier potential of a silicon diode is approximately,
- (a) 0.7 V (b) 0.3V (c) 2.0 V (d) 2.2V
127. If a small amount of antimony (Sb) is added to germanium crystal,
- (a) it becomes a p-type semiconductor
 (b) the antimony becomes an acceptor atom
 (c) there will be more free electrons than hole in the semiconductor
 (d) its resistance is increased
128. In an unbiased p-n junction, the majority charge carriers (that is, holes) in the p-region diffuse into n-region because of
- (a) the potential difference across the p-n junction
 (b) the higher hole concentration in p-region than that in n-region
 (c) the attraction of free electrons of n-region
 (d) All the above
129. If a positive half –wave rectified voltage is fed to a load resistor, for which part of a cycle there will be current flow through the load?
- (a) $0^\circ - 90^\circ$ (b) $90^\circ - 180^\circ$ (c) $0^\circ - 180^\circ$ (d) $0^\circ - 360^\circ$
130. The zener diode is primarily used as
- (a) Rectifier (b) Amplifier (c) Oscillator (d) Voltage regulator

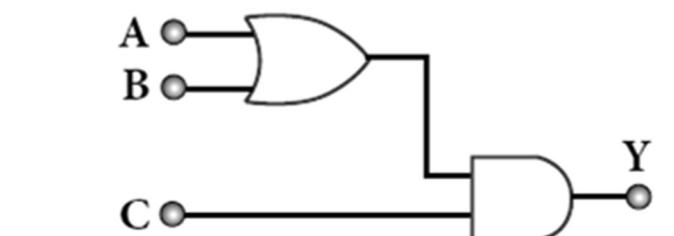
131. The principle based on which a solar cell operates is
 (a) Diffusion (b) Recombination (c) Photovoltaic action (d) Carrier flow
132. The light emitted in an LED is due to
 (a) Recombination of charge carriers
 (b) Reflection of light due to lens action
 (c) Amplification of light falling at the junction
 (d) Large current capacity.
133. The barrier potential of a p-n junction depends on i) type of semiconductor material ii) amount of doping iii) temperature. Which one of the following is correct?
 (a) (i) and (ii) only (b) (ii) only (c) (ii) and (iii) only (d) (i) (ii) and (iii)
134. To obtain sustained oscillation in an oscillator,
 (a) Feedback should be positive
 (b) Feedback factor must be unity
 (c) Phase shift must be 0 or 2π (d) All the above
135. If the input to the NOT gate is $A = 1011$, its output is
 (a) 0100 (b) 1000 (c) 1100 (d) 0011
136. Which one of the following represents forward bias diode?



137. The given electrical network is equivalent to



- (a) AND gate (b) OR gate (c) NOR gate (d) NOT gate
138. The output of the following circuit is 1 when the input ABC is



- (a) 101 (b) 100 (c) 110 (d) 010

UNIT - 11 : RECENT DEVELOPMENTS IN PHYSICS

DO you Know? and NOTES Topics

Do you know?

1. **Microwave oven works on the principle of torque acting on an electric dipole.**
The food we consume has water molecules which are permanent electric dipoles. Oven produces microwaves that are oscillating electromagnetic fields and produce torque on the water molecules. Due to this torque on each water molecule, the molecules rotate very fast and produce thermal energy. Thus, heat generated is used to heat the food.
2. Sometimes we notice that the ceiling fan does not start rotating as soon as it is switched on. But when we rotate the blades, it starts to rotate as usual. Why it is so? We know that to rotate any object, there must be a **torque applied on the object**. For the ceiling fan, the initial torque is given by the capacitor widely known as a condenser. If the condenser is faulty, it will not give sufficient initial torque to rotate the blades when the fan is switched on.
3. Computer keyboard keys are constructed using **capacitors with a dielectric**. When the key is pressed, **the separation between the plates decreases** leading to an **increase in the capacitance**. This in turn triggers the electronic circuits in the computer to identify which key is pressed.
4. Electric current is not only produced by batteries. In nature, lightning bolt produces enormous electric current in a short time. During lightning, **very high potential difference is created between the clouds and ground** and hence charges flow between the clouds and ground.
5. The human body contains a large amount of water which has **low resistance of around $200\ \Omega$** and the **dry skin has high resistance of around $500\ k\Omega$** . But when the skin is wet, the **resistance is reduced to around $1000\ \Omega$** . This is the reason why repairing the electrical connection with the wet skin is always dangerous.
6. This **temperature is known as critical temperature or transition temperature**. The materials which exhibit this property are known as superconductors. This phenomenon was first observed by Kammerlingh Onnes in 1911. He found that **mercury exhibits superconductor behaviour at $4.2\ K$** . Since $R = 0$, current once induced in a superconductor persists without any potential difference.
7. The electrical power produced (dissipated) by a resistor is I^2R . It depends on the **square of the current**. Hence, **if current is doubled, the power will increase by four times**. Similar explanation holds true for voltage also.
8. The Tamilnadu Electricity Board is charging for the amount of energy you use and not for the power. A current of $1A$ flowing through a potential difference of $1V$ produces a power of $1W$.

9. When the car engine is started with headlights turned on, they sometimes become dim. This is due to the **internal resistance of the car battery**.

10. A galvanometer is an instrument used **for detecting and measuring even very small electric currents**. It is extensively useful to compare the potential difference between various parts of the circuit.

11. Many birds and animals have magnetic sense in their eyes **using Earth's magnetic field for navigation**.

Magnetic sensing in eyes - for Zebra finch bird, due to protein cryptochromes Cry4 present in retina; the bird uses Earth's magnetic field for navigation

12. William Gilbert in 1600 proposed that Earth itself behaves like a gigantic powerful bar magnet. But this theory is not successful because the temperature inside the Earth is very high and so it will not be possible for a magnet to retain its magnetism.

Gover suggested that the Earth's magnetic field is due to hot rays coming out from the Sun. These rays will heat up the air near equatorial region. Once air becomes hotter, it rises above and will move towards northern and southern hemispheres and get electrified. This may be responsible to magnetize the ferromagnetic materials near the Earth's surface. Till date, so many theories have been proposed. But none of the theorium completely explains the cause for the Earth's magnetism.

13. People living at high latitude regions (near Arctic or Antarctic) might experience dazzling coloured natural lights across the night sky. This ethereal display on the sky is known as aurora borealis (northern lights) or aurora australis (southern lights). These lights are often called as polar lights. The lights are seen above the magnetic poles of the northern and southern hemispheres. They are called as "Aurora borealis" in the north and "Aurora australis" in the south. This occurs as a result of interaction between the gaseous particles in the Earth's atmosphere with highly charged particles released from the Sun's atmosphere through solar wind. These particles emit light due to collision and variations in colour are due to the type of the gas particles that take part in the collisions. A pale yellowish – green colour is produced when the ionized oxygen takes part in the collision and a blue or purplish – red aurora is produced due to ionized nitrogen molecules.

14. (a) Why a freely suspended bar magnet in your laboratory experiences only torque (rotational motion) but not any translatory motion even though Earth has non-uniform magnetic field?

It is because Earth's magnetic field is locally (physics laboratory) uniform.

(b) Suppose we keep a freely suspended bar magnet in a **non-uniform magnetic field. What will happen?**

It will undergo translatory motion (net force) and **rotational motion (torque)**

15. Magnetic levitated train is also called Maglev train. This train floats few centimetres above the guideway because of electromagnet used. Maglev train does not need wheels and also achieve greater speed. **The basic mechanism of working of Maglev train involves two sets of magnets. One set is used to repel which makes train to float above the track and another set is used to move the floating train ahead at very great speed.** These trains are quieter, smoother and environmental friendly compared conventional trains and have potential for moving with much higher speeds with technology in future.
16. Magnetism plays interesting role in various aspects of life. It has connection with archeological place Keezhadi too. To find whether any archeological structure exists under the surface of a given place, well established technique called 'magnetometer surveying' is used.
In this technique, the variation of the magnetic field in comparison with the neighbouring place is studied. The magnetic field variation is due to the presence of magnetic mineral magnetite and its related minerals present in the archeological structures like buried wall, pottery, bricks, buried tombs, monuments and inhabited sites. Those minerals are either diamagnetic or paramagnetic or ferromagnetic in nature and each type has different range of magnetic susceptibilities.
Indian Institute of Geomagnetism (IIG), Mumbai conducted magnetometer survey on Keezhadi site and found out that there were archeological structures like wall, pottery etc. From the picture (Figure 1), there was magnetic field variation in the range of 10 to 100nT over the particular area (coloured portion). In fact, the existence of massive brick structures at Keezhadi has been revealed through magnetism.
17. Like mass and charge for particles, spin is also another important attribute for an elementary particle. Spin is a quantum mechanical phenomenon which is responsible for magnetic properties of the material. Spin in quantum mechanics is entirely different from spin we encounter in classical mechanics. Spin in quantum mechanics does not mean rotation; it is intrinsic angular momentum which does not have classical analogue. For historical reason, the name spin is retained. Spin of a particle takes only positive values but the orientation of the spin vector takes plus or minus values in an external magnetic field. For an example, electron has spin $s=1/2$. In the presence of magnetic field, the spin will orient either parallel or anti-parallel to the direction of magnetic field.

18. This implies that the magnetic spin m_s takes two values for an electron, such as **$m_s = 1/2$ (spin up)** and **$m_s = -1/2$ (spin down)**. **Spin for proton and neutron is $s=1/2$. For photon, spin $s = 1$.**
19. MRI is Magnetic Resonance Imaging which **helps the physicians to diagnose or monitor treatment for a variety of abnormal conditions happening within the head, chest, abdomen and pelvis. It is a non-invasive medical test.** The patient is placed in a circular opening (actually interior of a solenoid which is made up of superconducting wire) and large current is sent through the superconducting wire to produce a strong magnetic field. So, it uses more powerful magnet, radio frequency pulses and a computer to produce pictures of organs which helps the physicians to examine various parts of the body.
20. For common household appliances, the voltage rating and current rating are generally specified in terms of their RMS value. **The domestic AC supply is 230V, 50 Hz. It is the RMS or effective value. Its peak value will be**
$$V_m = \sqrt{2} \quad V_{rms} = \sqrt{2} \times 230 = 325 \text{ V} .$$
21. ELI is an acronym which means that **EMF (voltage) leads the current in an inductive circuit.**
22. ICE is an acronym which means that **the current leads the EMF (voltage) in a capacitive circuit.**
23. It is surprising to realize that EM waves have linear momentum and angular momentum like particles. In the year 2018, Nobel prize in physics was awarded for the invention of optical tweezers and production of high intense light pulses. Optical tweezer is nothing but a laser light, used to move micro sized particles or molecules from one location to another location. It has a lot of applications in the medical field. The bacteria and virus can alone be separated from regular tissue using this optical tweezer and cancerous cells can be separated from normal healthy cells. The optical tweezer utilizes momentum property of EM waves. In fact, the comet has tail shape because the sun light imparts large amount of linear momentum which pushes the masses of the comet away from the sun. Angular momentum of EM waves can be understood in simple way. Consider a setup of oppositely-charged coaxial cylindrical shells and in between them a solenoid is kept. An AC current is flowing through it and when the current in the solenoid is reduced to zero, then the inner and outer cylindrical shells start to rotate in opposite directions. The rotation of these cylinders is due to the impart of angular momentum from the electromagnetic field produced by the AC current

24. Production of optical surfaces capable of refracting as well as reflecting is possible by properly coating the surfaces with suitable materials. Thus, a glass can be made partially see through and partially reflecting. These glasses are commercially called as two-way mirror, half-silvered mirror, semi-silvered mirror etc. This gives a perception of regular mirror if the other side is made dark. But, still hidden cameras can be kept behind such mirrors. We need to be cautious when we stand in front of mirrors kept in unknown places. There is a method to test the two-way mirror. Place the finger nail on the mirror surface. If there is a gap between nail and its image, then it is a regular mirror. If the fingernail directly touches its image, then it is a two-way mirror.
25. Atmospheric refraction: Due to refraction of light through different layers of atmosphere which vary in refractive index, the path of light deviates continuously when it passes through the atmosphere. For example, the Sun is visible a little before the actual sunrise and also until a little after the actual sunset due to refraction of light through the atmosphere. What we mean by actual sunrise is the actual crossing of the sun at the horizon. Figure shows the actual and apparent positions of the sun with respect to the horizon. The figure is highly exaggerated to show the effect. The apparent shift in the direction of the sun is around half a degree and the corresponding time difference between the actual and apparent positions is about 2 minutes. Sun appears flattened (oval shaped) during sun rise and sunset due to the same phenomenon.
The same is also applicable for the positions of stars as shown in Figure. Actually, the stars do not twinkle. They appear twinkling because of the movement of the atmospheric layers with varying refractive indices which is clearly seen in the night sky.
26. An **endoscope which has a bundle of optical fibres** is an instrument used by doctors to see inside of a patient's body. **Endoscopes work on the phenomenon of total internal reflection.** The optical fibres are inserted into the body through mouth, nose (or) a special hole made in the body. Even operations could be carried out with the endoscope cables which have the necessary instruments attached at their ends.
27. **Rainbow appears in sky during mild shower (or) near the fountains/falls** where there are water droplets remain suspended in air. A rainbow is seen when the sun is at the back of the observer. **Dispersion occurs when sunlight enters a water droplet and the white light is split into its constituent seven colours.** **A primary rainbow is formed when the light entering a droplet undergoes one total internal reflection inside it.** Sometimes, a secondary rainbow is also formed enveloping the primary rainbow. The secondary rainbow is formed when light entering a raindrop undergoes two **total internal reflections.** The order of colour in primary rainbow is from violet to red whereas in secondary rainbow it is from

red to violet. **The angle of view in primary rainbow from violet to red is from 40° to 42° . The angle of view for secondary rainbow from red to violet is from 52° to 54° .**

28. **Dazzling colours are exhibited by thin films of oil spread on the surface of water and also by soap bubbles.** These colours are due to interference of white light undergoing multiple reflections from the top and the bottom surfaces of thin films. The colour depends upon the thickness of the film, refractive index of the film and also the angle of incidence of the light.
29. A compact disc (CD) always appears colourful. On the read/writable side which looks shining, there are many narrow circular tracks with widths comparable to the wavelength of visible light. Hence, the diffraction takes place after the reflection of incident white light to give colourful appearance. The tracks act as reflecting grating.
30. It is interesting to note that the experiment of Hertz confirmed that light is an electromagnetic wave. But the same experiment also produced the first evidence for particle nature of light.
31. A reader may find it difficult to understand how light can be both a wave and a stream of particle. This is the case even for great scientist like Albert Einstein. Einstein once wrote a letter to his friend Michel Besso in 1954 expressing his frustration:
“All these fifty years of conscious brooding have brought me no closer to answer the question, ‘What are light quanta?’ Of course today everyone thinks he knows the answer, but he is deluding himself”
32. A single teaspoon of nuclear matter would **weigh about trillion tons.**
33. **A very interesting application of alpha decay is in smoke detectors** which prevent us from any hazardous fire.
The **smoke detector uses around 0.2 mg of man-made weak radioactive isotope called americium ($^{95}\text{Am}^{241}$)**. This radioactive source is placed between two oppositely charged metal plates and α radiations from $^{95}\text{Am}^{241}$ continuously ionize the nitrogen, oxygen molecules in the air space between the plates. As a result, there will be a continuous flow of small steady current in the circuit. If smoke enters, the radiation is being absorbed by the smoke particles rather than air molecules. As a result, the ionization and along with it the current is reduced. This drop in current is detected by the circuit and alarm starts.
The radiation dosage emitted by americium is very much less than safe level, so it can be considered harmless.

