# +2 PHYSICS MINIMUM LEVEL MATERIAL FOR LATE BLOOMERS

## THREE MARKS & FIVE MARKS

# UNIT – 1 ELECTROSTATICS

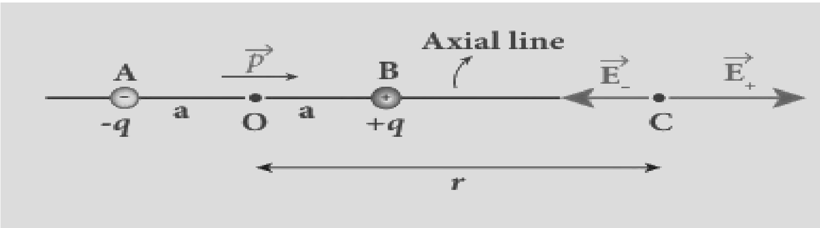
**Three marks & Five marks**

**1.Difference between electrostatic force and gravitational force**

| Gravitational force | Electrostatic force |
|---|---|
| 1. Force between two masses is always **attractive** | Force between two charges can be **attractive or repulsive**, depending on the nature of charges |
| 2. The value of the gravitational constant **$G = 6.626\times10^{-11}$ Nm$^2$Kg$^{-2}$** | The value of the constant k in Coulomb law is **$k = 9\times10^{9}$ Nm$^2$C$^{-2}$** |
| 3. Force between two masses is **independent of the medium**. | Force between the two charges **depends on nature of the medium** in which the two charges are kept at rest. |
| 4. Force between two point masses is the same whether two masses are at rest or in motion. | Force between two point charges will change with respect to motion |

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

- Consider an electric dipole placed on x axis.
- A point C is located at a distance of r from the midpoint O of the dipole along the axial line.




The electric filed at a point C due to +q

$$\overrightarrow{E_+} = \frac{1}{4\pi\varepsilon_o}\frac{q}{(r-a)^2}\ along\ BC$$

$\hat{p}$ – Direction is -q to +q and along BC

$$\overrightarrow{E_+} = \frac{1}{4\pi\varepsilon_o}\frac{q}{(r-a)^2}\hat{p} \quad \textbf{………..(1)}$$

The electric filed at a point C due to -q

$$\overrightarrow{E_-} = -\frac{1}{4\pi\varepsilon_o}\frac{q}{(r+a)^2}\hat{p} \quad \textbf{………..(2)}$$

Total electric field at C calculated using super position principle

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

$$= \frac{q}{4\pi\varepsilon_o}\left(\frac{4ra}{(r^2-a^2)^2}\right)\hat{p}$$

r>>a $\vec{E}_{\text{tot}} = \frac{1}{4\pi\varepsilon_o}\left(\frac{4aq}{r^3}\right)\hat{p}$ since $2aq\hat{p} = \vec{p}$

$= \frac{1}{4\pi\varepsilon_o}\left(\frac{2\vec{p}}{r^3}\right)$

**The direction of electric field is along the direction of the dipole moment**

**3. Calculate the electric field due to a dipole on axial and equatorial plane**

- ❖ Consider point C is located at a distance of r from the midpoint O of the dipole on the equatorial plane.
- ❖ C is equidistant from +q & -q , the magnitude of electric field of +q & -q are the same
- ❖ Direction of $\vec{E}_+$ along BC
- ❖ Direction of $\vec{E}_-$ along CA
- ❖ $\vec{E}_+$ & $\vec{E}_-$ resolved into two components : One component parallel to dipole and perpendicular to it
- ❖ Perpendicular components $E_+ \sin\theta$ & $E_- \sin\theta$ are oppositely directed so cancel each other .

$\vec{E}_{\text{tot}} = -\left|\vec{E}_+\right|\cos\theta\hat{p} - \left|\vec{E}_-\right|\cos\theta\hat{p}$

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

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

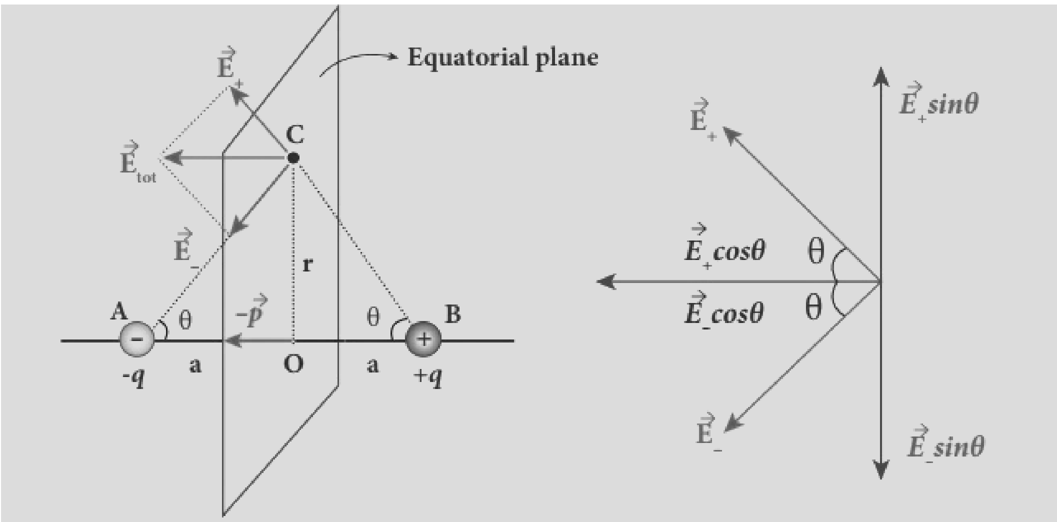
$\vec{E}_{\text{tot}} = -\frac{1}{4\pi\varepsilon_o}\frac{2a\,q\,\hat{p}}{(r+a)^{\frac{3}{2}}}$ since $\cos\theta = \frac{a}{\sqrt{r^2+a^2}}$

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

**r>>a $(r^2 + a^2)^{3/2} = r^3$**

$\vec{E}_{\text{tot}} = \boldsymbol{\frac{1}{4\pi\varepsilon_o}\left(\frac{\vec{p}}{r^3}\right)}$

**The direction of electric field acts opposite the direction of the dipole moment**



**4. Derive an expression for Torque experienced by a dipole due to a uniform electric field**

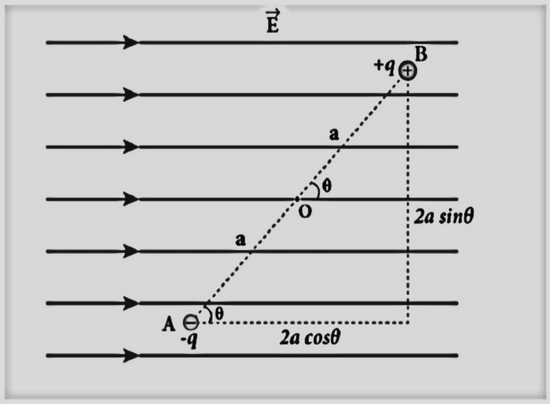


Figure 1.31 The dipole in a uniform electric field

- Consider an electric dipole of dipole moment $\vec{p}$ placed in a uniform electric field.
- The charge +q will experience a force q $\vec{E}$ in the direction of the field charge –q will experience a force -q$\vec{E}$ in a direction opposite to the field.
- Since the external field is uniform, the total force acting on the dipole is zero.
- These two forces acting at different points will constitute a couple and the dipole experience a torque.
- This torque tends to rotate the dipole.

**τ = one of the forces × perpendicular distances between the forces**

$= F\times 2d\sin\theta$

$= qE\times 2d\sin\theta$

$= \mathbf{pE\sin\theta}$ **( p = 2qd)**

- **In vector notation** $\vec{\tau} = \vec{p} \times \vec{E}$

**5. Obtain the expression for capacitance for a parallel plate capacitor**

Consider a capacitor with two parallel plates each of cross-sectional area A and separated by a distance d

The electric field between two infinite parallel plates is uniform and is given by

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

σ – Surface charge density on the plates (σ = Q/A)

The electric field between the plates is

$$E = \frac{Q}{A\varepsilon_0}$$

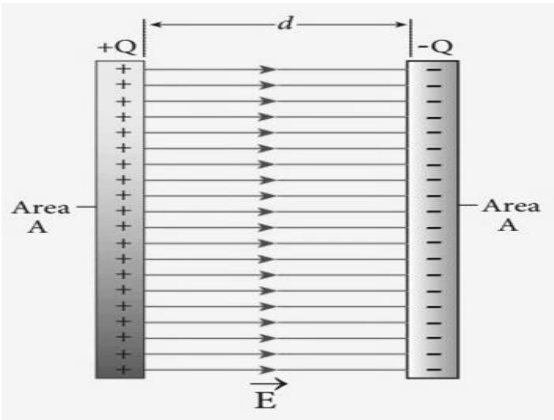


Figure 1.56 Capacitance of a parallel plate capacitor

Since the electric field is uniform, the electric potential between the plates having separation d is

$$V = Ed = \frac{Qd}{A\varepsilon_0}$$

capacitance of the capacitor is given by

$$C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{A\varepsilon_0}} = \frac{\varepsilon_{0A}}{d}$$

$$C \propto A \quad C \propto \frac{1}{d}$$

**6.Derive an expression for electrostatic potential due to point charge**

- Consider a positive charge q kept fixed at the origin.
- Let P be a point at distance r from the charge q.

Electric potential at point P

$V = -\int_{\infty}^{r} (\vec{E}).\overrightarrow{dr}$

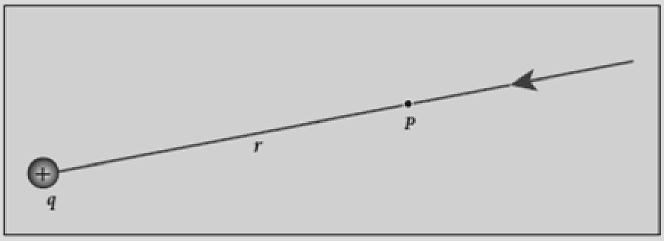


Figure 1.23 Electrostatic potential at a point P

Electric field due to positive charge q

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

$V = -\int_{\infty}^{r} \frac{1}{4\pi\varepsilon_o}\frac{q}{r^{2}}\hat{r}.\overrightarrow{dr}$

$\overrightarrow{dr} = dr\hat{r} \qquad \hat{r}.\hat{r} = 1$

$V = -\frac{1}{4\pi\varepsilon_o}\int_{\infty}^{r} \frac{q}{r^{2}}.dr$

Upon integration

$V = \frac{1}{4\pi\varepsilon_o}\frac{q}{r}$ which is potential at a point due to a point charge

**7. Obtain the expression for energy stored in parallel plate capacitor**

- When a battery is connected to the capacitor, electrons of total charge -Q are transferred from one plate to the other plate. To transfer the charge, work is done by the battery.
- This work done is stored as electrostatic potential energy in the capacitor.

To transfer an infinitesimal charge dQ for a potential difference V, the work done is given by

$$\mathbf{dW = V\,dQ}$$

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

The total work done to charge a capacitor is

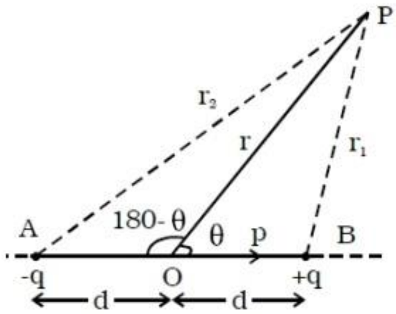
$$\mathbf{W = \int_0^Q \frac{Q}{C}\,dQ = \frac{Q^2}{2C}}$$

This work done is stored as electrostatic potential energy ($U_E$) in the capacitor

$$\mathbf{U_E = \frac{Q^2}{2C} = CV^2}$$

**$U_E$ α C** **$U_E$ α $V^2$**

**8.Derive an expression for electrostatic potential due to an electric dipole**




1. Consider an electric dipole AB. Let p be the point at a distance r from the midpoint of the dipole and θ be the angle between PO and the axis of the dipole OB.

