ELECTROSTATICS - 1

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Charge

Quantization of charge

$Q = \pm ne$ Q=Total charge

$n = 1,2,3....$

$e = 1.6 \times 10^{-19}C$

Additivity of charge

$Q' = Q_1 + Q_2$

Redistribution of charge

$Q' = \frac{Q_1+Q_2}{2}$

Q'=Charge on each shell after redistribution

Charge Density

Linear Charge density, $\lambda = \frac{Q}{L}$ Unit= $\frac{C}{m}$

Surface Charge density, $\sigma = \frac{Q}{S}$ Unit= $\frac{C}{m^2}$

Volume Charge density, $\rho = \frac{Q}{V}$ Unit= $\frac{C}{m^3}$

Q=Total charge V=Volume

L=Length S=Area

? If a charge on the body is 1 nC, then how many electrons are present on the body?

a) 1.6×10^{19} b) 6.25×10^{9}

c) 6.25×10^{27} d) 6.25×10^{28}

Coulomb's Law

$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$

ε_0=Permitivity of free space

$[\varepsilon_0] = \frac{[Q_1][Q_2]}{[r^2][F]} = \frac{[AT][AT]}{[L^2][MLT^{-2}]} = M^{-1}L^{-3}T^4A^2$

$F_{med} = \frac{F_{air}}{k}$

k=dielectric constant of the medium

Superposition

Direction:

a) Like- Towards the point at which force has to be evaluated (repulsion)

b) Unlike- Away from the point at which force has to be evaluated (attraction)

General rule: $F_{Net} = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$

When $\theta = 60°$: $F_{net} = \sqrt{3}F$

When $\theta = 90°$: $F_{net} = \sqrt{2}F$

When $\theta = 120°$: $F_{net} = F$

Equillibrium of Charges

Calculation of Charge

$\frac{Q_1}{Q_2} = \left(\frac{r_1}{r_2}\right)^2$ q in equillibrium

$q = -\left(\frac{r_1}{r_1+r_2}\right)^2 Q_2$ Q_1 in equillibrium

$q = -\left(\frac{r_2}{r_1+r_2}\right)^2 Q_1$ Q_2 in equillibrium

? A charge is placed at the centre of the line joining two equal charges Q. The system of the three charges will be in equilibrium if q is equal to

a) -Q/2 c) +Q/4

b) -Q/4 d) +Q/2

Charge on pendulum

$\tan\theta = \frac{qE}{mg}$

$\sin\theta = \frac{r}{2l}$

$r = 2l\sin\theta$

if θ is very small

$\tan\theta \approx \sin\theta$

$\frac{r}{2l} = \frac{qE}{mg}$

$\frac{r}{2l} = \frac{kq^2/r^2}{mg}$, $r^3 \propto q^2$

Density of ball "ρ"

if θ does not change on submerging in liquid Dielectric constant of liquid,

$K = \frac{\rho}{\rho - \sigma}$

density of liquid= σ

Electric Field

$E \propto \frac{1}{r^2}$

Electric field at a point, due to point charge $E = \frac{Kq}{r^2}$

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

Superposition

General rule: $E_{Net} = \sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos\theta}$

$E_{Net} = E_1 + E_2$

$E_{Net} = |E_1 - E_2|$

$E_{Net} = \sqrt{E_1^2 + E_2^2 + E_1E_2}$; If, $E_1 = E_2 = E$ Then, $E_{net} = \sqrt{3}E$

$E_{Net} = \sqrt{E_1^2 + E_2^2}$; If, $E_1 = E_2 = E$ Then, $E_{net} = \sqrt{2}E$

$E_{Net} = \sqrt{E_1^2 + E_2^2 - E_1E_2}$; If, $E_1 = E_2 = E$ Then, $E_{net} = E$

Direction

1) Positive charge:-Towards the point at which electric field has to be evaluated

2) Negative charge:-Away from the point at which electric field has to be evaluated

Neutral Point

Like Charges

$x_1 = \frac{\sqrt{Q_1}\,r}{\sqrt{Q_1}+\sqrt{Q_2}}$

$x_2 = \frac{\sqrt{Q_2}\,r}{\sqrt{Q_1}+\sqrt{Q_2}}$

Unlike Charges

Outside closer to smaller charge

$|Q_2| < |Q_1|$

$x = \frac{\sqrt{Q_2}\,r}{\sqrt{Q_1}-\sqrt{Q_2}}$

Distance from Q_1 = x+r

? Two point charges +8q and -2q are located at x = 0 and x = L respectively. The location of a point on the x axis at which the net electric field due to these two point charges is zero is:

a) 8L

b) 4L

c) 2L

d) L/4

Charged particle released in an electric field

1) Force, $F = qE$

2) Acceleration, $a = \frac{qE}{m}$

3) Velocity, $V = \frac{qE}{m}t$

4) Velocity, $V = \sqrt{\frac{2qE}{m}x}$

5) Kinetic energy, K.E $= \frac{q^2E^2t^2}{2m}$

accelerated in the direction of electric field

accelerated opposite to the direction of electric field

$V = \sqrt{V_x^2 + V_y^2}$

$V_x = \frac{qEt}{m}$

$\sqrt{U^2 + \left(\frac{qE}{m}t\right)^2}$

accelerated in the direction of field and perpendicular to initial velocity

$\frac{M_p}{M_e} = 1837$, $\frac{e}{m} = 1.7 \times 10^{-11}$

$\frac{1}{2}at^2 = h = $Constant

$\frac{1}{2}\frac{qE}{m}t^2 = h$

$t^2 \propto m$

$\frac{t_p}{t_e} = \left[\frac{m_p}{m_e}\right]^{1/2}$

$\Rightarrow t_p > t_e$

Time period of Charged Pendulum in an electric filed

$T = 2\pi\sqrt{\frac{l}{\left(g - \frac{QE}{m}\right)}}$ Time period will increase

$T = 2\pi\sqrt{\frac{l}{\left(g + \frac{QE}{m}\right)}}$ Time period will decrease

$T = 2\pi\sqrt{\frac{l}{\sqrt{g^2 + \left(\frac{QE}{m}\right)^2}}}$ Time period will decrease

Electric field inside a dielectric medium

$E_{net} = \frac{E}{k}$ K

$E_{net} = E - E_{induced}$, $E_{induced} = E - E_{net} = E\left(1 - \frac{1}{k}\right)$

Properties of field lines

1) Start from positive charge and end on negative charge

2) Never intersect each other. If they intersect there will be 2 directions for electric field which is not possible

3) Always perpendicular to Conducting surface

4) $E \propto$ Electric field line density

5) Never form closed loops (Conservative force)

6) $q \propto$ no. of field lines $|q_2| > |q_1|$

? Electric lines of force about negative point charge are:

a) circular, anticlockwise

b) circular, clockwise

c) radial, inward

d) radial, outward

Electric flux

Flux is proportional to total no. of field lines passing through an area

$\phi = \int E.ds\cos\theta$

$\phi = \int \vec{E}.\vec{ds}$

Gauss Law:- $\phi = \frac{q}{\varepsilon_0} = \oint E.ds\cos\theta$

Zero flux:- $\phi = \frac{q_{net}}{\varepsilon_0} = 0$, where $q_{net} = 0$

Electric flux for Cube

1) No charge inside the cube

$\phi = \frac{q}{\varepsilon_0} = 0$

2) Charge placed at the center

$\phi_{total} = \frac{q}{\varepsilon_0}$

$\phi_{one\ side} = \frac{q}{6\varepsilon_0}$

3) Charge placed at the face

$\phi_{cube} = \frac{q}{2\varepsilon_0}$

4) Charge placed at the corner

$\phi_{cube} = \frac{Q}{8\varepsilon_0}$

$\phi_{one\ face} = \frac{Q}{8\varepsilon_0} \times \frac{1}{3} = \frac{Q}{24\varepsilon_0}$

5) Charge placed at the edge

$\phi_{cube} = \frac{Q}{4\varepsilon_0}$

$\phi_{face} = \frac{Q}{\varepsilon_0} \times \frac{1}{4} = \frac{Q}{16\varepsilon_0}$

6) Flux through curved surface

$\phi_{effective} = \phi_{curve} + 2\phi_{cross\ section}$

Application of Gauss's Theorem

1) Point charge $E = \frac{Kq}{r^2}$

2) Metal sphere/Hollow sphere

$E_{surface} = \frac{KQ}{R^2}$

$E_{outside} = \frac{KQ}{r^2}$

$E_{inside} = 0$

3) Non-Conducting sphere

$E_{inside} = \frac{KQr}{R^3}$

$E_{surface} = \frac{KQ}{R^2}$

$E_{outside} = \frac{KQ}{r^2}$

4) Conducting sheet

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

5) Non-conducting sheet

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

Q_{outer} Q_{inner} Q_{plate}

$Q_{inner} = Q_{plate} - Q_{outer}$

7) Electric field due to a finite linear charge distribution

$E = \frac{2k\lambda}{r}\sin(\theta/2)$

8) Electric field due to a infinite linear charge distribution

$E = \frac{2k\lambda}{r}$

9) Electric field due to circular arc at its center

$E_o = \frac{2k\lambda}{r}\sin(\theta/2)$

eg: For a semicircle $\theta = 180°$

$E_o = \frac{2k\lambda}{r}\sin(180°/2)$

$= \frac{2k\lambda}{r}$

10) Electric field at the center of a circular ring

$E_o = 0$

11) Electric field due to a circular ring of charge

$E = \frac{1}{4\pi\varepsilon_0}\frac{qx}{(x^2+r^2)^{3/2}}$

(For large distance)

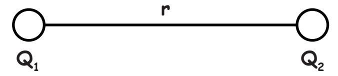
$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}$

E_{max} at $x = \frac{r}{\sqrt{2}}$

ELECTROSTATICS-02

ELECTROSTATIC POTENTIAL ENERGY

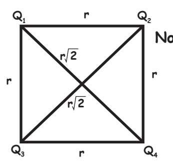
2 point charges



$\Delta U = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r}$ — like charges - positive (repulsive energy); Unlike charges - negative (attractive energy)

System of charges

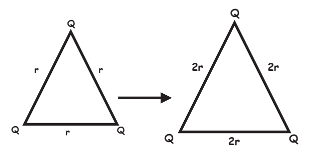
$\Delta U_{system} = \sum \Delta U_{pair}$ No. of pairs $= \frac{n(n-1)}{2}$



No. of pairs $= \frac{4 \times 3}{2} = 6$

Total P.E $= \frac{KQ_1 Q_2}{r} + \frac{KQ_1 Q_4}{r\sqrt{2}} + \frac{KQ_2 Q_3}{r\sqrt{2}} + \frac{KQ_2 Q_4}{r} + \frac{KQ_3 Q_4}{r} + \frac{KQ_1 Q_3}{r}$

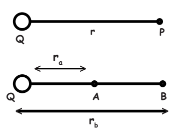
WORK DONE IN REARRANGEMENT OF THE SYSTEM



$U_i = \frac{3kQ^2}{r}$ $U_f = \frac{3kQ^2}{2r}$

$W = U_f - U_i = \frac{3kQ^2}{2r} - \frac{3kQ^2}{r}$
$= -\frac{3kQ^2}{2r}$

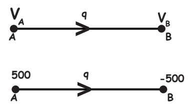
ELECTROSTATIC POTENTIAL



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

$V_{AB} = V_B - V_A = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r_b} - \frac{1}{r_a}\right]$

WORK DONE



$w = q[V_B - V_A]$

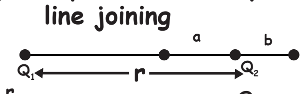
$w = 1 \times (-500-500) = -1000J$

Superposition of potential - Algebraic sum of all potentials

ZERO POTENTIAL

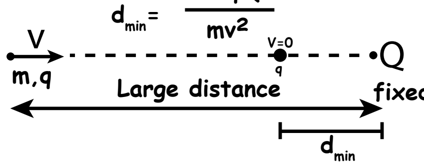
a) Like charge-no zero potential point

b) Unlike charge- 2 points of zero potential on line joining

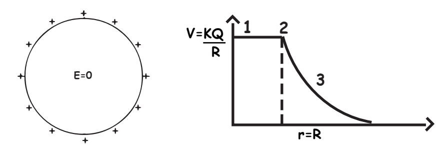


Inside point = $a = \frac{Q_2 r}{Q_1 + Q_2}$ Outside point = $b = \frac{Q_1 r}{Q_1 - Q_2}$

$d_{min} = \frac{2kqQ}{mv^2}$

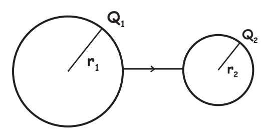


POTENTIAL OF CHARGED CONDUCTING SPHERE



case 1: V_{inside} = Const $= V_{surface} = \frac{KQ}{R}$ case 2: $V_{surface} = \frac{kQ}{R}$ case 3: $V_{outside} = \frac{kQ}{r}$

Redistribution of Charge when two Conducting sphere are connected



→ Charge flow from higher potential to lower potential
Final potentials of spheres are equal

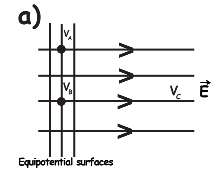
$\frac{1}{4\pi\varepsilon_0}\frac{Q_1'}{r_1} = \frac{1}{4\pi\varepsilon_0}\frac{Q_2'}{r_2}$

$Q_1' = \frac{(Q_1+Q_2)\, r_1}{r_1+r_2}$ $Q_2' = \frac{(Q_1+Q_2)\, r_2}{r_1+r_2}$

$\boxed{\frac{Q_1'}{Q_2'} = \frac{r_1}{r_2},\ \frac{E_1}{E_2} = \frac{r_2}{r_1},\ \frac{\sigma_1}{\sigma_2} = \frac{r_2}{r_1}}$

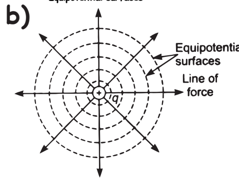
EQUIPOTENTIAL SURFACE

a)



$V_A = V_B > V_C$

b)



c) Field lines and equipotential surface are perpendicular to each other at every location.

d) work done in moving a charge on equipotential surface is 0

ELECTRIC FIELD & POTENTIAL

$E = \frac{-dV}{dr}$ $E_x = \frac{-\partial V}{\partial x}$ $E_y = \frac{-\partial V}{\partial y}$ $E_z = \frac{-\partial V}{\partial z}$

$\Delta V = -\int \vec{E}.\vec{dr}$

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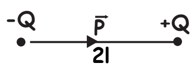
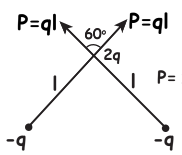
DIPOLE

Dipole moment

$\vec{P} = q\, \vec{2l}$



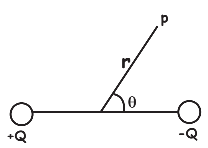
Direction is from -Q to +Q



$P = 2ql\cos 30° = 2\sqrt{3}ql(\uparrow)$

Q. Fine net dipole moment

ELECTRIC FIELD

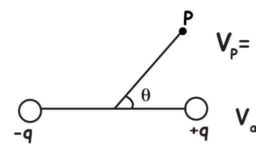


$E_p = \frac{Kp}{r^3}\sqrt{3\cos^2\theta + 1}$

$E_{axial} = \frac{Kp}{r^3}\sqrt{3+1} = \frac{2Kp}{r^3}$ 0° with dipole moment, E_{net} from -Q to +Q

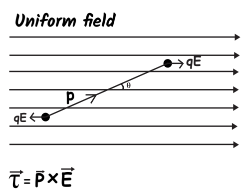
$E_{equitorial} = \frac{Kp}{r^3}\sqrt{0+1} = \frac{Kp}{r^3}$ 180° with dipole moment, E_{net} from +Q to -Q

ELECTRIC POTENTIAL



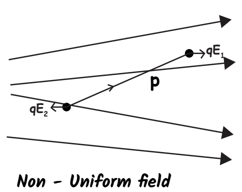
$V_p = \frac{kp\cos\theta}{r^2}$ $V_{axial} = \frac{Kp}{r^2}$ $V_{equitorial} = 0$

TORQUE



- Rotational motion only
- No translatory motion

$\vec{\tau} = \vec{P} \times \vec{E}$
$\tau = PE\sin\theta$



- Both rotatory and translatory motion

$\tau_{max} = pE\sin\theta = pE, (\theta = 90°)$

$\tau_{min} = pE\sin\theta = 0, (\theta = 0°)$

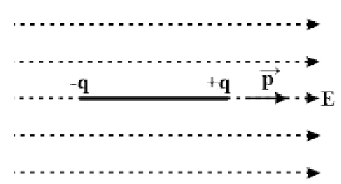
WORK DONE

$W = pE(\cos\theta_1 - \cos\theta_2)$

POTENTIAL ENERGY

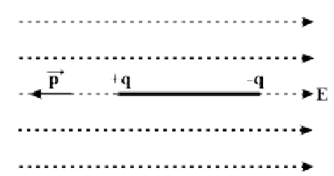
$U = -pE\cos\theta$

1) $U_{minimum}$ (stable equilibrium)



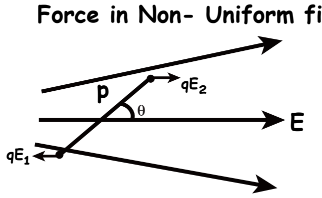
$\theta = 0°$
$\cos\theta = 1$
$U = -pE$

2) $U_{maximum}$ (Unstable equilibrium)



$\theta = 180$
$\cos\theta = -1$
$U = +pE$

Force in Non- Uniform field



$F_x = p\frac{dE}{dx}\cos\theta$

where, dE= small change in field at the two locations of the charges

CAPACITANCE

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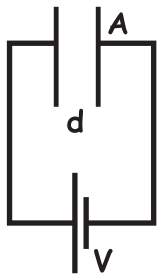
CAPACITANCE



$Q = CV$

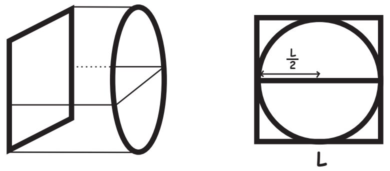
$C = \frac{Q}{V}$

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

Capacitance Depends on
1. Distance betweent plates
2. Area of plates
3. Medium b/w plates

Capacitance is Independent of
1. Charge
2. Potential difference

Unit Of Capacitance = Farad



$A_{eff} = \pi\left(\frac{L}{2}\right)^2 = \pi\frac{L^2}{4}$

$C = \frac{\varepsilon_0 A_{eff}}{d} = \frac{\pi\varepsilon_0 L^2}{4d}$

ENERGY STORED

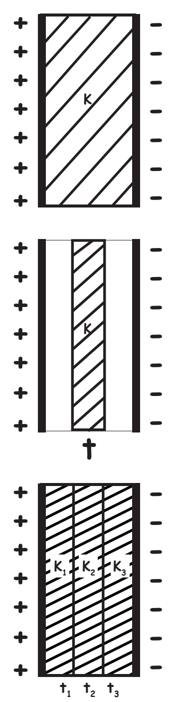
Work done by battery $= QV$ (100%)

- 50% Energy stored in capacitor: $= \frac{1}{2}QV = \frac{CV^2}{2} = \frac{Q^2}{2C}$
- 50% Energy dissipated: $= \frac{1}{2}QV = \frac{CV^2}{2} = \frac{Q^2}{2C}$

Variation with plate seperation

1. $Q = CV = \frac{\varepsilon_0 AV}{d}$
2. $C = \frac{\varepsilon_0 A}{d}$ $\quad C \propto \frac{1}{d}$
3. $V = \frac{Q}{C} = \frac{Qd}{\varepsilon_0 A}$ $\quad$ 4. $E = \frac{Q}{A\varepsilon_0} = \frac{V}{d}$
5. $F = \frac{Q^2}{2A\varepsilon_0} = \frac{CV^2}{2d}$
6. $U = \frac{CV^2}{2}$ OR $U = \frac{Q^2}{2C} = \frac{Q^2 d}{2\varepsilon_0 A}$ $= \frac{\varepsilon_0 AV^2}{2d}$

DIELECTRIC IN CAPACITOR



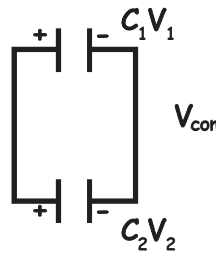
$C' = \frac{k\varepsilon_0 A}{d}$

$C' = KC$

$C' = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}}$

$C' = \frac{\varepsilon_0 A}{\frac{t_1}{K_1} + \frac{t_2}{K_2} + \frac{t_3}{K_3}}$

Connecting two charged capacitors - Case 1



$V_{common} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$

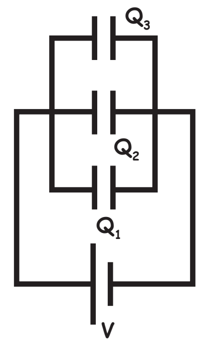
Initial Energy → Heat loss → Final Energy

$U_i = \frac{C_1V_1^2}{2} + \frac{C_2V_2^2}{2}$

$U_f = \frac{1}{2}(C_1 + C_2)\left(\frac{C_1V_1 + C_2V_2}{C_1 + C_2}\right)^2$

Energy loss $= \frac{C_1C_2}{2(C_1 + C_2)}(V_1 - V_2)^2$

2. Parallel combination



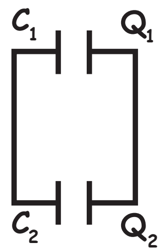
$C_{eq} = C_1 + C_2 + C_3$

$C_{eq} = nC$

[if $C_1 = C_2 = \ldots\ldots = C_n = C$]

Charge divider rule

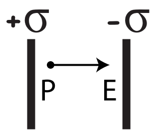
$Q \propto C$



$Q_1 = \left(\frac{C_1}{C_1 + C_2}\right)Q$

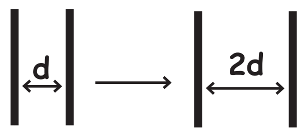
$Q_2 = \left(\frac{C_2}{C_1 + C_2}\right)Q$

ELECTRIC FIELD



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

when plate seperation doubled

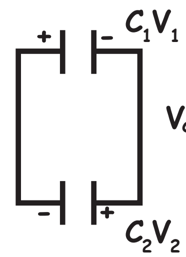


$C = \frac{\varepsilon_0 A}{d}$ $\quad C' = \frac{C}{2}$

Dielectric inserted in capacitor

Battery removed	Battery remains connected
1. $C = KC$	1. $C' = KC$
2. $Q' = Q$	2. $Q' = KQ$
3. $V' = \frac{V}{K}$	3. $V' = V$
4. $E' = \frac{E}{K}$	4. $E' = E$
5. $U' = \frac{U}{K}$	5. $U' = KU$

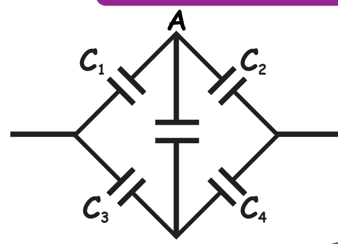
Connecting two charged capacitors - Case 2



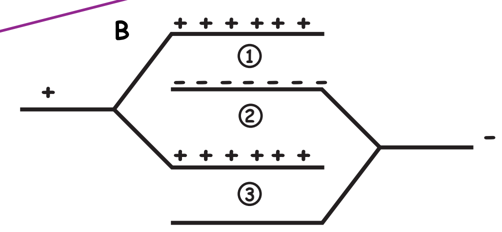
$V_{common} = \frac{C_1V_1 - C_2V_2}{C_1 + C_2}$

Energy loss $= \frac{C_1C_2}{2(C_1 + C_2)}(V_1 + V_2)^2$

WHEATSTONE'S BRIDGE



$\frac{C_1}{C_2} = \frac{C_3}{C_4}$ $\quad V_A = V_B$

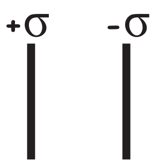


$C = \frac{3\varepsilon_0 A}{d}$

POTENTIAL

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

Force b/w plates of a parallel plate capacitor



$F = Q \times E_{\text{Due to one plate}}$

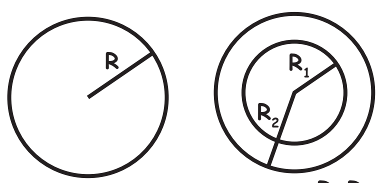
$= Q \times \frac{\sigma}{2\varepsilon_0} = Q \times \frac{Q}{2A\varepsilon_0}$

$= \frac{Q^2}{2A\varepsilon_0} = \frac{C^2V^2}{2A\varepsilon_0} = \frac{\varepsilon_0 A}{d} \times \frac{CV^2}{2A\varepsilon_0}$

$= \frac{CV^2}{2d}$

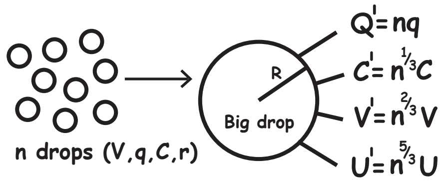
Battery connected	Battery Disconnected
$d \rightarrow 2d$	$d \rightarrow 2d$
1. V=Constant	1. Q=Constant
2. $C' = \frac{C}{2}$	2. $C' = \frac{C}{2}$
3. $Q = CV$, $Q' = \frac{Q}{2}$	3. $V = \frac{Q}{C}$, $V' = 2V$
4. $E = \frac{V}{d}$, $E' = \frac{E}{2}$	4. $E = \frac{Q}{A\varepsilon_0}$ = Constant
5. $F = \frac{CV^2}{2d}$, $F' = \frac{F}{4}$	5. $F = \frac{Q^2}{2A\varepsilon_0}$ = Constant
6. $U = \frac{CV^2}{2}$, $U' = \frac{U}{2}$	6. $U = \frac{Q^2}{2C}$, $U' = 2U$

SPHERICAL CAPACITOR



$C = 4\pi\varepsilon_0 R$ $\quad C = 4\pi\varepsilon_0\left[\frac{R_1R_2}{R_2 - R_1}\right]$

REDISTRIBUTION OF CHARGE



$Q' = nq$

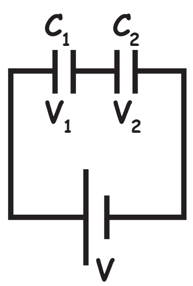
$C' = n^{1/3}C$

$V' = n^{2/3}V$

$U' = n^{5/3}U$

Grouping of capacitors

1. Series combination



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

$V = V_1 + V_2$

$C_{eq} = \left(\frac{C_1C_2}{C_1 + C_2}\right)$

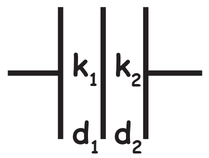
Voltage divider rule

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

$V_1 = \left(\frac{C_2}{C_1 + C_2}\right)V$ $\quad V_2 = \left(\frac{C_1}{C_1 + C_2}\right)V$

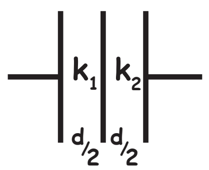
MULTIPLE DIELECTRICS

1. Series combination



$k_{eq} = \frac{\Sigma d}{\Sigma d/k}$

$k_{eq} = \frac{d_1 + d_2}{\frac{d_1}{k_1} + \frac{d_2}{k_2}}$

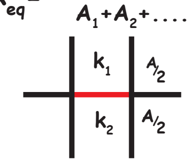


$k_{eq} = \frac{2k_1k_2}{k_1 + k_2}$

2. Parallel combination

$k_{eq} = \frac{\Sigma kA}{\Sigma A}$

$k_{eq} = \frac{k_1A_1 + k_2A_2 + \ldots}{A_1 + A_2 + \ldots}$



$k_{eq} = \frac{k_1\frac{A}{2} + k_2\frac{A}{2}}{\frac{A}{2} + \frac{A}{2}} = \frac{k_1 + k_2}{2}$

CURRENT ELECTRICITY

PHYSICS WALLAH

01 ELECTRIC CURRENT

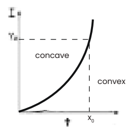
Current $I=\frac{q}{t}$

Average current $I_{av}=\frac{\Delta q}{\Delta t}$

Instantaneous current $I_{inst}=\frac{dq}{dt}$

Average current I_{av}

$=\frac{\text{area under I-t graph}}{\text{total time taken}}$

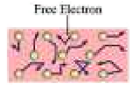


Concave area $=\frac{2}{3}x_0y_0$

Convex area $=\frac{1}{3}x_0y_0$

02 DRIFT VELOCITY

Free Electron



$\langle KE\rangle=\frac{3}{2}kT$

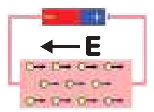
$<\frac{1}{2}mv^2>\approx 10^{-21}J$

Avg. Speed = 105 m/s

Electrons are in random motion

Avg. velocity = $\frac{\vec{v}_1+\vec{v}_2+\vec{v}_3+...\vec{v}_n}{n}=0$

$I_{net}=0$



E accelerates the electrons

$\vec{v}=\vec{u}+\vec{a}t$

$v_d=a\tau$

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

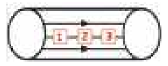
$E=\frac{V}{l}$

$v_d=\frac{eV}{ml}\tau$

03 FACTORS AFFECTING DRIFT VELOCITY

- Dependence on shape

1) Uniform shape



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

Here E is uniform so,

$v_{d1}=v_{d2}=v_{d3}$ $E_1=E_2=E_3$

2) Non Uniform shape

$E_1>E_2>E_3$

$V_d\ \alpha\ E$ $V_{d1}>V_{d2}>V_{d3}$

3) Relation B/w Current & Drift velocity

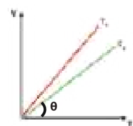
$I=nAV_de$

n= no. of e's per unit volume

04 OHM'S LAW

V = I × R

Voltage volts (V) | Current Amperes (A) | Resistance ohms(Ω)



$T_1>T_2$ Slope = tanθ = R

$R=\frac{\rho l}{A}$ Depends on
1. Material (n & τ changes)
2. Temperature (n & τ changes)
3. Dimension (Length & Area)

$\rho=\frac{RA}{l}=\frac{m}{ne^2\tau}$ Depends on
1. Material (n & τ changes)
2. Temperature (n & τ changes)

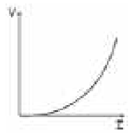
Non-Ohmic Conductor

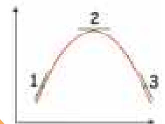
V-I graph is not linear

Slope of tangent $\frac{dV}{dI}=R$

Resistance is not constant

1) Slope=+ve
Resistance = +ve
V↑then I↑





2) Slope=0
Resistance=0

3) Slope=-ve
Resistance = - ve
V↑thenI↓

05 CURRENT DENSITY

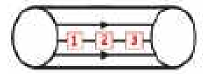
$J=\frac{I}{A}\hat{n}$

$I=\frac{V}{R}=\frac{V}{\rho l/A}$ $\frac{EA}{\rho}$ $J=\frac{E}{\rho}$, $J\propto E$

