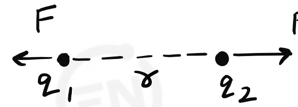
1. ELECTROSTATICS

1. COULOMB'S LAW



$$F = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1q_2}{r^2}\ N$$

$$\frac{1}{4\pi\varepsilon_0} = 9\times10^9\ Nm^2/C^2$$

ε_0 : permittivity of free space
$8.85\times10^{-12}\ C^2/Nm^2$

ε_r : Relative permittivity of medium

$Q = ne^-$, $n \in I$

$e = 1.6\times10^{-19}\ C$

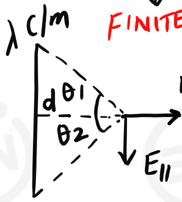
VECTOR Form : $\vec{F}_{21} = \dfrac{Kq_1q_2(\vec{r}_2-\vec{r}_1)}{|\vec{r}_2-\vec{r}_1|^3}$

* Put q_1 and q_2 with sign.

3. ELECTRIC FIELD DUE TO LINE CHARGE

(CHARGE IS UNIFORMLY DISTRIBUTED)

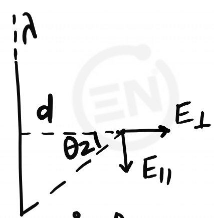
FINITE LENGTH



$$E_\perp = \frac{K\lambda}{d}(\sin\theta_1+\sin\theta_2)$$

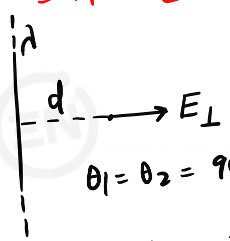
$$E_\parallel = \frac{K\lambda}{d}(\cos\theta_2-\cos\theta_1)$$

SEMI-INFINITE



$\theta_1 = 90^\circ$, θ_2

INFINITE

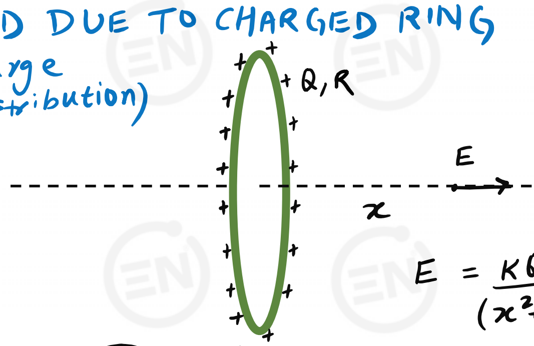


$\theta_1 = \theta_2 = 90^\circ$

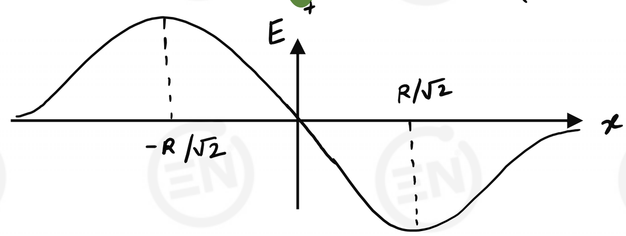
$$E_\perp = \frac{2K\lambda}{d} = \frac{\lambda}{2\pi\varepsilon_0 d}$$

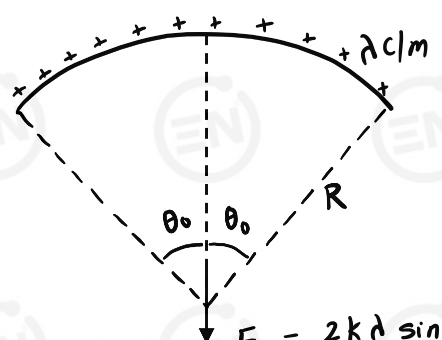
4. ELECTRIC FIELD DUE TO CHARGED RING

(uniform charge Distribution)



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

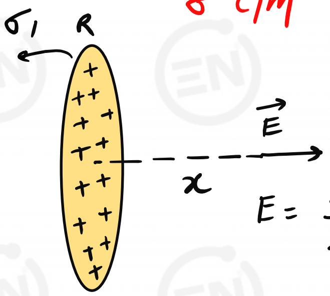




$$E = \frac{2K\lambda}{R}\sin\theta_0$$

5. ELECTRIC FIELD DUE TO CHARGED DISC

$\sigma\ C/m^2$ (UNIFORM CHARGE Distribution)



$$E = \frac{\sigma}{2\epsilon_0}\left(1 - \frac{x}{\sqrt{x^2+R^2}}\right)$$

Case: If Disc is very large ($x << R$)

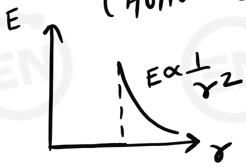
$$\boxed{E = \frac{\sigma}{2\epsilon_0}}$$

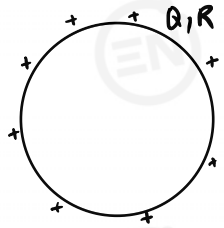
↳ for infinite sheet

6. ELECTRIC FIELD DUE TO CHARGED SPHERE

CONDUCTOR

(Hollow or solid, Q is on surface)



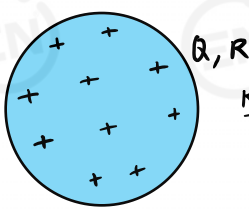


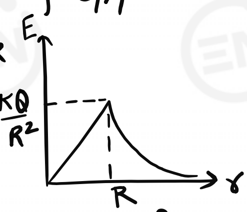
(1) For $r < R$, $E = 0$

(2) For $r \geq R$, $E = \frac{KQ}{r^2}$

NON-CONDUCTOR

(uniformly in solid) $\rho\ C/m^3$



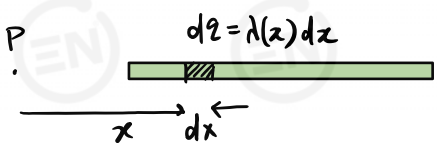


(1) $r < R$, $E = \frac{KQr}{R^3}$ or $\frac{\rho r}{3\epsilon_0}$

(2) $r \geq R$, $E = \frac{KQ}{r^2}$

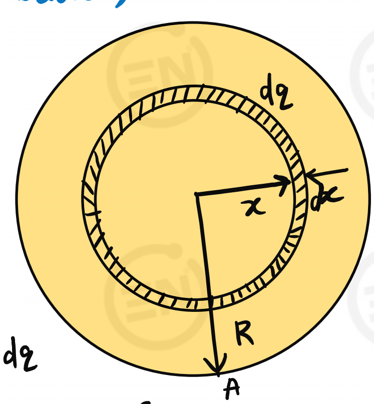
7. ELECTRIC FIELD (Non-UNIFORM CHARGE Distribution)

1.



$$E = \int_a^b \frac{K\lambda(x)\,dx}{x^2}$$

2.

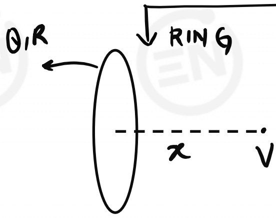


$$E_A = \frac{KQ_{in}}{R^2}$$

$$Q_{in} = \int dq = \int_0^R \rho(x) \times 4\pi x^2\,dx$$

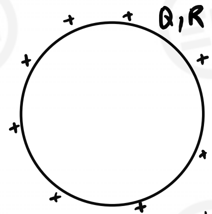
8. ELECTROSTATIC POTENTIAL $V = \frac{Kq}{r}$, put q with sign.

RING



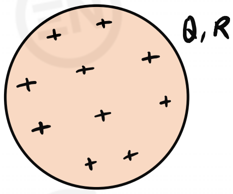
$V = \frac{KQ}{\sqrt{x^2+R^2}}$

SHELL

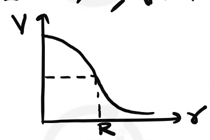


1. $r < R$, $V = KQ/R$
2. $r \geq R$, $V = KQ/r$

SOLID SPHERE



1. $r < R$, $V = \frac{KQ}{2R^3}(3R^2 - r^2)$
2. $r \geq R$, $V = KQ/r$



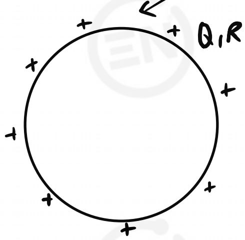
9. ELECTROSTATIC POTENTIAL ENERGY

q_1 • —— r —— • q_2

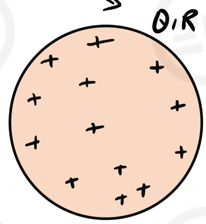
$U = Kq_1q_2/r$

↳ put q_1 and q_2 with sign

SELF ENERGY



$U = \frac{KQ^2}{2R}$



$U = \frac{3KQ^2}{5R}$

10. RELATION BETWEEN E and V

(1.) $\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$

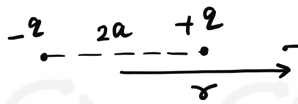
(2.) $\Delta V = -\int \vec{E} \cdot d\vec{r}$

Here $\frac{\partial V}{\partial x}$ means differentiate V w.r.t x keeping y and z constant.

11. ELECTRIC DIPOLE ($-q \; d \; +q$, $P = qd$, direction from -VE to +VE)

(a) ELECTRIC FIELD

AXIAL POINT



$$E = \frac{2PKr}{(r^2-a^2)^2}$$

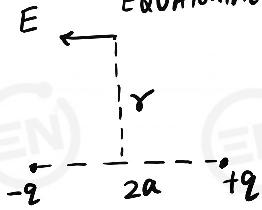
* SHORT DIPOLE ($r >> a$)

$$E_{axial} = 2PK/r^3$$

Direction : Along $\vec{P}$

$P = 2aq$

EQUATORIAL POINT



$$E = \frac{PK}{(r^2+a^2)^{3/2}}$$

* SHORT DIPOLE ($r >> a$)

$$E_{eq} = PK/r^3$$

Dir^n : opp $\vec{P}$

(b) POTENTIAL

AXIAL POINT

$$V = \frac{PK}{r^2-a^2}$$

SHORT DIPOLE ($r >> a$)

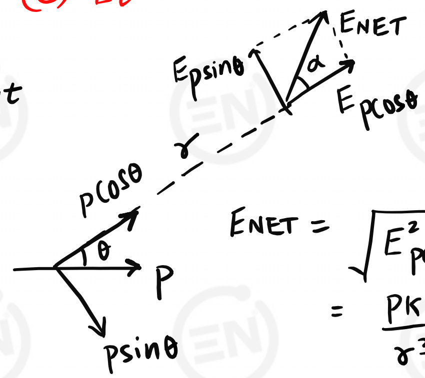
$$V = \frac{PK}{r^2}$$

$P = 2aq$

Equatorial Point

$V = 0$

(c) ELECTRIC FIELD AT GENERAL POINT



$$E_{p\cos\theta} = \frac{2p\cos\theta K}{r^3}$$

$$E_{p\sin\theta} = \frac{p\sin\theta K}{r^3}$$

$$E_{NET} = \sqrt{E^2_{p\cos\theta} + E^2_{p\sin\theta}}$$

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

$$\boxed{\tan\alpha = \frac{\tan\theta}{2}}$$

(d) DIPOLE IN E (uniform)

TORQUE

$\vec{\tau} = \vec{P} \times \vec{E}$

↳ SHM Based Question

Potential Energy

$U = -\vec{P} \cdot \vec{E}$

STABLE ↳ $\theta = 0°$, $U_{min} = -PE$

UNSTABLE ↳ $\theta = 180°$, $U_{max} = PE$

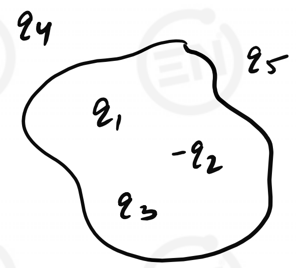
↳ $\theta = 90°$, $U = 0$

12. ELECTRIC FLUX ($\phi = \vec{E} \cdot \vec{A}$)

GAUSS'S LAW

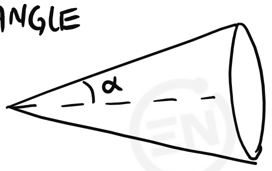
↳ $\oint \vec{E} \cdot d\vec{A} = \dfrac{q_{in}}{\varepsilon_0}$

1. q_{in} : charge enclosed
2. E : Electric field is due to all the charges.

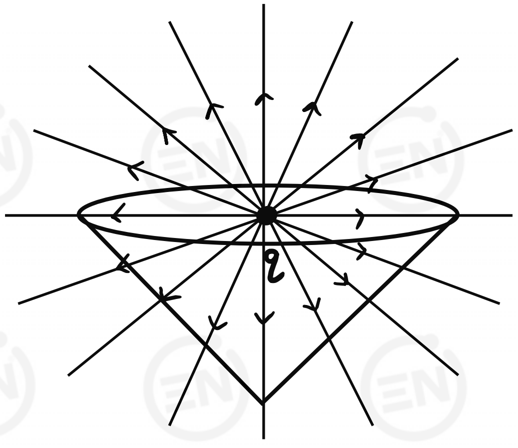


$\phi = \dfrac{q_1 - q_2 + q_3}{\varepsilon_0}$

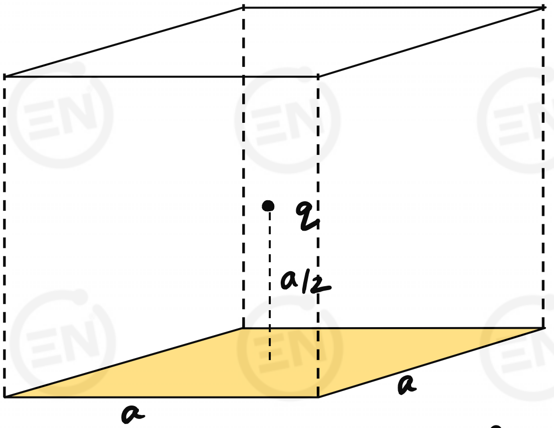
Solid ANGLE



$\Omega = 2\pi(1-\cos\alpha)$



$\phi = \dfrac{q}{2\varepsilon_0}$



$\phi = \dfrac{1}{6} \times \dfrac{q}{\varepsilon_0}$

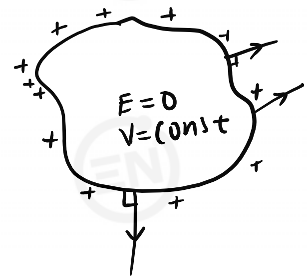
13. CONDUCTOR

(1.) charge remains on surface

(2.) Electric field inside is zero

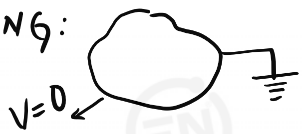
(3.) V is constant

(4.) Field lines are $\perp$ to surface



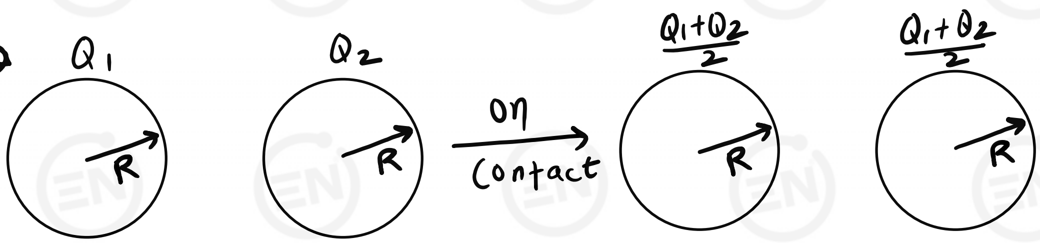
(5.) CONNECTING TWO CONDUCTORS
↳ They share charge untill V of both bodies are same.

(6.) EARTHING:



V of body will always be zero

Tip



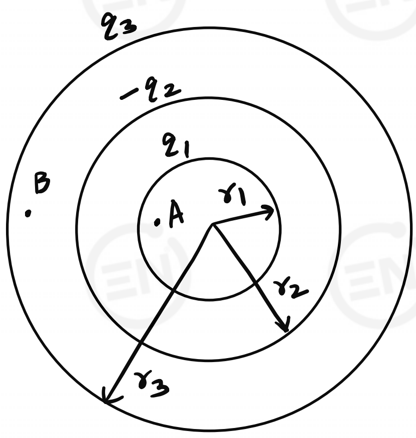
14. How Write E.F. & Potential in Concentric shells

(a) Potential at A, B & C

$$V_A = \frac{Kq_1}{r_1} - \frac{Kq_2}{r_2} + \frac{Kq_3}{r_3}$$

$$V_B = \frac{Kq_1}{r_B} - \frac{Kq_2}{r_B} + \frac{Kq_3}{r_3}$$

$$V_C = \frac{Kq_1}{r_C} - \frac{Kq_2}{r_C} + \frac{Kq_3}{r_C}$$



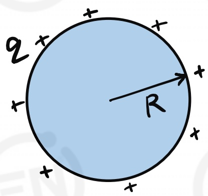
(b) E.F at A, B & C

$$E_A = 0, \quad E_B = \frac{K}{r_B^2}(q_1 - q_2), \quad E_C = \frac{K}{r_C^2}(q_1 - q_2 + q_3)$$

2. CAPACITORS

1. CAPACITANCE (unit: Farad)

ISOLATED SPHERE

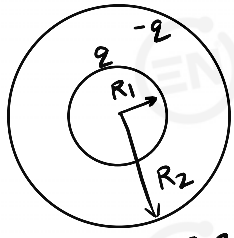


$$C = \frac{q}{V} = \frac{q}{Kq/R}$$

$$C = 4\pi\varepsilon_0 R$$

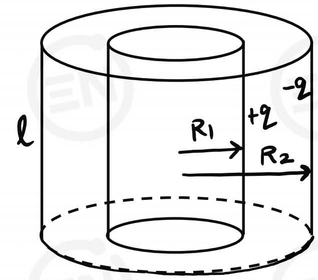
TWO CONDUCTORS

Spherical



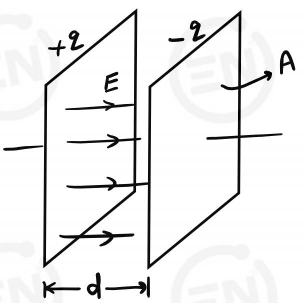
$$C = \frac{4\pi\varepsilon_0 R_1 R_2}{R_2 - R_1}$$

Cylindrical



$$C = \frac{2\pi\varepsilon_0 l}{\ln(R_2/R_1)}$$

2. PARALLEL PLATE CAPACITOR



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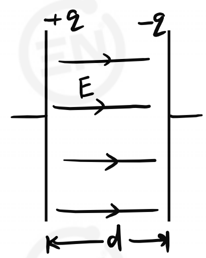
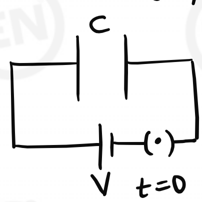


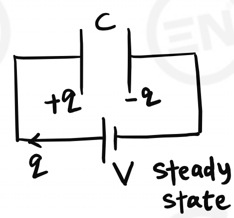
$$C = q/V = q/Ed$$
$$\left(E = \frac{\sigma}{\varepsilon_0} = \frac{q}{A\varepsilon_0}\right)$$

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

3. CHARGE/ENERGY STORED

$W_{battery}$ / HEAT DISSIPATION





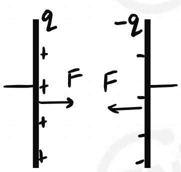
(i) $q = CV$

(ii) $W_b = q_{flown} \times V = CV^2$

(iii) $U = \frac{1}{2}CV^2 \quad \{q^2/2C$

(iv) Heat Dissipated
$= W_b - \Delta U$
$= CV^2 - \frac{1}{2}CV^2 = \frac{1}{2}CV^2$

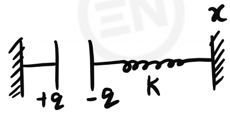
4. FORCE BETWEEN PLATES



$$F = q \times E_{-q} = q \times \frac{q}{2A\varepsilon_0}$$

$$\Rightarrow F = q^2/2A\varepsilon_0$$

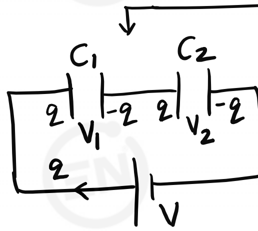
Ex:



x = spring elongation

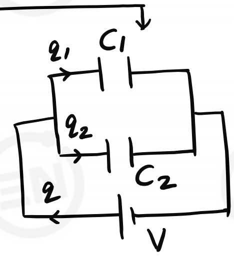
$$\therefore Kx = \frac{q^2}{2A\varepsilon_0}$$

5. COMBINATION OF CAPACITOR



(i) $C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$

(ii) $q = C_{eq} V$

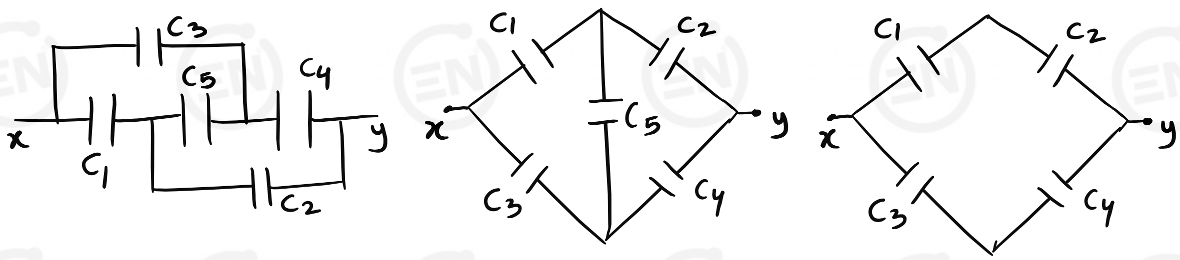


$C_{eq} = C_1 + C_2$

$q_1 = C_1 V, \; q_2 = C_2 V$

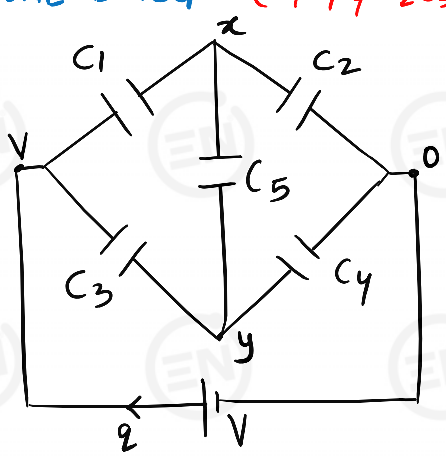
NOTE: (a) n identical capacitor in series, $C_{eq} = C/n$
(b) If in parallel, $C_{eq} = nC$

6. WHEATSTONE BRIDGE (BALANCED)



If $C_1C_4 = C_2C_3$

7. TECHNIQUE FOR UNBALANCED WHEATSTONE BRIDGE ($C_1C_4 \neq C_2C_3$)
(Point Potential + Junction Rule)



At x: $C_1(x-V) + C_5(x-y) + C_2(x-0) = 0$ — (1)

At y: $C_3(y-V) + C_5(y-x) + C_4(y-0) = 0$ — (2)

(a) solve (1) and (2) to find x and y.

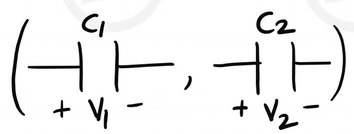
(b) Then we can find q_1, q_2, q_3, q_4 and q_5

(c) $q = q_1 + q_3$

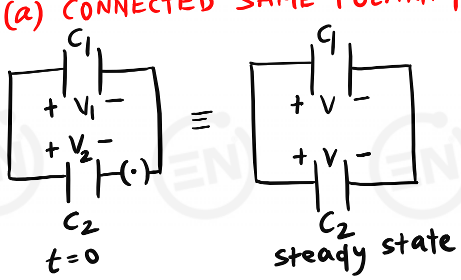
(d) $C_{eq} = \dfrac{q}{V}$

#NOTE : This method can be used to solve any kind of circuit.