2. Potential at P due to charge (+q) = $\frac{1}{4\pi\varepsilon_o}\frac{q}{r_1}$

Potential at P due to charge (–q) = $\frac{1}{4\pi\varepsilon_o}\left(-\frac{q}{r_2}\right)$

Total potential at P due to dipole is, V = $\frac{1}{4\pi\varepsilon_o}\frac{q}{r_1} - \frac{1}{4\pi\varepsilon_o}\frac{q}{r_2}$

$$V = \frac{q}{4\pi\varepsilon_o}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \qquad ...(1)$$

3. Applying cosine law, $r_1^2 = r^2 + d^2 - 2rd\cos\theta$

Using the Binomial theorem and neglecting higher powers,

$$\frac{1}{r_1} = \frac{1}{r}\left(1 + \frac{d}{r}\cos\theta\right) \qquad ...(2)$$

4. Similarly, $r_2^2 = r^2 + d^2 - 2rd\cos(180-\theta) = r^2 + d^2 + 2rd\cos\theta.$

5. $$\frac{1}{r_2} = \frac{1}{r}\left(1 - \frac{d}{r}\cos\theta\right) \qquad ...(3)$$

6. Substituting equation (2) and (3) in equation (1) and simplifying

$$V = \frac{q}{4\pi\varepsilon_o}\frac{1}{r}\left(1 + \frac{d}{r}\cos\theta - 1 + \frac{d}{r}\cos\theta\right)$$

$$\therefore \quad V = \frac{q\,2d\cos\theta}{4\pi\varepsilon_o\,.\,r^2} = \frac{1}{4\pi\varepsilon_o}\frac{p\,.\cos\theta}{r^2} \qquad ...(4)$$

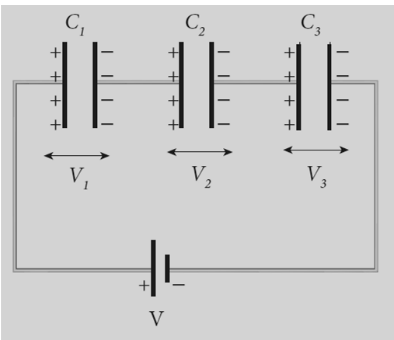
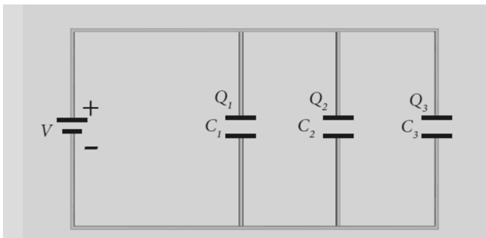
7. **Special cases:**

(i) If $\theta = 0^0$; $V = \frac{p}{4\pi\varepsilon_o r^2}$

(ii) If $\theta = 180^0$; $V = -\frac{p}{4\pi\varepsilon_o r^2}$

(iii) If $\theta = 90^0$; **V=0**

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

| Capacitance in series | Capacitance in parallel |
|---|---|
| $C_1$, $C_2$ and $C_3$ connected in series .$C_S$ is effective capacitance | $C_1$, $C_2$ and $C_3$ connected in Parallel .$C_P$ is effective capacitance |
| Charge in each capacitor is same | Potential in each capacitor is same |
| $V = V_1 + V_2 + V_3$ | $q = q_1 + q_2 + q_3$ |
| $V = \frac{q}{C_s}$ $V_1 = \frac{q}{C_1}$ , $V_2 = \frac{q}{C_2}$, $V_3 = \frac{q}{C_3}$ <br> $\frac{q}{C_s} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$ | $q_1 = C_1V$ , $q_2 = C_2V$ , $q_3 = C_3V$ <br> $q = C_PV$ <br> $C_PV = C_1V + C_2V + C_3V$ |
| $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ | $C_P = C_1 + C_2 + C_3$ |
| The inverse of the equivalent capacitance $C_S$ of three capacitors connected in series is equal to the sum of the inverses of each capacitance | The equivalent capacitance of capacitors connected in parallel is equal to the sum of the individual capacitances. |
|   |   (a) |

**10. Explain in detail the construction and working of a van de Graff generator**

It is a machine which produces a large amount of electrostatic potential difference, up to several million volts ($10^7$ V).

**Principle**

Electrostatic induction and action at points

**Construction**

1) A large hollow spherical conductor is fixed on the insulating stand .
2) Pulley B is mounted at the center of the hollow sphere
3) Pulley C is fixed at the bottom.

4) A belt made up of insulating materials like silk or rubber runs over both pulleys.
5) The pulley C is driven continuously by the electric motor.
6) Two comb shaped metallic conductors E and D are fixed near the pulleys.
7) The comb D is maintained at a positive potential of $10^4$ V by a power supply.
8) The upper comb E is connected to the inner side of the hollow metal sphere.

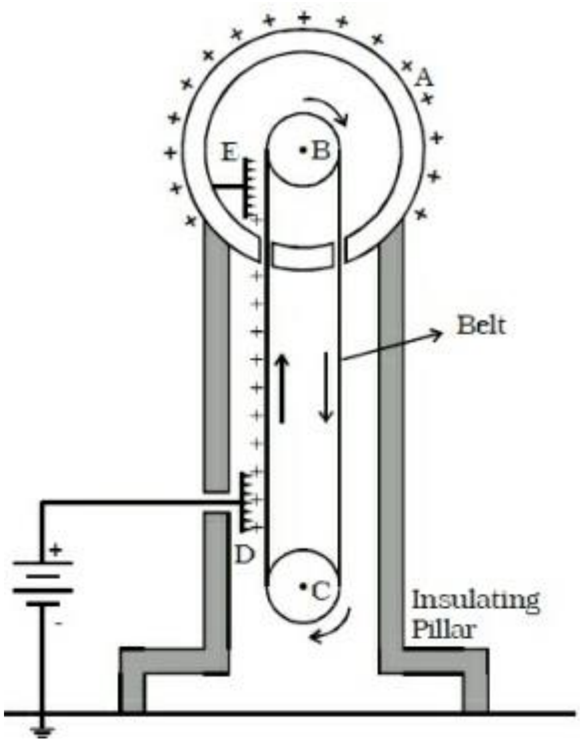
**Working**

**(i) Action of points**

1) 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.
2) The positive charges stick to the belt and move up.

**(ii) Electrostatic induction**

1) 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.
2) As a result, the positive charges are pushed away from the comb E and they reach the outer surface of the sphere.
3) At the same time, the negative charges nullify the positive charges in the belt due to corona discharge before it passes over the pulley.
4) When the belt descends, it has almost no net charge.
5) This process continues until the outer surface produces the potential difference of the order of $10^7$ which is the limiting value.




**Leakage and prevention**

1) We cannot store charges beyond this limit since the extra charge starts leaking to the surroundings due to ionization of air.
2) The leakage of charges can be reduced by enclosing the machine in a gas filled steel chamber at very high pressure.

**10.What are the properties of lines of force**

1) The electric field lines start from a positive charge and end at negative charges 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 (more closer) in a region where the electric field has larger magnitude and less dense in a region where the electric field is of smaller magnitude.
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.

**11. Obtain expression for electric filed due to an infinitely long charged wire**

- Consider an infinitely long straight wire having uniform linear charge density λ.
- Let P be a point located at a perpendicular distance r from the wire. .
- The electric field at the point P can be found using Gauss law. We choose two small charge elements $A_1$ and $A_2$ on the wire which are at equal distances from the point P.
- The resultant electric field due to these two charge elements points radially away from the charged wire and the magnitude of electric field is same at all points on the circle of radius r.
- Charged wire possesses a cylindrical symmetry of radius r and length L.

$$\phi_E = \oint \vec{E} \cdot \overrightarrow{dA}$$

$$= \underbrace{\oint \vec{E} \cdot \overrightarrow{dA}}_{\text{Curved Surface}} + \underbrace{\oint \vec{E} \cdot \overrightarrow{dA}}_{\text{top surface}} + \underbrace{\oint \vec{E} \cdot \overrightarrow{dA}}_{\text{bottom surface}}$$

Since $\vec{E}$ and $\overrightarrow{dA}$ are right angles to each other , the electric flux through the place caps = 0

Flux through the curved surface = $\oint E.dA\ cos\theta$

$\theta = 0\ \ cos0 = 1\ \ \phi_E = \oint E.dA$

= E(2πrl) ……(1)

The net charge enclosed by Gaussian surface is

**Q = λl**

By Gauss law $\phi_E = \frac{Q}{\varepsilon_0}$ **…………(2)**

**Equating (1) & (2)**

**E(**(2πrl) = $\frac{Q}{\varepsilon_0}$

**E(**(2πrl) = $\frac{\lambda l}{\varepsilon_0}$

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

In vector form $\vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r}\vec{r}$

**12. Discuss the various properties of conductors in electrostatic equilibrium**

- The electric field is zero everywhere **inside the conductor. This is true regardless of whether the conductor is solid or hollow.**
- There is no net charge inside the **conductors. The charges must reside only on the surface of the conductors.**
- The electric field outside the conductor **is perpendicular to the surface of the conductor and has a magnitude of** $\frac{\sigma}{\varepsilon_0}$ **where σ is the surface charge density at that point.**
- The electrostatic potential has the **same value on the surface and inside of the conductor.**
- Since the electric field is zero inside the conductor, the potential is the same as the surface of the conductor. Thus at electrostatic equilibrium, the conductor is always at equipotential

## UNIT – 2 CURRENT ELECTRICITY

**Three marks and five marks**

**1. State and explain Kirchhoff's rules**

**Kirchhoff's first rule (Current rule or Junction rule)**

- It states that the **algebraic sum of the currents at any junction of a circuit is zero**. It is a statement of **conservation of electric charge.**
- Current entering the junction is taken as positive and current leaving the junction is taken as negative.

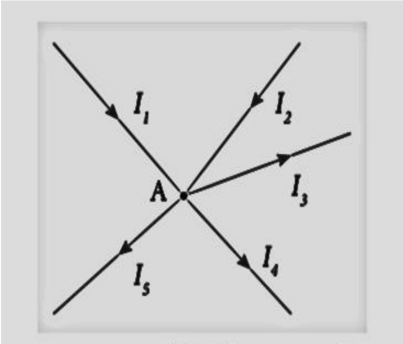


Figure 2.23 Kirchhoff's current rule

Applying this law to the junction A

$$I_1 + I_2 - I_3 - I_4 - I_5 = 0$$

**Kirchhoff's Second rule (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.
- This rule follows from the **law of conservation of energy** for an isolated system.

**2. Obtain the condition for bridge balance in Wheatstone's bridge**.

- ❖ An important application of Kirchhoff 's rules is the Wheatstone's bridge. It is used to compare resistances and also helps in determining the unknown resistance in electrical network.
- ❖ The bridge consists of four resistances P, Q, R and S connected .
- ❖ A galvanometer G is connected between the points B and D.
- ❖ The battery is connected between the points A and C. The current through the galvanometer is $I_G$ and its resistance is G.

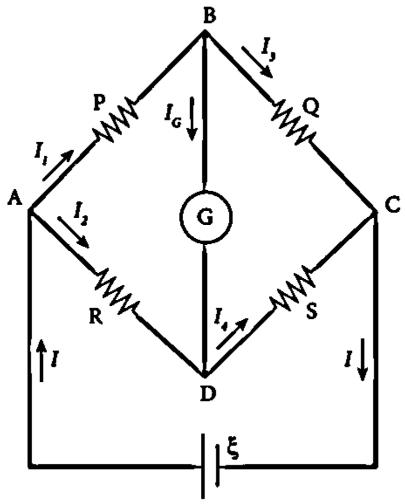


Figure 2.25 Wheatstone's bridge

Applying Kirchhoff 's current rule to junction B

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

Applying Kirchhoff 's current rule to junction D,

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

Applying Kirchhoff 's voltage rule to loop ABDA,

$$I_1P + I_GG - I_2R = 0 \quad \ldots\ldots\ldots\ldots\ldots(3)$$

Applying Kirchhoff 's voltage rule to loop ABCDA,

$$I_1P + I_3Q - I_2R - I_4S = 0 \quad \ldots\ldots\ldots\ldots\ldots(4)$$

When the points B and D are at the same potential, the bridge is said to be balanced , no current flows through galvanometer ($I_G = 0$).

Substituting $\mathbf{I_G = 0}$ in (1) , (2) , (3) , (4)

$I_1 = I_3$ ……………..(5) $I_2 = I_4$ ……………..(6) $I_1P = I_2R$ ……………..(7)

Substituting (5) & (6) in (4)

$I_1P + I_1Q - I_2R - I_2S = 0$

$I_1 (P + Q) = I_2(R + S)$ ………………(8)

Dividing (8) by (7)

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

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

$$\boldsymbol{\frac{P}{Q} = \frac{R}{S}}$$

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

- Potentiometer wire CD is connected to a battery *Bt* and a key K in series. This is the primary circuit.
- The end C of the wire is connected to the terminal M of a DPDT (Double Pole Double Throw) switch and the other terminal N is connected to a jockey through a galvanometer G and a high resistance HR.
- The cells whose emf $\xi_1$ and $\xi_2$ to be compared are connected to the terminals $M_1$,$N_1$ and $M_2$,$N_2$ of the DPDT switch.
- The DPDT switch is pressed towards $M_1$, $N_1$ so that cell $\xi_1$ is included in the secondary circuit and the balancing length $l_1$ is found by adjusting the jockey for zero deflection.
- Then the second cell $\xi_2$ is included in the circuit and the balancing length $l_2$ is determined.
- *r* - resistance per unit length of the potentiometer wire

*I*- be the current flowing through the wire.