34. The world's **first computer 'ENIAC'** was invented by J. Presper Eckert and John Mauchly at the University of Pennsylvania. The construction work started in 1943 and got over in 1946. It occupied an area of **around 1800 square feet**. It had 18,000 vacuum tubes and it weighed around 50 tons.
35. The n-type and p-type semiconductors are neutral because only neutral atoms are doped to the intrinsic semiconductors.
36. The concept of high (1) and low (0) is not a new one. In fact, it was applied in telephone switching circuits by Shannon in 1938.

NOTE:

1. The potential due to an electric dipole falls as $\frac{1}{r^2}$ and the potential due to a single point charge falls as $\frac{1}{r}$. Thus the potential due to the dipole falls faster than that due to a monopole (point charge). As the distance increases from electric dipole, the effects of positive and negative charges nullify each other.
2. Gauss law is a powerful technique whenever a given charge configuration possesses spherical, cylindrical or planar symmetry, then the electric field due to such a charge configuration can be easily found. If there is no such symmetry, the direct method (Coulomb's law and calculus) can be used. **For example, it is difficult to use Gauss law to find the electric field for a dipole since it has no spherical, cylindrical or planar symmetry.**
3. The typical **drift velocity of electrons in the wire is 10^{-4} m s^{-1}** . If an electron drifts with this speed, then the electrons leaving the battery will take hours to reach the light bulb. Then how electric bulbs glow as soon as we switch on the battery? **When battery is switched on, the electrons begin to move away from the negative terminal of the battery and this electron exerts force on the nearby electrons.** This process creates a propagating influence (electric field) that travels through the wire at the speed of light. In other words, **the energy is transported from the battery to bulb at the speed of light through propagating influence (electric field).** Due to this reason, the bulb glows as soon as the battery is switched on.
4. (i) **Pole strength is a scalar quantity with dimension [$M^0 L T^0 A$].**
Its SI unit is $N T^{-1}$ (newton per tesla) or $A m$ (ampere-metre).
- (ii) Like positive and negative charges in electrostatics, North Pole of a magnet experiences a force in the direction of magnetic field while South Pole of a magnet experiences force opposite to the magnetic field.
- (iii) Pole strength depends on the nature of materials of the magnet, area of cross-section and the state of magnetization.

- (iv) If a magnet is cut into two equal halves along the length then pole strength is reduced to half.
- (v) If a magnet is cut into two equal halves perpendicular to the length, then pole strength remains same.
- (vi) If a magnet is cut into two pieces, we will not get separate north and south poles. Instead, we get two magnets. In other words, isolated monopole does not exist in nature.
5. Superconductors are perfect diamagnetic materials. The expulsion of magnetic flux from a superconductor during its transition to the superconducting state is known as **Meissner effect**.
Superconductors behave like perfect diamagnetic materials below transition temperature T_C .
6. **Solenoid can be used as electromagnet.** It produces strong magnetic field that can be turned ON or OFF. This is not possible in case of permanent magnet. Further the strength of the magnetic field can be increased by keeping iron bar inside the solenoid. This is because the magnetic field of the solenoid magnetizes the iron bar and hence the net magnetic field is the sum of magnetic field of the solenoid and magnetic field of magnetised iron. Because of these properties, solenoids are useful in designing variety of electrical appliances.
7. This principle is used in **Bainbridge mass spectrograph to separate the isotopes**.
8. **Deutrons (bundles of one proton and one neutron) can be accelerated because it has same charge as that of proton.** But neutron (electrically neutral particle) cannot be accelerated by the cyclotron. When a deuteron is bombarded with a beryllium target, a beam of high energy neutrons are produced. These high-energy neutrons are sent into the patient's cancerous region to break the **bonds in the DNA of the cancer cells (killing the cells). This is used in treatment of fast-neutron cancer therapy.**
9. Alternating emf is generated by rotating a coil in a magnetic field or by rotating a magnetic field within a stationary coil.
The first method is used for small AC generators while the second method is employed for large AC generators. The rotating-field method is the one which is mostly used in power stations
10. The students should remember that in a single slit experiment, the formula, $\sin\theta = n\lambda$ is condition for minimum with n as order of minimum. But in the grating experiment, the formula, $\sin\theta = Nm\lambda$ is condition for maximum with m as the order of diffraction

11. The **SI unit of energy is joule**. But **electron volt is a commonly used unit of energy in atomic and nuclear physics**.

One electron volt is defined as **the kinetic energy gained by an electron when accelerated by a potential difference of 1 V**.

1 eV = KE gained by the electron

= Work done by the electric field

= $q V$

= $1.602 \times 10^{-19} \text{ C} \times 1 \text{ V}$

1 eV = $1.602 \times 10^{-19} \text{ J}$

12. It is to be noted that electrons are not the only particles with which wave nature can be demonstrated. The waves are associated with particles like neutrons and alpha particles also when they are in motion. They undergo diffraction when they are scattered by suitable crystals. Neutron diffraction studies are highly useful for investigating crystal structures

13. **Diffraction is one of the properties of waves.** Whenever waves are incident on an obstacle, they bend around the edges of the obstacle. This bending of waves is called diffraction. The amount of bending depends on the wavelength of the waves.

The wavelength of light is very small; diffraction effects of light are very small. In order to study diffraction of light, diffraction gratings are used.

Since x-rays and de Broglie waves of electrons have wavelengths (**in the order of 10^{-10} m**) much shorter than that of the light wave, diffraction grating cannot be used in x-ray diffraction studies. In a crystal, the spacing between atomic planes is comparable to the wavelength of x-rays and de Broglie waves of electrons. Hence, in x-ray diffraction studies, the crystals are used which serve as three-dimensional grating.

14. The **specific charge is independent of (a) gas used (b) nature of the electrodes**

15. In 1931, H.C. Urey and co-workers noticed that in the shorter wavelength region of the hydrogen spectrum lines, faint companion lines are observed. From the isotope displacement effect (isotope shift), the isotope of the same element can produce slightly different spectral lines. The presence of these faint lines confirmed the existence of isotopes of hydrogen atom (which is named as Deuterium).

On calculating wavelength or wave number difference between the faint and bright spectral lines, atomic mass of deuterium is measured to be twice that of atomic mass of hydrogen atom. Bohr atom model could not explain this isotopic shift. Thus by considering nuclear motion (although the movement of the nucleus is much smaller) into account in the Bohr atom model, the wave number or

wavelength difference between the lines produced by the hydrogen atom and deuterium is theoretically calculated which perfectly agreed with the spectroscopic measured values.

The difference between hydrogen atom and deuterium is in the number of neutrons. Hydrogen atom contains an electron and a proton, whereas deuterium has an electron, a proton and a neutron.

16. Using **Einstein's mass-energy equivalence, the energy equivalent of one atomic mass unit**

$$1u = 1.66 \times 10^{-27} \times (3 \times 10^8)^2 ; 14.94 \times 10^{-11} J ; \approx 931 \text{ MeV}$$

17. **India has 22 nuclear reactors in operation. Nuclear reactors are constructed in two places in Tamilnadu, Kalpakkam and Kudankulam.** Even though nuclear reactors are aimed to cater to our energy need, in practice nuclear reactors **now are able to provide only 2% of energy** requirement of India.

18. Passive components: components that **cannot generate power** in a circuit.
Active components: components that **can generate power** in a circuit.

19. The **energy of the orbiting electrons is measured in electron volts (eV).**

20. Ideal diode: It acts like a conductor when it is forward biased. When it is reverse biased, it acts like an insulator. For ideal diodes, the forward resistance is zero and barrier potential is considered negligible.

21. **Centre tap transformer:** There is a facility to tap at halfway point in the secondary windings. This helps to measure the induced voltage from one end of the secondary to the centre point. If the centre tap point is grounded, then the voltage across the secondary will be divided into two halves. **For example, if the voltage across the secondary is 240 V, then the voltage across one end and the centre tap point is +120 V and at the other end it is -120 V.**

22. In Avalanche breakdown, the minority charge carriers gain sufficient energy from excessive reverse bias voltage to break covalent bond in order to produce new charge carriers. But Zener breakdown occurs due to the direct rupture of covalent bonds because of the existence of the strong electric field. Since depletion region is thin, Zener breakdown occurs usually at lesser reverse bias voltage compared to Avalanche breakdown voltage.

23. The maximum reverse bias that can be applied before entering into the Zener region is called the peak inverse voltage, commercially referred as PIV rating.

24. **NAND and NOR gates are known as universal gates because any other logic gate can be made from NAND or NOR gates.**

**PUBLIC EXAMINATION – ONE MARK QUESTIONS
MARCH 2019**

1. The magnitude of electric intensity at a distance ‘r’ from the centre of an electric dipole along its axial line is E. The distance of the point from the centre of the electric dipole along its equatorial line at which the electric intensity has same value E is:
 (a) $\frac{r}{\sqrt{2}}$ (b) $\frac{r}{(3)^{\frac{1}{3}}}$ (c) $r(2)^{\frac{1}{3}}$ (d) $\frac{r}{(2)^{\frac{1}{3}}}$
2. A beam of protons and α -particle are successively accelerated in a cyclotron. The ratio of the normal magnetic field to be applied to the cyclotron so that protons and α -particles have the same period of rotation is :
 (a) 1:4 (b) 4:1 (c) 1:2 (d) 2:1
3. Two sample of radioactive substances have the same quantity. $\frac{1}{16}$ th portion of A and $\frac{1}{256}$ th portion of B remain un-decayed after 8 hours. The ratio of half-life periods of A and B is :
 (a) 1:4 (b) 4:1 (c) 1:2 (d) 2:1
4. The threshold frequency of a photo-sensitive surface is 5×10^{14} Hz. Then which of the following can produce photoelectric emission from the same surface?
 (a) Ruby-Laser light (b) He-Ne Laser light
 (c) **Xenon flash light** (d) Both (a) and (b)
5. Which of the following devices does not allow d.c. to pass through?
 (a) resistor (b) **capacitor** (c) inductor (d) all the above
6. The distance of closest approach of α -particle reaching a nucleus with momentum ‘p’ is r_0 . When the α -particle travels towards the same nucleus with momentum $\frac{p}{2}$, the distance of closest approach will be :
 (a) **4r₀** (b) $\frac{r_0}{4}$ (c) $2r_0$ (d) $\frac{r_0}{2}$
7. If β is the bandwidth, in Young’s double slit experiment, the distance between the first dark band and sixth bright band is:
 (a) $5\frac{1}{2}\beta$ (b) 6β (C) 11β (d) 5β
8. According to the laws of Boolean algebra, the expression (A+AB) is equal to:
 (a) B (b) \bar{A} (c) **A** (d) AB
9. Point charges $1 \mu\text{C}$ and $6 \mu\text{C}$ are placed in air at a certain distance apart. The magnitude of the force on $1 \mu\text{C}$ by $6 \mu\text{C}$ is F_1 . The magnitude of the force on $6 \mu\text{C}$ by $1 \mu\text{C}$ F_2 . Then $F_1 : F_2$ is :
 (a) **1:1** (b) 36:1 (c) 1:6 (d) 6:1
10. High frequency waves follow:
 (a) **ionospheric propagation** (b) the curvature of the earth
 (c) the ground wave propagation (d) the line of sight direction
11. When a hydrogen atom absorbs an energy of 10.2 eV, the change in its angular momentum is:
 (a) $4.14 \times 10^{-15} \text{ Js}$ (b) $0.525 \times 10^{-34} \text{ Js}$
 (c) **1.05 x 10⁻³⁴ Js** (d) $2.1 \times 10^{-34} \text{ Js}$

12. Avalanche breakdown is primarily dependent on the phenomenon of :
(a) doping (b) recombination
(c) collision (d) ionization

13. The alternating current in a circuit is given by the equation
 $i = 10\sin\left(100\pi t + \frac{\pi}{6}\right)$. The current attains its first maximum at t is :
(a) $\frac{1}{600}$ s (b) $\frac{1}{50}$ s (c) $\frac{1}{100}$ s (d) $\frac{1}{300}$ s

14. An electric bulb is marked 220 V, 100W. When it is connected across 110 V, its power is:
(a) 200 W (b) 173.2 W (c) 50 W (d) **25 W**

15. Phosphor-bronze wire is used for suspension in a moving coil galvanometer, because it has:
(a) large couple per unit twist (b) **small couple per unit twist**
(c) high conductivity (d) high resistivity

MARCH 2020

1. The frequency range of 30 MHz to 400 GHz is used for :
(a) Satellite communication (b) Ground wave propagation
(c) Space wave propagation (d) Sky wave propagation

2. In an oscillating LC circuit, the maximum charge on the capacitor is Q . The charge on the capacitor when the energy is stored equally between the electric and magnetic field is :
(a) Q (b) $\frac{Q}{2}$ (c) $\frac{Q}{\sqrt{3}}$ **(d)** $\frac{Q}{\sqrt{2}}$

3. Type of material which emits white light in LED :
(a) GaInN (b) SiC (c) AlGaP (d) GaAsP

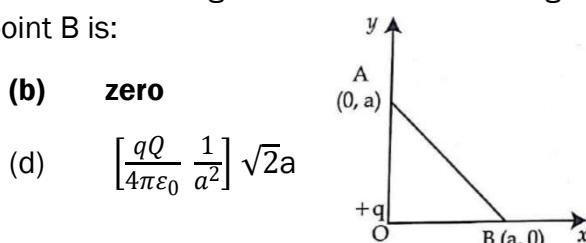
4. The force experienced by a particle having mass m and charge q accelerated through a potential difference V when it is kept under perpendicular magnetic field \vec{B} is
(a) $\sqrt{\frac{2q^3BV}{m}}$ (b) $\sqrt{\frac{q^3B^2V}{2m}}$ (c) $\sqrt{\frac{2q^3BV}{m^3}}$ **(d)** $\sqrt{\frac{2q^3B^2V}{m}}$