Uniform cross section

$E_1=E_2=E_3$

$\therefore J_1=J_2=J_3$

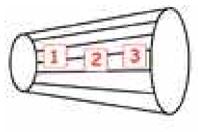


Non-Uniform cross-section

$E_1>E_2>E_3$ $J\propto\frac{I}{A}$

$\therefore J_1>J_2>J_3$

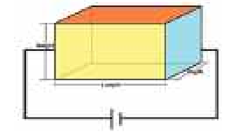
But current is same



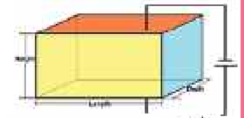
$I_1=I_2=I_3$

06 DEPENDANCE OF R ON DIMENSION

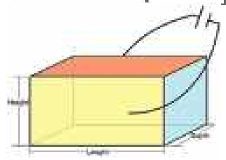
$R=\frac{\rho l}{A}=\frac{\rho l}{bh}$



$R=\frac{\rho h}{lb}$



$R=\frac{\rho b}{lh}$



$\frac{R_{max}}{R_{min}}=\frac{(\text{max length})^2}{(\text{min length})^2}$

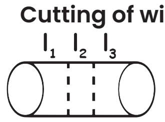
07 CUTTING & STRETCHING OF WIRE

$R_1\ \alpha\ l_1$

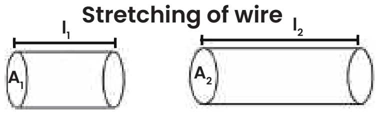
$R_2\ \alpha\ l_2$

$R_3\ \alpha\ l_3$

Cutting of wire



Stretching of wire



Before stretching After stretching

$\frac{R_1}{R_2}=\left(\frac{l_1}{l_2}\right)^2=\left(\frac{A_2}{A_1}\right)^2=\left(\frac{r_2}{r_1}\right)^4=\left(\frac{d_2}{d_1}\right)^4$

If l become nl then R become n² R

If r become r/n then R become n⁴ R

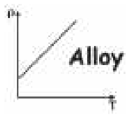
If change in length>10% $\frac{R_2-R_1}{R_1}\times100=\frac{l_2^2-l_1^2}{l_1^2}\times 100$

If change in length <10%

1) % change in R=2×% change in length
2) % change in R=2×% change in area
3) % change in R=4×% change in radius

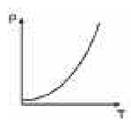
08 TEMPERATURE DEPENDANCE OF RESISTANCE

Metals, α =+Ve
If T↑R↑



For semiconductor α= -ve
If T↑,R↓

α= slightly increasing with temp.
Resistance slightly increases with T



Variation of resistance with temperature $\alpha=\frac{\Delta R}{R\Delta T}$

Equivalent temp. Coefficient

SERIES:

$\alpha_s=\frac{\alpha_1R_1+\alpha_2R_2}{R_1+R_2}$

if $R_1=R_2$ $\alpha=\frac{\alpha_1+\alpha_2}{2}$

PARALLEL:

$\alpha_p=\frac{\frac{\alpha_1}{R_1}+\frac{\alpha_2}{R_2}}{\frac{1}{R_1}+\frac{1}{R_2}}$

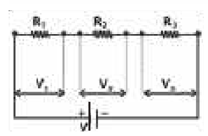
if $R_1=R_2$ $\alpha=\frac{\alpha_1+\alpha_2}{2}$

09 GROUPING OF RESISTANCE

Series Combination

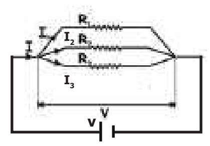
Current is constant
voltage is divided
$R_s=R_1+R_2+R_3+....R_n$

`If resistors are identical: $R_s=nR$



Parallel Combination

voltage is constant
current is divided



$\frac{1}{R_p}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+....\frac{1}{R_n}$

If resistors are identical: $R_P=\frac{R}{n}$

Shortcut for two resistors in parallel

$\frac{R_1R_2}{R_1+R_2}$

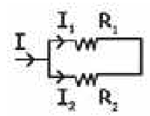
R_1, R_2 → R_s Bigger than largest value of resistance

→ R_p Lower than smallest value of resistance

10 CURRENT & VOLTAGE DIVIDER RULE

Current Divider Rule

V =Constant $I\alpha\frac{1}{R}$

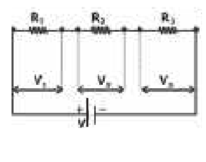


$I_1=\frac{I\times R_2}{R_1+R_2}$, $I_2=\frac{I\times R_1}{R_1+R_2}$

Voltage Divider Rule

$V_1=IR_1$ $V_2=IR_2$ $V_3=I_3R_3$

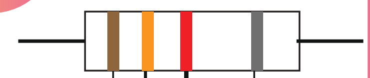
$V_1=\frac{V\times R_1}{R_1+R_2+R_3}$



$V_2=\frac{V\times R_2}{R_1+R_2+R_3}$

$V_3=\frac{V\times R_3}{R_1+R_2+R_3}$

11 COLOUR CODING



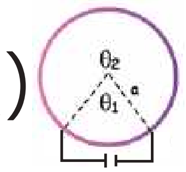
Resistor color code

Color	Digit	Multiplier	Tolerance (%)
Black	0	10^0	
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	0.5
Blue	6	10^6	0.25
Violet	7	10^7	0.1
Grey	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
silver		10^{-2}	10
none			20

12 GEOMETRICAL DIAGRAM

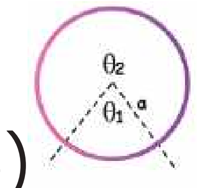
Circle formed by wire having uniform resistance per unit length (r)

$R_{eff}=ra\left(\frac{\theta_1\theta_2}{\theta_1+\theta_2}\right)$



When resistance of wire forming circle is given

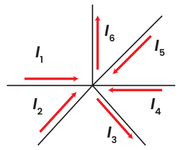
Reff $=\frac{R}{2\pi}\left(\frac{\theta_1\theta_2}{\theta_1+\theta_2}\right)$



PHYSICS WALLAH

13 KIRCHHOFF'S LAW

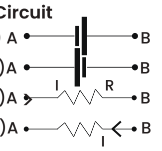
1. Junction Rule



$$\sum I_{in} = \sum I_{out}$$

$$I_1 + I_2 + I_4 + I_5 = I_3 + I_6$$

2. Open Circuit



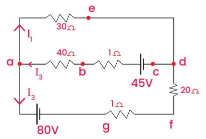
(1) $V_A - V_B = -E$

(2) $V_A - V_B = +E$

(3) $V_A - V_B = IR$

(4) $V_A - V_B = -IR$

Closed Circuit



(1) abcdea

$40I_3 + I_3 - 45 + 30I_1 = 0$

(1) aedfga

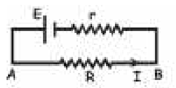
$-30I_1 + 20I_2 + I_2 + 80 = 0$

14 CELL & INTERNAL RESISTANCE

$V_A - V_B = E - Ir$

Terminal potential difference (TPD)

1)When current is drawn from cell



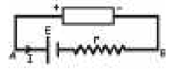
$V = V_A - V_B = E - Ir$

TPD< EMF

$V = E - Ir = IR \Rightarrow I = \frac{E}{R+r}$

So , $V = \frac{E}{R+r} R$

2) When current is given to cell



$V = V_A - V_B = E + Ir$

TPD> EMF

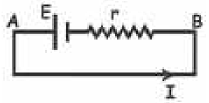
15 CELL & INTERNAL RESISTANCE

3) When cell is in open circuit

Here, I=0

TPD=E

3) When cell is in short circuit



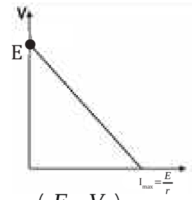
$$I = I_{max} = \frac{E}{r}$$

$$TPD = 0$$

16 CELL & INTERNAL RESISTANCE

Slope of graph =-r

y intercept=E

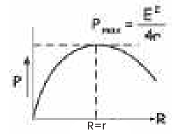


Internal Resistance $r = \left(\frac{E - V}{V}\right) R$

Power delivered by cell during withdrawl of current

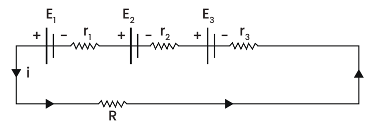
$P = I^2 R = \left(\frac{E}{R+r}\right)^2 R$ $\quad P_{max} = \frac{E^2}{4r}$, when R=r

Maximum power transfered



17 COMBINATION OF CELLS

1) **Series Combination**



(a) $E_{equivalent} = E_1 + E_2 + E_3 + \ldots\ldots + E_n$

(b) $r_{equivalent} = r_1 + r_2 + r_3 + \ldots\ldots + r_n$

(c) Current, $i = \frac{\sum E_i}{\sum r_i + R}$

(d) If all cells have equal emf E and equal internal resistance r then $i = \frac{nE}{nr + R}$

1) If nr > > R => $i = \frac{E}{r}$

2) If nr < < R => $i = \frac{nE}{R}$

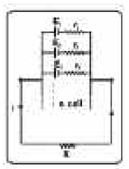
(e) Power dissipated in circuit $P = I^2R = \left(\frac{nE}{nr + R}\right)^2 R$

Conditions for maximum power: R=nr

$P_{max} = nE^2/4r$

18 COMBINATION OF CELLS

2) Parallel Combination



a) $E_{equivalent} = \dfrac{\frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3} \ldots\ldots \frac{E_n}{r_n}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \cdots \frac{1}{r_n}}$

b) $r_{equivalent} = \dfrac{1}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \cdots \frac{1}{r_n}}$

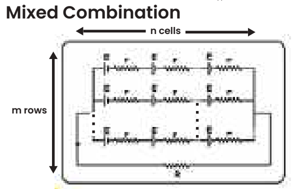
(c) If all cells have equal emf. E & internal resistance r then $E_{equivelent} = E$

$r_{equivalent} = \frac{r}{n} \Rightarrow$ current $i = \frac{E}{\frac{r}{n} + R}$

(d) Power dissipated in the circuit $P = I^2 R = \left(\frac{nE}{r + nR}\right)^2 R$

Conditions for maxiumum power $R = \frac{r}{n}$

3) Mixed Combination



$r_{net} = \frac{nr}{m}$ Total emf $= E_{net} = nE$

$I = \frac{E_{net}}{R + r_{net}} = \frac{nE}{R + \frac{nr}{m}}$

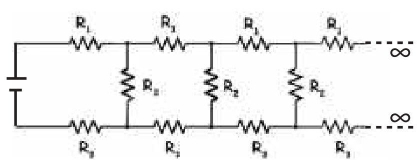
$$P_{max} = \frac{E_{eq}}{4R} = \frac{mnE^2}{4r} \quad [\because R = \frac{nr}{m}]$$

n cells connected in series and there are m such branches in the circuit.

Internal resistance of cells connected in a row =nr

19 COMBINATION OF CELLS

Infinite resistors

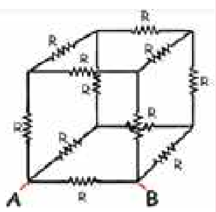


$$R_{eq} = \frac{R_1 + R_3}{2}\left[1 + \sqrt{1 + \frac{4R_2}{R_1 + R_3}}\right]$$

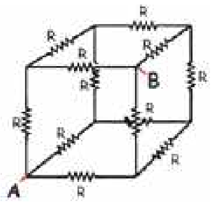
If all resistors are equal $R_{eq} = R(1 + \sqrt{3})$

20 3D CIRCUIT

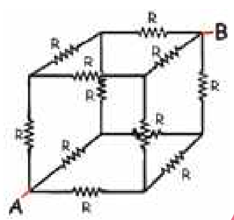
Edge $R_{eq} = \frac{7R}{12}$



Face $R_{eq} = \frac{3R}{4}$



Body $R_{eq} = \frac{5R}{6}$



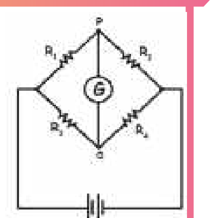
21 WHEATSTONE BRIDGE

1) Balanced WSB

Balanced Condition $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

$V_P = V_Q$

Current through G = 0

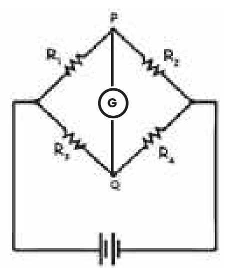


2) Unbalanced WSB

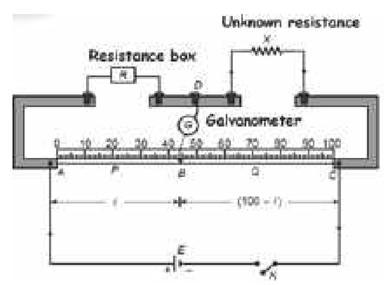
$V_P \neq V_Q$

if $\frac{R_1}{R_2} > \frac{R_3}{R_4}$

then $V_Q > V_P$

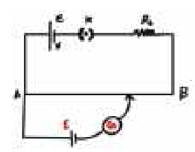


22 METER BRIDGE



$$\frac{P}{Q} = \frac{R}{X} = \frac{\ell}{100 - \ell}$$

POTENTIOMETER



23 POTENTIOMETER

POTENTIAL

$$V_{AB} = \left(\frac{e}{r + R_h + R}\right) R$$

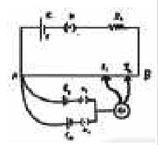
where, R= Resistance of potentiometer wire

POTENTIAL GRADIENT

$$x = \frac{V_{AB}}{L} = \frac{\frac{eR}{r + R_h + R}}{L} = \left(\frac{e}{r + R_h + R}\right)\frac{R}{L}$$

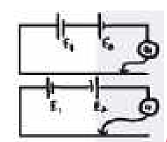
1. COMPARISON OF CELL

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$



2. BOTH BATTERIES ARE CONNECTED TOGETHER

(Once with same polarity then with opposite polarity)

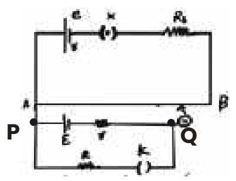


$$\frac{E_1}{E_2} = \frac{l_1 + l_2}{l_1 - l_2}$$

PHYSICS WALLAH

24 POTENTIOMETER

3. CALCULATION OF INTERNAL RESISTANCE



$$r = R\left(\frac{E}{V} - 1\right) = R\left(\frac{\ell_1}{\ell_2} - 1\right)$$

$E = V_{PQ}$ when key is open

$V = V_{PQ}$ when key is close

25 HEATING EFFECT OF ELECTRIC CURRENT

POWER

$$P = \frac{dH}{dt} = VI = \frac{V^2}{R} = I^2R$$

ELECTRIC KETTLE

Time taken for first coil- t_1, time taken for second coil-t_2

if they are connected in series	if they are connected in parallel
$t_s = t_1 + t_2$	$t_p = \frac{t_1 t_2}{t_1 + t_2}$

BULB

$$P_{rated} = \frac{V_{rated}^2}{R} \Rightarrow R = \frac{V_{rated}^2}{P_{rated}}$$

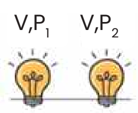
CONNECTED IN SERIES

$P_{dissipated} = I^2R$

$P_{dissipated} \propto R$

Brightness $\propto R$

26 HEATING EFFECT OF ELECTRIC CURRENT



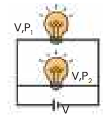
$$P_{dissipated} \,\alpha\, \frac{(V_{rated})^2}{P_{rated}}$$

$$P_{d(\text{ brighness})} \,\alpha\, \frac{1}{P_{rated}}$$

If $(P_1)_{rated} \geq (P_1)_{rated}$ then $P_{d_1} < P_{d_2}$

Brightness : $B_3 > B_1 > B_2$

CONNECTED IN PARALLEL



$$P_{rated} = \frac{(V_{rated})^2}{R}$$

$$P_d = \frac{V^2}{R} \Rightarrow P_d \,\alpha\, \frac{1}{R}$$

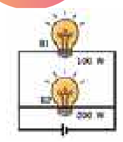
$$\Rightarrow P_{d(\text{brighness})} \propto \frac{1}{\frac{(V_{rated})^2}{P_{rated}}} \qquad \Rightarrow P_{d(\text{brighness})} \propto \frac{P_{rated}}{(V_{rated})^2}$$

$$P_{d(\text{ brighness})} \propto P_{rated}$$

if $(P_1)_R > (P_2)_R$

$\Rightarrow$ Brightness $(P_d)_1 > (P_d)_2$

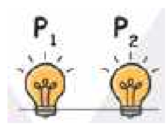
27 HEATING EFFECT OF ELECTRIC CURRENT



$P_{B2} > P_{B1}$

COMBINATION OF BULBS

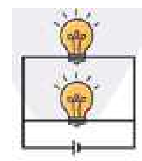
SERIES



TOTAL POWER

$$P = \frac{P_1 P_2}{P_1 + P_2}$$

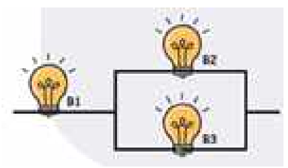
PARALLEL



$$P = P_1 + P_2$$

28 HEATING EFFECT OF ELECTRIC CURRENT

FUSED BULB

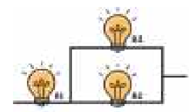


If bulb 2 is fused then,

for bulb 3	for bulb 1
R ↑	V ↓
V ↑	P ↓
P ↑	B ↓
B ↑	

If bulb is added in parallel:-

for example if bulb 3 is added in parallel to 2 then



for bulb 3	for bulb 1
R ↓	V ↑
V ↓	P ↑
P ↓	B ↑
B ↓	

29 CONVERSION OF GALVANOMETER

Current sensitivity

$$S_i = \frac{\theta}{I}$$

where, θ= angle of deflection in galvanometer

I= Corresponding current in galvanometer

Unit: $\frac{\text{divisions}}{\text{ampere}}$ OR $\frac{\text{rad}}{\text{A}}$

Voltage sensitivity

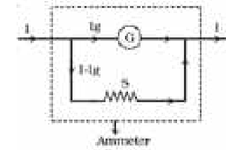
$$S_v = \frac{\theta}{V}$$

where, θ= angle of deflection in galvanometer

V=Corresponding voltage across galvanometer

$\frac{\text{divisions}}{\text{voltage}}$ OR $\frac{\text{rad}}{\text{V}}$

GALVANOMETER TO AMMETER



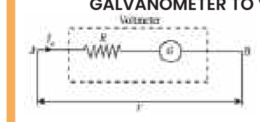
$$S = \frac{I_g G}{I - I_g} = \frac{G}{n - 1}$$

$$\text{Where } n = \frac{I}{I_g}$$

RESISTANCE OF AMMETER $R = \frac{GS}{G+S}$

RESISTANCE OF IDEAL AMMETER = 0

GALVANOMETER TO VOLTMETER



$$V = I_g G + I_g R$$

$$R = \frac{V}{I_g} - G = \left(\frac{V}{V_g} - 1\right)G$$

$= (n-1)G$

where, $n = \frac{V}{V_g}$

RESISTANCE OF VOLTMETER = G + R

RESISTANCE OF IDEAL VOLTMETER = ∞

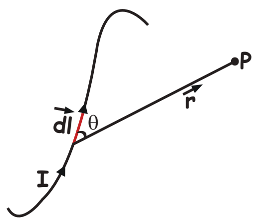
MOVING CHARGES AND MAGNETISM

1

Biot-Savart's Law

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

$dB = \dfrac{\mu_0}{4\pi}\dfrac{Idl\sin\theta}{r^2}$



$\mu_0 \rightarrow$ magnetic permeability of free space or vaccum

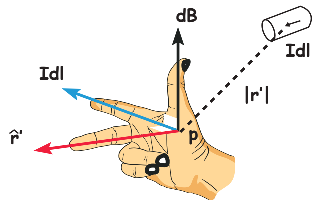
$\mu_0 = 4\pi\times10^{-7}$

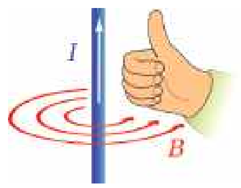
In vector form,

$\vec{dB} = \dfrac{\mu_0}{4\pi} I \dfrac{\vec{dl}\times\vec{r}}{r^3}$

$\vec{dB}$ is perpendicular to both $\vec{dl}$ and $\vec{r}$. BY using right hand screw rule we can find direction of magnetic field

Here, B is into the plane





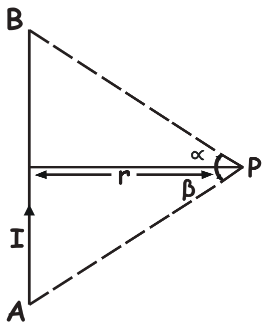
Magnetic field circulates around the current carrying wire

Formula of Field due to straight wire

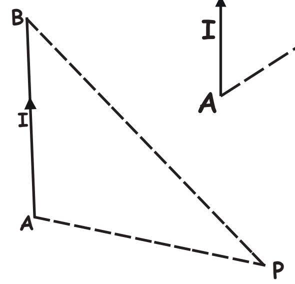
1) At point P

B is into the plane

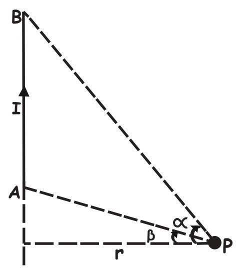
$B = \dfrac{\mu_0 I}{4\pi r}(\sin\alpha + \sin\beta)$, ⊗



2)



Extend AB downwards and draw a perpendicular from P



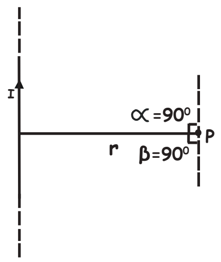
$B = \dfrac{\mu_0 I}{4\pi r}(\sin\alpha - \sin\beta)$, ⊗

3) Wire of infinite length

$\alpha = 90$ and $\beta = 90$

$B = \dfrac{\mu_0 I}{4\pi r}(\sin 90 + \sin 90)$

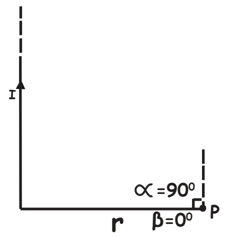
$= \dfrac{\mu_0 I}{2\pi r}$, ⊗

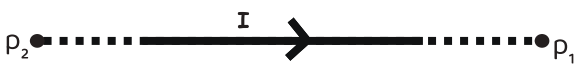


4) Wire of semi infinite length

$B = \dfrac{\mu_0 I}{4\pi r}(\sin 90 + \sin 0)$

$= \dfrac{\mu_0 I}{4\pi r}$

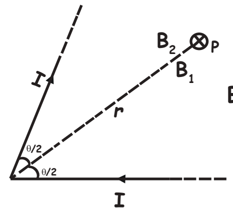




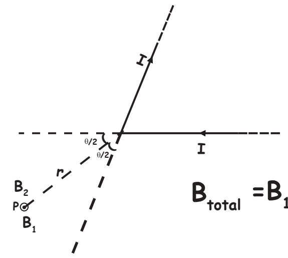
$B(P_1) = B(P_2) = 0$

PHYSICS WALLAH

Field Due to bent wire

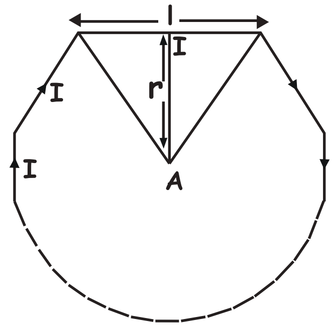


$B_{total} = B_1 + B_2 = 2\times\dfrac{\mu_0 I}{4\pi r}\dfrac{[1+\cos\theta/2]}{\sin\theta/2}$, ⊙



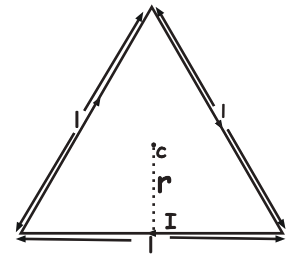
$B_{total} = B_1 + B_2 = 2\times\dfrac{\mu_0 I}{4\pi r}\dfrac{[1-\cos\theta/2]}{\sin\theta/2}$ ⊗

Field due to polygon



$B_A = \dfrac{\mu_0 n I}{\pi l}\tan\dfrac{\pi}{n}\sin\dfrac{\pi}{n}$

eg: equilateral triangle

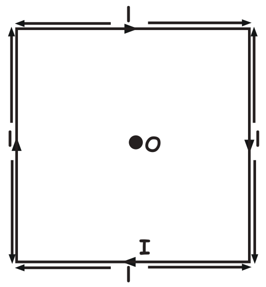


$B_c = \dfrac{9}{2}\dfrac{\mu_0 I}{\pi l}$

If a total lenght l is bent as an equilateral triangle, each side has length l/3 then,

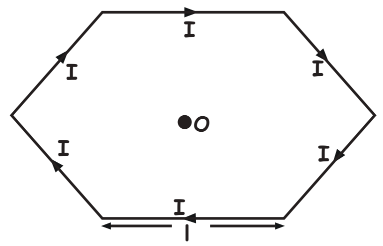
$B' = \dfrac{27}{2}\dfrac{\mu_0 I}{\pi l}$

Square



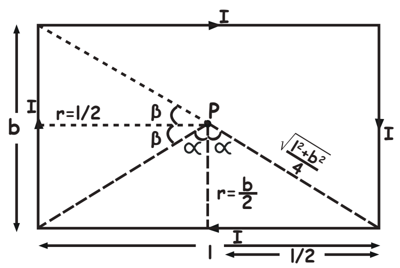
$B_o = \dfrac{2\sqrt{2}\,\mu_0 I}{\pi l}$

Hexagon



$B_o = \dfrac{\sqrt{3}\,\mu_0 I}{\pi l}$

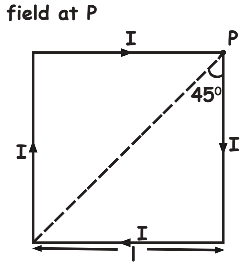
Rectangle



$B_p = \dfrac{2\mu_0 I}{\pi}\left(\dfrac{\text{diagonal}}{\text{area}}\right) = 2\mu_0 I\dfrac{\sqrt{l^2+b^2}}{lb}$

Note:-

To find field at P



Here P is a point at vertex

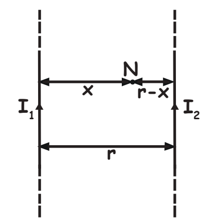
$B_p = \dfrac{\mu_0 I}{2\sqrt{2}\,\pi l}$

Neutral Points

Points at which magnetic field becomes zero are called neutral points.

Case 1: Parallel wires carrying current in same direction ($I_1 > I_2$)

$\therefore x = \dfrac{I_1 r}{I_1 + I_2}$

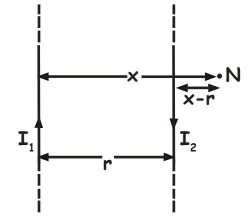


If y is the distance from 2nd conductor then

$y = \dfrac{I_2 r}{I_1 + I_2}$

Case 2: Parallel wires carrying currents in opposite direction ($I_1 > I_2$)

$x = \dfrac{I_1 r}{I_1 - I_2}$

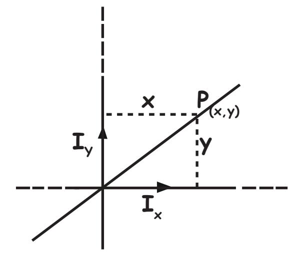


Case 3: Wires perpendicular to each other

Field wll be zero on all points of the line OP

Comparing with y=mx+C we get.

slope $m = \dfrac{I_x}{I_y}$



MOVING CHARGES AND MAGNETISM

2

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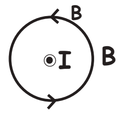
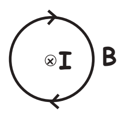
Wire perpendicular to plane

1) Current directed out of plane



B is in anticlockwise direction

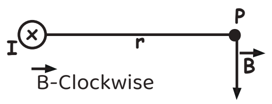
2) Current directed into the plane



B is in clockwise direction

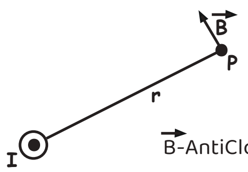
Direction of field

1)



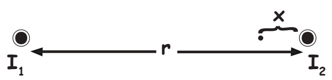
$B = \frac{\mu_0 I}{2\pi r}$

2)



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

Neutral Point

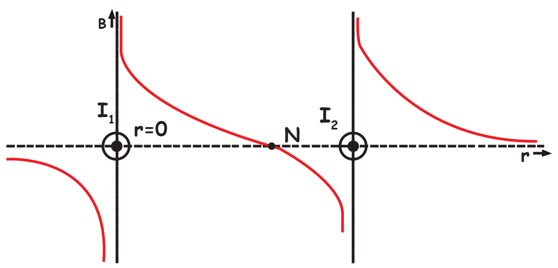


$I_1 > I_2$

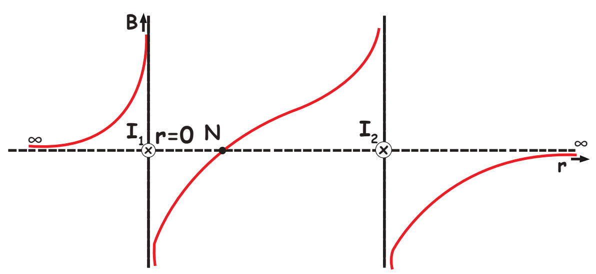
$x = \frac{I_1 r}{I_1 + I_2}$

Graphs

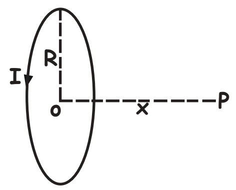
1) I out of the plane, $I_1 > I_2$



2) I into the plane $[I_1 < I_2]$



Field due to a circular ring & Field at the axis of a ring



$$\boxed{B_P = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}}$$

Every current carrying loop acts as a magnetic dipole

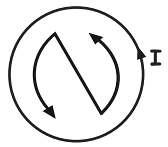
$\vec{M} = I\vec{A}$

Direction of A is determined using right hand thumb rule

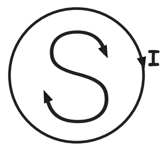
Here, $\vec{M} = I\vec{A} \implies M = I\pi R^2$

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

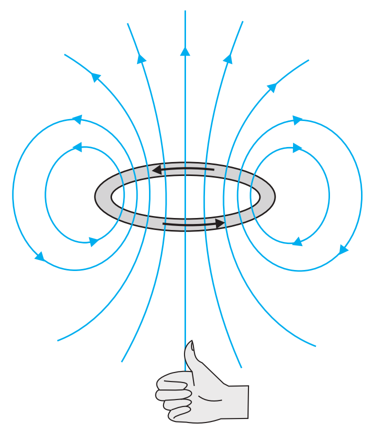
If current is flowing in anticlockwise direction



If current is flowing in clockwise direction

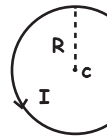


Magnetic field lines for a current loop



If there are N loops, $B = \frac{\mu_0 N I R^2}{2(x^2+R^2)^{3/2}}$

Field at the centre of ring

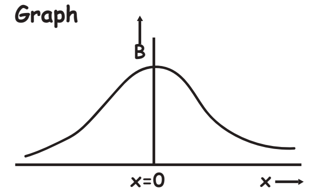


$B_c = \frac{\mu_0 I}{2R}$

Field at the axis in terms of Field at center

$$B_{axis} = \frac{B_c}{\left(1+\frac{x^2}{R^2}\right)^{3/2}}$$

Graph



Percentage change in field with respect to centre

For the points on the axis

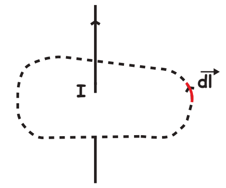
% change in B = $1-(1+x^2/R^2)^{-3/2} \times 100\%$