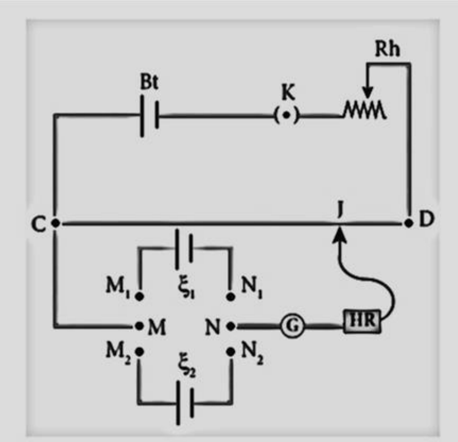


**Figure 2.28** Comparison of emf of two cells

$\xi_1 = Irl_1$ ……(1)

$\xi_2 = Irl_2$ ………… (2)

Dividing (1) & (2)

$$\boldsymbol{\frac{\xi_1}{\xi_2} = \frac{l_1}{l_2}}$$

**4.Explain determination of internal resistance of a cell by potentiometer**

1) The end C of the potentiometer wire is connected to the positive terminal of the battery Bt and the negative terminal of the battery is connected to the end D through a key $K_1$. This forms the primary circuit.
2) The positive terminal of the cell $\xi$ whose internal resistance is to be determined is also connected to the end C of the wire.
3) The negative terminal of the cell $\xi$ is connected to a jockey through a galvanometer and a high resistance.
4) A resistance box R and key $K_2$ are connected across the cell $\xi$.
5) With $K_2$ open, the balancing point J is obtained and the balancing length CJ = $l_2$ is measured.
6) Since the cell is in open circuit, its emf is $\xi_1 \propto l_1$
7) A suitable resistance (say, 10 Ω) is included in the resistance box and key $K_2$ is closed.

r - internal resistance of the cell.

$$I = \frac{\xi}{R+r} \quad \text{.........(1)}$$

The potential difference across R is

$$V = \frac{\xi R}{R+r}$$

When this potential difference is balanced on the potentiometer wire, let $l_2$ be the balancing length.

$$\frac{\xi R}{R+r} \propto l_2 \quad \text{..............(2)}$$

**From (1) & (2)**

$$\frac{R+r}{R} = \frac{l_1}{l_2}$$

$$\mathbf{r = R}\left(\frac{l_1 - l_2}{l_2}\right)$$

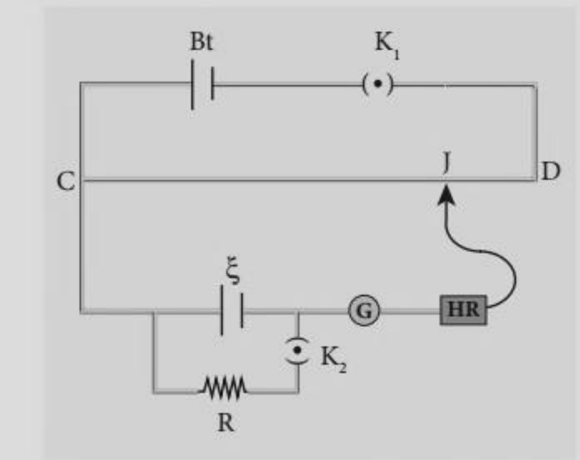


Figure 2.29 measurement of internal resistance

**5.Explain the determination of the internal resistance of a cell using voltmeter**

- The emf of cell $\xi$ is measured by connecting a high resistance voltmeter across it without connecting the external resistance R.
- Since the voltmeter draws very little current for deflection, the circuit may be considered as open. Hence the voltmeter reading gives the emf of the cell.

The potential drop across the resistor R is

$$\mathbf{V = IR} \quad \text{...........(1)}$$

Due to internal resistance r of the cell, th e voltmeter reads a value V, which is less than the emf of cell $\xi$.

$$V = \xi - Ir$$

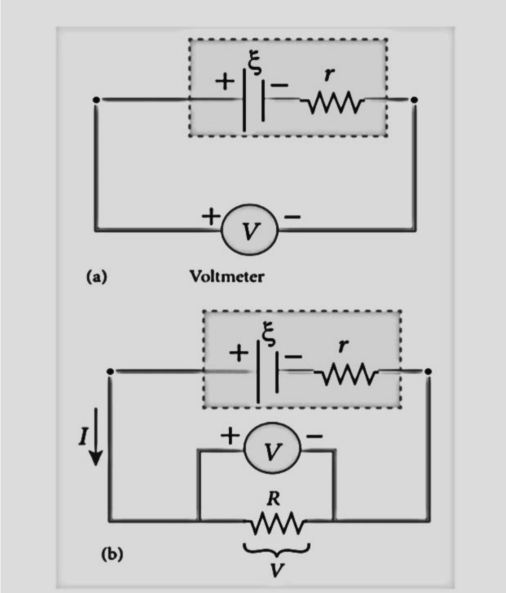


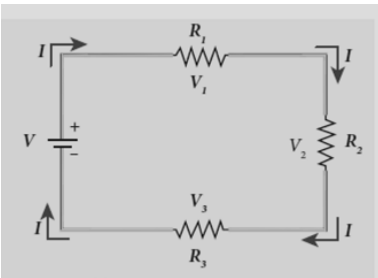
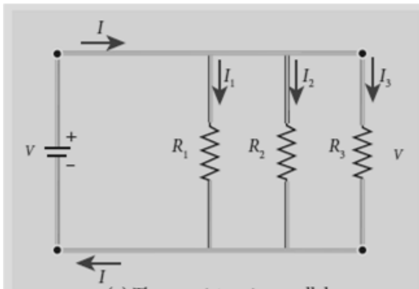
Figure 2.20 Internal resistance of the cell

$Ir = \xi - V$ **…………..(2)**

**Dividing (2) by (1)** we get

$\mathbf{r} = \left(\frac{\xi - V}{V}\right)\boldsymbol{R}$ Since ξ, *V* and *R* are known, internal resistance *r* can be determined.

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

| Resistors in series | Resistors in parallel |
|---|---|
| $R_1$, $R_2$ and $R_3$ connected in series .$R_S$ is effective resistance | $R_1$, $R_2$ and $R_3$ connected in Parallel .$R_P$ is effective resistance |
| Current in each resistor is same | Potential in each resistor is same |
| $V = V_1 + V_2 + V_3$ | $I = I_1 + I_2 + I_3$ |
| $V_1 = IR_1 , V_2 = IR_2 , qV_3 = IR_3$<br>$V = R_S I$<br>$R_S I = R_1 I + R_2 I + R_3 I$ | $I = \frac{V}{R_P}$ $I_1 = \frac{V}{R_1}$ , $I_2 = \frac{V}{R_2}$, $I_3 = \frac{V}{R_3}$<br>$\frac{V}{R_P} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$ |
| $R_S = R_1 + R_2 + R_3$ | $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ |
| When several resistances are connected in series, the total or equivalent resistance is the sum of the individual resistances | When a number of resistors are connected in parallel, the sum of the reciprocal of the values of resistance of the individual resistor is equal to the reciprocal of the effective resistance of the combination |
|  (a) Three resistors in series |  (a) Three resistors in parallel |

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

Consider a conductor with area of cross section A and an electric field applied from right to left. Suppose there are *n* electrons per unit volume in the conductor and assume that all the electrons move with the same drift velocity $v_d$

The electrons move through a distance *dx* within a small interval of *dt*

$v_d = \frac{dx}{dt}$ $dx = v_d dt$ **…………(1)**

A – area of cross section of the conductor

The electrons available in the volume of length dx = volume × n/V

$= Adx \times n$ **…………(2)**

**Sub (2) in (1)**

$= A\, v_d\, dt \times n$

Total charge in volume element dQ = charge × number of electrons in the volume element

$dQ = e\, A\, v_d\, dt \times n$

$I = \frac{dQ}{dt}$ **…………..(3)**

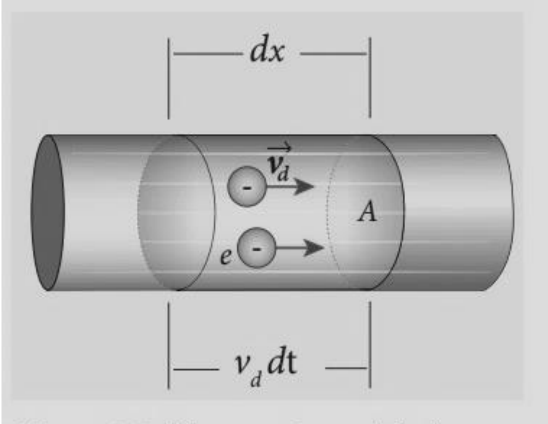



Figure 2.5 Microscopic model of current

**Sub (2) in (3)**

$$I = \frac{neAdtv_d}{dt}$$

$$I = neAv_d$$

**Since current density** **J = I/A**

$J = nev_d$ **……………(4)**

**Sub $v_d$ in (4)**

$$J = -\frac{n\tau e^2}{m}E$$

$$J = -\sigma E$$

But conventionally, we take the direction of (conventional) current density as the direction of electric field. So the above equation becomes

**J = σE ………(microscopic form's of ohm's law)**

$\boldsymbol{\sigma = \frac{n\tau e^2}{m}}$ is called conductivity

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

**J = σE. ……..(1)**

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.

We assume that the electric field is uniform in the entire length of the wire, the potential difference (voltage V) can be written as

**V = E*l*** ***E = V/l* ………** ***(2)***

**Sub (2) in (1)**

$J = \sigma\, V/l$

**J = I/A**

**I/A**$= \sigma\, V/l$

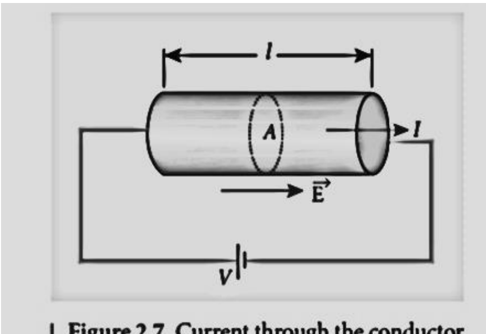



Figure 2.7 Current through the conductor

By rearranging above equation

$V = I\,(\,l / \sigma A\,)$

$l / \sigma A$ - Resistance of a conductor (R)

$R \propto l$ $\quad R \propto A$

Therefore, the macroscopic form of ohm's law can be stated as

**V = IR**

From the above equation, **the resistance is the ratio of potential difference across the given conductor to the current passing through the conductor.**

**R = V / I**

Unit ; Ohm or Ω

**Limitations**

1) A plot of I against V for a non-ohmic material is non-linear and they do not have a constant resistance
2) It is obeyed by many substance under certain conditions but it is not a fundamental law of nature
3) It is applicable only for simple circuits

## Unit – 3 MAGNETISM AND MAGNETIC EFFECTS OF ELECTRIC CURRENT

**Three marks and five marks**

**1.Compare dia , para & ferro magnetism**

| Dia magnetism | Para magnetism | Ferro magnetism |
|---|---|---|
| Magnetic susceptibility is **negative** | Magnetic susceptibility is **positive & small** | Magnetic susceptibility is **postive and large** |
| Relative permeability is slightly **less than unity**. | Relative permeability is slightly **greater than unity**. | Relative permeability is **large** . |
| Susceptibility is nearly **temperature independent**. | Susceptibility is **inversely proportional to temperature** | Susceptibility is **inversely proportional to temperature** |
| **Ex:** Bismuth, Copper and Water | **Ex:**Aluminium, Platinum & chromium | **Ex:** Iron, Nickel and Cobalt |

**2. State Biot – Savart's law**

Biot and Savart observed that the magnitude of magnetic field $d\vec{B}$ at a point P at a distance r from the small elemental length taken on a conductor carrying current varies

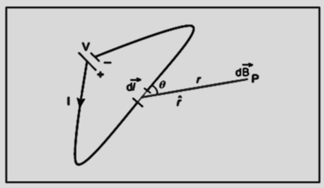


Figure 3.37 Magnetic field at a point P due to current carrying conductor

(i) directly as the strength of the current I

(ii) directly as the magnitude of the length element $d\vec{l}$

(iii) directly as the sine of the angle (say,θ) between $d\vec{l}$ and $\hat{r}$

(iv) inversely as the square of the distance between the point P and length element $d\vec{l}$ .

$$dB \propto \frac{Idl}{r^2} sin\theta$$

$$dB = k\ \frac{Idl}{r^2} sin\theta$$

$$dB = \frac{\mu_o}{4\pi} \frac{Idl}{r^2} sin\theta$$

In vector notation $dB = \frac{\mu_o}{4\pi} \frac{Id\vec{l} \times \hat{r}}{r^2}$

**3. Discuss the conversion of galvanometer into an ammeter**

- A galvanometer is converted into an ammeter by connecting a low resistance in parallel with the galvanometer. This low resistance is called shunt resistance S.
- When current I reaches the junction A, it divides into two components.
- Let $I_g$ be the current passing through the galvanometer of resistance $R_g$ through a path AGE and the remaining current $(I - I_g)$ passes along the path ACDE through shunt resistance S.

