

ELECTRIC FIELD

Electric Field due to Point Charge



$$E = \frac{kq}{x^2}$$

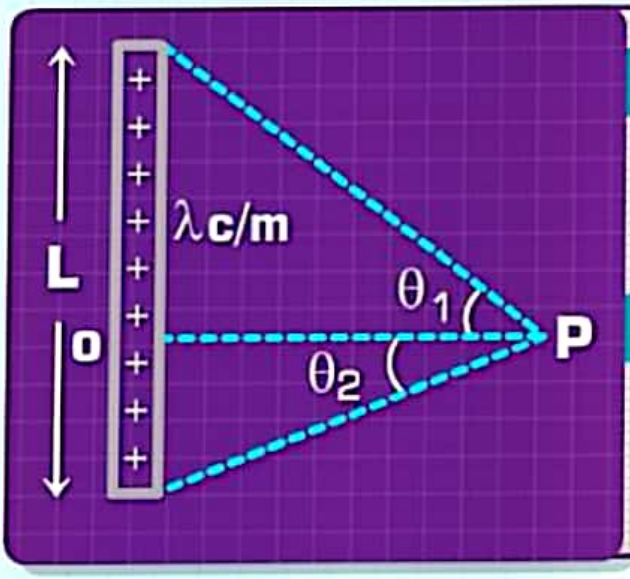
Vector Form $\vec{E} = \frac{kq}{x^3} \cdot \vec{x}$

$$k = \frac{1}{4\pi\varepsilon_0}$$

q = Charge ; x = Distance

If a charge q_0 is placed at a point in electric field, it experiences a net force $\vec{F}$ on it, then electric field strength at that point can be $\vec{E} = \frac{\vec{F}}{q_0}$

ELECTRIC FIELD DUE TO A UNIFORMLY CHARGED ROD



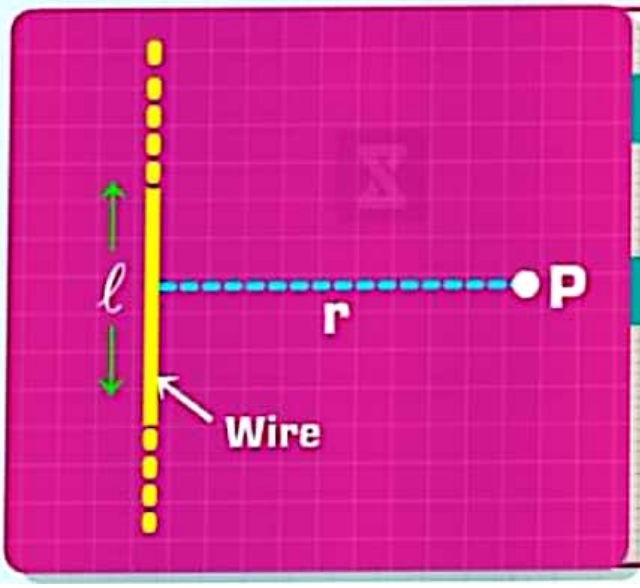
PARALLEL

$$E_{\parallel} = \frac{k\lambda}{r}(\cos\theta_2 - \cos\theta_1)$$

PERPENDICULAR

$$E_{\perp} = \frac{k\lambda}{r}(\sin\theta_2 - \sin\theta_1)$$

ELECTRIC FIELD DUE TO INFINITE WIRE ($\ell >> r$)



Since $\ell >> r \Rightarrow \theta_1 = \theta_2 = 90°$

PERPENDICULAR

$$E_{\perp} = \frac{k\lambda}{r}(\sin 90° + \sin 90°) \rightarrow E_{\perp} = \frac{2k\lambda}{r}$$

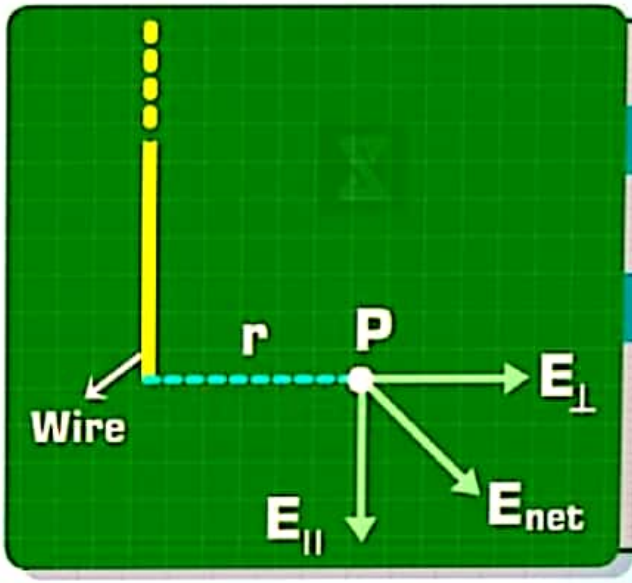
PARALLEL

$$E_{\parallel} = \frac{k\lambda}{r}(\cos 90° - \cos 90°) \rightarrow E_{\parallel} = 0$$

At P, $E_{net} = E_{\perp} + E_{\parallel}$ $\quad E_{net} = \frac{2k\lambda}{r}$

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ELECTRIC FIELD DUE TO SEMI INFINITE WIRE



$\theta_1 = 90^\circ$, $\theta_2 = 0^\circ$

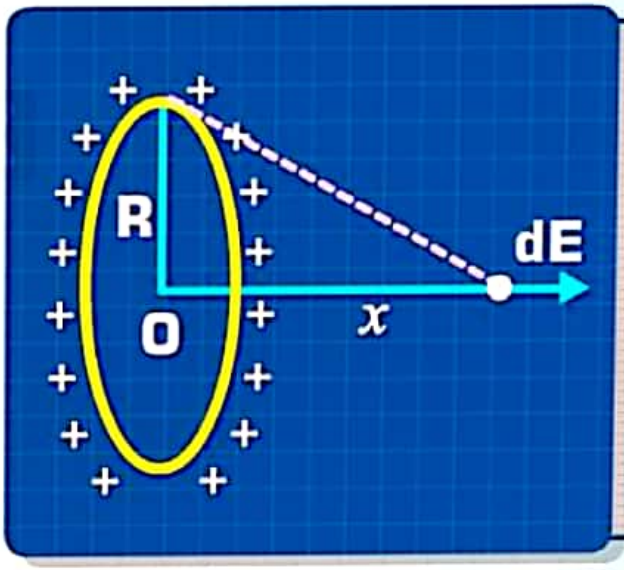
PERPENDICULAR

$$E_\perp = \frac{k\lambda}{r}(\sin 90^\circ + \sin 0^\circ) = \frac{k\lambda}{r}$$

PARALLEL

$$E_{||} = \frac{k\lambda}{r}(\cos 0^\circ - \cos 90^\circ) = \frac{k\lambda}{r}$$

ELECTRIC FIELD DUE TO UNIFORMLY CHARGED RING

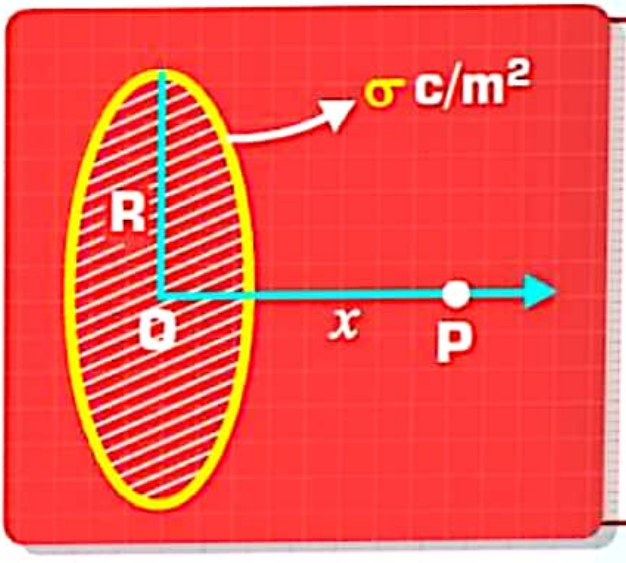


$$E = \frac{kQx}{(R^2 + x^2)^{3/2}}$$

For maxima, $x = \pm\frac{R}{\sqrt{2}}$

$$E_{max} = \pm\frac{2}{3\sqrt{3}}\frac{kQ}{R^2}$$

ELECTRIC FIELD ON THE AXIS OF DISC



$$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{x}{\sqrt{x^2 + R^2}}\right]$$ [along the axis]

If $x >> R$

$$E = 0$$

If $x << R$

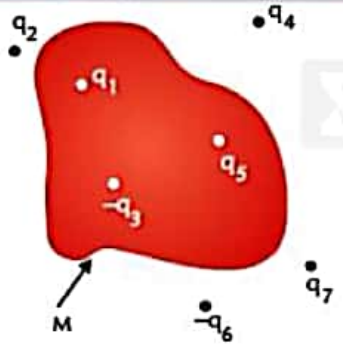
$$E = \frac{\sigma}{2\varepsilon_0}(1 - 0) = \frac{\sigma}{2\varepsilon_0}$$

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ELECTRIC FIELD STRENGTH

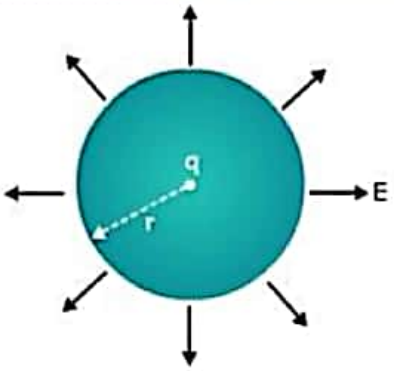
Part III

Gauss's Law



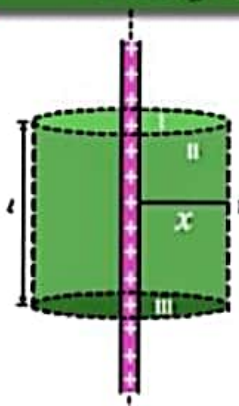
$$\oint_M \vec{E} \cdot d\vec{S} = \frac{q_1 + q_5 - q_3}{\varepsilon_0}$$

Electric Field due to a Point Charge



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

Electric Field Strength due to a Long Charged Wire

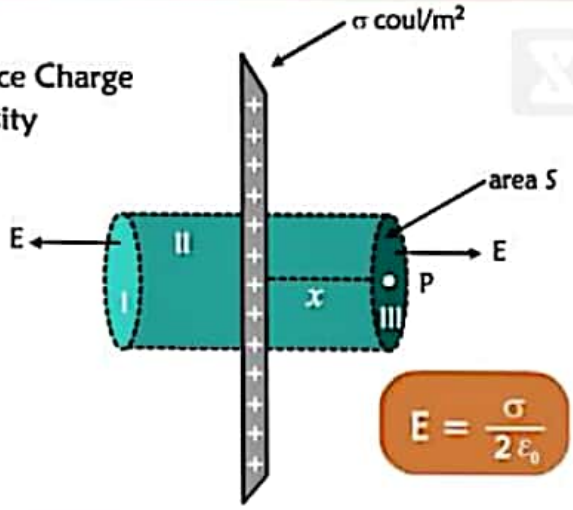


λ = Linear Charge Density

$$E = \frac{\lambda}{2\pi\varepsilon_0 x}$$

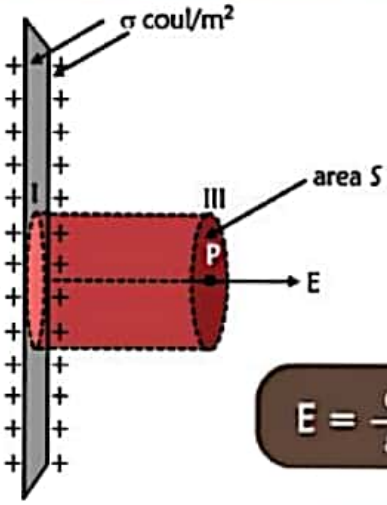
Electric Field Strength due to Non-Conducting Uniformly Charged Sheet

σ = Surface Charge Density



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

Electric Field Strength due to Charged Conducting Sheet

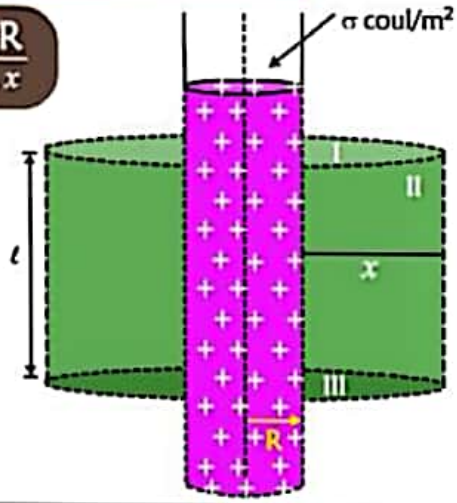


$$E = \frac{\sigma}{\varepsilon_0}$$

Electric Field Strength due to a Long Uniformly Charged Cylinder

Conducting Cylinder

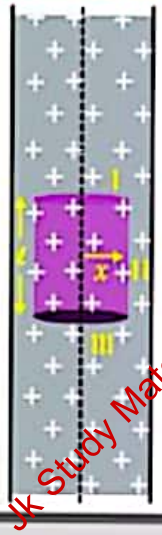
$$E = \frac{\sigma R}{\varepsilon_0 x}$$



Uniformly Charged Non – Conducting Cylinder

$$E_{inside} = \frac{\rho x}{2\varepsilon_0}$$

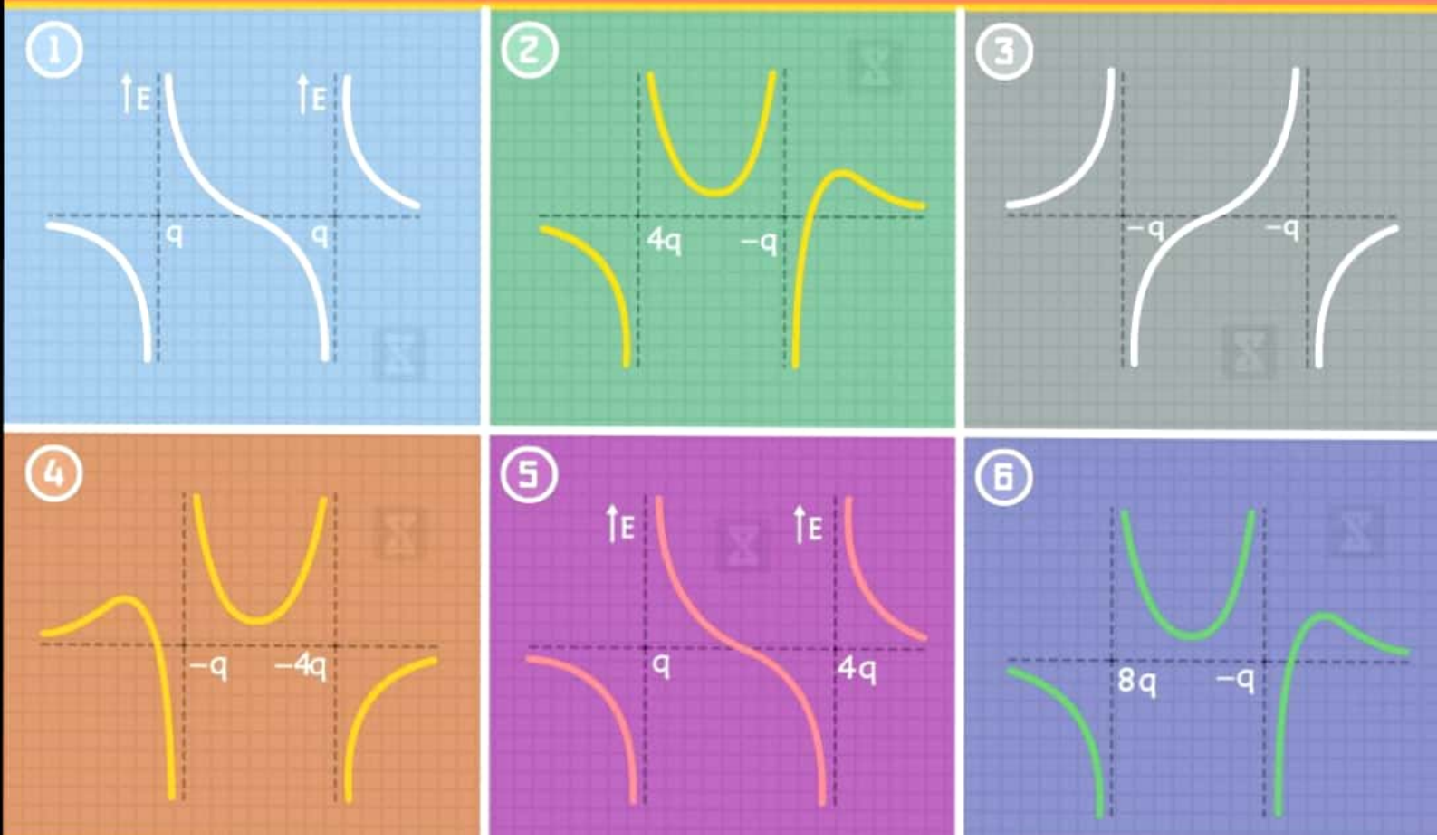
ρ = Volume Charge Density



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GRAPH OF ELECTRIC FIELD DUE TO BINARY CHARGES

Part IV

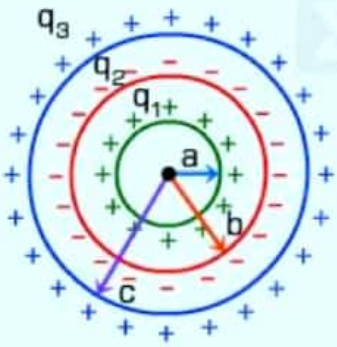


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ELECTRIC POTENTIAL

Part V

POTENTIAL DUE TO CONCENTRIC SPHERES



At a point $r > c$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q_1 - q_2 + q_3}{r}$$

At a point $a < r < b$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r} - \frac{1}{4\pi\varepsilon_0}\frac{q_2}{b} + \frac{1}{4\pi\varepsilon_0}\frac{q_3}{c}$$

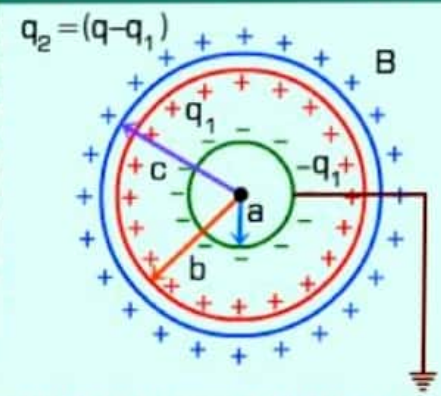
At a point $b < r < c$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q_1 - q_2}{r} + \frac{1}{4\pi\varepsilon_0}\frac{q_3}{c}$$