5. Charging current for a capacitor is 0.2 A, find the displacement current.
(a) zero **(b) 0.2 A** (c) 0.4 A (d) 0.1 A

6. In Bohr Atom Model when the principal quantum number (n) increases the velocity of electron:
(a) increases and then decreases (b) increases
(c) decreases (d) remains constant

7. In the given diagram a point charge $+q$ is placed at the origin O. Work done in taking another point charge $-Q$ from point A to point B is:

$$(a) \quad \frac{qQ}{4\pi\varepsilon_0 a^2} \left(\frac{a}{\sqrt{2}} \right)$$



8. The nucleus is approximately spherical in shape. Then the surface area of nucleus having mass number A varies as

(a) $A^{\frac{5}{3}}$ (b) $A^{\frac{2}{3}}$ (c) $A^{\frac{4}{3}}$ (d) $A^{\frac{1}{3}}$

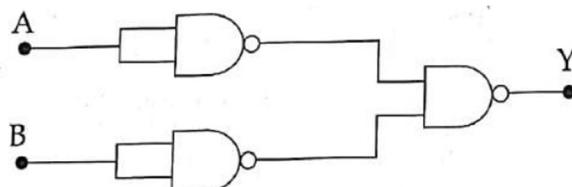
9. Two light waves from slit S_1 and S_2 on reaching points P and Q on a screen in Young's double slit experiment have a path difference zero and $\frac{\lambda}{4}$ respectively. The ratio of light intensities at P and Q will be :

(a) 4 : 1 (b) 3 : 2 (c) $\sqrt{2} : 1$ (d) 2 : 1

10. The radius of curvature of curved surface at a thin Plano convex lens is 10 cm and the refractive index is 1.5. If the plane surface is silvered, then the focal length will be,

(a) 20 cm (b) 5 cm (c) 10 cm (d) 15 cm

11. The given electrical network is equivalent to :



(a) NAND gate (b) OR gate (c) NOT gate (d) Ex-OR gate

12. Magnetic field at any point at a distance R due to a long straight conductor carrying current varies as :

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

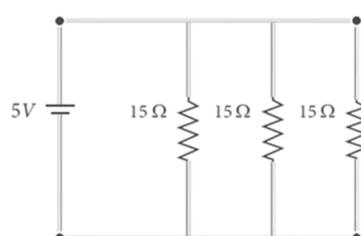
13. If voltage applied on a capacitor is increased from V to 2V, choose the correct conclusion.

(a) Both Q and C remain the same
 (b) Q remains the same, C is doubled
 (c) Q is doubled, C is doubled (d) **C remains the same, Q is doubled**

14. A light of wavelength 500 nm is incident on a sensitive plate of photoelectric work function 1.235 eV. The kinetic energy of the photo electrons emitted is :
 (Take $h = 6.6 \times 10^{-34}$ Js)

(a) 1.16 eV (b) 0.58 eV (c) 2.48 eV (d) 1.24 eV

15. What is the current drawn out from the battery?



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

SEPTEMBER 2020

11. When the current changes from 2 A to – 2 A in 0.05 s, an emf of 8 V is induced in a coil. The coefficient of self-induction of the coil is:
 (a) 0.2 H (b) 0.4 H (c) 0.8 H **(d) 0.1 H**
12. The average energy density of an electromagnetic wave is:
 (a) $\frac{1}{2}\epsilon_0 E$ **(b) $\frac{1}{2}\epsilon_0 E^2$** (c) $\frac{1}{4}\epsilon_0 E^2$ (d) $\frac{1}{4}\epsilon_0 E$
13. The threshold wavelength for a metal surface whose photoelectric work function is 3.313 eV is :
 (a) 4125 Å **(b) 37350 Å** (c) 6000 Å (d) 2062.5 Å
14. The dopant to be added with a pure Germanium Crystal to form n type semiconductor is:
 (a) Boron **(b) Phosphorus** (c) Aluminium (d) Indium
15. If a beam of un-polarized light is incident on a reflecting glass surface at an angle of 57.5° , then the angle between the reflected and refracted beam will be :
 (a) 45° (b) 60° **(c) 90°** (d) 30°

SEPTEMBER 2021

1. In an oscillating LC circuit, the maximum charge on the capacitor is Q. the charge on the capacitor when the energy is stored equally between the electric and magnetic field is:
(a) $\frac{Q}{\sqrt{2}}$ (b) $\frac{Q}{2}$ (c) Q (d) $\frac{Q}{\sqrt{3}}$
2. In a Young's double slit experiment, the slit separation is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed to :
 (a) $\sqrt{2} D$ **(b) $2D$** (c) $\frac{D}{\sqrt{2}}$ (d) $\frac{D}{2}$
3. Which charge configuration produces a uniform electric field?
 (a) **Uniformly charged infinite plate** (b) point charge
 (c) Uniformly charged spherical shell
 (d) Uniformly charged infinite line
4. The ratio of magnetic length and geometrical length is :
(a) 0.833 (b) 0.633 (c) 0.933 (d) 0.733
5. The internal resistance of a 2.1 V cell which gives a current of 0.2A through a resistance of 10Ω is :
 (a) 0.8Ω (b) 0.2Ω (c) 1.0Ω **(d) 0.5Ω**
6. If the nuclear radius of ^{27}Al is 3.6 fermi, the approximate nuclear radius of ^{64}Cu in fermi is:
(a) 4.8 (b) 2.4 (c) 3.6 (d) 1.2
7. If the velocity and wavelength of light in air is V_a and λ_a and that in water is V_w and λ_w then the refractive index of water is,
 (a) $\frac{\lambda_w}{\lambda_a}$ (b) $\frac{V_w}{V_a}$ (c) $\frac{V_a \lambda_a}{V_w \lambda_w}$ **(d) $\frac{V_a}{V_w}$**

8. The unit of electric flux is :
 (a) Nm^{-1}C^2 (b) $\text{Nm}^{-2}\text{C}^{-1}$ (c) **Nm^2C^{-1}** (d) N^2mC^{-1}
9. For a healthy eye, the distance of the near point is _____
 (a) 30 cm (b) 20 cm (c) 35 cm (d) **25 cm**
10. The blueprint for making ultra-durable synthetic material is mimicked from:
 (a) **Parrot fish** (b) Lotus leaf
 (c) Peacock feather (d) Morpho butterfly
11. Emission of electrons by the absorption of heat energy is called _____
 (a) **Thermionic** (b) Photoelectric
 (c) Secondary (d) Filed
12. The Zener diode is primarily used as :
 (a) Oscillator (b) Rectifier
 (c) **Voltage regulator** (d) Amplifier
13. Which of the following is false for electromagnetic waves?
 (a) **longitudinal** (b) transverse
 (c) produced by accelerating charges (d) non-mechanical waves
14. The force experienced by a particle having mass m and charge q accelerated through a potential difference V when it is kept under perpendicular magnetic field \vec{B} .
 (a) $\sqrt{\frac{2q^3B^2V}{m}}$ (b) $\sqrt{\frac{2q^3BV}{m}}$ (c) $\sqrt{\frac{2q^3BV}{m^3}}$ (d) $\sqrt{\frac{q^3B^2V}{2m}}$
15. In a transformer, the number of turns in the primary and the secondary are 410 and 1230 respectively. If the current in primary is 6 A, then that in the secondary coil is :
 (a) 12 A (b) **2 A** (c) 1 A (d) 18 A

MAY 2022

1. Which one of the following is the natural nanomaterial?
 (a) Grain of sand (b) **Peacock feather**
 (c) Skin of the whale (d) Peacock beak
2. In an electron microscope, the electrons are accelerated by a voltage of 14kV. If the voltage is charged to 224 kV, the de-Broglie wavelength associated with the electrons would:
 (a) **decrease by 4 times** (b) increase by 2 times
 (c) increase by 4 times (d) decrease by 2 times
3. The variation of frequency of carrier wave with respect to the instantaneous amplitude of the modulating signal is called:
 (a) Phase modulation (b) Amplitude modulation
 (c) Pulse width modulation (d) **Frequency modulation**
4. Q factor is equal to _____.
 (a) $\frac{\omega_r L}{R}$ (b) $\frac{1}{R} \sqrt{\frac{L}{C}}$
 (c) $\frac{X_L}{R}$ (d) **All the above**

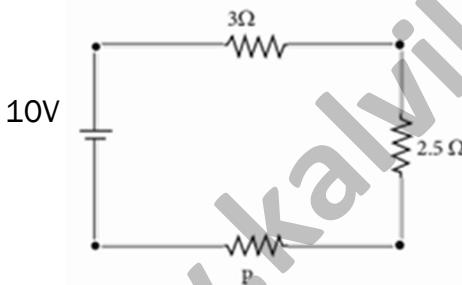
JULY 2022

1. The ratio between the radius of first three orbits of hydrogen atom is:
 (a) 1:2:3 (b) 1:2:2 (c) **1:4:9** (d) 1:3:5
2. Two coherent monochromatic light beams of intensities I and $4I$ are superposed. The maximum and minimum possible intensities in the resulting beam are:
 (a) $5I$ and I (b) $5I$ and $3I$ (c) **9I and I** (d) $9I$ and $3I$
3. A wire connected to a power supply of 230 V has power dissipation P_1 . Suppose the wire is cut into two equal pieces and connected parallel to the same power supply. P_2
 In this case power dissipation is P_2 The ratio $\frac{P_2}{P_1}$ is :
 (a) 1 (b) 2 (c) 3 (d) **4**
4. Stars twinkle due to:
 (a) Reflection (b) Total internal reflection
 (c) **Refraction** (d) Polarisation
5. The instantaneous values of alternating current and voltage in a circuit are $i = \frac{1}{\sqrt{2}} \sin(100\pi t)$ A and $v = \frac{1}{\sqrt{2}} \sin\left(100\pi t + \frac{\pi}{3}\right)$ V. The average power in watts consumed in the circuit is:
 (a) $\frac{1}{4}$ (b) $\frac{\sqrt{3}}{4}$ (c) $\frac{1}{2}$ (d) **$\frac{1}{8}$**
6. If the mean wavelength of light from Sun is taken as 550 nm and its mean power as 3.8×10^{26} W then, the average number of photons received by the human eye per second from Sunlight is of the order of:
 (a) **10^{45}** (b) 10^{42} (c) 10^{54} (d) 10^{51}
7. An electric dipole is placed at an alignment angle of 30° with an electric field of 2×10^5 NC $^{-1}$. It experiences a torque equal to 8 Nm. The charge on the dipole if the dipole length is 1 cm is
 (a) 4 mC (b) **8 mC** (c) 5 mC (d) 7 mC
8. Fraunhofer lines are an example of spectrum.
 (a) line emission (b) **line absorption**
 (c) band emission (d) band absorption
9. The mass of a 7_3 Li nucleus is 0.042 u less than the sum of the masses of all its 3 nucleons. The average binding energy per nucleon 7_3 Li nucleus is nearly
 (a) 46 MeV (b) **5.6 MeV** (c) 3.9 MeV (d) 23 MeV
10. The temperature co-efficient of resistance of a wire is 0.00125 per $^\circ$ C. At 20° C, its resistance is 1 Ω . The resistance of the wire will be 2 Ω at
 (a) 800° C (b) 700° C (c) 850° C (d) **820° C**
11. The particle size of ZnO material is 30 nm. Based on the dimension it is classified as:
 (a) Bulk material (b) **Nanomaterial**
 (c) Soft material (d) Magnetic material
12. The value of L, C and R of an AC circuit are 1 H, 9 F and 3 Ω respectively. The quality factor for this circuit is:
 (a) 1 (b) 9 (c) **$\frac{1}{9}$** (d) $\frac{1}{3}$

13. A circular coil of radius 5 cm and 50 turns carries a current of 3 ampere. The magnetic dipole moment of the coil is nearly
 (a) 1.0 Am^2 (b) **1.2 Am^2** (c) 0.5 Am^2 (d) 0.8 Am^2
14. Two radiations with photon energies 0.9 eV and 3.3 eV respectively are falling on a metallic surface successively. If the work function of the metal is 0.6 eV, then the ratio of maximum speeds of emitted electrons in the two cases will be
 (a) 1:4 (b) **1:3** (c) 1: 1 (d) 19
15. If a positive half-wave rectified voltage is fed to a load resistor, for which part of a cycle of the input signal there will be current flow through the load?
 (a) $0^\circ - 90^\circ$ (b) $90^\circ - 180^\circ$ (c) **$0^\circ - 180^\circ$** (d) $0^\circ - 360^\circ$

MARCH 2023

1. The alloys used for muscle wires in Robots are :
 (a) Gold silver alloys (b) **Shape memory alloys**
 (c) Two dimensional alloys (d) Gold copper alloys
2. If the magnitude of the magnetic field is 3×10^{-6} T, then magnitude of the electric field for a electromagnetic waves is
 (a) 600 Vm^{-1} (b) 100 Vm^{-1} (c) **900 Vm^{-1}** (d) 300 Vm^{-1}
3. There is a current of 1.0 A in the circuit shown below. What is the resistance of P?