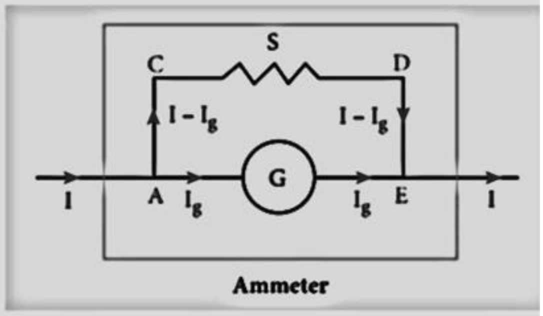



**Figure 3.69 Shunt resistance connected in parallel**

- value of shunt resistance is so adjusted that current $I_g$ produces full scale deflection in the galvanometer. The potential difference across galvanometer is same as the potential difference across shunt resistance.

$V_{galvanometer} = V_{shunt}$

$I_g R_g = (I - I_g) S$

$S = \frac{I_g}{(I - I_G)} R_g$

$I_g = \frac{S}{S + R_g} I$

$\boldsymbol{I_g \ \alpha \ I}$

Since, the deflection in the galvanometer is proportional to the current passing through it.

$\Theta = \frac{1}{G} I_g \quad \theta \ \alpha \ I_g \quad \theta \ \alpha \ I$

An **ideal ammeter is one which has zero resistance**.

4. **Discuss the conversion of galvanometer into a voltmeter**

- A galvanometer is converted into a voltmeter by connecting high resistance $R_h$ in series with galvanometer.
- The scale is now calibrated in volt and the range of voltmeter depends on the values of the resistance connected in series i.e. the value of resistance is so adjusted that only current Ig produces full scale deflection in the galvanometer.
- Let $R_g$ be the resistance of galvanometer and $I_g$ be the current with which the galvanometer produces full scale deflection.

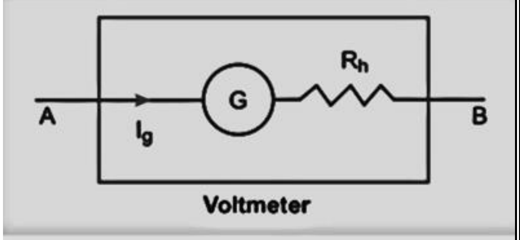



**Figure 3.70 Shunt resistance connected in series**

- Since the galvanometer is connected in series with high resistance, the current in the electrical circuit is same as the current passing through the galvanometer.

$I = I_g$

$I_g = \frac{potential\ difference}{total\ resistance}$

$R_V = R_S + R_h$

$I_g = \frac{V}{R_S+R_h}$

$R_h = \frac{V}{I_g} - R_s$

**$I_g \ \alpha \ V$**

An **ideal voltmeter is one which has infinite resistance**.

**4.Explain the principle and working of moving coil galvanometer**

Moving coil galvanometer is a device which is used to indicate the flow of current in an electrical circuit

**Principle**

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

**Working**

- Coil PQRS whose length be *l* and breadth b. PQ = RS = *l* and QR = SP = b.
- Let I be the electric current flowing through the rectangular coil PQRS The horse-shoe magnet has hemi - spherical magnetic poles which produces a radial magnetic field.

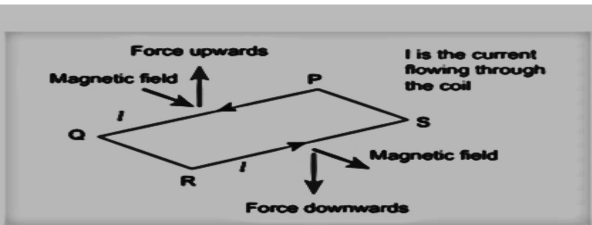



Figure 3.67 Force acting on current carrying coil

- Due to this radial field, the sides QR and SP are always parallel to to the B-field (magnetic field) and experience no force.
- The sides PQ and RS are always parallel to the B-field and experience force and due to this, torque is produced.

For single turn, the deflection couple as

$\boldsymbol{\tau = bF = bBIl = (lb)\,BI = ABI}$

$\mathbf{A} = l\mathbf{b}$

For coil with N turns, we get

**$\tau$ = NABI ……….. (1)**

- Due to this deflecting torque, the coil gets twisted and restoring torque (also known as restoring couple) is developed. Hence the magnitude of restoring couple is proportional to the amount of twist θ

**$\tau = K\theta$ ………….(2)**

- *K* is the restoring couple per unit twist or torsional constant of the spring

- At equilibrium, the deflection couple is equal to the restoring couple

$$NABI = K\theta$$

$$\mathbf{I} = K\frac{\theta}{NAB}$$

$$I = G\theta$$

$\mathbf{G} = \frac{K}{NAB}$ galvanometer constant or current reduction factor of the galvanometer

**5. Discuss the working of cyclotron in detail**

Cyclotron is a device used to accelerate the charged particles to gain large kinetic energy.

**Principle**

When a charged particle moves normal to the magnetic field, it experiences magnetic Lorentz force.

**Working**

- Ion ejected from source S is positively charged.
- As soon as ion is ejected, it is accelerated towards a Dee (say, Dee – 1) which has negative potential at that time.
- 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 q is provided by Lorentz force.

Lorentz force = Bqv

Centripetal force $= \frac{mv^2}{r}$

$$\frac{mv^2}{r} = Bqv$$

$$\mathbf{r} = \frac{mv}{qB} \quad \text{........ (1)}$$

$$r \propto v$$

From the equation (1), the increase in velocity increases the radius of circular path. This process continues and hence the particle undergoes spiral path of increasing radius. Once it reaches near the edge, it is taken out with the help of deflector plate and allowed to hit the target T.

Resonance happens when the frequency *f* at which the positive ion circulates in the magnetic field must be equal to the constant frequency of the electrical oscillator $f_{OSC} = \frac{qB}{2\pi m}$

**Time period of oscillation T** $= \frac{1}{f_{osc}}$

$$= \frac{2\pi m}{qB}$$

**Kinetic energy of a particle K.E = ½ mv$^2$**

**From (1) v =$\frac{rqB}{m}$**

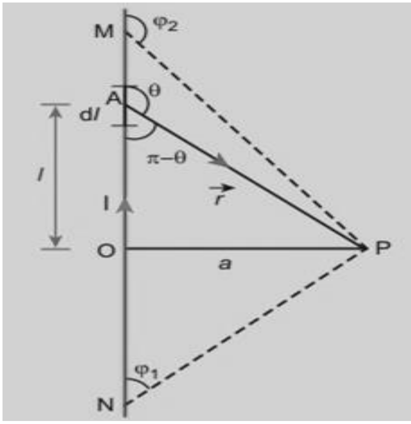
**K.E = $\frac{q^2B^2r^2}{2m}$**

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

- Consider a long straight wire NM with current I flowing from N to M.
- P be the point at a distance *a* from point O.
- Consider an element of length d*l* of the wire at a distance *l* from point O
- $\vec{r}$ be the vector joining the element d*l* with the point P.

$\theta -$ angle between $\vec{r}$ & $\overrightarrow{dl}$ Then, the magnetic field at P due to the element is

$\overrightarrow{dB} = \frac{\mu_0}{4\pi}\frac{I\,\overrightarrow{dl}}{r^2}\,sin\theta$………(1)




In a right angle triangle PAO

tan(π - $\theta$ ) = $\frac{a}{l}$

$l = \frac{a}{tan\theta}$ ………….. (2)

In a right angle triangle PAO

sin $\theta$ = $\frac{a}{r}$ r = a cosec $\theta$ ……..(3)

**Differentiating eq (2 )**

$dl$ = a cosec$^2$ $\theta d\theta$ …………….(4)

sub (3) & (4) in (1)

$\overrightarrow{dB} = \frac{\mu_0}{4\pi}\frac{acosec^2\theta d\theta}{(acosec\theta)^2}$ sin $\theta$ $\hat{n}$

**Cancelling cosec$^2$ $\boldsymbol{\theta}$ on both numerator & denominator**

= $\frac{\mu_0}{4\pi a}$ sin $\theta d\theta$ $\hat{n}$ …………..(5)

The net magnetic field at the point P which can be obtained by integrating $\overrightarrow{dB}$ by varying the angle from θ = $\varphi_1$ to θ = $\varphi_2$ is

$\vec{B} = \frac{\mu_0}{4\pi a}\int_{\varphi_1}^{\varphi_2}$ sin $\theta d\theta$ $\hat{n}$

= $\frac{\mu_0}{4\pi a}(\cos\varphi_1 - \cos\varphi_2)\,\hat{n}$

For a an infinitely long straight wire,

$\varphi_1$ = 0 $\varphi_2 = \pi$

The magnetic field is

$\boldsymbol{\vec{B}} = \frac{\boldsymbol{\mu_0}}{\boldsymbol{4\pi a}}\ \boldsymbol{\hat{n}}$

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

- Consider a current carrying circular loop of radius R.
- I be the current flowing through the wire in the direction as shown in Figure .
- The magnetic field at a point P on the axis of the circular coil at a distance *z* from its center of the coil O.
- It is computed by taking two diametrically opposite line elements of the coil each of length $\vec{dl}$ at C & D

According to Biot-Savart's law, the magnetic field at P due to the current element I $\vec{dl}$ is

$$\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\vec{dl}\times\hat{r}}{r^2} \quad \text{…………(1)}$$

- The magnitude of magnetic field due to current element $I\,\vec{dl}$ at C and D are equal because of equal distance from the coil.

- The magnetic field due to each current element $I\,\vec{dl}$ is resolved into two components; dB sin θ along y - direction and dB cos θ along z - direction.

Horizontal components of each current element cancels out while the vertical components (dB cos θ ) alone contribute to total magnetic field at the point P.

**PC = PD = r =** $\sqrt{R^2 + Z^2}$

Then the net magnetic field at point P is

$$\vec{B} = \int \vec{dB} = \int dB \cos\theta\,\hat{k}$$

$$= \frac{\mu_0}{4\pi}\, I \int \frac{dB}{r^2}\cos\theta\,\hat{k} \quad \text{…….. (2)}$$

By triangle POD

$$\cos\theta = \frac{R}{\sqrt{R^2+Z^2}}$$

sub cos $\theta$ value in (2) ,

integrating line element from 0 to 2πR, we get

$$\vec{B} = \frac{\mu_0}{2\pi}\, I\, \frac{R^2}{(R^2+z^2)^{\frac{3}{2}}}\,\hat{k}$$

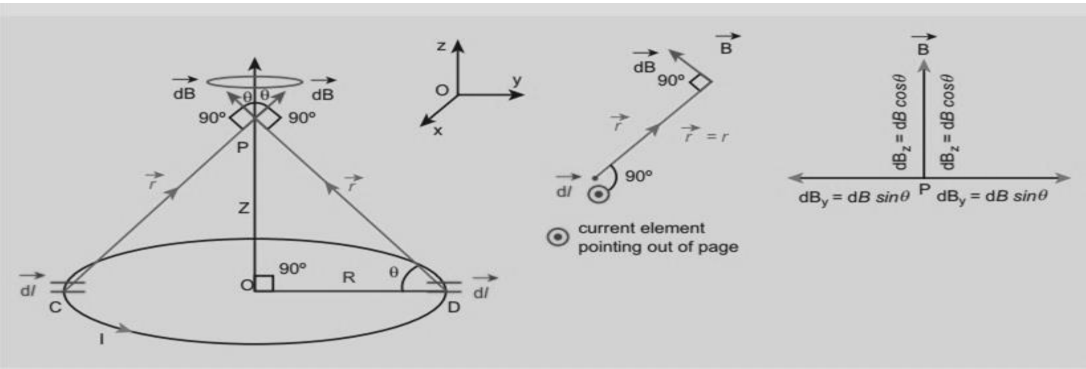



**Figure 3.40** Current carrying circular loop using Biot-Savart's law

**8.Derive Force on a current carrying conductor placed in a 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.
- Consider a small segment of wire of length d*l*, with cross- sectional area A and current I
- The free electrons drift opposite to the direction of current. So the relation between current I and magnitude of drift velocity $v_d$ is

**I = nAev$_d$ ………… (1)**

If the wire is kept in a magnetic field $\vec{B}$ , then average force experienced by the charge (here, electron) in the wire is

$\vec{F} = -e\,(\vec{v}_d \times \vec{B})$ **………(2)**

Let n be the number of free electrons per unit volume, therefore n = N/V ……. (3)

**N -** is the number of free electrons

**V = A.dl**

N = nAdl

q = Ne = enAdl ………….(4)

$\overrightarrow{dF} = -e\, nAdl\,(\vec{v}_d \times \vec{B})$

I. $\overrightarrow{dl}$ = -enA$\vec{v}_d$dl

$\overrightarrow{dF} = I\overrightarrow{dl} \times \vec{B}$

The force in a straight current carrying conducting wire of length *l* placed in a uniform magnetic field is

$\vec{F} = I\vec{l} \times \vec{B}$

**In magnitude F = BIl sin$\theta$**

(a) $\theta = 0^o$. F = 0

(b) $\theta = 90^o$ $F = BIl$.