8. CHARGE SHARING AND HEAT GENERATED



(a) CONNECTED SAME POLARITY

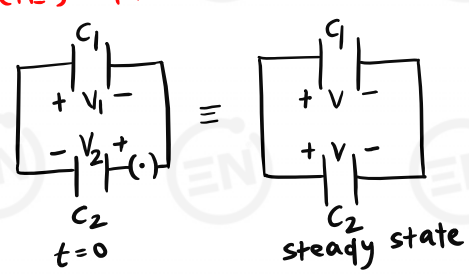


(i) $V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$ (ii) $H = \dfrac{C_1C_2}{2(C_1+C_2)}(V_1 - V_2)^2$

(b) CONNECTED OPPOSITE POLARITY

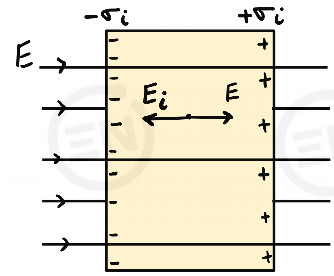
(i) $V = \dfrac{C_1V_1 - C_2V_2}{C_1 + C_2}$

(ii) $H = \dfrac{C_1C_2}{2(C_1+C_2)}(V_1 + V_2)^2$



9. DIELECTRIC IN EXTERNAL ELECTRIC FIELD

- Insulators (gets polarized in E)
- Dielectric constant (K or ε_r)
  - for air/vacuum $K = 1$
  - for metal $K \to \infty$



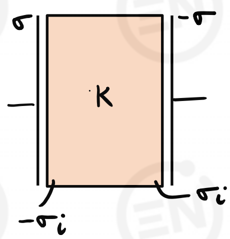
$E_{net} = E - E_i$

$\Rightarrow \frac{E}{K} = E - \frac{\sigma_i}{\varepsilon_0}$

$\Rightarrow \sigma_i = \varepsilon_0 E\left(1 - \frac{1}{K}\right)$

Induced charge density, $\sigma_i = \frac{Q_i}{A}$

10. SLAB IN CAPACITOR



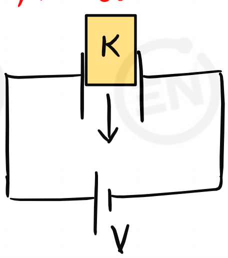
(i) $C = K A \varepsilon_0 / d$

(ii) $\sigma_i = \sigma\left(1 - \frac{1}{K}\right)$

$Q_i = Q\left(1 - \frac{1}{K}\right)$

11. EFFECT OF INSERTING DIELECTRIC IN CAPACITOR

(a) At constant V (Battery connected)



(i) $C \to KC$ ($C\uparrow$)

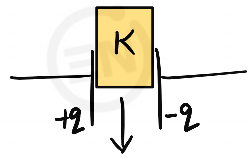
(ii) $q \to Kq$ ($q\uparrow$)

(iii) V is const.

(iv) E is const. $\left(E = \frac{V}{d}\right)$

(v) $U \to KU$ ($U\uparrow$) $\left(U = \frac{1}{2}CV^2\right)$

(b) At constant charge (Battery removed)



(i) q is const.

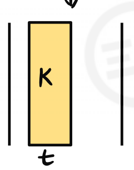
(ii) $C \to KC$ ($C\uparrow$)

(iii) $V \to \frac{V}{K}$ ($V\downarrow$) $(V = q/C)$

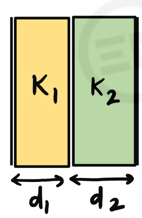
(iv) $E \to E/K$ ($E\downarrow$)

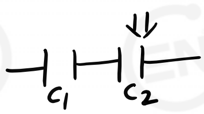
(v) $U \to U/K$ ($U\downarrow$) $U = \frac{q^2}{2C}$

12. CAPACITANCE FOR MULTIPLE DIELECTRIC MEDIUM

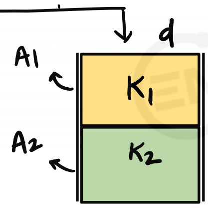


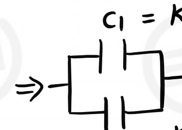
$C = \frac{A\varepsilon_0}{d - t + t/K}$





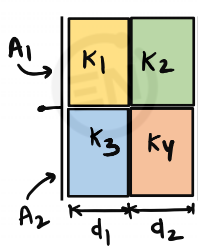
$C_1 = \frac{K_1 A \varepsilon_0}{d_1}$, $C_2 = \frac{K_2 A \varepsilon_0}{d_2}$

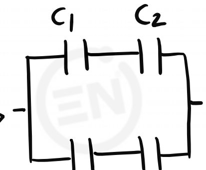




$C_1 = \frac{K_1 A_1 \varepsilon_0}{d}$

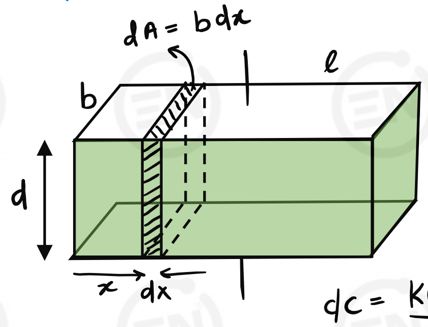
$C_2 = K_2 A_2 \varepsilon_0 / d$





13. CAPACITANCE WITH VARIABLE K

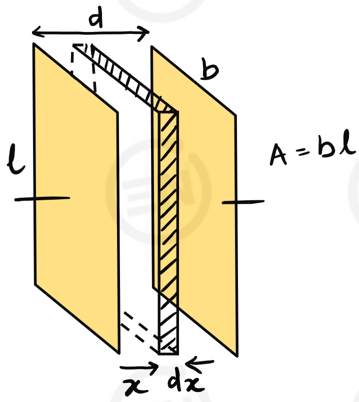
(a)



$$dC = \frac{K(x)\, b\, dx\, \varepsilon_0}{d}$$

$$\Rightarrow C = \frac{b\varepsilon_0}{d}\int_0^{l} K(x)\,dx$$

(b)

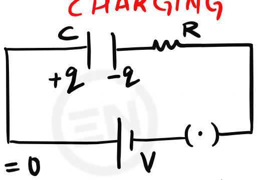


$$dC = \frac{K(x)\, A\, \varepsilon_0}{dx}$$

$$\Rightarrow \frac{1}{C} = \int \frac{1}{dC} = \frac{1}{A\varepsilon_0}\int_0^{d} \frac{dx}{K(x)}$$

15. RC, CHARGING AND DISCHARGING

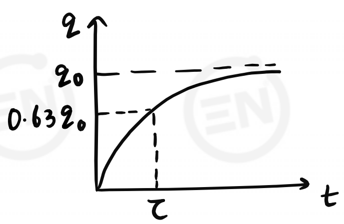
CHARGING



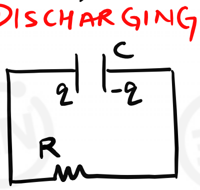
At $t=0$, $q=0$

At $t=t$, $q = q_0(1-e^{-t/RC})$ $\quad q_0 = CV$

$RC = \tau$, time const.

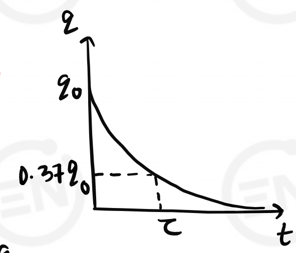


DISCHARGING



at $t=0$, $q = q_0$

at $t=t$, $q = q_0 e^{-t/RC}$



NOTE:

(1.) At $t=0$, capacitor behaves as conducting wire

(2) At steady state it acts as open circuit.

3. CURRENT ELECTRICITY

1. CHARGE FLOW

$$q_{flown} = \int_{t_1}^{t_2} i(t)\,dt$$

Ex: $i(t) = 2\sin 50\pi t$

$i(t) = 3t^2$

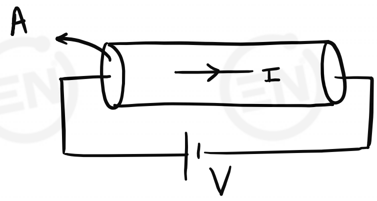
2. IMPORTANT CURRENT PARAMETERS

→ DRIFT VELOCITY, $V_d = \frac{eE\tau}{m}$

"τ" Relaxation time (avg time elapsed between two collisions)

→ $I = neAV_d$

n: no of free e^- per unit volume



→ MOBILITY (m^2/Vs), $\mu = \frac{V_d}{E} = \frac{eE\tau/m}{E} = \frac{e\tau}{m}$

→ CURRENT DENSITY (A/m^2), $J = I/A \Rightarrow I = \vec{J}\cdot\vec{A}$

$\boxed{E = \rho J}$ ρ: Resistivity

3. RESISTANCE $\left(R = \frac{m}{ne^2\tau}\frac{l}{A}\right)$, ohm (Ω)

R DEPENDS ON:

→ $R \propto l$

→ $R \propto 1/A$

→ If temperature increases, Resistance also increases. $\left\{ \rho = \frac{m}{ne^2\tau}, \text{ If } T\uparrow \Rightarrow R\uparrow \right.$

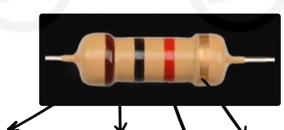
→ For SEMICONDUCTORS If $T\uparrow \Rightarrow R\downarrow$

For small variation in temp$^\circ$

$R_{T_2} = R_{T_1}(1+\alpha\Delta T)$,

$\rho_{T_2} = \rho_{T_1}(1+\alpha\Delta T)$

4. COLOUR CODE

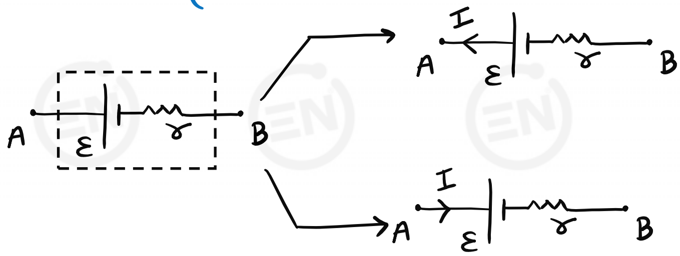


$R = 10 \times 10^2 \pm 5\%$

Resistor colour codes

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

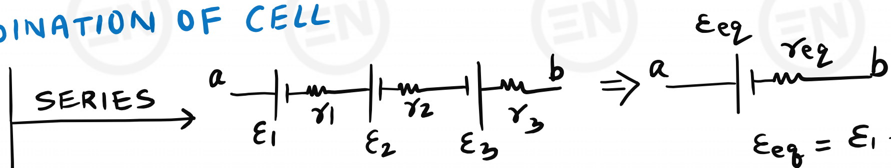
5. CELL (Emf, Internal Resistance)



$V_{AB} = \varepsilon - Ir$, Work done by battery

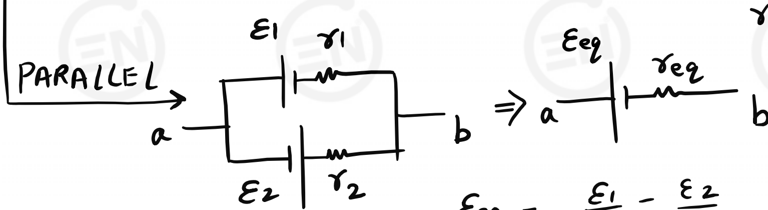
$V_{AB} = \varepsilon + Ir$, Work done on the battery (charging)

6. COMBINATION OF CELL



$\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2 - \varepsilon_3$

$r_{eq} = r_1 + r_2 + r_3$



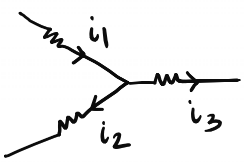
$$\varepsilon_{eq} = \frac{\frac{\varepsilon_1}{r_1} - \frac{\varepsilon_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}}, \quad \frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2}$$

7. KIRCHHOFF'S LAW (KVL and KCL)

KVL → LOOP RULE

KCL → JUNCTION RULE

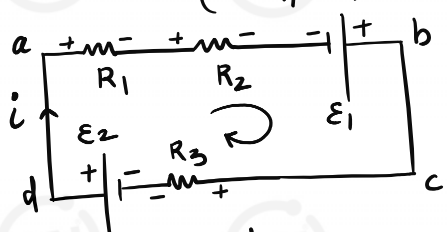
KCL ($\Sigma i_n = 0$)



$i_1 - i_2 - i_3 = 0$

(i towards junction is taken +VE)

KVL ($\Sigma V_n = 0$) In a Loop

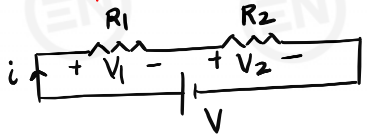


In Loop abcda

$iR_1 + iR_2 - \varepsilon_1 + iR_3 - \varepsilon_2 = 0$

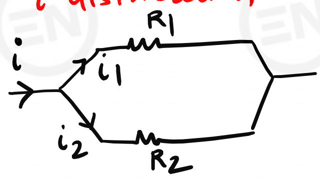
8. CIRCUIT ANALYSIS MORE TECHNIQUES

p.d. distribution



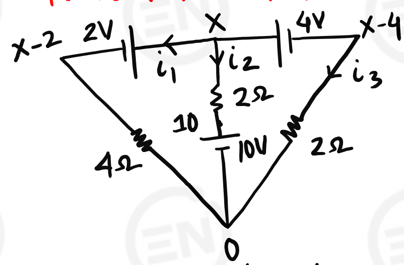
$$V_2 = \frac{VR_2}{R_1+R_2}, \quad V_1 = \frac{VR_1}{R_1+R_2},$$

i distribution



$$i_1 = \frac{iR_2}{R_1+R_2} \quad i_2 = \frac{iR_1}{R_1+R_2}$$

Point Potential Method

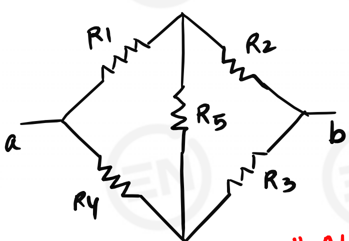


$$i_1 + i_2 + i_3 = 0$$

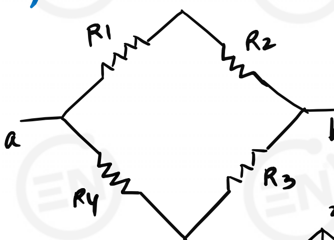
$$\Rightarrow \frac{x-2}{4} + \frac{x-10}{2} + \frac{x-4}{2} = 0$$

$$x = 6V$$

10. WHEATSTONE BRIDGE (BALANCED)

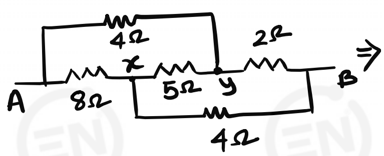


If $R_1R_3 = R_2R_4$ $\rightarrow$

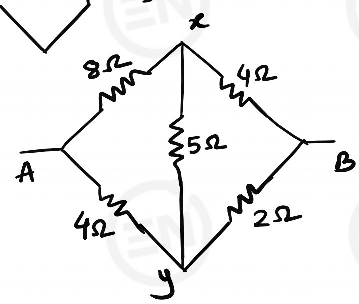


$$\left\{ \frac{R_1}{R_2} = \frac{R_4}{R_3} \right\}$$

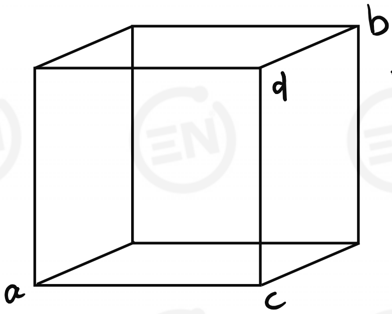
Alternative fig.



$\Rightarrow$



11. CUBE RESISTORS

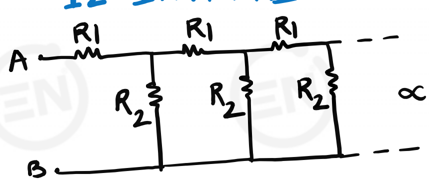


$\rightarrow R_{eq,ab} = 5R/6$ (body diagonal)

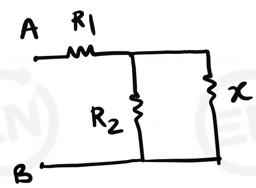
$\rightarrow R_{eq,ac} = 7R/12$ (edge)

$\rightarrow R_{eq,ad} = 3R/4$ (face diagonal)

12. INFINITE LADDER



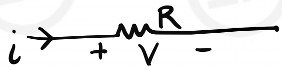
$\Rightarrow$



$$\underbrace{R_{AB}}_{x} = R_1 + \frac{xR_2}{x+R_2}$$

13. THERMAL EFFECT OF CURRENT (JOULES HEATING EFFECT)

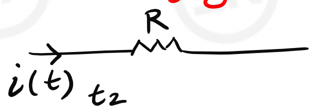
CONSTANT CURRENT



$P = i^2 R = \frac{V^2}{R} = Vi$ (Watt)

$H = i^2 R t = \frac{V^2}{R} t = Vit$ (Joules)

Time Varying Current

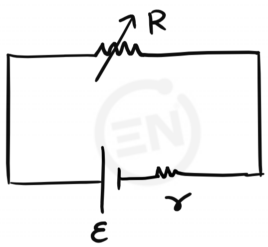


$H = \int_{t_1}^{t_2} i^2 R\, dt$

$P_{av} = \frac{\int i^2 R\, dt}{\int dt}$

Ex: $i(t) = i_0 \sin \omega t$

14. MAX POWER TRANSFER THEOREM



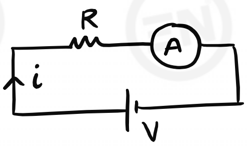
CONDITION: $\boxed{R = r}$

for maximum power transfer, External resistance must be equall to internal resistance.

16. GALVANOMETER TO AMMETER AND VOLTMETER

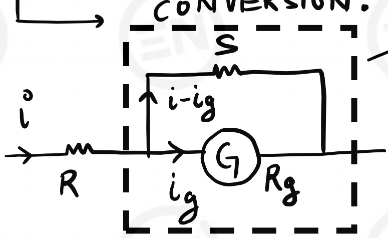
(a) AMMETER

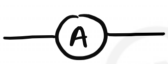
→ connected in series



→ IDEAL AMMETER has zero resistance (Practically it has very low resistance)

→ CONVERSION:





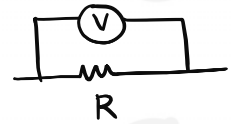
(i) i_g is max current that can pass through G for full deflection

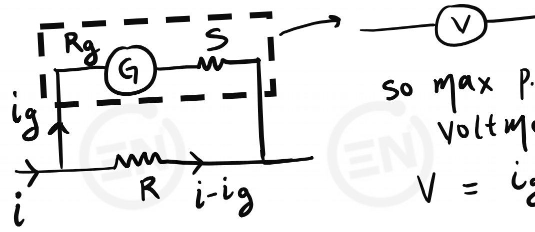
(ii) $(i - i_g) S = i_g R_g \Rightarrow i = i_g\left(1 + \frac{R_g}{S}\right)$

(b) Voltmeter

→ Connected in parallel

→ IDEAL VOLTMETER has infinite Resistance (Practically it has very resistance)

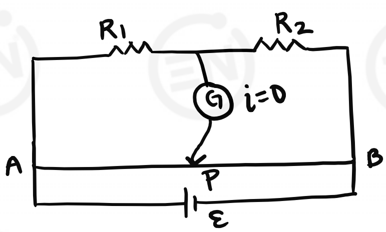




so max p.d. measured by voltmeter is,

$$V = i_g(R_g + S)$$

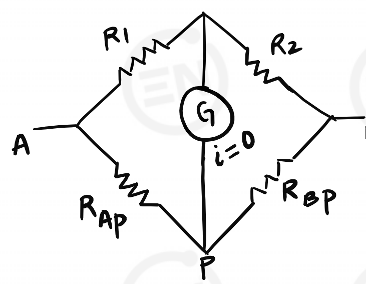
17. METER BRIDGE



$AP = l_1$

$BP = l_2$

⇒



$$\frac{R_1}{R_2} = \frac{R_{AP}}{R_{BP}}$$

$$\Rightarrow \boxed{\frac{R_1}{R_2} = \frac{l_1}{l_2}}$$

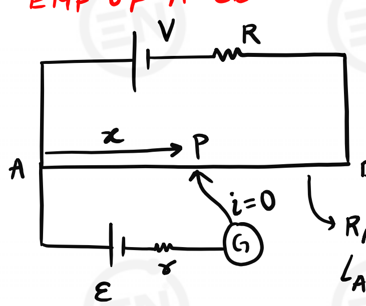
or

$$R_2 = R_1 \times \frac{l_2}{l_1}$$

18. POTENTIOMETER

→ Potential gradient (K) : $K = \frac{p.d.}{l}$ V/m

(a) FINDING EMF OF A CELL



$R_{AB} = R_0$

$L_{AB} = l_0$

(ii) $K = V_{AB}/l_0$, $V_{AB} = \frac{VR_0}{R_0 + R}$

(iii) $\varepsilon = V_{AP}$

$$\Rightarrow \boxed{\varepsilon = kx}$$

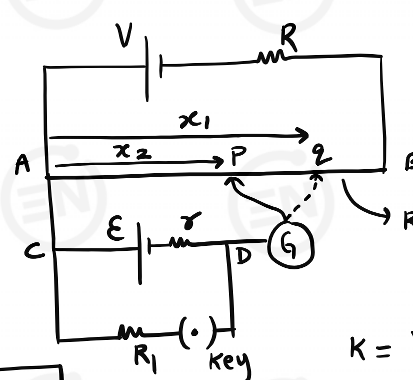
(b) FINDING Internal resistance (r)

(i) When key is open: (Null deflection at Q)

$\varepsilon = kx_1$ ---- (1)

(ii) When key is closed (Null deflection at P)

$V_{CD} = kx_2 \Rightarrow \frac{\varepsilon R_1}{R_1 + r} = kx_2$ --- (2)



$R_{AB} = R_0$

$L_{AB} = l_0$

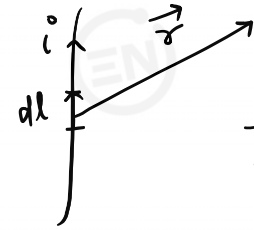
$K = V_{AB}/l_0$

$= \left(\frac{VR_0}{R + R_0}\right)\frac{1}{l_0}$

(1)/(2) : $\frac{R_1 + r}{R_1} = \frac{x_1}{x_2} \Rightarrow \boxed{r = R\left(\frac{x_1 - x_2}{x_2}\right)}$

4. MEC & MOVING CHARGES

1. BIOT SAVART'S LAW

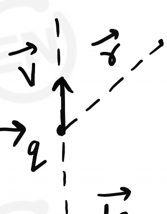


$$\otimes\ \vec{dB} = \frac{\mu_0}{4\pi}\frac{i(\vec{dl}\times\vec{r})}{r^3}$$

→ direction of $\vec{dB}$ is decided by dir^n of $\vec{dl}\times\vec{r}$.