At a point $r < a$

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{a} - \frac{q_2}{b} + \frac{q_3}{c}\right]$$

DIFFERENCE BETWEEN TWO CONCENTRIC SPHERES WHEN ONE OF THEM IS EARTHED



$$V_{in} = \frac{1}{4\pi\varepsilon_0}\left[-\frac{q_1}{a} + \frac{q_2}{b}\right]$$

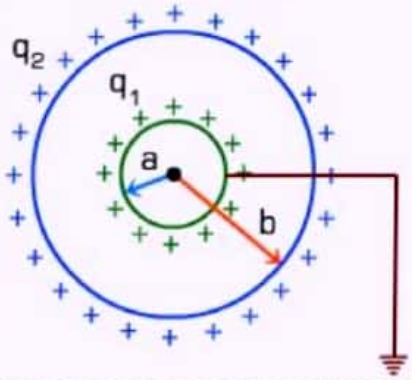
$$V_{out} = \frac{1}{4\pi\varepsilon_0}\left[-\frac{q_1}{b} + \frac{q_2}{b}\right]$$

$$\frac{q_2}{c} = q_1\left(\frac{1}{a} - \frac{1}{b}\right) \quad .....(i)$$

$$q_1 + q_2 = q \quad .....(ii)$$

Solving (i) and (ii) we can get q_1 and q_2

DIFFERENCE BETWEEN TWO CONCENTRIC UNIFORMLY CHARGED METALLIC SPHERES

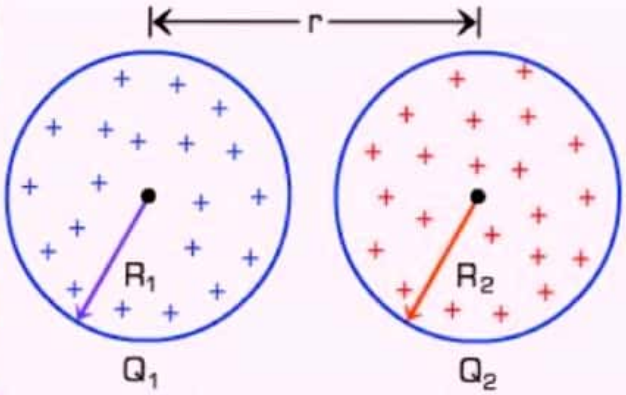


$$V_{in} = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{a} + \frac{1}{4\pi\varepsilon_0}\frac{q_2}{b}$$

$$V_{out} = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{b} + \frac{1}{4\pi\varepsilon_0}\frac{q_2}{b}$$

$$\Delta V = V_{in} - V_{out} \Rightarrow \Delta V = \frac{q_1}{4\pi\varepsilon_0}\left(\frac{1}{a} - \frac{1}{b}\right)$$

TOTAL ELECTROSTATIC ENERGY OF A SYSTEM OF CHARGES



$$U = U_{self} + U_{interaction}$$

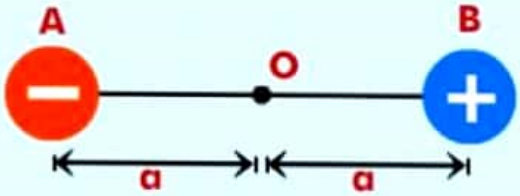
$$U = \frac{3KQ_1^2}{5R_1} + \frac{3KQ_2^2}{5R_2} + \frac{KQ_1Q_2}{r}$$

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ELECTRIC DIPOLE

ELECTRIC DIPOLE

$\vec{p} = q.2\vec{a}$



SI unit : Coulomb - meter

It is a vector quantity

Direction of dipole moments ($\vec{p}$) is from negative charge to positive charge

ELECTRIC FIELD ON AXIAL LINE OF AN ELECTRIC DIPOLE

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2qa}{(r^2-a^2)^2}$$

For a<<r

$$\vec{E}_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$$

E_{axial} is along the direction of dipole moment

ELECTRIC FIELD ON EQUATORIAL LINE OF AN ELECTRIC DIPOLE

$$E = -\frac{1}{4\pi\varepsilon_0}\cdot\frac{q.2a}{(r^2-a^2)^{3/2}}$$

For a<<r

$$\vec{E}_{equiatoral} = -\frac{1}{4\pi\varepsilon_0}\cdot\frac{\vec{p}}{r^3}$$

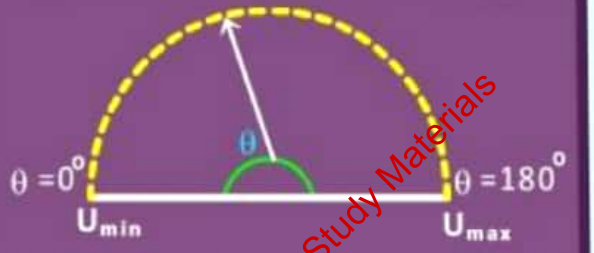
$E_{equatorial}$ is along the opposite direction of dipole moment

DIPOLE IN A UNIFORM EXTERNAL ELECTRIC FIELD

VECTOR FORM

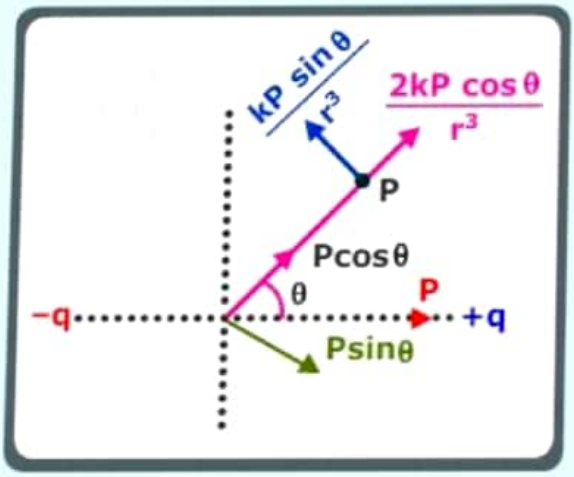
$\vec{\tau} = \vec{p}.\vec{E}$

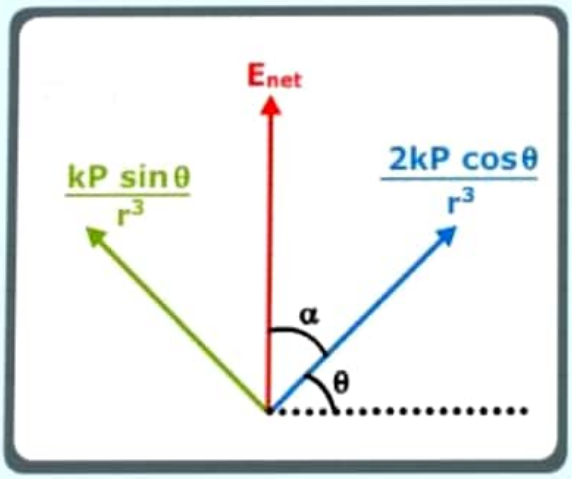
$U = -pE\cos\theta$



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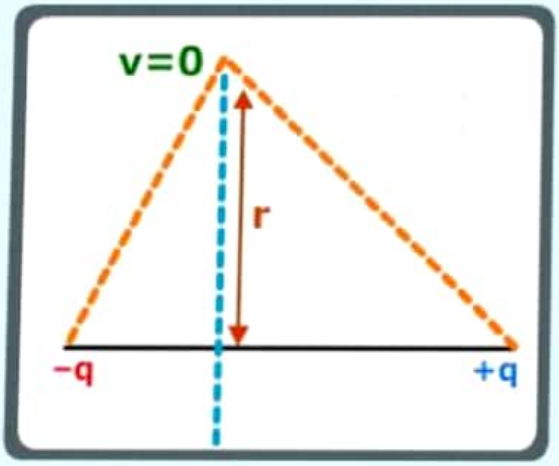
ELECTRIC FIELD AT A GENERAL POINT DUE TO A DIPOLE

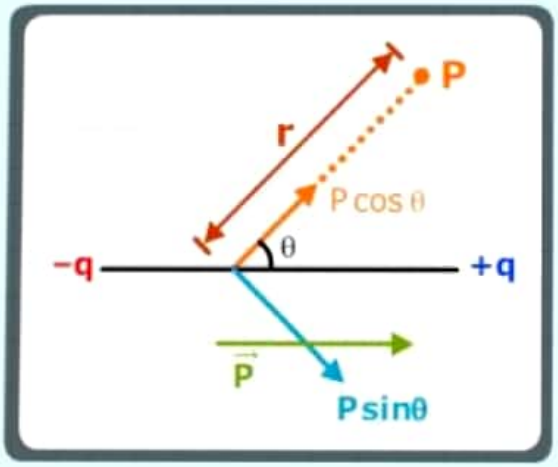




$$E_{net} = \frac{kP}{r^3}\sqrt{1+3\cos^2\theta}\ ,\ \tan\alpha = \frac{\tan\theta}{2}\ ;\ k = \frac{1}{4\pi\varepsilon_0}$$

ELECTRIC POTENTIAL DUE TO A DIPOLE





POTENTIAL AT 'P' DUE TO DIPOLE, $V_p = \frac{2kP\cos\theta}{r^2}$

AT AN AXIAL POINT, $V_{net} = \frac{kp}{r^2}$ (As P = q.2a)

AT PERPENDICULAR BI-SECTOR, $V_{net} = 0$

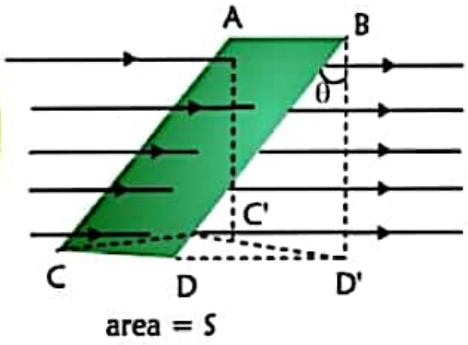
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ELECTRIC FLUX

Electric Field Strength in terms of Electric Flux

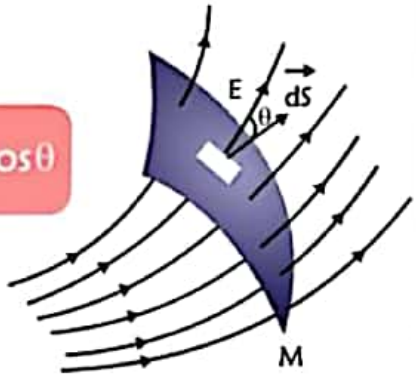
$$\phi = \vec{E}.\vec{S}$$

$$\phi = E.S.\cos\theta$$



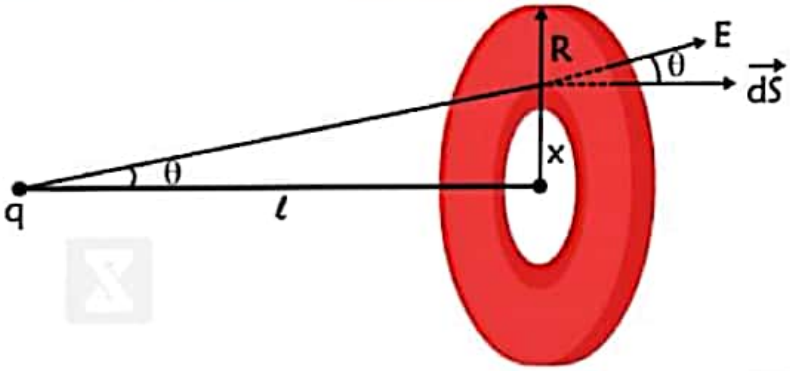
Electric Flux in Non-uniform Electric Field

$$\phi = \int d\phi = \int_M E dS \cos\theta$$



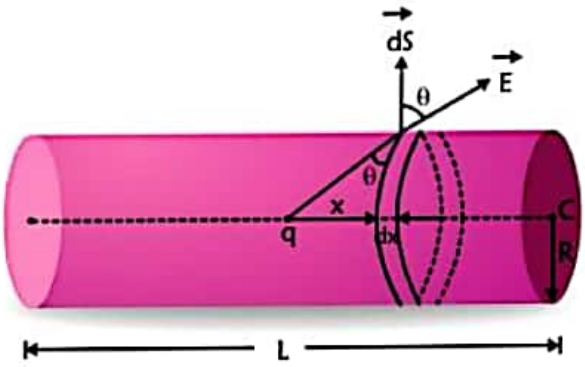
Electric Flux through a Circular Disc

$$\phi = \frac{q}{\epsilon_0}\left[1 - \frac{\ell}{\sqrt{R^2 + x^2}}\right]$$



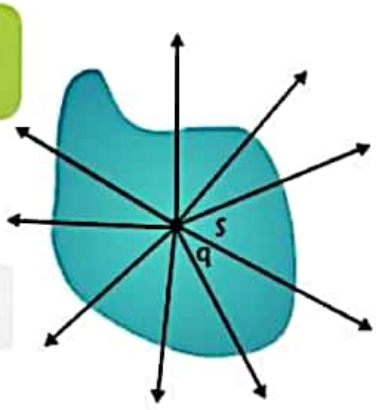
Electric Flux through the Lateral Surface of a Cylinder due to a Point Charge

$$\phi = \frac{q}{\epsilon_0} \cdot \frac{\ell}{\sqrt{R^2 + x^2}}$$



Electric Flux produced by a Point Charge

$$\phi_s = \frac{q}{\epsilon_0}$$

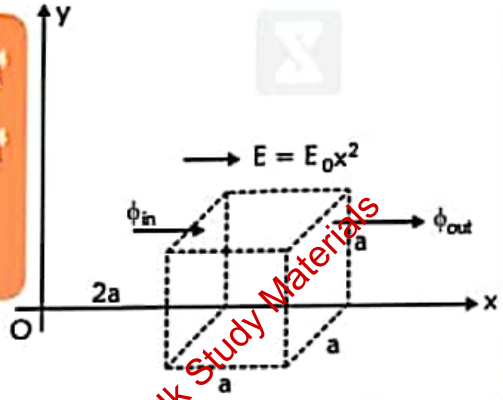


Flux Calculation in the Region of Varying Electric Field

$$\phi_{in} = E_0 (2a)^2 . a^2 = 4E_0a^4$$

$$\phi_{out} = E_0 (3a)^2 . a^2 = 9E_0a^4$$

$$\phi_{net} = 5E_0a^4$$



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CAPACITOR



1 Capacitor



Capacitor is a passive device of the circuit which stores electrical energy or charge. It is also known as **condenser**.

$$C = \frac{Q}{V} \quad \text{or} \quad C = \frac{\epsilon_0 A}{d}$$

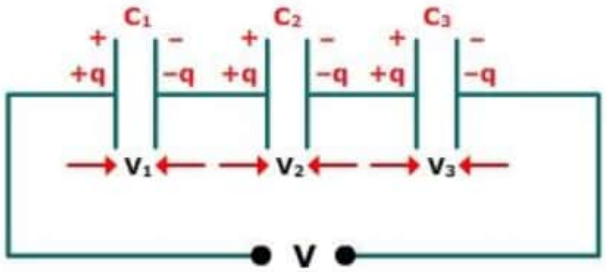
Capacitance is measured in **Farad (F)**

Q = Charge **A** = Area

V = Voltage **d** = Diameter

2 Combination

i Series



- Charge stored on each capacitor is same and equal to the magnitude of the charge, which comes from the battery..

$$Q = q_1 = q_2 = q_3$$

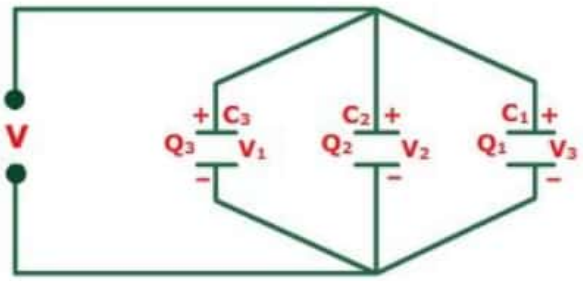
- The sum of voltage across the individual capacitor is equal to the voltage of the battery.

$$V = V_1 + V_2 + V_3$$

- $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

- Equivalent capacitance of the capacitor is always less than the smallest value of the capacitance of the capacitor in the circuit.

ii Parallel



- The Voltage across each capacitor is the same,and it is equal to the voltage of the battery.

$$V = V_1 = V_2 = V_3$$

- The sum of the charge stored on an individual capacitor is equal to the magnitude of the charge, which comes from the battery.

$$Q = q_1 + q_2 + q_3$$

- $C_{eq} = C_1 + C_2 + C_3$

- Equivalent capacitance of the capacitor is always greater then the largest value of the capacitance of the capacitor in the circuit.

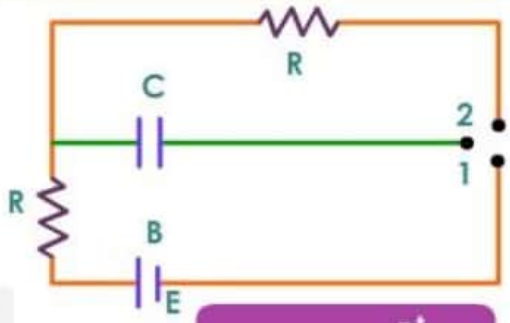
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Part I

CIRCUIT SOLUTION

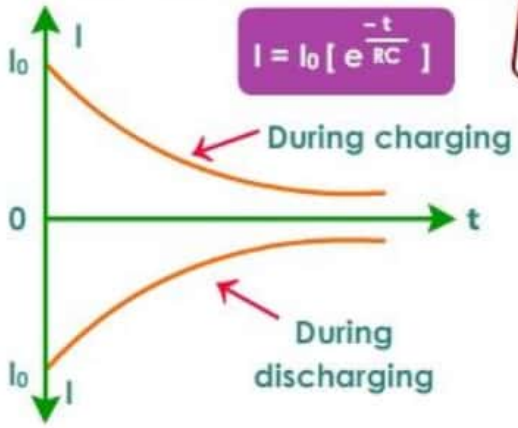
CHARGING AND DISCHARGING OF A CAPACITOR

CHARGING OF A CAPACITOR



$$q = q_0[1 - e^{\frac{-t}{RC}}]$$

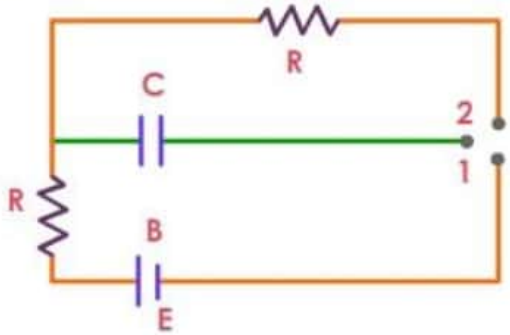
Where q_0 = maximum final value of charge at $t = \infty$.
Time $t = RC$ is known as Time Constant.