For change < 10% $= \left(\frac{3}{2}\times\frac{x^2}{R^2}\right) \times 100\%$

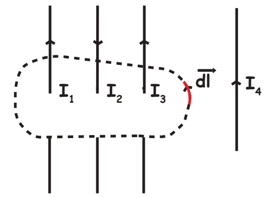
Ampere's Cicutal Law

The line integral of magnetic field over a closed loop is equal to μ_0 times the total current enclosed by the loop

$\oint \vec{B}.\vec{dl} = \mu_0 I_{enclosed}$

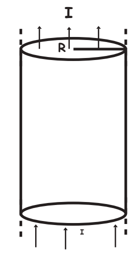


Example

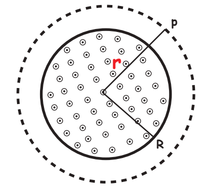


$\oint \vec{B}.\vec{dl} = \mu_0 [I_1 - I_2 + I_3]$

Solid Cylinder



Outside : r > R



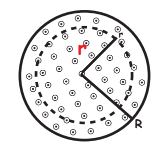
$B_{out} = \frac{\mu_0 I}{2\pi r}$

$B_{out} \propto \frac{1}{r}$

On the surface r = R

$B_s = \frac{\mu_0 I}{2\pi R}$

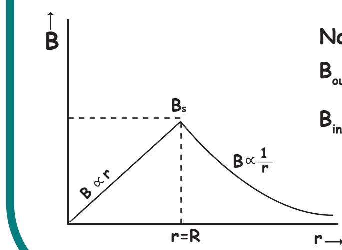
Inside (r < R)



$B_{in} = \left(\frac{\mu_0 I}{2\pi R^2}\right) r$

$B_{in} \propto r$

Graph

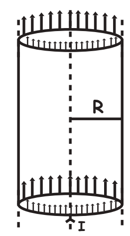


Note

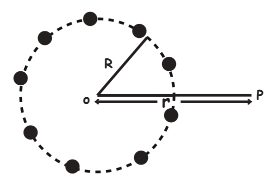
$B_{out} = B_s \frac{R}{r}$

$B_{in} = B_s \frac{r}{R}$

Hollow cylinder (pipe)



Outside : r > R

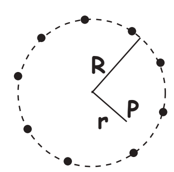


$B_{out} = \frac{\mu_0 I}{2\pi r}$

$B_{out} \propto \frac{1}{r}$

On the surface : r = R

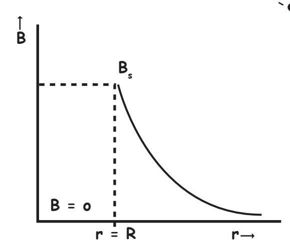
$B_s = \frac{\mu_0 I}{2\pi R}$



Inside : r < R

$B_{in} = o$

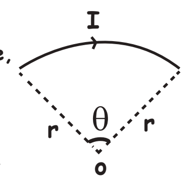
Graph



Field at the Centre due to circular arc

Field at centre of full Circle,

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

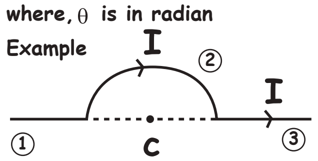


Then field at centre of arc,

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

where, θ is in radian

Example



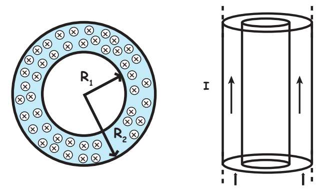
$B_c = B_1 + B_2 + B_3$

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

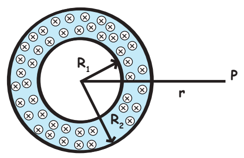
MOVING CHARGES AND MAGNETISM

3

Annular pipe

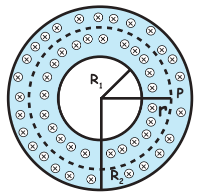


- Outside ($r > R_2$)



$$B_{out} = \frac{\mu_0 I}{2\pi r}$$

- In between $R_1 < r < R_2$



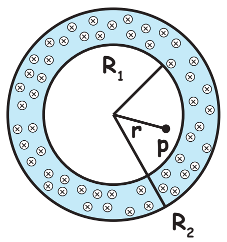
$$I_{enc} = \frac{I}{\pi(R_2^2 - R_1^2)} \times \pi(r^2 - R_1^2)$$

$$B_{btw} = \frac{\mu_0}{2\pi r} \times I \frac{(r^2 - R_1^2)}{(R_2^2 - R_1^2)}$$

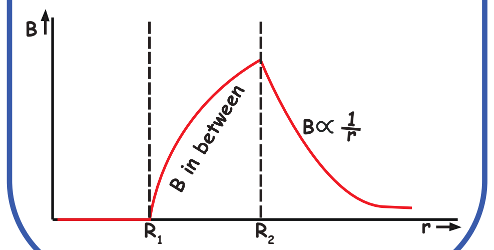
Inside

$r < R_1$

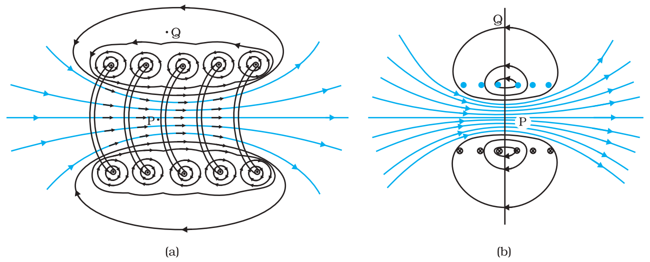
$B_{in} = 0$

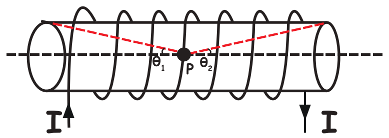


Graph



Solenoid





$$B_p = \frac{1}{2}\mu_0 n I(\cos\theta_1 + \cos\theta_2)$$

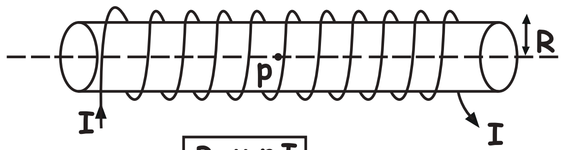
where $n \longrightarrow$ no.of turns per unit length

Tightly packed long solenoid

Long solenoid: Radius is small compared to the length of the solenoid

For a long solenoid the middle region will have a uniform magnetic field

1) At centre



$\boxed{B_{out} = 0}$

$\boxed{B = \mu_0 n I}$, Along the axis

2) End point

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

$$\boxed{B_{end} = \frac{1}{2}\mu_0 n I = \frac{B_{axis}}{2}}$$

Charged particle in **magnetic field**

Magnetic Force on particle

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

Case $\vec{v} \perp \vec{B}$

Path: Circle

Radius of circular path

i) $F_m = \frac{mv^2}{r}$

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

$\Rightarrow r = \frac{mv}{qB}$

ii) Momentum

$p = mv = \sqrt{2mk}$

$$\Rightarrow r = \frac{\sqrt{2mk}}{qB}$$

If charged particle at rest is accelerated by a voltage of 'V' volt then,

K.E $= qV$

$r = \frac{\sqrt{2mqV}}{qB}$

If $K_i \neq 0$, then $K_f = qV + K_i$

$$r = \frac{\sqrt{2mK}}{qB} = \frac{\sqrt{2m(qV + K_i)}}{qB}$$

Time Period

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

$\Rightarrow T \propto r^0$

$T \propto v^0$

We have $\frac{q}{m}$ = specific charge

$$\Rightarrow T \propto \frac{1}{\text{specific charge}}$$

Calculation of ratio of radii

1) All particles are projected with same speed:

V=Constant

$$r = \frac{mv}{qB} \Rightarrow r \propto \frac{m}{q}$$

$$r_p : r_d : r_\alpha = \frac{1}{e} : \frac{2}{e} : \frac{4}{2e} = 1:2:2$$

2) All particles are projected with same momentum

$$r = \frac{p}{qB} \Rightarrow r \propto \frac{1}{q}$$

$$r_p : r_d : r_\alpha = \frac{1}{e} : \frac{1}{e} : \frac{1}{2e} = 2:2:1$$

As radius ↑ Curvature ↓

3) All particles are projected with same kinetic energy

$$r = \frac{mv}{qB} = \frac{\sqrt{2mk}}{qB}$$

$$\Rightarrow r \propto \frac{\sqrt{m}}{q}$$

$$r_p : r_d : r_\alpha = \frac{\sqrt{1}}{e} : \frac{\sqrt{2}}{e} : \frac{\sqrt{4}}{2e}$$

$$1 : \sqrt{2} : 1$$

4) All particles are projected by same accelerating potential

$$r = \frac{\sqrt{2mqV}}{qB} \Rightarrow r \propto \sqrt{\frac{m}{q}}$$

$$r_p : r_d : r_\alpha = \sqrt{\frac{1}{e}} : \sqrt{\frac{2}{e}} : \sqrt{\frac{4}{2e}} = 1 : \sqrt{2} : \sqrt{2}$$

Helical path & pitch

$\vec{V}$ makes angle θ with $\vec{B}$ $(\theta \neq 0, \pi, \pi/2)$

Path of charge is Helical

$\vec{V}$: $V_{\parallel} \rightarrow$ || to $\vec{B}$; $V_{\perp} \rightarrow \perp$ to $\vec{B}$

1) Radius

$$R = \frac{mv_{\perp}}{qB}$$

$$R = \frac{mv\sin\theta}{qB} = \frac{\sqrt{2mqV}}{qB}\sin\theta$$

2) Time period

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

3) Pitch $= V_{\parallel} \times T$

$= V\cos\theta \times \frac{2\pi m}{qB}$

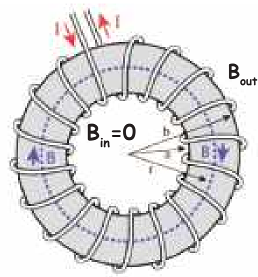
$= 2\pi\left(\frac{mv}{qB}\right)\cos\theta$

$= 2\pi \frac{\sqrt{2mK}}{qB}\cos\theta$

$= 2\pi \frac{\sqrt{2mqV}}{qB}\cos\theta$

PHYSICS WALLAH

Toroid



r is the mean radius

$$r = \frac{a_1 + b_2}{2}$$

$B_{out} = 0$

$B_{inside} = 0$

$B_{in\ between} = \mu_0 n I$

unit and dimension of B

$F = qvB\sin\theta$

$$B = \frac{F}{qv\sin\theta}$$

$$[B] = \frac{MLT^{-2}}{AT \times LT^{-1}} = MA^{-1}T^{-2}$$

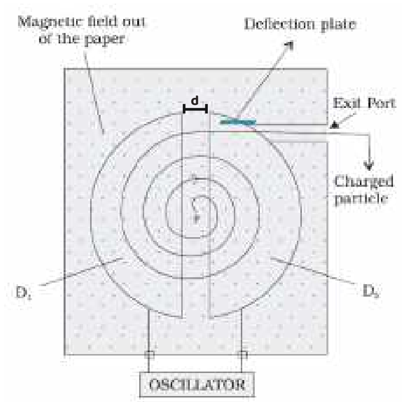
Unit $\rightarrow kgA^{-1}s^{-2}$ = Tesla (T)

MOVING CHARGES AND MAGNETISM

4

PHYSICS WALLAH

Cyclotron



1) Maximum kinetic energy

$$K_{max}=\frac{q^2B^2R^2_{dee}}{2m}$$

2) Number of oscillations ,N

Work done=ΔK

$$NxqEd=\frac{q^2B^2R^2}{2m}$$

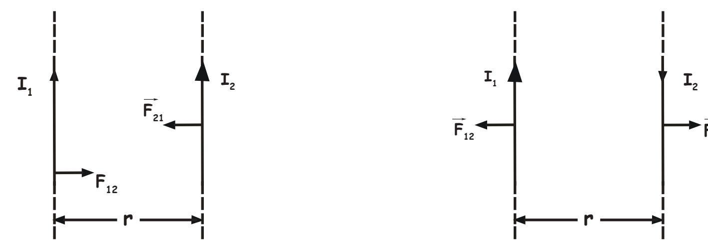
E is in the plane of the dees

3) Time period of revolution= $\frac{2\pi m}{qB}$

4) Cyclotron frequency $\nu_c=\frac{qB}{2\pi m}$

Force between parallel conductors

1) Force between two long parallel current conductors



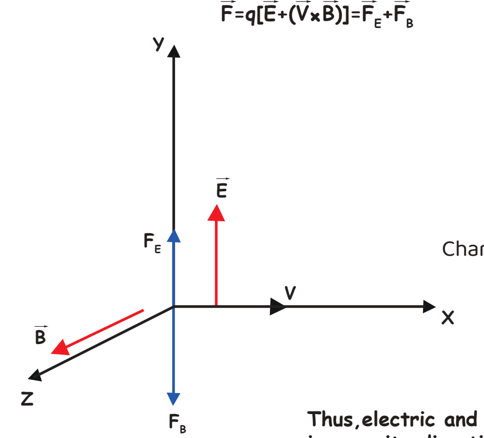
Parallel currents attract each other. Anti parallel currents repel each other.
Force per unit length of conductor

$$F_{12}=F_{21}=\frac{\mu_0}{2\pi}\frac{I_1I_2}{r}$$

Net force on 'l' length of conductor= $\frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}\times l$

Motion of charged particle in Crossed Electric and Magnetic field ($\vec{E}\perp\vec{B}$)[velocity selector]

$$\vec{F}=q[\vec{E}+(\vec{V}\times\vec{B})]=\vec{F}_E+\vec{F}_B$$



$\vec{F}_E=q\vec{E}=qE\hat{j}$

$\vec{F}_B=q(\vec{V}\times\vec{B})=q(V\hat{i}\times B\hat{k})$

$=-qvB\hat{j}$

$\therefore \vec{F}=q(E-VB)\hat{j}$

If $v=E/B$, $F_{net}=0$

Charge moves in a Straight line

Thus, electric and magnetic forces are in opposite directions as shown in figure.

Force on current carrying Conductor in magnetic field

consider a small element $d\vec{l}$ of the conductor

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

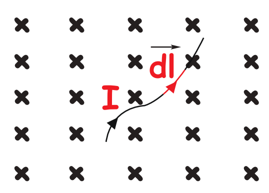
To find resulting force

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

$=I\int d\vec{l}\times\vec{B}$

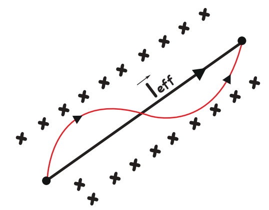
In uniform field

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



The above equation can be used in the following situations

1)



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

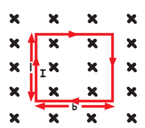
$=I\ l_{eff}B\sin\theta$

2) $\vec{l}_{eff}$ perpendicular to $\vec{B}$

$\theta=90$

$F_{max}=I\ l_{eff}B$

For closed Loop in uniform field



Here, $l_{eff}=0$

$\therefore \vec{F}=0$

Lorentz force

A charge q in an electric field $\vec{E}$ experiences the electric force

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

The magnetic force experienced by the charge q moving with velocity $\vec{V}$ in the magnetic field $\vec{B}$ is given by

$\vec{F}_m=q(\vec{V}\times\vec{B})$

The total force,or the Lorentz force,experienced by the charge q due to both electric and magnetic field is given by

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

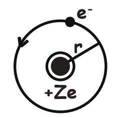
Magnetic dipole moment of a revolving electron

$I=\frac{e}{T}$

T is the time period of revolution

$T=\frac{2\pi r}{V}$

$I=\frac{eV}{2\pi r}$



There will be a magnetic moment,usually denoted by μ associated with this circulating current

$\mu=I\pi r^2=\frac{eVr}{2}$

$\mu=\frac{e}{2m_e}(m_evr)=\frac{e}{2m_e}L$ $\vec{L}=\vec{r}\times\vec{P}$ $=rmv\sin\theta$ $=mvr$

In vector form

$\vec{\mu}=\frac{-e}{2m_e}\vec{L}$

The negative sign indicates that the angular momentum of the electron is opposite in direction to the magnetic moment

The ratio of magnetic moment to the angular momentum is called gyromagnetic ratio

$$\frac{\mu}{L}=\frac{e}{2m_e}$$

Its value is a constant and is equal to 8.8×10^{10} C/kg for an electron

According to Bohr's quantization condition, angular momentum assumes a discrete set of values, namely.

$L=\frac{nh}{2\pi}$ where n= 1, 2, 3.....

h→planck's constant

Taking n=1, we get,

$$\mu_{min}=\frac{e}{4\pi m_e}h=9.27\times10^{-24}\ Am^2$$

Moving Coil Galvanometer (MCG)

$\tau=NIAB\sin\theta$

Sensitivity of a Galvanometer

Current sensitivity, $I_s=\frac{\Phi}{I}=\frac{NAB}{K}$

Where K→torsional constant

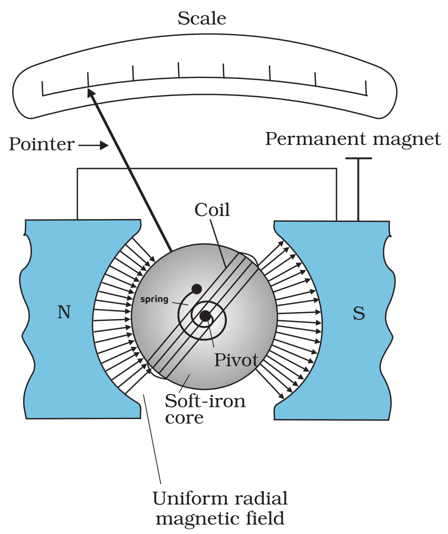
Φ→ deflection of galvanometer

Voltage Sensitivity

Voltage Sensitivity, $V_s=\frac{\Phi}{V}=\frac{\Phi}{IR}$

$=\frac{NAB}{KR}$

Voltage Sensitivity= $\frac{\text{Current Sensitivity}}{R}$



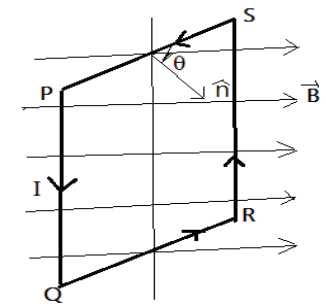
Note:

1) The constant, $\frac{K}{NAB}$ is called galvanometer constant or current reduction factor of the galvanometer.

2) Figure of merit of a galvanometer

$$G=\frac{I}{\Phi}=\frac{K}{NAB}$$

Torque on a current loop in a uniform magnetic field



Then τ = NIABsinθ

Special cases:

i) When $\theta=0°$

τ =0 , ie, the torque is minimum when the plane of the loop is perpendicular to the magnetic field

ii) When = 90°

τ = NIAB ie, the torque is maximum when the plane of the loop is parallel to the magnetic field. Thus,

τ_{max} = NIAB

ELECTROSTATICS - 1

PHYSICS WALLAH

Charge

Quantization of charge

$Q = \pm ne$ Q=Total charge
n=1,2,3....
$e = 1.6 \times 10^{-19}C$

Additivity of charge

$Q' = Q_1 + Q_2$

Redistribution of charge

$Q' = \frac{Q_1 + Q_2}{2}$

Q'=Charge on each shell after redistribution

Charge Density

Linear Charge density, $\lambda = \frac{Q}{L}$ Unit= $\frac{C}{m}$

Surface Charge density, $\sigma = \frac{Q}{S}$ Unit= $\frac{C}{m^2}$

Volume Charge density, $\rho = \frac{Q}{V}$ Unit= $\frac{C}{m^3}$

Q=Total charge V=Volume
L=Length S=Area

? If a charge on the body is 1 nC, then how many electrons are present on the body?

a) 1.6×10^{19} b) 6.25×10^{9}
c) 6.25×10^{27} d) 6.25×10^{28}

Coulomb's Law

$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$

ε_0=Permitivity of free space

$[\varepsilon_0] = \frac{[Q_1][Q_2]}{[r^2][F]} = \frac{[AT][AT]}{[L^2][MLT^{-2}]} = M^{-1}L^{-3}T^4A^2$

$F_{med} = \frac{F_{air}}{k}$

k=dielectric constant of the medium

Superposition

Direction:
a) Like- Towards the point at which force has to be evaluated (repulsion)
b) Unlike- Away from the point at which force has to be evaluated (attraction)

General rule: $F_{Net} = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$

When $\theta = 60°$: $F_{net} = \sqrt{3}F$

When $\theta = 90°$: $F_{net} = \sqrt{2}F$

When $\theta = 120°$: $F_{net} = F$

Equillibrium of Charges

Calculation of Charge

$\frac{Q_1}{Q_2} = \left(\frac{r_1}{r_2}\right)^2$ q in equillibrium

$q = -\left(\frac{r_1}{r_1+r_2}\right)^2 Q_2$ Q_1 in equillibrium

$q = -\left(\frac{r_2}{r_1+r_2}\right)^2 Q_1$ Q_2 in equillibrium

? A charge is placed at the centre of the line joining two equal charges Q. The system of the three charges will be in equillibrium if q is equal to

a) -Q/2 c) +Q/4
b) -Q/4 d) +Q/2

Charge on pendulum

$\tan\theta = \frac{qE}{mg}$

$\sin\theta = \frac{r}{2l}$

$r = 2l\sin\theta$

if θ is very small

$\tan\theta \approx \sin\theta$

$\frac{r}{2l} = \frac{qE}{mg}$

$\frac{r}{2l} = \frac{kq^2/r^2}{mg}$, $r^3 \propto q^2$

Density of ball "ρ"

it θ does not change on submerging in liquid Dielectric constant of liquid,

$K = \frac{\rho}{\rho - \sigma}$

density of liquid= σ

Electric Field

$E \propto \frac{1}{r^2}$

Electric field at a point, due to point charge $E = \frac{Kq}{r^2}$

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

Superposition

General rule: $E_{Net} = \sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos\theta}$

$E_{Net} = E_1 + E_2$

$E_{Net} = |E_1 - E_2|$

$E_{Net} = \sqrt{E_1^2 + E_2^2 + E_1E_2}$
If, $E_1 = E_2 = E$ Then, $E_{net} = \sqrt{3}E$

$E_{Net} = \sqrt{E_1^2 + E_2^2}$
If, $E_1 = E_2 = E$ Then, $E_{net} = \sqrt{2}E$

$E_{Net} = \sqrt{E_1^2 + E_2^2 - E_1E_2}$
If, $E_1 = E_2 = E$ Then, $E_{net} = E$

Direction

1) Positive charge:-Towards the point at which electric field has to be evaluated
2) Negative charge:-Away from the point at which electric field has to be evaluated

Neutral Point

Like Charges

$x_1 = \frac{\sqrt{Q_1}\,r}{\sqrt{Q_1}+\sqrt{Q_2}}$

$x_2 = \frac{\sqrt{Q_2}\,r}{\sqrt{Q_1}+\sqrt{Q_2}}$

Unlike Charges

Outside closer to smaller charge

$|Q_2| < |Q_1|$

$x = \frac{\sqrt{Q_2}\,r}{\sqrt{Q_1}-\sqrt{Q_2}}$

Distance from Q_1=x+r

? Two point charges +8q and -2q are located at x = 0 and x = L respectively. The location of a point on the x axis at which the net electric field due to these two point charges is zero is:

a) 8L
b) 4L
c) 2L
d) L/4

Charged particle released in an electric field

1) Force, F=qE
2) Acceleration, $a = \frac{qE}{m}$
3) Velocity, $V = \frac{qE}{m}t$
4) Velocity, $V = \sqrt{\frac{2qE}{m}x}$
5) Kinetic energy, $K.E = \frac{q^2E^2t^2}{2m}$

accelerated in the direction of electric field

accelerated opposite to the direction of electric field

$V = \sqrt{V_x^2 + V_y^2}$

$V_x = \frac{qEt}{m}$

$\sqrt{U^2 + \left(\frac{qE}{m}t\right)^2}$

accelerated in the direction of field and perpendicular to initial velocity

$\frac{M_p}{M_e} = 1837$, $\frac{e}{m} = 1.7 \times 10^{-11}$

$\frac{1}{2}at^2 = h = Constant$

$\frac{1}{2}\frac{qE}{m}t^2 = h$

$t^2 \propto m$

$\frac{t_p}{t_e} = \left[\frac{m_p}{m_e}\right]^{1/2}$

$\Rightarrow t_p > t_e$

Time period of Charged Pendulum in an electric filed

$T = 2\pi\sqrt{\frac{l}{\left(g - \frac{qE}{m}\right)}}$ Time period will increase

$T = 2\pi\sqrt{\frac{l}{\left(g + \frac{qE}{m}\right)}}$ Time period will decrease

$T = 2\pi\sqrt{\frac{l}{\sqrt{g^2 + \left(\frac{qE}{m}\right)^2}}}$ Time period will decrease

Electric field inside a dielectric medium

$E_{net} = \frac{E}{k} \Rightarrow K$

$E_{net} = E - E_{induced}$, $E_{induced} = E - E_{net} = E\left(1 - \frac{1}{k}\right)$

Properties of field lines

1) Start from positive charge and end on negative charge
2) Never intersect each other. If they intersect there will be 2 directions for electric field which is not possible
3) Always perpendicular to Conducting surface
4) E α Electric field line density
5) Never form closed loops (Conservative force)
6) q α no. of field lines $|q_1| > |q_2|$

? Electric lines of force about negative point charge are:

a) circular, anticlockwise
b) circular, clockwise
c) radial, inward
d) radial, outward

Electric flux

Flux is proportional to total no. of field lines passing through an area

$\Phi = \int E.ds\cos\theta$

$\Phi = \int \vec{E}.\vec{ds}$

Gauss Law:- $\Phi = \frac{q}{\varepsilon_0} = \oint E.ds\cos\theta$

Zero flux:- $\Phi = \frac{q_{net}}{\varepsilon_0} = 0$, where $q_{net} = 0$

Electric flux for Cube

1) No charge inside the cube

$\Phi = \frac{q}{\varepsilon_0} = 0$

2) Charge placed at the center

$\Phi_{total} = \frac{q}{\varepsilon_0}$

$\Phi_{one\ side} = \frac{q}{6\varepsilon_0}$

3) Charge placed at the face

$\Phi_{cube} = \frac{q}{2\varepsilon_0}$

4) Charge placed at the corner

$\Phi_{cube} = \frac{Q}{8\varepsilon_0}$

$\Phi_{one\ face} = \frac{Q}{8\varepsilon_0} \times \frac{1}{3} = \frac{Q}{24\varepsilon_0}$

5) Charge placed at the edge

$\Phi_{cube} = \frac{Q}{4\varepsilon_0}$

$\Phi_{face} = \frac{Q}{\varepsilon_0} \times \frac{1}{4} = \frac{Q}{16\varepsilon_0}$

6) Flux through curved surface

$\Phi_{effective} = \Phi_{curve} + 2\Phi_{cross\ section}$

Application of Gauss's Theorem

1) Point charge $E = \frac{Kq}{r^2}$

2) Metal sphere/Hollow sphere

$E_{surface} = \frac{KQ}{R^2}$

$E_{outside} = \frac{KQ}{r^2}$

$E_{inside} = 0$

3) Non-Conducting sphere

$E_{inside} = \frac{KQr}{R^3}$

$E_{surface} = \frac{KQ}{R^2}$

$E_{outside} = \frac{KQ}{r^2}$

4) Conducting sheet

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

5) Non-conducting sheet

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

Q_{outer} Q_{inner} Q_{plate}

$Q_{inner} = Q_{plate} - Q_{outer}$

7) Electric field due to a finite linear charge distribution

$E = \frac{2k\lambda}{r}\sin(\theta/2)$

8) Electric field due to a infinite linear charge distribution

$E = \frac{2k\lambda}{r}$

9) Electric field due to circular arc at its center

$E_0 = \frac{2k\lambda}{r}\sin(\theta/2)$

eg: For a semicircle $\theta = 180°$

$E_0 = \frac{2k\lambda}{r}\sin(180°/2)$
$= \frac{2k\lambda}{r}$

10) Electric field at the center of a circular ring

$E_0 = 0$

11) Electric field due to a circular ring of charge

$E = \frac{1}{4\pi\varepsilon_0}\frac{qx}{(x^2+r^2)^{3/2}}$

(For large distance)

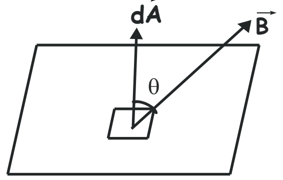
$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}$

$x = \frac{r}{\sqrt{2}}$

ELECTROMAGNETIC INDUCTION

ELECTROMAGNETIC INDUCTION

MAGNETIC FLUX $\propto$ no of lines of force



$d\Phi_B = \vec{B}.d\vec{A} = BdA\cos\theta$

$\Phi_B = \int \vec{B}.d\vec{A} = \int BdA\cos\theta$

for uniform field, $\vec{B}$ $\quad \Phi_B = \vec{B}.\vec{A}$

$\Phi_B = BA\cos\theta$

- Scalar quantity ⟶ Unit ⟶ Weber(Wb)
- $[\Phi_B] = ML^2T^{-2}A^{-1}$

FARADAY'S LAW

1) Whenever the amount of magnetic flux linked with a circuit changes, an emf is induced in the circuit

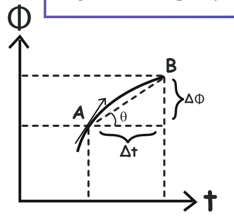
2) The induced EMF is given by rate of change of magnetic flux linked with the circuit

$\mathcal{E}_{Ind} = -\frac{d\Phi_B}{dt}$

Negative sign indicates that induced emf opposes the cause of flux change

$\boxed{\mathcal{E}_{Ind} = -\frac{Nd\Phi_B}{dt}}$

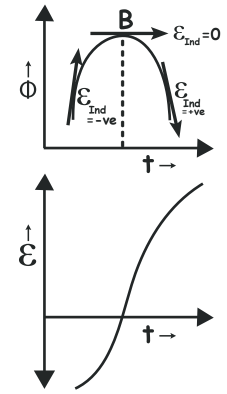
References from Φ_B V/S t graph



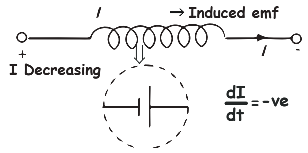
Slope of chord AB in Φ-t Graph $= \mathcal{E}_{Ind} = \frac{\Delta\Phi}{\Delta t}$

Slope of the tangent in the Φ-t Graph $= |\mathcal{E}_{Ind}| = \frac{d\Phi}{dt}$

CHANGING Φ-t GRAPH INTO OTHER GRAPH



CASE 2



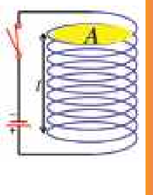
$\frac{dI}{dt} = -ve$

self inductance of a long solenoid

$B = \frac{\mu_0 NI}{\ell} \quad \Phi_{B_1} = \frac{\mu_0 NIA}{\ell}$

$E = -\frac{d\Phi_B}{dt} = -N\frac{d}{dt}\Phi_{B_1} = -\frac{d}{dt}\left(\frac{\mu_0 N^2 IA}{\ell}\right) = -\frac{\mu_0 N^2 A}{\ell}\frac{dI}{dt}$

$\boxed{E = -L\frac{dI}{dt}} \quad \boxed{L = \mu_0 N^2 A/\ell}$



L=Coefficient of self inductance $\quad L = \mu_0 N^2\ A/l$

$L = \mu_0 n^2 Al$

Unit of inductance:Henry [H]

$= [ML^2T^{-2}A^{-2}]$

MUTUAL INDUCTANCE

Change in current in one coil causes change in flux in another coil and vice versa.