→ μ_0 : Permeability of free space $4\pi\times10^{-7}\ Tm/A$

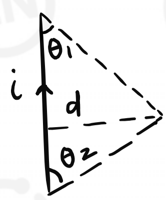
→ $\vec{dl}$ is along current



$$\vec{dB} = \frac{\mu_0}{4\pi}\frac{q(\vec{V}\times\vec{r})}{r^3}$$

2. B DUE TO CURRENT CARYING STRAIGHT WIRE

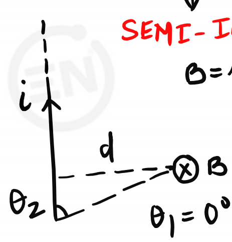
FINITE WIRE



$$\otimes\ B = \frac{\mu i}{4\pi d}(\cos\theta_1 + \cos\theta_2)$$

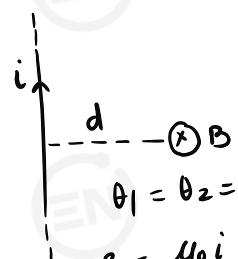
SEMI-INFINITE WIRE

$$B = \frac{\mu_0 i}{4\pi d}(1+\cos\theta_2)$$



$\theta_1 = 0°$

INFINITE WIRE

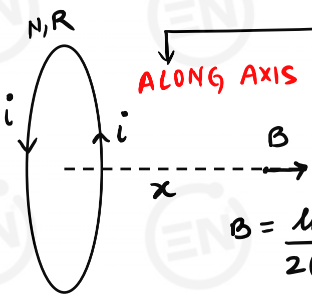


$\theta_1 = \theta_2 = 0°$

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

3. B DUE TO CURRENT CARYING CIRCULAR WIRE

ALONG AXIS



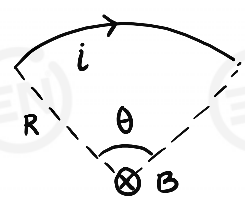
$$B = \frac{\mu_0 i R^2 N}{2(R^2+x^2)^{3/2}}$$

N: No of turns

AT CENTER

$$B = \frac{\mu_0 i N}{2R}$$

AT CENTER DUE TO ARC



$$B = \frac{\mu_0 i}{2R}\times\frac{\theta}{2\pi}$$

4. B DUE TO SOLENOID AND TOROID

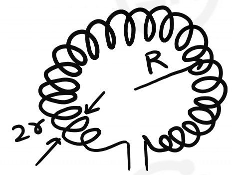
SOLENOID

$B = \mu_0 n i$

n: no of turns / Length (N/ℓ)

Valid for ideal solenoid $(\ell >> r)$

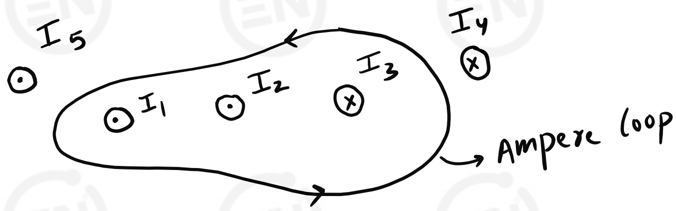
TOROID



$B = \mu_0 \frac{N}{2\pi R} i \quad (R >> r)$

N: No of turns

5. AMPERE CIRCUITAL LAW



NOTE: Outward I is +VE.

$\oint \vec{B} \cdot \vec{d\ell} = \mu_0 (I_1 + I_2 - I_3)$

NOTE: (i) only I enclosed by Ampere Loop considered

(ii) B is due to all current

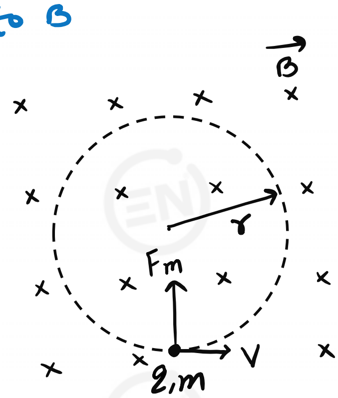
FORCE ON q MOVING IN B, $\vec{F}_m = q(\vec{V} \times \vec{B})$

$\vec{F}_m$ is always perpendicular to $\vec{V}$

⇒ Thus no Work done.

⇒ no change in speed or K.E.

6. If V is ⊥ to B



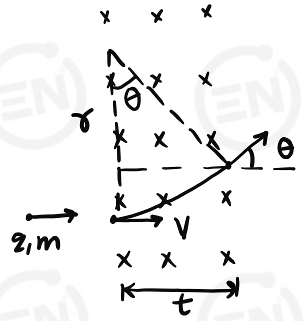
NOTE $K = q\Delta V$

(i) $r = \frac{mV}{qB}$ or $\frac{\sqrt{2mK}}{qB}$

(ii) $T = \frac{2\pi m}{qB}$, time period

(iii) $\omega = \frac{qB}{m}$

8. ANGLE OF DEVIATION



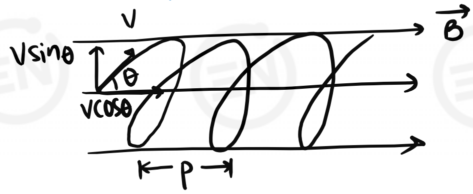
$r > t$

$\sin\theta = t/r$

$= \dfrac{tqB}{mV}$

$\therefore \boxed{\theta = \sin^{-1}\left(\dfrac{qBt}{mV}\right)}$

9. V AT ANGLE θ to B (Helical path)



(i) $r = \dfrac{mV\sin\theta}{qB}$

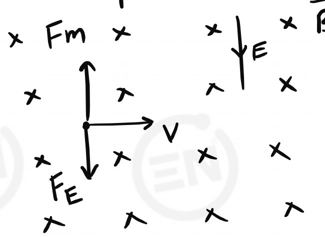
(ii) $T = 2\pi m/qB$

(iii) pitch, $P = V\cos\theta \times T$

10. SPECIAL CASE

$E \perp B \perp V$

IN this situation possibility of q moving undeviated.



COND^n:

$F_E = F_M$

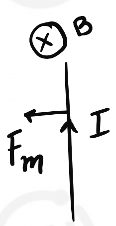
$\Rightarrow qE = qVB$

$\Rightarrow \boxed{V = \dfrac{E}{B}}$

11. FORCE ON I CARYING CONDUCTOR IN B (UNIFORM FIELD)

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

STRAIGHT WIRE



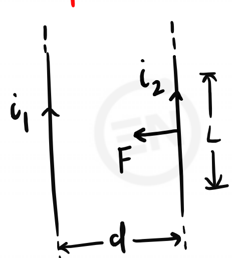
$F_m = IlB$

Closed Loop

$F_{Net} = 0$

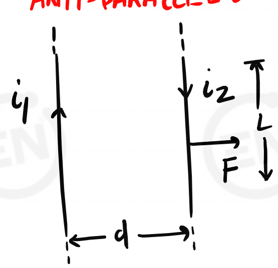
Parallel wire

Parallel i



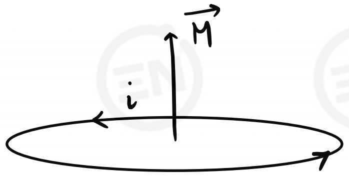
$F = \dfrac{\mu_0 i_1 i_2 L}{2\pi d}$

ANTI-PARALLEL i



$F = \dfrac{\mu_0 i_1 i_2 L}{2\pi d}$

12. MAGNETIC MOMENT



$\vec{M} = N i \vec{A}$

NOTE:

(i) N : No of turns

(ii) A = Loop area

(iii) Dirn of M using right hand thumb rule.

13. TORQUE ON LOOP in B

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

14. POTENTIAL ENERGY OF LOOP in B

$U = -\vec{M} \cdot \vec{B}$

STABLE → $\theta = 0^\circ \Rightarrow U_{min} = -MB$

UNSTABLE → $\theta = 180^\circ \Rightarrow U_{max} = MB$

15. FORCE ON LOOP IN B (NON-UNIFORM B)

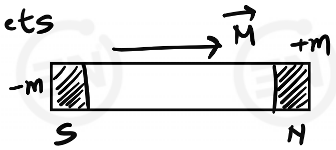
$F = M \frac{dB}{dx}$ [USE IF VARIATION OF B IS SMALL]

M : Magnetic moment of loop

5. EARTH'S MAGNETISM

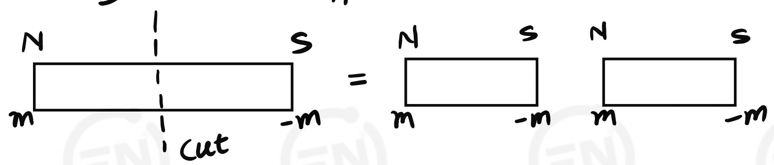
Magnets

(1)

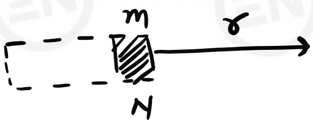


$\vec{M} = m\vec{d}$ → magnetic length

(2)



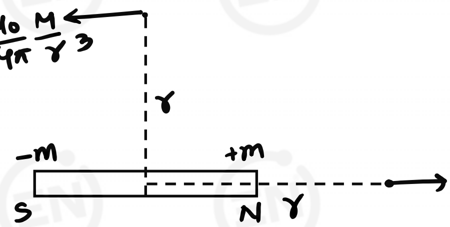
(3) Magnetic field due to a pole



$B = \frac{\mu_0}{4\pi}\frac{m}{r^2}$

4. B due to short magnet ($M = md$)

$B = \frac{\mu_0}{4\pi}\frac{M}{r^3}$



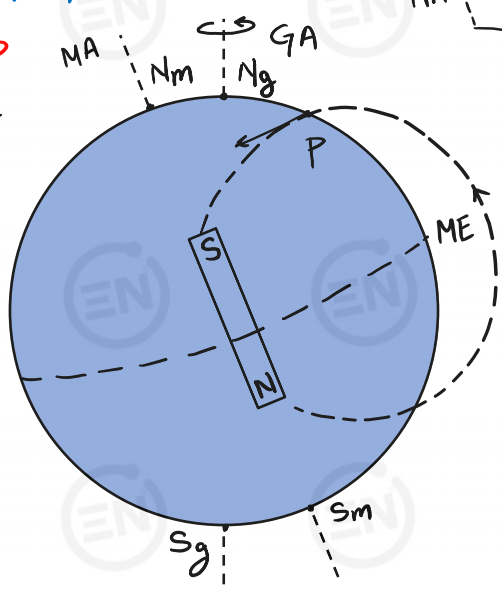
$B = \frac{\mu_0}{4\pi}\frac{2M}{r^3}$

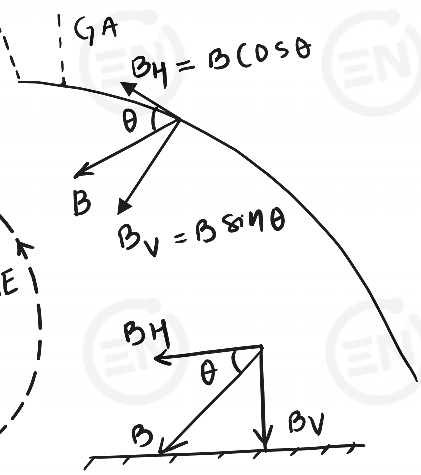
5. $\vec{\tau} = \vec{M}\times\vec{B}$, $U = -\vec{M}\cdot\vec{B}$

7. ELEMENTS OF MAGNETIC FIELD

(a) ANGLE OF DIP

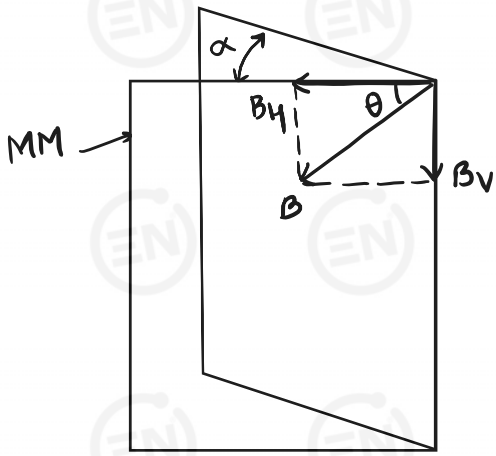
↳ Angle which magnetic field makes with horizontal in Magnetic Meridian.



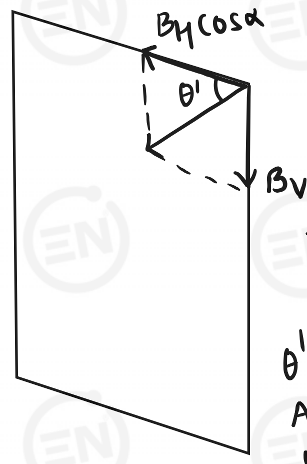


$$\boxed{\tan\theta = \frac{B_V}{B_H}}$$

8. TRUE (θ) AND APPARENT (θ') ANGLE OF DIP



$\tan\theta = \frac{B_V}{B_H}$



$\tan\theta' = \frac{B_V}{B_H\cos\alpha}$

$\Rightarrow \boxed{\tan\theta' = \frac{\tan\theta}{\cos\alpha}}$

θ' is called Apparent angle of DIP.

9. OSCILLATION OF COMPASS NEEDLE

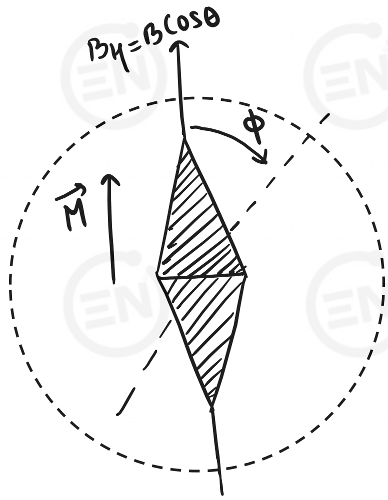
$\vec{M}$: Magnetic moment (md)

$\tau = MB_H \sin\phi$

$\Rightarrow I\alpha = MB_H \sin\phi$

$\Rightarrow \alpha = \frac{MB_H\phi}{I}$ $\left\{ \phi \text{ is small} \right.$

$$\boxed{T = 2\pi\sqrt{\frac{I}{MB_H}}}$$



6. MAGNETIC PROPERTIES

1. $\vec{H}$, $\vec{I}$, $\vec{B}_{net}$, χ

(a) $\vec{H}$, Magnetizing Field

For external magnetic field $\vec{B}_{ext}$, $\vec{H}$ is defined.

$\vec{B}_{ext} = \mu_0 \vec{H}$, unit of $\vec{H}$ is A/m.

(b) $\vec{I}$, Intensity of Magnetization (A/m)

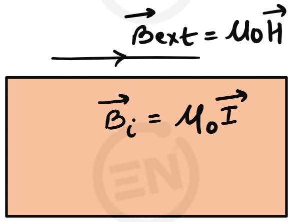
Total magnetic moment of material per unit volume.

$\vec{I} = \frac{\vec{M}}{V}$ (It tells how much a material is magnetized)

(c) χ, Magnetic Susceptibility

Tells about the ease with which a material can be magnetized.

$\chi = I/H$

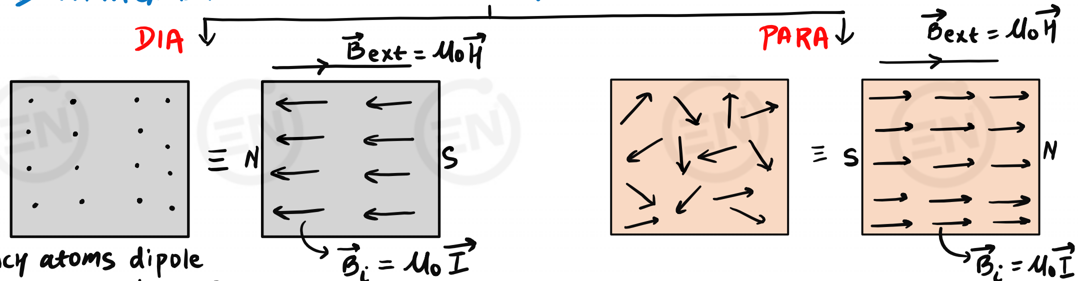


$\vec{B}_{net} = \vec{B}_{ext} + \vec{B}_i$

$\Rightarrow \mu_0\mu_r\vec{H} = \mu_0\vec{H} + \mu_0\vec{I}$

$\Rightarrow \mu_r\vec{H} = \vec{H} + \chi\vec{H}$ $\quad \boxed{\mu_r = 1 + \chi}$

2. DIAMAGNETIC AND PARAMAGNETIC MATERIAL



Each atoms dipole moment is zero

DIA

(i) Weakly magnetized

(ii) Material repels $\vec{B}_{ext}$

(iii) $\mu_r = 1 + \chi$

$\mu_r < 1$ and χ is –ve

(iv) Graphite, Bismuth

PARA

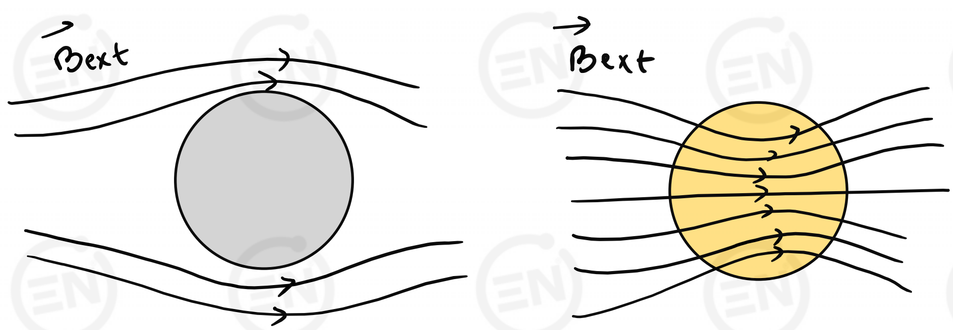
(i) Weakly magnetized

(ii) Material gets weakly attracted to $\vec{B}_{ext}$

(iii) $\mu_r = 1 + \chi$

$\mu_r > 1$ and χ is +ve

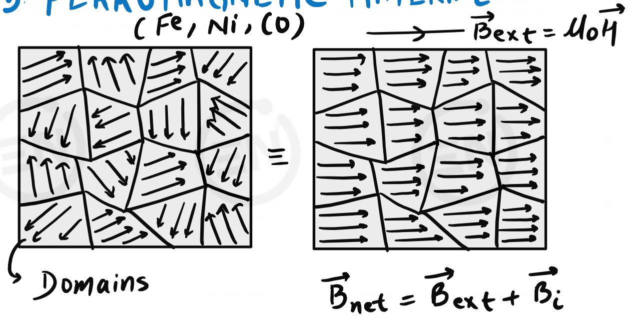
(iv) Al, Li, Mg



DIA PARA

3. FERROMAGNETIC MATERIAL

(Fe, Ni, Co)



$\vec{B}_{net} = \vec{B}_{ext} + \vec{B}_i$

Here, $B_i >> B_{ext}$

$\Rightarrow I >> H$

$\therefore \chi >> 1$

4. CURIE'S LAW

If $T\uparrow$, due to thermal agitation, the alignment of dipoles gets disturbed and overall $I\downarrow$ for a given H.

$\because I\downarrow \Rightarrow \chi\downarrow$

(a) FOR PARAMAGNETIC MATERIAL

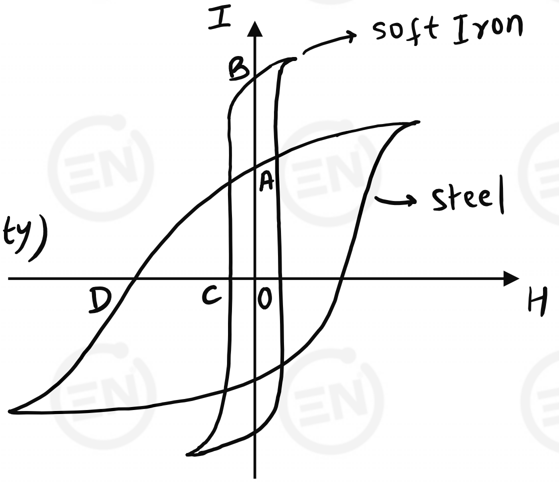
$\chi = \frac{C}{T}$ C: Curie const. T: Abs Temp°

(b) For Ferromagnetic material on heating it to T_c, it changes to Paramagnetic. on further $\uparrow T$

$\chi = \frac{C'}{T - T_c}$ T_c: Curie Temp°

6. HYSTERESIS CURVE:

SOFT IRON VS STEEL



(i) $\because$ Soft Iron gets easily magnetized and Looses almost all magnetism easily (Low coercivity) It is used for "Electromagnets".

(ii) $\because$ Steel is difficult to demagnetize (OD = coercivity) it is used to make "Permanent Magnets".

7. EMI

1. FARADAY'S LAW, $\varepsilon = -\dfrac{d\phi}{dt}$

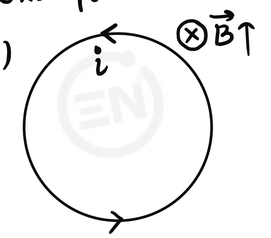
Flux, $\phi = \vec{B}\cdot\vec{A} = BA\cos\theta$

2. DIRECTION OF INDUCED CURRENT

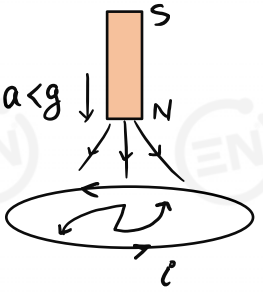
LENZ'S LAW : Direction of i will such that its effect will oppose the change in flux.