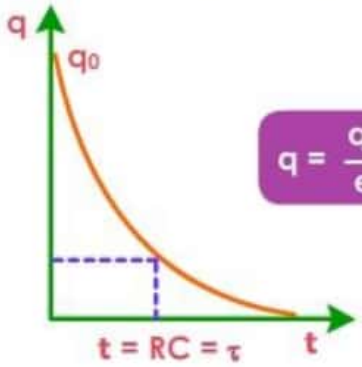
$$I = I_0[e^{\frac{-t}{RC}}]$$

If $t = RC = \tau$ = Time constant
Then, $I = 0.37\ I_0$

DISCHARGING OF A CAPACITOR



$$q = q_0[e^{\frac{-t}{RC}}]$$



$$q = \frac{q_0}{e} = 0.37q_0$$

If $t = RC = \tau$ = time constant,
Then, $q = 0.37\ q_0$

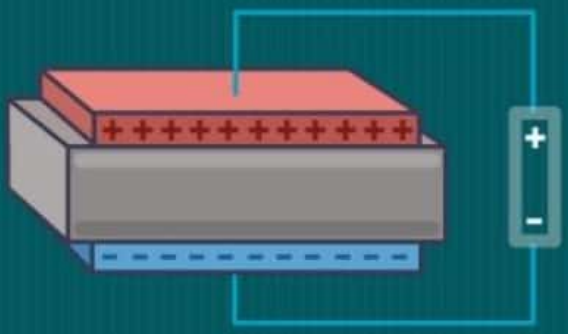
FORCE BETWEEN THE PLATES OF A CAPACITOR

$$F = -\frac{d}{dx}\left[\frac{q^2}{2\varepsilon_0 A}x\right] = \frac{-1}{2}\frac{q^2}{\varepsilon_0 A}$$

The negative sign implies that the force is attractive.

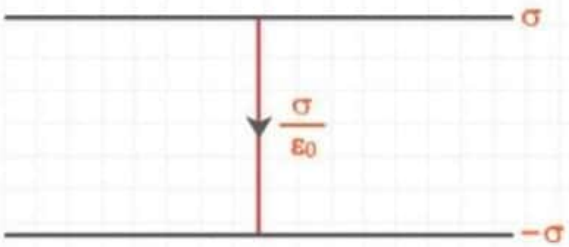
Jk Study Materials

Part II



CAPACITOR WITH DIELECTRIC

1. Without Dielectric



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

2. With Dielectric



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

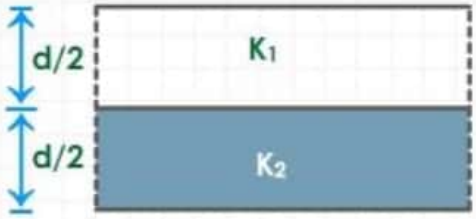
A = Area of Dielectric Slab

3. Dielectric Placed Vertically



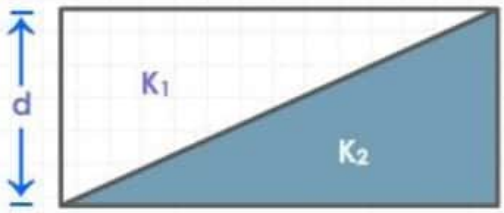
$$C = C_1 + C_2 \longrightarrow C = \frac{\varepsilon_0(K_1+K_2)A}{2d}$$

4. Dielectric Placed Horizontally



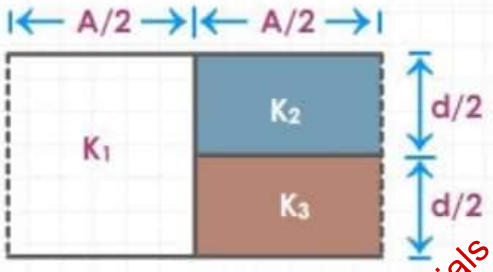
$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \longrightarrow C = \frac{2\varepsilon_0 AK_1K_2}{(K_1+K_2)d}$$

5. Dielectric Placed Diagonally



$$C = \frac{\varepsilon_0 AK_1K_2}{(K_2-K_1)} \log_e \frac{K_1}{K_2}$$

6. Capacitor With 3 Dielectrics

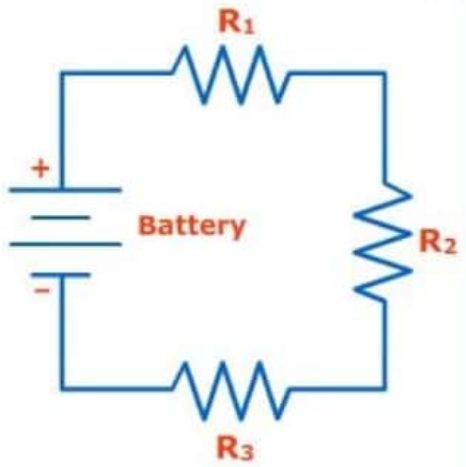


$$C = \frac{\varepsilon_0 A}{d}\left[\frac{K_1}{2} + \frac{K_2K_3}{K_2+K_3}\right]$$

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RESISTANCE

1 Resistance



The opposing effect to the flow of current is known as Resistance of the conductor. It is denoted by "R".

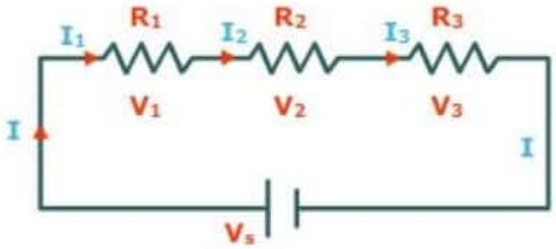
$$R = \frac{\rho l}{A}$$

ρ = Resistivity
l = Length
A = Area

Resistance (R) is measured in **Ohm** (Ω).

2 Combination

i Series



- The current passing through the individual resistance is same and its equal to magnitude of current that comes from the battery.

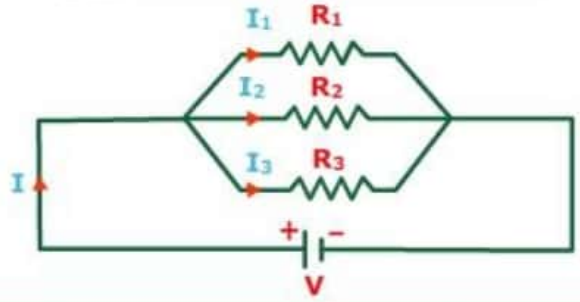
$$I = I_1 = I_2 = I_3$$

- The sum of the voltage across the individual resistance is equal to the voltage of the battery.

$$V = V_1 + V_2 + V_3$$

- $R_{eq} = R_1 + R_2 + R_3$
- The equivalent resistance of the circuit is always greater than the value of resistance in the circuit.

ii Parallel



- The sum of current passing through each resistance is equal to the total current coming from the battery.

$$I = I_1 + I_2 + I_3$$

- The voltage across the individual resistance is same and is equal to the voltage of the battery.

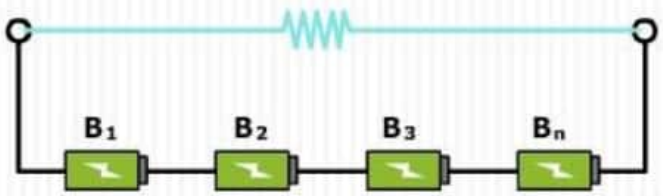
$$V = V_1 = V_2 = V_3$$

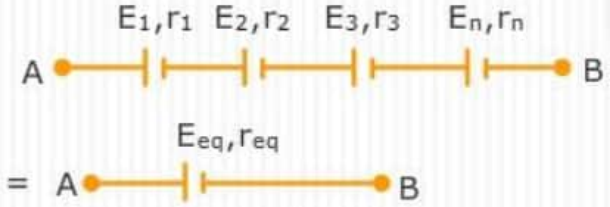
- $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
- The equivalent resistance of the circuit is always less than the smallest value of resistance in the circuit.

Jk Study Materials

GROUPING OF CELLS

1 CELLS IN SERIES





Equivalent EMF

$$E_{eq} = E_1 + E_2 + ... + E_n$$

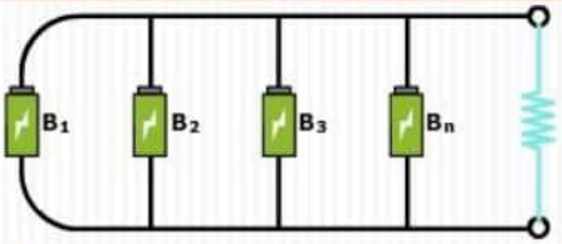
Equivalent internal resistance

$$r_{eq} = r_1 + r_2 + r_3 + r_4 + ...r_n$$

In n cells each of emf E are arranged in series and if r is internal resistance of each cell, then the total emf is equal to nE

and, current in the circuit, $I = \frac{nE}{R + nr}$

2 CELLS IN PARALLEL



$$E_{eq} = \frac{E_1/r_1 + E_2/E_2 + ...E_n/r_n}{1/r_1 + 1/r_2 + ... + 1/r_n}$$

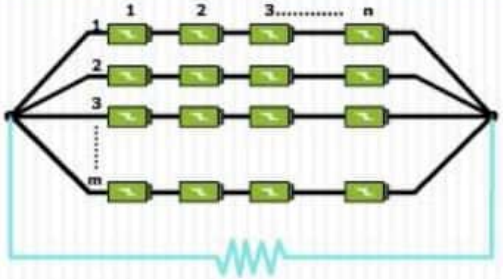
$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + ...+ \frac{1}{r_n}$$

If m cells, each of emf E and internal resistance r be connected in parallel and if this combination is connected to an external resistance (R) then the emf of the circuit = E.

internal resistance of the circuit = $\frac{r}{m}$

and $I = \frac{E}{R + \frac{r}{m}} = \frac{mE}{mR + r}$

3 CELLS IN MULTIPLE ARC



n = number of rows

m = number of cells in each row

Current $I = \frac{mE}{R + \frac{mr}{n}}$

for maximum current nR = mr

4 ELECTRICAL POWER

$$\text{Power, } P = \frac{V.dq}{dt} = VI = I^2 R = \frac{V^2}{R}$$

$$\text{Work, } W = VIt = I^2 Rt = \frac{V^2}{R} t$$

$$\text{Heat, } H = I^2 Rt \text{ Joule} = \frac{I^2 Rt}{J} \text{ calorie}$$

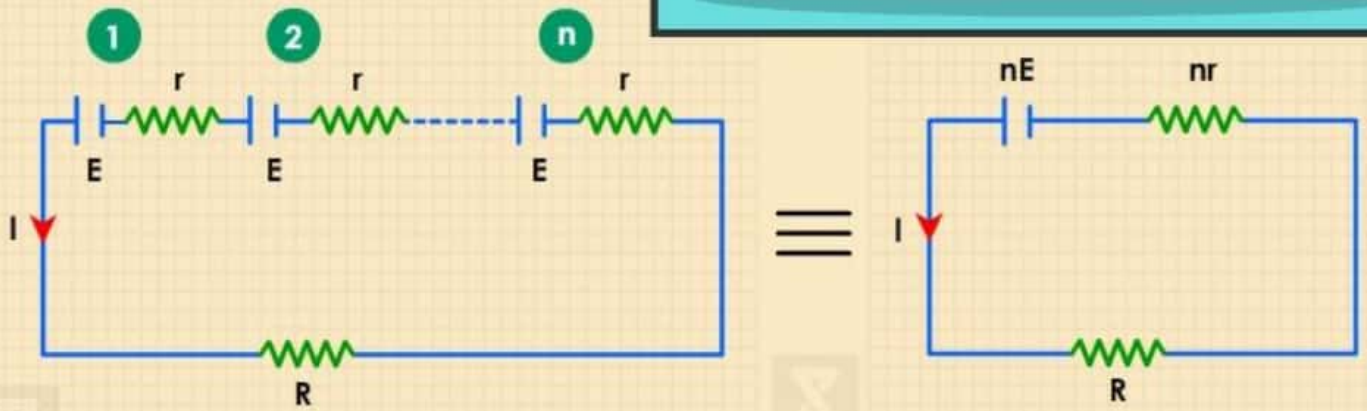
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Part I

CELLS AND ELECTRIC POWER

COMBINATIONS OF CELLS

1 CELL IN SERIES



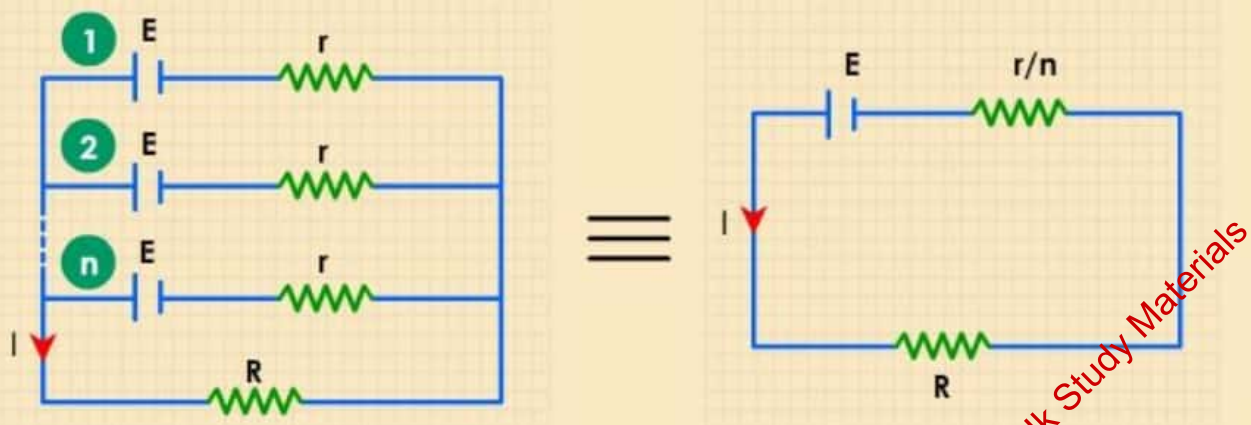
- Net EMF of the cells = nE,
- Total internal resistance = nr,
- Hence total resistance of the circuit = nr + R,

$$I = \frac{\text{net EMF}}{\text{Total Resistance}} = \frac{nE}{nr + R}$$

Case I If $nr << R$, then $I \cong nE/R$ i.e. current obtained from the cells is approximately equal to n times the current obtained from a single cell.

Case II If $nr >> R$, then $I \cong nE/nr = E/r$ i.e. current obtained from the combination of n cells is nearly the same as obtained from a single cell.

2 CELL IN PARALLEL



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When E.M.F's and internal resistance of all the cells are equal

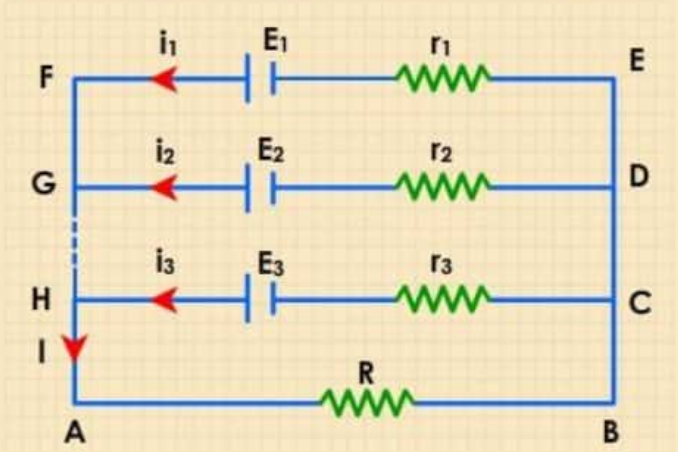
- E.M.F of battery = E.
- Total internal resistance of the combination of n cells = r/n
- Total resistance of the circuit = (r/n) + R

$$I = \frac{\text{net E.M.F}}{\text{Total Resistance}} = \frac{E}{(r/n)+R} = \frac{nE}{r+nR}$$

Case I If $r << R$, the $I \cong nE/nR = E/R$; then total current obtained from combination is approximately equal to current given by one cells only.

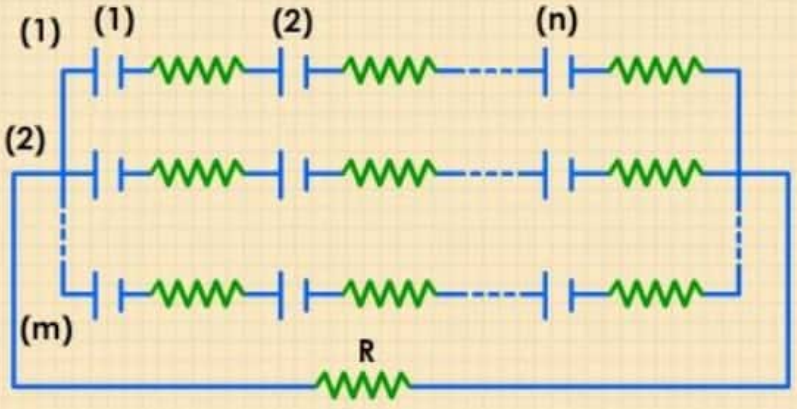
Case II If $r >> R$, then $I \cong nE/r$; then total current is approximately equal to n times the current given by one cell.

When E.M.F's and internal resistance of all the cells connected in parallel are different



$$I = \frac{\sum_{i=0}^{n} \frac{E_i}{r_i}}{1+R\sum_{i} \frac{1}{r_i}} \quad \text{and} \quad E_{eq.} = \frac{\sum \frac{E_i}{r_i}}{\sum \frac{1}{r_i}}, \quad r_{eq.} = \frac{1}{\sum \frac{1}{r_i}}$$

3 CELL IN MIXED GROUPING



$$\text{Total resistance of the circuit} = \left[\left(\frac{nr}{m}\right) + R\right]$$

$$I = \frac{\text{net E.M.F}}{\text{Total Resistance}} = \frac{nE}{(nr/m)+R} = \frac{nmE}{nr+mR}$$

ELECTRICAL POWER

The energy liberated per second in a device is called its power. The electrical power P delivered by an electrical device is given by

$$P = \frac{dq}{dt}V \qquad P = VI \qquad P = I^2R \qquad P = \frac{V^2}{R} \quad \text{watt}$$

Jk Study Materials

Part I

INSTRUMENTS MEASURING VARIOUS ELECTRICAL QUANTITIES

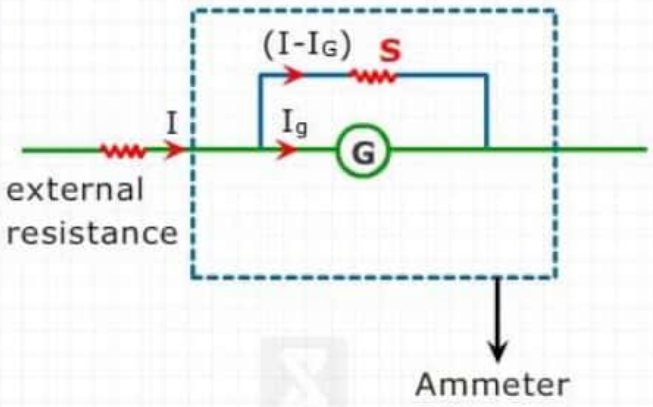
01 AMMETER

A shunt (small resistance) is connected is parallel with galvanometer to convert it into ammeter.