- (a) 3.5Ω (b) 1.5Ω (c) **4.5Ω** (d) 2.5Ω
4. An example of Diamagnetic material is
 (a) Nickel (b) **Water** (c) Aluminium (d) Iron
5. The flux linked with a coil at any instant t is given by $\Phi_B = 15t^2 - 50t + 250$. The induced emf at $t = 3$ s is :
 (a) **- 40 V** (b) $- 190 \text{ V}$ (c) 40 V (d) $- 10 \text{ V}$
6. An electromagnetic wave is propagating in a medium with a velocity $\vec{v} = v\hat{i}$. The instantaneous oscillating electric field of this e.m. wave is along +Y-axis, then the direction of oscillating magnetic field of the electromagnetic wave will be along:
 (a) **+Z direction** (b) -Y direction
 (c) -Z direction (d) -X direction
7. A parallel plate capacitor stores a charge Q at a voltage V. Suppose the area of the parallel plate capacitor and the distance between the plates are each doubled then which is the quantity that will change?
 (a) Voltage (b) Capacitance
 (c) **Energy density** (d) Charge

8. In a Young's double slit experiment, the slit separation is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed to :
 (a) $\sqrt{2} D$ (b) **2D** (c) $\frac{D}{\sqrt{2}}$ (d) $\frac{D}{2}$
9. What is value of Forbidden energy gap for silicon at room temperature?
 (a) 0.3 eV (b) 0.7 eV (c) 0.9 eV (d) **1.1 eV**
10. Two polaroids are kept with their transmission axes inclined at 30° . Unpolarised light of intensity I falls on the first polaroid. Intensity of light emerging from the second polaroid:
 (a) $\frac{1}{8} I$ (b) $\frac{1}{4} I$ (c) $\frac{3}{8} I$ (d) $\frac{3}{4} I$
11. For light incident from air on a slab of refractive index 2, the maximum possible angle of refraction is :
 (a) 60° (b) **30°** (c) 90° (d) 45°
12. A carbon resistor of $(47 \pm 4.7) \text{ k}\Omega$ to be marked with rings of different colours for its identification. The colour code sequence will be :
 (a) Yellow – Violet – Orange – Silver (b) Yellow – Green – Violet – Gold
 (c) Green – Orange – Violet - Gold (d) **Violet – Yellow – Orange – Silver**
13. In an hydrogen atom, the electron revolving in the second orbit, has angular momentum:
 (a) $\frac{4h}{\pi}$ (b) h (c) $\frac{2h}{\pi}$ (d) $\frac{h}{\pi}$
14. The Zener diode is primarily used as :
 (a) Oscillator (b) Rectifier
 (c) **Voltage regulator** (d) Amplifier
15. The wavelength λ_e of an electron and λ_p of a photon of same energy E are related by
 (a) $\lambda_p \propto \frac{1}{\sqrt{\lambda_e}}$ (b) $\lambda_p \propto \lambda_e$ (c) $\lambda_p \propto \lambda_e^2$ (d) $\lambda_p \propto \sqrt{\lambda_e}$

JUNE 2023

1. The speed of light in an isotropic medium depends on ,
 (a) its density (b) **its wavelength**
 (c) the nature of propagation
 (d) the motion of the source w.r.t. medium
2. A circular coil of radius 5 cm and 50 turns carries a current of 3 ampere. The magnetic dipole moment of the coil is nearly:
 (a) 1.0 Am^2 (b) **1.2 Am^2** (c) 0.5 Am^2 (d) 0.8 Am^2
3. Two wires of A and B with circular cross section are made up of the same material with equal lengths. Suppose $R_A = 3 R_B$, then what is the ratio of radius of wire A to that of B?
 (a) 3 (b) $\sqrt{3}$ (c) $\frac{1}{\sqrt{3}}$ (d) $\frac{1}{3}$

4. Which of the following electromagnetic radiation is used for viewing objects through fog?
 (a) Microwave (b) Gamma rays (c) X- rays **(d) Infrared**
5. Emission of electrons by the absorption of heat energy is called.....emission.
 (a) photoelectric (b) field **(c) thermionic** (d) secondary
6. In a series RL circuit, the resistance and inductive reactance are the same. Then the phase difference between the voltage and current in the circuit is
(a) $\frac{\pi}{4}$ **(b)** $\frac{\pi}{6}$ **(c)** $\frac{\pi}{2}$ **(d)** zero
7. If the nuclear radius of Al^{27} is 3.6 fermi, the approximate nuclear radius of Cu^{64} is
 (a) 2.4 (b) 1.2 **(c) 4.8** (d) 3.6
8. The barrier potential of a silicon diode is approximately,
(a) 0.7 V (b) 0.3V (c) 2.0 V (d) 2.2V
9. An electric dipole is placed at an alignment angle of 30° with an electric field of $2 \times 10^5 \text{ NC}^{-1}$. It experiences a torque equal to 8 N m. The charge on the dipole if the dipole length is 1 cm is
 (a) 4 mC **(b) 8 mC** (c) 5 mC (d) 7 mC
10. For light incident from air on a slab of refractive index 2, the maximum possible angle of refraction is,
(a) 30° (b) 45° (c) 60° (d) 90°
11. Light transmitted by Nicol prism is,
 (a) partially polarised (b) un polarised
(c) plane polarised (d) elliptically polarised
12. The vertical component of Earth's magnetic field at a place is equal to the horizontal component. What is the value of angle of dip at this place?
 (a) 30° **(b) 45°** (c) 60° (d) 90°
13. The materials used in Robotics are
 (a) Aluminium and silver (b) Silver and gold
 (c) Copper and gold **(d) Steel and aluminium**
14. The threshold wavelength for a metal surface whose photoelectric work function is 3.313 eV is
 (a) 4125Å **(b) 3750Å** (c) 6000Å (d) 20625.Å
15. The principle based on which a solar cell operates is
 (a) Diffusion (b) Recombination
(c) Photovoltaic action (d) Carrier flow

MARCH 2024

1. The principle based on which a solar cell operates is
 (a) **Photovoltaic action** (b) Diffusion
 (c) Carrier flow (d) Recombination

2. If the amplitude of the magnetic field is 3×10^{-6} T, then amplitude of the electric field for a electromagnetic waves is
 (a) 600 Vm^{-1} (b) 100 Vm^{-1} (c) **900 Vm^{-1}** (d) 300 Vm^{-1}

3. A toaster operating at 240V has a resistance of 120Ω . The power is
 (a) 240 W (b) 400 W (c) **480 W** (d) 2 W

4. Atomic number of H-like atom with ionization potential 122.4 V for $n = 1$ is
 (a) 3 (b) 4 (c) 2 (d) 1

5. The transverse nature of light is shown in,
 (a) scattering (b) interference (c) **polarization** (d) diffraction

6. In an oscillating LC circuit, the maximum charge on the capacitor is Q. The charge on the capacitor when the energy is stored equally between the electric and magnetic fields is
 (a) $\frac{Q}{\sqrt{2}}$ (b) $\frac{Q}{2}$ (c) Q (d) $\frac{Q}{\sqrt{3}}$

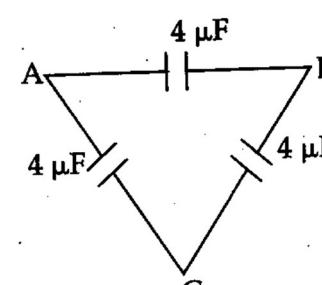
7. A bar magnet of length l and magnetic moment p_m is bent in the form of an arc as shown in figure. The new magnetic dipole moment will be
 (a) $\frac{2}{\pi} p_m$ (b) p_m (c) $\frac{1}{2} p_m$ (d) $\frac{3}{\pi} p_m$

8. The speed of light in an isotropic medium depends on,
 (a) the nature of propagation (b) its intensity
 (c) the motion of the source w.r.t medium (d) **its wavelength**

9. In a series RL circuit, the resistance and inductive reactance are the same. Then the phase difference between the voltage and current in the circuit is
 (a) $\frac{\pi}{6}$ (b) $\frac{\pi}{4}$ (c) zero (d) $\frac{\pi}{2}$

10. Two identical conducting balls having positive charges q_1 and q_2 are separated by a centre to centre distance r . If they are made to touch each other and then separated to the same distance, the force between them will be
 (a) **more than before** (b) less than before (c) zero (d) same as before

11. Three capacitors re connected in tringle as shown in figure. The equivalent capacitance between the points A and C is :



(a) $4 \mu\text{F}$ (b) $2 \mu\text{F}$ (c) $8 \mu\text{F}$ (d) $6 \mu\text{F}$

12. The threshold wavelength for a metal surface whose photoelectric work function is 3.313 eV is
 (a) 6000 Å (b) 4125 Å (c) 2062.5 Å **(d) 3750 Å**
13. Light transmitted by Nicol prism is,
 (a) **plane polarised** (b) partially polarised
 (c) elliptically polarized (d) unpolarised
14. The gravitational waves were theoretically proposed by
 (a) **Albert Einstein** (b) Conrad Rontgen
 (c) Edward Purcell (d) Marie Curie
15. The value of forbidden energy gap for Si at room temperature is :
 (a) 1.1 V (b) 0.7 eV **(c) 1.1eV** (d) 0.7 V

JUNE 2024

1. Which of the following electromagnetic radiation is used for viewing objects through fog?
 (a) microwave (b) gamma rays
 (c) X-rays **(d) infra-red rays**
2. If the input to the NOT gate is A = 1011, its output is :
 (a) **0100** (b) 1000 (c) 1100 (d) 0011
3. The temperature coefficient of resistance of a wire is $0.00125/\text{ }^{\circ}\text{C}$. At $20\text{ }^{\circ}\text{C}$, its resistance is 1Ω . The resistance of the wire will be 2Ω at :
 (a) $800\text{ }^{\circ}\text{C}$ (b) $700\text{ }^{\circ}\text{C}$ (c) $850\text{ }^{\circ}\text{C}$ **(d) 820 $\text{ }^{\circ}\text{C}$**
4. The particle which gives mass to Protons and Neutrons are :
 (a) **Higgs particle** (b) Einstein particle
 (c) Nano particle (d) Bulk particle
5. Stars twinkle due to :
 (a) reflection (b) total internal reflection
(c) refraction (d) polarization
6. In Joule's heating law, when R and t are constant, if H is taken along the Y-axis and I^2 along the X-axis, the graph is a :
 (a) **straight line** (b) parabola
 (c) circle (d) ellipse
7. A non-conducting charged ring carrying a charge of q, mass m and radius r is rotated about its axis with constant angular speed ω . The ratio of its magnetic moment with angular momentum is :
 (a) $\frac{q}{m}$ (b) $\frac{2q}{m}$ **(c) $\frac{q}{2m}$** (d) $\frac{q}{4m}$
8. Emission of electrons by the absorption of heat energy is called ----- emission.
 (a) photoelectric (b) field
(c) thermionic (d) secondary

9. For light incident from air on a glass slab of refractive index 2, the maximum possible angle of refraction is :
(a) **30°** (b) 45° (c) 60° (d) 90°
10. Two points A and B are maintained at a potential of 7 V and – 4 V respectively. The work done in moving 50 electrons from A to B is :
(a) **8.80 x 10⁻¹⁷ J** (b) – 8.80 x 10⁻¹⁷ J
(c) 4.40 x 10⁻¹⁷ J (d) 5.80 x 10⁻¹⁷ J
11. The barrier potential of a silicon diode is approximately:
(a) **0.7 V** (b) 0.3 V (c) 2.0 V (d) 2.2 V
12. A step-down transfer reduces the supply voltage from 220 V to 11 V and increases the current from 6 A to 100 A. Then its efficiency is :
(a) 1.2 (b) **0.83** (c) 0.12 (d) 0.9
13. In a hydrogen atom, the electron revolving in the fourth orbit, has angular momentum equal to :
(a) h (b) $\frac{h}{\pi}$ (c) $\frac{4h}{\pi}$ (d) $\frac{2h}{\pi}$
14. $\frac{20}{\pi^2}$ H inductor is connected to a capacitor of capacitance C. The value of C in order to impart maximum power at 50 Hz is :
(a) 50 μ F (b) 0.5 μ F (c) 500 μ F (d) **5 μ F**
15. In Young's double slit experiment, the slit separated is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed to :
(a) **2 D** (b) $\frac{D}{2}$ (c) $\sqrt{2} D$ (d) $\frac{D}{\sqrt{2}}$

PUBLIC EXAMINATION – TWO MARKS QUESTIONS
MARCH 2019

1. Define electric dipole moment. Give its unit.
2. State Ohm's Law.
3. Define Peltier Coefficient. (Old Syllabus) : Peltier Effect : New Syllabus
4. State De-Morgan's theorems.
5. Write the uses of infra-red rays.
6. What are the characteristics of laser? (Old Syllabus)
7. The de-Broglie wavelength of a neutron of kinetic energy K is λ . When its kinetic energy is $4 K$, what is the de-Broglie wavelength of the neutron?
8. Define curie.
9. The number of turns in the primary of an ideal transformer is 400 and that in the secondary is 2000. If the output power from the secondary at 1000 V is kW then calculate the voltage and current in the primary coil.

MARCH 2020

1. What do you mean by doping?
2. What are the uses of X-rays?
3. 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 coil if the transformer is connected to a 230 V AC main.
4. Distinguish between Fresnel and Fraunhofer types of diffraction.
5. What is corona discharge?
6. What is skip area?
7. What are the properties of neutrino?
8. Two materials X and Y are magnetized whose intensity of magnetization are 500 Am^{-1} and 2000 Am^{-1} respectively. The magnetizing field is 1000 Am^{-1} . What is the ratio between the susceptibilities of the two material?
9. Why electron is preferred over X-ray in microscope?

SEPTEMBER 2020

1. Define skip distance.
2. Calculate the cut-off wavelength and cut-off frequency of X-rays from an X-ray tube of accelerating potential 20,000 V.
3. State Lenz's law.
4. Potential in a given region is given as a function of distance x , $V=5(x^2+x)$ Volt. Find the electric field when $x = 1 \text{ cm}$.
5. What is Photovoltaic cell?
6. What are paraxial rays and marginal rays?
7. What are the constituent particles of Neutron and Proton?
8. What are the uses of X-rays?
9. If an electric field of magnitude 570 NC^{-1} is applied in the copper wire, find the acceleration experienced by the electron.

SEPTEMBER 2021

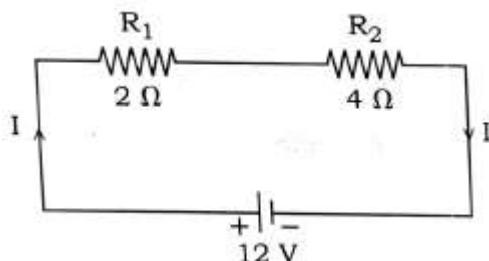
1. Mention the ways of producing induced emf.
2. Find the Polarizing angle for glass of refractive index 1.5
3. What is Peltier effect?
4. Define “Electrostatic Potential”.
5. How will you define threshold frequency?
6. State Ampere’s Circuital Law.
7. Why does sky appear blue?
8. Give two uses of IR radiation.
9. Dielectric strength of air is 4×10^6 Vm⁻¹. Suppose the radius of a hollow sphere in the Van de Graaff generator is $R = 0.4$ m, calculate the maximum potential difference created by this Van de Graaff generator.

MAY 2022

1. What is corona discharge?
2. How will you increase the current sensitivity of a galvanometer?
3. Define work function of a metal. Mention its unit.
4. Calculate the radius of $^{197}_{79} Au$ nucleus.
5. State Fleming’s right hand rule.
6. What do you mean by Doping?
7. What is displacement current?
8. Define electrical resistivity.
9. The angle of minimum deviation for the equilateral prism is 40° . Find the refractive index of the material of the prism.