**9.Derive Force between two long parallel current carrying conductors**

Two long straight parallel current carrying conductors separated by a distance r are kept in air

$I_1$ and $I_2$ be the electric currents passing through the conductors A and B in same direction (i.e. along z - direction)

The net magnetic field at a distance r due to current $I_1$ in conductor A is

$\vec{B}_1 = \frac{\mu_0 I_1}{2\pi r}(-\hat{\imath}) = -\frac{\mu_0 I_1}{2\pi r}\hat{\imath}$ **…….(1)**

From thumb rule, the direction of magnetic field is perpendicular to the plane of the paper and inwards i.e along negative $\hat{\imath}$ direction .

Lorentz force on the element d$l$ of conductor B at which the magnetic field $\vec{B}_1$ is present is

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

$$= -\frac{\mu_0 I_1 I_2 dl}{2\pi r}\ \hat{\jmath}$$

The force per unit length of the conductor B due to the wire conductor A is

$$\frac{\vec{F}}{l} = -\frac{\mu_0 I_1 I_2}{2\pi r}\ \hat{\jmath} \quad \ldots\ldots\ldots\ldots(1)$$

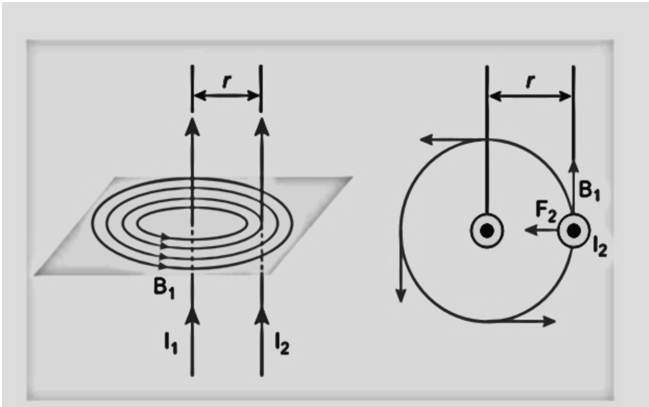


**Figure 3.58** Two long straight parallel wires

In the same manner, we compute the magnitude of net magnetic induction due to current $I_2$ (in conductor A) at a distance r in the elemental length *dl* of conductor A is

$$\vec{B}_2 = \frac{\mu_0 I_2}{2\pi r}\text{-}\hat{\imath}$$

From the thumb rule, direction of magnetic field is perpendicular to the plane of the paper and outwards i.e., along positive $\hat{\imath}$ direction

Lorentz force on the element d$l$ of conductor A at which the magnetic field $\vec{B}_2$ is present is

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

$$= -\frac{\mu_0 I_1 I_2 dl}{2\pi r}\ \hat{\jmath}$$

The force per unit length of the conductor B due to the wire conductor A is

$$\frac{\vec{F}}{l} = -\frac{\mu_0 I_1 I_2}{2\pi r}\ \hat{\jmath} \quad \ldots\ldots\ldots\ldots(2)$$

**10. Calculate the magnetic field inside and outside of the long solenoid using Ampere's circuital law**

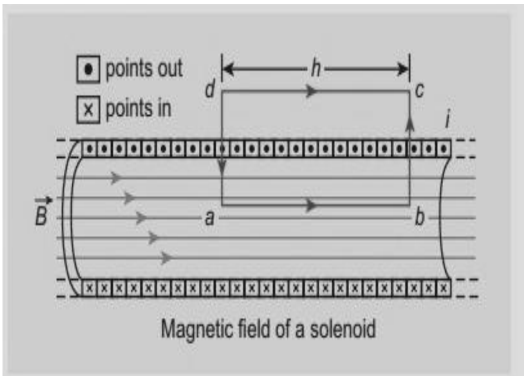


**Figure 3.46** Amperian loop for solenoid

Consider a solenoid of length L having N turns. The diameter of the solenoid is assumed to be much smaller when compared to its length and the coil is wound very closely.

We use Ampere's circuital law by considering a rectangular loop abcd

From Ampere's circuital law

$$\oint_C \vec{B}\ \overrightarrow{dl} = \mu_0 I_{enclosed} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\oint \vec{B}\ \overrightarrow{dl} = \int_a^b \vec{B}\ \overrightarrow{dl} + \int_b^c \vec{B}\ \overrightarrow{dl} +$$

$\int_c^d \vec{B}\,\vec{dl} + \int_d^a \vec{B}\,\vec{dl}$

For elemental length along bc & da magnetic field perpendicular to them

$\int_b^c \vec{B}\,\vec{dl} = \int_b^c |\vec{B}|\,|\vec{dl}| \cos 90^0 = 0$

Similarly $\int_d^a \vec{B}\,\vec{dl} = 0$

Magnetic field outside the solenoid is zero

$\boldsymbol{\int_c^d \vec{B}\,\vec{dl} = 0}$

For the path along ab , integral is

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

NI – current passing through the solenoid of N turns

$\boldsymbol{\mu_0 I_{enclosed} = \mu_0 N I = \mu_0 \frac{NI}{L} = \mu_0 nI}$ **.....(3)**

Equating (2) & (3)

**B = $\mu_0$nI**

**11. Explain about Motion of a charged particle in a uniform magnetic field.Deduce the period of rotation in it**

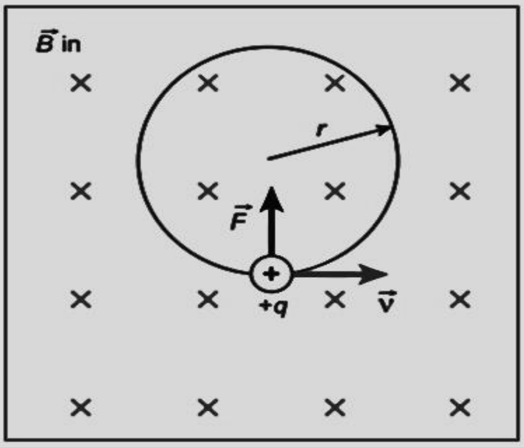



**Figure 3.50** Circular motion of a charged particle in a perpendicular uniform magnetic field

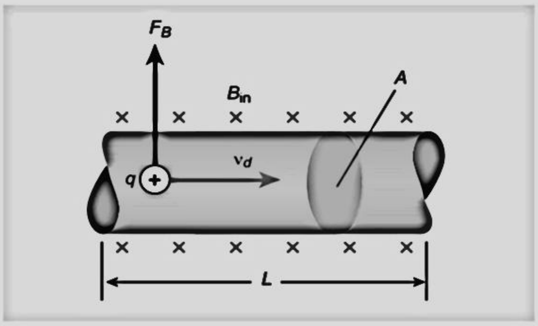



**Figure 3.56** Current carrying conductor in a magnetic field

- Consider a charged particle of charge q having mass m enters into a region of uniform magnetic field $\vec{B}$ with velocity$\vec{v}$ such that velocity is perpendicular to the magnetic field.
- As soon as the particle enters into the field, Lorentz force acts on it in a direction perpendicular to both magnetic field and velocity .
- As a result, the charged particle moves in a circular orbit
- Since Lorentz force acts as centripetal force for the particle to execute circular motion.

Lorentz force F = Bqv ……….. (1)

Centripetal force F = $mv^2$ / r ………..(2)

Equating (1) & (2)

Bqv = $mv^2$ / r

r = $\frac{mv}{qB}$ …………(3)

T be the time taken by the particle to finish one complete circular motion, then

T = $\frac{2\pi r}{v}$ ………..(4)

Sub (3) in (4)

**T = $\boldsymbol{\frac{2\pi m}{qB}}$ ………(5)**

Above equation is time period of cyclotron

The reciprocal of time period is the frequency *f*,

f = $\frac{qB}{2\pi m}$

In terms of angular frequency ω,

**ω = 2πf = $\boldsymbol{\frac{qB}{m}}$**

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

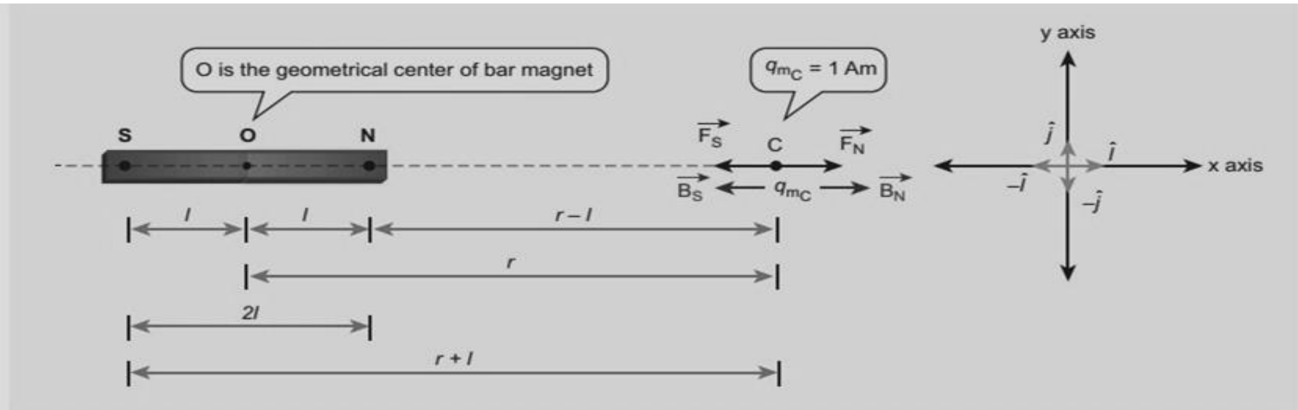



**Figure 3.16** Magnetic field at a point along the axial line due to magnetic dipole

- Consider a bar magnet NS.

- Let N be the North Pole and S be the south pole of the bar magnet, each of pole strength $q_m$ and separated by a distance of $2l$.
- The magnetic field at a point C (lies along the axis of the magnet) at a distance from the geometrical center O of the bar magnet can be computed by keeping unit north pole ($q_{mc}$ = 1 A m) at C.
- The force experienced by the unit north pole at C due to pole strength can be computed using Coulomb's law of magnetism

The force of repulsion between north pole of the bar magnet and unit north pole at point C (in free space) is

$$\overrightarrow{F_N} = \frac{\mu_0}{4\pi}\frac{q_m}{(r-l)^2}\hat{\imath} \quad ..........(1)$$

The force of attraction between South Pole of the bar magnet and unit North Pole at point C (in free space) is

$$\overrightarrow{F_S} = -\frac{\mu_0}{4\pi}\frac{q_m}{(r+l)^2}\hat{\imath} \quad ..........(2)$$

$$\vec{F} = \overrightarrow{F_N} + \overrightarrow{F_S}$$

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

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q_m}{(r-l)^2}\hat{\imath} - \frac{\mu_0}{4\pi}\frac{q_m}{(r+l)^2}\hat{\imath}$$

$$= \frac{\mu_0}{4\pi} 2r \left(\frac{q_m\, 2l}{(r^2 - l^2)^2}\right)\hat{\imath}$$

**$P_m = q_m \times 2l$**

$$= \frac{\mu_0}{4\pi}\frac{2r\,P_m}{(r^2 - l^2)^2}\hat{\imath}$$

**$r^2 >> l^2$ $l^2$ can ne neglected**

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{2\,P_m}{r^3}\hat{\imath}$$

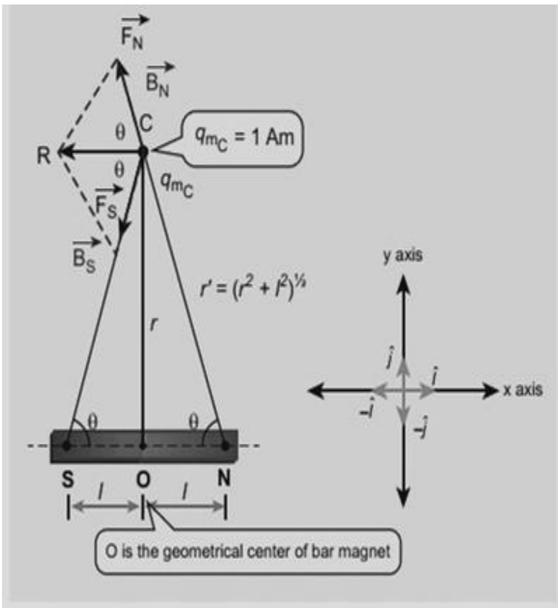
$$= \frac{\mu_0}{4\pi}\frac{2}{r^3}\overrightarrow{P_m}$$

**13.Obtain the magnetic induction at a point on the equatorial line of bar magnet**

Consider a bar magnet NS .