I_G = Current through galvanometer

R_G = Resistance of galvanometer

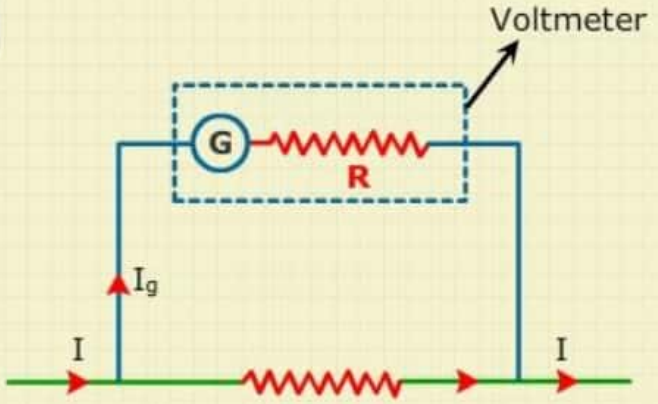
$$S = \frac{I_G R_G}{I - I_G}$$



02 VOLTMETER

A high resistance is put in series with galvanometer. It is used to measure potential difference across a resistor in a circuit.

$$I_G = \frac{V}{R_G + R}$$

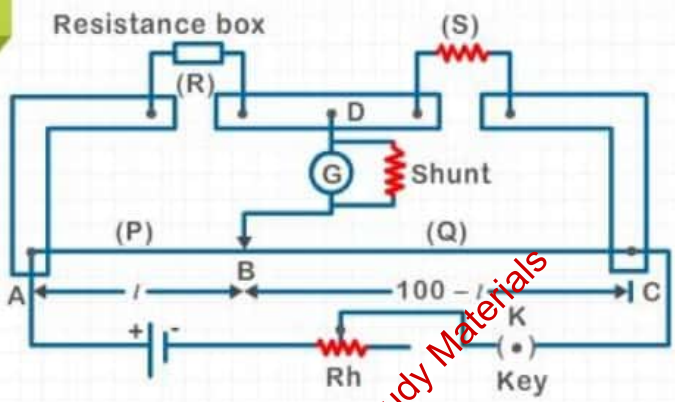


03 METRE-BRIDGE

$$S = \frac{R(100 - l)}{l}$$

R = Resistance taken in the resistance box

l = Length measured



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Part II

POTENTIOMETER

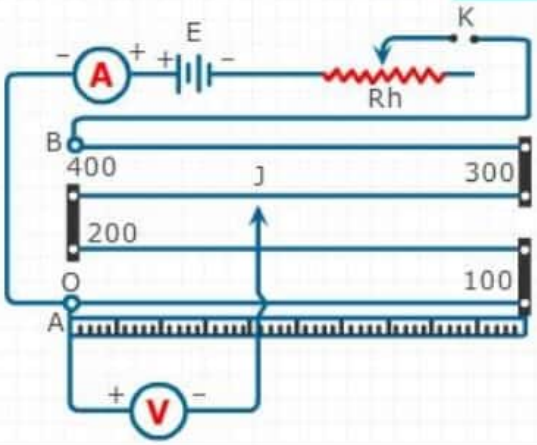
l = Length

A = Area of cross-section

ρ = Resistivity of material

I = Current

$$V = I\rho\frac{l}{A}$$



APPLICATION OF POTENTIOMETER

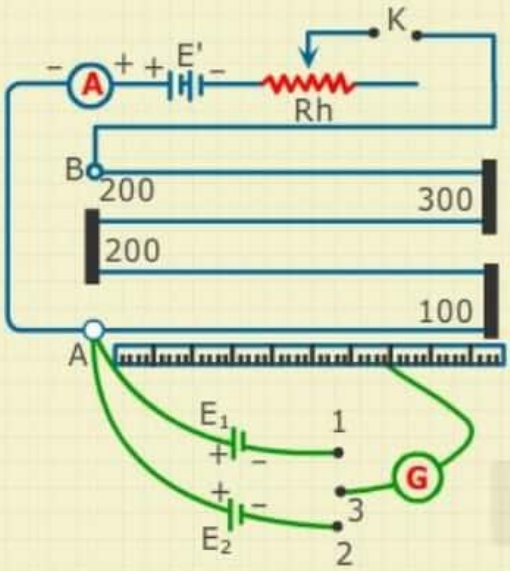
APPLICATION-01

To find EMF of an unknown cell and compare EMF of two cells

$$\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$$

ℓ_1 = Balancing length when key is between gaps of terminal 1 and 2

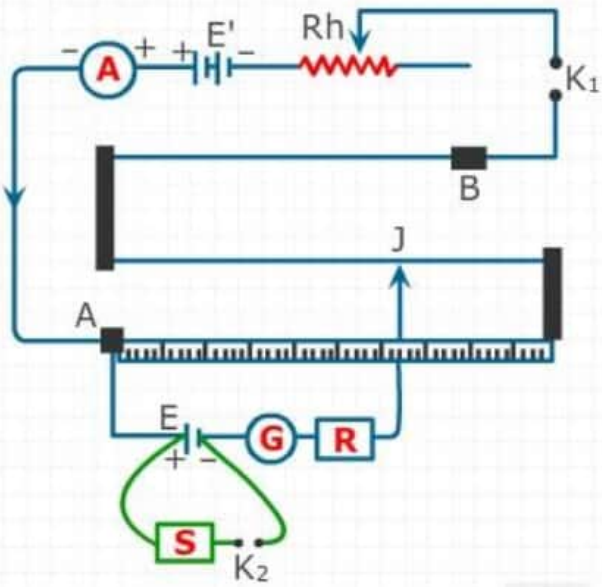
ℓ_2 = Balancing length when key is between gaps of terminal 2 and 3



APPLICATION-02

To find the internal resistance of a cell

$$r' = \left[\frac{\ell_1 - \ell_2}{\ell_2}\right]$$



APPLICATION-03

To find current if resistance is known

$$I = \frac{X\ell_1}{R}$$

JK Study Materials

ELECTROMAGNETIC FORCE

MAGNETIC FLUX

Magnetic Flux is the amount of magnetic field passing through a given area.



$$\phi = \int \vec{B}.d\vec{A} \Rightarrow \phi = \vec{B}.\vec{A} = BA\cos\theta$$

Unit ⟶ weber (Wb)

FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION

Whenever the flux of a magnetic field through the area bounded by a closed conducting loop changes, an emf is produced in the loop. The emf is given by

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

LENZ'S LAW

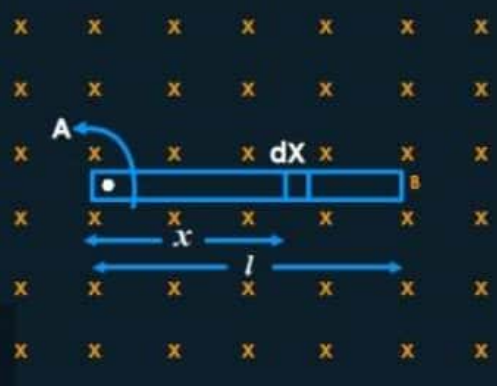
According to lenz's law, if the flux associated with any loop changes than the induced current flows in such a fashion that it tries to oppoose the cause which has produced it.

MOTIONAL EMF

$$E = \int (\vec{v} \times \vec{B}).d\vec{l}$$

EMF developed across the ends of the rod moving perpendicular to magnetic field v velocity perpendicular to the rod is $\varepsilon = vB\ell$

INDUCED EMF IN A ROTATING ROD



$$\int dE = \int_0^{\ell} B\omega x\,dx$$

$$V_A - V_B = \frac{B\omega l^2}{2}$$

INDUCED ELECTRIC FIELD

$$\text{EMF, } e = \oint \vec{E}.d\vec{l}$$

Using Faraday's law of induction

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

$$\text{or, } \oint \vec{E}.d\vec{l} = -\frac{d\phi}{dt}$$

JK Study Materials

Part I

SELF INDUCTION

1 SELF INDUCTION

If current in the coil changes by Δi in a time interval Δt, the average emf induced in the coil is given as

$$\varepsilon = -\frac{\Delta(N\phi)}{\Delta t} = -\frac{\Delta(Li)}{\Delta t} = -\frac{L\Delta i}{\Delta t}$$

, S.I unit of inductance is wb/amp or Henry (H)

SELF INDUCTANCE OF SOLENOID

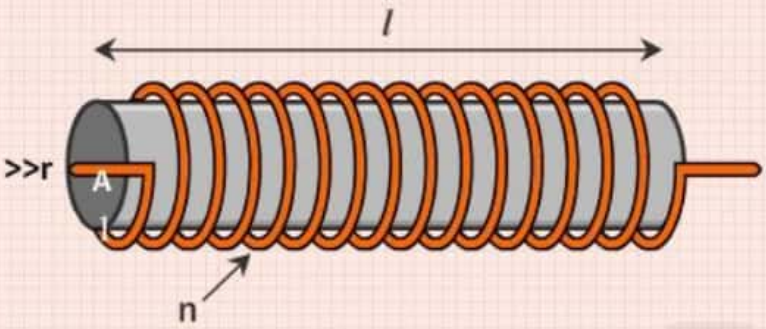
$L = \mu_o n^2 \pi r^2 l$

n = no. of turns/length

r = radius ; μ_o = Permeability

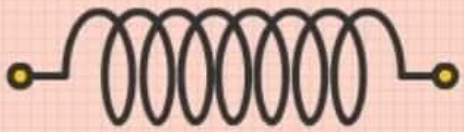
l = length

Inductance/Volume = $\mu_o n^2$



2 INDUCTOR

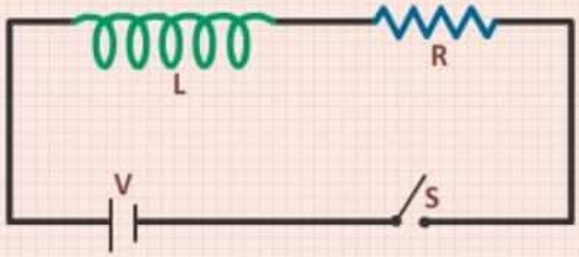
$V_A - L\frac{di}{dt} = V_B$, Energy stored in inductor , $U = \frac{1}{2}Li^2$



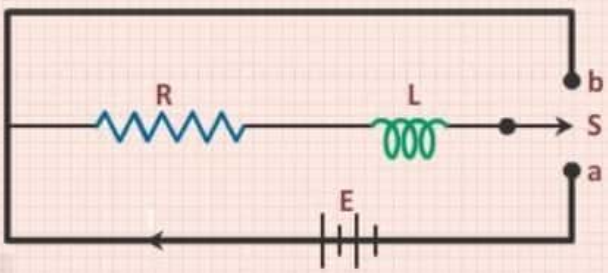
3 L – R CIRCUIT

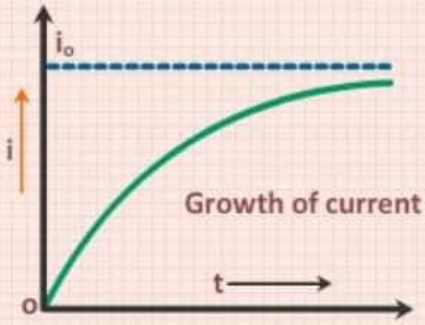
At t = 0, inductor behaves as an open switch.

At t = ∞, inductor behaves as plane wire.



GROWTH OF CURRENT

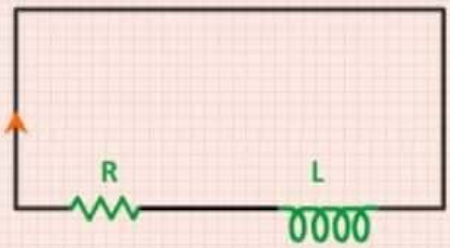


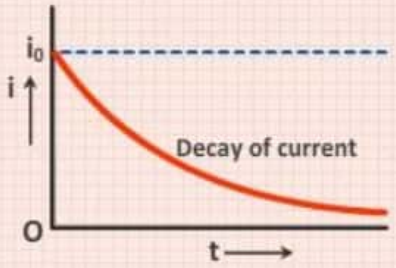


The maximum current in the circuit $i_0 = E/R$. So $i = i_0\left\{1 - e^{-\frac{R}{L}t}\right\}$

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4 DECAY OF CURRENT





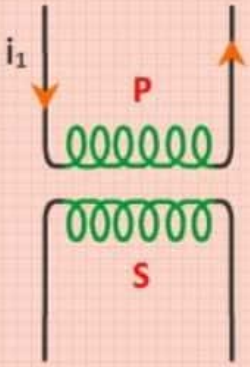
$$i = i_0 e^{-\frac{R}{L}t} = i_0 e^{-\frac{t}{\tau}}$$

5 MUTUAL INDUCTANCE

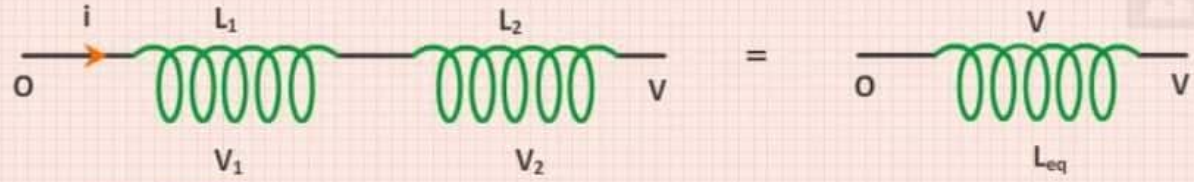
$$\mathcal{E} = -M\frac{di_1}{dt} = \Rightarrow \quad \phi_2 = Mi_1$$

M = Mutual inductance

Unit of Mutual inductance is Henry (H)



6 SERIES COMBINATION OF INDUCTORS



$$\therefore V = V_2 + V_1$$

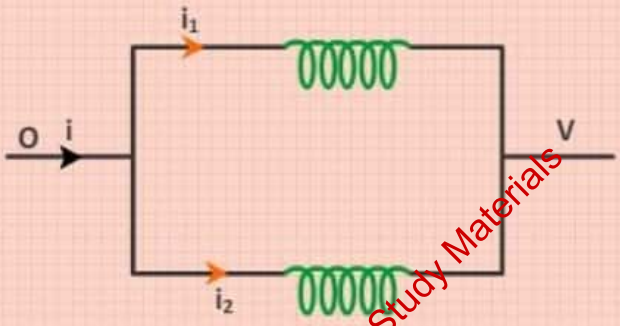
$$L_{eq}\frac{di}{dt} = L_1\frac{di}{dt} + L_2\frac{di}{dt} \Rightarrow L_{eq} = L_1 + L_2 + \ldots\ldots$$

7 PARALLEL COMBINATION OF INDUCTOR

$$i = i_1 + i_2 \Rightarrow \frac{di}{dt} = \frac{di_1}{dt} + \frac{di_2}{dt}$$

$$\frac{V}{L_{eq}} = \frac{V}{L_1} + \frac{V}{L_2}$$

$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots\ldots$$



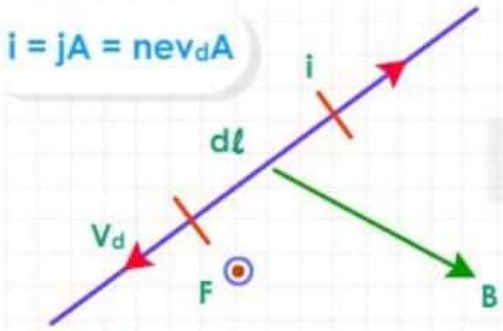
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Part I

MAGNETIC PROPERTY

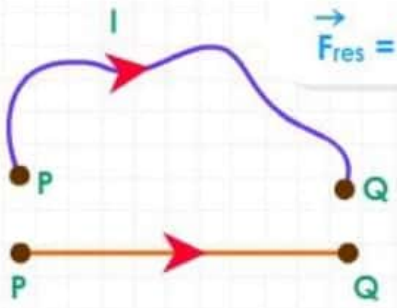
MAGNETIC FORCE ON A CURRENT CARRYING WIRE

$i = jA = nev_dA$



v_d = Drift speed
n = No. of free electrons per unit volume
j = Current density

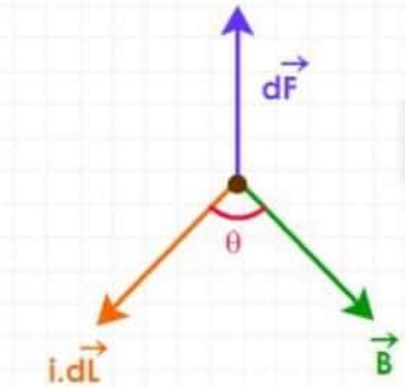
$\vec{F}_{res} = i\vec{L} \times \vec{B}$

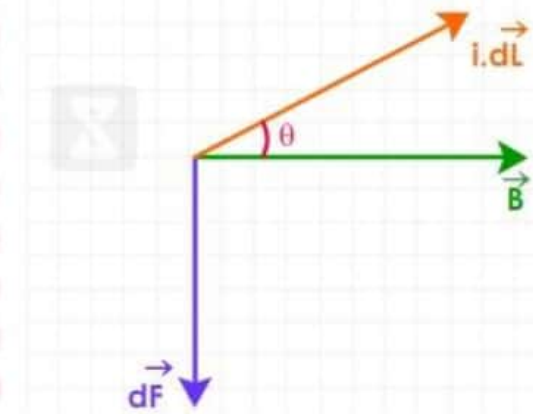


$\vec{L}$ = Vector length of the wire

DIRECTION OF FORCE

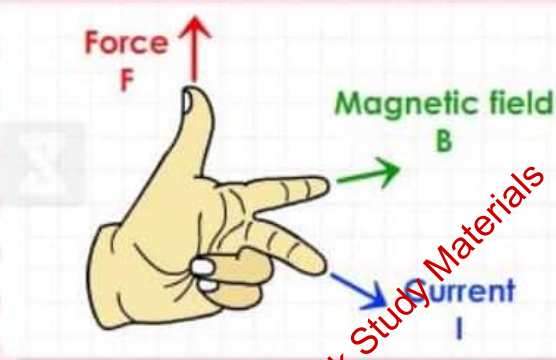
The direction of force is always perpendicular to the plane containing $i.d\vec{L}$ and $\vec{B}$ and is same as that of cross-product of two vectors $(\vec{a} \times \vec{b})$ with $a = i.d\vec{L}$ and $b = \vec{B}$





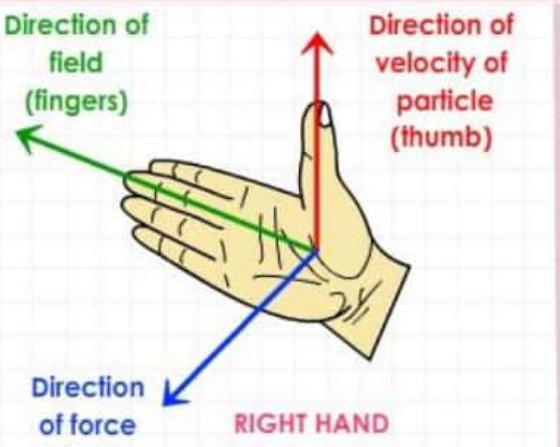
The direction of force when current element $i.d\vec{L}$ and $\vec{B}$ are perpendicular to each other can also be determined by applying either of the following rules:

1. **Fleming's Left-hand Rule :** Stretch the forefinger, central finger and thumb of the left hand mutually perpendicular. Then if the forefinger points in the direction of the field ($\vec{B}$) and the central finger is in the direction of current, the thumb will point in the direction of force (or motion).