Let there be two coils A and B, having currents I_1 and I_2.

$\phi_B \propto I_1 \qquad \phi_A \propto I_2$

$\Rightarrow \phi_B = MI_1 \qquad \Rightarrow \phi_A = MI_2$

M is called as mutual inductance of the coils.

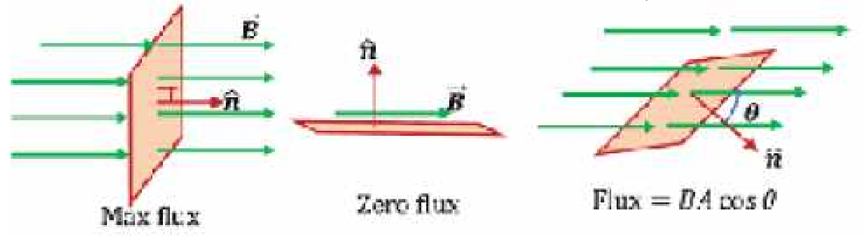
EMF induced,

$\mathcal{E}_B = -\frac{d\phi_B}{dt} \Rightarrow \mathcal{E}_B = -M\frac{dI_1}{dt}$

& $\mathcal{E}_A = -\frac{d\phi_A}{dt} \Rightarrow \mathcal{E}_A = -M\frac{dI_2}{dt}$

In uniform $\vec{B}$

$\hat{n}$ =Normal to the surface



$\Phi_B = BA$ (maximum)

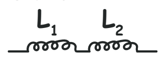
ENERGY STORED IN INDUCTOR

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

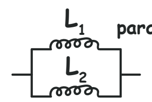
MAGNETIC ENERGY STORED PER UNIT VOLUME ENERGY DENSITY

$u = \frac{U_B}{V} = \frac{U_B}{Al} = \frac{\mu_0 n^2 I^2}{2} = \frac{B^2}{2\mu_0}$

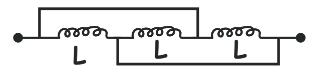
SERIES & PARALLEL COMBINATION OF INDUCTORS



$L_{eq} = L_1 + L_2$



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



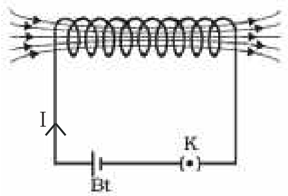
$L_{eq} = \frac{L}{3}$

INDUCTANCE

- Scalar quantity
- Unit of inductance (H)
- Dimension : $ML^2T^{-2}A^{-2}$

INDUCTANCE → Self Inductance, Mutual Inductance

Self Inductance



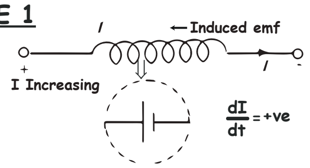
Current I in the coil changes due to external source
↓
Causes change in magnetic field inside the coil
↓
Results in change in magnetic flux inside the coil
↓
EMF is induced which opposes the changing magnetic flux
↓
Creates an induced current which is opposing in nature

$E = -L\frac{dI}{dt}$

where, L= Self Inductance
I= Current in the coil

NATURE OF INDUCED CURRENT DUE TO SELF INDUCTION

CASE 1



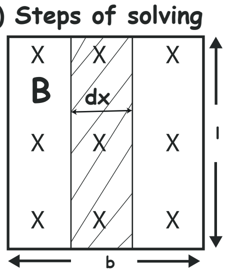
$\frac{dI}{dt} = +ve$

LENZ'S LAW & CONSERVATION OF ENERGY

The direction of any induced magnetic effect is such as to oppose the change that produces it

FLUX IN NON-UNIFORM FIELD

1) Steps of solving



1. Take a small strip 'dx'
2. flux $d\Phi = BdA$
[dA=ldx]
3. Total flux $\Phi = \int d\Phi = \int_0^b BdA$
$= \int_0^b Bldx$

EMF

Average value

$\mathcal{E}_{Ind} = -\frac{\Delta\Phi}{\Delta t}$

$[\Delta\Phi = \Phi_2 - \Phi_1]$

Instantaneous value

$\mathcal{E}_{Ind} = -\frac{d\Phi}{dt}$

Induced current

$I_{ind} = \frac{\mathcal{E}_{Ind}}{R} = -\frac{1}{R}\frac{\Delta\Phi}{\Delta t} \qquad I_{ind} = \frac{\mathcal{E}_{Ind}}{R} = -\frac{1}{R}\frac{d\Phi}{dt}$

Charge flown due to induced current

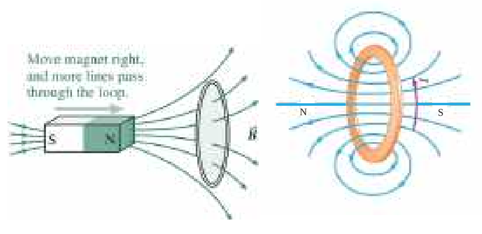
$q_{flown} = \frac{\Delta\Phi}{R}$

Charge flown due to induced current depends only on change in flux

DIRECTION OF INDUCED CURRENT

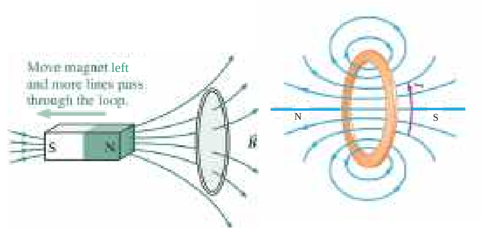
1.If flux is decreasing, the magnetic field due to induced current will be along the existing magnetic field

2.If flux is increasing, the magnetic field due to induced current will be opposite to existing magnetic field



Field causing flux change

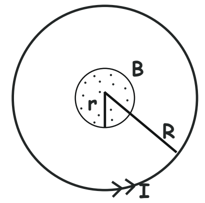
Induced Field



Field causing flux change

Induced Field

MUTUAL INDUCTANCE OF SOME STANDARD CASES



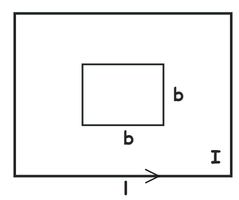
R>>>r

$\Phi = BA \quad B = \frac{\mu_0 I}{2R}$

$\Phi = \frac{\mu_0 I \times \pi r^2}{2R} = MI$

$M = \frac{\mu_0 \times \pi r^2}{2R}$

l>>>b



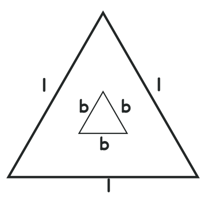
$\Phi = BA$

$B = \frac{\mu_0 2\sqrt{2}\ I}{\pi l}$

$\Phi = \frac{\mu_0 2\sqrt{2}\ I}{\pi \ell} \times b^2$

$M = \frac{\mu_0 2\sqrt{2}}{\pi \ell} \times b^2$

l>>>b



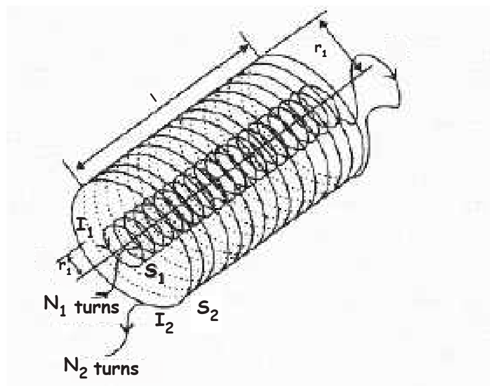
$\Phi = BA$

$B = \frac{9}{2}\frac{\mu_0 I}{\pi l}$

$\Phi = BA = \frac{9}{2}\frac{\mu_0 I}{\pi l} \times \frac{\sqrt{3}}{4}b^2$

$M = \frac{9}{2}\frac{\mu_0}{\pi l} \times \frac{\sqrt{3}}{4}b^2$

MUTUAL INDUCTANCE OF TWO CO-AXIAL SOLENOIDS



I_2 = Current through outer coil

$B = \mu_0 n_2 I_2$

$\Phi_{12} = \mu_0 n_2 I_2 \times \pi r_1^2 n_1 l$

$M = M_{12} = \mu_0 n_1 n_2 \times \pi r_1^2 l$

$= \frac{\mu_0 N_1 N_2}{l}\pi r_1^2$

PHYSICS WALLAH

Relation between mutual inductance & self inductance

$M = K\sqrt{L_1 L_2}$ $0 \le K \le 1$

K → coefficient of coupling

If K=1, Perfect flux linkage

$M = \sqrt{L_1 L_2}$

Otherwise → imperfect linkage

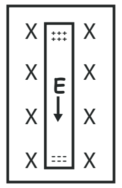
K<I

If K=0

no linkage

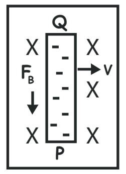
⇒ M=0

DYNAMIC MOTIONAL EMF DUE TO TRANSLATORY MOTION



- Charges accumulate at the ends of the conductor due to its movement in external magnetic field
- This separation of charges at the ends of the conductor causes a voltage difference

At steady state



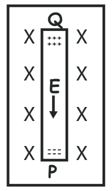
$F_B = F_e$

$evB = eE$

$E = vB$

$\frac{V_{PQ}}{l} = vB$

V_{PQ} or $\mathcal{E} = Blv$



Direction to find the positive terminal

By using right hand rule,

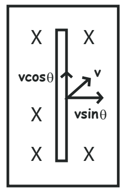
Thumb - velocity

Fingers - Magnetic field

Palm - Positive terminal of the rod

Modification

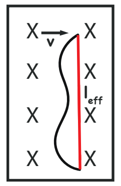
i) Velocity is not perpendicular



$\mathcal{E} = Blv\sin\theta$

ii) Conductor of arbitrary shape

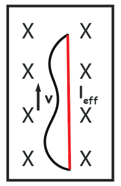
$\vec{v}$ Perpendicular to effective length



$\mathcal{E}_{ind} = Bl_{eff}v$

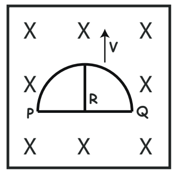
l_{eff} = effective length

$\vec{v}$ Parallel to effective length



$\mathcal{E}_{ind} = 0$

Semi circular loop in a magnetic field



$l_{eff} = 2R$

$\mathcal{E} = Bl_{eff}v$

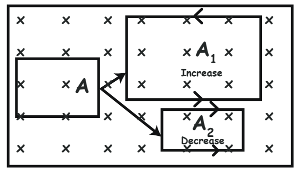
$\mathcal{E} = Bx2Rv$

from right hand rule,

P is at higher potential

Q is at lower potential

change of area in magnetic field region



$\Phi = BA$

$\Delta\Phi = B\Delta A$

$\mathcal{E}_{Ind} = \frac{\Delta\Phi}{\Delta t} = \frac{B\Delta A}{\Delta t}$

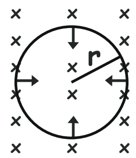
$A \to A_1 \to$ Area increases, current will be anticlockwise

$A \to A_2 \to$ Area decreases, current will be clockwise

Shrinking Loop

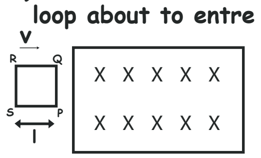
Loop shrinking at rate $\frac{dr}{dt}$

$\mathcal{E}_{Ind} = Bx2\pi rx\frac{dr}{dt}$

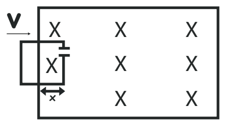


MOTIONAL EMF : FARADAY'S LAW

i) At t=0 → loop about to entre



ii) At time t=t, 'x' length inside loop



A=lx

$B_{ind} \to \odot$

$I_{ind} \to$ anticlockwise

$\Phi = BA = Blx$

x=vt

$\Phi = Blvt$

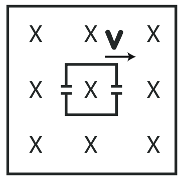
$\mathcal{E}_{Ind} = Blv$

$I_{ind} = \frac{\mathcal{E}_{Ind}}{R} = \frac{Blv}{R}$

iii) Loop has fully entered

$\mathcal{E}_{Ind} = 0$

$I_{ind} = 0$



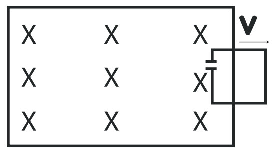
iv) Loop exiting. Field is decreasing

B_{ind} ⊗

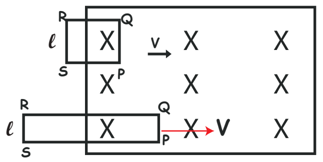
I_{ind} clockwise

$\mathcal{E}_{Ind} = Blv$

$I_{ind} = \frac{Blv}{R}$



MOTION OF A SQUARE, RECTANGLE, CIRCLE & ELLIPSE IN UNIFORM MAGNETIC FIELD



For square,

PQ → $\mathcal{E}$ = Blv = Constant

RQ & SP → l_{eff} Parallel to velocity

RS → $\mathcal{E}$=0 (Outside B)

Q - Higher potential

P - Lower potential

Current - Anticlockwise direction

For Rectangle

PQ → $\mathcal{E}$ = Blv = Constant

RQ & SP → l_{eff} Parallel to velocity

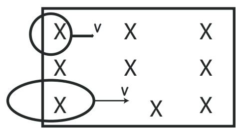
RS → $\mathcal{E}$ =0 (Outside B)

Q - Higher potential

P - Lower potential

Current - Anticlockwise direction

For Circle & Ellipse



Effective length is constantly varying

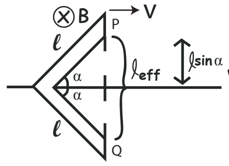
Induced EMF is varying. When loop is entering, EMF first increases reaches a maximum and then decreases

induced current in anticlockwise direction

Instantaneous Induced EMF = $B(l_{eff})_{inst}v$

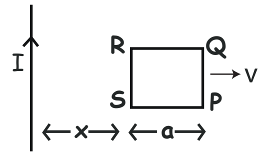
TRANSLATORY MOTION OF METALLIC FRAME IN UNIFORM / NON UNIFORM MAGNETIC FIELD

Metal frame of different shapes moving in uniform magnetic field



$V_P - V_Q = 2Bl\sin\alpha v$

MOVING METAL FRAME IN NON UNIFORM MAGNETIC FIELD

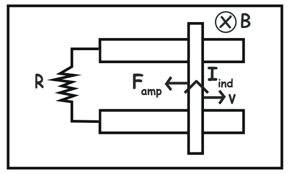


$B_{at\ RS} = \frac{\mu_o I}{2\pi x}$, $\mathcal{E}_{RS} = \frac{\mu_o I}{2\pi x}av$

$B_{at\ QP} = \frac{\mu_o I}{2\pi(x+a)}$, $\mathcal{E}_{QP} = \frac{\mu_o I}{2\pi(x+a)}av$

$\mathcal{E}_{net} = \mathcal{E}_1 - \mathcal{E}_2 = \frac{\mu_o I a^2 v}{2\pi x(x+a)}$

INDUCED CURRENT AND AMPERIAN FORCE



- Amperian force

$F_{amp} = \frac{B^2 l^2 v}{R}$ → Opposes motion

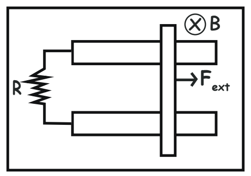
- Work done by amperian force

$W = \Delta KE = 0 - \frac{1}{2}mv_0^2$ [Initial vel.=v_0, Final vel.=0]

- Power developed in circuit

$P = I^2R$ $P = \frac{B^2l^2v^2}{R}$

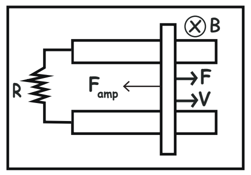
Terminal velocity



t=0

slider at rest

F_{ext} starts acting on rod



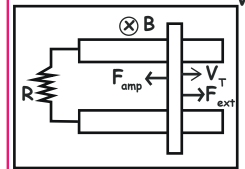
t=t

$F_{amp} = \frac{B^2l^2v}{R}$

when is terminal velocity achieved

a=0

$V = V_T$ = constant

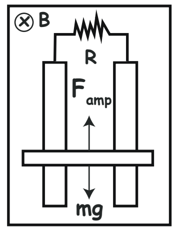


$F = \frac{B^2l^2V_T}{R}$

At t=∞

$V_T = \frac{FR}{B^2l^2}$

Motion of conductor in a vertical plane



At $V = V_T$

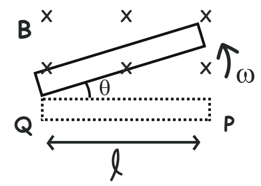
$F_{amp} = mg$

$mg = \frac{B^2l^2V_T}{R}$

$V_T = \frac{mgR}{B^2l^2}$

MOTIONAL EMF DUE TO ROTATIONAL MOTION

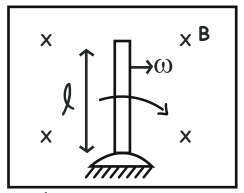
i)



$\mathcal{E} = \frac{1}{2}Bl^2\omega$

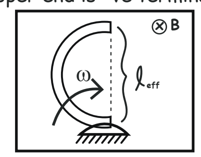
End Q is positive terminal

ii)



$\mathcal{E} = \frac{1}{2}Bl^2\omega$

Upper end is +ve terminal



$\mathcal{E} = \frac{1}{2}B(4R^2)\omega$

Lower end is +ve

INSTANTANEOUS VALUE OF INDUCED EMF

ϕ = NBA cosθ

= NBA cosωt

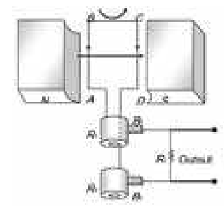
$\mathcal{E}_{Ind}$ = NBAω sin ωt

$\mathcal{E}_0$ = NBAω

when t=0

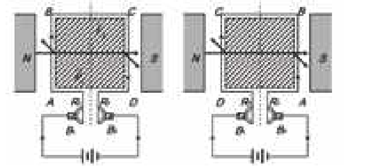
$\mathcal{E}_{Ind} = \mathcal{E}_0 \sin\omega t$

AC GENERATOR



$\mathcal{E}_{Ind} = \mathcal{E}_0 \sin\omega t$

DC MOTOR



electrical machine which converts electrical energy into mechanical energy

EQUATION FOR BACK EMF

$I = \frac{E - NBA\omega\sin\omega t}{R}$

MECHANICAL POWER & EFFICIENCY OF DC MOTOR

$\eta = \frac{\text{back emf}}{\text{supply voltage}} = \frac{\text{Pout}}{\text{Pin}} = \frac{e}{E}$

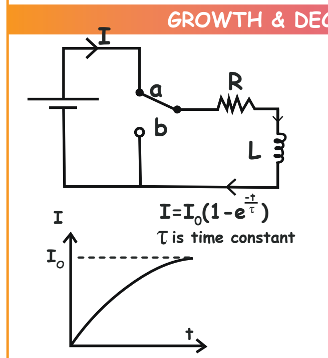
L-R CIRCUIT

Steady state → inductor → zero resistance

For current growth in a circuit

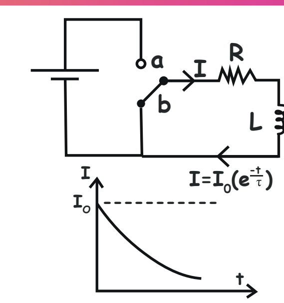
- at t=0 Inductor offers infinite resistance
- at t=∞ Inductor offers zero resistance

GROWTH & DECAY IN L-R CIRCUIT



$I = I_0(1 - e^{-\frac{t}{\tau}})$

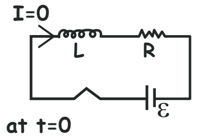
τ is time constant



$I = I_0(e^{-\frac{t}{\tau}})$

INITIAL & FINAL STATE OF L-R CIRCUIT

Initial state

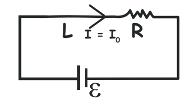


at t=0

Initial state - inductor open

$\mathcal{E} = V_L$

final state

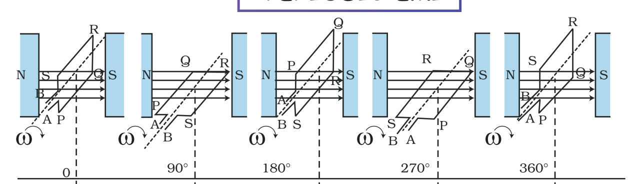


at t=∞

final state -replace inductor with a wire

$I_0 = \frac{\mathcal{E}}{R}$

PERIODIC EMI



Φ_1=NBAcos0 =NBA Φ_2=NBAcos90 =0 Φ_3=NBAcos180 =-NBA Φ_4=NBAcos270 =0 Φ_5=NBAcos360 =NBA

Average induced emf

- when coil is rotated from θ=0° to 90° $\mathcal{E}_{ind} = \frac{2NBA\omega}{\pi}$
- when coil is rotated from θ=90° to 180° $\mathcal{E}_{ind} = \frac{-2NBA\omega}{\pi}$

ALTERNATING CURRENT

PHYSICS WALLAH

ALTERNATING CURRENT

"If the direction of current in a resistor or any other element changes alternately, the current is called an alternating current"

ROOT MEAN SQUARE CURRENT

$I_{rms} = \sqrt{\overline{I^2}} = \sqrt{\frac{I_o^2}{2}} = \frac{I_o}{\sqrt{2}}$

$I_{rms} = \frac{I_o}{\sqrt{2}}$ $\quad V_{rms} = \frac{V_o}{\sqrt{2}}$

Average value of ac is defined for positive or negative half cycle

$\bar{I} = \frac{2I_o}{\pi}$ $\quad \bar{V} = \frac{2V_o}{\pi}$

AVERAGE AND RMS VALUE OF AC

If the current or voltage is sinusoidal than it can be expressed as

$i = i_o \sin(\omega t + \Phi)$

$v = v_o \sin(\omega t + \Phi)$

$i_o \rightarrow$ Peak current or current amplitude

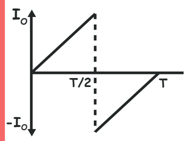
$v_o \rightarrow$ Peak voltage or voltage amplitude

$\omega = \frac{2\pi}{T} = 2\pi f$ $\quad$ T: Time period

f: frequency (Hz or cycle/sec)

$(\omega t + \Phi)$: Total phase

SAWTOOTH FUNCTION



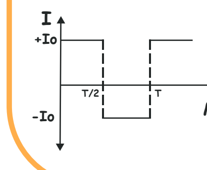
For half cycle $\bar{I} = \frac{I_o}{2}$

For full cycle $\bar{I} = 0$

Mean square current $\overline{I^2} = \frac{I_o^2}{3}$

rms current $I_{rms} = \frac{I_o}{\sqrt{3}}$

RECTANGULAR FUNCTION



For half cycle $\bar{I} = I_o$

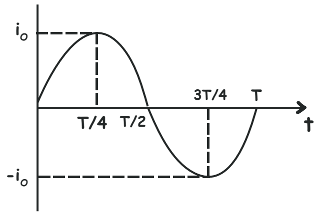
For full cycle $\bar{I} = 0$

Mean square current $\overline{I^2} = I_o^2$

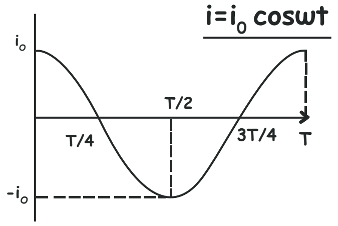
rms current $I_{rms} = I_o$

GENERAL GRAPH

if $i = i_o \sin\omega t$



$i = i_o \cos\omega t$



⇒ for measuring ac hot wire instruments are used

AVERAGE HEAT PRODUCED DURING A CYCLE OF AC

$H_{avg} = \frac{1}{2} I_o^2 R = I_{rms}^2 R$

Keep in mind

⇒ rms value is also called virtual value or effective value

⇒ AC ammeter and voltmeter always measure rms value

⇒ Values printed on ac circuits are rms values

⇒ In houses ac is supplied at 220V which is the rms of voltage

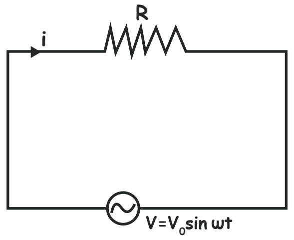
⇒ Peak value is $220\sqrt{2} = 311$V

⇒ Frequency in general is 50Hz

⇒ $\omega = 2\pi f = 100\pi$ rad/sec (314 rad/sec)

SINGLE COMPONENT CIRCUITS

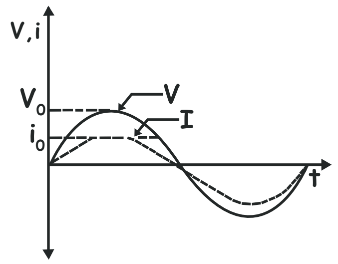
Resistor only



1. $V = V_o \sin\omega t$
2. $i = i_o \sin\omega t$
3. V&i are in phase
4. 

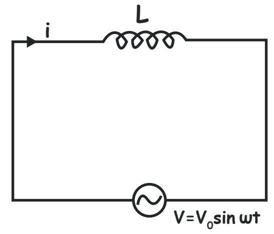
5. $\Phi = 0, \cos\Phi = 1$

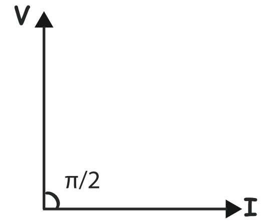
   $\bar{P} = \varepsilon_{rms} I_{rms}$



6. $i_o = \frac{V_o}{R}$ & $i_{rms} = \frac{V_{rms}}{X_L}$

Inductor only



1. $V = V_o \sin\omega t$
2. $i = i_o \sin(\omega t - \pi/2)$
3. or current leads to the voltage by $\pi/2$
4. 

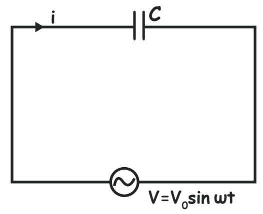
5. $\Phi = \pi/2, \cos\Phi = 0$
6. $\bar{P} = 0$ (wattless circuits)
7. Inductive reactance (X_L)

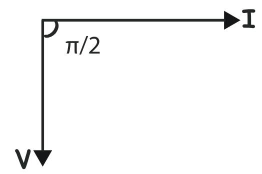
   $X_L = L\omega$

   Unit-ohm(Ω)

   plays role of resistance
8. $i_o = \frac{V_o}{X_L}$ & $i_{rms} = \frac{V_{rms}}{X_c}$

Capacitor only



1. $V = V_o \sin\omega t$
2. $i = i_o \sin(\omega t + \pi/2)$
3. Current leads the voltage by $\pi/2$
4. 

5. $\Phi = \pi/2, \cos\Phi = 0$
6. $\bar{P} = 0$ (wattless circuits)
7. Inductive reactance

   $X_c = \frac{1}{c\omega}$

   Unit-ohm(Ω)

   plays role of resistance
8. $i_o = \frac{V_o}{X_c}$ & $i_{rms} = \frac{V_{rms}}{X_c}$

SUMMARY

	Z (Impedance)	Φ
1. R only	R	0
2. L only	$X_L = \omega L$	$-\pi/2$
3. C only	$X_c = \frac{1}{c\omega}$	$\pi/2$

AVERAGE VALUE OF AC FOR ONE TIME PERIOD

$\bar{I} = \frac{\int_0^T I dt}{\int_0^T dt} = \frac{\int_0^T I_o \sin\omega t \, dt}{\int_0^T dt} = \frac{\text{area of I-t graph}}{\text{time}}$

$\bar{I} = 0$ for $0 \rightarrow T$ for a sinusoidal ac wave.

The average value of sin or cos function for one time period or n time periods (n=1,2...) is zero

Keep in mind

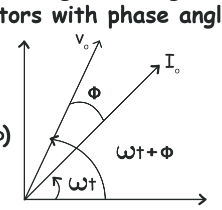
Long period is equivalent to one time period

PHASOR DIAGRAM

Diagram representing ac voltage or current as vectors with phase angle between them.