Examples:

(a)



(b) $a < g \downarrow$



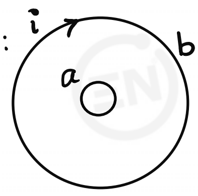
3. CHARGE FLOWN, $q_{flown} = \dfrac{\Delta\phi}{R}$

(a) $\Delta\phi$ is change in flux, $|\phi_f - \phi_i|$

(b) R is resistance of coil

Example:

$a \ll b$



If direction of i is reversed,

$\Delta\phi = 2\times BA$

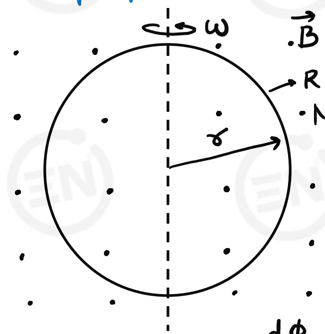
$= 2\times\dfrac{\mu_0 i}{2b}\times\pi a^2$

q_{flown} in small coil

$= \dfrac{\Delta\phi}{R}$

R is resistance of small coil

4. COIL ROTATION IN UNIFORM MAGNETIC FIELD



At $t=0$, $\vec{A}\parallel\vec{B}$

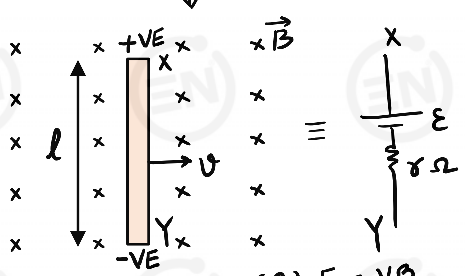
At $t=t$, $\theta=\omega t$

$\phi = NBA\cos\omega t$

$\varepsilon = -\dfrac{d\phi}{dt} = \underbrace{NBA\omega}_{\varepsilon_0}\sin\omega t$

$i = \underbrace{\dfrac{\varepsilon_0}{R}}_{i_0}\sin\omega t$

5. MOTIONAL EMF

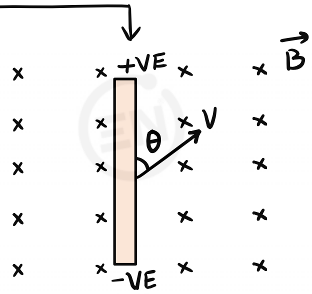


(a) $E = vB$

(b) $\varepsilon = Blv$

(c) applicable only if v, B and l are mutually perpendicular

NOTE: If any two are parallel $\varepsilon = 0$

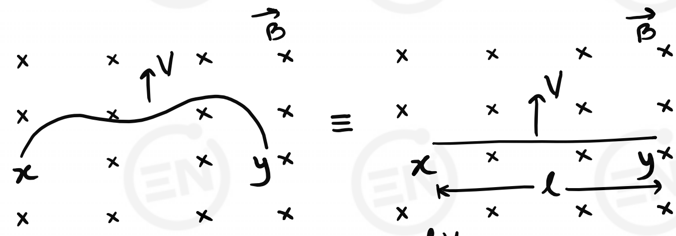


$\varepsilon = Bl$ (component of $v \perp$ to l)

$= Blv\sin\theta$

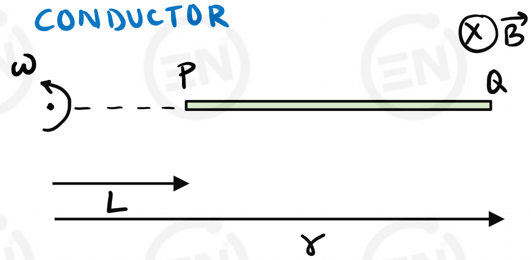
$\boxed{\text{+VE Polarity is towards direction of } \vec{v}\times\vec{B}.}$

6. MOTIONAL EMF IN RANDOM SHAPED WIRE



$\varepsilon = B\ell v$

7. MOTIONAL EMF OF ROTATING CONDUCTOR



$\Rightarrow \epsilon = \frac{1}{2}B\omega(r^2 - L^2)$

NOTE: (a) If $L=0$, $\epsilon = \frac{1}{2}B\omega r^2$

(b) For above fig. P at higher potential.

8. PARALLEL RAIL TRACK PROBLEMS

$F_m = i\ell B = \frac{B\ell v}{R} \times \ell B$

$$m$$

$$V = \frac{F_0 R}{B^2\ell^2}\left(1 - e^{-\frac{B^2\ell^2 t}{mR}}\right)$$

At $t \to \infty$ (steady state)

Terminal Vel, $V_t = \frac{F_0 R}{B^2\ell^2}$

$P = F_0 V_t$ = Power across R

$q = C\varepsilon \Rightarrow q = CB\ell v$

$\Rightarrow i = \frac{dq}{dt} = CB\ell a$

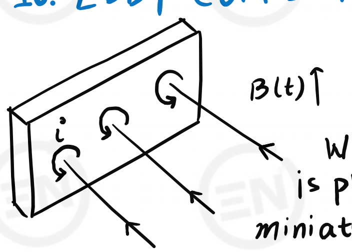
$F_0 - F_m = ma$

$\Rightarrow F_0 - (CB\ell a)\ell B = ma$

$\therefore a = \frac{F_0}{m + B^2\ell^2 C}$

↳ a is const.

10. EDDY CURRENTS



When a metal body is placed in TVMF, miniature currents are induced.

Due to this current heat is dissipated.

11. SELF INDUCTION

If I varies, emf induced

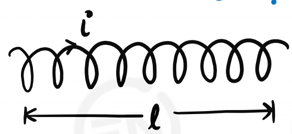
$\varepsilon = -L\frac{dI}{dt}$ or $\varepsilon = \left|L\frac{dI}{dt}\right|$

↳ Polarity of ε can be found by LENZ's LAW

12. HOW TO FIND L ?

Example:

INDUCTOR or SOLENOID



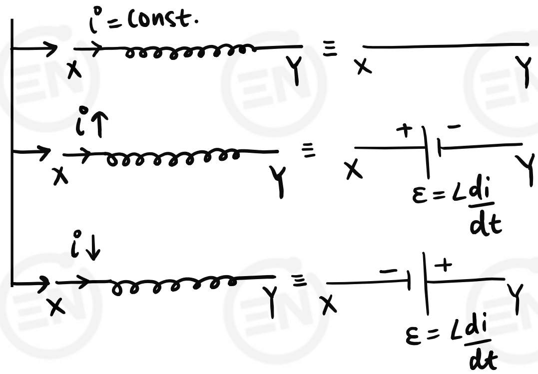
$\phi = NBA \Rightarrow \phi = N \times \frac{\mu_0 N i}{l} A$

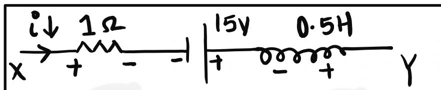
$\Rightarrow \phi = \left(\frac{\mu_0 N^2 A}{l}\right) i \qquad \therefore L = \frac{\mu_0 N^2 A}{l}$

NOTE: If any medium inside

$L = \frac{\mu_0 \mu_r N^2 A}{l}$

13. BATTERY POLARITY INDUCED IN INDUCTOR





$i = 5\,A$

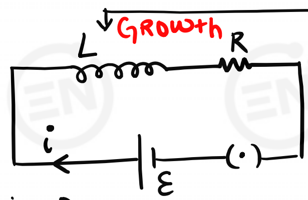
$\frac{di}{dt} = 10\,A/s$

$V_x - V_y = 5 - 15 - 5 = -15\,V$

14. GROWTH AND DECAY OF CURRENT (LR)

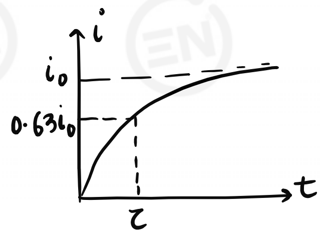
GROWTH

at time t

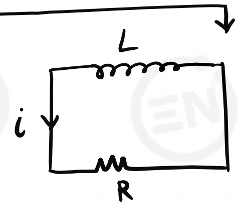


at $t = 0$, $i = 0$

at $t = t$, $i = i_0(1 - e^{-Rt/L})$ $\left\{ \begin{array}{l} i_0 = \varepsilon/R \\ \tau = L/R \rightarrow \text{Time const.} \end{array} \right.$



DECAY

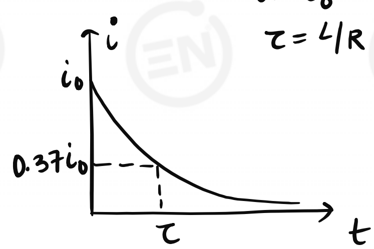


→ at time t

at $t = 0$, $i = i_0$ | at $t = t$

$i = i_0 e^{-Rt/L}$

$\tau = L/R$

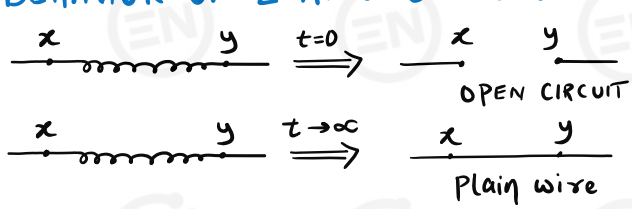


15. ENERGY STORED

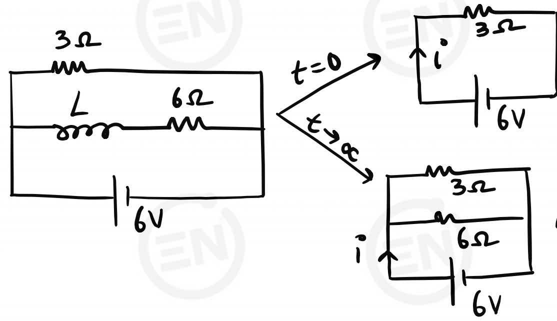
Magnetic energy stored is,

$U = \frac{1}{2} L i^2$

16. BEHAVIOR OF L AT $t=0$ AND $t \to \infty$



Example:



$i = 2A$

$i = 3A$

17. MUTUAL INDUCTION

Property of pair of Coils due to which a change in current in 1 coil is opposed by Emf induced in other Coil because of ϕ LINKAGE.

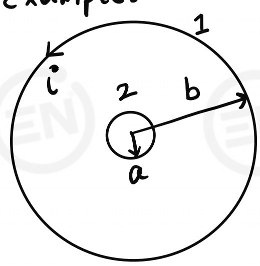
$\phi_2 = M i_1$

↳ M is Mutual Inductance

↳ $\varepsilon_2 = -M \dfrac{di_1}{dt}$

18. HOW TO FIND M ?

Example:



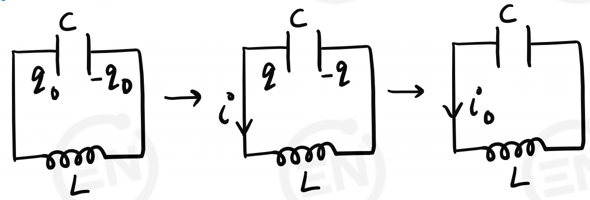
$a << b$

$\phi_2 = \dfrac{\mu_0 i}{2b} \times \pi a^2$

$\Rightarrow \phi_2 = \left(\dfrac{\mu_0 \pi a^2}{2b}\right) i$

$\therefore M = \dfrac{\mu_0 \pi a^2}{2b}$

19. LC OSCILLATION



(a) Total energy is Const.

$\dfrac{q_0^2}{2C} = \dfrac{q^2}{2C} + \dfrac{1}{2} L i^2 = \dfrac{1}{2} L i_0^2$

(b) $\omega = \dfrac{1}{\sqrt{LC}}$, $T = 2\pi\sqrt{LC}$

(c) General equation

$q = q_0 \sin(\omega t + \phi)$, $i = i_0 \cos(\omega t + \phi)$

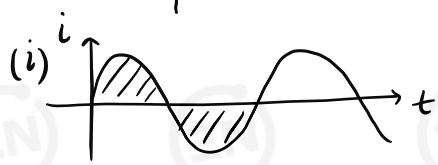
8. ALTERNATING CURRENT

1. I_{av} AND I_{rms}

$$I_{av} = \frac{\int_{t_1}^{t_2} i(t)\,dt}{t_2 - t_1}$$

NOTE: $\int i\,dt$ is area under i v/s t curve

(i)

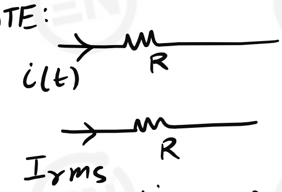


for $i = i_0 \sin\omega t$

$i_{av} = 0$

$$I_{rms} = \sqrt{\frac{\int_{t_1}^{t_2} i^2(t)\,dt}{t_2 - t_1}}$$

NOTE:

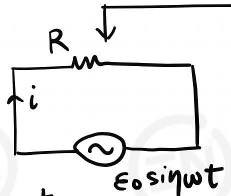


In same time, same heat is dissipated

Ex: If $i = i_0 \sin\omega t$

$i_{rms} = i_0/\sqrt{2}$

2. PHASE RELATION BETWEEN ε AND i (R, L, C TAKEN INDIVIDUALLY)

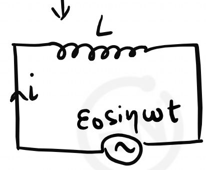


$i = i_0 \sin\omega t$

(a) $i_0 = \varepsilon_0/R$

(b) i and ε in phase

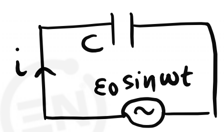
(c) R doesn't depend on ω



$i = i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

(a) $i_0 = \dfrac{\varepsilon_0}{X_L}$, $X_L = \omega L$ → Inductive Reactance

(b) i lags by $\pi/2$



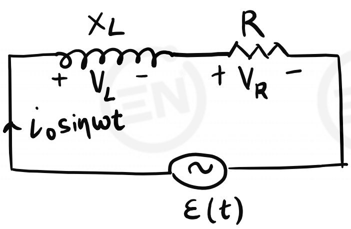
$i = i_0 \sin\left(\omega t + \frac{\pi}{2}\right)$

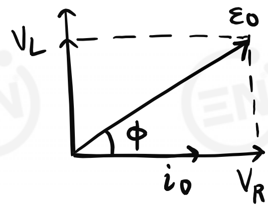
(a) $i_0 = \varepsilon_0 / X_C$

$X_C = 1/\omega C$ → CAPACITIVE REACTANCE

(b) i Leads by $\pi/2$

3. LR CIRCUIT (PHASOR Dig.)





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

(b) $\tan\phi = X_L / R$

(c) ε leads i by ϕ

$\therefore \varepsilon = \varepsilon_0 \sin(\omega t + \phi)$

$\hookrightarrow \varepsilon_0 = i_0 Z$

(d) $v_L = V_L \sin(\omega t + \pi/2)$

$\hookrightarrow V_L = i_0 X_L$

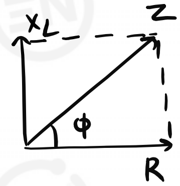
$\varepsilon_0 = \sqrt{V_L^2 + V_R^2} \Rightarrow i_0 Z = \sqrt{(i_0 X_L)^2 + (i_0 R)^2}$

$Z = \sqrt{X_L^2 + R^2} \rightarrow$ Impedance

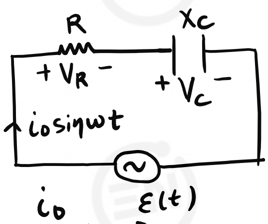
$\tan\phi = \frac{V_L}{V_R} = \frac{X_L}{R}$

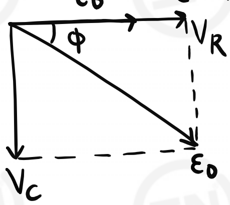
NOTE:

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



4. RC CIRCUIT





$\varepsilon_0 = \sqrt{V_R^2 + V_C^2}$

$i_0 Z = \sqrt{(i_0 R)^2 + (i_0 X_C)^2}$

$\Rightarrow Z = \sqrt{R^2 + X_C^2}$

$\hookrightarrow$ Impedance

$\tan\phi = \frac{V_C}{V_R} = \frac{X_C}{R}$

(a) $Z = \sqrt{X_C^2 + R^2}$, $X_C = \frac{1}{\omega C}$

(b) $\tan\phi = X_C / R$

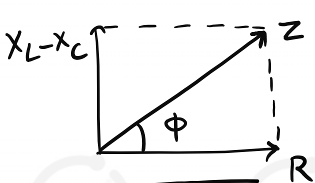
(c) ε lags i by ϕ

$\therefore \varepsilon = \varepsilon_0 \sin(\omega t - \phi)$

$\hookrightarrow \varepsilon_0 = i_0 Z$

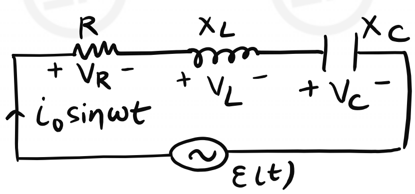
(d) $v_C = V_C \sin(\omega t - \frac{\pi}{2})$

6. RLC (SERIES)



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

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



$\varepsilon = \varepsilon_0 \sin(\omega t + \phi)$

$\hookrightarrow i_0 Z$

(a) If $X_L > X_C$ (Inductive) $\Rightarrow$ ε leads by ϕ

If $X_C > X_L$ (capacitive) $\Rightarrow$ ε lags by ϕ

$\varepsilon = \varepsilon_0 \sin(\omega t - \phi)$

(b) $v_L = V_L \sin(\omega t + \pi/2)$

$\hookrightarrow V_L = i_0 X_L$

$v_C = V_C \sin(\omega t - \pi/2)$

$\hookrightarrow V_C = i_0 X_C$

7. POWER IN AC CIRCUIT

$$P_{av} = \mathcal{E}_{rms}\, i_{rms} \cos\phi$$

NOTE: In questions If nothing mentioned, take given supply voltage as $\mathcal{E}_{rms}$.

Power factor, $\cos\phi = R/Z$

- only C, $\cos\phi = 0 \Rightarrow P_{av} = 0$
- only L, $\cos\phi = 0, \Rightarrow P_{av} = 0$
- only R, $\cos\phi = 1, \Rightarrow P_{av}$ is Max
- RL, $\cos\phi = \dfrac{R}{\sqrt{X_L^2 + R^2}}$
- RC, $\cos\phi = \dfrac{R}{\sqrt{X_C^2 + R^2}}$
- RLC, $\cos\phi = \dfrac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$

8. RESONANT FREQUENCY (SERIES RLC)

↳ That value of ω for which impedance is purely resistive. $(Z = R)$

(a) $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$

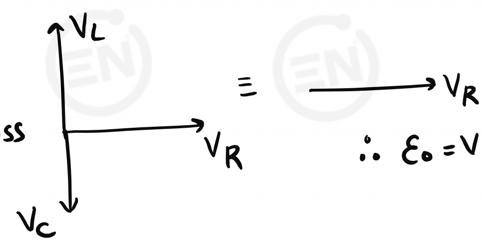
$\therefore$ for $\omega L = \dfrac{1}{\omega C}$, $Z = R \Rightarrow \omega_R = \dfrac{1}{\sqrt{LC}}$

(b) At resonance, $P_{av} = i_{rms}^2 R = \dfrac{\mathcal{E}_{rms}^2}{R}$ $(\cos\phi = 1)$

(c) $\because X_L = X_C$

$\Rightarrow V_L = V_C$

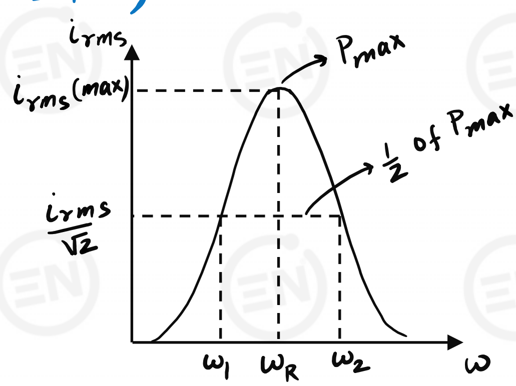
$\therefore$ All supply is across Resistor.



$\therefore \mathcal{E}_0 = V_R$

9. CURRENT VARIATION WITH ω (SERIES RLC)

$$i_{rms} = \frac{\mathcal{E}_{rms}}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$



(a) For ω_1 and ω_2

P_{av} is $\frac{1}{2}$ of P_{max}.

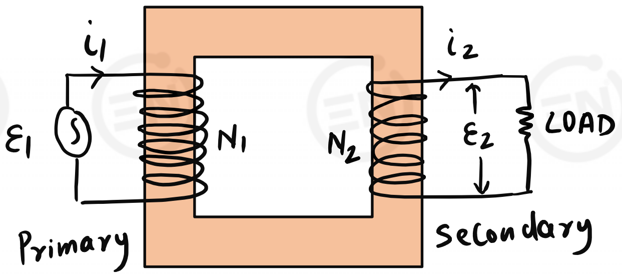
(b) BANDWIDTH

$\Delta\omega = \omega_2 - \omega_1 = R/L$

(c) QUALITY FACTOR (Q factor)

$$Q = \frac{\omega_R}{\Delta\omega} = \frac{1}{\sqrt{LC}} \times \frac{L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

11. TRANSFORMER



N_1 and N_2 are number of turns.

(a) $\frac{\varepsilon_1}{\varepsilon_2} = \frac{N_1}{N_2}$

→ $N_1 > N_2 \Rightarrow \varepsilon_1 > \varepsilon_2$ (step down transformer)

→ $N_2 > N_1 \Rightarrow \varepsilon_2 > \varepsilon_1$ (step up transformer)

(b) For ideal transformer (No losses)

$\varepsilon_1 i_1 = \varepsilon_2 i_2$

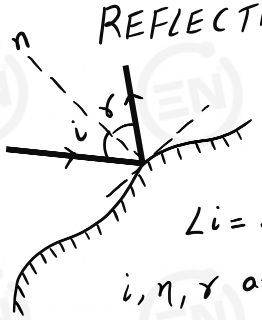
(c) Losses

→ Cu loss (Joules heating)

→ Eddy current (Heat due to it)

9. RAY OPTICS

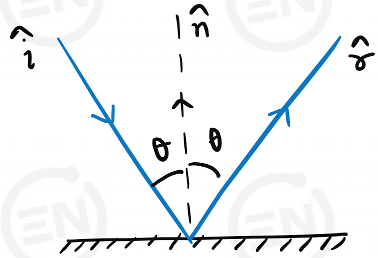
1. REFLECTION



$\angle i = \angle r$

i, n, r are in same plane

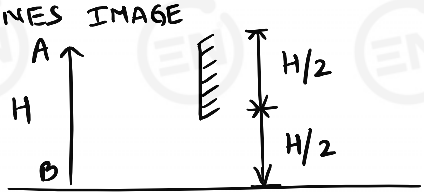
2. VECTOR FORM OF REFLECTED RAY



$$\boxed{\hat{r} = \hat{i} - 2(\hat{i}\cdot\hat{n})\cdot\hat{n}}$$

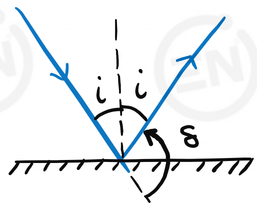
$\hat{i}$, $\hat{r}$ and $\hat{n}$ are unit vectors along incident ray, reflected ray and normal.

3. MINIMUM MIRROR LENGTH TO SEE ONES IMAGE



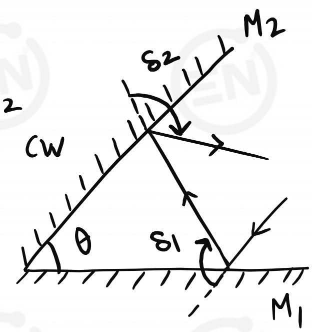
* Assuming eye level at A

4. ANGLE OF DEVIATION (δ)



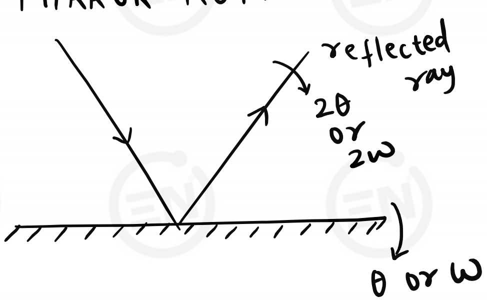
$\delta = \pi - 2i$

Here it is ACW rotation



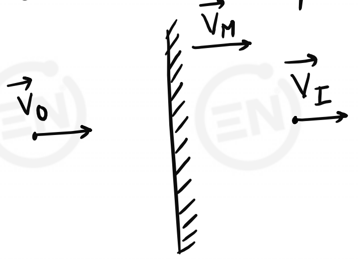
$\delta_{NET} = \delta_1 + \delta_2$
$= 2\pi - 2\theta$ CW

5. MIRROR ROTATION



↳ If mirror rotated by angle θ, reflected ray rotates by 2θ. (ω is angular vel)

6. IMAGE VELOCITY



$$\vec{V}_{O/M} = -\vec{V}_{I/M}$$

$$\Rightarrow \vec{V}_O - \vec{V}_M = -(\vec{V}_I - \vec{V}_M)$$

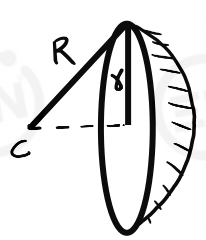
$$\Rightarrow \boxed{\vec{V}_I = 2\vec{V}_M - \vec{V}_O}$$

* these are all velocities Normal to mirror surface.