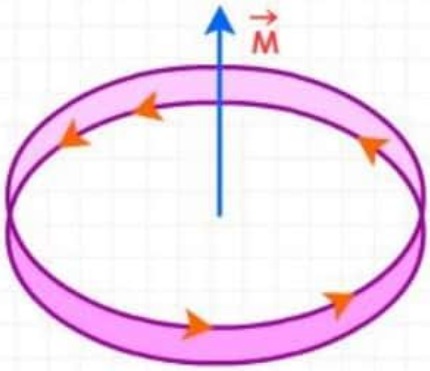
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2. Right-hand Palm rule : Stretch the fingers and thumb of the right-hand at right angles to each other. To find the direction of the magnetic force on a positive moving charge, the thumb of the right hand ponts in the direction of velocity of particle v, the fingers in the direction of Magnetic Field B, then the Force F is directed perpendicular to the right hand palm



CURRENT LOOP IN A UNIFORM MAGNETIC FIELD

MAGNETIC MOMENT

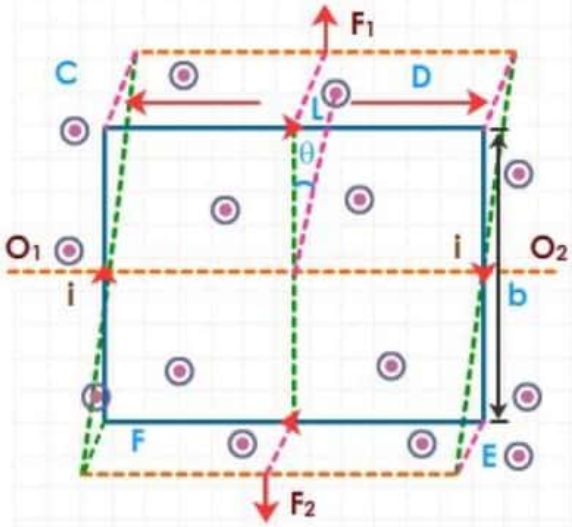


$$\vec{M} = NI\pi R^2 = NIA$$

A = Area of loop | R = Radius of loop

N = No. of loops | I = Current

TORQUE ON A CURRENT LOOP

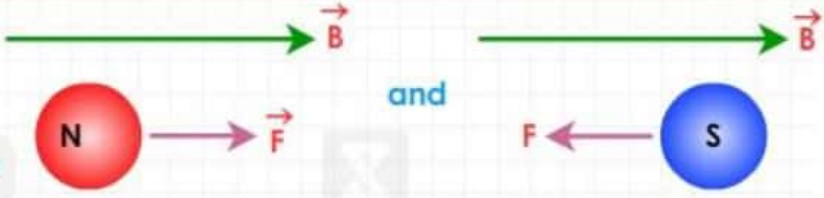


$$\vec{\tau} = \vec{M} \times \vec{B}$$

MAGNETIC FIELD AND STRENGTH OF MAGNETIC FIELD

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

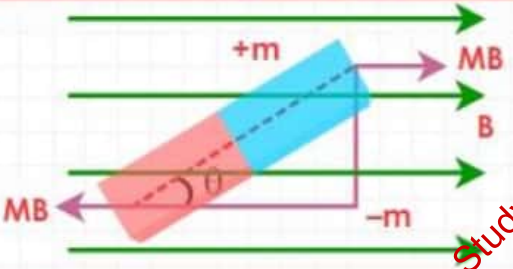
S.I. unit of $\vec{B}$ is Tesla or weber/m^2



MAGNETIC IN AN EXTERNAL UNIFORM MAGNETIC FIELD

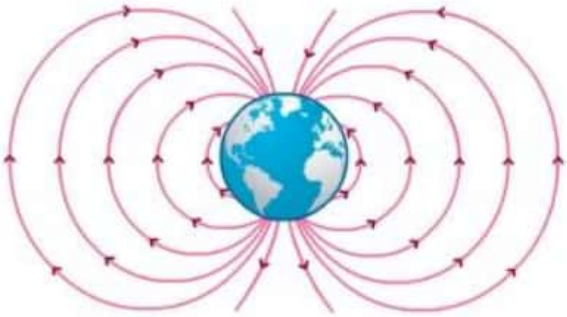
$F_{res} = 0$ (for any angle)

$\tau = MB \sin\theta$



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Part I



MAGNETIC FIELD

Magnetic field is the region surrounding a moving charge in which its magnetic effects are perceptible on another moving charge (electric current).

BIOT-SAVART LAW

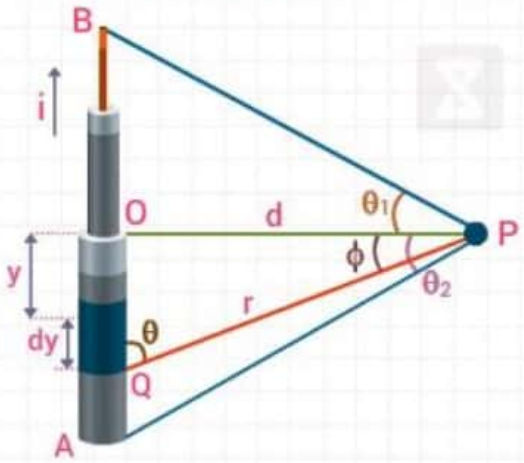
Biot-Savart law gives the magnetic induction due to an infinitesimal current element. According to 'Biot-Savart Law', the magnetic field induction dB at P due to the current element $d\vec{l}$ is given by,

$$\vec{dB} = k\frac{i(\vec{dl} \times \vec{r})}{r^3}$$

FIELD DUE TO A STRAIGHT CURRENT CARRYING WIRE

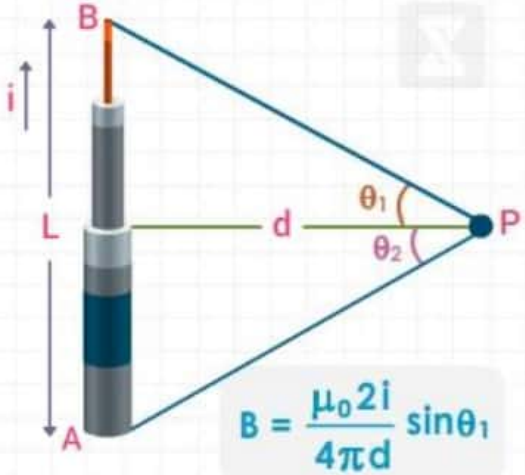
1 When the wire is of finite length

At any point P



$$B = \frac{\mu_0 i}{4\pi d}[\sin\theta_1 + \sin\theta_2]$$

P is on perpendicular Bi-sector

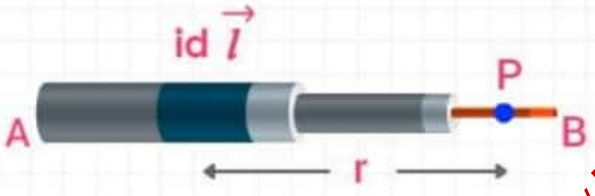


$$B = \frac{\mu_0 2i}{4\pi d}\sin\theta_1$$

where $\sin\theta_1 = \frac{L}{L^2 + 4d^2}$

When the point lies along the length of wire (but not on it)

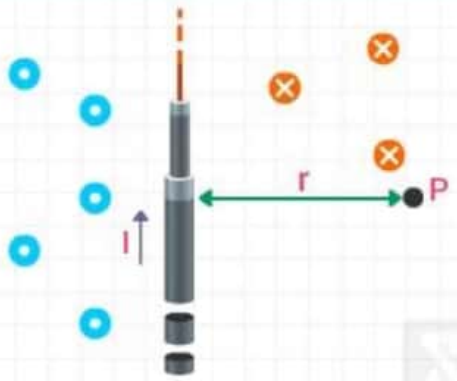
$$\vec{B} = \int_A^B \vec{dB} = 0$$



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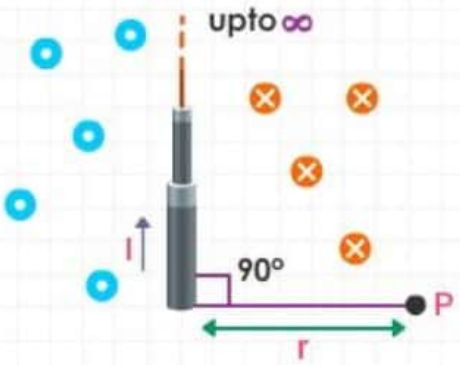
2 When the wire is of infinite length

Case-I



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

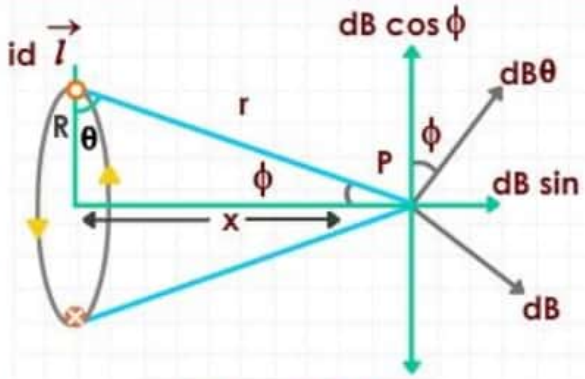
Case-II



$$B = \frac{\mu_0 I}{4\pi r}$$

MAGNETIC FIELD AT AN AXIAL POINT OF A CIRCULAR COIL

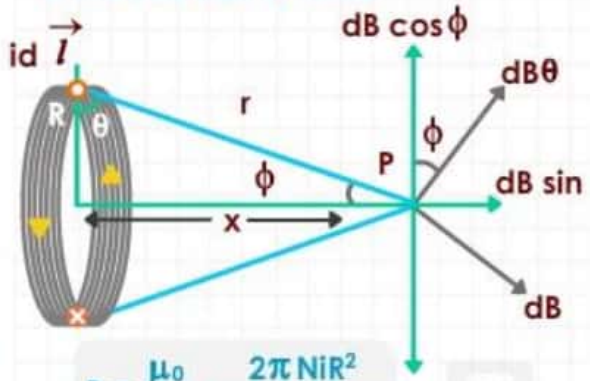
Case - I



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

Case - II

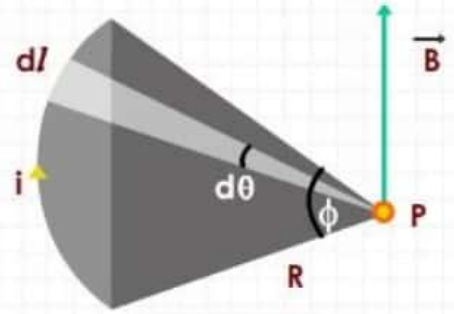
If the coil has 'N' turns-



$$B = \frac{\mu_0}{4\pi} \frac{2\pi N i R^2}{(R^2 + x^2)^{3/2}}$$

FIELD AT THE CENTRE OF A CURRENT ARC

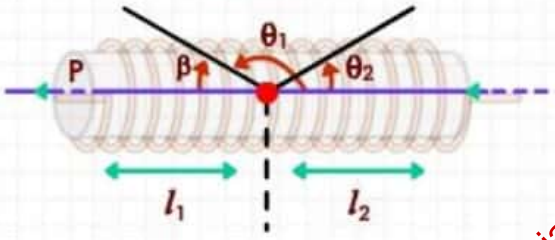
Case - I



$$B = \frac{\mu_0}{4\pi} \frac{i\phi}{R}$$

Case - II

SOLENOID



$$B = \frac{\mu_0 n i}{2} (\cos\theta_1 - \cos\theta_2)$$

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MAGNETIC FORCE
DUE TO CHARGE PARTICLES

Charge q moving with velocity $\vec{v}$, in a magnetic field has magnetic force $\vec{F} = q(\vec{v} \times \vec{B})$

MOTION OF A CHARGED PARTICLE IN A UNIFORM MAGNETIC FIELD

CHARGED PARTICLE GIVEN VELOCITY PERPENDICULAR TO THE FIELD

The particle will move on a circular path.



Time period

$$T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$$

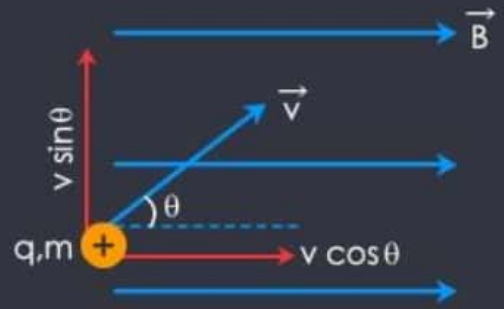
Frequency

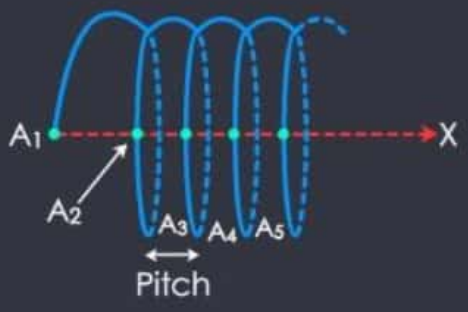
$$v = \frac{1}{T} = \frac{qB}{2\pi m}$$

$$\frac{mv^2}{r} = qvB \Rightarrow r = \frac{mv}{qB}$$

CHARGED PARTICLE IS MOVING AT AN ANGLE TO THE FIELD

$v_{\parallel} = v\cos\theta$ and $v_{\perp} = v\sin\theta$





The radius of path is, $r = \frac{mv_{\perp}}{qB} = \frac{mv\sin\theta}{qB}$, Time period $(T) = \frac{2\pi r}{v_{\perp}} = \frac{2\pi m}{qB}$

Frquency $(f) = \frac{qB}{2\pi m}$

MOTION OF CHARGED PARTICLE IN COMBINED ELECTRIC & MAGNETIC FIELD

When the moving charged particle is subjected simultaneously to both electric field **E** and magnetic field **B**, the moving charged particle will experience electric force $F_e = q\vec{E}$ and magnetic force $F_m = q(\vec{v} \times \vec{B})$

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

which is 'Lorentz force equation'.

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WAVE OPTICS

WAVE FRONT

- Wave front is a locus of particles having same phase.
- Direction of propagation of wave is perpendicular to wave front.
- Every particle of a wave front acts as a new source and is known as secondary wavelet.

Coherent source

If the phase difference due to two source at a particle point remains constant with time, then the two sources are considered as coherent source

INTERFERENCE

$$A_{net}^2 = A_1^2 + A_2^2 + 2A_1A_2\cos\phi$$

$$I_{net} = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

For constructive interference

$$I_{net} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$$

For destructive interference

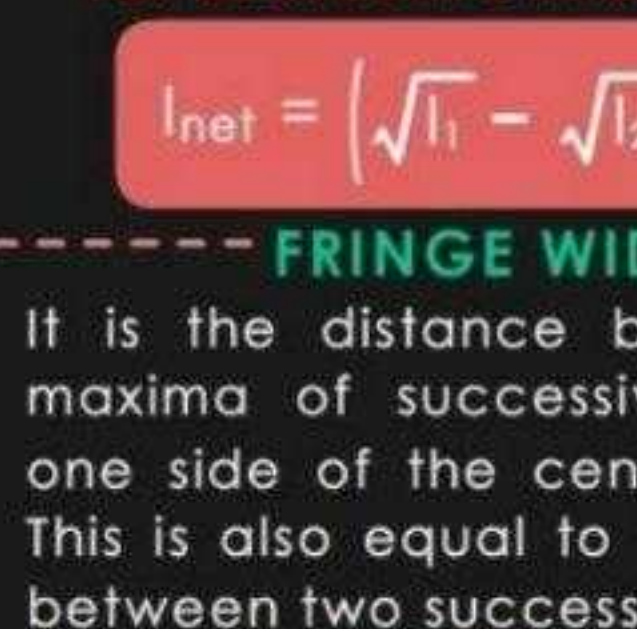
$$I_{net} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$$

FRINGE WIDTH

It is the distance between two maxima of successive order on one side of the central maxima. This is also equal to the distance between two successive minima.

$$\beta = \frac{\lambda D}{d}$$

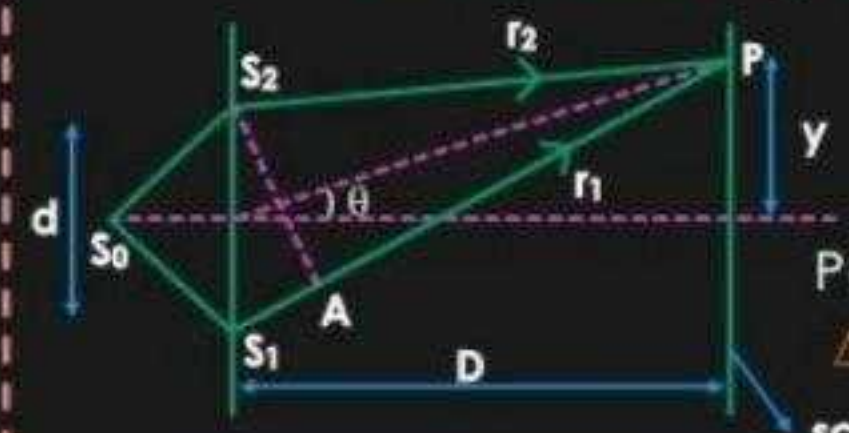
DISPLACEMENT OF FRINGE



for central bright fringe;

$$\frac{yd}{D} = t(\mu - 1)$$

YOUNG'S DOUBLE SLIT EXPERIMENT (Y.D.S.E)



Path difference

$\Delta p = S_1P - S_2P$

$$\sqrt{\left(y + \frac{d}{2}\right)^2 + D^2} - \sqrt{\left(y - \frac{d}{2}\right)^2 + D^2} \quad ...(1)$$

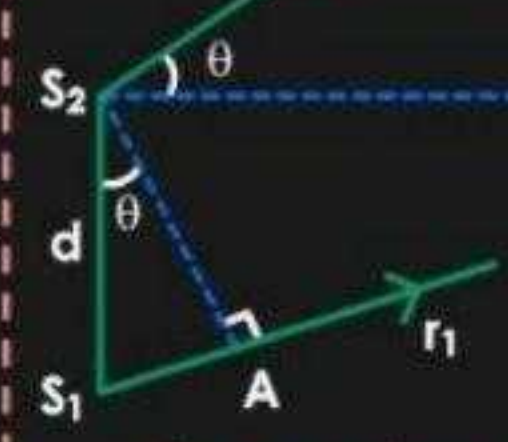
Approximation I :

For $D >> d$, We can approximate rays $\vec{r_1}$ and $\vec{r_2}$ as being approximately parallel, at angle θ to the principle axis.