$I = I_o \sin(\omega t)$

$v = v_o \sin(\omega t + \Phi)$



Mean square current for one time Period

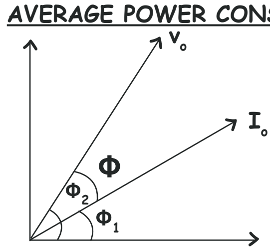
$\overline{I^2} = \frac{\int_0^T I^2 dt}{\int_0^T dt} = \frac{I_o^2}{2}$

Remember

The average value of square of sin or cosine function for one time period is $\frac{1}{2}$

$$\boxed{\begin{array}{l} \int_0^T \sin^2 k\omega t = \frac{1}{2} \times T \\ \int_0^{nT} \sin^2 k\omega t = \left(\frac{n}{2}\right) \times T \end{array}}$$

AVERAGE POWER CONSUMPTION



P= VI

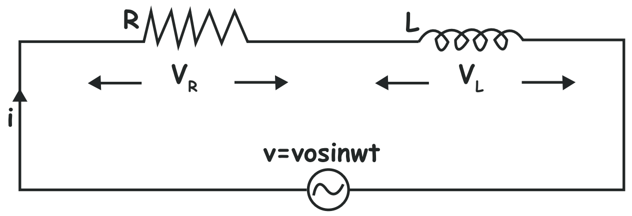
$\boxed{\bar{P}_{avg} = V_{rms} I_{rms} \cos\Phi}$

for $\cos\Phi = 1$ or $\Phi = 0°$

$\bar{P}_{avg} = V_{rms} I_{rms}$

SERIES AC CIRCUITS

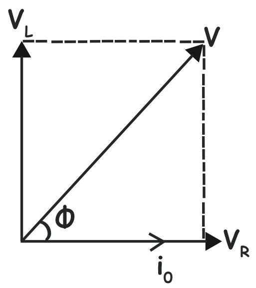
1) R-L CIRCUITS



1. $V = V_o \sin\omega t$ $\quad V_R = i_o R, \; V_L = i_o X_L$
2. Voltage phasor diagram

   $V = \sqrt{V_R^2 + V_L^2}$

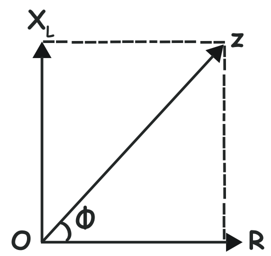
   $\tan\Phi = \left[\frac{V_L}{V_R}\right]$



3. $i = i_o \sin(\omega t - \Phi)$
4. $\frac{V_o}{i_o} = \frac{V_{rms}}{i_{rms}} = Z = \sqrt{R^2 + X_L^2}$
5. Impedance phasor

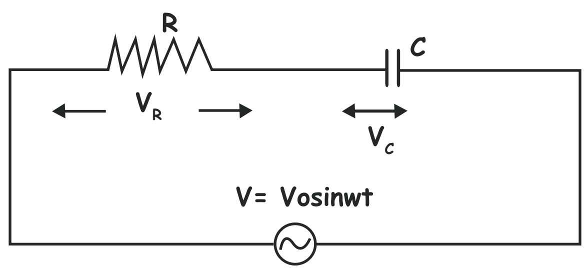
   $Z = \sqrt{R^2 + l^2}$

   $\tan\Phi = \frac{X_L}{R}$



6. $i_o = \frac{V_o}{Z}$

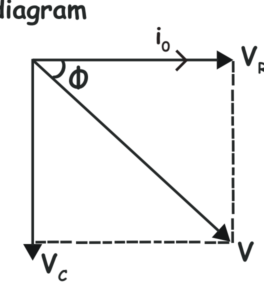
2) R-C CIRCUITS



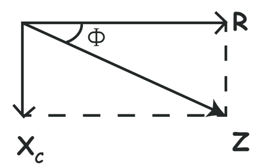
1. $V = V_o \sin\omega t$ $\quad V_R = i_o R, \; V_c = i_o X_c$
2. Voltage phasor diagram

   $V = \sqrt{V_R^2 + V_c^2}$

   $\tan\Phi = \left[\frac{V_c}{V_R}\right]$



3. $i = i_o \sin(\omega t + \Phi)$
4. Impedance phasor

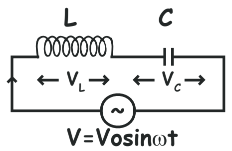


   $Z = \sqrt{R^2 + X_c^2}$

   $\tan\Phi = \left(\frac{X_c}{R}\right)$
5. $i_o = \left(\frac{V_o}{Z}\right)$

   or $i_{rms} = \frac{V_{rms}}{Z}$

3) L-C CIRCUIT



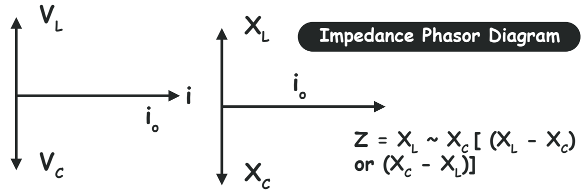
$V = V_0 \sin \omega t$

$V_L = i_0 X_L,\ V_C = i_0 X_C$

Voltage phasor diagram

$V = V_L \sim V_C$ [ie, $(V_L - V_C)$ or $(V_C - V_L)$]

Impedance Phasor Diagram



$Z = X_L \sim X_C$ [$(X_L - X_C)$ or $(X_C - X_L)$]

if $X_L > X_C$, Voltage leads the current by $\frac{\pi}{2}$

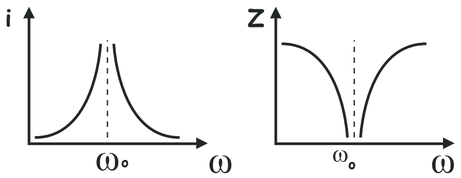
if $X_C > X_L$, current leads the voltage by $\frac{\pi}{2}$

if $X_L = X_C$, $Z = 0$, $i = \infty$

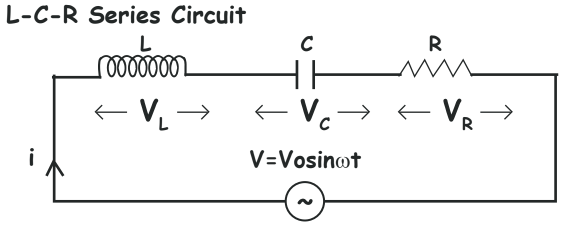
or,

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

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



L-C-R Series Circuit

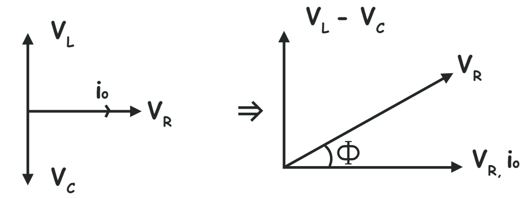


$V = V_0 \sin \omega t$

$V_R = i_0 R$, $V_L = i_0 X_L$, $V_C = i_0 X_C$

Assuming $V_L > V_C$ for drawing phasor

Voltage phasor diagram

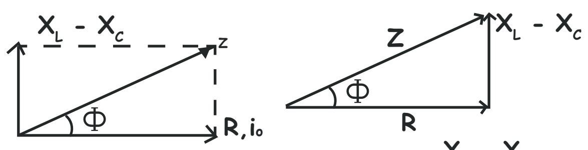


$V = \sqrt{V_R^2 + (V_L - V_C)^2}$

Here $i = i_0 \sin(\omega t - \Phi)$

(since V_L is leading)

Impedance Triangle



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

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

RESONANCE IN LCR SERIES CIRCUIT

In series resonance, impedance of circuit is minimum & equal to resistance $\Rightarrow Z = R$, and curent is maximum

Condition for resonance

$X_L = X_C \Rightarrow L\omega = \frac{1}{C\omega}$

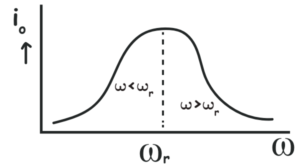
$\omega = \omega_r = \frac{1}{\sqrt{LC}}$ rad / sec

$\omega_r \rightarrow$ resonant frequency (angular)

$f = f_r = \frac{1}{2\pi\sqrt{LC}}$ H_z

f_r = resonant frequency

GRAPH



Variation of peak current with applied frequency

$\omega < \omega_r$, $X_C > X_L$ current leads

$\omega > \omega_r$, $X_L > X_C$ current lags

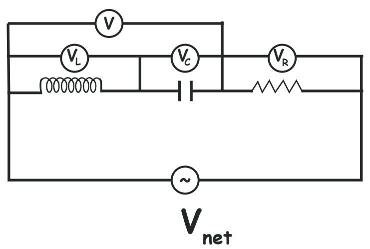
In resonance

$V = V_R$ (applied voltage = voltage across resistance)

$Z = R$ (impedance is minimum and equal to resistance)

Voltmeter connected across V_L & V_C will show the same reading

Voltmeter connected commonly across inductor & capacitor shows no reading



Here $V = 0$

$V_L = V_C$

$V_N = V_R$

$i_{max} = \frac{V_{net}}{Z} = \frac{V_R}{R}$

APPLICATION OF RESONANT CIRCUIT

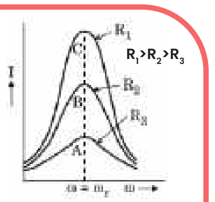
Tuning mechanism of a radio or TV set

1. Antenna of radio accepts signals
2. Signal acts as an AC source in tuning the radio
3. In tuning, capacitance of capacitor is varied such that the resonant frequency of the circuit becomes nearly equal to the frequency of the radio signal received. So, the simple is largely amplified and distinctly heard

QUALITY FACTOR

$Q = \frac{\omega_r L}{R} = \frac{1}{\omega_r CR} = \frac{1}{R}\sqrt{\frac{L}{C}}$

or $Q = \left[\frac{\text{Voltage across } C \text{ or } L}{\text{applied voltage}}\right]_{\text{resonance}}$



Less sharp the resonance, less is the selectivity of the circuit. If the Quality factor is large, R is low or L is large, the circuit is more selective.

Sharpness of Resonance

Sharpness= $Q = \frac{\omega_r}{2\Delta\omega}$; $2\Delta\omega$ -bandwidth

smaller $\Delta\omega$, sharper or narrower the resonance.

POWER IN AC CIRCUIT

Average Power $\bar{P} = V_{rms} I_{rms} \cos\Phi$

$\bar{P} = I_{rms}^2 Z \cos\Phi$

Case 1

Purely Resistive circuit - $\Phi = 0$, $\cos\Phi = 1$

Maximum power dissipation

Case 2

Purely inductive or capacitive circuit-

$\Phi = 90^\circ$ $\cos\Phi = 0$

No power is dissipated even though a current is flowing in the circuit

Case 3

LCR Series circuit

Φ non zero in R-L, C-R, or CLR circuit.

$\bar{P} = V_{rms} I_{rms} \cos\Phi$

Case 4

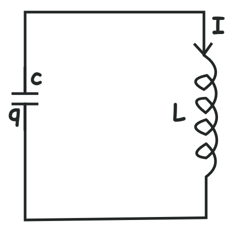
Power dissipation at resonance

$X_L - X_C = 0$ or $\Phi = 0$ $\Rightarrow \cos\Phi = 1$ $\Rightarrow Z = R$

$P = I^2 Z = I^2 R$

Maximum power is dissipated in a circuit at resonance.

LC OSCILLATIONS



Capacitor $\longrightarrow$ stores electrical energy

Inductor $\longrightarrow$ stores magnetic energy

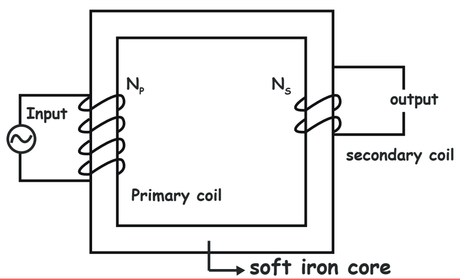
When connected, charge on the capacitor and current in the inductor perform electrical oscillations between each other.

COMPARISON OF LC OSCILLATION WITH A MASS SPRING SYSTEM

Mass spring system	LC Circuit
1. Displacement (x)	1. Charge (q)
2. Velocity $V = \frac{dx}{dt}$	2. Current $I = \frac{dq}{dt}$
3. Acceleration $a = \frac{dv}{dt}$	3. Rate of change of current $= \left(\frac{dI}{dt}\right)$
4. Mass (m), (inertia)	4. Inductance (L), inertia of circuit
5. Force constant K	5. Capacitance (C)
6. Momentum $p = mv$	6. Magnetic flux $\Phi = LI$
7. Retarding force $-m\frac{dv}{dt}$	7. Self induced emf $\left(-L\frac{dI}{dt}\right)$
8. Differential equation $\frac{d^2x}{dt^2} + \omega^2 x = 0$, $\omega = \sqrt{\frac{k}{m}}$	8. Differential equation $\frac{d^2q}{dt^2} + \omega^2 q = 0$, $\omega = \sqrt{\frac{1}{LC}}$
9. K.E $= \frac{1}{2}mv^2$, Elastic U $= \frac{1}{2}kx^2$	9. Magnetic energy $= \frac{1}{2}LI^2$, Elastic U $= \frac{q^2}{2C}$

TRANSFORMERS

"Device which raises or lowers voltage in ac circuits through mutual induction". Transformer can increase or decrease voltage or current but not both simultaneously.



EQUATIONS

1) $\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$

2) Efficiency $\eta = \frac{P_{out}}{P_{in}} = \frac{V_S I_S}{V_P I_P}$

3) For ideal transformer, $\eta = 1$

V_s -Voltage in secondary

V_p -Voltage in primary

N_s -No of turns in secondary

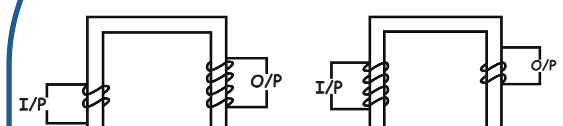
N_p -No of turns in primary

I_p -Current in primary

I_s -Current in secondary

TRANSFORMER TYPES

step up transformer — step down transformer



step up			step down		
N_p	<	N_s	N_p	>	N_s
V_p	<	V_s	V_p	>	V_s
I_p	>	I_s	I_p	<	I_s
R_p	<	R_s	R_p	>	R_s

LOSSES IN TRANSFORMER

1) Cu loss (I^2R loss)
   → To minimise, windings are made of thick Cu wires (high resistance)
2) Eddy current loss
   → To minimise Cores are laminated
3) Hysteresis loss
   → select material of narrow hysteresis loop
   → Cores of transformer is made of soft iron
4) Magnetic flux linkage
   → To minimise, secondary winding is kept inside the primary winding
5) Humming loss

PHYSICS WALLAH

EM WAVES

ELECTRO MAGNETIC WAVES

- Time varying electric and magnetic fields that propogate in space
- Oscillating electric and magnetic fields are mutually perpendicular to each other and both are perpendicular to direction of propagation
- Speed of wave = Speed of light = 3×10^8 m/s

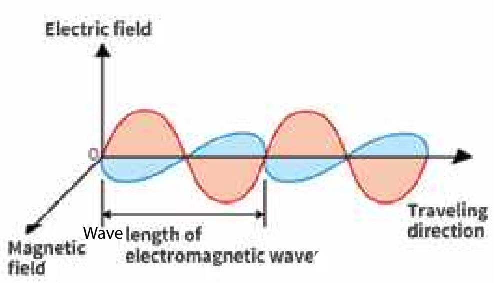
SOURCE OF ELECTROMAGNETIC WAVES IS ACCELERATING / OSCILLATING CHARGE

ENERGY DENSITY

1. U_E (Electric field) $= \frac{1}{2}\varepsilon_0 E^2$
2. U_B (Magnetic field) $= \frac{1}{2}\frac{B^2}{\mu_0}$
3. Average energy density $\bar{u}_E = \frac{1}{4}\varepsilon_0 E^2$, $\bar{u}_B = \frac{1}{4}\frac{B^2}{\mu_0}$
4. $\bar{u}_E = \bar{u}_B$
5. Total average energy density

$$u = u_E + u_B = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\frac{B^2}{\mu_0} \quad [\bar{u}_E = \bar{u}_B]$$

TRANSVERSE NATURE OF EM WAVES



$E_y = E_0 \sin(\omega t - kx)$

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

$E_0 = C B_0$

INTENSITY OF WAVE

Energy crossing per unit time area perpendicular to the direction of wave propagation

$$\text{Intensity} = \frac{\text{Energy}}{\text{time} \times \text{area}} = \frac{\text{Power}}{\text{area}}$$

FORMULAE TO REMEMBER

$$I = \frac{1}{2}\varepsilon_0 E^2 \times c$$

$$I = \frac{B^2}{2\mu_0} \times c$$

SPEED OF EM WAVE (VACUUM) $C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8$ m/s

SPEED OF EM WAVE (MEDIUM) $V_{med} = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}} = \frac{1}{\sqrt{\mu_m \varepsilon_m}}$

REFRACTIVE INDEX $\mu_{med} = \frac{c}{V_{med}} = \sqrt{\mu_r \varepsilon_r}$

REMARKS

$$C = \frac{E_0}{B_0}, \quad C = \frac{\omega}{K}$$

Maximum electric force $F_{E(max)} = qE_0$

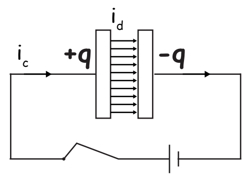
Maximum magnetic force $F_{B(max)} = qvB_0$

DISPLACEMENT CURRENT

Displacement current - Current in vacuum or dielectric when electric field is changing with time

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

Displacement current = Conduction current



POYNTING VECTOR

$$S = \frac{\text{Energy}}{\text{time} \times \text{area}} = \frac{\text{Power}}{\text{area}} \qquad \vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$$

POYNTING VECTOR

- Magnitude represents power per unit area
- Direction is along the direction of wave propagation
- SI unit :- $\frac{\text{Joule}}{\text{sec m}^2}$ $\frac{\text{Watt}}{\text{m}^2}$

MOMENTUM OF EM WAVES

1) $P = \frac{U}{c}$ (If wave is completely absorbed)

2) $P = \frac{2U}{c}$ (If wave is completely reflected)

MAXWELL'S EQUATIONS

$\oint \vec{E}.d\vec{A} = \frac{Q}{\varepsilon_0}$ [Gauss's Law of Electrostatics]

$\oint \vec{B}.d\vec{A} = 0$ [Gauss's Law of Magnetism]

$\oint \vec{E}.\vec{dl} = \frac{-d\phi_E}{dt}$ [Faraday's Law of Electromagnetic Induction]

$\oint \vec{B}.\vec{dl} = \mu_0 (i_c + i_d) = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$ [Ampere-Maxwell's Law]

ELECTROMAGNETIC SPECTRUM

Radio Waves
Produced by : Accelerated motion of charges in conducting wires
Frequency : 500 kHz - 1000MHz
Application : Cellular phones

Microwaves
Produced by : Special vacuum tubes - Klystrons, magnetrons, Gunn diodes
Detection by : Point contact diodes
Application : Radar systems, microwave oven in domestic purposes

Infrared waves
Produced by : Vibration of atoms and molecules
Detection by : Thermopiles, Bolometer, Infrared photographic film
Application : Used in remote switches for TV set, maintains average temperature through green house effect, Infrared lamps, Infrared detectors

Visible light
Wavelength : 400nm to 700nm
Frequency : 4×10^{14} Hz to 7×10^{14}

Ultraviolet rays
Wavelength : 4×10^{-7} m to 6×10^{-10} m
Produced by : Very hot bodies
Important source : Sun
Application : LASIK Surgery, UV lamps - Kills germs in purifiers
Detection by : Photocells, photographic film

X-RAYS
Produced by : High energy electrons striking metal targets
Wavelength range : 10nm to 10^{-4} nm
Application : Diagnostic tool, treatment of cancer
Detection : Photographic film, Geiger tubes, Ionisation chamber

GAMMA rays
Produced in : Nuclear reactions, Radioactive decay of nucleus
Wavelength range : 10nm to 10^{-14} nm
Application : In medicine to Kill cancer cells.

Decreasing order of wavelength $\longrightarrow$

R M I V U X G

$\longrightarrow$ Increasing order of frequency

NUCLEI

NUCLEAR COMPOSITION

$_{11}Na^{23}$ mass number = p+n=A

Atomic number = Z

Z = proton = 11

Neutron = 23-11=12

01 NUCLEAR RADIUS

$R \propto A^{1/3}$ $R = R_0 A^{1/3}$

$R_0 = 1.2$ fm

02 NUCLEAR VOLUME

$V \propto A$

03 NUCLEAR DENSITY

Independent of A

It is same for all atoms

$\rho = 2.3 \times 10^{17}$ kg/m^3

If radius of the $^{27}_{13}Al$ nucleus is taken to be R_{Al}, then the radius of $^{125}_{53}Te$ nucleus is nearly

(a) $\frac{53^{1/3}}{13}R_{Al}$ (b) $\frac{5}{3}R_{Al}$ (b) $\frac{3}{5}R_{Al}$ (a) $\frac{13^{1/3}}{53}R_{Al}$

MASS DEFECT

P + n → nucleus

mass of nucleus $< \Sigma(Z)m_p + \Sigma(A-Z)m_n$

$\Delta M = [Zm_p + (A-Z)m_n] - m_{nucleus}$

BINDING ENERGY

$B.E = \Delta Mc^2$

$B.E = \Delta M$ (in amu) $\times$ 931 MeV

$\underbrace{A + B}_{m_R} \rightarrow \underbrace{C + D}_{m_P}$ $m_R > m_P$

$\Delta m = m_R - m_P$

$\boxed{B.E = \Delta m \times 931 \text{ MeV}}$

$\boxed{Q \text{ valve} = B.E_P - B.E_R}$

BINDING ENERGY PER NUCLEON

$E_{bn} = E_b / A$

As E_{bn} increases the nucleus becomes more stable

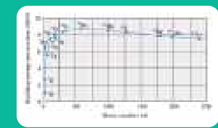
B.E / nucleon given

$\overset{A_1}{A} + \overset{A_2}{B} \rightarrow \overset{A_3}{C} + \overset{A_4}{D}$

B.E / nucleon E_A E_B E_C E_D

Q value = $(E_C A_3 + E_D A_4) - (E_A A_1 + E_B A_2)$

BINDING ENERGY CURVE



- The curve has a maximum of about 8.75 MeV for A=56
- For nuclei of middle mass number (30<A<170) E_{bn} is a constant
- E_{bn} is lower for both light nuclei (A<30) and heavy nuclei (A>170)

NUCLEAR FORCE

01 Strongest force existing in nature

02 Nuclear force is short ranged

r>0.8 fm - attractive

r<0.8 fm - repulsive

03 Nuclear force is charge independent

$F_{p-p} = F_{n-n} = F_{p-n}$

Alpha Decay

$^A_ZX \rightarrow {}^{A-4}_{Z-2}Y + \alpha$ particle + Q

$Q = [m_x - m_y - m_\alpha]C^2$

Momentum Conservation

$0 = v_y(A-4) - v_\alpha 4$ $v_y = \frac{v_\alpha 4}{A-4}$

K.E

$Q = K.E_\alpha + K.E_y$

$K.E = \frac{P^2}{2m}$; $K.E \propto \frac{1}{m}$ → K.E of α particle is more than daughter nucleus

$K.E_y = \frac{4}{A} \times Q$ $K.E_\alpha = \frac{A-4}{A} \times Q$

No.of alpha decays $n_\alpha = \frac{A-A'}{4}$

Beta Decay

β^- Decay | β^+ Decay

β^- Decay

$n \rightarrow p + \beta^-$

$^A_ZX \rightarrow {}^A_{Z+1}Y + \beta^-$

Atomic number increases by one and mass number remains same

β^+ Decay

$p \rightarrow n + \beta^+$

$^A_ZX \rightarrow {}^A_{Z-1}Y + \beta^+$

Atomic number decreases by one and mass number remains same

Gamma Decay

No change in atomic number & mass number

Penetrating power : Gamma > Beta > Alpha | Ionizing power : Alpha > Beta > Gamma

In the uranium radioactive series the initial nucleus is $_{92}U^{238}$ and final nucleus is $_{82}Pb^{206}$. When the uranium nucleus decays to lead, the number of a-particles emitted is α and the number of β-particles emitted =

(d) 6, 8 (d) 8, 6 (d) 16, 6 (d) 32, 12

A nucleus of uranium decays at rest into nuclei of thorium and helium. Then:

(a) The helium nucleus has less kinetic energy than the thorium nucleus.

(b) The helium nucleus has more kinetic energy than the thorium nucleus.

(c) The helium nucleus has less momentum than the thorium nucleus.

(d) The helium nucleus has more momentum than the thorium nucleus.

Decay law at radio activity

$\frac{dN}{dt} = \lambda N$

$N_t = N_0 e^{\lambda t}$ (N→No. of undecayed nuclei)

Activity

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

$A = \frac{-dN}{dt}$

$A = \lambda N$

Time at which ratio of nuclei will be 1/e

$t = \frac{2.303}{\lambda} \log \frac{N_0}{N}$

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

Two radioactive materials A and B have decay constants 10λ and λ, respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of A to that of B will be 1/e after a time:

(a) $\frac{1}{9\lambda}$ (b) $\frac{1}{11\lambda}$ (c) $\frac{11}{10\lambda}$ (d) $\frac{1}{10\lambda}$

Shortcut

Undecayed = $\frac{N_0}{2^n}$

$t = nt_{1/2}$

Decayed	Undecayed	Time
$\frac{N_0}{2}$	$\frac{N_0}{2}$	$t_{1/2}$
$\frac{3N_0}{4}$	$\frac{N_0}{4} = \left(\frac{N_0}{2^2}\right)$	$2t_{1/2}$
$\frac{7N_0}{8}$	$\frac{N_0}{8} = \left(\frac{N_0}{2^3}\right)$	$3t_{1/2}$

No. of undecayed nuclei:

$N = \frac{N_0}{2^{t/t1/2}}$

Half-lives of two radioactive elements A and B are 20 minutes and 40 minutes, respectively. Initially, the samples have equal number of nuclei. After 80 minutes, the ratio of decayed number of A and B nuclei will be:

(a) 1 : 4 (b) 5 : 4 (c) 1 : 16 (d) 4 : 1

t_1 t_2

Undecayed N_1 N_2

$t_1 - t_2 = \frac{2.303}{\lambda} \log \frac{N_1}{N_2}$

Time interval between 33% (1/3) & 67% (2/3) is $t_{1/2}$

Time interval between 20 % and 80% decay , or b/w 40 % and 85 % decay $(t_2 - t_1)$ is 2 $t_{1/2}$

The half-life of a radioactive substance is 30 min. The time (in minutes) taken between 40% decay & 85% decay of the same radioactive substance is:

(a) 15 (b) 60 (c) 45 (d) 30

Age of rock

X→Y (Y is stable)

Method 1

$\frac{N_x}{N_y} = \frac{m}{n}$ $N_0 = N_x + N_y = m+n$

$t = \frac{2.303}{\lambda} \log\left(\frac{m+n}{m}\right)$

Method 2

$\frac{N_0}{N} = 2^a = \frac{m+n}{m}$

Age= $at_{1/2}$

The half life of a radioactive isotope 'X' is 20 years. It decays to another element "Y" which is stable. The two elements 'X' and 'Y' were found to be in the ratio 1:7 in a sample of a given rock. The age of the rock is estimated to be

(a) 40 years (b) 60 years (c) 80 years (d) 100 years

Two deuterons undergo nuclear fusion to form a Helium nucleus. Energy released in this process is: (given binding energy per nucleon for deuteron-1.1 MeV and for helium=7.0 MeV)

(a) 30.2 MeV (b) 32.4 MeV (c) 23.6 MeV (d) 25.8 MeV

A radioactive nucleus (initial mass number A and atomic number Z emits 3 α - particles and 2 positrons. The ratio of number of neutrons to that of protons in the final nucleus will be

(a) $\frac{A-Z-8}{Z-4}$ (b) $\frac{A-Z-4}{Z-8}$ (c) $\frac{A-Z-12}{Z-4}$ (d) $\frac{A-Z-8}{Z-2}$

NUCLEAR FISSION

$^1_0n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,{}^1_0n$

NUCLEAR REACTOR

Multiplication Factor k=1 → critical

- Moderator : water,heavy water (D_2O), graphite and beryllium oxide.
- Control rods : Boron, cadmium
- Coolant : CO_2, water, nitrogen

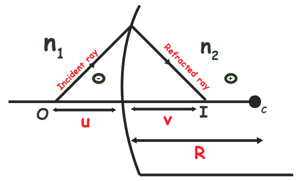
NUCLEAR FUSION

$4\,{}^1_1H + 2\bar{e} \rightarrow {}^4_2He + 2\nu + 6\gamma + 26.7$ MeV

Four hydrogen atoms combine to form an ^4_2He atom with the release of 26.7 MeV of energy

Achieved at very high temperature in order to overcome electrostatic repulsion

REFRACTION AT CURVED SURFACES



u = -ve
V = +ve
R = +ve

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

all lengths on the side of incident ray are taken as -ve
all lengths on the side of reflected ray are taken as +ve

I-O=S

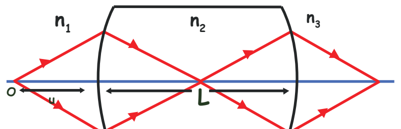
$$\frac{\text{Medium}}{\text{I.Distance}} - \frac{\text{Medium}}{\text{O.Distance}} = \frac{\text{Change in medium}}{\text{Radius of curvature}}$$

Transverse Magnification $T.M = m = \dfrac{\frac{v}{n_2}}{\frac{u}{n_1}} = \dfrac{v \times n_1}{u \times n_2}$

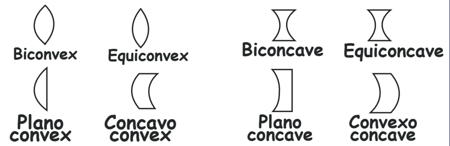
LENSES

Types

Thick lens - Two surfaces are at some distance apart.
Thin lens - Two surfaces are close

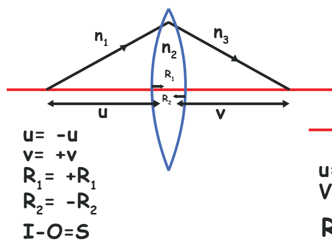


Thin Lens



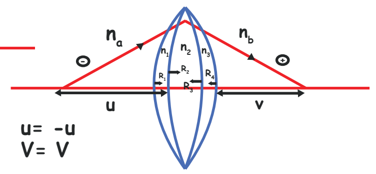
Convex mirror, Convex lens } f=+ve
Concave mirror, Concave lens } f=-ve

IOS METHOD



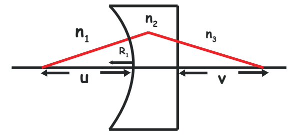
u = -u
v = +v
$R_1 = +R_1$
$R_2 = -R_2$
I-O=S

$$\frac{n_3}{v} - \frac{n_1}{-u} = \frac{n_2 - n_1}{R_1} + \frac{n_3 - n_2}{-R_2}$$



u = -u
V = V
$R = +R_1, +R_2, -R_3, -R_4$

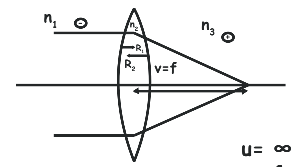
$$\frac{n_b}{v} - \frac{n_a}{-u} = \frac{n_1 - n_a}{R_1} + \frac{n_2 - n_1}{R_2} + \frac{n_3 - n_2}{-R_3} + \frac{n_b - n_3}{-R_4}$$



u = -ve
V = V
$R_1 = -ve = -R_1$
$R_2 = \infty$
I-O=S

$$\frac{n_3}{v} - \frac{n_1}{-u} = \frac{n_2 - n_1}{-R_1}$$

IOS METHOD FOR FOCAL LENGTH

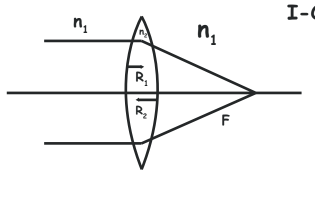


u = ∞
v = f
$R = +R_1, -R_2$

$$\frac{n_3}{f} = \frac{n_2 - n_1}{R_1} + \frac{n_3 - n_2}{-R_2}$$

LENS MAKERS FORMULA

To find focal length if refractive index is same on both sides of lens.