- ❖ N - north pole and S - south pole of the bar magnet, each with pole strength $q_m$ and separated by a distance of $2l$.
- ❖ The magnetic field at a point C (lies along the equatorial line) at a distance *r* from the geometrical center O of the bar magnet can be computed by keeping unit north pole ($q_{mC}$ = 1 A m) at C. The force experienced by the unit north pole at C due to pole strength N-S can be computed using Coulomb's law of magnetism

The force of repulsion between North Pole of the bar magnet and unit north pole at point C (in free space) is




$\vec{F_N} = -F_N \cos\theta\,\hat{i} - F_N \sin\theta\,\hat{j}$

$F_N = \frac{\mu_0}{4\pi}\frac{q_m}{(r')^2}$

$\vec{F_S} = -F_S \cos\theta\,\hat{i} - F_S \sin\theta\,\hat{j}$

$F_S = \frac{\mu_0}{4\pi}\frac{q_m}{(r')^2}$

$\vec{F} = \vec{F_N} + \vec{F_S}$

$\vec{B} = -(F_N + F_S)\cos\theta\,\hat{i}$

$F_N = F_S$

$\vec{B} = -2\frac{\mu_0}{4\pi}\frac{q_m}{(r')^2}\cos\theta\,\hat{i}$

$r'^2 = r^2 + l^2$

In right angle triangle

$\cos\theta = \frac{l}{(r^2+l^2)^{\frac{1}{2}}}$

Sub $\cos\theta = \frac{1}{(r^2+l^2)^{\frac{1}{2}}}$ in above quation

$\vec{B} = -2\frac{\mu_0}{4\pi}\frac{q_m}{r^2+l^2} \times \frac{1}{(r^2+l^2)^{\frac{1}{2}}}\,\hat{i}$

$= -\frac{\mu_0}{4\pi}\frac{P_m}{(r^2+l^2)^{\frac{3}{2}}}\,\hat{i}$ (since $P_m = q_m \times 2l$ )

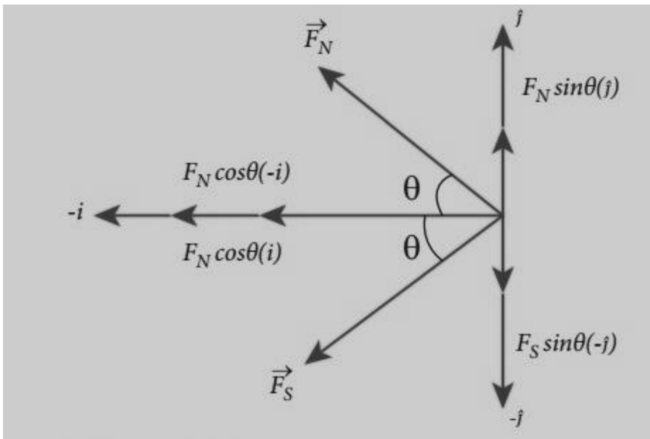



**Figure 3.18** Components of force

$r >> l$ $l^2$ can neglected

$\vec{B} = -\frac{\mu_0}{4\pi}\frac{P_m}{r^3}\,\hat{i}$

**14.Find the magnetic induction due to a straight conductor using ampere's circuital law**

- ❖ Consider a straight conductor of infinite length carrying current I.
- ❖ Construct an Ampèrian loop in the form of a circular shape at a distance *r* from the centre of the conductor

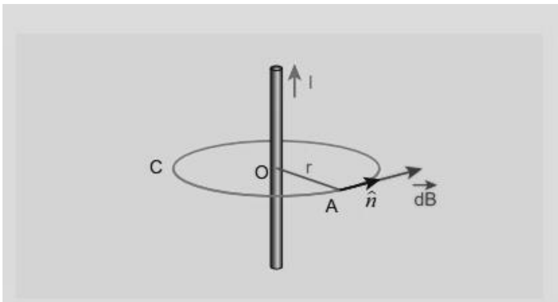



**Figure 3.42** Ampèrian loop for current carrying straight wire

$\oint \vec{B}\cdot\vec{dl} = \mu_0 I$
**C**

$\vec{dl}$ is the line element along the amperian loop (tangent to the circular loop).

Hence, the angle between magnetic field vector and line element is zero

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

**C**

Magnitude of the magnetic field is uniform over the Ampèrian loop

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

**C**

$B \int_0^{2\pi r} dl = \mu_0 I$

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

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

**In vector form**

$$\vec{B} = \frac{\mu_0}{2\pi r} I\, \hat{n}$$

$\hat{n}$ – the unit vector along the tangent to the Ampèrian loop

This perfectly agrees with the result obtained from Biot-Savart's law

# UNIT – 4 ELCTROMAGNETIC INDUCTION AND ALTERNATING CURRENT

**Three marks and two marks**

**1.Mention the various energy losses in a transformer**

**i) Core loss or Iron loss**

- This loss takes place in **transformer core.**
- **Hysteresis loss and eddy current loss** are known as core loss or Iron loss.
- When transformer core is magnetized and demagnetized repeatedly by the alternating voltage applied across primary coil, hysteresis takes place due to which some energy is lost in the form of heat.

**Hysteresis loss minimization** - using **steel of high silicon content i**n 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.

**Eddy current minimization -** using very **thin laminations** of transformer core.

**ii)Copper loss**

- Transformer windings have electrical resistance.
- When an electric current flows through them, some **amount of energy is dissipated** due to **Joule heating.** This energy loss is called copper loss

**Copper loss minimization -** using **wires of larger diameter**.

**iii) Flux leakage**

Flux leakage happens when the magnetic lines of primary coil are not completely linked with secondary coil.

**Flux leakage minimization -** using **winding coils one over the other.**

**2. Find out phase relationship between voltage and current in a pure inductor circuit**

Consider a circuit containing a pure inductor of **inductance $L$** connected across an alternating voltage source).

**$V = V_m \sin\omega t$ ………. (1)**

The alternating current flowing through the inductor induces a self-induced emf or back emf in the circuit.

**Back emf $\varepsilon = -L\frac{di}{dt}$ …….(2)**

By applying Kirchoff's loop rule to the purely inductive circuit, we get

**$V + \varepsilon = 0$**

$V_m \sin \omega t - L\frac{di}{dt} = 0$

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

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

Integrating both sides

$I = \frac{V_m}{L} \int \sin\omega t dt$

$= \frac{V_m}{L\omega}(-cos\ \omega t) + \text{constant}$

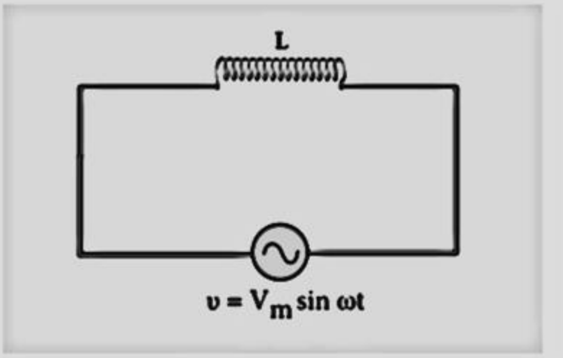


Figure 4.47 AC circuit with inductance

The integration constant in the above equation is independent of time so integration constant is zero

$I = \frac{V_m}{L\omega} \sin(\omega t - \pi/2)$

$I = I_m \sin(\omega t - \pi/2)$ **………(3)**

**where** $\frac{V_m}{L\omega} = I_m$ the peak value of the alternating current in the circuit.

**From (1) and (3)** it is evident that current lags behind the applied voltage by π/2 in an inductive circuit.

**Inductive reactance** $X_L = \omega L$

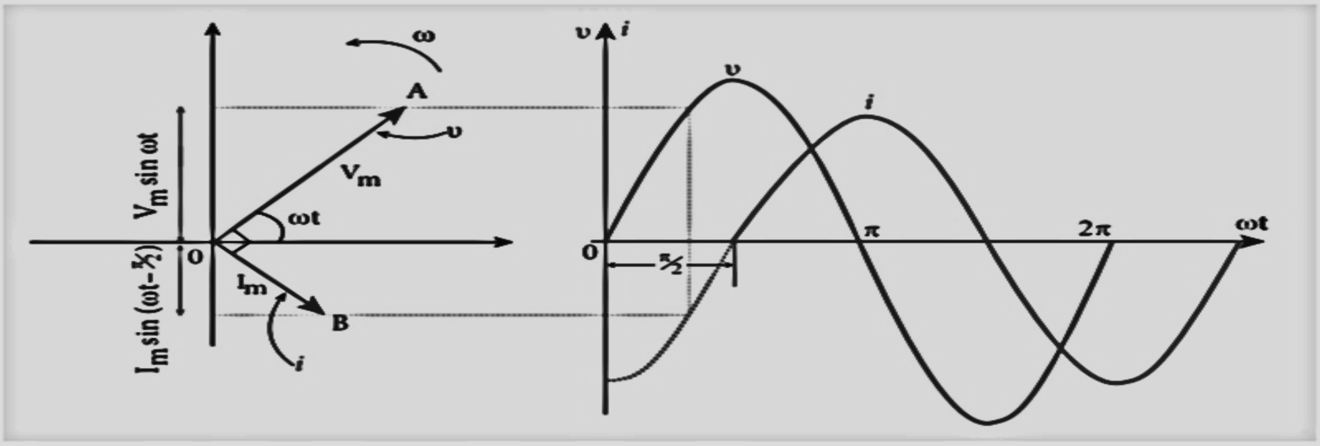


Figure 4.48 Phasor diagram and wave diagram for AC circuit with L

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

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

The applied alternating voltage is

**$V = V_m \sin\omega t$ ………. (1)**

As a result, the voltage is developed across *R*, *L* and *C*.

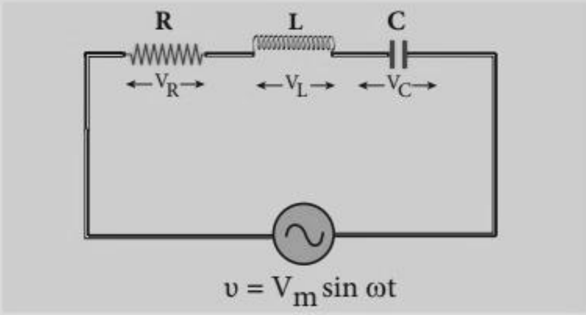


Figure 4.51 AC circuit containing *R*, *L* and *C*

**Voltage across R ($V_R$) is in phase with i**
**Voltage across L ($V_L$) Leads i by $\pi/2$**
**Voltage across C ($V_C$) Lags i by $\pi/2$**

$V_L$ & $V_C$ are 180° out of phase with each other and the resultant of $V_L$ and $V_C$ is ($V_L - V_C$)

Assuming circuit to be predominantly inductive.

The applied voltage equals the vector sums of $V_L$, $V_C$, $V_R$

***OI = $I_m$***

**$V_R$ = OA = $I_mR$ $V_L$ = OB = $I_mX_L$**

**$V_C$ = OC = $I_mX_C$**

$V_m^2 = V_R^2 + (V_L - V_C)^2$

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

**$I_m = V_m / Z$**

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

**Z** - impedance of the circuit which refers to the effective opposition to the circuit current by the series *RLC* circuit

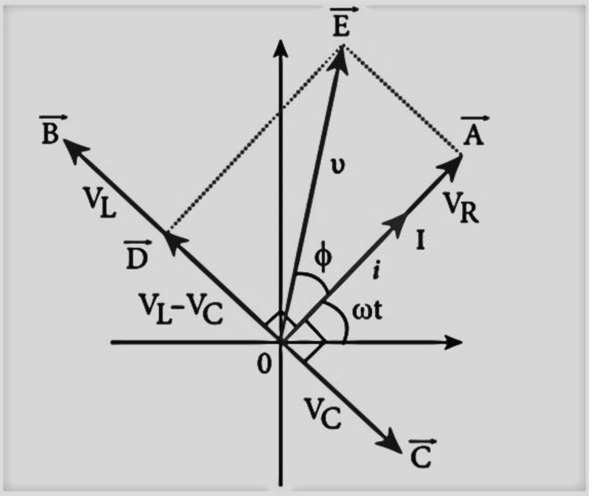


Figure 4.52 Phasor diagram for a series *RLC* – circuit when $V_L > V_C$

$$\tan\emptyset = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$$

**4. Obtain an expression for average power of AC over a cycle .Discuss its special cases.**

- Power of a circuit is defined as the rate of consumption of electric energy in that circuit.
- P = VI
- In an AC circuit, the voltage and current vary continuously with time.
- The power at an instant was calculated and then it is averaged over a complete cycle.

$V = V_m \sin\omega t$ $i = I_m \sin(\omega t + \emptyset)$

$\emptyset$ - phase angle between $\upsilon$ and *i*.