Now, $S_1p - S_2P = S_1A = S_1S_2\sin\theta$

$\Longrightarrow$ Path difference $= d\sin\theta$ ...(2)

Approximation II :



Further if θ is small, i.e.

$y << D$, $\sin\theta \simeq \tan\theta = \frac{y}{D}$

and hence,

path difference $= \frac{dy}{D}$ ..(3)

for maxima

$$\Delta p = \frac{dy}{D} = n\lambda$$

for minima

$$\Delta p = \pm\frac{\lambda}{2}, \pm\frac{3\lambda}{2} \pm\frac{5\lambda}{2}$$

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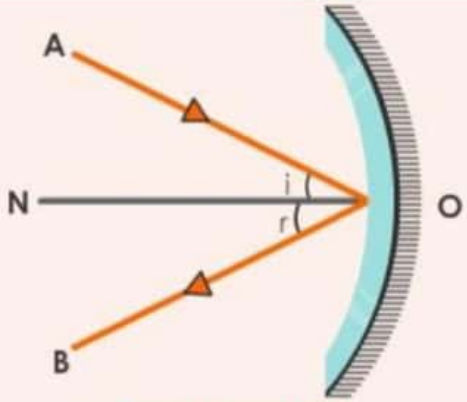


Part I

MIRRORS

1 REFLECTION

When a ray of light is incident at a point on the surface of a mirror, the surface throws **partly or wholly** the incident energy back into the **medium of incidence**. This phenomennon is called reflection.



Concave mirror

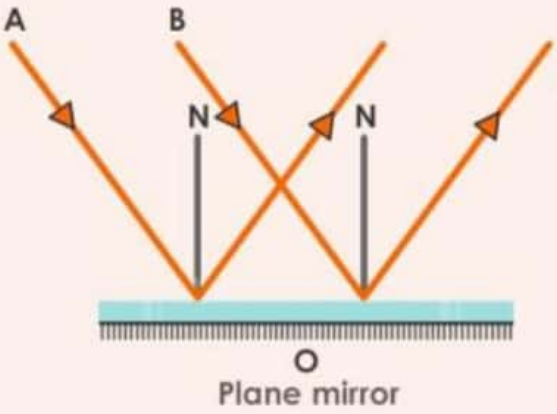
2 LAW OF REFLECTION

- The **incident ray**, the **reflected ray** and the **normal** to the reflecting surface at the point of incidence, **all lie in the same plane.**
- The angle of incidence is **equal to** the angle of reflection, i.e., $\angle i = \angle r$

Note: These laws hold good for all reflecting surfaces either plane or curved.

3 PLANE MIRROR

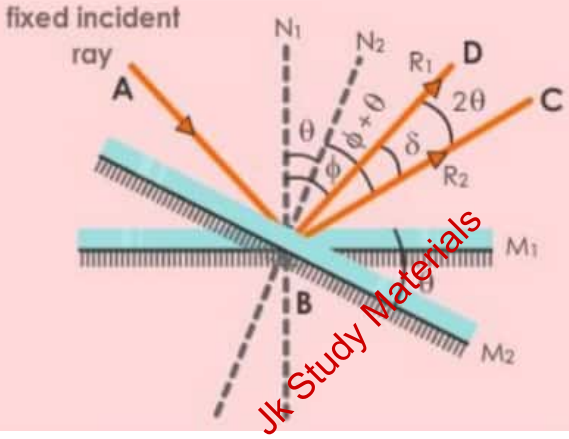
A beam of parallel rays of light, incident on a plane mirror will get reflected as a beam of parallel reflected rays.



Plane mirror

4 ROTATION OF MIRROR

For a **fixed incident light ray**, if the mirror be **rotated** by an **angle θ** (about an axis which lies in the plane of mirror and perpendicular to the plane of incidence), the **reflected ray turns through an angle of 2θ** in the same direction.



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5 NUMBER OF IMAGES FORMED BY TWO INCLINED MIRRORS

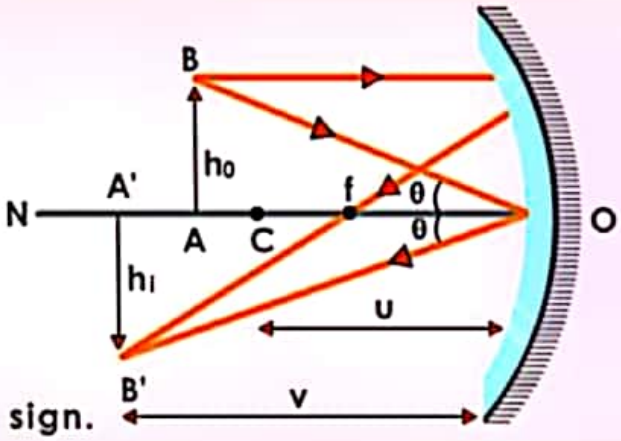
θ = Angle between mirrors

- If $\frac{360^\circ}{\theta}$ = **even number** ; number of images = $\frac{360^\circ}{\theta} - 1$.
- If $\frac{360^\circ}{\theta}$ = **odd number** ; number of images = $\frac{360^\circ}{\theta} - 1$, If the object is placed on the angle bisector.
- If $\frac{360^\circ}{\theta}$ = **odd number** ; number of images = $\frac{360^\circ}{\theta}$, If the object is not placed on the angle bisector.
- If $\frac{360^\circ}{\theta} \neq$ **integer**, then the number of images = **nearest even integer.**

6 TRANSVERSE MAGNIFICATION

$\Delta ABO \sim \Delta A'B'O$

$$x = \frac{h_i}{v} = \frac{h_0}{u} \Rightarrow m = \frac{h_i}{h_0} = -\frac{v}{u}$$



- The above formula is valid for **both concave and convex mirror.**
- **h_I, h_0, v** and **u** should be **put with appropriate sign.**

7 CONCAVE MIRROR

S.No	Position of object	Details of images			
		Location	Type	Orientation	Magnification
1.	At ∞	At F	real	inverted	|m|<< 1
2.	Between C and ∞	Bet. F and C	real	inverted	|m| < 1
3.	At C	At C	real	inverted	|m| = 1
4.	Between F and C	Bet. C and ∞	real	inverted	|m| > 1
5.	At F	At infinity	real	inverted	|m| >> 1
6.	Between F and P	Behind the mirror	virtual	erect	|m| > 1

8 CONVEX MIRROR

Position of object	At infinity	In front of mirror
Details of images	At F, virtual, erect, |m|<< 1	Between P and F, virtual, erect, |m| < 1

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9 VELOCITY IN SPHERICAL MIRROR

Velocity of Image

- Object moving along the principal axis, $V_{IM} = -\frac{v^2}{u^2}(V_{OM})$
- Object moving perpendicular to the principal axis, $\frac{dh_I}{dt} = -\frac{v}{u}\frac{dh_o}{dt}$
- Object moving parallel to the Principal axis, $v_y = \frac{dh_I}{dt} = -h_0\left[\frac{dv}{dt}\cdot\frac{1}{u} - \frac{v}{u^2}\cdot\frac{du}{dt}\right]$

Refraction of Light

$$\mu = \frac{c}{v} = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$$

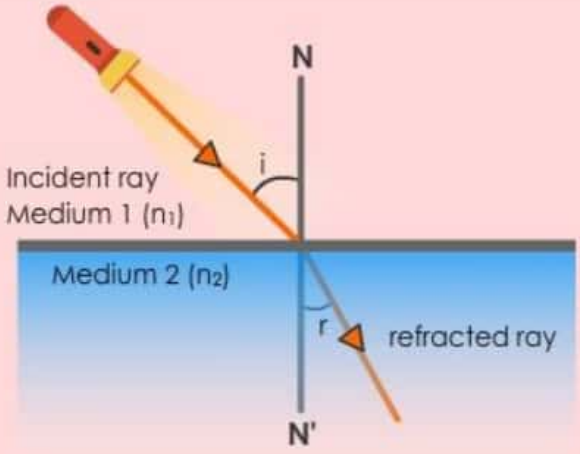
μ = Refractive Index

10 LAWS OF REFRACTION

- The **incident ray, the normal** to any refracting surface at the point of incidence and the **refracted ray,** all **lie in the same plane** called the plane of incidence or plane of refraction.
- $\frac{\sin i}{\sin r}$ = **Constant** for any pair of media and for light of a given wavelength.

This is known as **Snell's Law.**

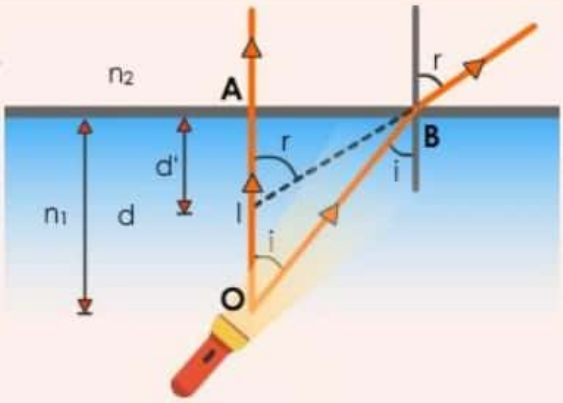
Also, $\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$



11 APPARENT DEPTH AND NORMAL SHIFT

When the object is in denser medium and the observer is in rarer medium (near normal incidence)

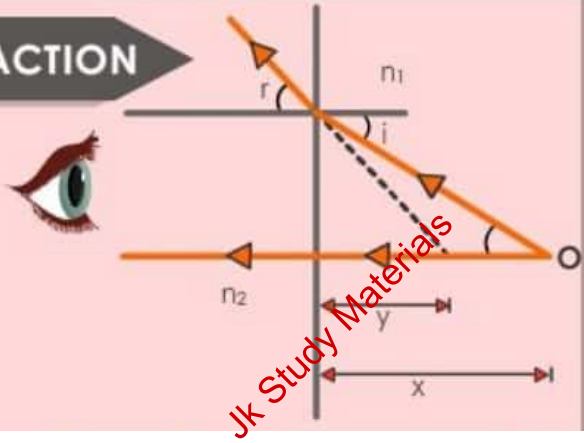
$$\frac{n_2}{n_1} = \frac{d'}{d} = \frac{\text{Apparent depth}}{\text{Real depth}}$$



12 IMAGE VELOCITY IN CASE OF PLANE REFRACTION

$$\frac{n_2}{n_1} = \frac{y}{x} \Rightarrow y = \frac{n_2}{n_1}.x$$

$$\frac{dy}{dt} = \frac{n_2}{n_1}\frac{dy}{dt} \Rightarrow V_{IS} = \frac{n_2}{n_1}V_{OS}$$



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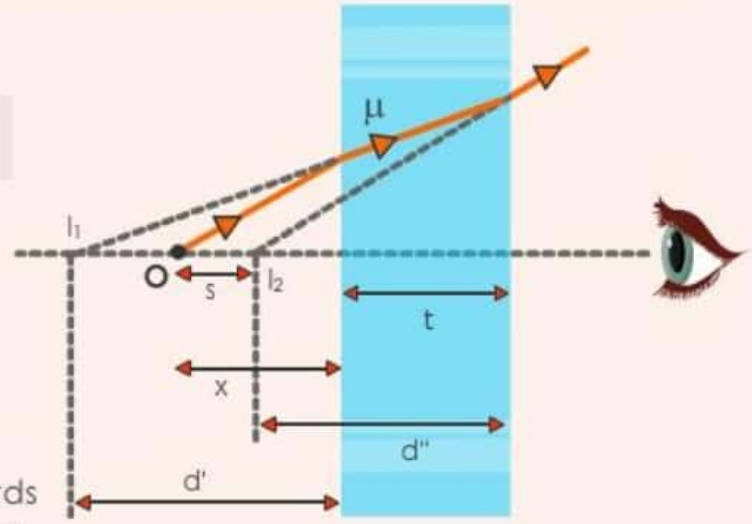
13 REFRACTION THROUGH A GLASS SLAB

Apparent shift due to the slab when object is seen normally through the slab

$$S = t\left[1 - \frac{\mu_{surrounding}}{\mu_{slab}}\right]$$

IMPORTANT POINTS

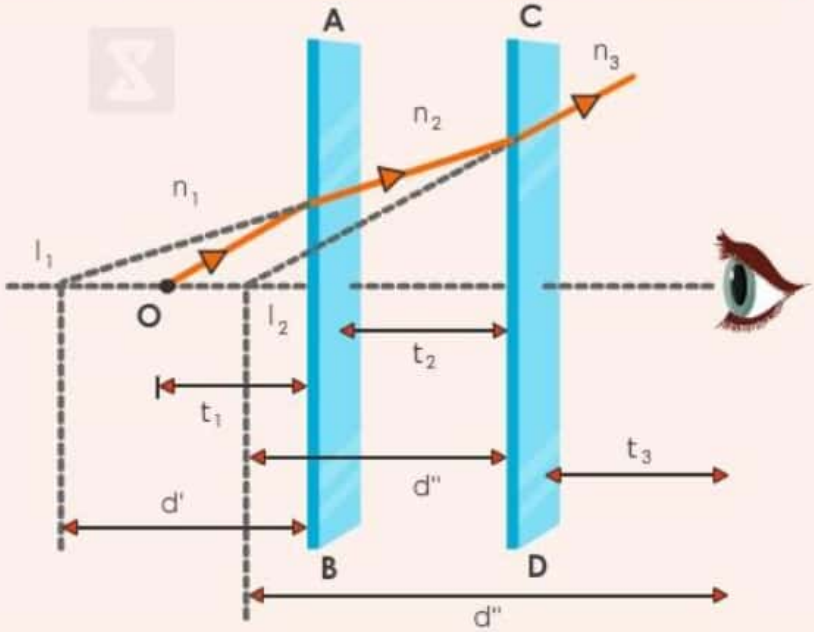
- Rays should be **paraxial.**
- **Medium** on both side of the slab **should be same.**
- Shift comes **out from** the object.
- Shift is **independent** of the **distance of the object** from the slab.
- If shift comes **out Positive** then shift is towards the **direction of incident rays** and vice versa.



Apparent distance between object and observer when both are in different medium

$$d'' = n_3\left[\frac{t_1}{n_1} + \frac{t_2}{n_2} + \frac{t_3}{n_3}\right]$$

If object and observer are in **same medium** then **shift formula** should be used and if both are in **different medium** then the **above formula** of apparent distance should be used.



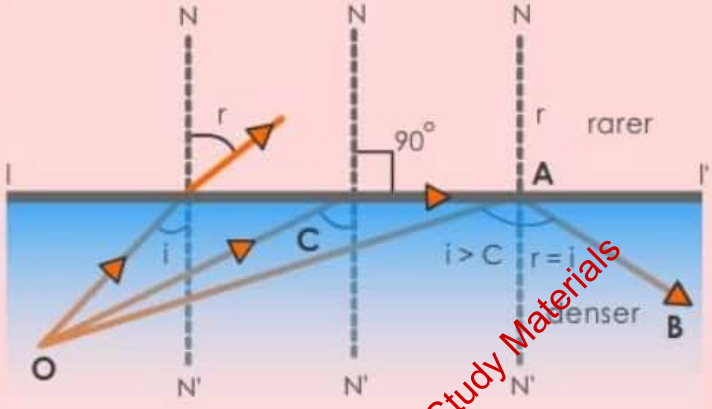
14 CRITICAL ANGLE AND TOTAL INTERNAL REFLECTION

Critical angle is the angle made in a **denser medium** for which the **angle of refraction in rarer medium is 90°.**

$$\therefore\ C = \sin^{-1}\frac{n_r}{n_d}$$

Conditions of Total Internal Reflection

- Light is incident on the interface from denser medium.
- Angle of incidence should be **greater than** the critical angle (i > c).

