Chapter – Electrostatics

Electric charge & Field & Potential

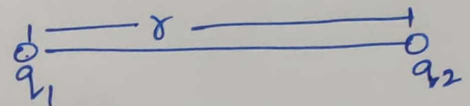
⇒ Total charge on an object

$$Q = (n_p - n_e)e \quad [\text{where } e = 1.6\times10^{-19}\,C]$$

n_p = number of Proton

n_e = " " electron

⇒ Coulomb force between two charges



$$\boxed{F = \frac{1}{4\pi\epsilon_0 K}\frac{|q_1 q_2|}{r^2}}$$

K = Dielectric constant of medium

$\frac{1}{4\pi\epsilon_0} = 9\times10^{9}$ (SI unit), K = 1, vacuume

$\epsilon_0 = 8.854\times10^{-12}\,C^2N^{-1}m^{-2}$

⇒ Relation b/w Electric field and ~~Potential~~ Coulomb force

$$\vec{E} = \frac{\vec{F}}{q_0} \quad N/C$$

⇒ Relation b/w Electric potential (V) & Potential energy (U)

$$V = \frac{W_{\infty P}}{q_0} = \frac{U}{q_0}$$

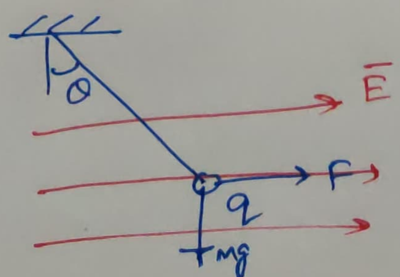
$W_{\infty P}$ → Work done to move charge q_0 from '∞' to 'P'

⇒ Acceleration of charged particle in electric field

$$\vec{a} = \frac{\vec{F}}{m} = \frac{q\vec{E}}{m}$$

⇒ Common case

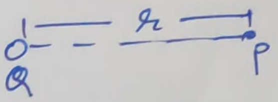
$$\tan\theta = \frac{F}{mg}$$



Electric Field & Potential Due to different object

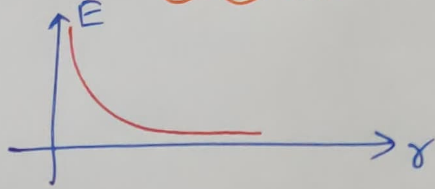
E | V

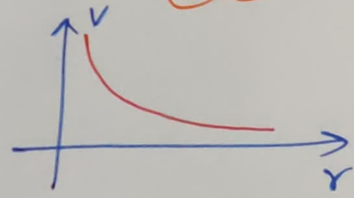
(I) Point charge



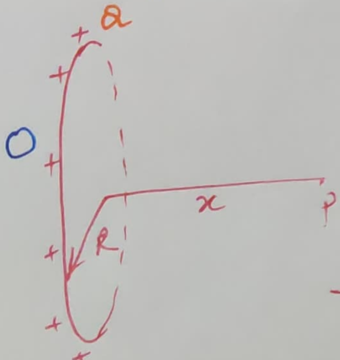
$$\boxed{E = \frac{1}{4\pi\epsilon_0}\frac{|Q|}{r^2}}$$