The instantaneous power

$$P = V\,i$$

Sub V & I values in above equation

$P = V_m \sin\omega t \; I_m \sin(\omega t + \emptyset)$

$= V_m I_m \sin\omega t \sin(\omega t + \emptyset)$

$= V_m I_m[\sin^2\omega t\cos\emptyset - \sin\omega t \; \cos\omega t \sin\emptyset]$

Average of $\sin^2$ **ωt** over a cycle is ½

Average of **sinωt cosωt is 0**

$P_{av} = V_m I_m \cos\emptyset \times \frac{1}{2}$

$= \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos\emptyset$

$\frac{V_m}{\sqrt{2}} = V_{RMS} \; \frac{I_m}{\sqrt{2}} = I_{RMS}$

$P_{av} = V_{RMS} I_{RMS} \cos\emptyset$

$V_{RMS} I_{RMS}$ **- Apparent power**

cos∅ **- power factor**

**Average power** of an AC circuit is also known as the **true power** of the circuit

Special cases

(i) For purely resistive circuit $\emptyset = 0 \;\; \cos\emptyset = 1$

$P_{av} = V_{RMS} I_{RMS}$

(ii) For purely inductive or capacitive circuit $\emptyset = \pm\frac{\pi}{2} \;\; \cos\pm\frac{\pi}{2} = 0 \;\; P_{av} = 0$

(iii)For series RLC circuit , $\emptyset = tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

$P_{av} = V_{RMS} I_{RMS} \cos\emptyset$

(iv) For series RLC circuit at resonance,

$\emptyset = 0 \;\; \cos\emptyset = 1 \;\; P_{av} = V_{RMS} I_{RMS}$

**5. Give the uses of Foucault current or Eddy current**

i. Induction stove

ii. Eddy current brake

iii. Eddy current testing

iv. Electromagnetic damping

**i. Induction stove**

- **It is used to** cook the food quickly and safely with less energy consumption.
- Below the cooking zone, there is a tightly wound **coil of insulated wire.**
- The cooking pan made of suitable material, is placed over the cooking zone.
- When the stove is switched on, an **alternating current** 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.

**ii. Eddy current brake**

- This eddy current braking system is 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 or resist the movement of the train.**
- This is **Eddy current linear brake.**

**iii. Eddy current testing**

- It is one of the **simple non–destructive** testing methods to find defects like surface cracks, 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 the test surface.
- **The presence of defects** causes the **change in phase and amplitude** of the eddy current that can be detected by some other means.
- In this way, the defects present in the specimen are identified

**iv. Electromagnetic damping or dead beat galvanometer**

- 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 then galvanometer shows a steady deflection.

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

- Consider a conducting rod of length $l$ moving with a velocity $\vec{v}$ towards left on a rectangular metallic framework .
- The whole arrangement is placed in a uniform magnetic field $\vec{B}$ whose magnetic lines are perpendicularly directed into the plane of the paper.
- 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.

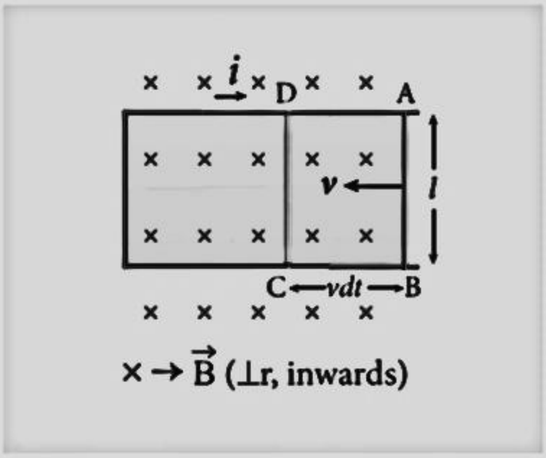


**Figure 4.24 Induction of emf by changing the area enclosed by the loop**

The change in magnetic flux in time dt is

$d\phi_B = B \times dA$

dA = area of ABCD

area of ABCD(rectangle) = l × b

v = dx/dt = b/dt ( dx = b)

b = vdt

area of ABCD(rectangle) = l × vdt

$\frac{d\phi_B}{dt} = Blv$ ……….. (1)

As a result of change in flux , induced emf is generated in the loop

$\varepsilon = \frac{d\phi_B}{dt}$ ………..(2)

**Comparing (1) & (2)**

$$\boldsymbol{\varepsilon = Blv}$$

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

- Consider a rectangular coil of N turns kept in magnetic field $\vec{B}$ .
- It is rotated in anticlockwise direction with an angular velocity ω about an axis perpendicular to field.
- **At time = 0**, the plane of the coil is perpendicular to the field and the flux linked with the coil has its maximum value $\boldsymbol{\phi_m}$ **= BA**
- In a time *t* seconds, the coil is rotated through an angle ( **θ = *ωt*)** in anti–clockwise direction.
- In this position, the flux linked is **$\Phi_m$ cos ωt**, a component of $\Phi_m$ **norma**l to the plane of the coil
- The component parallel to the plane **($\Phi_m$ sin ωt)** has no role in electromagnetic induction. Therefore, the flux linkage at this deflected position is

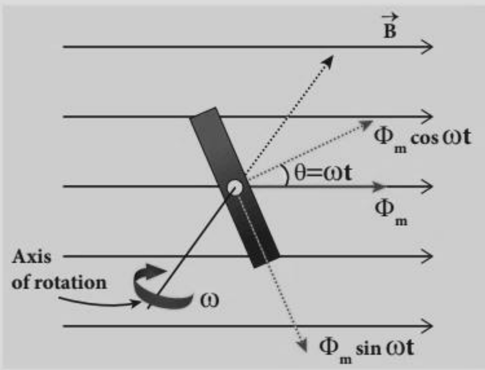


Figure 4.25(b) The coil has rotated through an angle θ = ω*t*

$N\phi_B = N\phi_M cos\omega t$

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

$$\varepsilon = -\frac{d}{dt}(N\phi_m cos\omega t)$$

$$= N\phi_m \omega sin\omega t$$

- When the coil is rotated through **90°** from initial position, **sin ωt = 1**.

- Then the maximum value of induced emf is

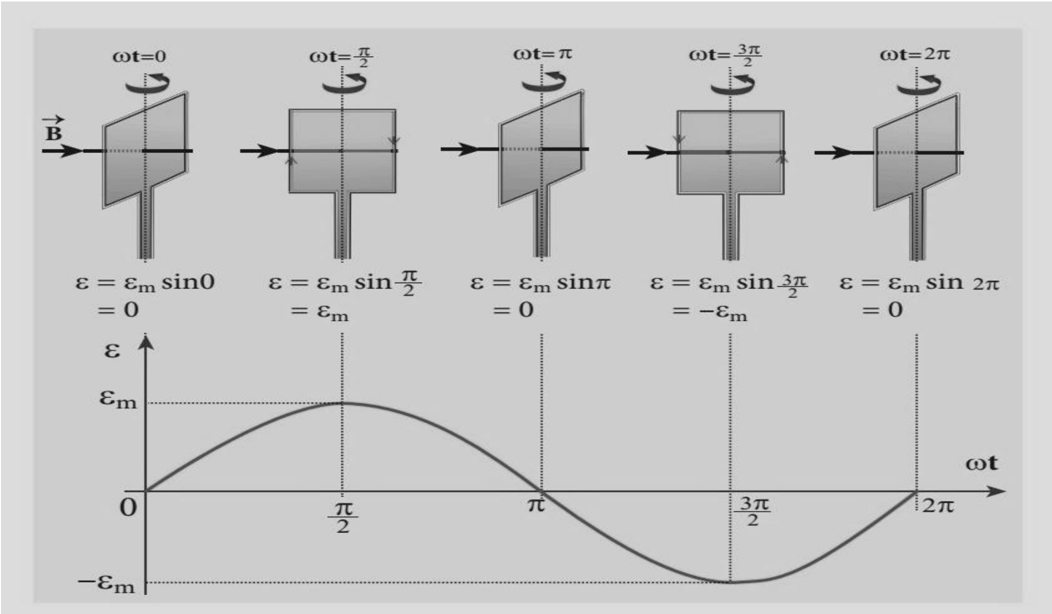
$$\varepsilon = N\phi_m \omega \sin\omega t$$

**sin ωt = 1 → $\varepsilon_m = N\phi_m\omega$**

**sub $\varepsilon_m = N\phi_m\omega$ in above equation**

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

$\varepsilon = \varepsilon_m \sin\omega t$




**8.Explain the construction and working of transformer**

**Principle ;** Mutual induction between two coils.

**Construction**

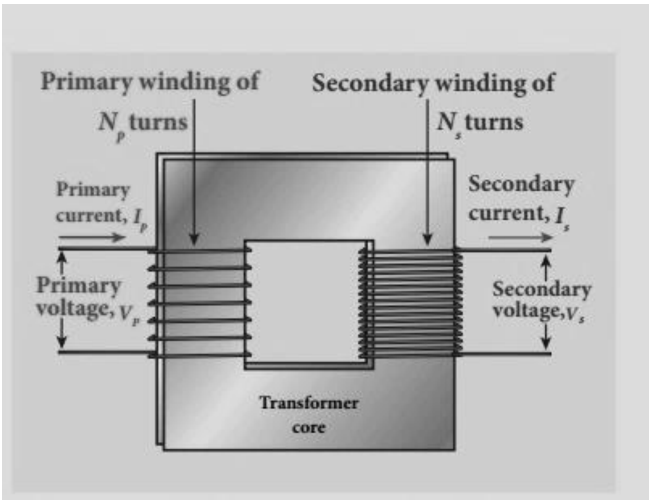


Figure 4.37(a) Construction of transformer

- There are **two coils of high mutual inductance** wound over the same transformer core.
- The core is **generally laminated** and is made up of a good magnetic material like silicon steel.
- The coil across which **alternating voltage is applied is called primary coil *P*** and the coil from which **output power is drawn out is called 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.
- Coils are **electrically insulated** but magnetically linked via transformer core

**Working**

- If the primary coil is connected to a source of alternating voltage, an alternating magnetic flux is set up in the laminated core.
- Rate at which magnetic flux changes through each turn is same for both primary and secondary coils.
- As a result of flux change, emf is induced in both primary and secondary coils.
- The emf induced in the primary coil $\varepsilon_p$ is almost equal and opposite to the applied voltage $v_p$ and is given by

$$V_P = \varepsilon_P = -N_P \frac{d}{dt}(N\phi_B) \quad ..........(1)$$

- The frequency of alternating magnetic flux in the core is same as the frequency of the applied voltage.
- Therefore, induced emf in secondary will also have same frequency as that of applied voltage. The emf induced in the secondary coil $\varepsilon_s$ is given by

$$\varepsilon_S = -N_S \frac{d}{dt}(N\phi_B)$$

**$N_P$ , $N_S$ -** number of turns in the primary and secondary coil

If the secondary circuit is open, then $\varepsilon_s = v_s$ where $v_s$ is the voltage across secondary coil.

$$V_S = \varepsilon_S = -N_S \frac{d}{dt}(N\phi_B) \quad .........(2)$$

Dividing (2) by (1)

$$\frac{V_S}{V_p} = \frac{N_S}{N_P} = K$$

K – **voltage Transformer ratio**

**For an ideal transformer,**

**Input power = Output power**

$$v_P i_P = v_S i_S$$

$$\frac{V_S}{V_p} = \frac{N_S}{N_P} = \frac{I_P}{I_S} = K$$

**For step-up transformer**

**$K > 1$ $V_S > V_P$ $I_S < I_P$**

voltage is increased and the corresponding current is decreased.

**For step down transformer**

**$K < 1$ $V_S < V_P$ $I_S > I_P$**

voltage is decreased and the current is increased.

**9.Find out the phase relationship between voltage and current in pure resistive circuit**

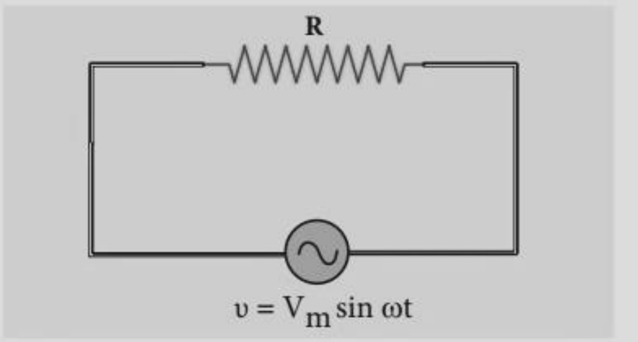


Figure 4.45 AC circuit with resistance

- Consider a circuit containing a pure resistor of resistance *R* connected across an alternating voltage source

$V = V_m \sin\omega t$ …………(1)

$V_R = iR$ …………….(2)

Kirchoff 's loop rule states that the algebraic sum of potential differences in a closed circuit is zero.