SPHERICAL MIRROR

7. MIRROR IMPORTANT TERMS

(a)



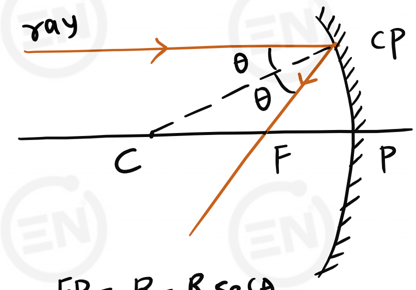
r: radius of aperture

2r: Aperture size

C: center of Curvature

R: Radius of Curvature

(b)



$$FP = R - \frac{R}{2}\sec\theta$$

NOTE:

If rays were PARAXIAL (close to axis)

then θ is very small ⇒ $\sec\theta \simeq 1$

⇒ F is FOCUS

and $\boxed{FP = \frac{R}{2}}$

8. MIRROR FORMULAE

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \quad \text{or} \quad \boxed{v = \frac{uf}{u-f}}$$

– Put u, f with sign

– f is –VE for concave and +VE for convex Mirror

9. MAGNIFICATION

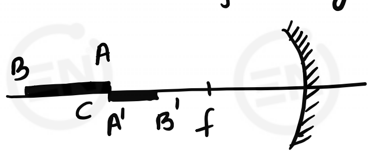
→ TRANSVERSE, $m = \frac{h_i}{h_o} = \frac{-v}{u} = -\frac{f}{u-f}$

* Put terms with sign
* Erect image ⇒ m is +VE
* INVERTED ⇒ m is –VE

→ LONGITUDNAL

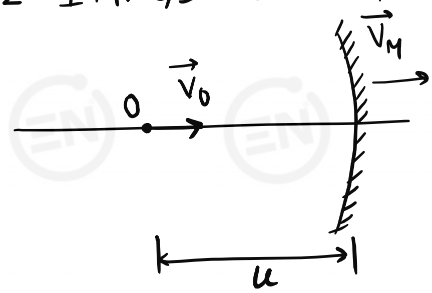
$$m = \frac{\text{Image Length along P.A.}}{\text{Object Length along PA}}$$

Ex:



$$m = \frac{A'B'}{AB}$$

12. IMAGE VELOCITY



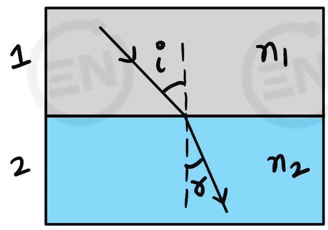
$$V_{I/M} = -\left(\frac{v}{u}\right)^2 V_{0/M}$$

If $V_M = 0$ then, $V_I = -\left(\frac{f}{u-f}\right)^2 V_0$

↳ put u, f, V_0 with sign

REFRACTION

13. SNELL'S LAW



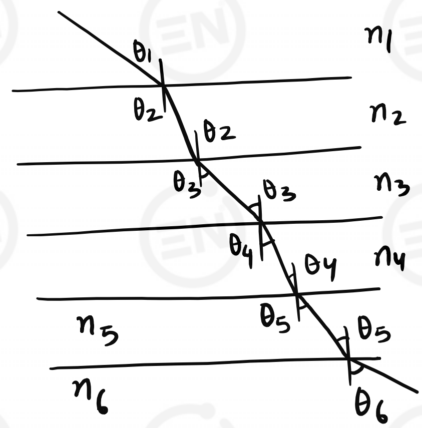
(a.) $n_1 \sin i = n_2 \sin r$

(b) As per this fig. $n_2 > n_1$

(c) $\frac{n_2}{n_1} = \frac{V_1}{V_2} = \frac{\lambda_1}{\lambda_2}$

V_1 and V_2 are speed of light in medium 1 and 2.

#

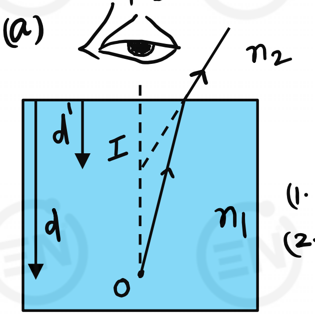


$n_1 \sin\theta_1 = n_2 \sin\theta_2 = n_3 \sin\theta_3 = \dots = n_6 \sin\theta_6$

$\therefore \boxed{n \sin\theta = \text{Constant}}$

14. IMAGE FORMATION DUE TO PLANE SURFACE

(a)



$$\boxed{d' = d\,\frac{n_2}{n_1}}$$

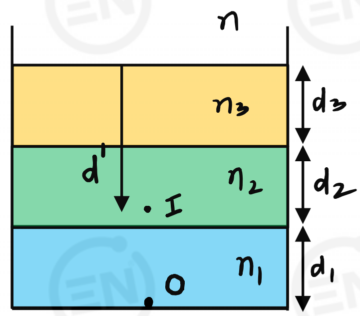
(1.) d' is Apparent depth

(2.) $d' < d$ If $n_1 > n_2$

$d' > d$ If $n_1 < n_2$

(3.) Paraxial rays or observer is looking from above.

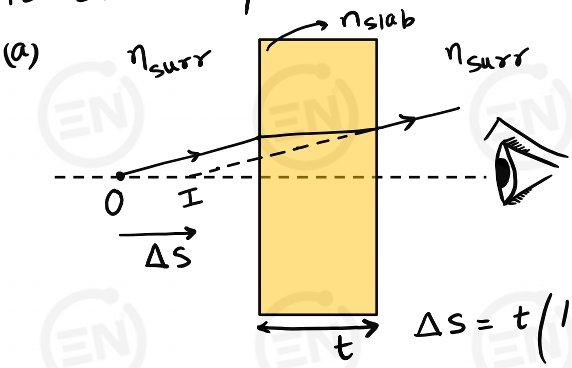
(b)



$$d' = n\left(\frac{d_1}{n_1} + \frac{d_2}{n_2} + \frac{d_3}{n_3}\right)$$

15. SHIFTING DUE TO SLAB

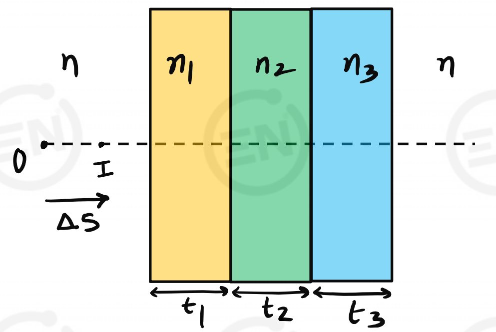
(a)



$$\Delta s = t\left(1 - \frac{n_{surr}}{n_{slab}}\right)$$

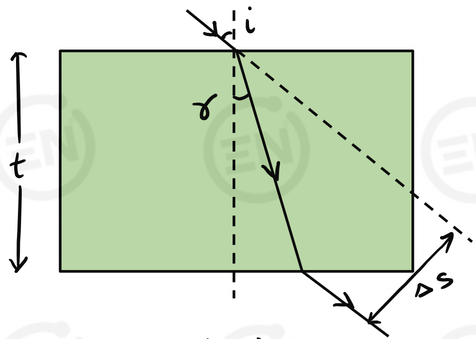
(1.) valid for paraxial
(2.) valid only if medium around slab is same

(b)



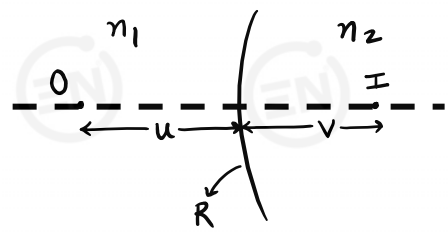
$$\Delta s = t_1\left(1 - \frac{n}{n_1}\right) + t_2\left(1 - \frac{n}{n_2}\right) + t_3\left(1 - \frac{n}{n_3}\right)$$

16. LATERAL DISPLACEMENT



$$\Delta s = \frac{t\sin(i-r)}{\cos r}$$

17. SPHERICAL REFRACTION IMAGE FORMULAE



$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

(1.) Put u, v, R with sign
(2.) n_2 is medium where rays are going

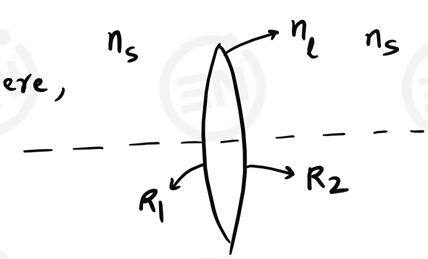
18. THIN LENSES: LENS FORMULAE

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \text{or} \quad v = \frac{uf}{u+f}$$

(1.) f is +VE for converging lens and -VE for diverging lens
(2.) Valid for paraxial rays

LENS MAKER'S FORMULAE

Here,



$$\frac{1}{f} = \left(\frac{n_l}{n_s} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

(1.) Valid only if lens is surrounded by only one medium.
(2.) Put R_1, R_2 with sign

19. MAGNIFICATION

$$\boxed{m = \frac{h_i}{h_o} = \frac{v}{u} = \frac{f}{u+f}}$$

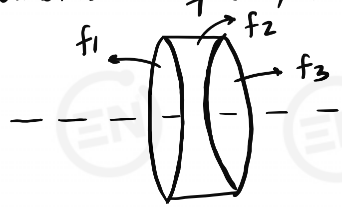
↳ Transverse mag.

20. OPTICAL POWER

$$P = \frac{1}{f_l}$$

- UNIT: DIOPTER
- put f_l with sign
- put f_l in meters

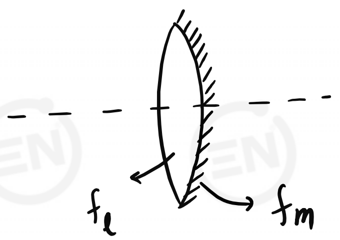
21. Combination of thin lenses, f_{eq}



$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$$

(1.) put f_1, f_2, f_3 with sign
(2.) Lenses must be in contact
(3.) f_1, f_2, f_3 are individual focal lengths w.r.t surrounding medium.

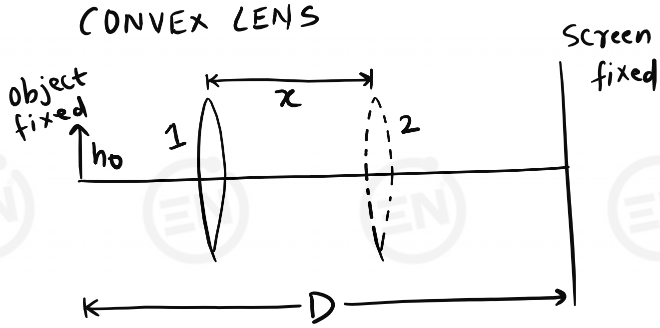
22. COMBINATION OF LENS and MIRRORS (f_{eq})



$$\frac{1}{f_{eq}} = \frac{1}{f_m} - \frac{2}{f_l}$$

(1.) Put f_m, f_l with sign.
(2.) If f_{eq} is +VE $\Rightarrow$ equivalent convex mirror
If f_{eq} is −VE $\Rightarrow$ concave mirror
If f_{eq} is ∞ $\Rightarrow$ Plane Mirror

23. DISPLACEMENT METHOD TO MEASURE FOCAL LENGTH OF CONVEX LENS



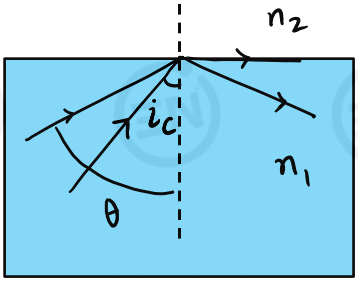
$$\boxed{f = \frac{D^2 - x^2}{4D}}$$

D: Distance between screen and object
x: Distance between two positions of lens.

$$\boxed{h_0 = \sqrt{h_1 h_2}}$$

h_1: image height when LENS is at posn 1
h_2: when at posn 2

24. CRITICAL ANGLE AND TIR



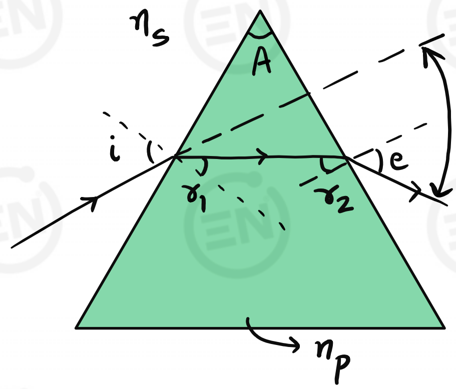
(1.) Here $n_1 > n_2$

(2.) i_c : critical angle for which $r = 90°$

(3.) If $\theta > i_c \Rightarrow$ TIR

$$\sin i_c = \frac{n_2}{n_1} \quad \text{or} \quad \boxed{i_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)}$$

25. PRISM



n_p : R.I of PRISM

n_s : RI of Surrounding

(1.) A: ANGLE of PRISM , $A = r_1 + r_2$

(2.) δ : ANGLE of Deviation

$$\delta = i + e - A$$

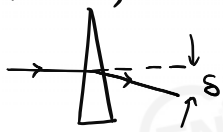
(3.) For δ to be minimum, δ_{min}

$$i = e \Rightarrow r_1 = r_2 = r$$

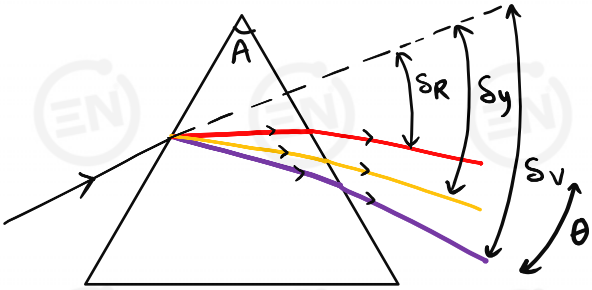
$$\therefore \frac{n_p}{n_s} = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

(4.) If A is very small (THIN PRISM), then

$$\boxed{\delta = A\left(\frac{n_p}{n_s} - 1\right)}$$



26. DISPERSIVE POWER (ω)



$\delta_R = A(n_R - 1)$, $\delta_y = A(n_y - 1)$, $\delta_V = A(n_V - 1)$

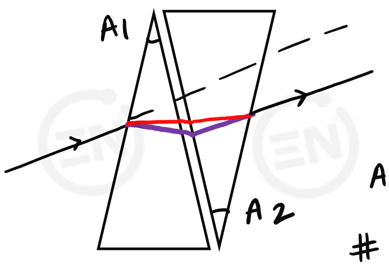
n_R, n_y, n_V are R.I. of medium for Red, yellow and violet color

(Cauchy's eq^n, $n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \dots$)

(a.) θ (Dispersion ANGLE) $= \delta_V - \delta_R = \boxed{A(n_V - n_R)}$

(b.) ω (Dispersive Power) $= \dfrac{\delta_V - \delta_R}{\delta_y} = \boxed{\dfrac{n_V - n_R}{n_y - 1}}$

27. CONDITION for DEVIATION WITHOUT DISPERSION



$\theta_{NET} = 0$

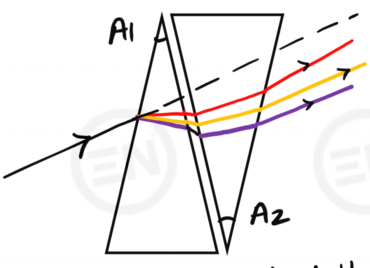
$\Rightarrow \theta_1 = \theta_2$

or

$A_1(n_{V_1} - n_{R_1}) = A_2(n_{V_2} - n_{R_2})$

Achromatic prism Combination

28. CONDITION FOR DISPERSION WITHOUT DEVIATION



Here final emergent yellow is parallel to incident white light.

so, $\delta_{net} = 0 \Rightarrow \delta_1 = \delta_2$

$\Rightarrow A_1(n_{y_1} - 1) = A_2(n_{y_2} - 1)$

10. OPTICAL INSTRUMENT

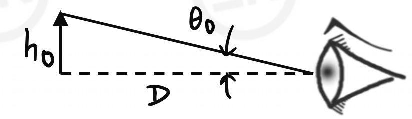
2. EYE DEFECTS

NAME	DEFECT	CORRECTIVE LENS
Myopia Nearsightedness	- Far object not clear - Rays converge before Retina	Concave Lens
Hypermetropia Farsightedness	- Near object not clear - Rays converge after Retina	Convex Lens
Presbyopia	Elderly person, generally is not able to read a book at about 25 cm distance from the eye	Bifocal lens
Astigmatism	- Distorted image - generally occurs if the eye is myopic or hypermetropic.	Cylindrical lens

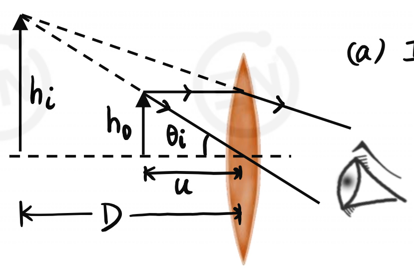
old age issue of hardening of eye lens

Cornea not spherical in shape

4. SIMPLE MICROSCOPE



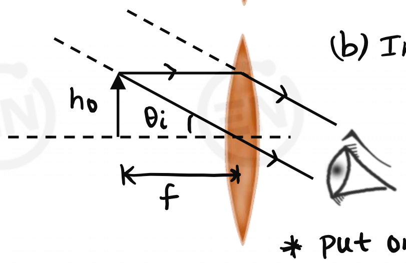
Angular size of Object, $\theta_o = \frac{h_o}{D}$



(a) Image at Near point, D

$\theta_i = \frac{h_o}{u}$, $u = \frac{Df}{D+f}$

$m = \frac{\theta_i}{\theta_o} = 1 + \frac{D}{f}$



(b) Image at Far Point, ∞

$\theta_i = h_o / f$

$m = \frac{\theta_i}{\theta_o} = \frac{D}{f}$

* put only magnitudes

5. COMPOUND MICROSCOPE

$m = m_o \times m_e$

normal Adjustment

Image at D

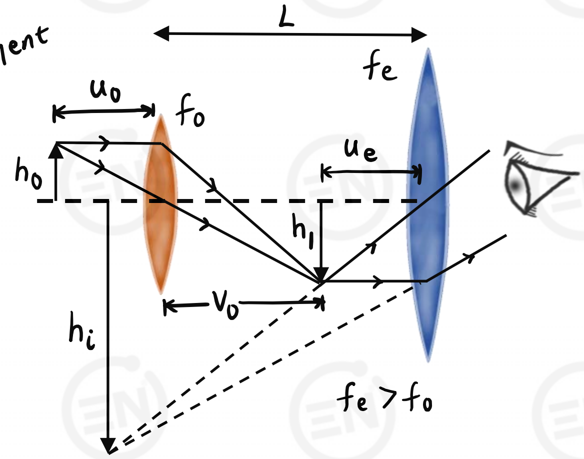
$m = \frac{V_o}{u_o}\left(1+\frac{D}{f_e}\right)$

Image at ∞

$m = \frac{V_o}{u_o}\frac{D}{f_e}$

Generally $f_o \ll L$, $f_e \ll L$

$m = \frac{L}{f_o}\left(1+\frac{D}{f_e}\right)$ $\qquad$ $m = \frac{L}{f_o}\frac{D}{f_e}$



Tube length (L)

(a) If image at D, $L = V_o + u_e$

(b) If image at ∞, $L = V_o + f_e$

6. REFRACTING TELESCOPE

$\theta_o = h_1/f_o$, $\theta_i = h_1/u_e$, $u_e = \frac{Df_e}{D+f_e}$

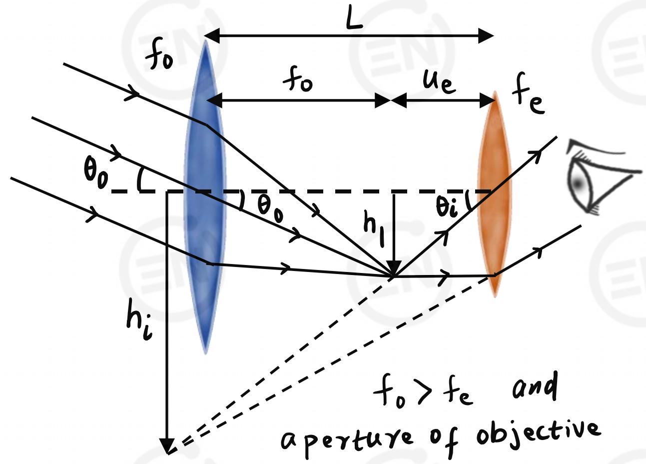
Image at D

$m = \frac{\theta_i}{\theta_o} = \frac{f_o}{f_e}\left(1+\frac{f_e}{D}\right)$

Image at ∞

$\theta_i = h_1/f_e$

$\therefore m = \frac{\theta_i}{\theta_o} = \frac{f_o}{f_e}$



$f_o > f_e$ and aperture of objective is large to capture more light.

Tube length

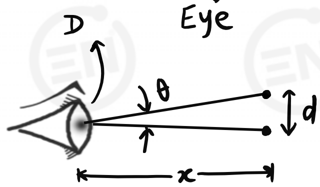
(a) If image at D, $L = f_o + u_e$

(b) If image at ∞, $L = f_o + f_e$

* In all formulae Put only magnitudes.

7. LIMIT OF RESOLUTION, RESOLVING POWER (RP)

Eye



Limit of Resolution, $\theta = \frac{1.22\lambda}{D}$

$RP = 1/\theta$, $d = \theta x$

Telescope

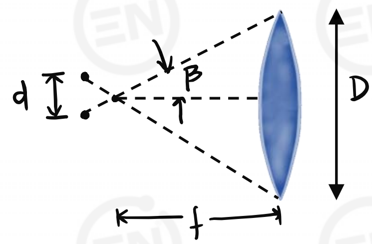
D = Aperture of Objective Lens

Two stars will be just resolved if,

$\theta = \frac{1.22\lambda}{D}$, $RP = \frac{D}{1.22\lambda}$

If distance of star is x, separation between them, $d = x\theta$

Microscope



$d_{min} = \frac{1.22\lambda}{2\mu \sin\beta}$

$RP = \frac{1}{d_{min}}$

(i) Numerical Aperture (NA) $= \mu \sin\beta$

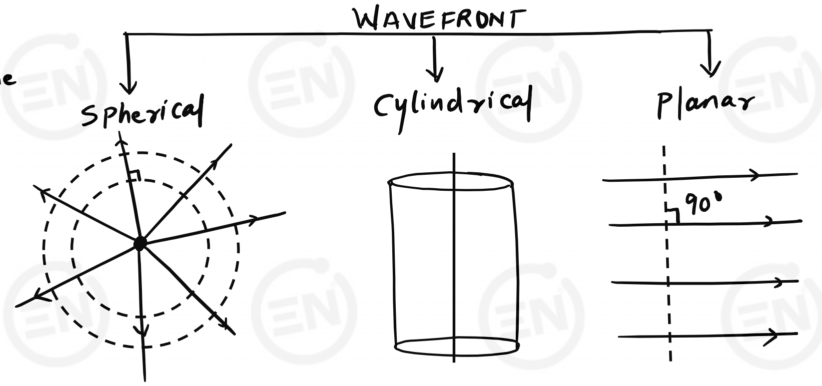
(ii) μ: Refractive index of medium between lens and object

11. INTERFERENCE & YDSE

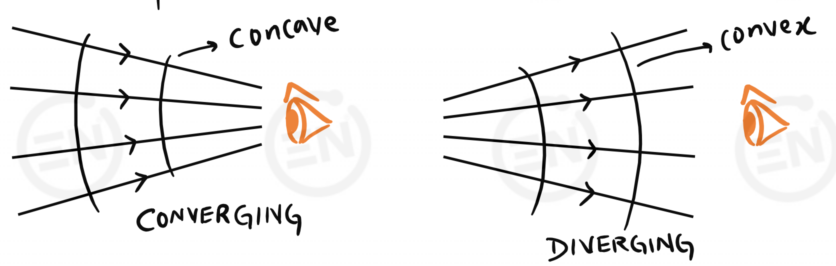
1. WAVEFRONT

When light propagates, the cross section where all particles oscillate in same phase is called Wavefront.