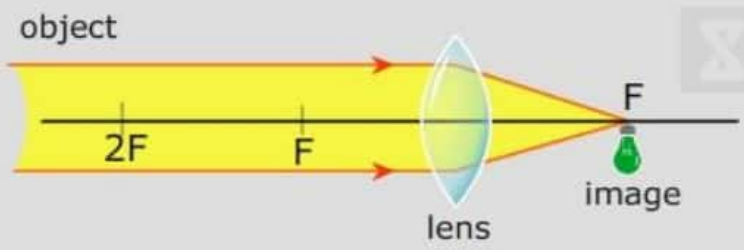


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IMAGE FORMED BY LENSES

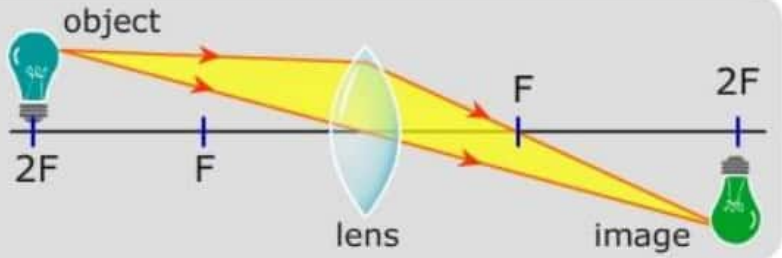
Distant Object

- Real
- Inverted
- Smaller than object
- At Focus



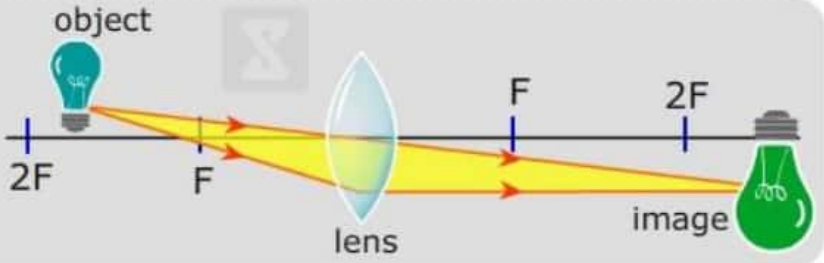
Object at 2F

- Real
- Inverted
- Same size as object
- At 2F



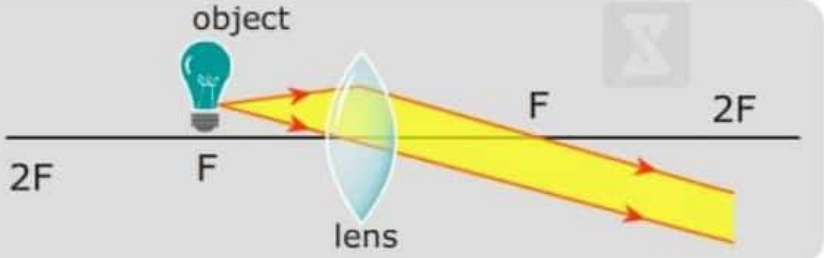
Object between 2F and F

- Real
- Inverted
- Larger than object
- Beyond 2F



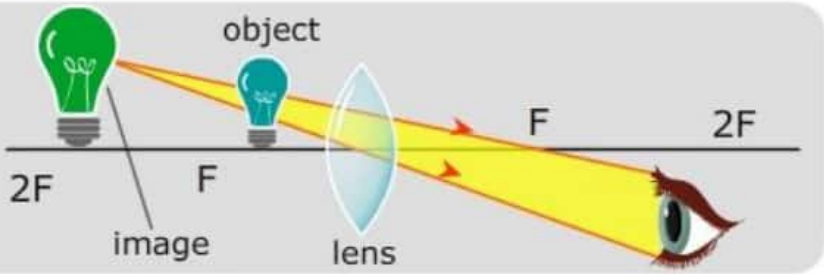
Object at F

- Real
- Inverted
- Highly magnified
- At infinity



Object between F and lens

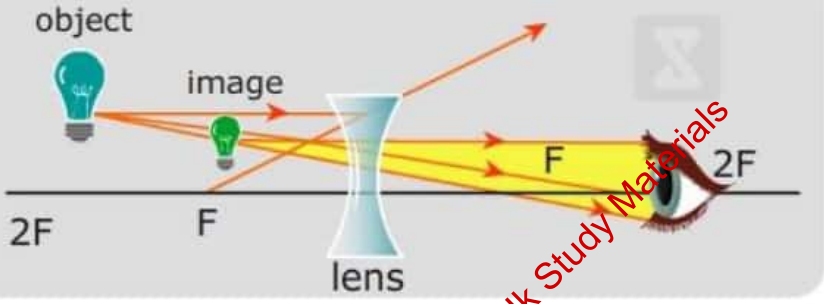
- Virtual
- Erect
- Magnified
- At same side as object



Images formed by a concave lens

Object is at F

- Virtual
- Upright
- Smaller than object
- Between object and the lens



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Part I

ALTERNATING CURRENT

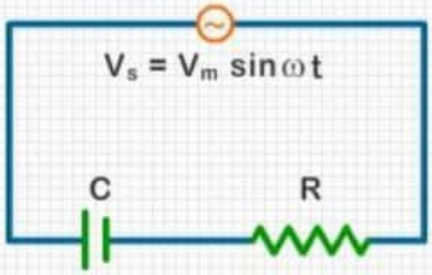
It is the movement of electrical charge through a medium that changes direction periodically

1 SUMMARY

AC SOURCE CONNECTED WITH	PHASE ϕ	PHASE DIFFERENCE	IMPEDANCE Z	PHASOR DIAGRAM
Pure Resistor	0	V_R is in same phase with i_R	R	
Pure Inductor	$\frac{\pi}{2}$	V_L leads i_L by 90^0	X_L	
Pure Capacitor	$-\frac{\pi}{2}$	V_C lags i_C by 90^0	X_C	

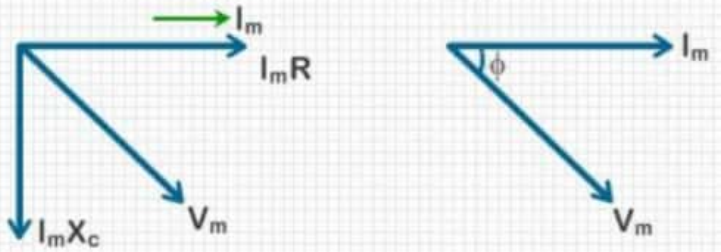
2 RC SERIES CIRCUIT WITH AN AC SOURCE

Circuit Diagram



$$I_m = -\frac{V_m}{\sqrt{R^2 + X_C^2}} \Rightarrow Z = \sqrt{R^2 + X_C^2}$$

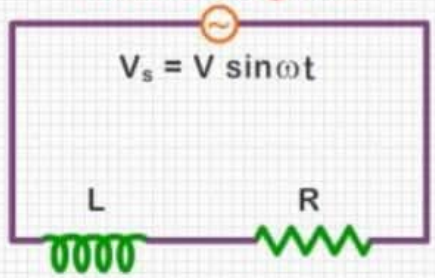
Phasor Diagram



$$\tan\phi = \frac{I_mX_c}{I_mR} = \frac{X_c}{R}$$

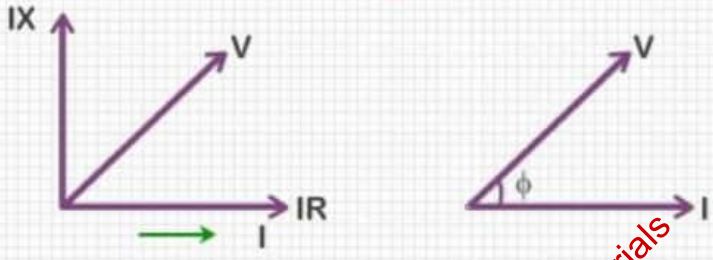
3 LR SERIES CIRCUIT WITH AN AC SOURCE

Circuit Diagram



$$V = I\sqrt{R^2 + X_L^2}$$

Phasor Diagram

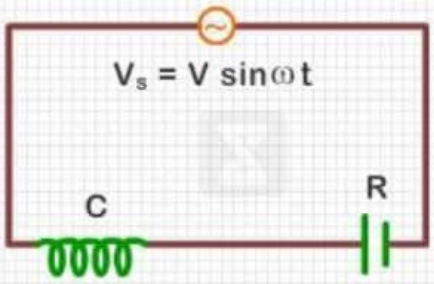


$$\tan\phi = \frac{IX_L}{IR} = \frac{X_L}{R}$$

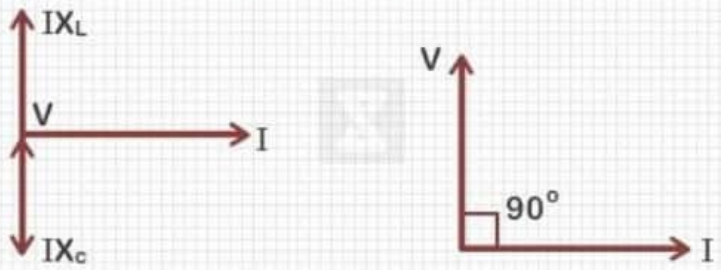
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4 LC SERIES CIRCUIT WITH AN AC SOURCE

Circuit Diagram



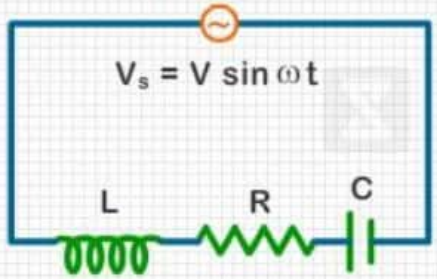
Phasor Diagram



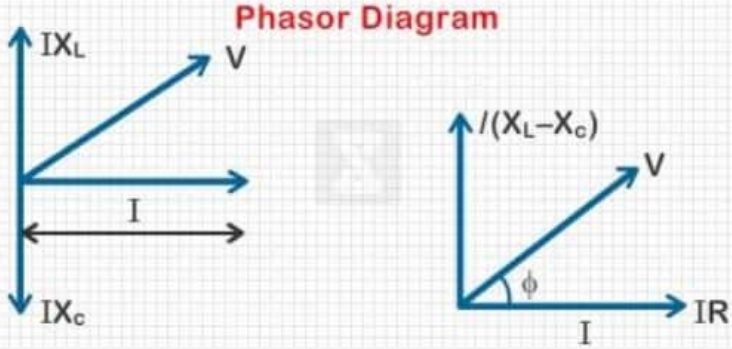
From the phasor diagram $V = I|(X_L - X_c)| = IZ$, $\varphi = 90°$

5 RLC SERIES CIRCUIT WITH AN AC SOURCE

Circuit Diagram



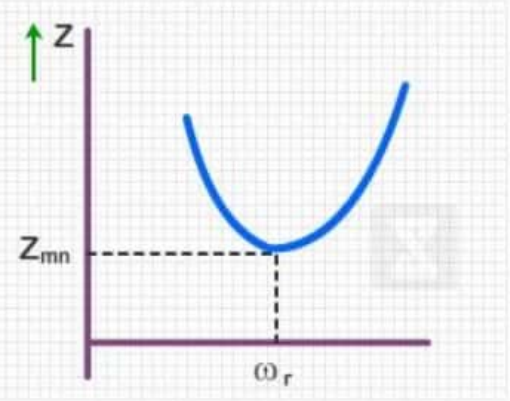
Phasor Diagram

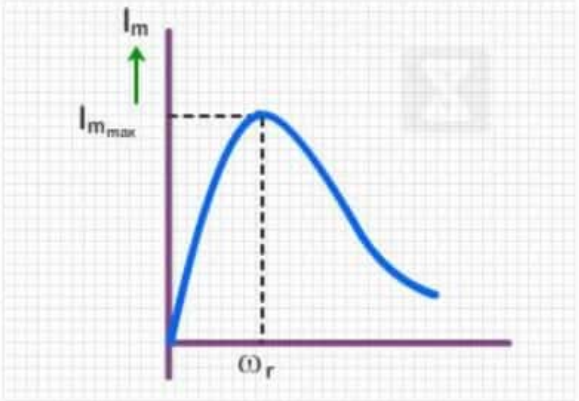


From the phasor diagram $V = \sqrt{(IR)^2 + (IX_L - IX_c)^2}$, $Z = \sqrt{R^2 + (X_L - X_c)^2}$

$$\tan\phi = \frac{I(X_L - X_c)}{IR} = \frac{(X_L - X_c)}{R}$$

6 RESONANCE





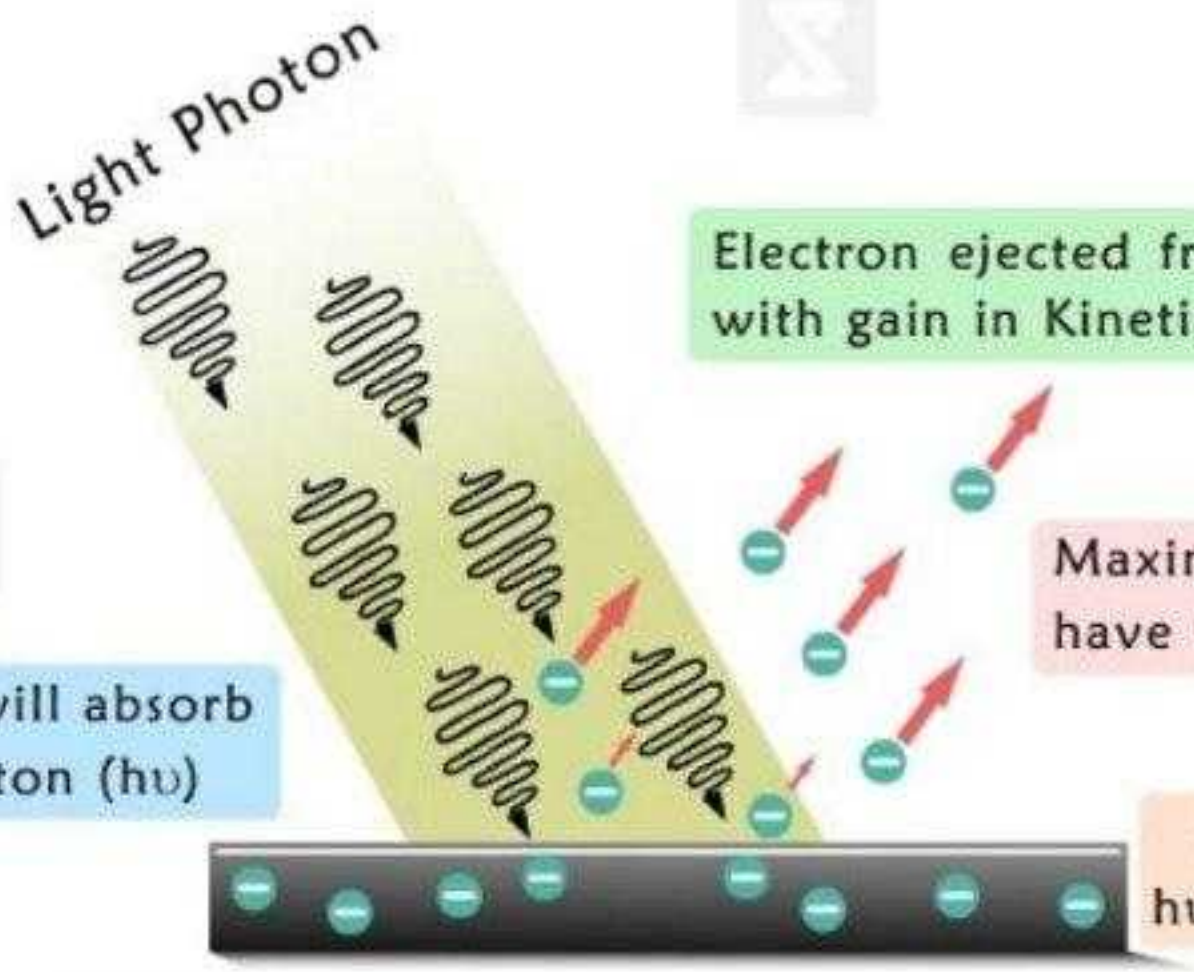
Amplitude of current (and therefore I_{rms} also) in an RLC series circuit is maximum for a given value of V_m and R, if the impedance of the circuit is minimum, which will be when $X_L - X_C = 0$. This condition is called resonance.

So at resonance: $X_L - X_C = 0 \Rightarrow \omega = \frac{1}{\sqrt{LC}}$

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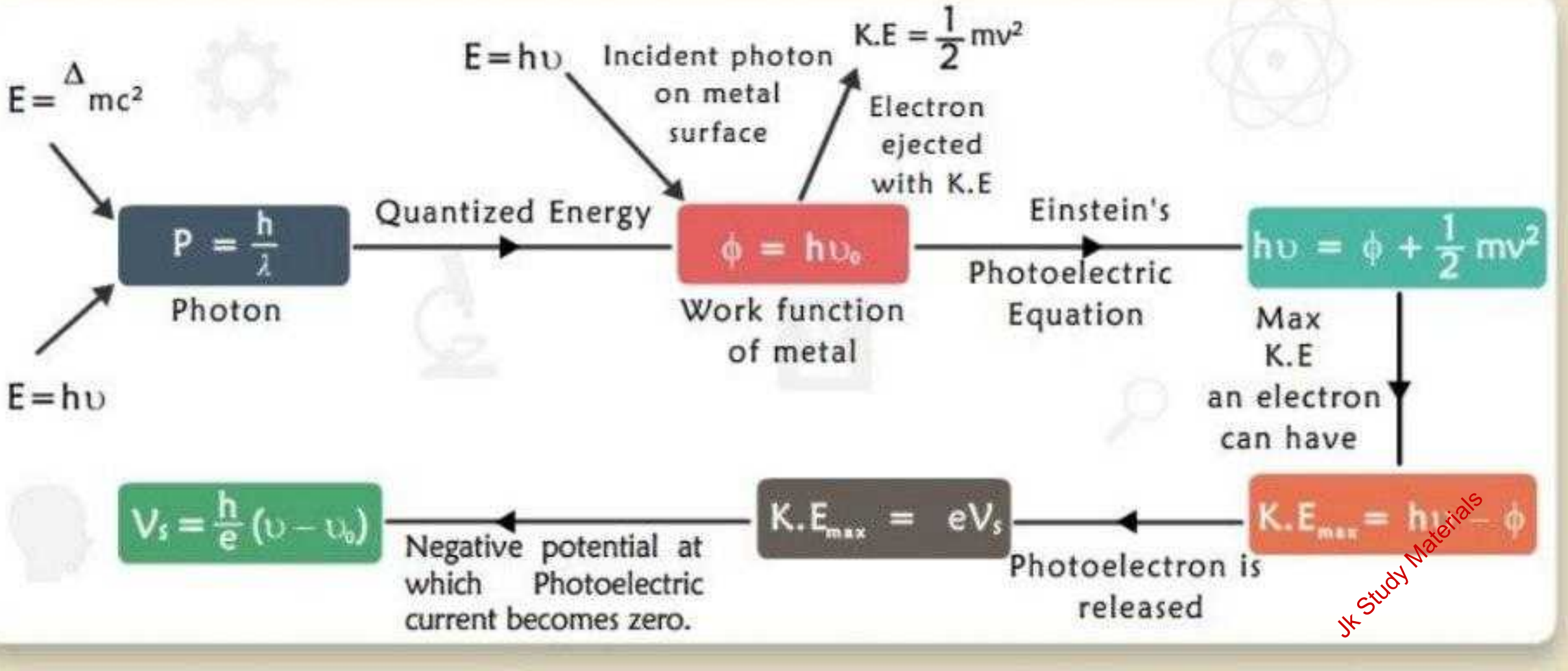
PHOTOELECTRIC EFFECT

Photoelectric effect is the observation that many metals emit electrons when light shines upon them.



Work function ($\phi = h\upsilon_0$) is the energy binding electron to the metal surface.

Only 0.01% of electrons are ejected from the surface.



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Part I

NUCLEAR PHYSICS

MASS DEFECT

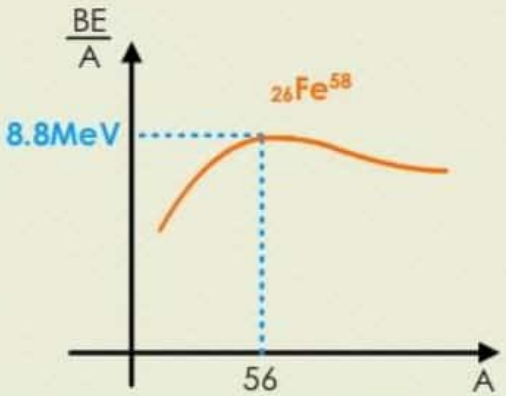
Mass Defect = $M_{expected} - M_{observed}$

$\Delta m = [Zm_p + (A - Z)m_n - [M_{atom} - Zm_e]$

BINDING ENERGY

It is the minimum energy required to break the nucleus into its constituent particles.

Binding Energy (B.E.) = Δmc^2 = $\Delta m \times 931$ MeV



- Binding energy per nucleon is more for medium nuclei than for heavy nuclei. Hence, medium nuclei are highly stable.
- *The heavier nuclei* being unstable have tendency to split into medium nuclei. This process is called **Fission**.
- *The Lighter nuclei* being unstable have tendency to fuse into a medium nucleus. This process is called **Fusion**.