JULY 2022

1. Mention the ways of producing induced emf.
2. Define stopping potential.
3. Give two uses of UV radiation.
4. Pure water has refractive index 1.33. What is the speed of light through it ?
5. Define ampere in terms of force.
6. What is rectification?
7. State Gauss law.
8. Define atomic mass unit.
9. Calculate the equivalent resistance for the circuit which is connected to 12 V battery and also find the potential difference across 2Ω and 4Ω resistors in the circuit.



MARCH 2023

1. Define 'electric field'.
2. How will you define Q-factor?
3. State Ampere's Circuital Law.
4. Explain the reason for the glittering of diamond.
5. The ratio of intensities of two waves in an interference pattern is 36 : 1. What is the ratio of the amplitudes of the two interfering waves?
6. Define work function of a metal. Give its unit.
7. What is meant by activity or decay rate? Give its unit.
8. Draw the circuit diagram of a full wave rectifier.
9. If the resistance of coil is 3Ω at 20°C and $\alpha = 0.004/\text{^oC}$, then , determine its resistance at 100°C .

JUNE 2023

1. What is photoelectric effect?
2. State Fleming's left hand rule.
3. Find the polarising angle for glass of refractive index 1.5
4. State Lenz's law.
5. What is the reason for reddish appearance of sky during sunset and sunrise?
6. Define capacitance.
7. Distinguish between intrinsic and extrinsic semiconductor.
8. Determine the number of electrons flowing per second through a conductor, when a current of 32 A flows through it?
9. The radius of the 5th orbit of hydrogen atom is 13.25 \AA . Calculate the de Broglie wavelength of the electron orbiting in the 5th orbit.

MARCH 2024

1. What is meant by hysteresis?
2. State Malus' Law
3. Define Electrostatic Potential.
4. A straight metal wire crosses a magnetic field of flux 4 mWb in a time 0.4 s . Find the magnitude of the emf induced in the wire.
5. State the applications of Seebeck Effect.
6. The half-life of radioactive sample is 5.01 days . Calculate the decay constant.
7. What are electromagnetic waves?
8. What is meant by biasing? Mention its types.
9. If the focal length is 150 cm for a glass lens, what is the power of the lens?

JUNE 2024

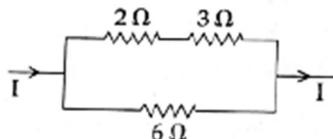
1. Mention the ways of producing induced emf.
2. What is double refraction?
3. Define ionization energy.
4. A copper wire of 10^{-6} m² area of cross section, carries a current of 2 A. Calculate the current density.
5. Why does sky appear blue?
6. State Ampere's Circuital law.
7. Calculate the cut-off wavelength of X-rays from an X-ray tube of accelerating potential 20,000 V
8. Write any two uses of Infrared radiation.
9. A sample of HCl gas is placed in a uniform electric field of magnitude 3×10^4 NC⁻¹. The dipole moment of each HCl molecule is 3.4×10^{-30} cm. Calculate the maximum torque experienced by each HCl molecule.

PUBLIC EXAMINATION – THREE MARKS QUESTIONS

MARCH 2019

1. Write the properties of electric lines of forces.

2.

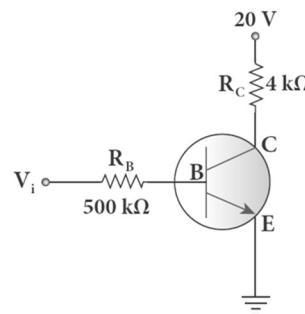


The heat developed across $6\ \Omega$ resistor per second is 50 J. Calculate the heat developed per second across $2\ \Omega$ resistor in the given electric circuit.

3. Write the special features of Magnetic Lorentz force.
4. Obtain an expression for the energy associated with an inductor.
5. Explain frequency modulation.
6. State and obtain Bragg's Law (**Old Syllabus**)
7. Explain length contraction. (**Old Syllabus**)
8. Half lives of two radioactive elements are 12 hrs and 16 hrs respectively. If at any instant, the ratio of the amounts of radioactive substance is 2 : 1 , then after 2 days, What will be the ratio of the un-decayed portions?
9. In Young's double slit experiment two coherent sources of intensity ratio of 64:1, produce interference fringes. Calculate the ratio of maximum and minimum intensities.

MARCH 2020

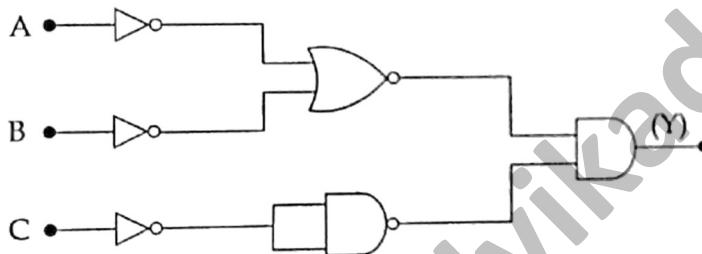
1. Explain the conversion of galvanometer into voltmeter.
2. The resistance of a nichrome wire at 0°C is 10Ω . If its temperature coefficient of resistance is $0.004/\text{ }^\circ\text{C}$, find its resistance at boiling point of water. Comment on the result.
3. What are the important inferences from the average binding energy curve?
4. In the circuit shown in the figure, the input voltage V_i is 20 V, $V_{BE} = 0\text{ V}$ and $V_{CE} = 0\text{ V}$. What are the values of I_B , I_C , β ?



5. Derive the expression for equivalent capacitance, when capacitors are connected in parallel.
6. What are the advantages and disadvantages of AC over DC?
7. Two light sources of equal amplitudes interfere with each other. Calculate the ratio of maximum and minimum intensities.
8. Derive an expression for de-Broglie wavelength of electrons.
9. Modulation helps to reduce the antenna size in wireless communication – Explain.

SEPTEMBER 2020

1. Half lives of two radioactive elements A and B are 20 minutes and 40 minutes respectively. Initially the samples have equal number of nuclei. Calculate the ratio of decayed number of A and B nuclei after 80 minutes.
2. State Kirchhoff's Current and Voltage laws.
3. An $500 \mu\text{H}$, $\frac{80}{\pi^2} \text{ pF}$ capacitor and a 628Ω resistor are connected to form a series RLC circuit. Calculate the resonant frequency and Q-factor of this circuit at
4. Obtain Gauss's law of electrostatics from Coulomb's inverse square law.
5. Compare the properties of dia, para and ferromagnetic materials.
6. Fibre optic communication is gaining popularity among various transmission media. Justify.
7. What are the characteristics of photons?
8. Write the output (Y) Boolean expression for the following circuit with inputs A, B and C.



9. What is total internal reflection? Give the condition for the total internal reflection takes place.

SEPTEMBER 2021

1. State Kirchhoff's current and voltage rule.
2. What are critical angle and total internal reflection?
3. List out the characteristics of Photons.
4. Obtain the expression for energy stored in the parallel plate capacitor.
5. Mention the differences between interference and diffraction.
6. 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.
7. Draw the circuit diagram of a full wave rectifier and draw its input and output waveforms.
8. Mention the various energy losses in a transformer.
9. $^{92}\text{U}^{235}$ nucleus emits 2α particles, 3β particles and 2γ particles. What is the resulting atomic number and mass number?

MAY 2022

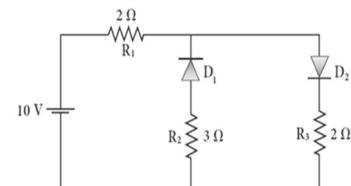
1. Derive the relation between f and R for a spherical mirror.
2. Obtain a relation between current and drift velocity.
3. List out the laws of photo electric effect.
4. Draw the circuit diagram of NPN transistor in Common Emitter Configuration.
5. Give the uses of Polaroids.
6. Derive the expression for resultant capacitance, when capacitors are connected in series.
7. Find the :
 - (i) Angular momentum
 - (ii) Velocity of the electron revolving in the 5th orbit of hydrogen atom.
($h = 6.6 \times 10^{-34} \text{ Js}$; $m = 9.1 \times 10^{-31} \text{ kg}$)
8. List out salient features of magnetic Lorentz force.
9. Find the impedance of a series RLC circuit, if the inductive reactance, capacitive reactance and resistance are 184Ω , 144Ω , and 30Ω respectively. Also calculate the phase angle between voltage and current.

JULY 2022

1. Obtain an expression for energy stored in the parallel plate capacitor.
2. An electron moving perpendicular to a uniform magnetic field 0.500 T undergoes circular motion of radius 2.50 mm . What is the speed of electron?
3. Give the construction and working of a photo emissive cell.
4. Mention the differences between interference and diffraction.
5. What is Zener diode? Mention any two uses of Zener diode.
6. What is Seebeck effect? State the applications of Seebeck effect.
7. What are the properties of Cathode rays?
8. AC is advantageous than DC. Explain.
9. Light travels from air into a glass slab of thickness 50 cm and refractive index 1.5 . What is the speed of light in the glass slab and what is the time taken by the light to travel through the glass slab.

MARCH 2023

1. Derive an expression for electrostatic potential due to a point charge.
2. State Kirchhoff's First and Second Rules.
3. Explain the conversion of galvanometer into an ammeter.
4. How will you induce an emf by changing the area enclosed by the coil?
5. What are Fraunhofer lines? How are they useful in the identification of elements present in the Sun?
6. The given circuit has two ideal diodes connected as shown in figure below. Calculate the current flowing through the resistance R_1



7. What is optical path? Write down the equation for optical path and mention what each term represents.
8. Write any three Laws of Photoelectric Effect.
9. Calculate the amount of energy released in joules when 1 kg of $^{235}_{92}U$ undergoes fission reaction.

JUNE 2023

1. State and explain the principle of potentiometer.
2. Find the ratio of the intensities of light with wavelength 500 nm and 300 nm which undergo Rayleigh scattering.
3. Explain the various energy losses in a transformer.
4. State and prove Brewster's law.
5. Calculate the electric flux through the rectangle of side 5 cm and 10 cm kept in the region of a uniform electric field 100 NC^{-1} . The angle θ is 60° . If θ becomes zero, what is the electric flux?
6. Explain the alpha decay process with example.
7. Write down Maxwell equations in integral form.
8. List out the advantages and limitations of frequency modulation.
9. A coil of a tangent galvanometer of diameter 0.24 m has 100 turns. If the horizontal component of Earth's magnetic field is $25 \times 10^{-6} \text{ T}$ then, calculate the current which gives a deflection of 60° .

MARCH 2024

1. Discuss the Beta⁺ (β^+) decay process with an example.
2. 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 $8.4 \times 10^{28} \text{ m}^{-3}$ then compute the drift velocity of free electrons.
3. Derive the equation for effective focal length for lenses in contact.
4. Define current sensitivity. State the factors which increase the current sensitivity of a galvanometer.
5. How many photons per second emanate from a 50 mW laser of 640 nm?
6. Derive the equation for inductance of a solenoid. Assume that the length of the solenoid is greater than its diameter.
7. What are the differences between interference and diffraction?
8. Obtain Gauss law from Coulomb's law.
9. Determine the wavelength of light emitted from LED which is made up of GaAsP semiconductor whose forbidden energy gap is 1.875 eV. Mention the colour of the light emitted (Take $h = 6.6 \times 10^{-34} \text{ Js}$).

JUNE 2024

1. State and prove De Morgan's first theorem.
2. A coil of 200 turns carries a current of 4 A. If the magnetic flux through the coil is 6×10^{-5} Wb, find the magnetic energy stored in the medium surrounding the coil.
3. List out the characteristics of photons.
4. Explain the equivalent resistance of series resistor network.
5. The radius of the 5th orbit of hydrogen atom is 13.25 Å. Calculate the de Broglie wavelength of the electron orbiting in the 5th orbit.
6. What are the differences between coulomb force and gravitational force ?
7. Derive the relation between f and R for a spherical mirror.
8. Write down the properties of electromagnetic waves.
9. A diffraction grating consists of 4000 slits per centimeter. It is illuminated by a monochromatic light. The second order diffraction maximum is produced at an angle of 30°. What is the wavelength of the light used?

PUBLIC EXAMINATION – FIVE MARKS QUESTIONS
MARCH 2019

1. (a) Derive an expression for electric field intensity due to an electric dipole at a point on its axial line. **(OR)**
(b) Obtain an expression for the magnetic induction at a point due to an infinitely long straight conductor carrying current.
2. (a) State Faraday's II Law of electrolysis. How is it verified experimentally? (Old Syllabus)
(OR)
(b) Explain Raman Scattering of Light. **(Old Syllabus)**
3. (a) Discuss with theory the method of inducing emf in a coil by changing its orientation with respect to the direction of the magnetic field.
(OR)
(b) Explain the working of a half wave diode rectifier.
4. (a) Explain the spectral series of hydrogen atom. (Diagram not necessary)
(OR)
(b) Explain the function of AM radio transmitter with neat block diagram.
5. (a) Explain the construction and working of a Geiger-Muller Counter. (Old Syllabus)
(OR)
(b) Explain the working of photo emissive cell. Write any two applications of photoelectric cells.

MARCH 2020

1. (a) Obtain the expression for the induced emf by changing relative orientation of the coil with the magnetic field (Graph not necessary)
(OR)
(b) Derive the mirror equation and the equation for lateral magnification.
2. (a) Deduce the expression for the force between two long parallel current carrying conductors.
(OR)
(b) Write down Maxwell equations in integral form.
3. (a) Describe Davission – Germer experiment which demonstrated the wave nature of Electrons.
(OR)
(b) (i) Derive an expression for the orbital energy of an electron in hydrogen atom using Bohr theory.

(ii) An electron in Bohr's hydrogen atom has an energy of -3.4 eV. What is the angular momentum of the electron?

4. (a) Explain the working of the transistor as an oscillator.
(OR)
(b) Find out the phase relationship between voltage and current in a pure inductive circuit.
5. (a) State Gauss Law in electrostatics. Obtain an expression for Electric field due to an infinitely long charged wire.
(OR)
(b) How the emf of two cells compared using potentiometer?