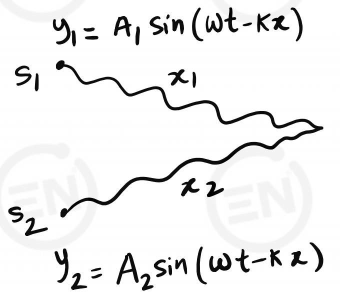
Wave front is Normal to Propagation direction



Ex:



2. A_{net} and I_{net} IN INTERFERENCE (coherent source, same ω)



$$y = y_1 + y_2 = A_1 \sin(\omega t - kx_1) + A_2 \sin(\omega t - kx_2)$$

Phase difference, $\Delta\phi = k(x_2 - x_1) = k\Delta x$

$$\Rightarrow \boxed{\Delta\phi = \frac{2\pi}{\lambda}\Delta x}$$

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

If $A_1 = A_2 = A$

$$A_{net} = 2A\cos\frac{\Delta\phi}{2}$$

$(I = kA^2)$

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

If $I_1 = I_2 = I_0$

$$I_{net} = 4I_0\cos^2\frac{\Delta\phi}{2}$$

3. $\Delta\phi, \Delta x, A_{net}, I_{net}$

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

$$I_{net} = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\Delta\phi$$

INTERFERENCE

CONSTRUCTIVE

(i) $\Delta\phi = 2n\pi$

(ii) $2n\pi = \frac{2\pi}{\lambda}\Delta x$

$\Delta x = n\lambda$

(iii) $A_{net} = A_1 + A_2$

If $A_1 = A_2 = A$

$A_{net} = 2A$

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

If $I_1 = I_2 = I_0$

$I_{net} = 4I_0$ (MAXIMA)

DESTRUCTIVE

(i) $\Delta\phi = (2n+1)\pi$

(ii) $(2n+1)\pi = \frac{2\pi}{\lambda}\Delta x$

$\Delta x = (2n+1)\frac{\lambda}{2}$

(iii) $A_{net} = A_1 - A_2$

If $A_1 = A_2 = A$

$A_{net} = 0$

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

If $I_1 = I_2 = I_0$

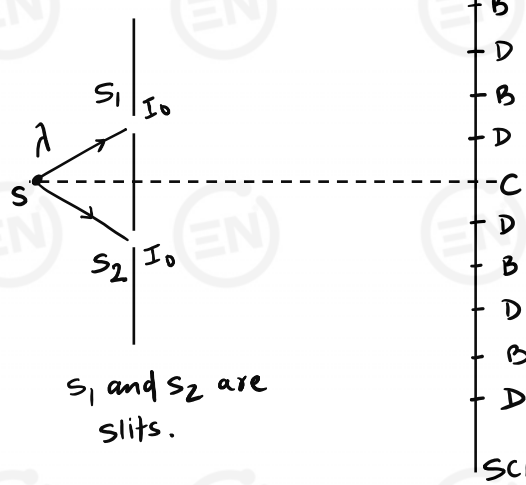
$I_{net} = 0$ (MINIMA)

4. YOUNG'S DOUBLE SLIT EXPERIMENT (YDSE)

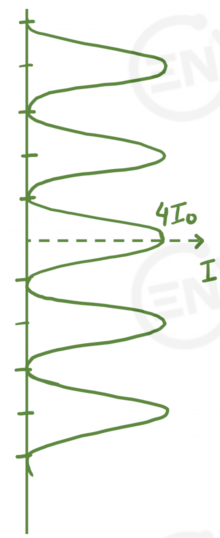
C: Central Bright fringe

B: Bright fringe

D: Dark fringe

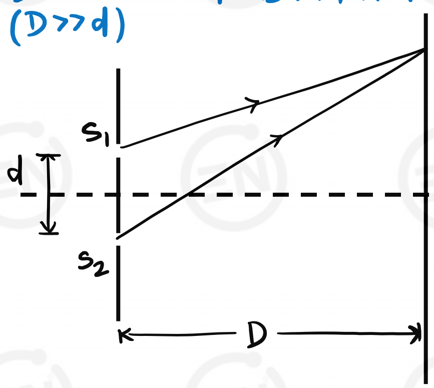


	Δx	I_{net}
D	$5\lambda/2$	0
B	2λ	$4I_0$
D	$3\lambda/2$	0
B	λ	$4I_0$
D	$\lambda/2$	0
C	0	$4I_0$
D		
B		
D		
B		
D		



S_1 and S_2 are slits.

5. DISTANCE OF BRIGHT AND DARK FRINGES ($D \gg d$)



Path difference at y, $\Delta x = \frac{yd}{D}$

BRIGHT FRINGE

$\Delta x = n\lambda$

$\Rightarrow \frac{y_n d}{D} = n\lambda$

$\Rightarrow y_n = \frac{n\lambda D}{d}$

DARK FRINGE

$\Delta x = (2n-1)\frac{\lambda}{2}$

$\Rightarrow \frac{y_n d}{D} = (2n-1)\frac{\lambda}{2}$

$\Rightarrow y_n = (2n-1)\frac{\lambda D}{2d}$

6. FRINGE WIDTH AND ANGULAR FRINGE WIDTH

↳ Distance between two successive Bright or dark fringe.

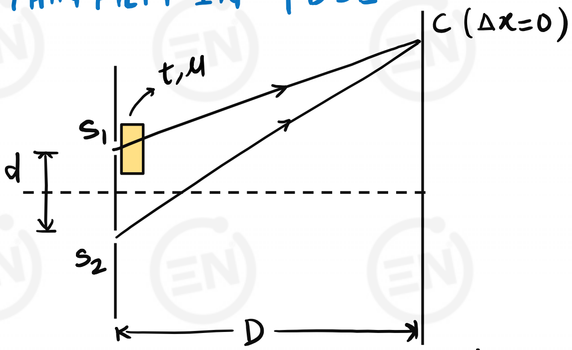
(a) $\beta = \dfrac{\lambda D}{d}$ (b) $\beta_\theta = \dfrac{\lambda}{d}$

7. β IF YDSE SETUP IS IN A MEDIUM OF RERACTIVE INDEX μ.

If in air, $\beta = \dfrac{\lambda D}{d}$

In medium, $\beta' = \dfrac{\lambda D}{\mu d} = \dfrac{\beta}{\mu}$

9. THIN FILM IN YDSE

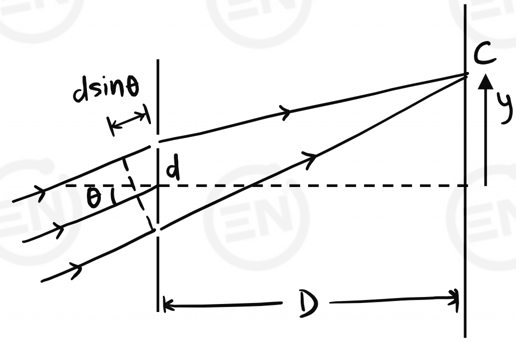


$t(\mu - 1) = \dfrac{yd}{D}$

$\Rightarrow y = \dfrac{tD(\mu - 1)}{d}$

↳ shift in fringe Pattern

10. SHIFTING OF FRINGE IN OBLIQUE INCIDENCE



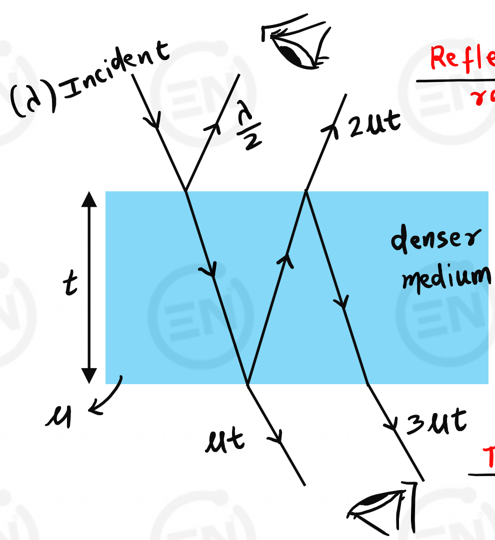
FRINGE SHIFTS UP.

$d\sin\theta = \dfrac{yd}{D}$

$\Rightarrow y = D\sin\theta$

13. INTERFERENCE IN THIN FILMS (normal incidence)

NOTE: When reflection is from denser medium $\frac{\lambda}{2}$ path difference is added



Reflected rays
- CONSTRUCTIVE: $2\mu t - \frac{\lambda}{2} = n\lambda$
- DESTRUCTIVE: $2\mu t - \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$

Transmitted rays
- Constructive: $2\mu t = n\lambda$
- Destructive: $2\mu t = (2n+1)\frac{\lambda}{2}$

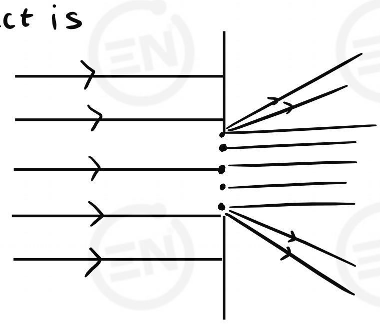
12. DIFFRACTION & POLARIZATION

1. DIFFRACTION

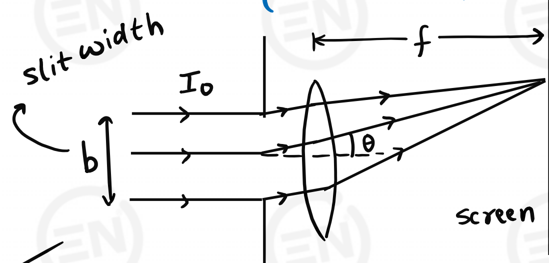
It is bending of Light around corners/edges.

If slit size is very Large, Diffraction effect is negligible.

But if small, effect is significant



2. INTENSITY IN DIFFRACTION (SINGLE SLIT)



$$I(\theta) = I_0 \frac{\sin^2\beta}{\beta^2}, \quad \beta = \frac{\pi b \sin\theta}{\lambda}$$

↳ MINIMA at $\beta = n\pi$

$\therefore \; n\pi = \frac{\pi b \sin\theta}{\lambda}$

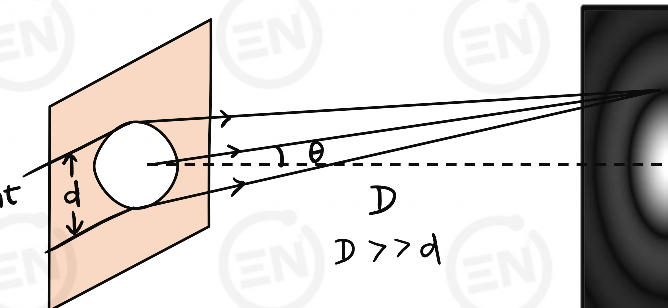
$\boxed{\sin\theta = \frac{n\lambda}{b}}$ and $\boxed{\theta = \frac{n\lambda}{b}}$ if θ is small.

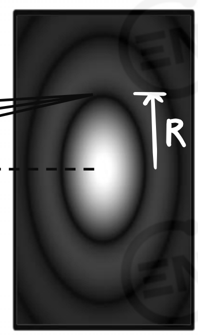
4. DIFFRACTION BY CIRCULAR APERTURE

First MINIMA on screen,

$$\theta = \frac{1.22\lambda}{d}$$

(a) RADIUS of 1st Dark fringe or radius of central bright fringe, $R = \theta D = \frac{1.22\lambda D}{d}$





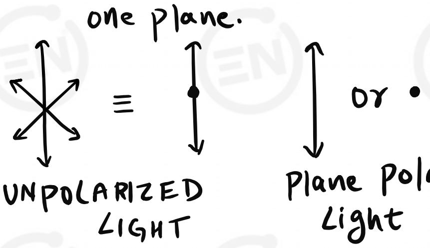
Circular fringes

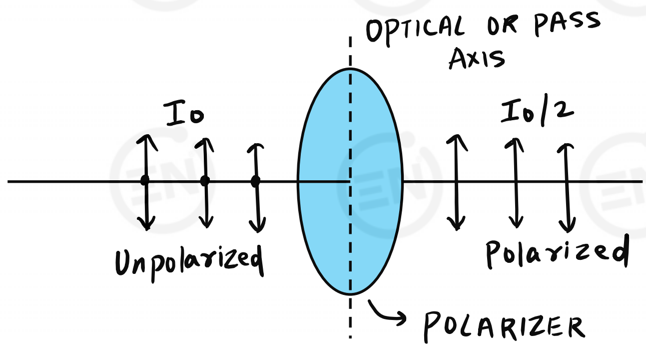
(b) If light is converged using convex lens at the screen placed at focal plane of Lens,

$$R = \theta f = \frac{1.22\lambda f}{d}$$

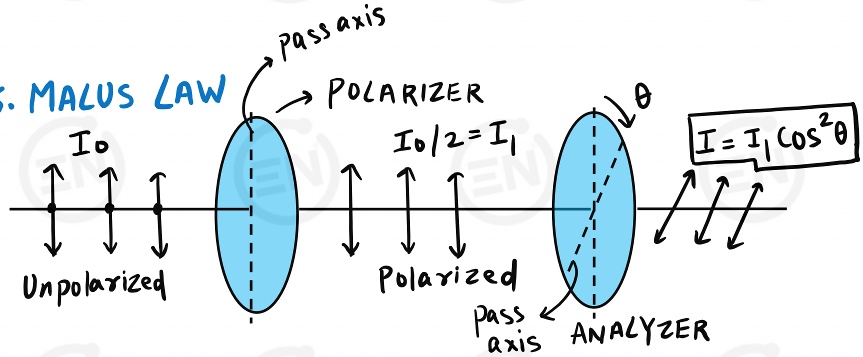
5. POLARIZATION OF LIGHT

↳ Electric Field oscillating in one plane.

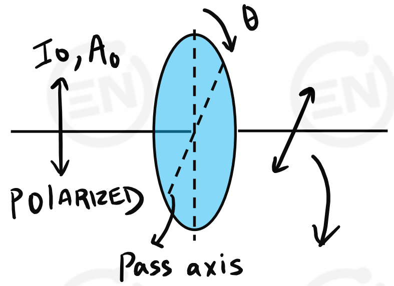




6. MALUS LAW



#Generalized

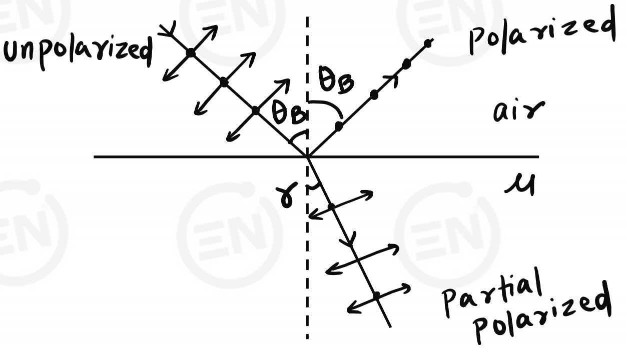


$A = A_0 \cos\theta$

$I = I_0 \cos^2\theta$

7. METHODS OF POLARIZATION OF LIGHT

(a) REFLECTION (BREWSTER'S LAW)



BREWSTER'S ANGLE (θ_B)

θ_B for which angle between reflected and refracted ray is $90°$

$\therefore\ r = 90 - \theta_B$

SNELL'S LAW :

$\sin\theta_B = \mu \sin(90 - \theta_B)$

$\Rightarrow \boxed{\theta_B = \tan^{-1}\mu}$

Brewster's Law

13. EM WAVES

1. TYPES OF EM WAVES

↳ Transverse waves
↳ Electric and magnetic field Energy density is same.

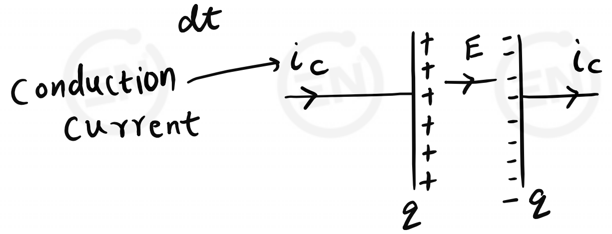
$u_B = \frac{B^2}{2\mu_0}$, $u_E = \frac{1}{2}\varepsilon_0 E^2$

Type	Wavelength Range	Production	Detection
Radio	>0.1 m	Rapid acceleration and deceleration of electrons in aerials	Receiver's aerials
Microwave	0.1 m to 1 mm	Klystron valve or magnetron valve	Point contact diodes
Infra-red	1 mm to 700 nm	Vibration of atoms and molecules	Thermopiles, Bolometer, Infrared photographic film
Light	700 nm to 400 nm	Electrons in atom emit light when they move from one energy level to a lower energy level	The eye, photocells, photographic film
Ultraviolet	400 nm to 1 nm	Inner shell electrons in atoms moving from one energy level to lower level	Photocells, Photographic film
X-rays	1 nm to 0.001 nm	X-ray tubes or inner shell electrons	Photographic film, Geiger tubes
Gamma rays	< 0.001 nm	Radioactive decay of the nucleus	Photographic film, Geiger tubes

2. DISPLACEMENT CURRENT (i_d)

i_d is due to time varying Electric field.

$i_d = \varepsilon_0 \frac{d\phi_E}{dt}$, ϕ_E is Electric flux



(a) If q changes, E changes

$\Rightarrow i_d = \varepsilon_0 A \times \frac{1}{A\varepsilon_0}\frac{dq}{dt} = \frac{dq}{dt}$

∴ In capacitor for time varying current conduction current is same as i_d.

(b) Between plates $i_d \neq 0$, $i_c = 0$

outside plates $i_c \neq 0$, $i_d = 0$

(c) i_d is uniform across plate cross-section

3. AMPERE'S LAW

$\oint \vec{B}\cdot\vec{dl} = \mu_0 i_{enclosed}$ ⟶ $i_c + \varepsilon_0 \frac{d\phi_E}{dt}$

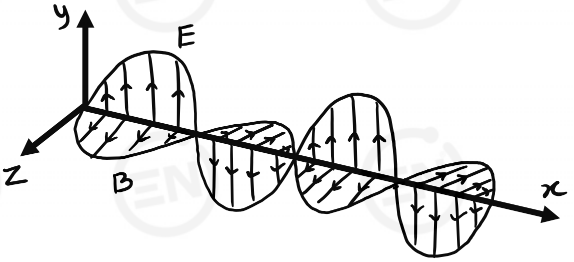
4. MAXWELL'S EQUATIONS

1. Gauss's Law in Electrostatics, $\phi_E = \oint \vec{E}\cdot d\vec{A} = q_{in}/\varepsilon_0$
2. Gauss's Law for Magnetism, $\phi_B = \oint \vec{B}\cdot d\vec{A} = 0$ { due to closed loop lines of field. This explains why monopole can't exist
3. Faraday's Law, $\oint \vec{E}\cdot d\vec{l} = -\dfrac{d\phi_B}{dt}$
4. Ampere-Maxwell Law, $\oint \vec{B}\cdot d\vec{l} = \mu_0 i_c + \mu_0 \varepsilon_0 \dfrac{d\phi_E}{dt}$

5. EM WAVES EQUATION AND KEY POINTS

$\vec{E} = E_0 \sin(\omega t - kx)\,\hat{j}$

$\vec{B} = B_0 \sin(\omega t - kx)\,\hat{k}$



KEY POINTS

(a) RELATION AMONG $\hat{C}, \hat{E}, \hat{B}$ (unit vectors along direction of propagation, Electric field and magnetic field)

$\hat{C} = \hat{E} \times \hat{B}$, $\hat{B} = \hat{C} \times \hat{E}$, $\hat{E} = \hat{B} \times \hat{C}$

(b) FROM WAVE Equation

$\vec{E} = E_0 \sin(\omega t - kx)\,\hat{j}$ → E along $\hat{j}$, $E_{rms} = E_0/\sqrt{2}$; → Wave propagation along +VE x-axis

(c) RELATION BETWEEN E_0 and B_0

$$E_0 = c B_0$$

(d) SPEED OF EM WAVES

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \text{ in free space}$$

$$c_{medium} = \frac{1}{\sqrt{\mu_r \mu_0 \varepsilon_r \varepsilon_0}} = \frac{c}{\sqrt{\mu_r \varepsilon_r}}$$

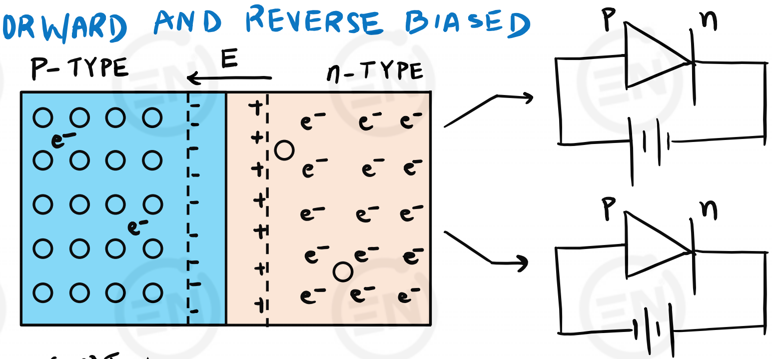
(e) INTENSITY

$$I = \frac{1}{2}\epsilon_0 c E_0^2 = \epsilon_0 c E_{rms}^2$$

NOTE: In above intensity due to Electric field $= \dfrac{I}{2} = \dfrac{1}{2}\epsilon_0 c E_{rms}^2$

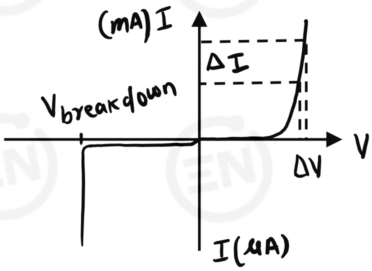
14. SEMICONDUCTORS

2. FORWARD AND REVERSE BIASED



Forward biased
↳ Current due to majority charge carriers.

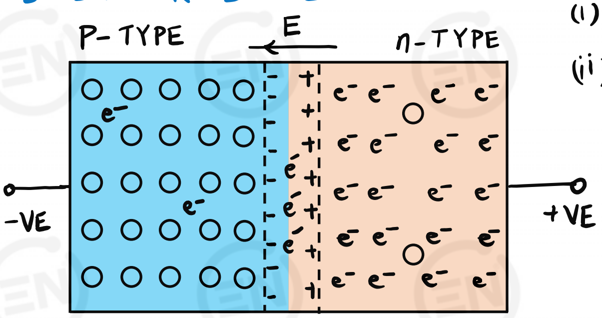
Reverse biase
↳ very small current due to minority charge carriers.



① For ideal diode Resistance is zero (FB) and infinite (RB).