RADIOACTIVITY

- It was discovered by **Henry Becquerel**.
- Spontaneous emission of radiations (α, β, γ) from unstable nucleus is called **radioactivity**. Substances which show radioactivity are known as **radioactive substance**.
- ***In radioactive decay,*** an unstable nucleus emits α particle or β particle. After emission of α or β particle the remaining nucleus may emit γ- particle, and convert into a more stable nucleus.

α- particle

It is a doubly charged helium nucleus. It contains two protons and two neutrons.

Mass of α - particle = Mass of $_2H$ e^4 atom $- 2m_e = 4\ m_p$

Charge of α - particle = + 2e

β- particle

β^- (electron)

Mass = m_e : Charge = – e

β^+ (positron)

Mass = m_e : Charge = + e

positron is an antiparticle of electron.

γ- particle

They are energetic photons of energy of the order of MeV and having zero rest mass.

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RADIOACTIVE DECAY (DISPLACEMENT LAW)

1 α - DECAY

$$_zX^A \rightarrow {}_{z-2}Y^{A-4} + {}_2He^4 + Q$$



Q value is definied as energy released during the decay process.

Q value = rest mass energy of reactants − rest mass energy of products

Let, M_x = mass of atom $_zX^A$, M_y = mass of atom $_{z-2}Y^{A-4}$, M_{He} = mass of atom $_2He^4$

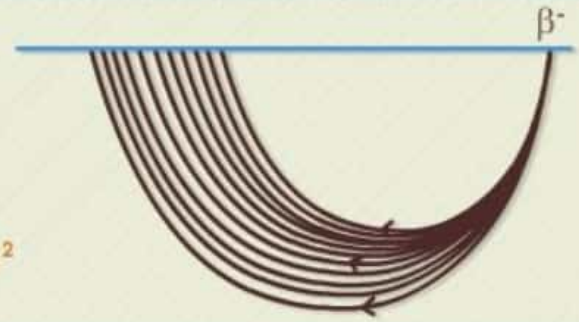
$$\text{Q value} = [M_x - M_y - M_{He}]c^2$$

2 β⁻ - DECAY

$$_zX^A \rightarrow {}_{z+1}Y^A + {}_{-1}e^0 + Q$$

$$T_e = \frac{m_y}{m_e + m_y} Q, \quad T_y = \frac{m_e}{m_e + m_y} Q,$$

$$\text{Q value} = [M_x - \{(M_Y - m_e) + m_e\}]\, c^2 = [M_x - M_y]c^2$$



3 β⁺ - DECAY

$$_zX^A \rightarrow {}_{z-1}Y^A + {}_{+1}e^0 + \nu + Q$$

$$\text{Q value} = [M_x - \{(M_Y + m_e) + m_e\}]\, c^2 = [M_x - M_y - 2M_e]c^2$$

RADIOACTIVE DECAY : STATISTICAL LAW

- Rate of radioactive decay is directly proportional to N
- where N = number of active nuclei.
- Rate of radioactive decay of $A = \frac{-dN}{dt} = \lambda N$
- where λ = decay constant of the radioactive substance.
- Number of nuclei decayed (i.e., the number of nuclei of B formed)

$$N = N_0(1 - e^{-\lambda t})$$

1 HALF LIFE ($T_{1/2}$)

$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

2 ACTIVITY

Activity is defined as the rate of radioactive decay of nuclei

$$A = A_0 e^{-\lambda t}$$

3 AVERAGE LIFE

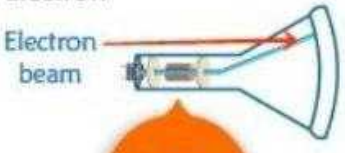
$$T_{avg} = \frac{\text{sum of ages of all the nuclei}}{N_0} = \frac{\int_0^\infty \lambda N_0 e^{-\lambda t} dt \,.t}{N_0} = \frac{1}{\lambda}$$

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KRAKA TOOM

HISTORY OF ATOMIC MODEL

1885 — Johann Balmer derived a formula for mathematically predicting hydrogen spectrum.

1897 — J J Thomson discovered Electron



1904 — J J Thomson proposed plum pudding model

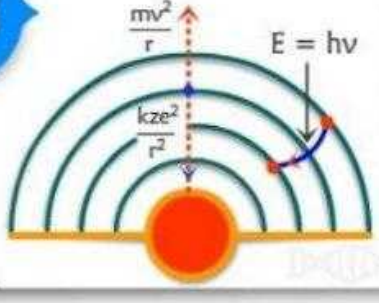


1911 — Rutherford proposed a model where positive charge is at the center, and electron moves around in a spiral path and losses energy.

1913 — Bohr's Atomic Model

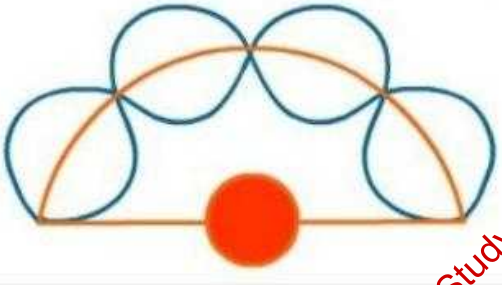
$$r = 0.529 \times \frac{n^2}{z}\ \text{Å}$$

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



- Bohr worked with J J Thomson and found flaws in his theory
- He proposed electron revolves around nucleus in orbits.
- Electron is stabilized by centripetal and electrostatic forces.
- Electron don't lose energy in an orbit.
- Electron losses or gains energy by moving across orbits.
- He proved Balmer was right by derving his formula theoretically.
- Only applicable for one electron systems.
- Failed to predict dual nature of electron.

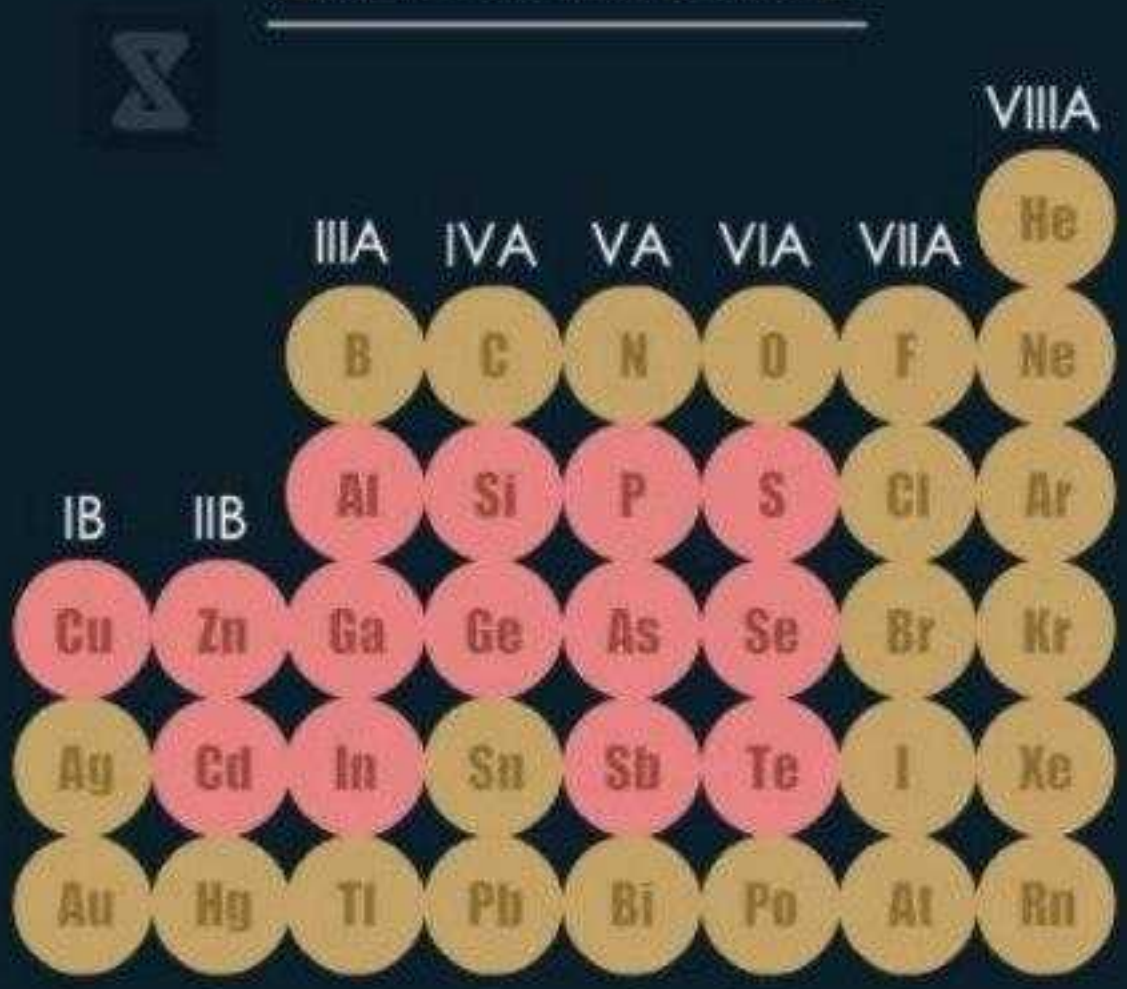
1923 — De Broglie introduced the concept of dual nature in electrons. He used Einstein's $E = mc^2$ and proposed any moving particle or object has an associated wave.



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N-TYPE SEMICONDUCTOR P-TYPE

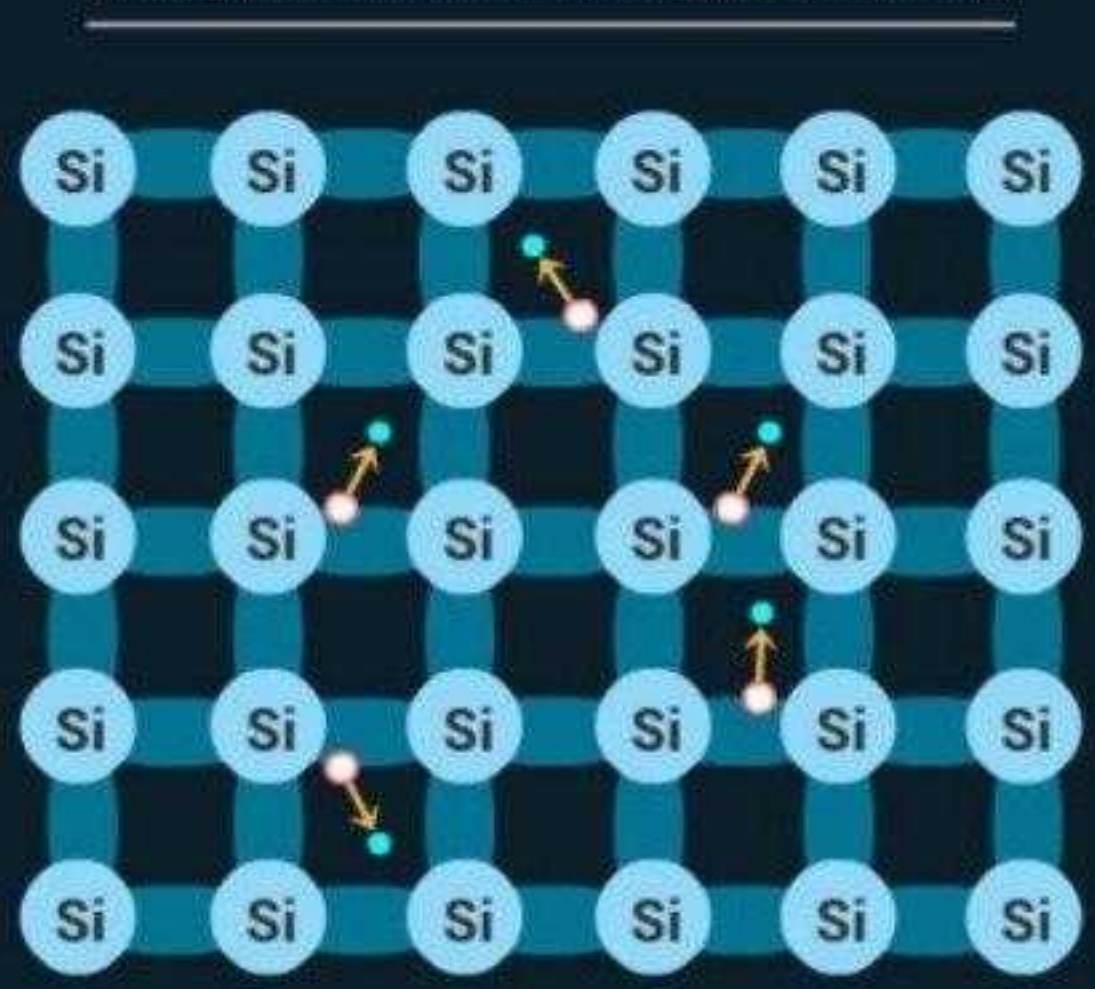
SEMICONDUCTOR



The elements of 4th group of the periodic table are called semiconductors.

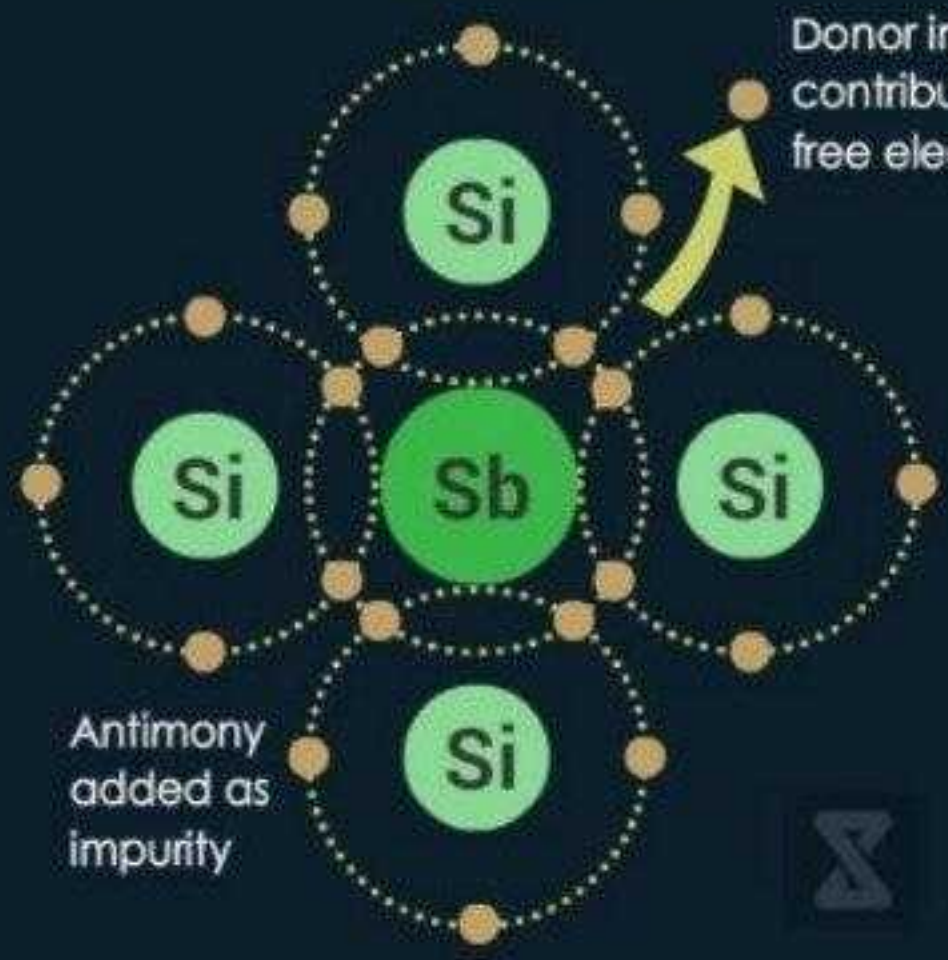
Eg: Germanium, Silicon, etc.

INTRINSIC SEMICONDUCTOR



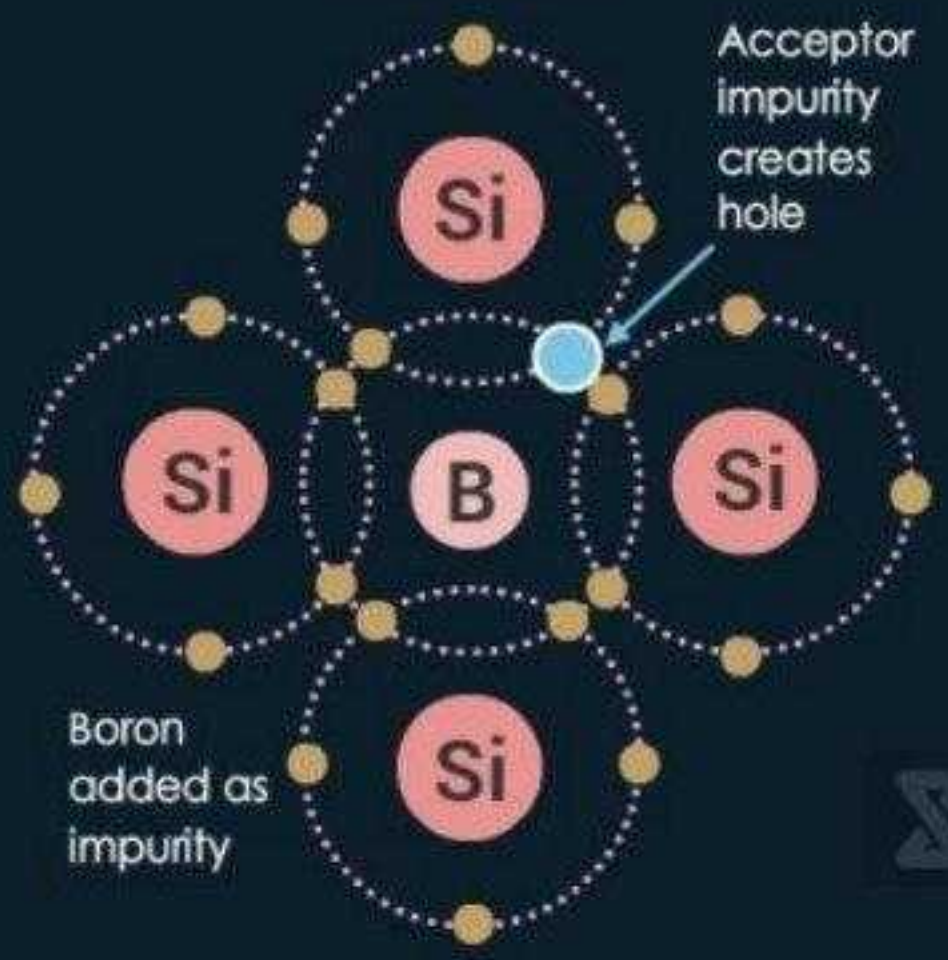
Pure semiconductor is called intrinsic semiconductor.

N-Type



When impurity of 5th group is added in an intrinsic semiconductor, then N-type semiconductor is formed.

P-Type



When impurity of 3rd group is added in an intrinsic semiconductor, then P-type semiconductor is formed.

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