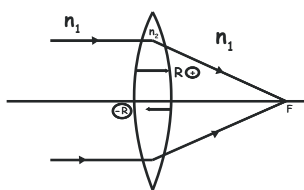


I-O=S $\quad \dfrac{n_1}{F} - 0 = \dfrac{n_2 - n_1}{R_1} + \dfrac{n_1 - n_2}{R_2}$

$$\frac{1}{F} = \left[\frac{n_2}{n_1} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{F} = \left[{}_1n_2 - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

EQUICONVEX LENS



$$F = \frac{R}{2[{}_1n_2 - 1]}$$

If Prism is placed in air

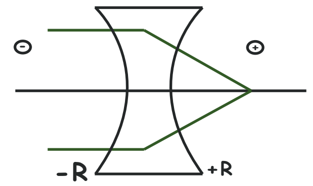
$$F = \frac{R}{2\left[\frac{n_2}{1} - 1\right]} = \frac{R}{2[n_2 - 1]}$$

In water,

$$F = \frac{R}{2\left[\frac{n_2}{n_w} - 1\right]}$$

⇒ F↑ than air

FOCAL LENGTH OF EQUICONCAVE LENS IN AIR



$$f = \frac{-R}{2[{}_1n_2 - 1]}$$

PLANO CONVEX LENS

F of planoconvex lens = 2 x f of equiconvex lens

$$f = \frac{R}{{}_1n_2 - 1}$$

PLANO CONCAVE LENS

Equiconvex = f ⟶ Equi Concave = - f
⇓ ⇓
Plano Convex = 2f   Plano Concave = -2 f

$$f = -\frac{R}{{}_1n_2 - 1}$$

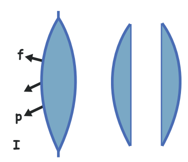
POWER

$$\text{Power} = \frac{1}{\text{F in metre}}$$

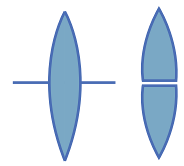
[Power = 1 dioptre = $1m^{-1}$]

In centimetre, $P = \dfrac{100}{\text{f in cm}}$

CUTTING OF LENS

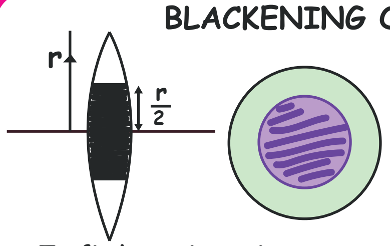


	Before cutting	After cutting
Focal Length	f	2f
Power	P	P/2
Area	A	A
Intensity	I	I



	Before cutting	After cutting
Focal Length	f	f
Power	P	P
Area	A	A/2
Intensity	I	I/2

BLACKENING OF LENS



Intensity ∝ Area of transmission of light
$I \propto A_T$

Blackening of lens ⇒ A_T↓ ⇒ I↓

To find new intensity :

i) Find total A_T (Area of lens before blackening)
ii) Find new $A_T = (A_{total} - A_{opaque})$
iii) I ∝ original A_T (Total A_T)

I' ∝ new A_T

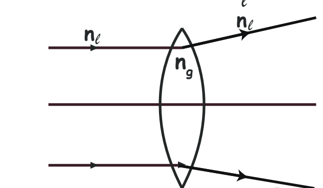
Taking ratio of these two equations we can find I'

Comparison of focal length in air & Liquid

1) If $n_{air} < n_{liquid} < n_{glass}$
 - Nature of lens remains same
 - Focal length increases

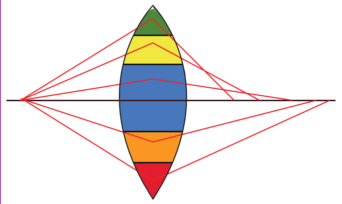
2) Same refractive index $[n_l = n_{glass}]$
 - Lens become invisible

3) $n_\ell > n_g \quad f = \dfrac{R}{2\left(\frac{n_g}{n_\ell} - 1\right)}$ = negative

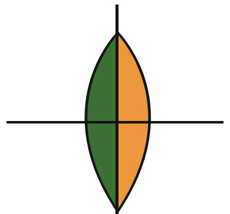


Convex become concave
Concave become convex } Nature of lens changes

NUMBER OF IMAGES FORMED IN MULTIPLE MEDIUM LENS



Number of medium = Number of images



Number of images = 1

MAGNIFICATION

To find size of image

$$m = \frac{[I]}{[O]} = \frac{v}{u}$$

$$m = \frac{f}{f+u}$$

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

m_T:
- $|m_T| = 1$ ⇒ Same size
- $|m_T| < 1$ ⇒ Small
- $|m_T| > 1$ ⇒ magnified

m_T:
- +ve ⇒ Virtual image, Erect
- -ve ⇒ Real image, Inverted

LENS FORMULA

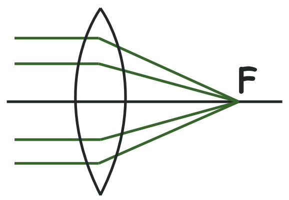
To find v when f and u are given

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

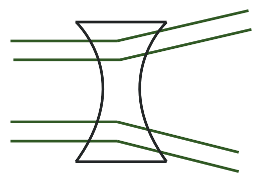
$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{u+f}{uf}$$

$$v = \frac{uf}{u+f}$$

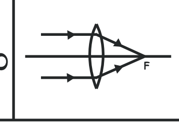
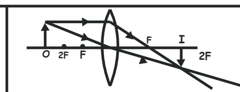
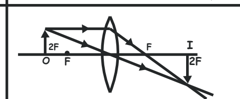
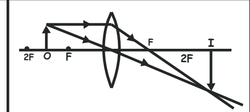
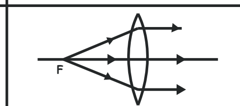
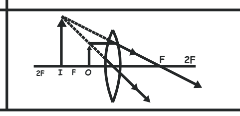
IMAGE FORMATION BY CONVEX AND CONCAVE LENSES



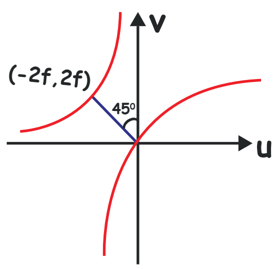
Convex lens
- Converging lens
- Similar to concave mirror



Concave lens
- Diverging lens
- Similar to convex mirror

Sl NO	Position of the object	Ray Diagram	Position of image	Nature of Image
1	At $\lvert u\rvert = \infty$		At F	Real, inverted, diminished
2	Beyond 2F $\lvert u\rvert > 2\lvert f\rvert$		Between F and 2F	Real, inverted, diminished
3	At 2F $\lvert u\rvert = 2\lvert f\rvert$		At 2F	Real, inverted, same size
4	Between F & 2F $f < \lvert u\rvert < 2f$		Beyond 2F	Real, inverted, enlarged
5	At F $\lvert u\rvert = \lvert f\rvert$		At ∞	Cannot be defined
6	within F $\lvert u\rvert < \lvert f\rvert$		On the side of object	Virtual, erect, enlarged

U - V GRAPH

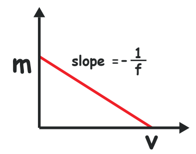


MAGNIFICATION VS V GRAPH

Concave lens

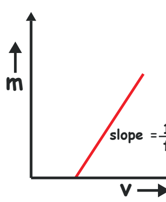
$$m = \frac{f-v}{f}$$

$$m = 1 - \frac{v}{f} = -\frac{v}{f} + 1$$

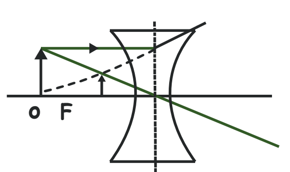


Convex lens

$$m = \frac{v}{f} + 1$$

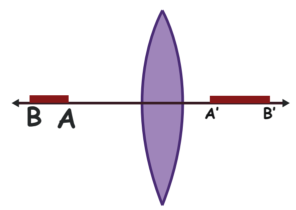


Concave lens



-Real object
-Virtual image
-Formed between F and Pole

AXIAL MAGNIFICATION



$$m_L = \frac{\text{length of image}}{\text{length of object}} = \frac{A'B'}{AB} = \frac{V_A - V_B}{U_A - U_B}$$

For short object

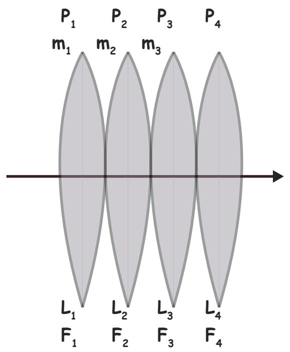
$$m_L = \frac{dv}{du} = m_T^2$$

PHYSICS WALLAH

RAY OPTICS 2

COMBINATION OF LENSES

Lenses are combined such that there is no gap between them



Power

$P_{comb} = P_1 + P_2 + P_3 + \ldots\ldots$

Focal length

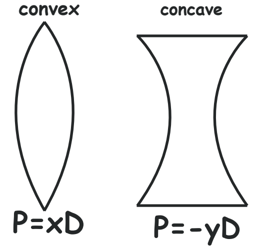
$\frac{1}{f_{comb}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \ldots\ldots$

Magnification ,

$m_T = m_1 \times m_2 \times m_3 \ldots\ldots$

Note :

P_{Comb} determines whether the combination act as converging lens or diverging lens.



System acts as converging lens if total power > 0

$P_T > 0$

$\Rightarrow P_{convex} > P_{concave}$

$\Rightarrow f_{concave} > f_{convex}$

System acts as diverging lens if total power < 0

$P_T < 0$

$\Rightarrow P_{concave} > P_{convex}$

$\Rightarrow f_{convex} > f_{concave}$

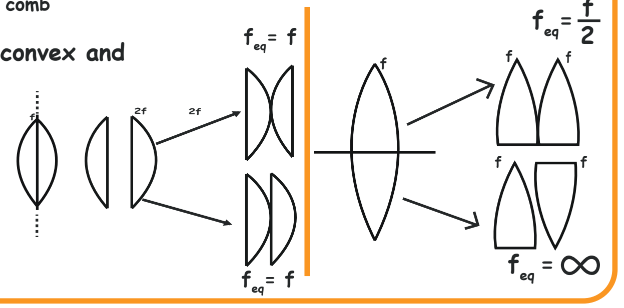
System acts as plane lens /glass if $P_{comb} = 0$

$P_{concave} = P_{convex}$ =0

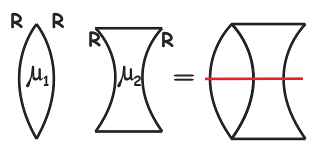
$f_{concave} = f_{convex} = f_{comb} = \infty$

For a combination of convex and concave lenses if $P_{convex} > P_{concave}$

→ combination acts as convex lens



F_{EQ} USING LENS MAKERS FORMULA



$f_{eq} = \frac{R}{2[\mu_1 - \mu_2]}$

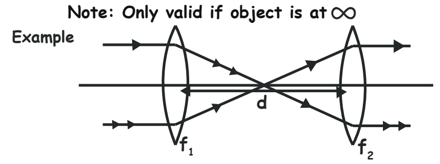
LENSES COMBINED SUCH THAT THERE IS A GAP BETWEEN THEM

Power : $P_{comb} = P_1 + P_2 - dP_1P_2$

$\frac{1}{f_{comb}} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$

Note: Only valid if object is at ∞

Example



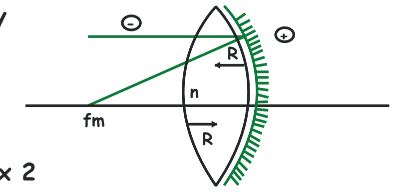
If $P_{comb} = 0$

$\frac{1}{f_{comb}} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2} = 0$

$\boxed{d = f_1 + f_2}$

NATURE OF MIRROR IS DETERMINED BY FOCAL LENGTH

To find focal length, split the silvered lens into a lens and a mirror and apply IOS



$u = \infty$

$v = f_m$

$R_1 = +R$

$R_2 = -R$

$I - O = S$

$\frac{-1}{f_m} = \frac{n-1}{R} \times 2 + \left[\frac{0+n}{+R}\right] \times 2$

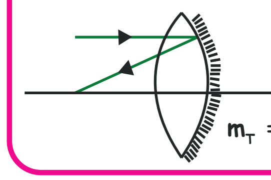
[Ray passes through the surface 2 times thus multiplied by 2]

$f_m = \frac{-R}{4n-2} = \frac{-R}{2(2n-1)}$

When equiconvex lens is silvered (mirrored) its focal length become negative (concave mirror) with magnitude

$f_m = \frac{-R}{2(2n-1)}$

SILVERING OF LENS



Lens → Mirror

$m_T = \frac{v}{u} = \frac{[I]}{[o]} = \frac{f}{f-u} = \frac{f-v}{f}$

OPTICAL INSTRUMENTS

Simple Microscope

Only one lens [convex lens]

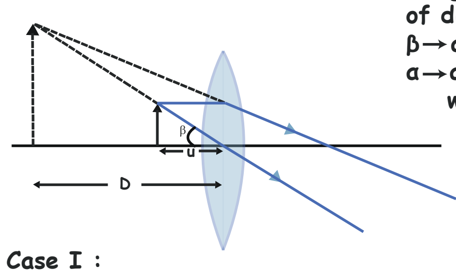


Image is formed at least distance of distinct vision (D)

β → angle subtended by image at eye.

α → angle subtended by object at eye when placed at distance D.

Case I :

Eye under relaxed state or normal vision

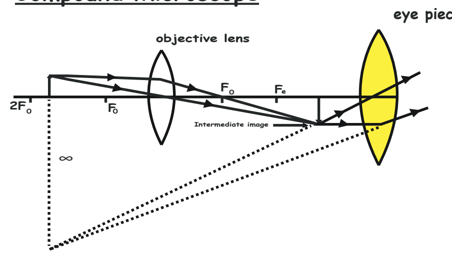
Final image at infinity

Object at f → $u = u_{max}$ $\boxed{m_{min} = \frac{D}{u_{max}} = \frac{D}{f}}$

Case 2 : Eye under strain

Final image at D $u = u_{min}$ $\boxed{m_{max} = \frac{D}{u_{min}} = \frac{1+D}{f}}$

Compound Microscope



- Has 2 lenses
- Length of microscope = Distance between lenses.
- Magnification $m = m_o \times m_e$

[m_e - same as simple microscope]

To get magnified image, object placed between F_o & $2F_o$ of objective lens. This image is called intermediate image.

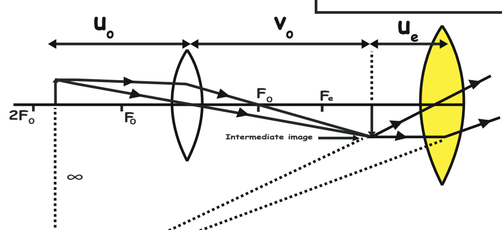
Intermediate image → real, inverted , magnified.

Intermediate image is formed within or at the focus of eyepiece.

Total magnification $m_T = -m_o \times m_e$

m_e same as simple microscope

$\boxed{m_T = -m_o \times m_e = -\left[\frac{v_o}{u_o} \times \frac{D}{u_e}\right]}$



SILVERING OF PLANO-CONVEX LENS

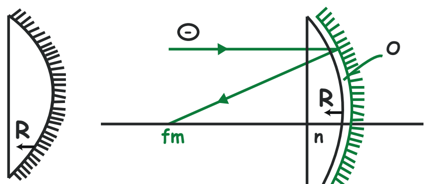
2 possibilities

i) silvering curved surface

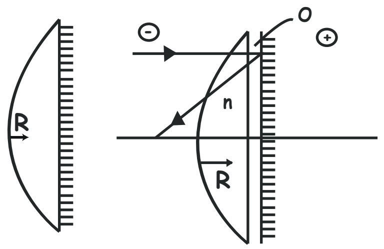
ii) Silvering plane surface

Silvering curved surface

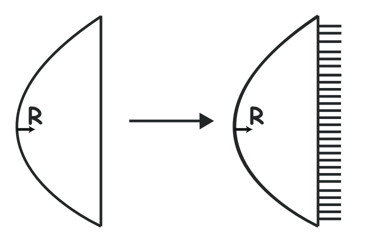
$f_m = \frac{-R}{2n}$



Silvering plane surface



$f_m = \frac{-R}{2(2n-1)}$



Before silvering

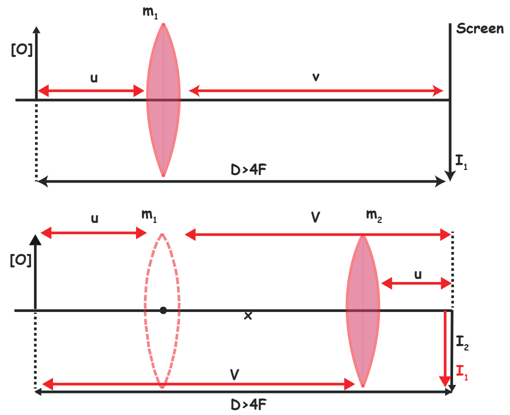
$f = \frac{R}{(n-1)}$

After silvering

$f_m = \frac{-R}{2(n-1)} = \frac{f}{2}$

LENS DISPLACEMENT METHOD

Distance between object & image > 4F



In lens Displacement method

1) $D \geq 4F$

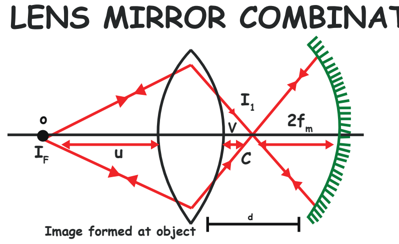
2) $F = \frac{D^2 - x^2}{4D}$ x → distance between 2 position of lens

3) $F = \frac{x}{m_1 - m_2}$ F= Focal length of lens

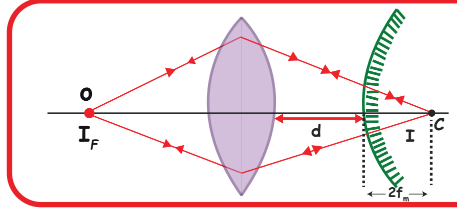
4) $m_1\, m_2 = 1$

$[O] = \sqrt{I_1 I_2}$

LENS MIRROR COMBINATION



If both lens and mirror are converging. $d = v + 2f_m$



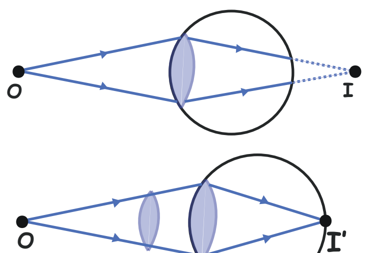
If one is converging & other is diverging $d = v - 2f_m$

HUMAN EYE

Least distance of distinct vision is 25 cm

Defects of vision and their correction

i) Hypermetropia



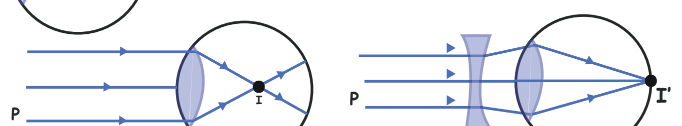
- Long sightedness –Cannot see nearby objects
- Eye focuses incoming light from nearby objects at a point behind retina.
- Correction : Convex lens

  F = +ve , Power P= +ve

  Focal length = Dd/(D-d)

D → Least distance of distinct vision.

ii) Myopia



- Short sightedness -Cannot see faraway objects
- Light from a distant object arriving at the eye lens may get converged at a point in front of the retina.
- Correction : Concave lens

F = -ve , P = - ve , F = - d , $P = \frac{1}{F}$

iii) Astigmatism

eye cannot focus in horizontal and vertical planes simultaneously

- Correction : Cylindrical lens

iv) Presbyopia

eye suffers both myopia and hypermetropia

- Correction : Bifocal lens

Case I :

Eye in relaxed state or final image at ∞, $u_e = f_e$

$m_T = m_{min} = -\left[\frac{V_o}{u_o}\ \frac{D}{f_e}\right]$ Also $L = L_{max} = V_o + u_{max} = V_o + f_e$

Case 2 : Strained eye

$u = u_{min}$

$L = L_{min} = L_D = V_o + U_e = V_o + u_{min} = V_o + \frac{Df_e}{D+f_e}$

$\boxed{m_D = m_{max} = \frac{-V_o}{u_o}\left[1 + \frac{D}{f_e}\right]}$ $\frac{m_{max}}{m_{min}} = \frac{D+f_e}{D}$

$$\boxed{\begin{array}{l} m_D = \left[\frac{L}{f_o}\right]\left[1 + \frac{D}{f_e}\right] \\ m_\infty = \left[\frac{L}{f_o}\ \frac{D}{f_e}\right] \end{array}}$$

Note :

$L_\infty = V_o + U_{max}$ $\quad L_\infty = V_o + f_e$

$L_\infty = \frac{U_o f_o}{U_o - f_o} + f_e$ $\quad L_D = V_o + U_{min}$

$L_D = V_o + \frac{Df_e}{D+f_e}$ and $L_D = \frac{U f_o}{U_o - f_o} + \frac{Df_e}{D+f_e}$

For microscope, eyepiece larger than objective

$f_e\uparrow \Rightarrow m\uparrow \quad f_e\downarrow \Rightarrow m\downarrow$

For telescope, eyepiece smaller than objective to increase magnification.

<u>Telescope</u>

Magnification $m = \frac{f_o}{u_e}$ $\quad u = u_{max} \Rightarrow m = m_{min}$

$u = u_{min} \Rightarrow m = m_{max}$

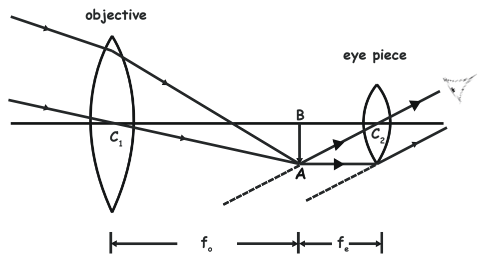
Length of telescope $L = f_0 + u_e$

Normal adjustment /Relaxed eye/final image at ∞

$m_{min} = \frac{f_o}{f_e}$

$\boxed{L_\infty = f_o + f_e}$

Length $= L_\infty = f_0 + u_e = f_0 + f_e$



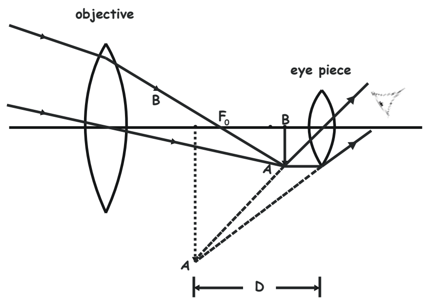
Eye under strain/Final image at least distance of distinct vision.

$u = u_{min} = \frac{Df_e}{D+f_e}$

$m_{max} = \frac{f_o}{f_e}\left[1 + \frac{f_e}{D}\right]$

$L_D = f_o + u_e$

$L_D = f_o + \frac{Df_e}{D+f_e}$



Length of Telescope

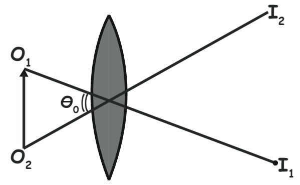
u_e can have values : f_e or $\frac{Df_e}{D+f_e}$

v_o can have values : f_o only

$L_D = v_o + u_e$

RESOLVING POWER

Resolving power$= \frac{1}{\text{Resolving limit}}$



X=Limit of resolution

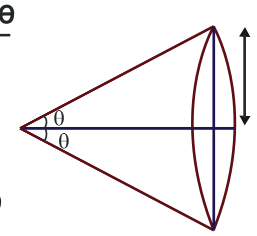
= Resolving limit

MICROSCOPE

Resolving Limit$= \frac{1.22\lambda}{a} = \frac{1.22\lambda}{2n\sin\theta}$, where a = diameter of lens

R.P$= \frac{a}{1.22\lambda} = \frac{2n\sin\theta}{1.22\lambda}$

R.P α $\frac{1}{\lambda}$



TELESCOPE

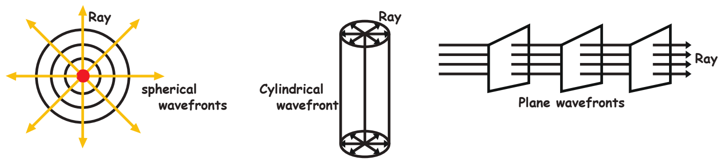
R.P$= \frac{a}{1.22\lambda} = \frac{2n\sin\theta}{1.22\lambda}$

RAY OPTICS 2

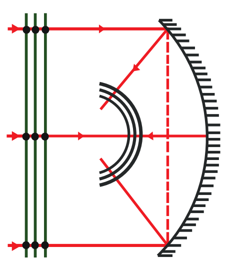
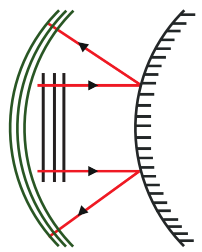
WAVE OPTICS

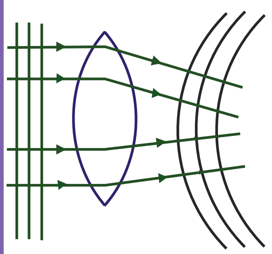
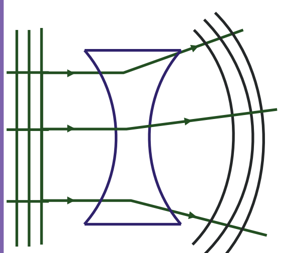
PHYSICS WALLAH

Wave Front



Point light source → spherical wavefront
Linear light Source → cylindrical wavefront
Source at infinity → Plane wave front

	Incident wavefront	Reflected wavefront
Concave Mirror 	Plane wavefront	Spherical converging wavefront
Convex Mirror 	Plane wavefront	Spherical diverging wavefront

	Incident wavefront	Refracted wavefront
Convex Lens 	Plane wavefront	Spherical converging wavefront
Concave Lens 	Plane wavefront	Spherical diverging wavefront

Huygen's principle

i) Each point on a wavefront acts as a fresh source of new disturbance, called secondary waves or wavelets.
The secondary wavelets spread out in all directions with the speed of light in the given medium.

ii) A common envelope or common tangent to these secondary wavelets at any later time gives secondary wavefront at that time

Phase Difference & Path Difference

$\Phi = \frac{2\pi}{\lambda}\Delta x$

Phase Difference & Time Difference

$\Phi = \frac{2\pi}{T}\Delta t$

Resultant Amplitude

$Y_1 = A_1 \sin \omega t$ and

$Y_2 = A_2 \sin(\omega t + \Phi)$

Resultant $A = \sqrt{A_1 + A_2 + 2A_1A_2\cos\Phi}$

- $\cos\Phi = 1 \Rightarrow A = A_{max} = \sqrt{(A_1+A_2)^2} = A_1 + A_2$
- $\cos\Phi = -1 \Rightarrow A = A_{min} = \sqrt{(A_1-A_2)^2} = A_1 - A_2$

$\frac{A_{max}}{A_{min}} = \frac{A_1+A_2}{A_1-A_2}$

- Intensity $\propto$ (amplitude)^2

Resultant Intensity

We have, $I = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\Phi$

- $\cos\Phi = 1 \Rightarrow I = I_{max}$

$I_{max} = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}$

$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$

- $\cos\Phi = -1 \Rightarrow I = I_{min}$

$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$

$\frac{I_{max}}{I_{min}} = \frac{(\sqrt{I_1} + \sqrt{I_2})^2}{(\sqrt{I_1} - \sqrt{I_2})^2}$

$I_{max} \propto A^2_{max}$ & $I_{min} \propto A^2_{min}$

$\frac{I_{max}}{I_{min}} = \frac{A^2_{max}}{A^2_{min}} = \frac{(A_1+A_2)^2}{(A_1-A_2)^2}$

If $I_1 = I_2 = I_0$

$\Rightarrow I = 4I_0 \cos^2\frac{\phi}{2}$

YDSE in Liquid

When YDSE setup is immersed in a liquid, there is change in wavelength

$n = \frac{c}{v} = \frac{v\lambda}{v\lambda'} = \frac{\lambda}{\lambda'}$ $\quad$ n → refractive index

$\lambda_{medium} = \lambda' = \frac{\lambda}{n}$ or $\lambda' = \frac{\lambda}{\mu}$ $\quad$ μ → refractive index

In air $Y_n = n\frac{D\lambda}{d}$

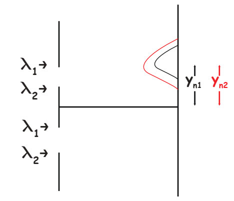
In medium $Y'_n = \frac{nD\lambda'}{d} = \frac{nD\lambda}{d\mu}$

Fringe width in air $\beta = \frac{D\lambda}{d}$

In medium $\beta' = \frac{D\lambda}{\mu d} \Rightarrow \beta_{med} = \frac{\beta_{air}}{\mu}$

$\Rightarrow \beta_{med} < \beta_{air}$

Overlapping



Let n_1^{th} max of λ_1 wavelength overlaps with n_2^{th} max of λ_2 wavelength

$Y_{n1} = Y_{n2}$

$\frac{n_1 D\lambda_1}{d} = \frac{n_2 D\lambda_2}{d}$

$n_1\lambda_1 = n_2\lambda_2$

→ As we move further away, then overlapping of colours increases if white light is used

→ At larger distance, all colours again overlap to give white light pattern

Introduction Of Thin Transparent Sheet in YDSE

Optical path length and geometrical path length

Refractive index $\mu = \frac{c}{v}$

$\mu = \frac{v\lambda}{v\lambda_m} \Rightarrow \lambda_m = \frac{\lambda}{\mu}$

Time taken by light to travel x length in medium,

$t = \frac{x}{c/\mu} = \frac{\mu x}{c}$

Distance travelled by light in vaccum in same time = optical path length

Optical Path Length (OPL)=velocity x time $= c \times \frac{\mu x}{c} = \mu x$

If Geometrical Path Length (GPL) = x, then OPL=μx, where μ is the refractive index of the medium

Young's Double-slit experiment (YDSE)

Path difference $\Delta x = \frac{y_n d}{D}$

In general $\Delta x = \frac{y_n d}{D}$

Distance of Minima and Maxima from Central maximum

Maxima

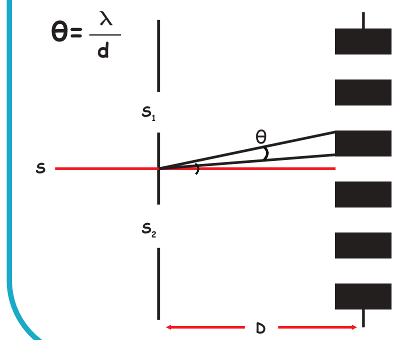
$Y_n = \frac{nD\lambda}{d}$ $\quad$ n = 0,1,2...

Minima

$Y_n = (2n-1)\frac{D\lambda}{2d}$ $\quad$ n = 1,2...

Angular fringe width

$\theta = \frac{\lambda}{d}$



Constructive interference	Destructive interference
Phase difference at the point of observation $\Phi = 0°$ or $2n\pi$, n = 0,1,2,.....	$\Phi = 180°$ or $\Phi = (2n-1)\pi$; n=1,2...
Also, $\Delta x = n\lambda$, n = 0,1,2,.....	Also, $\Delta x = (2n-1)\frac{\lambda}{2}$, n = 1,2,3,.....
Resultant intensity at the point of observation is maximum	Resultant intensity at the point of observation will be minimum
$I = I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$	$I = I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$

Intensity at any point on screen

For all maxima $I = 4I_0$ (If $I_1 = I_2 = I_0$)

For all minima, I = 0

Note:

Fringe visibility $\quad V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$

Fringe Width or Band width (β)

$\beta_{dark} = \frac{D\lambda}{d}$

$\beta_{bright} = \frac{D\lambda}{d}$

For interference pattern $\beta_{dark} = \beta_{bright} = \frac{D\lambda}{d}$

WAVE OPTICS 02

PHYSICS WALLAH

Introduction of thin transparent sheet

Path difference $\Delta x = s_2P - s_1P$

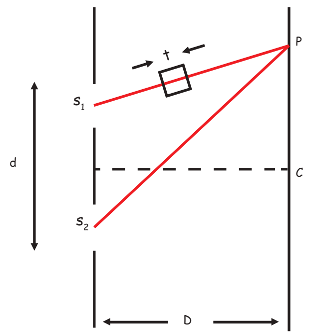
Additional path difference = $(\mu - 1)t$

Geometrical path difference before inserting sheet, $\Delta x = \frac{yd}{D}$

$$y = \frac{D}{d}\Delta x$$

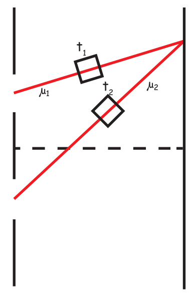
After introducing sheet, $y' = \frac{D}{d}[\Delta x + (\mu - 1)t]$

Shift $S = y' - y = \frac{D}{d}(\mu - 1)t$



If two plates are introduced,

Shift $S = |(\mu_1 - 1)t_1 - (\mu_2 - 1)t_2| \frac{D}{d}$



Interference of reflected light :
For normal incidence $r = 0$ so, $2\mu t = (2n-1)\frac{\lambda}{2}$

Interference of refracted light :
For normal incidence $2\mu t = n\lambda$

Single Slit Diffraction

Path difference = $\Delta x = d \sin\theta$

- Formation of first secondary minima

  Path difference = $\frac{\lambda}{2}$

- Formation of 2ndsecondary minima

  Path difference = 2λ

- Formation of n^{th} secondary minima

  $d \sin\theta_n = n\lambda$

  n=1,2,3,......