SEPTEMBER 2020

1. (a) Explain the construction and working of transformer and define its efficiency.
(OR)
(b) Derive the equation for the angle of deviation produced by a prism and thus obtain the expression for refractive index of material of the prism.
2. (a) Obtain the condition for bridge balance in Wheatstone's bridge.
(OR)
(b) (i) State Ampere's Circuital Law.
(ii) Find the magnetic induction due to a long straight conductor using Ampere's Circuital Law.
3. (a) Derive an expression for the radius of the orbit of electron in an atom using Bohr atom model.
(OR)
(b) (i) Write down any six properties of electromagnetic wave.
(ii) Compute the speed of electromagnetic wave in a medium if the amplitudes of electric and magnetic fields in it are $3 \times 10^4 \text{ NC}^{-1}$ and $2 \times 10^{-4} \text{ T}$ respectively.
4. (a) Obtain Lens Maker's Formula, from that derive Lens equation.
(OR)
(b) Describe the function of transistor as an amplifier with the neat circuit diagram. Sketch the input and output waveform.
5. (a) (i) Obtain Einstein's Photoelectric equation with necessary explanation.
(ii) What will happen to the stopping potential in the following cases when;
(A) Work function of the metal is increased.
(B) Intensity of incident ray is increased.
(OR)
(b) Explain in detail the effect of introducing a dielectric medium between the plates of a parallel plate capacitor, when the capacitor is disconnected from the battery.

SEPTEMBER 2021

1. (a) Deduce the relation for the magnetic field at a point due to an infinitely long straight conductor carrying current.
(OR)
(b) Obtain the law of radioactivity.
2. (a) Calculate the electric field due to a dipole on its axial line.
(OR)
(b) What is Frequency Modulation? List out the advantages and limitations of frequency modulation.
3. (a) (i) Derive an expression for de-Broglie wavelength of electrons.
(ii) Calculate the momentum of an electron with kinetic energy 2 eV.
(OR)
(b) Write down Maxwell equations in integral form.
4. (a) Explain about Astronomical telescope and obtain the equation for the magnification.
(OR)
(b) (i) Explain the equivalent resistance of a series resistor network.
(ii) 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 $8.4 \times 10^{28} \text{ m}^{-3}$ then compute the drift velocity of free electrons.
5. (a) Obtain Lens maker's formula.
(OR)
(b) Derive an expression for phase angle between the applied voltage and current in a series RLC circuit.

MAY 2022

1. (a) Explain the construction and working of full wave rectifier.
(OR)
(b) Explain the construction and working of transformer.
2. (a) Derive an expression for electrostatic potential due to an electric dipole.
(OR)
(b) Obtain the equation for bandwidth in Young's Double Slit Experiment.
3. (a) Using Biot-Savart Law deduce the relation for the magnetic field at a point due to an infinitely long straight conductor carrying current.
(OR)
(b) Discuss the spectral series of hydrogen atom.
4. (a) (i) How do you obtain characteristic X-ray spectra?
(ii) Calculate the cut-off wavelength and cut-off frequency of X-rays from an X-ray tube of accelerating potential 20,000 V.
(OR)
(b) What is spectrum? Explain the types of emission spectrum.

5. (a) Obtain Lens maker's formula.
(OR)
(b) Explain the determination of the internal resistance of cell using voltmeter.

JULY 2022

1. (a) Obtain the condition for bridge balance in Wheatstone's bridge.
(OR)
(b) (i) What is half-life and mean life of a radioactive nucleus?
(ii) Calculate the number of nuclei of carbon-14 un-decayed after 22,920 years if the initial number of carbon-14 atoms is 10,000. The half – life of carbon-14 is 5730 years.
2. (a) Describe the Fizeau's method to determine the speed of light.
(OR)
(b) (i) Write down the properties of electromagnetic waves.
(ii) The relative magnetic permeability of the medium is 2.5 and the relative electrical permittivity of the medium is 2.25. Compute the refractive index of the medium.
3. (a) Explain in detail the construction and working of a Van de Graaff generator.
(OR)
(b) Explain about Compound Microscope and obtain the equation for the Magnification.
4. (a) Show that the mutual inductance between a pair of coils is same ($M_{12} = M_{21}$).
(OR)
(b) State and prove De Morgan's first and second theorem.
5. (a) (i) Obtain Einstein's photoelectric equation with necessary explanation.
(ii) List out the characteristics of photons.
(OR)
(b) Derive the expression for the force on a current carrying conductor in a magnetic field.

MARCH 2023

1. (a) (i) State Coulomb's Law in electrostatics
(ii) State the differences between Coulomb force and Gravitational force.
(OR)
(b) Describe the Fizeau's method to determine the speed of light.
2. (a) Discuss the working of Cyclotron in detail.
(OR)
(b) Discuss the diffraction at single slit and obtain the condition for n^{th} minimum.

3. (a) Derive an expression for phase angle between the applied voltage and current in a series RLC circuit.
- (OR)**
- (b) Describe Davisson-Germer experiment which demonstrated the wave nature of the electrons.
4. (a) Describe the microscopic model of current and obtain microscopic form of Ohm's Law.
- (OR)**
- (b) Derive an expression for Radius and Velocity of an electron in the n^{th} orbit using Bohr atom model.
5. (a) (i) Write down the properties of electromagnetic waves.
(ii) The relative magnetic permeability of the medium is 2.5 and the relative electrical permittivity of the medium is 2.25. Compute the refractive index of the medium.
- (OR)**
- (b) Describe the function of a transistor as an amplifier with the neat circuit diagram. Sketch the input and output waveforms.

JUNE 2023

1. (a) What is absorption spectrum? Explain its types.
- (OR)**
- (b) Obtain the law of radioactive decay.
2. (a) Obtain the conditions for bridge balance in Whetstone's bridge.
- (OR)**
- (b) Obtain the equation for bandwidth in Young's double slit experiment.
3. (a) Explain in detail the principle, construction and working of a Van de Graff generator.
- (OR)**
- (b) What is dispersion? Obtain the equation for dispersive power of a medium.
4. (a) (i) State Ampere's circuital law.
(ii) Find the magnetic field due to long, straight conductor using Ampere's circuital law.
- (OR)**
- (b) State and prove De Morgan's first and second theorems.
5. (a) Explain the working of a single - phase AC generators with necessary diagram.
- (OR)**
- (b) (i) List out the characteristics of photons. (any two)
(ii) Calculate the momentum of an electron with kinetic energy 2 eV

MARCH 2024

1. (a) Explain about simple microscope and obtain equation for magnification for near point focusing and normal focusing.
(OR)
(b) Explain the determination of unknown resistance using metre bridge.
2. (a) Calculate the magnetic field produced at a point along the axis of the current carrying circular coil. Write down the equation of the magnetic field at the centre of the coil using Biot-Savar law.
(OR)
(b) Derive the equation for angle of deviation produced by a prism and thus obtain the equation for refractive index of material of the prism.
3. (a) Obtain Einstein's photoelectric equation with necessary explanations.
(OR)
(b) Find out the phase relationship between the voltage and current in a pure inductive circuit. Draw the phase and wave diagrams.
4. (a) List out the advantages and limitations of frequency modulation.
(OR)
(b) Explain the Maxwell's modifications of Ampere's circuit law.
5. (a) Calculate the electric field due to a dipole at a point on the axial line.
(OR)
(b) What is nuclear reactor? Write note on Moderators, Control rods and Cooling system.

JUNE 2024

1. (a) (i) What is rectification?
(ii) Draw the circuit diagram of a half wave rectifier and explain its working.
OR
(b) Show mathematically that the rotation of a coil in a magnetic field over one rotation induces an alternating emf of one cycle.
2. (a) Deduce the relation for the magnetic field at a point due to an infinitely long straight conductor carrying current using Biot-savart law.
OR
(b) Derive an expression for de Broglie wavelength of matter waves and electrons.
3. (a) Derive an expression for electrostatic potential due to an electric dipole.
OR
(b) Explain about compound microscope and obtain the equation for the magnification.

4. (a) Write down Maxwell equations in integral form.
OR
(b) Explain the J.J Thomson experiment to determine the specific charge of electron.
5. (a) Derive the mirror equation.
OR
(b) How the emf of two cells are compared using potentiometer?

**PUBLIC EXAMINATION YEAR WISE (MARCH 2019 – JUNE 2024)
(TWO MARKS NUMERICAL PROBLEMS QUESTION WITH SOLUTION)**

- 1. The de-Broglie wavelength of a neutron of kinetic energy K is λ . When its kinetic Energy is 4 K, what is the de-Broglie wavelength of the neutron? (MARCH – 2019)**

$$\text{de Broglie wavelength } \lambda = \frac{h}{\sqrt{2mE}} \quad \text{Here } E = K$$

$$\text{de Broglie wavelength } \lambda = \frac{h}{\sqrt{2mK}} \quad E = 4K$$

$$\text{de Broglie wavelength } \lambda' = \frac{h}{\sqrt{2m4k}} ; \lambda' = \frac{h}{2\sqrt{2mk}} \quad (\text{or}) \lambda' = \frac{h}{2}$$

- 2. The number of turns in the primary of an ideal transformer is 400 and that in the secondary 2000. If the output power from the secondary at 1000 V is kW then calculate the voltage and current in the primary coil. (MARCH – 2019)**

$$\frac{E_S}{E_P} = \frac{N_S}{N_P} ; E_P = 1000 \times \frac{400}{2000} ; E_P = 200 \text{ V}$$

Ideal Transformer = $E_P I_P = E_S I_S$

$$I_P = \frac{10000}{200} ; I_P = 50 \text{ A}$$

- 3. 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 coil if the transformer is connected to a 230 V AC main. (MARCH – 2020)**

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

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

- 4. Two materials X and Y are magnetized whose intensity of magnetization are 500 Am^{-1} and 2000 Am^{-1} respectively. The magnetizing field is 1000 Am^{-1} . What is the ratio between the susceptibilities of the two material? (MARCH – 2020)**

$$\text{The susceptibility of material X is } \chi_m X = \frac{|\vec{M}|}{|\vec{H}|} = \frac{500}{1000} = 0.5$$

$$\text{The susceptibility of material Y is } \chi_m Y = \frac{|\vec{M}|}{|\vec{H}|} = \frac{2000}{1000} = 2$$

Since, susceptibility of material Y is greater than that of material X, material Y can be easily magnetized than X. $0.5 : 4$ or $1 : 4$

- 5. An electron in Bohr's hydrogen atom has an energy of -3.4 eV . What is the angular momentum of the electron? (MARCH – 2020)**

$$\text{Total Energy } E_n = \frac{-13.6}{-3.4} = 4 : n^2 = 4 : n = 2$$

$$\text{Angular momentum } L = \frac{nh}{2\pi} ; = \frac{h}{\pi} ; = \frac{6.63 \times 10^{-34}}{3.14}$$

$$L = 2.11 \times 10^{-34} \text{ kg m}^2 \text{s}^{-1}$$

- 6. Calculate the cut-off wavelength and cut-off frequency of X-rays from an X-ray tube of accelerating potential 20,000 V.**

(SEPTEMBER – 2020, MAY – 2022, JUNE - 2024)

$$\begin{aligned}\text{The cut-off wavelength of the characteristic x-rays is } \lambda_0 &= \frac{12400}{V} \text{ \AA} \\ &= \frac{12400}{20000} \text{ \AA} ; = 0.62 \text{ \AA}\end{aligned}$$

$$\text{The corresponding frequency is } v_0 = \frac{c}{\lambda_0} ; = \frac{3 \times 10^8}{0.62 \times 10^{-10}} ; v_0 = 4.84 \times 10^{18} \text{ Hz}$$

- 7. Potential in a given region is given as a function of distance x, $V=5(x^2+x)$ Volt. Find the electric field when $x = 1$ cm. (SEPTEMBER – 2020)**

$$\begin{aligned}E &= \frac{dv}{dx} ; = \frac{d}{dx} (5x^2 + 5x) ; \\ &= 10x + 5 ; x = 1 ; E = 10 + 5 = 15 \text{ Vcm}^{-1}\end{aligned}$$

- 8. If an electric field of magnitude 570 NC^{-1} . Is applied in the copper wire, find the experienced by the electron. (SEPTEMBER – 2020)**

$$a = \frac{Ee}{m} ; = \frac{570 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}} ; a = 100.29 \times 10^{12} \text{ ms}^{-2}$$

- 9. Compute the speed of electromagnetic wave in a medium if the amplitudes of electric and magnetic fields in it are $3 \times 10^4 \text{ NC}^{-1}$ and $2 \times 10^{-4} \text{ T}$ respectively.**

(SEPTEMBER – 2020)

$$\text{Speed of the electromagnetic wave in a medium is } v = \frac{E}{B}$$

$$v = \frac{3 \times 10^4}{2 \times 10^{-4}} ; v = 1.5 \times 10^8 \text{ ms}^{-1}$$

- 10. Find the Polarizing angle for glass of refractive index 1.5.**

(SEPTEMBER – 2021, JUNE – 2023)

Brewster's law, $\tan i_p = n$

For glass, $\tan i_p = 1.5$; $i_p = \tan^{-1} 1.5$; $i_p = 56.3^\circ$

- 11. Dielectric strength of air is $4 \times 10^6 \text{ Vm}^{-1}$. Suppose the radius of a hollow sphere in the Van de-Graaff generator is $R = 0.4 \text{ m}$, calculate the maximum potential difference created by this Van de Graaff generator. (SEPTEMBER – 2021)**

The electric field on the surface of the sphere (by Gauss law) is given by

$$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{R^2}$$

The potential on the surface of the hollow metallic sphere is given by

$$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{R} = ER ; \quad \text{With } V_{\max} = E_{\max} R$$

Here $E_{\max} = 4 \times 10^6 \frac{V}{m}$. So, the maximum potential difference created is given by $V_{\max} = 4 \times 10^6 \times 0.4$; **$V_{\max} = 1.6 \times 10^6 \text{ V (or) 1.6 million volt}$**

- 12. Calculate the momentum of an electron with kinetic energy 2 eV.**

(SEPTEMBER – 2021, JUNE – 2023)

Momentum of the electron is

$$p = \sqrt{2mK} = \sqrt{2 \times 9.1 \times 10^{-31} \times 2 \times 1.6 \times 10^{-19}} ; \sqrt{58.24 \times 10^{-50}}$$

$$p = 7.63 \times 10^{-25} \text{ kg ms}^{-1}$$

- 13. 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 $8.4 \times 10^{28} \text{ m}^{-3}$ then compute the drift velocity of free electrons. (SEPTEMBER – 2021)**

The relation between drift velocity of electrons and current in a wire of cross-

$$\text{sectional area } A \text{ is } V_d = \frac{I}{neA} ; = \frac{0.2}{8.4 \times 10^{28} \times 1.6 \times 10^{-19} \times 0.5 \times 10^{-6}} ;$$

$$= \frac{2 \times 10^{-3}}{6.72} \quad V_d = 0.03 \times 10^{-3} \text{ ms}^{-1}$$

- 14. Calculate the radius of $^{197}_{79} \text{Au}$ nucleus. (MAY – 2022)**

$$(R = R_0 A^{\frac{1}{3}}), R = 1.2 \times 10^{-15} \times (197)^{\frac{1}{3}}$$

$$= 6.97 \times 10^{-15} \text{ m (or) } R = 6.97 \text{ F}$$

- 15. The angle of minimum deviation for the equilateral prism is 40° . Find the refractive index of the material of the prism. (MAY – 2022)**

$$\text{Equation for refractive index is, } n = \frac{\sin \left(\frac{A+D}{2} \right)}{\sin \left(\frac{A}{2} \right)}$$

$$\text{Substituting the values, } n = \frac{\sin \left(\frac{60^\circ + 40^\circ}{2} \right)}{\sin \left(\frac{60^\circ}{2} \right)} ; = \frac{\sin (50^\circ)}{\sin (30^\circ)} ; = \frac{0.766}{0.5} ; = 1.532;$$

The refractive index of the material of the prism is, $n = 1.532$ (No Unit)

- 16. Pure water has refractive index 1.33. What is the speed of light through it?
(JULY – 2022)**

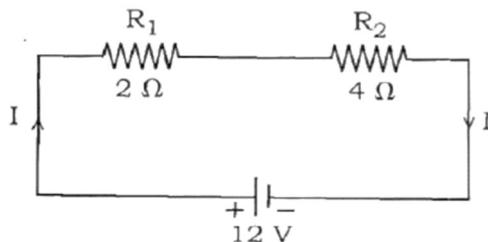
$$n = \frac{c}{v} ; v = \frac{c}{n} ; v = \frac{3 \times 10^8}{1.33} ; = 2.25 \times 10^8 \text{ ms}^{-1}$$

Light travels with a speed of $2.25 \times 10^8 \text{ ms}^{-1}$ through pure water.