② Dynamic Resistance, $R = \frac{\Delta V}{\Delta I}$

3. ZENER DIODE

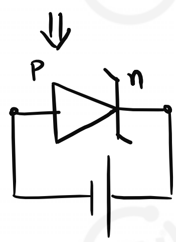


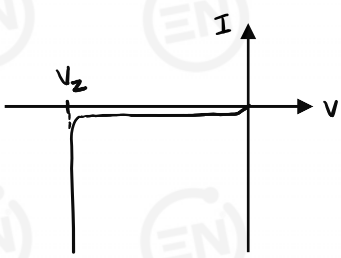
(i) It is heavily doped

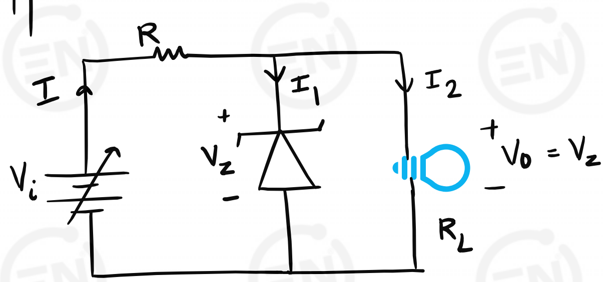
(ii) Depletion region very thin
⇒ E is very large.

(iii) In RB state, E strength ↑ and e⁻ covalent bonds in depletion region breaks.

⇓







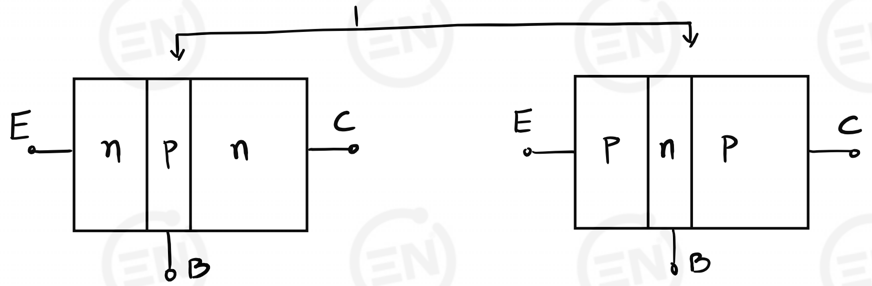
① ↳ As p.d. across crosses V_Z (breakdown voltage), almost all current passes through diode.

② ↳ And constant V_Z is across it

③ $I_2 = \frac{V_Z}{R_L}$

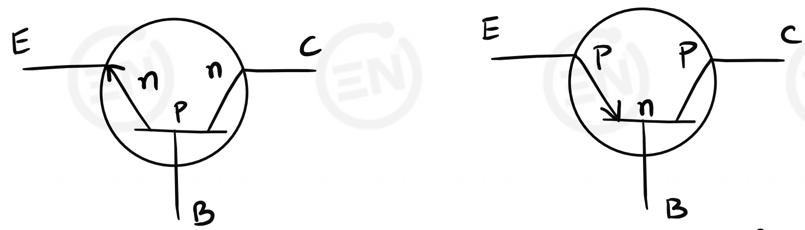
④ $I = I_1 + I_2$

1. TRANSISTORS (3 terminal – 2 Junction Device)



	SIZE	DOPING
E, Emitter	Moderate	Highly Doped
B, BASE	Very thin	Lightly Doped
C, Collector	Large	Moderately Doped

2. CIRCUIT SYMBOL



Arrow from P → n

4. DC CURRENT GAINS

↳ Base current Amplification factor, $\beta = \dfrac{I_C}{I_B}$

↳ Emitter current Amplification factor, $\alpha = I_C / I_E$

↳ $I_E = I_C + I_B \Rightarrow \dfrac{I_C}{\alpha} = I_C + \dfrac{I_C}{\beta}$

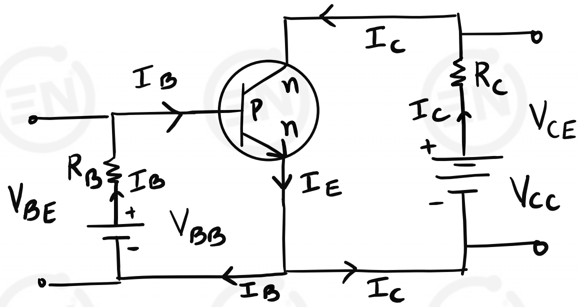
$$\Rightarrow \boxed{\alpha = \frac{\beta}{1+\beta}}$$

NOTE: $\because I_B << I_C$

$\Rightarrow \beta$ is large

and α is a little smaller than 1.

5. CHARACTERISTIC CURVE



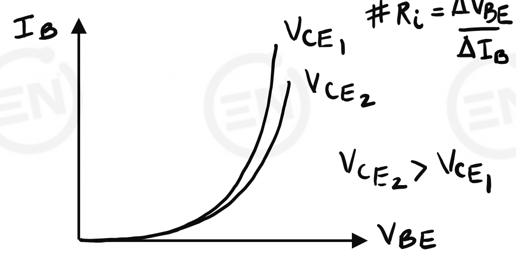
(1) $V_{CE} = V_{CC} - I_C R_C$

(2) $V_{BE} = V_{BB} - I_B R_B$

\# $R_o = \dfrac{\Delta V_{CE}}{\Delta I_C}$

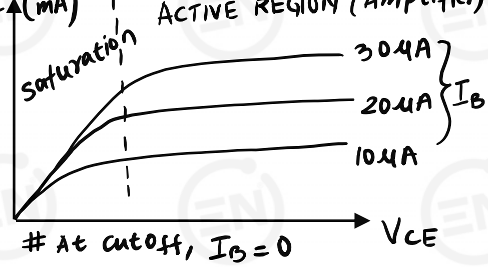
\# At saturation $V_{CE} = 0$

(a) Input characteristic



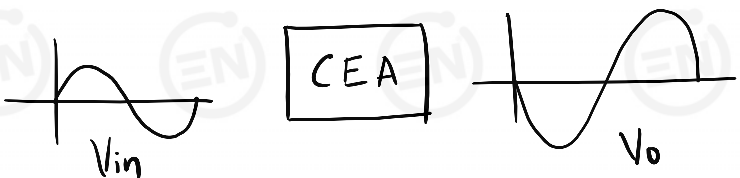
\# $R_i = \dfrac{\Delta V_{BE}}{\Delta I_B}$

(b) output characteristic



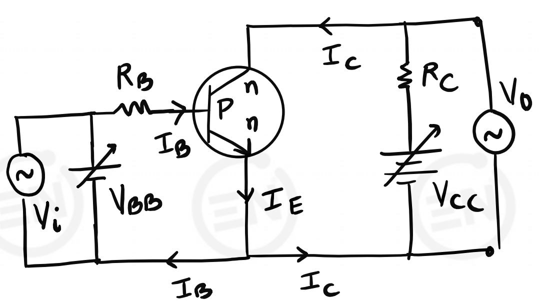
\# At cutoff, $I_B = 0$

7. COMMON EMITTER AMPLIFIER



↳ 180° phase out.

8. GAIN IN CE Amplifier



A small variation in input current causes large variation in output current.

(i) AC current gain, $\beta_{AC} = \dfrac{\Delta I_C}{\Delta I_B}$

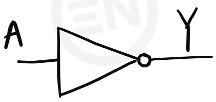
(ii) AC voltage gain, $A_V = \dfrac{\Delta V_o}{\Delta V_i} = \dfrac{\Delta I_C R_o}{\Delta I_B R_i}$

$\Rightarrow A_V = \beta_{AC} \dfrac{R_o}{R_i}$

(iii) AC Power gain, $A_P = A_V \times \beta_{AC}$

$= \beta_{AC}^2 \dfrac{R_o}{R_i}$

3. NOT GATE (Inversion Gate)



$Y = \bar{A}$

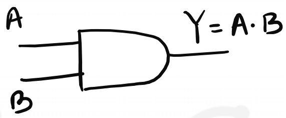
TRUTH TABLE

A	$Y = \bar{A}$
1	0
0	1

Truth Table : Relation between Input and Output.

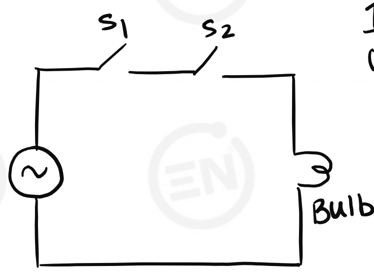
4. AND GATE

↳ output high (1), if both input is high (1)
↳ output low (0), if either input is low (0)



TRUTH TABLE

A	B	$Y = A \cdot B$
1	0	0
0	1	0
1	1	1
0	0	0



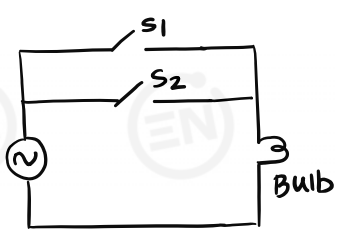
⇒ switch close : 1
switch open : 0
Bulb Glow = 1
else = 0

5. OR GATE

↳ output high (1), if either input is high (1)
↳ output low (0), if both input low (0)

TRUTH TABLE

A	B	$Y = A + B$
1	0	1
0	1	1
1	1	1
0	0	0



6. RULES OF BOOLEAN ALGEBRA & DE MORGAN'S THEOREM

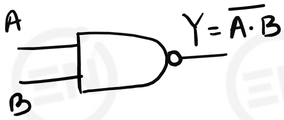
(a) $A + 0 = A$
(b) $A + A = A$
(c) $A \cdot A = A$
(d) $A \cdot \bar{A} = 0$
(e) $\bar{\bar{A}} = A$

DE MORGAN'S THEOREM

$\overline{A \cdot B} = \bar{A} + \bar{B}$ $\overline{A + B} = \bar{A} \cdot \bar{B}$

↳ Boolean Expressions

7. NAND GATE (AND + NOT)

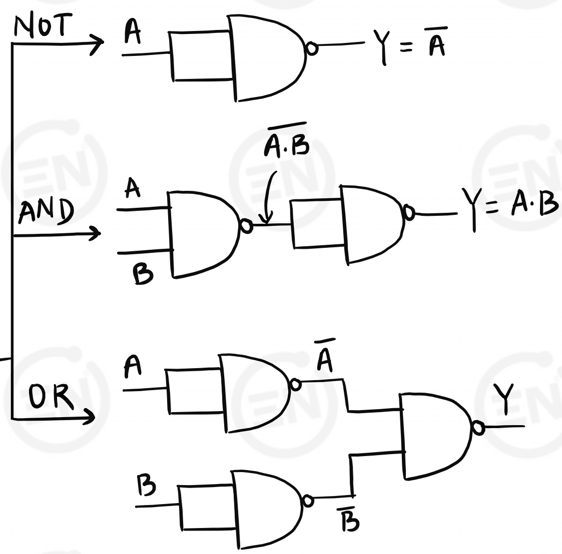


Inverts the AND Gate output.

TRUTH TABLE

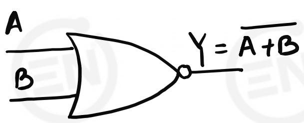
A	B	$Y=\overline{A\cdot B}$
1	0	1
0	1	1
1	1	0
0	0	1

NAND GATE (UNIVERSAL GATE)



$Y=\overline{\overline{A}\cdot\overline{B}}=\overline{\overline{A}}+\overline{\overline{B}}=\boxed{A+B}$

8. NOR GATE (OR + NOT)

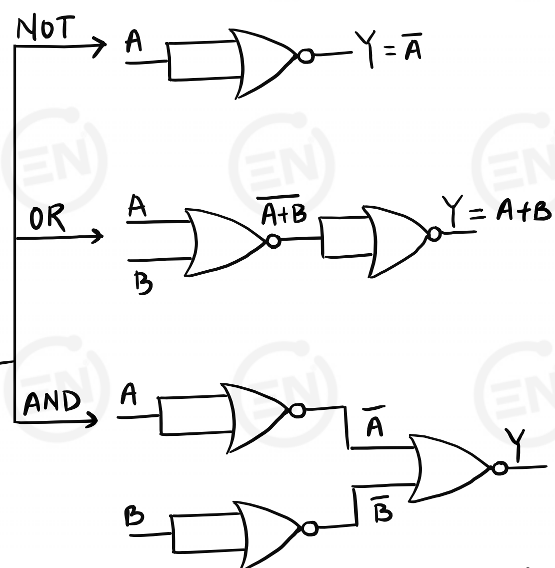


Inverts the AND Gate output.

TRUTH TABLE

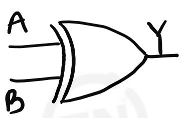
A	B	$Y=\overline{A+B}$
1	0	0
0	1	0
1	1	0
0	0	1

NOR GATE (UNIVERSAL GATE)



$Y=\overline{\overline{A}+\overline{B}}=\overline{\overline{A}}\cdot\overline{\overline{B}}=\boxed{A\cdot B}$

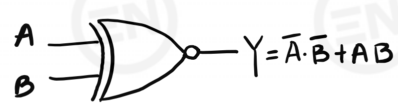
9. EXCLUSIVE GATES



XOR (Exclusive OR GATE)

$Y=\overline{A}\cdot B+A\cdot\overline{B}$

A	B	Y
1	0	1
0	1	1
1	1	0
0	0	0

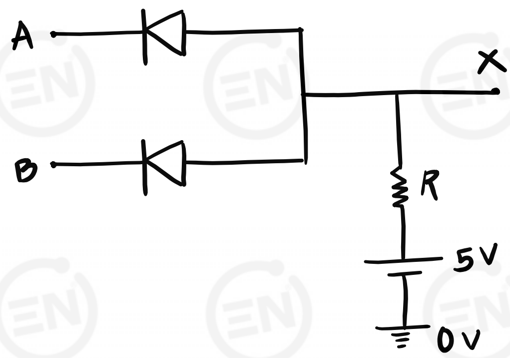


XNOR (EXCLUSIVE NOR GATE)

A	B	Y
1	0	0
0	1	0
1	1	1
0	0	1

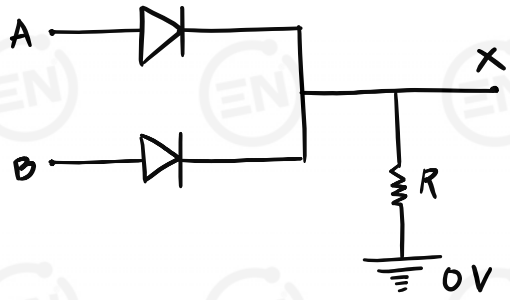
AND gate using Diodes

1.



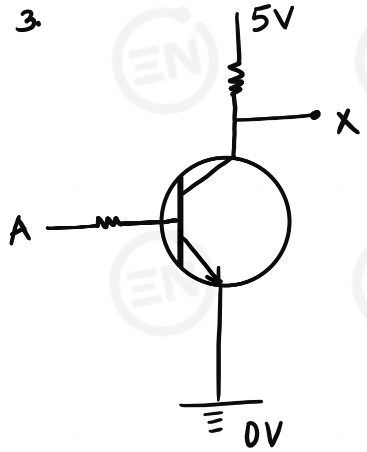
OR gate using Diodes

2.



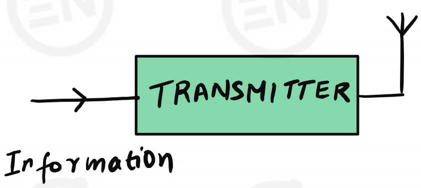
NOT gate using npn Transistor

3.



15. COMMUNICATIONS

5. TRANSMISSION OF EM WAVES THROUGH SPACE



Power radiated, $P_{rad} \propto \left(\frac{l}{\lambda}\right)^2$ → Antenna length

↳ For optimum power transmission of signals, size of antenna $\geq \frac{\lambda}{4}$

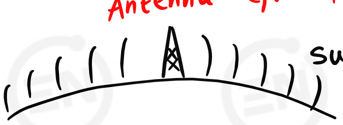
Why high frequency signals for transmission?

$f\uparrow \Rightarrow \lambda\downarrow$

- Practical Antenna size
- $\lambda\downarrow \Rightarrow P_{rad}\uparrow$

6. PROPAGATION MODES FOR EM WAVES

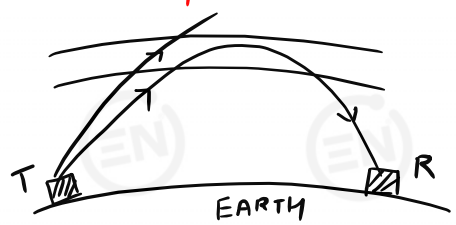
Ground Waves ①



→ The mode of propagation is called surface wave propagation and the wave glides over the surface of the earth

→ It is attenuated due to absorption of energy by earth surface.

Sky wave ②

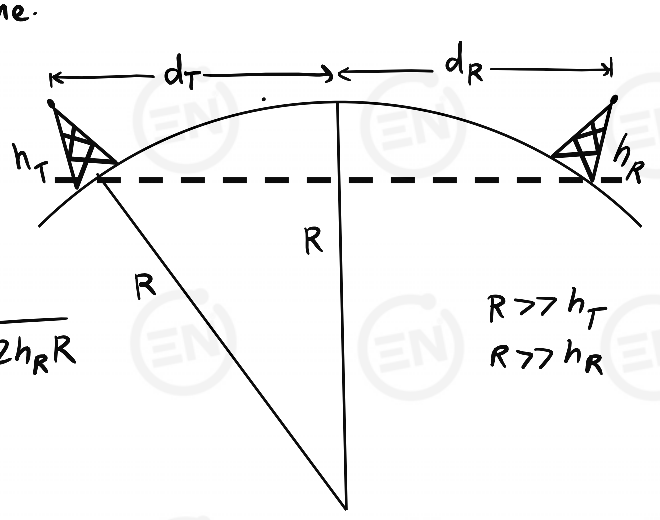


↳ Long distance propagation done by Ionospheric Reflection. Ionosphere : 65 - 400 km

(a) 3 to 30 MHz is reflected

(b) $f > 30$ MHz penetrates ionosphere

↳ ③ Space wave → for $f > 40$ MHz Line of sight propagation is done.



$\therefore$ Max LOS distance $= d_T + d_R$

$$= \sqrt{2h_T R} + \sqrt{2h_R R}$$

$R \gg h_T$

$R \gg h_R$

10. AMPLITUDE MODULATION (AM)

$y_m = A_m \sin \omega_m t$ Modulating signal → **AM MODULATOR** ← $y_c = A_c \sin \omega_c t$ Carrier signal

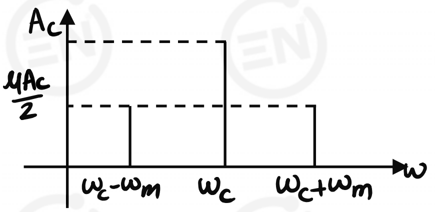
$\omega_c >> \omega_m$

$$y = (\underbrace{A_c + A_m \sin \omega_m t}_{\text{Amplitude varies as per modulating signal.}}) \sin \omega_c t$$

$$\Rightarrow y = A_c \left(1 + \frac{A_m}{A_c} \sin \omega t\right) \sin \omega_c t$$

↳ Modulation index, $\mu = \frac{A_m}{A_c}$

$$\Rightarrow y = A_c \sin \omega_c t + \frac{\mu A_c}{2} \cos(\omega_c - \omega_m)t - \frac{\mu A_c}{2} \cos(\omega_c + \omega_m)t$$



3 frequency:

(a) Carrier freq : ω_c

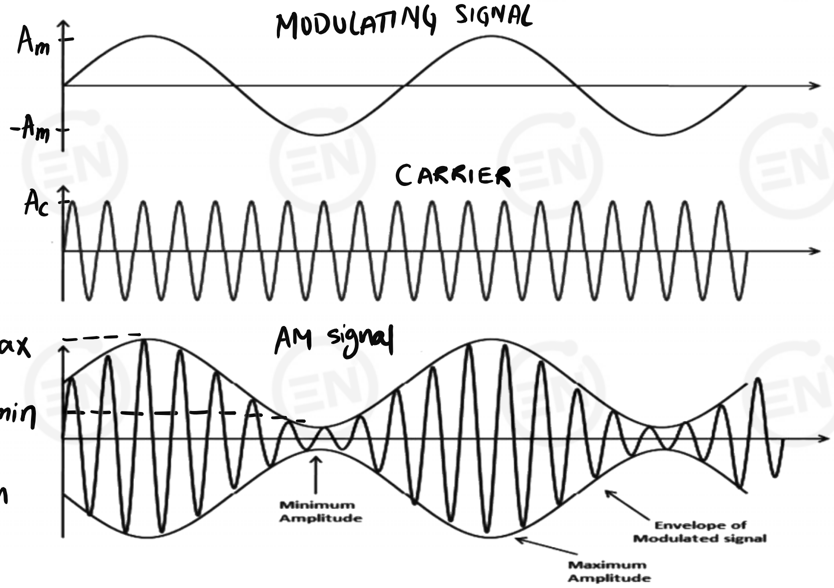
(b) Lower side freq: $\omega_c - \omega_m$

(c) Upper side freq: $\omega_c + \omega_m$

BANDWIDTH $= 2\omega_m \quad (2f_m)$

NOTE: Modulation Index,

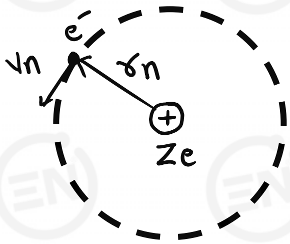
$$\mu = \frac{A_m}{A_c} = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$



16. MODERN PHYSICS – ATOMS

1. BOHR'S POSTULATES (for single e^- system)

1st



$$\frac{kZe^2}{r_n^2} = \frac{mv_n^2}{r_n}$$

2nd

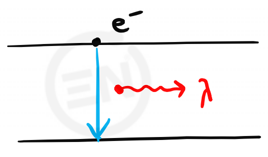
Bohr's Quantization

$$mv_n r_n = \frac{nh}{2\pi}$$

$(n \in I)$

3rd

Release of energy



$$\frac{hc}{\lambda} = E_{n_2} - E_{n_1}$$

2. BOHR'S MODEL ($1e^-$ system)

- Radius of n^{th} orbit, $r_n = \dfrac{n^2h^2}{4\pi^2 kZe^2 m} = 0.529 \times \dfrac{n^2}{Z}$ Å ($r_n \propto \dfrac{1}{m_e}$)
- Velocity in n^{th} orbit, $V_n = \dfrac{2\pi kZe^2}{nh} = 2.18 \times 10^6 \times \dfrac{Z}{n}$ m/s
- $\omega_n = \dfrac{V_n}{r_n}$ $\omega_n \propto \dfrac{Z^2}{n^3}$ rad/s
- $T_n = \dfrac{2\pi}{\omega_n}$ $T_n \propto \dfrac{n^3}{Z^2}$ s

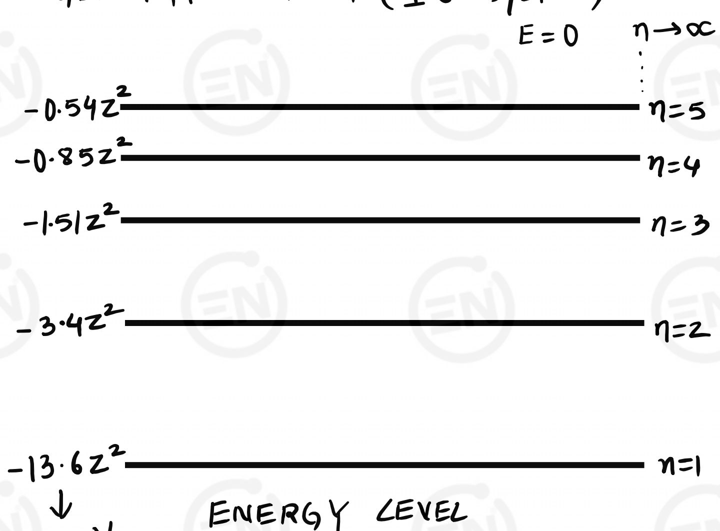
Focus more on relations

- $E_n = K_n + U_n = -\dfrac{kZe^2}{2r_n} = -13.6 \times \dfrac{Z^2}{n^2}$ eV

3. ENERGY LEVEL OF HYDROGEN TYPE ATOM ($1e^-$ system)

$$E_n = -13.6 \times \frac{Z^2}{n^2} \text{ eV}$$

NOTE: Learn them for speed solving.