First secondary maxima

But the intensity of 1^{st} secondary maxima is lower than central maximum

N^{th} secondary Maxima

$x = (2n + 1)\frac{\lambda}{2}$

n = 1,2,3....

$d \sin\theta_n = (2n + 1)\frac{\lambda}{2}$

Ratio of intensities of central maxima and secondary maximas

$1 : \frac{1}{2} : \frac{1}{61} : \frac{1}{121} : \ldots\ldots\ldots\ldots$

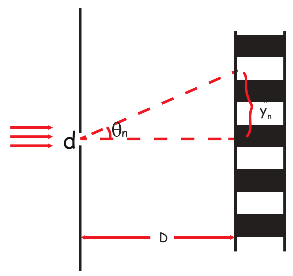
Distance of N^{th} secondary maxima from CM

$\theta_n = (2n+1)\frac{\lambda}{2d}$

n = 1,2,3.....

$y = (2n+1)\frac{D\lambda}{d}$

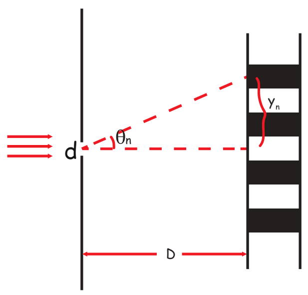
n = 1,2,3.....



Distance of N^{th} secondary minima from CM

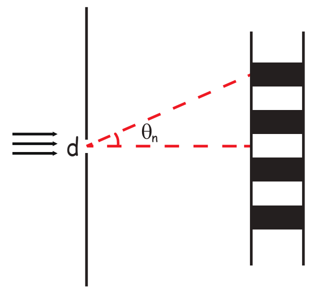
$y = \frac{nD\lambda}{d}$

n = 1,2,3.....



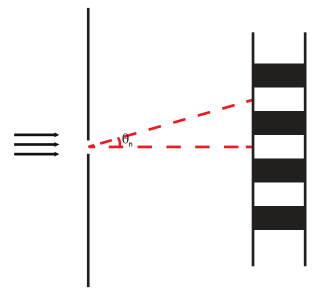
Angular position of N^{th} secondary minima

$\theta n \approx \frac{n\lambda}{d}$

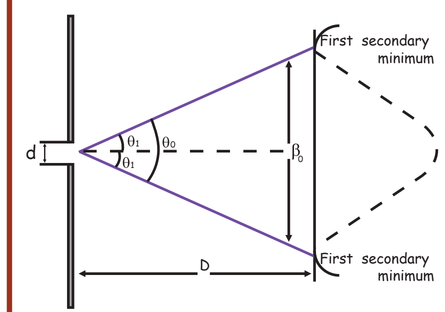


Angular position of N^{th} secondary Maxima

$\theta_n \approx (2n + 1)\frac{\lambda}{2d}$



Angular width and linear width of central maximum



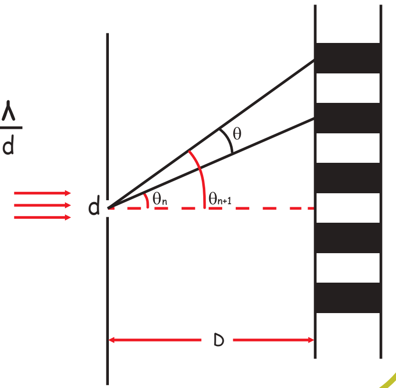
$\beta_0 = \theta_0 D = \frac{2D\lambda}{d}$

Angular width and linear width of secondary maxima

Angular position of n^{th} minimum, $\theta_n = n\frac{\lambda}{d}$

Angular position of $n+1^{th}$ minimum, $\theta_{n+1} = n+1\frac{\lambda}{d}$

Linear width, $\beta = \frac{D\lambda}{d}$



Angular width and Linear width of secondary minima

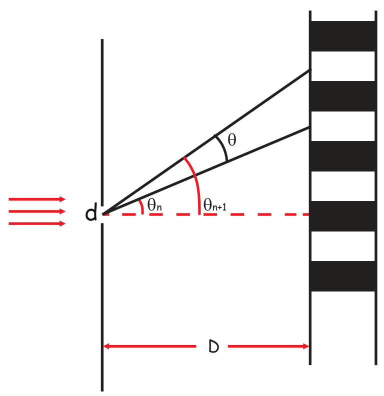
Angular position of n^{th} maximum $\theta_n = (2n+1)\frac{\lambda}{2d}$

Angular position of $(n+1)^{th}$ maximum $\theta_{n+1} = (2(n+1)+1)\frac{\lambda}{2d}$

$\theta = \frac{\lambda}{d}$

Linear width $\beta = \theta D$

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



Validity of Ray Optics: Fresnel's Distance

$Z_F = \frac{d^2}{\lambda}$

Resolving Power (R.P) of a microscope

$\frac{1}{d} = \frac{2n \sin\theta}{\lambda}$

Resolving Power

$R.P = \frac{1}{\text{limit of resolution}}$

Resolving power of a telescope

$R.P = \frac{1}{d\theta} = \frac{D}{1.22\lambda}$

Law of Malus

$I \propto \cos^2\theta$

$I = I_0 \cos^2\theta$

When $\theta = 0^0$ or 180^0, $\cos\theta = \pm 1 \Rightarrow I = I_0$

When $\theta = 90^0$, $\cos\theta = 0 \Rightarrow I = 0$

Polarisation by Reflection

Brewster found that at the polarising angle ,the reflected and transmitted rays are perpendicular to each other

$n = \tan i_p$

This is Brewster's Law

DUAL NATURE OF RADIATION & MATTER

PHYSICS WALLAH

Photon Theory

- Intensity (I) $= \frac{Power}{Area} = \frac{E}{tA}$

= energy per unit area per unit time

Point source $I = \frac{P}{4\pi r^2} \Rightarrow I \propto \frac{1}{r^2}$

Line source $I = \frac{P}{2\pi r l} \rightarrow I \propto \frac{1}{r}$

① no.of Photons

$E = n\,h\nu \Longrightarrow n = \frac{E}{h\nu} = \frac{E\lambda}{hC}$

② no.of Photons per unit time

$\frac{n}{t} = \frac{E}{th\nu} = \frac{P}{h\nu} = \frac{IA}{h\nu} = \frac{IA\lambda}{hc}$

③ no.of Photons per area per unit time

$\frac{n}{At} = \frac{E}{tAh\nu} = \frac{P}{Ah\nu} = \frac{I}{h\nu} = \frac{I\lambda}{hc}$

- Power of incident radiation (P)

$P = \frac{nthc}{\lambda}$ $\quad P \propto \left(\frac{n}{\lambda}\right)$

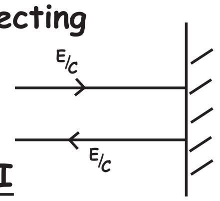
source1 $P_1 \rightarrow \lambda_1 \rightarrow n_1$

source1 $P_2 \rightarrow \lambda_2 \rightarrow n_2$

$\frac{P_1}{P_2} = \frac{n_1}{n_2} \times \frac{\lambda_2}{\lambda_1}$

Dual Nature of Radiation

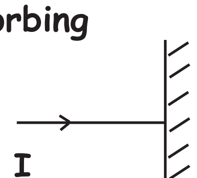
- Momentum of photon (p) $= \frac{E}{c} = \frac{h}{\lambda}$
- Force (F) $= \frac{\Delta p}{\Delta t}$
- Radiation Pressure $= \frac{F}{A}$
- For perfectly reflecting surface



$\Delta p = \frac{2E}{c}$ $\quad F = \frac{2P}{c}$

Rad. Pressure $= \frac{2I}{C}$

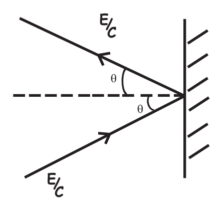
- For Perfectly Absorbing Surface



$\Delta p = \frac{E}{c}$ $\quad F = \frac{P}{c}$

Rad. Pressure(P_R) $= \frac{I}{C}$

- Perfectly Reflecting at an angle



$\Delta p = \frac{2E}{C}\cos\theta$

$F = \frac{2P}{C}\cos\theta$

Rad. Pressure $= \frac{2I}{C}\cos\theta$

PHOTOELECTRIC EFFECT

Energy of photon $E = h\nu$

- ν = Frequency of incident light in Hz $= \frac{c}{\lambda}$

Max.kinetic energy of emitted photoelectron

- $(K.E)_{max} = E - w = \frac{1}{2}mV^2_{max}$

Work function (w)

- Minimum energy required for photoelectric effect to occur

$w = h\nu_0 = h\frac{c}{\lambda_0}$ $\quad h = 6.63\times10^{-34}$ Js

ν_0 = Threshold frequency in Hz

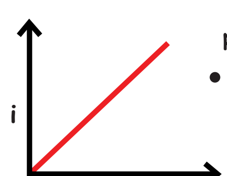
λ_0 = Threshold wavelength in m

- Work function only depends on nature of metal

Factors affecting photoelectric effect

- Intensity

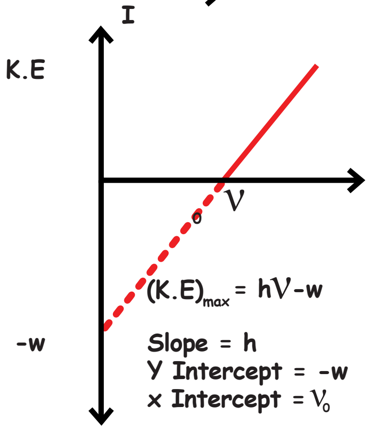
Intensity ↑, photoelectrons ↑, photocurrent ↑ (K.E Remains same)



photocurrent (i) ∝ Intensity (I)

- Frequency

Frequency↑, Energy↑, K.E↑ (Work function Remains same)



$(K.E)_{max} = h\nu - w$

Slope = h

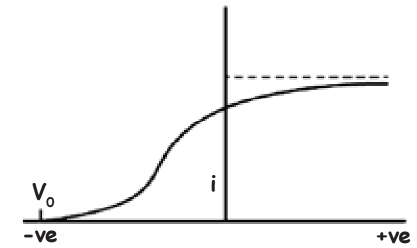
Y Intercept = -w

x Intercept = ν_0

- Anode potential

Opposes K.E of electron

Max Negative anode potential = Stopping potential (V_0) for which Photocurrent (i) = 0



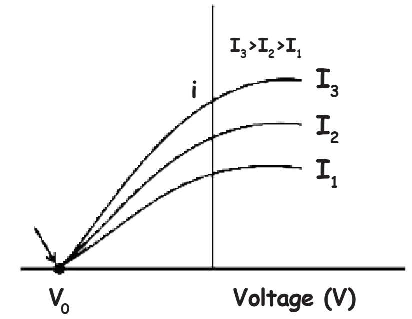
$(K.E)_{max} = eV_0 = \frac{1}{2}mV^2_{max} = h(\nu - \nu_0) = h\left(\frac{c}{\lambda} - \frac{c}{\lambda_0}\right)$

Factors affecting stopping potential

- Intensity (I)

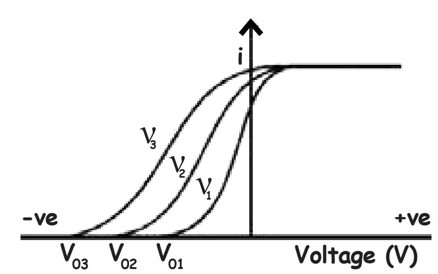
Intensity ↑, K.E Remains same

Stopping potential remains same



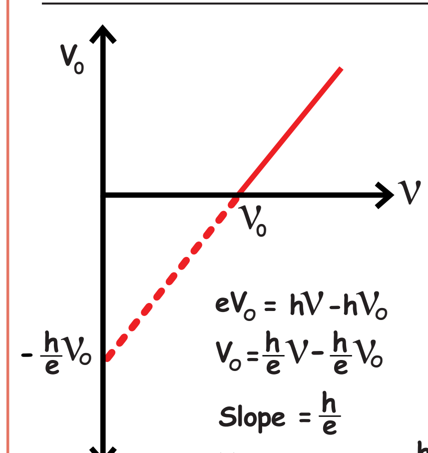
- Frequency

Frequency↑, Energy↑, K.E↑, V_0↑



$\nu_3 > \nu_2 > \nu_1 \longrightarrow V_{03} > V_{02} > V_{01}$

Stopping potential V_0 vs frequency graph



$eV_0 = h\nu - h\nu_0$

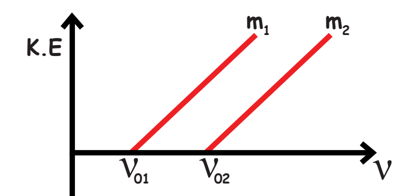
$V_0 = \frac{h}{e}\nu - \frac{h}{e}\nu_0$

Slope $= \frac{h}{e}$

Y Intercept $= -\frac{h}{e}\nu_0$

x Intercept $= \nu_0$

- Nature of material



for same energy E

$\nu_{02} > \nu_{01}$

$w_{02} > w_{01}$

$K.E_2 < K.E_1$

$V_{02} < V_{01}$

- Conceptual question

If green color have just sufficient energy for photoelectric effect

increasing order of λ

V	I	B	G	Y	O	R

$\underbrace{V\ I}_{\text{sure photo electric effect}}$ $\quad \overbrace{G}^{E}$ $\quad \overbrace{Y\ O\ R}^{\text{no photo electric effect}}$

E↑ λ↓ ν↑

Useful conversions

- Wave Length (nm) ⟶ K.E (eV)

$K.E = \frac{1240}{\lambda}$ (eV)

- Wave Length (Å) ⟶ K.E (eV)

$K.E = \frac{12400}{\lambda}$ (eV)

- Two Identical photo cathode recieve light of frequencies f_1 & f_2. If velocity of photo elecrons are v_1 & v_2 then $v_1^2 - v_2^2 = \frac{2h}{m}[f_1 - f_2]$

Dual Nature of Matter

Wave nature of Matter

Debroglie waves

fast moving particles like electron with much smaller mass behaves like a wave ie., Circular stationary waves

$E = mc^2 = \frac{hc}{\lambda}$

$\lambda = \frac{h}{mc} \rightarrow \lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2m(K.E)}} = \frac{h}{\sqrt{3kmT}} = \frac{h}{\sqrt{2mqV}}$

K.E = qV (for charged particle)

V = accelerating potential in Volt

$K.E = \frac{3}{2}K_BT$ (thermal neutron)

K_B = Boltzmann's constant

T = Temperature in Kelvin

- Thermal Neutron

$\lambda = \frac{h}{\sqrt{3mk_BT}} = \frac{30.83}{\sqrt{T}}$ Å

- Electron $\lambda = \frac{12.27}{\sqrt{V}}$ Å
- Proton $\lambda = \frac{0.286}{\sqrt{V}}$ Å
- Deutron $(\lambda) = \frac{0.202}{\sqrt{V}}$ Å
- ∝ -Particle $(\lambda) = \frac{0.101}{\sqrt{V}}$ Å

^1H (Proton) ⟶ 1 Proton ⟶ m,q

^2H (Deuteron) ⟶ 1 Proton + 1Neutron ⟶ 2m,q

^4_2He (∝-Particle) ⟶ 2 Proton+2 Neutron ⟶ 4m,2q

Relationship b/w wavelength of photon & that of electron

- Ratio of wavelength of photon to that of electron with same energy E

$\frac{\lambda_{photon}}{\lambda_e} = c\sqrt{\frac{2m}{E}}$ $\quad \lambda_{photon} \propto \lambda_e^2$

- Ratio of K.E of electron to that of photon with same wavelength

for Same $\frac{K.E_e}{K.E_{photon}} = \frac{V}{2C}$

- A particles formed due to completely inelastic collision of particle 'x' and 'y' having debroglie wave length λx and λy respectively.

If they are moving in opposite directions

$p = p_x - p_y$ $\quad \overrightarrow{P_x} \quad \overleftarrow{P_y}$

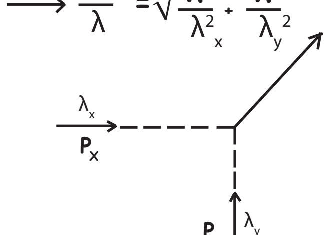
then

$\frac{h}{\lambda} = \frac{h}{\lambda_x} - \frac{h}{\lambda_y}$ $\quad \lambda = \frac{\lambda_x\lambda_y}{\lambda_x - \lambda_y}$

- If they are moving at right angle to each other

$\Rightarrow p = \sqrt{p_x^2 + p_y^2} \longrightarrow \frac{h}{\lambda} = \sqrt{\frac{h^2}{\lambda_x^2} + \frac{h^2}{\lambda_y^2}}$

$\frac{1}{\lambda} = \sqrt{\frac{1}{\lambda_x^2} + \frac{1}{\lambda_y^2}}$



ATOMS

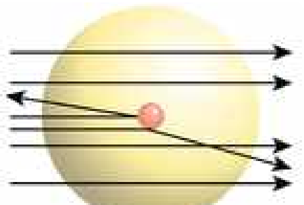
PHYSICS WALLAH

RUTHERFORD'S ATOM MODEL

i) Majority of α - particles passed without any deviation.

ii) Some are scattered at small angle θ (impact parameter is equal to that of nuclear radius)

iii) Only few alpha particle retrace the path (impact parameter = 0)

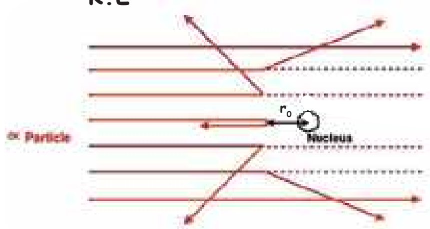


DISTANCE OF CLOSEST APPROACH OF α-PARTICLES

$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{4Ze^2}{mv^2}$

$r_0 \alpha \frac{1}{m}$ $\quad r_0 \alpha \frac{1}{v^2}$

$r_0 \alpha \frac{1}{K.E}$ $\quad r_0 \alpha Z_1 Z_2$

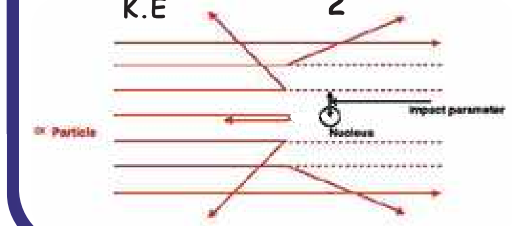


IMPACT PARAMETER

$b = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2\cot\frac{\theta}{2}}{\frac{1}{2}mv^2}$

$b \alpha \frac{1}{m}$ $\quad b \alpha \frac{1}{v^2}$

$b \alpha \frac{1}{K.E}$ $\quad b \alpha \cot\frac{\theta}{2}$



BOHR ATOM MODEL

First postulate

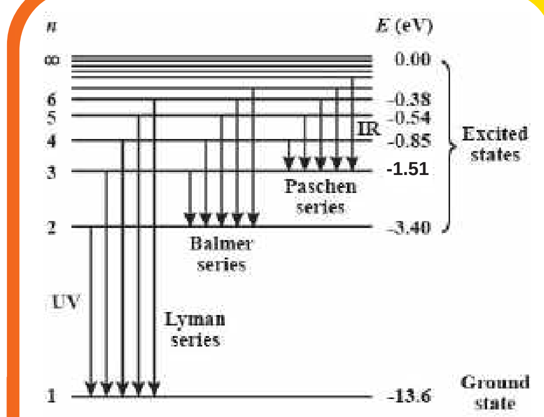
$F = \frac{1}{4\pi\varepsilon_0}\frac{Ze \times e}{r^2}$

Second postulate

$mvr = \frac{nh}{2\pi}$

$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2}$

- RADIUS OF ORBIT $\quad r_n = 0.53\frac{n^2}{Z}$
- VELOCITY OF ELECTRON $\quad v_n \alpha \frac{Z}{n}$
- TIME PERIOD $\quad T \alpha \frac{n^3}{z^2}$
- FREQUENCY $\quad = \frac{1}{T} \alpha \frac{z^2}{n^3}$
- CURRENT $\quad = \frac{e}{T} \alpha \frac{z^2}{n^3}$
- MAGNETIC FIELD $\quad B \alpha \frac{v}{r^2} \Rightarrow B \alpha \frac{z^3}{n^5}$
- MAGNETIC DIPOLE MOMENT $\quad M \alpha n$



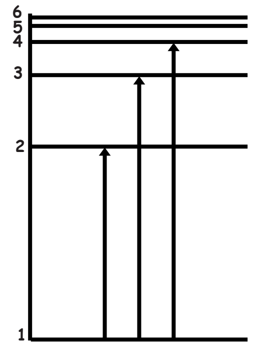
As the n value increases, the energy difference betwen adjacent level decreases

$5\to1 > 4\to1 > 3\to1 > 2\to1 > > 4\to2 > 3\to2$

$E_{max} \propto \lambda_{min} \propto V_{max}$

HYDROGEN SPECTRUM

Absorption spectrum



Electrons absorb only those photons whose energy =Energy difference of 2 shells

If atomic excitation takes place upto n^{th} shell starting from ground state then (n-1)different photons are absorbed

ENERGY

Total energy $= -13.6\frac{z^2}{n^2}$eV

$K.E = -T.E = +13.6\frac{z^2}{n^2}$eV

$P.E = 2T.E$

λ_{max}

E_{min} (first line)

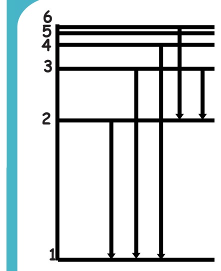
$\lambda_{max} = \frac{n^2(n+1)^2}{(2n+1)R}$

λ_{min}

E_{max} (Last line/ Series Limit)

$\lambda_{min} = \frac{n^2}{R}$

EMISSION SPECTRUM



Total no. of different wavelength photons in emission spectrum $= \frac{n(n-1)}{2}$

All absorbed photons are emitted in emission spectrum

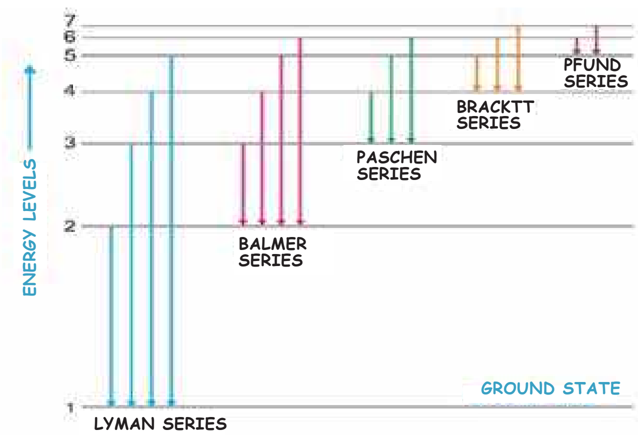
Wavelength of emitted photon

$\bar{V} = \frac{1}{\lambda} = R Z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ $\quad R \approx 10^5\ cm^{-1}$

$R \approx 10^7\ m^{-1}$

$\frac{1}{R} = 91nm = 910Å$

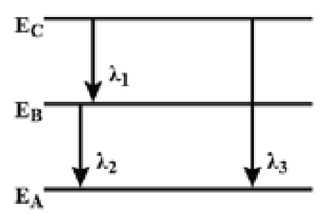
LINE SPECTRUM OF HYDROGEN ATOM



LINE SPECTRUM OF HYDROGEN ATOM

Spectral series	n_1	n_2	Wavelength	λ_{max} $(n_2=n_1+1)$	λ_{min} $(n_2=\infty)$	$\frac{\lambda_{max}}{\lambda_{min}}$	Region	Range
Lyman	1	2,3,4	$\frac{1}{\lambda_{Ly}} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$	$\frac{4}{3R}$	$\frac{1}{R}$	$\frac{4}{3}$	Ultra - violet	911.6 Å to 1216 Å
Balmer	2	3,4,5	$\frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$	$\frac{36}{5R}$	$\frac{4}{R}$	$\frac{9}{5}$	Visible	3646 Å to 6563 Å
Paschen	3	4,5,6	$\frac{1}{\lambda_P} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$	$\frac{144}{7R}$	$\frac{9}{R}$	$\frac{16}{7}$	Near infar-red	8204 Å to 18753 Å
Brackett	4	5,6,7	$\frac{1}{\lambda_{Br}} = R\left(\frac{1}{4^2} - \frac{1}{n^2}\right)$	$\frac{400}{9R}$	$\frac{16}{R}$	$\frac{25}{9}$	Middle infra-red	14585 Å to 40515 Å
Pfund	5	6,7,8	$\frac{1}{\lambda_{Pf}} = R\left(\frac{1}{5^2} - \frac{1}{n^2}\right)$	$\frac{900}{11R}$	$\frac{25}{R}$	$\frac{36}{11}$	Far infra-red	22790 Å to 74583 Å

Energy levels A,B & C of a certain atom correspond to increasing values of energy, i.e. $E_A < E_B < E_C$. If $\lambda_1, \lambda_2, \lambda_3$ are the wavelengths of radiations corresponding to transitions C to B, B to A and C to A respectively then



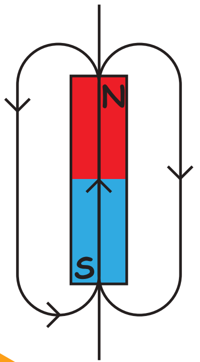
a) $\lambda_3 = \lambda_1 + \lambda_2$ $\quad$ c) $\lambda_1 + \lambda_2 + \lambda_3 = 0$

b) $\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$ $\quad$ d) $\lambda_3^2 = \lambda_1^2 + \lambda_2^2$

PHYSICS WALLAH

MAGNETISM AND MATTER

THE MAGNETIC FIELD LINES



1. The magnetic field lines of a magnet form continous closed loops
2. The tangent to the field lines at a given point represents the direction of the net magnetic field B at that point
3. The larger no. of field lines $\longrightarrow$ stronger $\vec{B}$
4. Do not intersect

CUTTING OF BAR MAGNET

LENGTHWISE / TRANSVERE

$\longleftarrow l \longrightarrow$

$l/2$ $l/2$

Pole strength $\longrightarrow$ same

length $\longrightarrow$ reduce to half

$M_{new} = \frac{ml}{2}$

HORIZONTAL

$\longleftarrow l \longrightarrow$

Pole strength $\longrightarrow$ reduce to half

length $\longrightarrow$ same

$M_{new} = \frac{ml}{2}$

FACTS

A) Magnetic monopoles does not exist
B) A solenoid and bar magnet produce similar magnetic fields

POTENTIAL AT ANY GENERAL POINT

$V = \frac{1}{4\pi\varepsilon_0}\frac{P\cos\theta}{r^2}$ $\qquad$ $V_m = \frac{\mu_0}{4\pi}\frac{M\cos\theta}{r^2}$

TORQUE

1) $F_{net} = 0$ $\qquad$ 1) $(F_m)_{net} = 0$

2) $\vec{\tau} = \vec{p}\times\vec{E} = pE\sin\theta$ $\qquad$ 2) $\vec{\tau} = \vec{M}\times\vec{B} = MB\sin\theta$

WORK DONE IN ROTATING A DIPOLE

1. $W = PE\,(\cos\theta_1 - \cos\theta_2)$ $\qquad$ 1. $W_B = MB\,(\cos\theta_1 - \cos\theta_2)$

Maximum work done is from $\theta_1 = 0^\circ$ to $\theta_2 = 180^\circ$

POTENTIAL ENERGY

$U = -\vec{P}.\vec{E}$ $\qquad$ $U_B = -\vec{M}.\vec{B}$

$\theta_1 = 0^\circ$ Stable position; $\theta = 180^\circ$ Unstable position

APPARENT ANGLE OF DIP

Inclination of magnetic needle in plane other than magnetic meridian

$\tan\delta' = \frac{\tan\delta}{\cos\theta}$

δ' Apparent angle of dip
δ true angle of dip
θ Angle between MM and the plane other than MM

RELATION BETWEEN TWO FALSE ANGLE OF DIPS (δ_1&δ_2) IN MUTUALLY PERPENDICULAR PLANES AND TRUE ANGLE OF DIP (δ)

$\cot^2\delta_1 + \cot^2\delta_2 = \cot^2\delta$

MAGNETIC DIPOLE MOMENT ($\vec{M}$)

$\vec{\ell}$ S N $\vec{M}$

$\vec{M} = m\vec{l}$
m $\rightarrow$ pole strength
l $\rightarrow$ Straight line distance b/w poles

Direction from southpole to N pole

Unit of M $\rightarrow$ Am^2
Unit of m $\rightarrow$ Am

THE ELECTROSTATIC ANALOG

(Help from electrostatics to magnetism)

SHORT ELECTRIC DIPOLE

'q' $\vec{p}$ d

$\vec{p} = q\,\vec{d}$

SHORT MAGNETIC DIPOLE

'm' l S N $\vec{m}$

$\vec{M} = m\,\vec{l}$

COULOMB'S LAW

$\vec{F}$ q_1 r q_2 $\vec{F}$

$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

$\vec{F}_m$ m_1 r m_2 $\vec{F}_m$

$F_m = \frac{\mu_0}{4\pi}\frac{m_1m_2}{r^2}$

AXIAL & EQUITORIAL LINE OF DIPOLE

$E_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2P}{r^3}$ $\qquad$ $B_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2M}{r^3}$

$E_{eq} = \frac{1}{4\pi\varepsilon_0}\frac{P}{r^3}$ $\qquad$ $B_{eq} = \frac{\mu_0}{4\pi}\frac{M}{r^3}$

$\vec{E}_{axial} = -2\vec{E}_{eq}$ $\qquad$ $\vec{B}_{axial} = -2\vec{B}_{eq}$

MAGNETISM AND GAUSS' LAW

"The net magnetic flux through any closed surface is zero"

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

NOTE: "The simplest magnetic element is a magnetic dipole or a current loop." Magnetic monopoles do not exist.