**For this resistive circuit,**

$V - V_R = 0$

$V_m \sin\omega t - iR = 0$

$V_m \sin\omega t = iR$

$$i = \frac{V_m}{R}\sin\omega t$$

the peak value of alternating current in the circuit $I_m = \frac{V_m}{R}$

$$i = I_m \sin\omega t \text{ ………(3)}$$

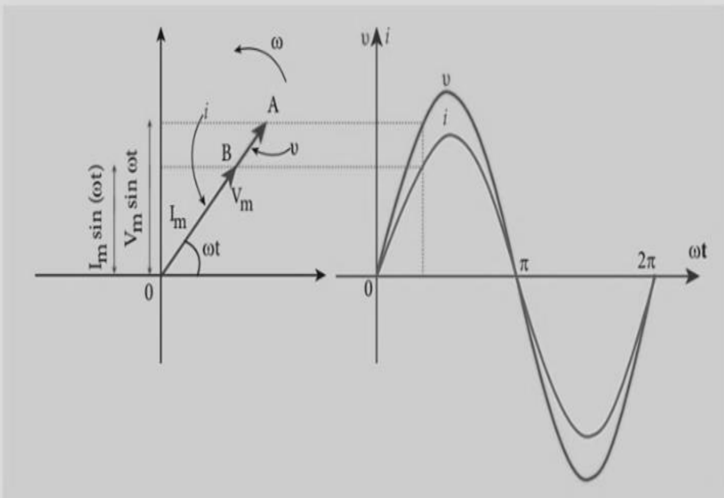


Figure 4.46 Phasor diagram and wave diagram for AC circuit with R

From (1) & (3) applied voltage and the current are in phase with each other in a resistive circuit.

**10. Calculate the Mutual inductance between two long co-axial solenoids OR Show that the mutual inductance between a pair of coil is same ($M_{12} = M_{21}$)**

- Consider two long co-axial solenoids of same length *l*.
- The length of these solenoids is large when compared to their radii so that the magnetic field produced inside the solenoids is uniform and the fringing effect at the ends may be ignored.
- $A_1$ **and** $A_2$ **-** Area of cross section of the solenoids
- $A_1 > A_2$
- $n_1$ **&** $n_2$ **-** The turn density of these solenoids
- $i_1$ - current flowing through solenoid 1
- Then the magnetic field produced inside it is

$B_1 = \mu_o n_1 i_1$

$\emptyset_{21} = B_1 A_2$

$\emptyset_{21} = (\mu_o n_1 i_1)A_2$

The flux linkage of solenoid 2 with total turns $N_2$ is

$N_2\emptyset_{21} = (\mu_o n_1 n_2 l A_2)i_1$…….(1)

$N_2\emptyset_{21} = M_2 i_1$……..(2)

Comparing (1) and (2)

$M_2 i_1 = (\mu_o n_1 n_2 l A_2)i_1$

$M_2 = \mu_o n_1 n_2 l A_2$

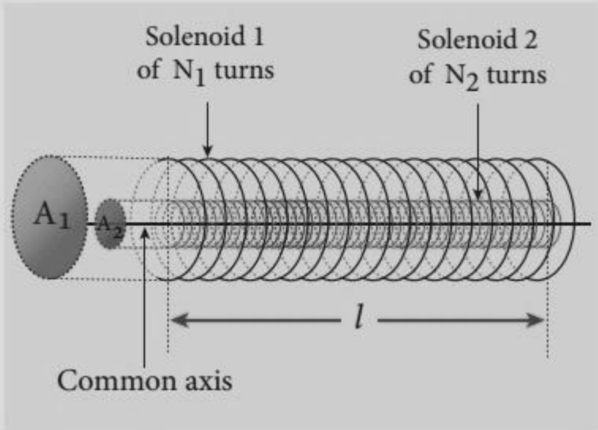



**Figure 4.23** Mutual inductance of two long co-axial solenoids

mutual inductance of the solenoid 2 with respect to solenoid 1 is

$M_2 = \mu_o n_1 n_2 l A_2$……..(3)

$B_2 = \mu_o n_2 i_2$

$$\emptyset_{12} = B_2 A_2$$

Sub $B_1$ in above equation

$$\emptyset_{12} = (\mu_o n_2 i_2)\, A_2$$

The flux linkage of solenoid 2 with total turns $N_2$ is

$N_1\emptyset_{12} = (\mu_o n_2 i_2)\,(n_1 l)A_2$ where $N_1$ = nl

$= (\mu_o n_1 n_2 l A_2)i_2$…….(4)

$N_1\emptyset_{12} = M_1 i_2$……..(5)

Comparing (4) and (5)

$$M_1 i_2 = (\mu_o n_1 n_2 l A_2)i_2$$
$$M_1 = \mu_o n_1 n_2 l A_2$$

mutual inductance of the solenoid 2 with respect to solenoid 1 is

$M_1 = \mu_o n_1 n_2 l A_2$……..(6)

From (3) & (6)

$$\boldsymbol{M_1 = M_2 = M}$$

**11. Explain the working of single – phase AC generator with necessary diagram**

- In a single phase AC generator, th**e 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
- Consider a stator core consisting of 2 slots in which 2 armature conductors 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.
- When field windings are excited, magnetic field is produced around it.
- Let the field magnet be rotated in clockwise direction by the prime mover.
- The axis of rotation is perpendicular to the plane of the paper.
- Assume that 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
- When field magnet rotates through $90^\circ$, magnetic field becomes parallel to PQRS.
- The induced emf's across PQ and RS would become maximum.
- Since they are connected in series, emfs are added up and the direction of total induced emf is given by Fleming's right hand rule.

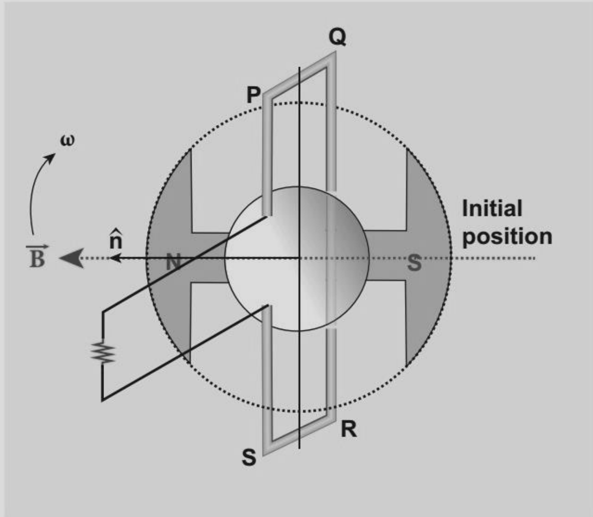
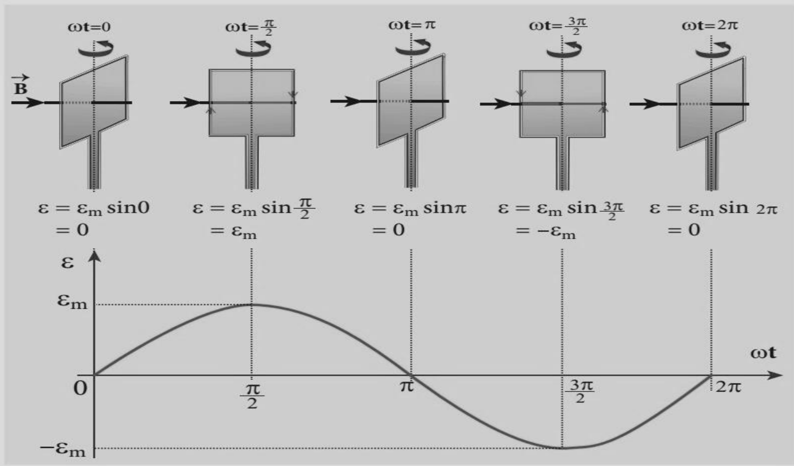



**Figure 4.33** The loop PQRS and field magnet in its initial position

- For PQ, it is downwards and for RS upwards. Therefore, the current flows along PQRS. The point A in the graph represents this maximum emf.
- For the rotation of **$180^\circ$** from the initial **position, the field is again perpendicular to PQRS** and the induced **emf becomes zero**. This is represented by point B.
- The field magnet becomes again parallel to PQRS **for $270^\circ$** rotation of field magnet. 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 **$360^\circ$**, the induced **emf becomes zero** and is represented by the point D. From the graph, it is clear that emf induced in PQRS is alternating in nature.




- Therefore, when field magnet completes one rotation, induced emf in PQRS finishes one cycle.

- The **frequency** of the induced emf depends on the **speed** at which the field magnet rotates.

**12.An inductor of inductance L carries an electric current I .How much energy is stored while establishing the current in it**

- Whenever a current is established in the circuit, the inductance opposes the growth of the current.
- In order to establish a current in the circuit, **work** is done **against this opposition** by some external agency.
- This **work done** is stored as **magnetic potential energy.**

The induced emf at any instant *t* is

$\varepsilon = -L\frac{di}{dt}$…………(1)

Let dW be work done in moving a charge dq in a time dt against the opposition, then

dW = Vdq …………(2)

$V = -\varepsilon$ $dq = idt$

Sub V & dq values in (2) equation

$dW = = -\varepsilon\ idt$

Sub $\varepsilon = -L\frac{di}{dt}$ in above equation

$= -\ (-L\frac{di}{dt})\ idt$

dW = Lidi

On integration

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

This work done is stored as magnetic potential energy

$U_B = \frac{1}{2} Li^2$

# Unit – 5 ELECTROMAGNETIC WAVES

**Three marks and five marks**

**1.Write down Maxwell equation in integral form.**

**1. First equation -** Gauss's law.

It relates the net electric flux to net electric charge enclosed in a surface

$\oint \vec{E}.\vec{dA} = \frac{Q_{enclosed}}{\varepsilon_0}$ **(Gauss law )**

$Q_{enclosed}$ **-** Charge enclosed

$\vec{E}$ **–** Electric field

It means that isolated positive charge or negative charge can exist

**2. Second equation** has no name. But this law is similar to Gauss's law in electrostatics. So this law can also be called as Gauss's law in magnetism.

$\oint \vec{B}.\vec{dA} = 0$

$\vec{B}$**- Magnetic field**

It means that no isolated magnetic monopole exists

**3.** Third equation is Faraday's law of electromagnetic induction

$\oint \vec{E}.\vec{dl} = \frac{d}{dt}\phi_B$

$\vec{E}$ **–** Electric field

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.

4. Fourth equation is **modified Ampere's circuital law**. This is also known 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.

$$\oint \vec{B}.\vec{dl} = \mu_o I_{enclosed} + \mu_o \varepsilon_o \frac{d}{dt}\int_s \vec{E}.\vec{dA}$$

**2. Write down properties of electromagnetic waves**

1) They are produced by any **accelerated charge**.

2) They do not **require any medium for propagation**. So it is a **non-mechanical wave**.

3) They are **transverse** in nature. Oscillating electric field vector, oscillating magnetic field vector and propagation vector (gives direction of propagation) are **mutually perpendicular to each other.**

4) Electromagnetic waves travel with speed which is equal to the speed of light in vacuum or free space,

   c = $\frac{1}{\sqrt{\mu_o \varepsilon_0}}$ = **3 × 10$^{-}$ m s$^{-1}$**

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

6) They can show **interference, diffraction and can also be polarized**.

7) They also carry energy and momentum.The force exerted by an electromagnetic wave on unit area of a surface is called **radiation pressure**.

8) Electromagnetic waves carries not only energy and momentum but **also angular momentum.**

**3.What is emission spectra? Give their types**

**Emission spectra**

- ❖ When the **spectrum of self luminous source** is taken, we get emission spectrum.
- ❖ Each source has its **own characteristic emission spectrum**.
- ❖ It has **three** types

**(i) Continuous emission spectra (or continuous spectra)**

- ❖ If the light from incandescent lamp (filament bulb) is allowed to pass through prism (simplest spectroscope), it splits into seven colours.
- ❖ Thus, it consists of wavelengths containing all the visible colours ranging from violet to red.

**Examples:**

- ❖ Spectrum obtained from carbon arc, incandescent solids
- ❖ liquids gives continuous spectra.

**(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 **are sharp lines of definite wavelengths or frequencies.**
- ❖ Such spectra arise due to excited atoms of elements.
- ❖ These lines are the characteristics of the element which means it **is different for different elements**.
- ❖ **For diagram refer book**

**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 overlapped together forming specific bands which are **separated by dark spaces**, known as band spectra.
- 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 hence, the **structure of the molecules can be studied using their band spectra**.

**Examples,**

Spectra of hydrogen gas, ammonia gas in the discharge tube etc.

**4.What is absorption spectra ?Give their types**

**Absorption spectra**

- When **light** is allowed to **pass** through a medium or an **absorbing substance** then the **spectrum** obtained is known as **absorption spectrum.**
- It is the **characteristic of absorbing substance**.
- It 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.
- **Example**
- When we pass white light through a blue glass plate, it absorbs everything except blue.

**(ii) Line absorption spectrum**

- When **light from the incandescent** lamp is passed through **cold gas** (medium), the **spectrum obtained** through the dispersion due to prism **is line absorption spectrum**.

- **For diagram refer book**

**Example**

- Similarly, if the light from the 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 type of band is also obtained when white light is passed through diluted solution of blood or chlorophyll or through certain solutions of organic and inorganic compounds.

"You can't have a better tomorrow

if you're still thinking about yesterday"