- 17. The relative magnetic permeability of the medium is 2.5 and the relative electrical permittivity of the medium is 2.25. Compute the refractive index of the medium. (JULY – 2022, MARCH – 2023)**

$$\text{Refractive index of the medium, } n = \sqrt{\epsilon_r \mu_r} ; = \sqrt{2.25 \times 2.5} ; \\ = \sqrt{5.625} ; n = 2.37 \text{ No Unit}$$

- 18. Calculate the equivalent resistance for the circuit which is connected to 12 V battery and find the potential difference across 2Ω and 4Ω resistors in the circuit. (JULY – 2022)**



Since the resistors are connected in series, the effective resistance in the circuit = $2\Omega + 4\Omega = 6\Omega$

$$\text{The Current } I \text{ in the circuit} = \frac{V}{R_{eq}} = \frac{12}{6} = 2 \text{ A}$$

Voltage across 4Ω resistor

$$V_1 = IR_1 = 2A \times 2\Omega = 4 \text{ V}$$

Voltage across 6 Ω resistors

$$V_2 = IR_2 = 2A \times 4\Omega = 8 \text{ V}$$

- 19. The ratio of intensities of two waves in an interference pattern is 36 : 1. What is the ratio of the amplitudes of the two interfering waves? (MARCH – 2023)**

$$I \propto a^2 \quad (\text{OR}) \quad I_1 \propto a_1^2 \quad (\text{OR}) \quad I_2 \propto a_2^2$$

$$\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} \quad (\text{OR}) \quad \frac{a_1}{a_2} = \sqrt{\frac{I_1}{I_2}} = \sqrt{\frac{36}{1}} ; \frac{a_1}{a_2} = \frac{6}{1}$$

$$I \propto a^2 \quad (\text{OR}) \quad I_{ma} \propto (a_1 + a_2)^2 \text{ and } I_{min} \propto (a_1 - a_2)^2$$

$$\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} \quad (\text{OR}) \quad \frac{a_1+a_2}{a_1-a_2} = \sqrt{\frac{I_{max}}{I_{min}}} = \sqrt{\frac{36}{1}}$$

$$\frac{(a_1+a_2)}{(a_1-a_2)} = \frac{6}{1} \quad (\text{OR}) \quad \frac{a_1}{a_2} = \frac{7}{5}$$

- 20. If the resistance of coil is 3Ω at 20° C and α = 0.004/°C, then , determine its resistance at 100°C. (MARCH – 2023)**

$$R_T = R_0(1 + \alpha(T-T_0))$$

$$R_{100} = 3(1 + 0.004 \times 80) ; R_{100} = 3(1 + 0.32)$$

$$R_{100} = 3(1.32) ; R_{100} = 3.96 \Omega$$

- 21. Determine the number of electrons flowing per second through a conductor, when a current of 32 A flows through it? (JUNE – 2023)**

I = 32 A, t = 1 s Charge of an electron, e = 1.6×10^{-19} C The number of electrons flowing per second, n = ?

$$I = \frac{q}{t} = \frac{ne}{t} ; n = \frac{It}{e} ; n = \frac{32 \times 1}{1.6 \times 10^{-19} \text{ C}}$$

$$n = 20 \times 10^{19} ; n = 2 \times 10^{20} \text{ electrons}$$

- 22. The radius of the 5th orbit of hydrogen atom is 13.25 Å. Calculate the de Broglie wavelength of the electron orbiting in the 5th orbit. (JUNE – 2023, JUNE - 2024)**

$$2\pi r = n\lambda ; 2 \times 3.14 \times 13.25 \text{ Å} = 5 \times \lambda ; \therefore \lambda = 16.64 \text{ Å}$$

$$(\text{or}) \lambda = \frac{2\pi r}{n} ; = \frac{2 \times 3.14 \times 13.24 \times 10^{-10}}{5} ; = 2 \times 3.14 \times 2.68 \times 10^{-10}$$

$$\lambda = 16.64 \times 10^{-10} \text{ m} ; \lambda = 16.64 \text{ Å}$$

- 23. A straight metal wire crosses a magnetic field of flux 4 mWb in a time 0.4 s. Find the magnitude of the emf induced in the wire. (MARCH – 2024)**

Magnetic flux (ϕ) = 4 mWb = 4×10^{-3} Wb ; time (t) = 0.4 Sec.

$$\text{The magnitude of induced emf (e)} = \frac{d\phi}{dt} = \frac{4 \times 10^{-3}}{0.4} = 10^{-2} ; e = 10 \text{ mV}$$

- 24. The half-life of radioactive sample is 5.01 days. Calculate the decay constant. (MARCH – 2024)**

$$\lambda = \frac{0.6931}{T_{1/2}} ; = \frac{0.6931}{5.01 \text{ Day}} \lambda = 0.1383 \text{ d}^{-1}$$

$$(\text{or}) \lambda = \frac{0.6931}{T_{1/2}} ; = \frac{0.6931}{5.01 \times 24 \times 60 \times 60} ; \lambda = 1.6 \times 10^{-6} \text{ s}^{-1}$$

- 25. If the focal length is 150 cm for a glass lens, what is the power of the lens? (MARCH – 2024)**

focal length, f = 150 cm (or) f = 1.5 m

$$\text{Equation for power of lens is, } P = \frac{1}{f}$$

$$\text{Substituting the values, } P = \frac{1}{1.5} = 0.67 \text{ diopter}$$

As the power is positive, it is a converging lens.

- 26. A copper wire of 10^{-6} m^2 area of cross section, carries a current of 2 A. If the number of electrons per cubic meter is 8×10^{28} , calculate the current density and average drift velocity. (JUNE – 2024)**

Solution:

Cross – sections area of copper wire, A = 10^{-6} m^2 , I = 2A

Number of electron, n = 8×10^{28}

$$\text{Current density, } J = \frac{I}{A} = \frac{2}{10^{-6}} ; J = 2 \times 10^6 \text{ Am}^{-2}$$

$$\text{Average drift velocity, } V_d = \frac{I}{neA}$$

e is the charge of electron = $1.6 \times 10^{-19} \text{ C}$

$$V_d = \frac{2}{8 \times 10^{28} \times 1.6 \times 10^{-19} \times 10^{-6}} = \frac{1}{64 \times 10^3}$$

$$V_d = 0.15625 \times 10^{-3} ; V_d = 15.625 \times 10^{-3} \text{ ms}^{-1}$$

No.	Log
1	0.0000
6.490	0.8062
(–)	1.1938
Antilog	1.562×10^{-1}

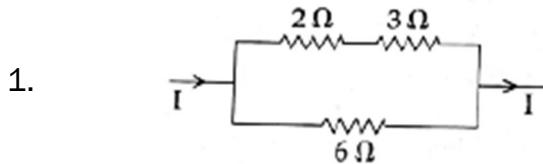
27. A sample of HCl gas is placed in a uniform electric field of magnitude 3×10^4 N C⁻¹. The dipole moment of each HCl molecule is 3.4×10^{-30} Cm. Calculate the maximum torque experienced by each HCl molecule. (JUNE – 2024)

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

$$\tau_{max} = pE \sin 90^\circ ; = 3.4 \times 10^{-30} \times 3 \times 10^4 \text{ N m}$$

$$\tau_{max} = 10.2 \times 10^{-26} \text{ Nm}$$

**PUBLIC EXAMINATION YEAR WISE (MARCH 2019 – JUNE 2024)
(THREE MARKS NUMERICAL PROBLEMS QUESTION WITH SOLUTION)**



The heat developed across $6\ \Omega$ resistor per second is 50 J. Calculate the heat developed per second across $2\ \Omega$ resistor in the given electric circuit.

(MARCH – 2019)

$$H = \frac{V^2 t}{R} ; = \frac{V^2 \times 1}{6} ; = V^2 = 6H ; V^2 = 6 \times 50 ; V^2 = 300$$

$$I_1 = \frac{V}{(R_1 + R_2)} ; = \frac{\sqrt{300}}{5}$$

$$H = I^2 R t ; = \frac{300}{25} \times 2 \times 1 ; H = 24J$$

2. **Half lives of two radioactive elements are 12 hrs and 16 hrs respectively. If at any instant, the ratio of the amounts of radioactive substance is 2 : 1 , then after 2 days, What will be the ratio of the un-decayed portions? (MARCH – 2019)**

$$N_1 = (N_0)_1 (\frac{1}{2})^{n_1} \quad \dots \dots 1$$

$$N_2 = (N_0)_2 (\frac{1}{2})^{n_2} \quad \dots \dots 2$$

$$n_1 = \frac{2 \times 24}{12} = 4 ; n_2 = \frac{2 \times 24}{16} = 3 \quad \dots \dots 3$$

$$n_1 = \frac{2 \times 24}{12} = 4 ;$$

$$\frac{(N_0)_1}{(N_0)_2} = \frac{2}{1} ; \frac{N_1}{N_2} = \frac{2 \left(\frac{1}{2}\right)^4}{1 \left(\frac{1}{2}\right)^3} ; \frac{N_1}{N_2} = 2 \times \frac{1}{2} ; \frac{N_1}{N_2} = 1 \quad N_1 : N_2 = 1 : 1$$

3. **In Young's double slit experiment two coherent sources of intensity ratio of 64:1, produce interference fringes. Calculate the ratio of maximum and minimum intensities. (MARCH – 2019)**

$$\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{64}{1} = \frac{a_1}{a_2} = \frac{8}{1} \quad a_1 = 8a_2$$

$$\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} ; = \frac{(8a_2 + a_2)^2}{(8a_2 - a_2)^2} ; = \frac{(9a_2)^2}{(7a_2)^2} ; = \frac{81}{49}$$

$$I_{max} : I_{min} : 81 : 49$$

4. **Two light sources of equal amplitudes interfere with each other. Calculate the ratio of maximum and minimum intensities. (MARCH – 2019)**

$$I \propto 4a^2 \cos^2 \left(\frac{\phi}{2} \right) \text{ (or) } I = 4 I_0 \cos^2 \left(\frac{\phi}{2} \right)$$

Resultant Intensity for maximum : $\phi = 0$, $\cos \theta = 1$; $I_{max} \propto 4a^2$

Resultant Intensity for minimum : $\phi = \pi$, $\cos \frac{\pi}{2} = 0$; $I_{min} \propto 0$

$$I_{max} = I_{min} = 4a^2 : 0$$

5. The resistance of a nichrome wire at 0°C is 10Ω . If its temperature coefficient of resistance is $0.004/\text{ }^\circ\text{C}$, find its resistance at boiling point of water. Comment on the result. (MARCH – 2020)

Temperature of boiling point of water,

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

$$R_T = 10(1+0.4) = 10 \times 1.4 ; R_T = 14 \Omega$$

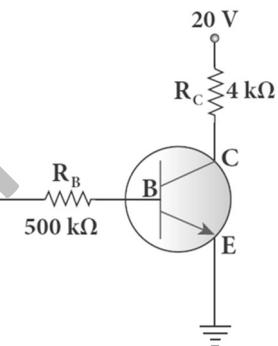
As the temperature increases the resistance of the wire also increases.

6. In the circuit shown in the figure, the input voltage V_i is 20 V, $V_{BE} = 0$ V and $V_{CE} = 0$ V. What are the values of I_B , I_C , β ? (MARCH – 2020)

$$I_B = \frac{V_i}{R_B} = \frac{20 \text{ V}}{500 \text{ k}\Omega} ; = 40 \mu\text{A} \quad [\because V_{BE} = 0\text{V}]$$

$$I_C = \frac{V_{CC}}{R_C} = \frac{20 \text{ V}}{4 \text{ k}\Omega} ; = 5 \text{ mA} \quad [\because V_{CE} = 0\text{V}]$$

$$\beta = \frac{I_C}{I_B} = \frac{5 \text{ mA}}{40 \mu\text{A}} ; \beta = 125$$



7. Half lives of two radioactive elements A and B are 20 minutes and 40 minutes respectively. Initially the samples have equal number of nuclei. Calculate the ratio of decayed number of A and B nuclei after 80 minutes.