ENERGY LEVEL DIAGRAM

4. EXCITATION OF ATOM

↳ For e^- to absorb energy and excite from n_1 to n_2, the energy absorbed must be exactly equal to $E_{n_2} - E_{n_1}$

Ex:

$n=3$ ——— $-1.51\,eV$

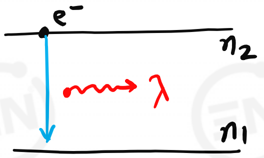
$n=1$ ——— $-13.6\,eV$

$\because E_3 - E_1 = 12.09\,eV$

* Thus $12.09\,eV$ of energy must be absorbed.

5. λ OF EMITTED RADIATION

$$\frac{hc}{\lambda} = E_{n_2} - E_{n_1}$$



$$\Rightarrow \frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right), \quad R \sim 10^7\,m^{-1}$$

↳ Rydberg's constant

IMPORTANT:

(a) $\lambda = \dfrac{12430}{\Delta E\ (\text{in eV})}$ Å or $= \dfrac{1243}{\Delta E\ (\text{in eV})}$ nm

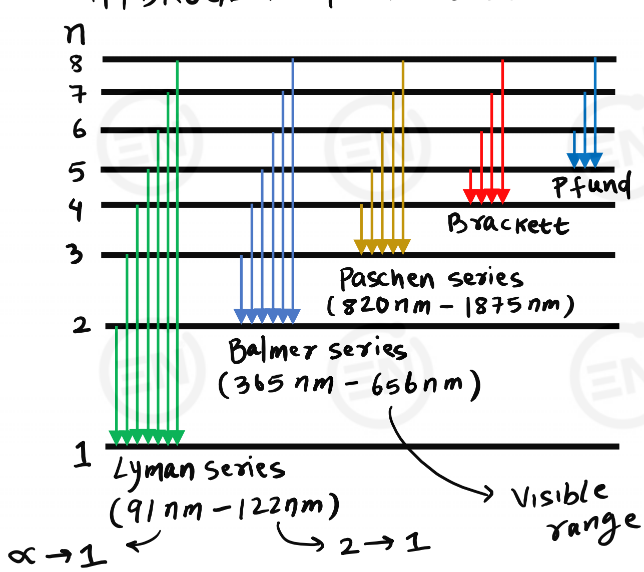
(b) $\Delta E = \dfrac{12430}{\lambda(\text{Å})}$ eV

6. NUMBER OF SPECTRAL LINES

↳ possible number of photon energies emitted due to de excitation of e^- from $n = n_2$ to $n=1$ state

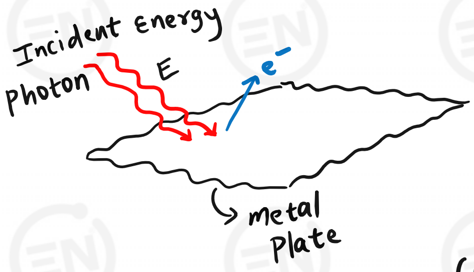
$$= {}^{n}C_2 = \frac{n(n-1)}{2}$$

7. HYDROGEN SPECTRAL SERIES



16. MODERN PHYSICS – PHOTOELECTRIC

2. PHOTOELECTRIC EMISSION



(a) Threshold frequency (ν_{th}), Threshold wavelength (λ_{th})

$$\phi = h\nu_{th} = \frac{hc}{\lambda_{th}}$$

ν_{th}: minimum freq. to start photoelectric effect.

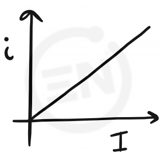
(b) If $\nu > \nu_{th}$ ($E > \phi$)

e^- comes out with V_{max}, $\frac{1}{2}mv_{max}^2 = E - \phi$

$\Rightarrow K_{max} = h\nu - h\nu_{th}$

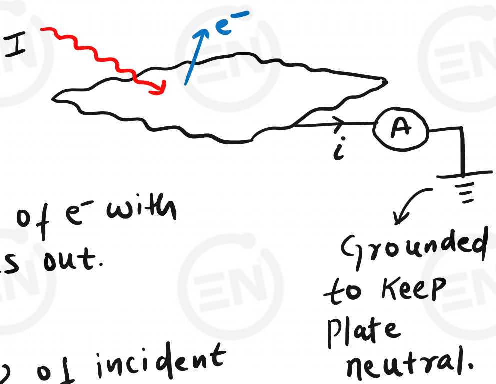
NOTE: e^- may come out with $V < V_{max}$ if it collides with other e^-.

3. EFFECT OF INTENSITY (I) and TEMP° (T) ON PHOTOELECTRIC EFFECT



(a) If $I \uparrow \Rightarrow i$ also $\uparrow$

(b) If Temp° $\uparrow \Rightarrow$ No effect

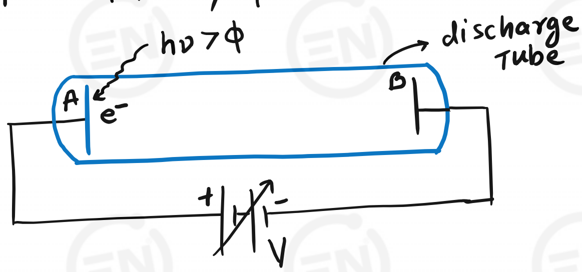


NOTE: $\uparrow I$ does'nt $\uparrow$ K.E of e^- with which it comes out.

$$[K = h\nu - \phi]$$

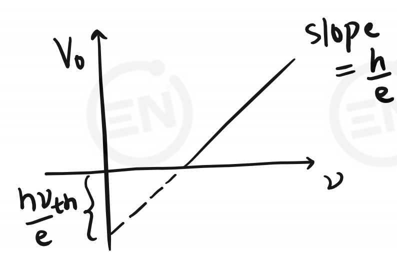
K depends on ν of incident energy.

4. STOPPING POTENTIAL



$$\boxed{V_0 = \frac{h}{e}\nu - \frac{h\nu_{th}}{e}}$$

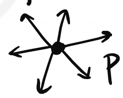
Einstein Photoelectric Equation



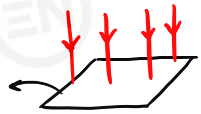
16. MODERN PHYSICS – DUAL NATURE

1. PHOTON FLUX / PHOTON DENSITY

→ Number of photons emitted /sec, $N = \frac{P}{hc/\lambda} = \boxed{\frac{P\lambda}{hc}}$

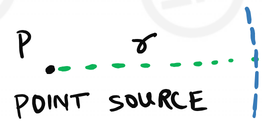


→ PHOTON FLUX, ϕ_p (no. of photons per sec per unit Area)



$$\phi_p = \frac{N}{A} = \frac{1}{A} \times \frac{P\lambda}{hc} = \boxed{\frac{I\lambda}{hc}}$$

→ PHOTON DENSITY, $\rho_N = \frac{\phi_p}{c} = \boxed{\frac{I\lambda}{hc^2}}$ $\left\{ \text{Just put } I \text{ to get } \rho_N \right.$

Ex: 

$I = \frac{P}{4\pi r^2}$

2. WAVE PARTICLE DUALITY

PARTICLE NATURE

(a) Treated as photon

(b) Energy, $E = pc$

momentum

WAVE NATURE

Treated as EM waves

$E = \frac{hc}{\lambda}$

$\therefore pc = \frac{hc}{\lambda}$

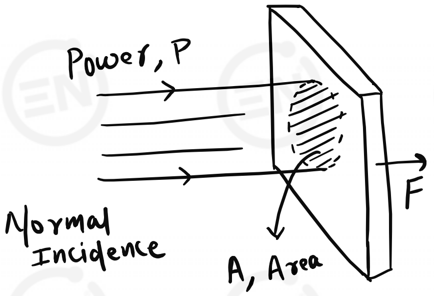
$\Rightarrow \boxed{p = \frac{h}{\lambda}}$ → photon momentum

3. DE BROGLIE'S HYPOTHESIS

(If light behaves as particle then physical particle too can behave as waves)

$\lambda = \frac{h}{p}$ or $\boxed{\lambda = \frac{h}{mv}}$

4. RADIATION FORCE / PRESSURE



F = no. of photons/sec × momentum change

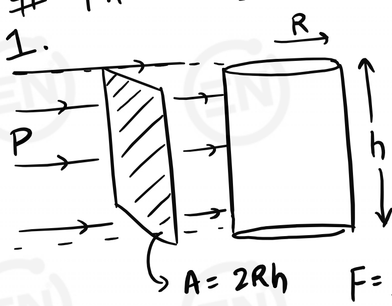
$$= \frac{P\lambda}{hc} \times \frac{h}{\lambda} = \boxed{\frac{P}{c}}$$ { P: Power, $P = IA$

Radiation Pressure $= \frac{F}{A} = \frac{P/c}{A} = \boxed{\frac{I}{c}}$

NOTE: If surface is perfectly reflective, $F = \frac{2P}{c}$, Pressure $= 2I/c$

PROJECTED AREA

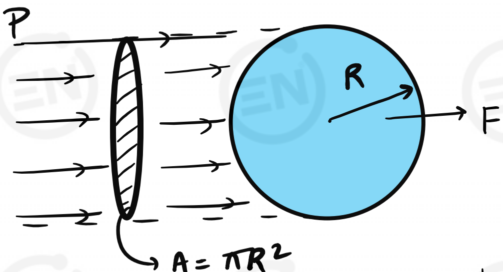
1.



$F = \frac{P}{c} = \frac{I\,2Rh}{c}$ (Assuming Black Body)

power

2.



$F = \frac{P}{c} = \frac{I\pi R^2}{c}$ { Black Body

5. ATOM RECOIL DURING DE-EXCITATION

Hydrogen type atom ($1e^-$ system)

$$\lambda = \frac{12430}{\Delta E \text{ (in eV)}} \text{ Å}$$

$$\therefore mV_{recoil} = \frac{h}{\lambda}$$

$$\Rightarrow \boxed{V_{recoil} = \frac{h}{\lambda m}}$$

↳ m : mass of atom
λ : wavelength of photon
h : Planck's constant

16. MODERN PHYSICS – RADIOACTIVITY

1. RADIOACTIVITY (ACTIVITY, UNITS)

(a) Unstable nucleus disintegrate spontaneously.

(b) This phenomena of disintegration is called "ACTIVITY", A_c

Also known as decay rate

$A_c = -dN/dt$

$X \longrightarrow Y$

Parent Nucleus → Daughter Nucleus

(c) UNIT of Activity is dps (decay per sec)

- 1 Bq (Becquerel) = 1 dps
- 1 Ci (curie) = 3.7×10^{10} dps $= 3.7\times10^{10}$ Bq
- 1 Ru (Rutherford) = 10^6 dps

2. RADIOACTIVE DECAY LAW ($X \xrightarrow{\lambda} Y$)

X → ACTIVE NUCLEI

(a) Activity ∝ Number of Active nuclei

$$-\frac{dN}{dt} \propto N \Rightarrow -\frac{dN}{dt} = \lambda N$$

{Activity, $A_c = \lambda N$}

λ → Decay constant (tells how fast decay occurs)

Integrate

Radioactive decay eqn

$$\boxed{N = N_0 e^{-\lambda t}}$$

(i) N_0 is No. of Nuclei at $t=0$

(ii) $A_c = A_{c0}\, e^{-\lambda t}$

3. HALF LIFE TIME (T)

→ time taken to become half

At $t=0$, $N = N_0$

$t = T$, $N = \frac{N_0}{2}$

$$\Rightarrow \frac{N_0}{2} = N_0 e^{-\lambda T}$$

$$\Rightarrow \boxed{T = \frac{\ln 2}{\lambda}} \text{ or } \frac{0.693}{\lambda}$$

NOTE: Radioactive decay eqn in terms of T:

$$N = N_0 e^{-\lambda t} \Rightarrow N = N_0\, e^{-\frac{\ln 2}{T} t}$$

$$\boxed{N = N_0 (2)^{-t/T}}$$

and, $A_c = A_{c0} (2)^{-t/T}$

4. MEAN LIFE TIME

$$\boxed{\tau = \frac{1}{\lambda}}$$

5. SIMULTANEOUS DECAY

$X \xrightarrow{\lambda_1} Y$

$X \xrightarrow{\lambda_2} Z$

X (N)

$$A = \lambda_1 N + \lambda_2 N$$

$$\Rightarrow -\frac{dN}{dt} = N(\lambda_1 + \lambda_2)$$

$$\boxed{N = N_0\, e^{-(\lambda_1+\lambda_2)t}}$$

16. MODERN PHYSICS – NUCLEAR PHYSICS

3. NUCLEUS SIZE AND STABILITY OF HEAVY NUCLEUS

↳ Size of Nucleus ∝ Atomic mass

$\Rightarrow \frac{4}{3}\pi R^3 \propto A \Rightarrow \boxed{R = R_0 A^{1/3}}$

R_0 : fermi-const. $R_0 \sim 10^{-15}$ m

↳ If $R\uparrow \Rightarrow F_n \downarrow$

So, Nucleus gets unstable

⇒ Decay starts

$X \longrightarrow Y$ + Radiation

4. NUCLEAR BINDING ENERGY

$$Zp + (A-Z)n \longrightarrow {}^{A}_{Z}X + \underbrace{E_b}_{\text{BINDING ENERGY}}$$

NOTE: When reactants combine to form stable product, THERE IS MASS LOSS Called "MASS DEFECT"

$$\boxed{\Delta m = Zm_p + (A-Z)m_n - M_X}$$

and, $E_b = \Delta m c^2$ {Δm if in AMU, 1 AMU = 1.66×10^{-27} kg

or

$$\boxed{E_b = \Delta m \text{ (in AMU)} \times 931.5 \text{ MeV}}$$

6. NUCLEAR FISSION AND FUSION

Fission: $X \longrightarrow Y + Z + \Delta E_2$ (splitting)

Fusion: ↳ $A + B \longrightarrow C + \Delta E_1$ (JOINING of nucleus)

(i) In both Energy released

(ii) $\Delta E_1 = (m_A + m_B - m_C)c^2$

$\Delta E_2 = (m_X - m_Y - m_Z)c^2$

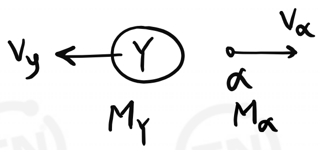
*NOTE: Energy released (+VE) or even supplied (−VE) is called Q-Value

$$Q = \Delta m c^2$$

7. Alpha, BETA AND GAMMA DECAY

(a) α-decay (He Nucleus) $\quad {}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha + E$, $\quad Q = (M_X - M_Y - M_\alpha)c^2$

NOTE: THIS energy is released in form of Kinetic energy.



$M_Y V_Y = M_\alpha V_\alpha$ —(i), $\quad Q = \frac{1}{2}M_Y V_Y^2 + \underbrace{\frac{1}{2}M_\alpha V_\alpha^2}_{K_\alpha}$ —(ii)

from (i) and (ii):

$$K_\alpha = \frac{Q M_Y}{M_\alpha + M_Y} = \boxed{\frac{Q(A-4)}{A}}$$

(b) Beta Decay (e^- or e^+) — e^- → electron, e^+ → positron

$\nu \rightarrow$ neutrino

$\bar{\nu} \rightarrow$ antineutrino

β^+ Decay

$p \longrightarrow n + e^+ + \nu$

${}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + e^+ + \nu$

$\Delta m = M_X - M_Y - 2m_e$

β^- Decay

$n \rightarrow p + e^- + \bar{\nu}$

${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^- + \bar{\nu}$

K capture

$p + e^- \longrightarrow n + \nu$

${}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + \nu$

$\Delta m = M_X - M_Y$

(In K capture, e^- is captured from K-shell)

(C) Gamma Decay (EM Radiation

$\Rightarrow X \rightarrow Y + \alpha + \gamma$

NOTE: It can happen even for β-decay

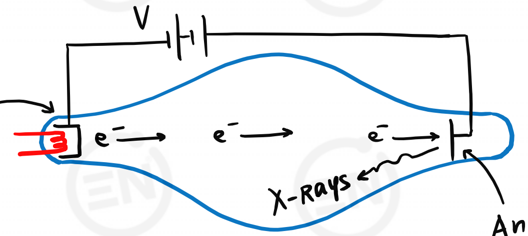
16. MODERN PHYSICS – X RAYS

1. X-RAYS (≈ 1 Å)

Soft X-Rays
- High wavelength
- Low energy

Hard X Rays
- Low wavelengths
- High Energy

2. PRODUCTION OF X-RAYS (X-ray tubes)



Cathode (heated electrically)

Coolidge Tube

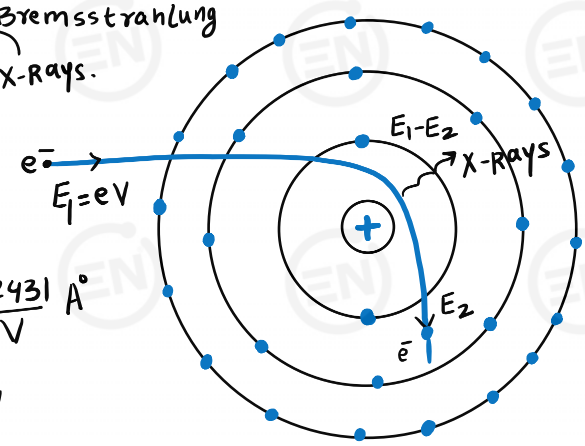
Anode (Target)

\# X-Rays are produced by incidence of accelerated e⁻ on target material.
- Continuous X-Rays (Bremsstrahlung)
- Characteristic X-Rays

3. CONTINUOUS X-RAY

↳ Deceleration of e⁻ when deflected by atomic nucleus causes production of X-Rays.

This Phenomena is called Bremsstrahlung



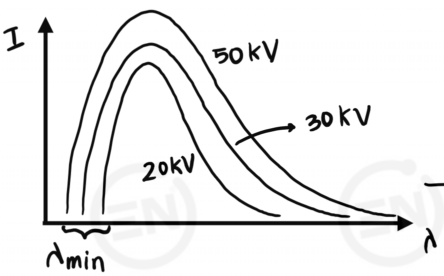
(a) Energy of X-rays, $E = E_1 - E_2$

$E_{max} = E_1 = eV \quad (E_2 = 0)$

∴ Cutoff Wavelength of X-Ray,

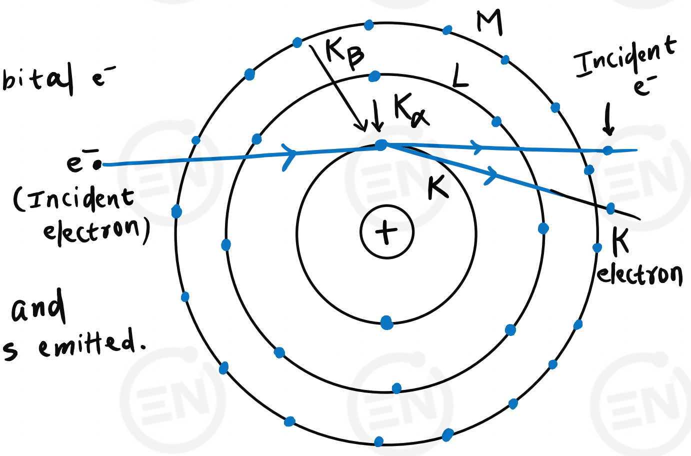
$$\# \ \lambda_{min} = \frac{hc}{E_{max}} = \frac{hc}{eV} = \frac{12431}{V} \text{ Å}$$

\#



→ X-Rays Continuum Radiation spectra

4. CHARACTERISTIC X-RAY



(i) some incident e^- knocks off orbital e^- of K, L, M .. shell.

(ii) If $eV >$ Binding Energy of "K shell e^-", only then it is removed.

(iii) e^- from L, M, N.. can jump to K and during this photon (x-ray) is emitted.

$\hookrightarrow \lambda = \dfrac{hc}{\Delta E}$

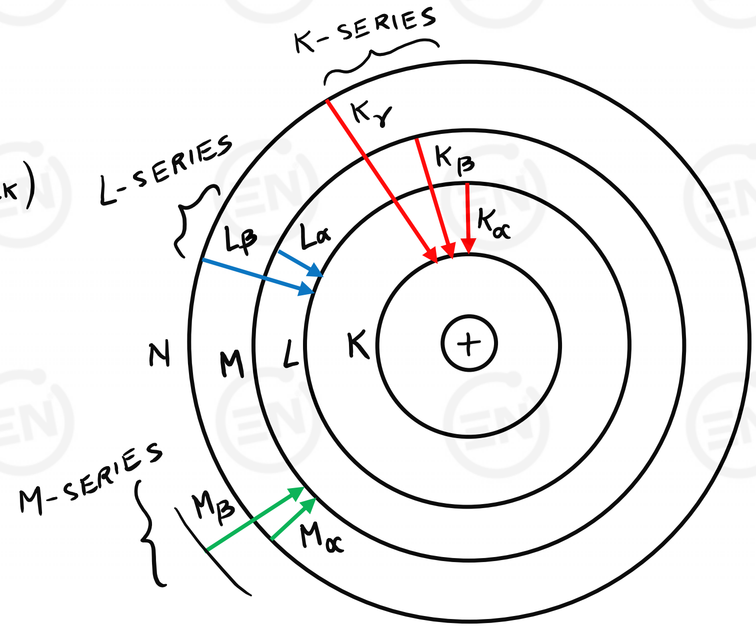
(a) K_α X-Ray $\rightarrow$ If e^- jumps from $L \rightarrow K$
(b) K_β $\rightarrow$ e^- jumps from $M \rightarrow K$
(c) K_γ $\rightarrow$ e^- jumps from $N \rightarrow K$

K-Series

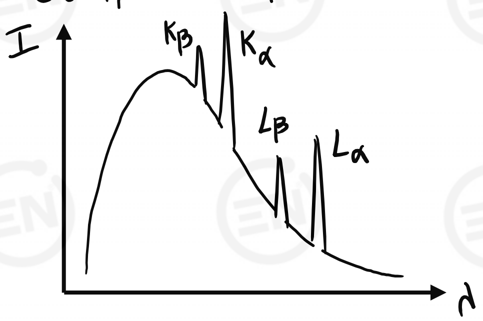
NOTE:

(i) If you compare K_β and K_α

$\lambda_{K_\beta} < \lambda_{K_\alpha}$ $(\because \Delta E_{MK} > \Delta E_{LK})$



5. COMPLETE SPECTRUM



$K_\beta : M \rightarrow K$
$K_\alpha : N \rightarrow K$
$L_\beta : N \rightarrow L$
$L_\alpha : M \rightarrow L$

6. MOSELEY'S LAW ($\sqrt{\nu} = a(z-\sigma)$)

λ of characteristic X-Rays :

$$\frac{1}{\lambda} = R(z-\sigma)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$\underbrace{z-\sigma}$ effective atomic no

$$\therefore \nu = \frac{c}{\lambda}$$

$$\Rightarrow \nu = Rc(z-\sigma)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

For K-series
$\sigma = 1$

R : $10^7\ m^{-1}$ → Rydbergs const.

$$\therefore \sqrt{\nu} = a(z-\sigma)$$

$$a = \sqrt{Rc\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)}$$

→ square root of frequency is linearly proportional to Atomic number.