BAR MAGNET TO DIFFERENT SHAPES

l S N $\longrightarrow$ S l' θ N

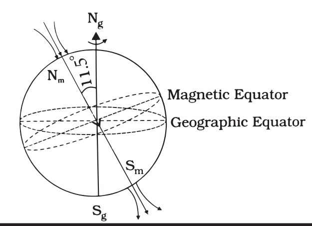
$M_{new} = \frac{M\sin(\frac{\theta}{2})}{(\frac{\theta}{2})}$ $\qquad$ $l' = \frac{l\sin(\frac{\theta}{2})}{(\frac{\theta}{2})}$

RESULTANT DIPOLE MOMENT

M_2 θ M_1

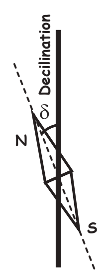
$M_{net} = \sqrt{M_1^2 + M_2^2 + 2M_1M_2\cos\theta}$

THE EARTH'S MAGNETISM



MAGNETIC ELEMENTS OF EARTH

Magnetic declination $-\delta$



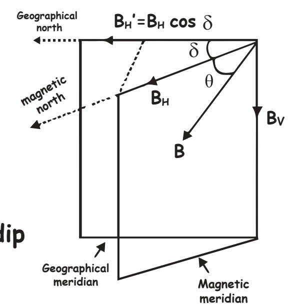
Angle between geographic meridian & magnetic meridian (MM)

Inclination or Dip $-\theta$

True angle of dip

$\tan\theta = \frac{B_V}{B_H}$

Horizontal component $- B_H$



FACTS

1. Declination is greater at poles and smaller near equator
2. Angle of dip is maximum at poles and minimum at equator

COMPASS NEEDLE AND DIP NEEDLE

1. A compass needle at the North pole can point along any direction.
2. A dip needle at the north pole points down and at South pole points straight up.

TIME PERIOD

of a magnetic dipole in uniform magnetic field

$T = 2\pi\sqrt{\frac{I}{MB}}$

I - Moment of Inertia of the body
M - Magnetic dipole moment
B - Magnetic field

Frequency $\nu = \frac{1}{2\pi}\sqrt{\frac{MB}{I}}$

To find B, $B = \frac{4\pi^2 I}{MT^2}$

Magnetism

MAGNETIC PROPERTIES

1) Magnetic Permeability

Absolute Permeability of air or free space: $\mu_0 = 4\pi \times 10^{-7} \dfrac{\text{Tesla metre}}{\text{Ampere}} \left[\dfrac{Tm}{A}\right]$

Relative Permeability of medium: $\mu_r = \dfrac{\mu_{medium}}{\mu_0}$

2) Intensity of magnetizing field ($\vec{H}$)

$\vec{H} = \dfrac{B_{ext}}{\mu_0}$ vector quantity

SI unit $\rightarrow \dfrac{A}{M}$ CGS unit $\rightarrow$ Oersted

3) Magnetisation ($\vec{M}$)

$\vec{M} = \dfrac{\vec{M}_{net}}{V} \rightarrow \left[\dfrac{\text{Induced dipole moment}}{\text{volume}}\right]$ also, $\vec{M} = \dfrac{\vec{B}_{ind}}{\mu_0}$

vector quantity

SI unit $\rightarrow \dfrac{A}{m}$ $[M] \rightarrow [L^{-1}A]$

4) Magnetic Susceptibility (χ_m)

$\chi_m = \dfrac{M}{H}$ Also $\chi = \dfrac{B_{ind}}{B_{ext}}$

scalar quantity
no unit
no dimension

5) Relation between relative permeability and susceptibility

$\mu_r = (1+\chi_m)$ Also $\mu = \mu_0\mu_r = \mu_0(1+\chi_m)$

6) Relation between B, M and H

$B = \mu_m H$ $M = \chi H$

MAGNETIC MATERIALS

1. Diamagnetic

a. Weakly repelled by a magnet
b. Eg: Cu, Ag, Au, NaCl, H_2O etc.
c. Superconductors - Perfect conductivity
perfect diamagnetism
$\chi = -1, \mu_r = 0$
d. Perfect diamagnetism in superconductors is called as MEISSNER EFFECT
e. Important

$$\boxed{\begin{array}{l} -1 \le \chi < 0 \\ 0 \le \mu_r < 1 \\ \mu < \mu_0 \end{array}}$$

f. Individual atoms do not possess permanent magnetic dipole moment
g. No effect of temperature on magnetisation

2. Paramagnetic substances

a. Weakly attracted by a magnet
b. Eg : Al, Mn, Pt, Na, $CuCl_2$, O_2, Crown glass
c. Individual atom possesses permanent dipole moment
d. Curie's law
Magnetisation of a paramagnetic material is inversely proportional to the absolute temperature

$$\left.\begin{array}{l} M = C\dfrac{B_0}{T} \\ \chi = C\dfrac{\mu_0}{T} \end{array}\right\} \text{Curie's law}$$

e. Important

$$\boxed{\begin{array}{l} 0 < \chi < \varepsilon \\ 1 < \mu_r < 1+\varepsilon \ (\varepsilon \rightarrow \text{Small positive number}) \\ \mu > \mu_0 \end{array}}$$

f. Graph

3. Ferromagnetic substances

a. Strongly attracted by a magnet
b. Eg : Fe, Co, Ni, Cd, Fe_3O_4
c. Individual atoms possess permanent magnetic moment and magnetic moments of neighbouring atoms tend to align due to a force called exchange coupling
d. Due to exchange coupling, atoms form domains inside which magnetic moments are aligned in the same direction
e. Important

$$\boxed{\begin{array}{l} \chi >>> 1 \\ \mu_r >> 1 \\ \mu >> \mu_0 \end{array}}$$

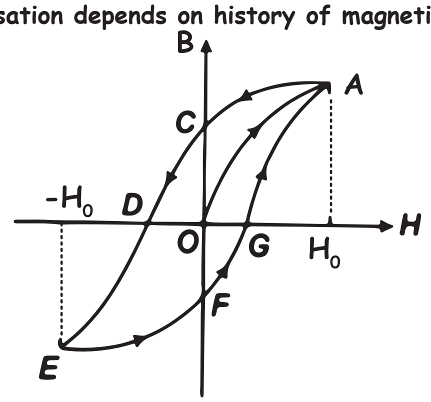
f. At high temperature, a ferromagnetic substance becomes paramagnetic

Curie's temperature

$\chi = \dfrac{C}{T-T_c}$ $(T > T_c)$

HYSTERESIS CURVE / B-H CURVE

Magnetisation depends on history of magnetisation



Important terms
Retentivity - OC - Residual magnetism
Coercivity -OD-Demagnetising process
1. High coercivity - Hard substance - Steel
2. Low coercivity - Soft substance - Soft iron

Important result
B-H curve signifies the energy loss/heat loss in the process and is proportional to the area of the loop.

Area of hysteresis loop
- ↗ Smaller for soft iron
- ↘ Higher for steel

Permanent magnets

should have
1. High retentivity
2. High coercivity
3. High permeability

Steel is used for making permanent magnets

Steel	soft iron
Smaller retentivity High coercivity	Higher retentivity than steel Smaller coercivity than steel

ELECTROMAGNETS
Materials should have
high permeability
low retentivity
Soft iron is used

Used in electric bells, Loudspeakers, telephone diaphragms, heavy cranes to lift machinery

PHYSICS WALLAH

SEMICONDUCTORS

EXTRINSIC SEMICONDUCTORS

- Impure semiconductor
- When pure semiconductor material is mixed with small amounts of certain specific impurities with valency different from that of the parent material, the number of mobile electrons or holes drastically changes. This process is called doping

- $n_e \neq n_h$
- $n_e \times n_h = n_i^2$

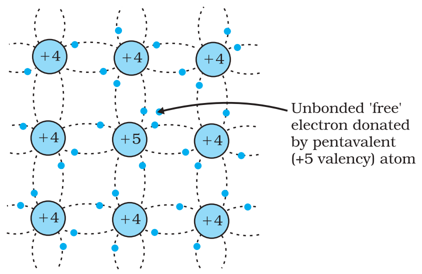
ISC + Impurity → Extrinsic SC

2 TYPES

n Type

Intrinsic semiconductor → Pentavalent Impurity ⇒ N type S C

1) Majority charge carriers - electrons
2) Minority charge carriers - holes
3) n type semiconductor is electrically neutral (not negatively charged)
4) Donor energy level lies just below the conduction band

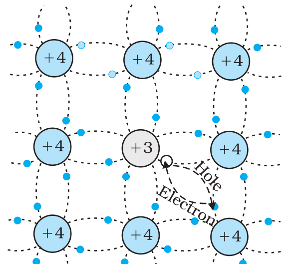


p Type

Intrinsic semiconductor + trivalent Impurity ⇒ P type SC

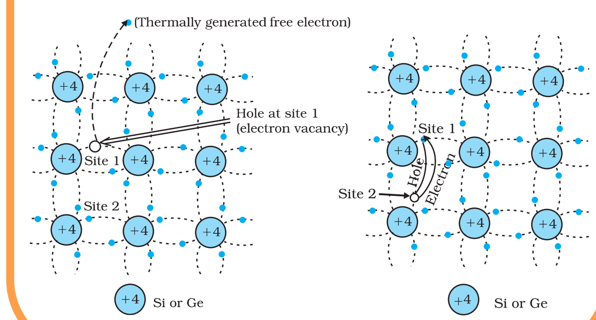
B, Al, Ga, In, Tl

1) Majority charge carriers - holes
2) Minority charge carriers - electrons
3) P type is electrically neutral (not positively charged)
4) Acceptor energy level lies just above the valence band

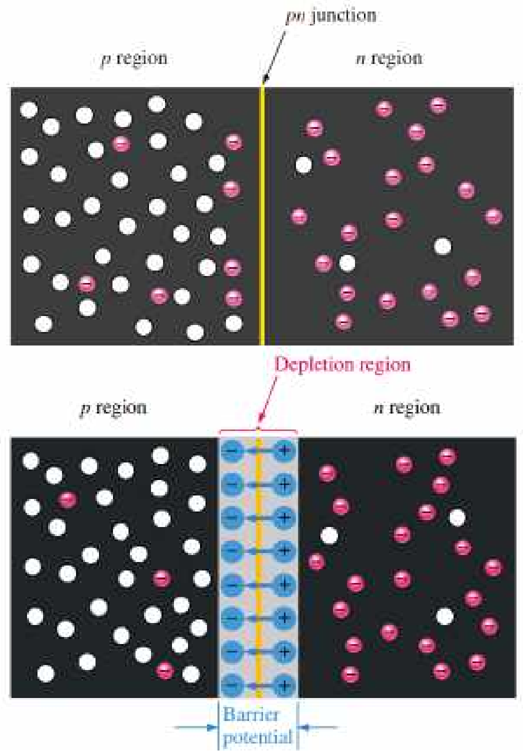


INTRINSIC SEMICONDUCTORS

- Pure semiconductor
- At absolute temperature (0K) conduction band of semiconductor is completely empty and the semiconductor behaves as an insulator.
- As temperature increases, the valence electrons acquire thermal energy to jump into the conduction band (due to breakage of covalent bond)
- when they leave the CB they leave behind the deficiency of electrons in the valence band.
- This deficency of electrons is known as HOLES or cotter
- $n_e = n_h = n_i$



p-n Junction Diode



Depletion layer

Due to diffusion, neutrality of both N and P type semiconductor is disturbed

A layer of negatively charged ions appear near the junction in the p crystals and a layer of positive ions appear near the Junction in n crystals

This layer is called depletion layer

1) The thickness of depletion layer is 1 micron = 10^{-6} m
2) Width of depletion layer $\propto \frac{1}{\text{Doping}}$
3) Depletion is directly proportional to temperature
4) The P N junction diode is equivalent to capacitor in which the depletion layer acts as a dielectric

Barrier potential

The potential difference created across the P N junction due to diffusion of electron and holes is called potential barrier

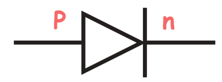
For Ge, V_B = 0.3 V

For Si V_B = 0.7V

Diffusion Current-
Due to flow of majority charge carriers

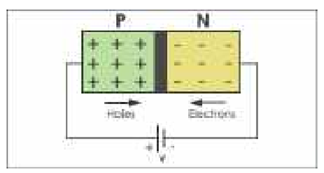
Drift Current -
Due to flow of minority charge carriers

Symbol of p-n Junction Diode

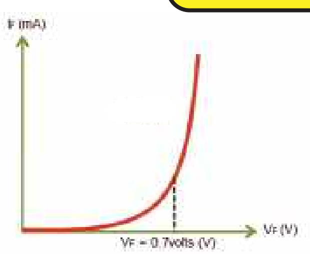


BIASING

Forward biasing



p-side is connected to higher potential and n-side to lower potential.
Forward bias opposes the potential barrier.
In F.B, width of depletion region decreases.
If the applied potential, $V > V_B$, a forward current is set up across the junction.

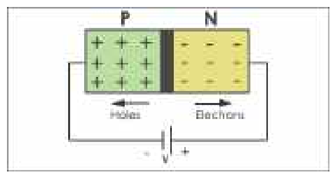


Cut in voltage or knee voltage is the voltage at which current starts to increase rapidly.
It is equal to
V_B For Ge V_B = 0.3V,
Si V_B = 0.7V

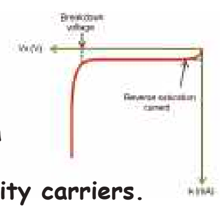
DYNAMIC RESISTANCE

$R_f = \frac{\Delta V}{\Delta I}$

Reverse biasing



p-side is connected to lower potential and n-side to higher potential.
Width of the depletion layer increases.
No current flows through the junction
due to diffusion of majority carriers.
A small current inthe order of μA exists due to drift of minority charge carriers.



BREAKDOWN VOLTAGE

The reverse bias voltage at which breakdown of S.C occurs Eg:- Ge 2.5V , Si 3.5V

Zener Breakdown

- When reverse bias voltage is increased, the electric field at the junction also increases.
- At some stage, electric field becomes so high it can break covalent bond at the junction creating minority charge carriers (e - hole pairs).
- Thus a large no. of charge carriers are generated. This causes a large current flow

Avalanche breakdown

- At high voltage, more minority charge carriers are generated due to breakage of covalent bond by collision of electrons
- Thus more number of charge carriers are generated. A chain reaction is established giving rise to even more collisions, thus creating high current.

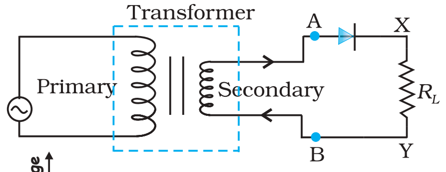
PHYSICS WALLAH

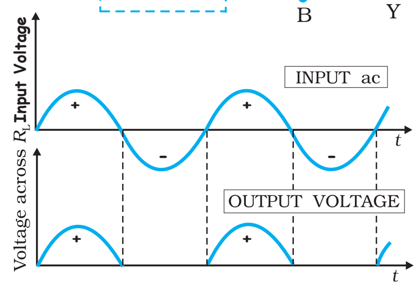
ELECTRONICS

RECTIFICATION

Rectification
- $\frac{1}{2}$ wave rectification-1 Diode
- full wave rectification-2 Diodes

Half wave rectification

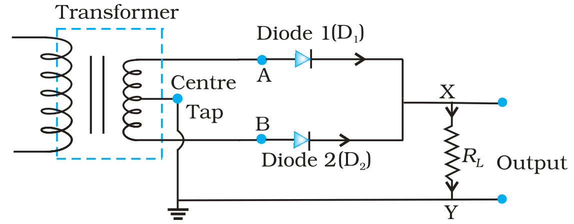


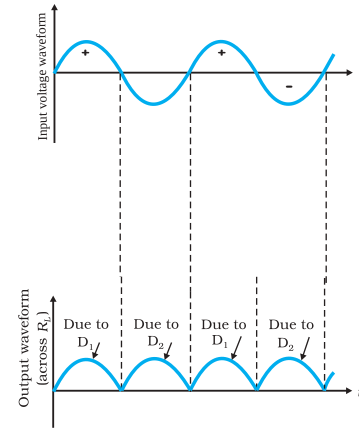


- Rectifies half of the AC wave
- In Positive half cycle, diode is forward biased and output signal is obtained
- In Negative half cycle, diode is reverse biased, output signal is not obtained.

Full wave rectification

It uses a center-tap

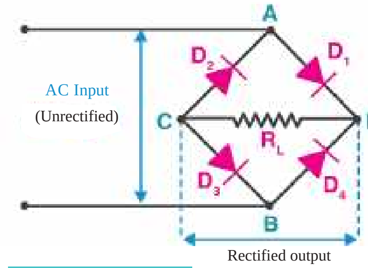




- Positive half cycle diode: D_1- forward bias D_2-Reverse biased
- Negative half cycle, diode: D_1- reverse bias D_2-forward biased

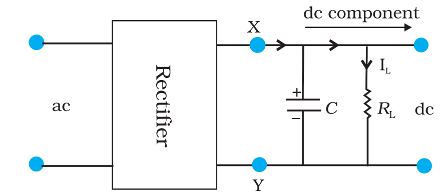
Bridge Rectifier

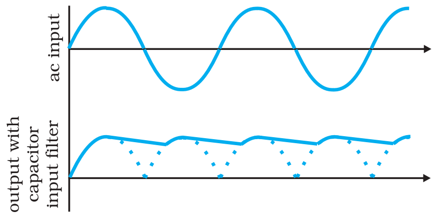
- 4 Diodes & full wave rectification
- Output is taken from diagonal where both the terminals are same



Filter circuit

- Converts rippled DC into pure DC
- Using parallel capacitor method or by series inductor method



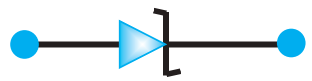


$$AC \xrightarrow{\text{Rectifier}} \text{Rippled DC} \xrightarrow{\text{Filter}} \text{Pure DC}$$

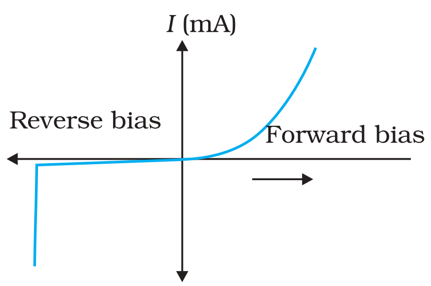
SPECIAL PURPOSE DIODES

Zener diode

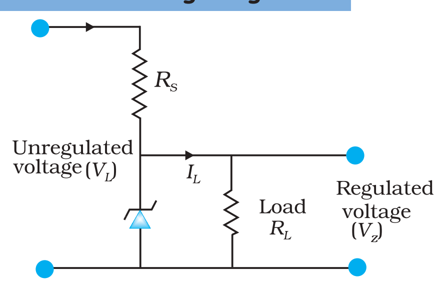
Representation



- Heavily doped p-n junction diode
- Cannot be damaged by high reverse current Always operated in reverse biased condition
- Can operate continuously without being damaged
- Can be used as a voltage regulator (in the region of reverse breakdown voltage)



Zener diode as a voltage regulator

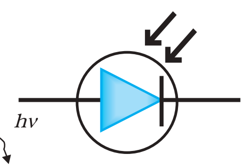


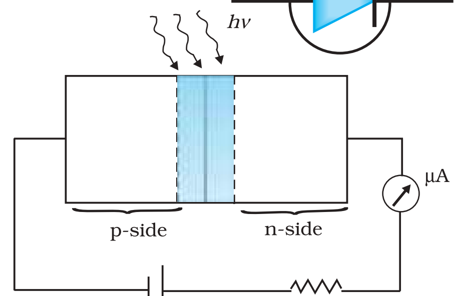
Condition for working, $V > V_z$ V=Applied voltage
V_z=Zener voltage

- Applied voltage will be divided between zener diode and series resistance (R_S)
- Output is obtained from resistance R_L which is connected parallel to zener

Photodiode

Representation

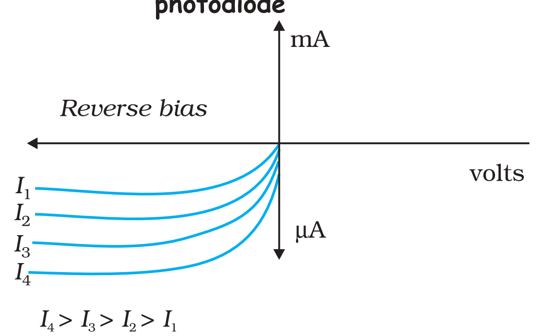




- Special type of photo detector
- Connected in reverse bias
- p-n junction is fabricated from a photosensitive conductor & provided with transparent window
- $h\nu > E_g$, electron hole pairs are generated due to incident light & photo current can be detected in external circuit

$$\lambda(\text{Å}) = \frac{12400}{E_g(eV)}$$

where λ is maximum value of wavelength which can be detected by photodiode



photocurrent increases with increase in light intensity

Light emitting diode

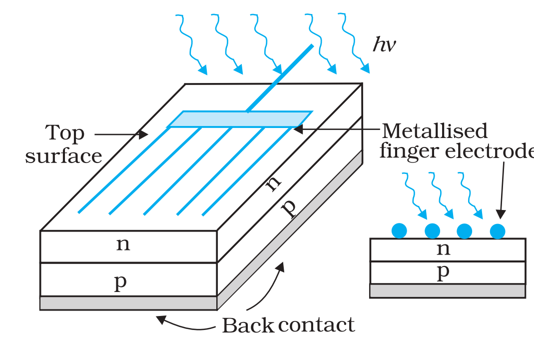
Representation

- Heavily doped; should be connected in forward biased
- Spontaneously converts electrical energy into optical energy
- Recombination of charge carriers at depletion layer results in release of energy in the form of light

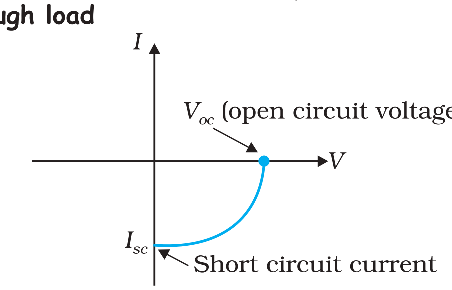
Choices of semi conductor material used in LED:

- λ of visible light ranges from 400-700 nm
- To emit visible light minimum band gap should be 1.8 eV
- Gallium arsenide phosphate (GaAsP) - 1.9 eV (Red light)
- Gallium arsenide -1.5 eV (Infrared)

Solar cell



- Diode is unbiased
- Charge carriers are formed by breaking of covalent bond when light falls on depletion region
- p side becomes positive n side becomes negative giving rise to photo voltage
- When external load is connected, photocurrent I_L flows through load



PHYSICS WALLAH

ELECTRONICS

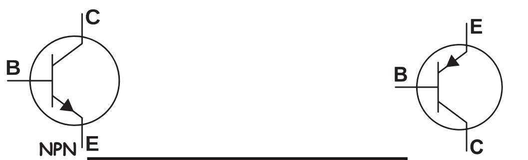
ELECTRONICS

PHYSICS WALLAH

TRANSISTOR

npn — n | p | n

pnp — p | n | p



IT HAS THREE PARTS

EMITTERS

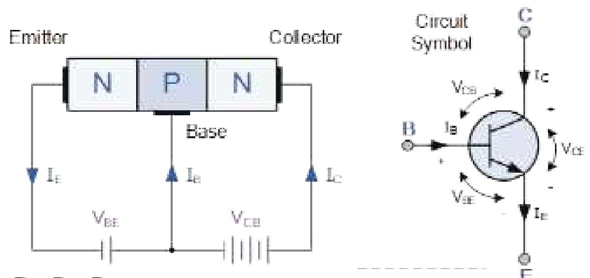
It is a section on one side of the transistor. It is moderate in size and heavily doped. It supplies a large number of majority charge carriers for current to flow through a transistor.

BASE

Very thin and lightly doped.

COLLECTOR

It is on the other side of the transistor. Moderately doped and larger in size as compared to the emitter



$I_E = I_B + I_C$

Action of n-p-n Transistor

emitter-base junction - forward biased
base-collector junction - reverse biased

Forward bias of emitter-base circuit repels the electrons of the emitter towards base

Base is very thin and lightly doped, so very few electrons (less than 5%) are neutralised by the holes giving rise to base current I_B

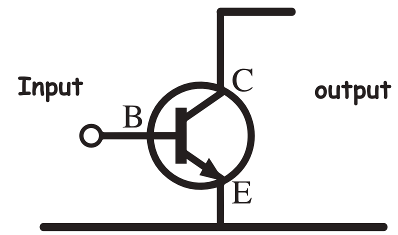
Remaining electrons (greater than 95%) are pulled by the collector which is at higher potential.

The electrons are finally collected by the positive terminal of V_{cc} giving rise to collector current I_c

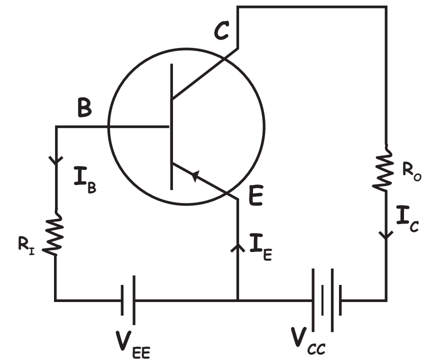
CONFIGURATION OF TRANSISTORS

It is of three types

1 COMMON EMITTER



common emitter

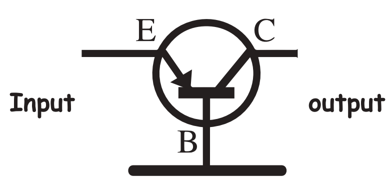


Current gain $\beta = \frac{I_c}{I_B}$

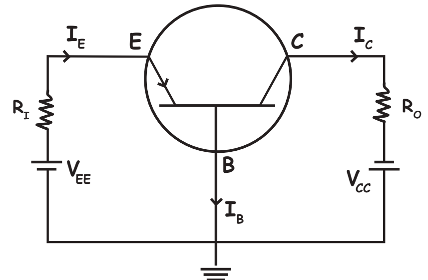
Voltage gain $= \frac{V_o}{V_I} = \frac{I_c R_o}{I_B R_I} = \beta \frac{R_o}{R_I}$

Power gain $= P_g = V_g I_g = \frac{P_{out}}{P_{in}} = \beta \frac{R_o}{R_I} \times \beta = \beta^2 \frac{R_o}{R_I}$

2 COMMON BASE



common base

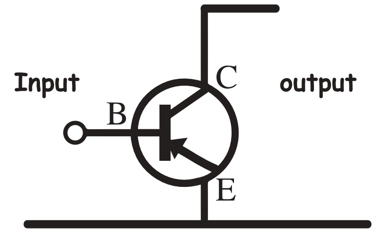


Current gain $\alpha = \frac{I_c}{I_E}$

Voltage gain $= \frac{V_o}{V_I} = \frac{I_c R_o}{I_E R_I} = \alpha \frac{R_o}{R_I}$

Power gain $= P_g = V_g I_g = \alpha^2 \frac{R_o}{R_I}$

3 COMMON COLLECTOR



Common Collector

Current gain $\gamma = \frac{I_B}{I_E}$

RELATIONSHIP BETWEEN α & β

$\alpha = \frac{\beta}{1+\beta}$

$\beta = \frac{\alpha}{1-\alpha}$

TRANSCONDUCTANCE

$T_c = \frac{I_o}{V_I} = \frac{\text{Output current}}{\text{Input voltage}}$

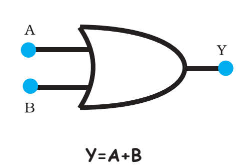
$V_g = \frac{V_o}{V_I} = \frac{I_c \times R_o}{V_I} = T_c \times R_o$

$T_c \propto V_g$

LOGIC GATE

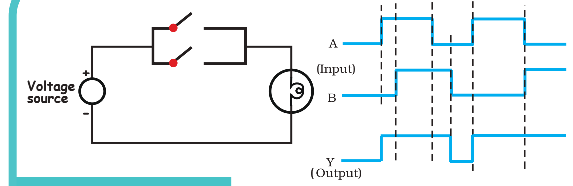
- Principal gates: OR, AND, NOT
- Universal gates: NAND, NOR

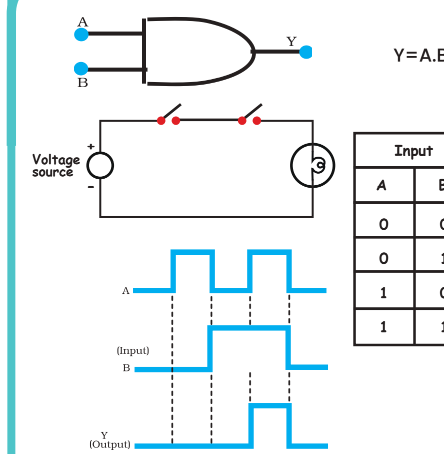
OR GATE



Input		Output
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

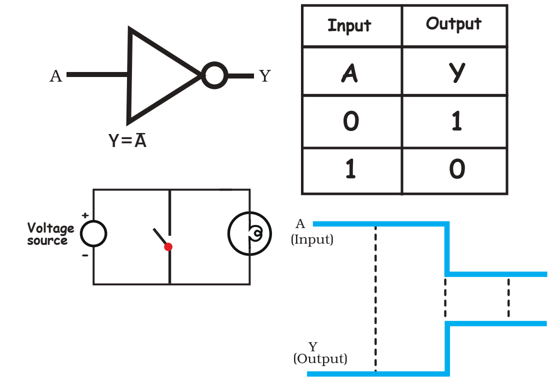
AND GATE





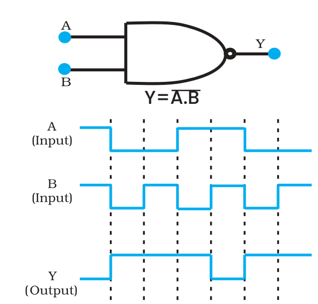
Input		Output
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

NOT GATE



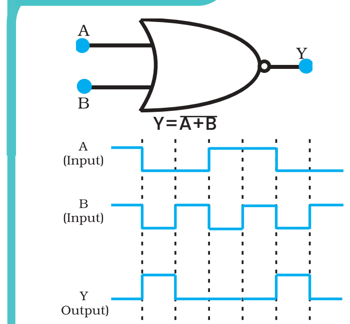
Input	Output
A	Y
0	1
1	0

NAND GATE



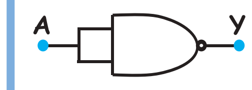
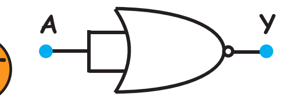
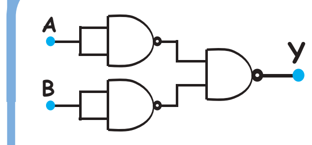
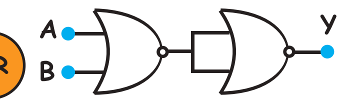
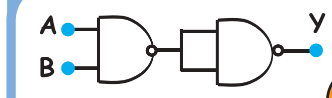
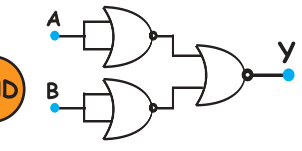
Input		Output
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

NOR GATE



Input		Output
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

REALISATION OF BASIC GATES USING NAND OR NOR GATE

	USING NAND	USING NOR
NOT	 $Y = \overline{A.A} = \bar{A}$	 $Y = \overline{A+A} = \bar{A}$
OR	 $Y = \overline{\bar{A}.\bar{B}} = A+B$	 $Y = \overline{\overline{A+B}} = A+B$
AND	 $Y = \overline{\overline{A.B}} = A.B$	 $Y = \overline{\bar{A}+\bar{B}} = A.B$

BOOLEAN LOGIC

$A+A=A$
$A.A=A$
$A+1=1$
$A.1=A$

$A+0=A$
$A.0=0$
$A.\bar{A}=0$
$A+\bar{A}=1$

$\overline{A+B} = \bar{A}.\bar{B}$
$\overline{A.B} = \bar{A}+\bar{B}$
De-Morgan's law