(SEPTEMBER – 2020)

Decayed part of A atom : $\frac{15}{16}$ or 93.75 %

Decayed part of B atom : $\frac{3}{4}$ or 75 %

Ratio between A and B atom $\frac{N_A}{N_B} = \frac{5}{4}$ or $N_A = N_B = 5 : 4$

$N_A = N_B = 1.25\%$ (or)

80 minutes = 4 half-lives of A = 2 half live of B

Let the initial number of nuclei in each sample be N.

$$N_A \text{ after 80 minutes} = \frac{N}{2^4}$$

$$\text{Number of A nuclides decayed} = \frac{15}{16} N$$

$$N_B \text{ after 80 minutes} = \frac{N}{2^4}$$

$$\text{Number of B nuclides decayed} = \frac{3}{4} N$$

$$\text{Required ratio} = \frac{15}{16} \times \frac{4}{3} = \frac{5}{4} ; N_A : N_B = 5 : 4$$

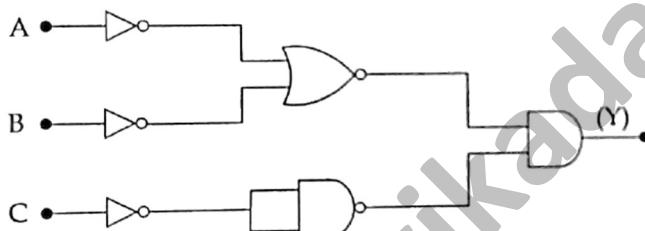
8. An $500 \mu\text{H}$, $\frac{80}{\pi^2} \text{ pF}$ capacitor and a 628Ω resistor are connected to form a series RLC circuit. Calculate the resonant frequency and Q-factor of this circuit at resonance. (SEPTEMBER – 2020)

$$f = \frac{1}{2\pi\sqrt{LC}} ; = \frac{1}{2\pi\sqrt{500 \times 10^{-6} \times \frac{80}{\pi^2} \times 10^{-12}}} \\ = \frac{1}{2\sqrt{40000 \times 10^{-10}}} ; = \frac{10000 \times 10^3}{4} ; f = 2500 \text{ kHz}$$

$$\text{Q factor} = \frac{\omega_r L}{R}, \frac{2 \times 3.14 \times 2500 \times 10^3 \times 500 \times 10^{-6}}{628}$$

$$\text{Q factor} = 12.5$$

9. Write the output (Y) Boolean expression for the following circuit with inputs A, B and C. (SEPTEMBER – 2020)



Output of A and B = $\overline{A + B}$ or \overline{AB} or AB

Output of C = C

Output of circuit Y = ABC

10. 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. (SEPTEMBER – 2021)

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 = 10×10^{-2} m

Therefore, $9 \times 10^{-3} = 10^{-7} \times \frac{q_m^2}{(10 \times 10^{-2})^2} \Rightarrow q_m^2 = 900 ; q_m = 30 \text{ NT}^{-1}$

11. $^{92}\text{U}^{235}$ nucleus emits 2α particles, 3β particles and 2γ particles. What is the resulting atomic number and mass number? (SEPTEMBER – 2021)

The α - decay process symbolically written as ${}_{Z}^{A}\text{X} \rightarrow {}_{Z-2}^{A-4}\text{Y} + {}_2^4\text{He}$.

(e.g.) ${}_{92}^{235}\text{U} \rightarrow 2\alpha \ {}_{92-4}^{235-8}\text{X} + 2{}_{2}^4\text{He} ; {}_{88}^{227}\text{X} + 2{}_{2}^4\text{He}$

In β^- decay,

${}_{Z}^{A}\text{X} \rightarrow {}_{Z+1}^{A}\text{Y} + {}_{-1}^0\text{e} + \bar{\nu}$. (e.g.) ${}_{88+}^{227}\text{Y} + 3 {}_{-1}^0\text{e} ; {}_{91}^{227}\text{Y} + 3 {}_{-1}^0\text{e}$

During gamma decay there is no change in atomic number and mass number.

${}_{Z}^{A}\text{X}^* \rightarrow {}_{Z}^{A}\text{X} + \text{gamma rays } (\gamma)$

12. Find the:

- (i) **Angular momentum**
- (ii) **Velocity of the electron revolving in the 5th orbit of hydrogen atom.**
($h = 6.6 \times 10^{-34} \text{ Js}$; $m = 9.1 \times 10^{-31} \text{ kg}$) (MAY – 2022)

$$(i) \text{Angular momentum is given by } = n\hbar = \frac{n\hbar}{2\pi} ; = \frac{5 \times 6.6 \times 10^{-34}}{2 \times 3.14} \\ = 5.25 \times 10^{-34} \text{ kgm}^2\text{s}^{-1}$$

$$(ii) \text{Velocity is given by velocity, } = \frac{l}{mr} ; = \frac{(5.25 \times 10^{-34} \text{ kgm}^2\text{s}^{-1})}{(9.1 \times 10^{-31} \text{ kg})(13.25 \times 10^{-10} \text{ m})} \\ v = 4.4 \times 10^5 \text{ ms}^{-1}$$

13. 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. (MAY – 2022)

$$(i) \text{The impedance is Impedance, } Z = \sqrt{R^2 + (X_L - X_C)^2} \\ = \sqrt{30^2 + (184 - 144)^2} ; = \sqrt{900 + 1600}$$

$$\text{Impedance, } Z = 50 \Omega$$

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

14. Light travels from air into a glass slab of thickness 50 cm and refractive index 1.5.

(a) What is the speed of light in the glass slab?

(b) What is the time taken by the light to travel through the glass slab?

(JULY – 2022)

$$\text{Speed of light in glass is, } v = \frac{c}{n} ; = \frac{3 \times 10^8}{1.5} ; = 2 \times 10^8 \text{ ms}^{-1}$$

Time taken by light to travel through glass slab is,

$$t = \frac{d}{v} ; = \frac{0.5}{2 \times 10^8} = 2.5 \times 10^{-9} \text{ s}$$

Optical path, $d' = nd = 1.5 \times 0.5 ; = 0.75 \text{ m} ; = 75 \text{ cm}$

Light would have travelled 25 cm more ($75 \text{ cm} - 50 \text{ cm}$) in vacuum by the same time had there not been a glass slab.

15. Calculate the number of nuclei of carbon-14 un-decayed after 22,920 years if the initial number of carbon-14 atoms is 10,000. The half-life of carbon-14 is 5730 years. (JULY – 2022)

$$\text{To get the time interval in terms of half-life, } n = \frac{t}{T_{1/2}} = \frac{22920 \text{ years}}{5730 \text{ years}} = 4$$

The number of nuclei remaining un-decayed after 22,920 years,

$$N = \left(\frac{1}{2}\right)^n N_0 ; = \left(\frac{1}{2}\right)^4 \times 10000 ; N = 625$$

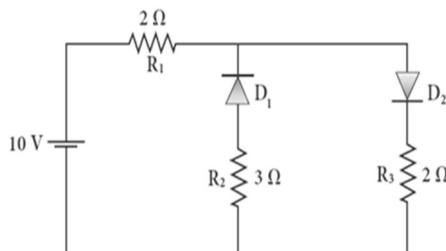
- 16. An electron moving perpendicular to a uniform magnetic field 0.500 T Undergoes circular motion of radius 2.50 mm. What is the speed of electron?**
(JULY – 2022)

$$\text{Velocity of the electron, } v = |q| \frac{rB}{m}$$

$$v = 1.60 \times 10^{-19} \times \frac{2.50 \times 10^{-3} \times 0.500}{9.11 \times 10^{-31}} ;$$

$$v = 2.195 \times 10^8 \text{ ms}^{-1}$$

- 17. The given circuit has two ideal diodes connected as shown in figure below. Calculate the current flowing through the resistance R_1 (MARCH – 2023)**



Diode D_1 is reverse biased so, it will block the current and Diode D_2 is forward biased, so it will pass the current.

$$R_{\text{net}} = 2 + 2 = 4\Omega$$

$$\text{Current in the circuit is } I = \frac{V}{R} ; = \frac{10}{2+2} = \frac{10}{4} ;$$

$$I = 2.5\text{A}$$

- 18. Calculate the amount of energy released in joules when 1 kg of $^{235}_{92}\text{U}$ undergoes fission reaction. (MARCH – 2023)**

235 g of $^{235}_{92}\text{U}$ has 6.02×10^{23} atoms. In one gram of $^{235}_{92}\text{U}$, the number of atoms is equal to $\frac{6.02 \times 10^{23}}{235} = 2.56 \times 10^{21}$;

So the number of atoms present in 1 kg of $^{235}_{92}\text{U}$
 $= 2.56 \times 10^{21} \times 1000 = 2.56 \times 10^{24}$

Each $^{235}_{92}\text{U}$ nucleus releases 200 Mev of energy during the fission. The total energy released by 1 kg of $^{235}_{92}\text{U}$ is

$$Q = 2.56 \times 10^{24} \times 200 \text{ Mev} = 5.12 \times 10^{26} \text{ MeV}$$

In terms of joules, $5.12 \times 10^{26} \times 1.6 \times 10^{-13} \text{ J} = 8.192 \times 10^{13} \text{ J}$

- 19. Find the ratio of the intensities of light with wavelength 500 nm and 300 nm which undergo Rayleigh scattering. (JUNE – 2023)**

$$\lambda_1 = 500 \text{ nm} = 500 \times 10^{-9} \text{ m} ; \lambda_2 = 300 \text{ nm} = 300 \times 10^{-9} \text{ m} ;$$

From Rayleigh's Scattering law, the intensity of scattered light $I \propto \frac{1}{\lambda^4}$

$$\text{Hence, } I_1 \propto \frac{1}{\lambda_1^4} \text{ and } I_2 \propto \frac{1}{\lambda_2^4}$$

$$\text{From this, } \frac{I_1}{I_2} = \frac{\lambda_2^4}{\lambda_1^4} ; = \left(\frac{300 \times 10^{-9}}{500 \times 10^{-9}} \right)^4 ; = \left(\frac{3}{5} \right)^4 ; = \frac{81}{625}$$

$$I_1 : I_2 = 81 : 625$$

- 20. Calculate the electric flux through the rectangle of side 5 cm and 10 cm kept in the region of a uniform electric field 100 NC^{-1} . The angle θ is 60° . If θ becomes zero, what is the electric flux? (JUNE – 2023)**

The electric flux $\Phi_E = \vec{E} \cdot \vec{A} = EA \cos\theta = 100 \times 5 \times 10 \times 10^{-4} \times \cos 60^\circ$
 $\Rightarrow \Phi_E = 0.25 \text{ Nm}^2\text{C}^{-1}$.

For $\theta = 0^\circ$, $\Phi_E = \vec{E} \cdot \vec{A} = EA \cos\theta = 100 \times 5 \times 10 \times 10^{-4}$
 $\Phi_E = 0.5 \text{ Nm}^2\text{C}^{-1}$

- 21. A coil of a tangent galvanometer of diameter 0.24 m has 100 turns. If the horizontal component of Earth's magnetic field is $25 \times 10^{-6} \text{ T}$ then, calculate the current which gives a deflection of 60° . (JUNE – 2023)**

The diameter of the coil is 0.24 m.
 Therefore, radius of the coil is 0.12 m.
 Number of turns is 100 turns.
 Earth's magnetic field is $25 \times 10^{-6} \text{ T}$
 Deflection is $\theta = 60^\circ \Rightarrow \tan 60^\circ = \sqrt{3} = 1.732$
 $I = \frac{2RB_H}{\mu_0 N} \tan\theta ; = \frac{2 \times 0.12 \times 25 \times 10^{-6}}{4 \times 10^{-7} \times 3.14 \times 100} \times 1.732$
 $= 0.82 \times 10^{-1} \text{ A} \text{ (or)} I = 0.082 \text{ A.}$

- 22. 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 $8.4 \times 10^{28} \text{ m}^{-3}$ then compute the drift velocity of free electrons. (MARCH- 2024)**

The relation between drift velocity of electrons and current in a wire of cross- sectional area A is $V_d = \frac{I}{neA} ; = \frac{0.2}{8.4 \times 10^{28} \times 1.6 \times 10^{-19} \times 0.5 \times 10^{-6}} ; = \frac{2 \times 10^{-3}}{6.72}$
 $V_d = 0.03 \times 10^{-3} \text{ ms}^{-1}$

- 23. How many photons per second emanate from a 50 mW laser of 640 nm? (MARCH- 2024)**

$$P = 50 \text{ mW}, \lambda = 640 \text{ nm}, h = 6.6 \times 10^{-34} \text{ Js}, c = 3 \times 10^8 \text{ ms}^{-1}$$

Number of photons emanate per second

$$n_p = \frac{P}{E} = \frac{P\lambda}{hc} ; = \frac{50 \times 10^{-3} \times 640 \times 10^{-9}}{6.6 \times 10^{-34} \times 3 \times 10^8} ; = \frac{32000 \times 10^{-6}}{19.8 \times 10^{-26}} ; = 1616.16 \times 10^{20}$$
 $n_p = 1.6 \times 10^{17} \text{ s}^{-1}$

- 24. Determine the wavelength of light emitted from LED which is made up of GaAsP semiconductor whose forbidden energy gap is 1.875 eV. Mention the colour of the light emitted (Take $h = 6.6 \times 10^{-34} \text{ Js}$). (MARCH- 2024)**

$$E_g = \frac{hc}{\lambda} ; \text{Therefore, } \lambda = \frac{hc}{E_g} ; = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.875 \times 1.6 \times 10^{-19}} ; \lambda = 660 \text{ nm}$$

The wavelength 660 nm corresponds to red colour light.

- 25. A coil of 200 turns carries a current of 4 A. If the magnetic flux through the coil is 6×10^{-5} Wb, find the magnetic energy stored in the medium surrounding the coil.**

(JUNE 2024)

Number of turns of the coil, $N = 200$, Current, $I = 4$ A

Magnetic flux through the coil, $\phi = 6 \times 10^{-5}$ Wb

Energy stored in the coil, $U = \frac{1}{2} LI^2$; Self-inductance of the coil, $L = \frac{N\phi}{I}$

$$U = \frac{1}{2} \frac{N\phi}{I} \times I^2 = \frac{1}{2} N\phi I ; = \frac{1}{2} \times 200 \times 6 \times 10^{-5} \times 4$$

$$U = 2400 \times 10^{-5}; \mathbf{U = 0.024 \text{ J (or) Joules}}$$

- 26. A diffraction grating consisting of 4000 slits per centimeter is illuminated with a monochromatic light that produces the second order diffraction at an angle of 30° . What is the wavelength of the light used? (JUNE – 2024)**

Number of lines per cm = 4000; $m = 2$; $\theta = 30^\circ$; $\lambda = ?$

Number of lines per unit length, $N = \frac{4000}{1 \times 10^{-2}} ; = 4 \times 10^5$

Equation for diffraction maximum in grating is, $\sin \theta = Nm \lambda$

Rewriting,, $\lambda = \frac{\sin \theta}{Nm}$;

$$\begin{aligned} \text{Substituting, } \lambda &= \frac{\sin 30^\circ}{4 \times 10^5 \times 2} = \frac{0.5}{4 \times 10^5 \times 2} ; \\ &= \frac{1}{2 \times 10^5 \times 2} ; = \frac{1}{16 \times 10^5} \end{aligned}$$

$$\lambda = 6250 \times 10^{-10} \text{ m}$$

$$\lambda = 6250 \text{ \AA}$$

Notes:

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