$$\boxed{V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}}$$



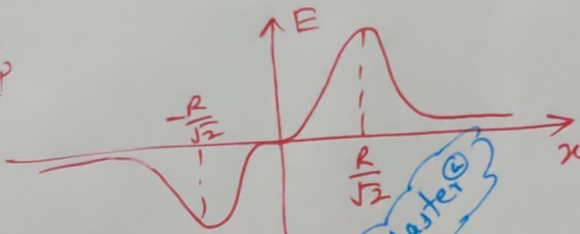


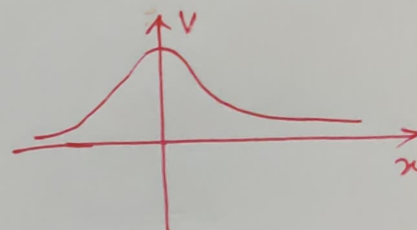
(II) Charged Ring



$$\boxed{E = \frac{1}{4\pi\epsilon_0}\frac{Qx}{(x^2+R^2)^{3/2}}}$$

$$\boxed{V = \frac{1}{4\pi\epsilon_0}\frac{Q}{\sqrt{R^2+x^2}}}$$

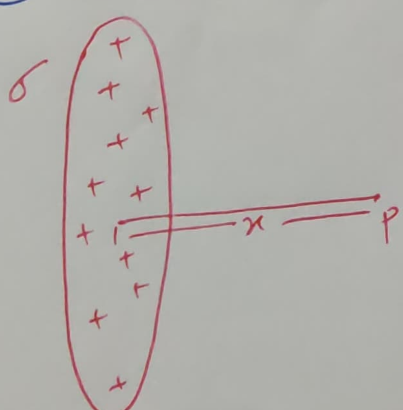




(III) Charged Disc *

σ = surface charge density

$\cancel{E = \frac{1}{4\pi\epsilon_0}}$

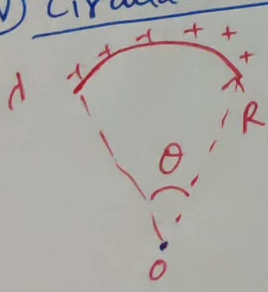


$$\boxed{E = \frac{\sigma}{2\epsilon_0}\left(1 - \frac{x}{\sqrt{R^2+x^2}}\right)}$$

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

(IV) Circular Arc *

λ = linear charged density



$$\boxed{E = \frac{\lambda}{4\pi\epsilon_0 R} 2\sin\left(\frac{\theta}{2}\right)}$$

$$\boxed{V = \frac{1}{4\pi\epsilon_0}\frac{\lambda\theta}{R}}$$

Note 'θ' is in Radian

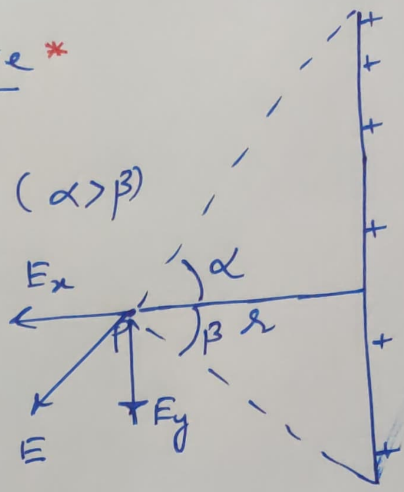
* → Mark for → not for NEET Aspirants.

(V) ~~long~~ Electric charged straight wire *

$$\boxed{E_x = \frac{\lambda}{4\pi\epsilon_0 R}(\sin\alpha + \sin\beta)}$$

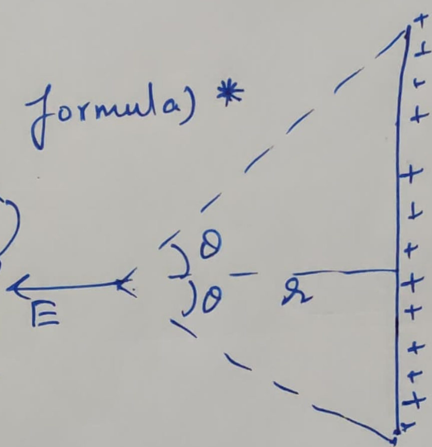
$$\boxed{E_y = \frac{\lambda}{4\pi\epsilon_0 R}(\cos\alpha - \cos\beta)}$$

$$\boxed{E = \sqrt{E_x^2 + E_y^2}}$$



(VI) $\alpha = \beta$ (In above formula) *

$$\boxed{E = \frac{\lambda}{4\pi\epsilon_0}\,\frac{2\sin\theta}{R}}$$



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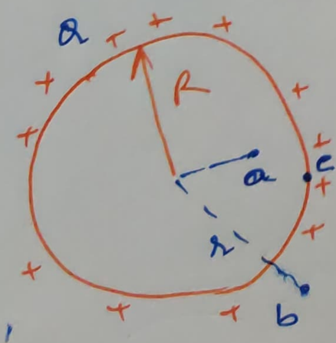
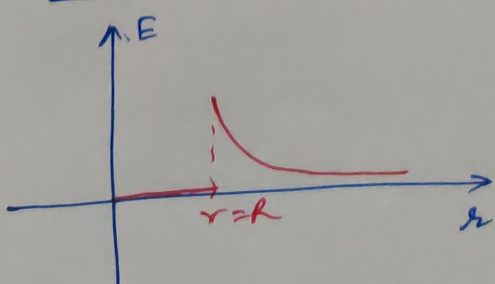
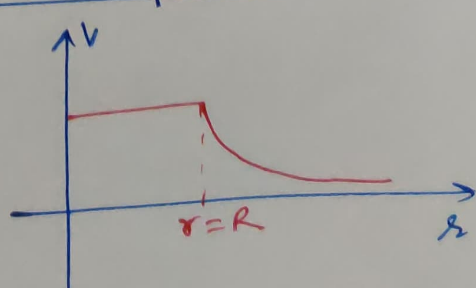
Note for long wire
put $\theta = \pi/2$

(VII) Thin spherical shell or Conducting sphere or any sphere having charge only at outermost surface



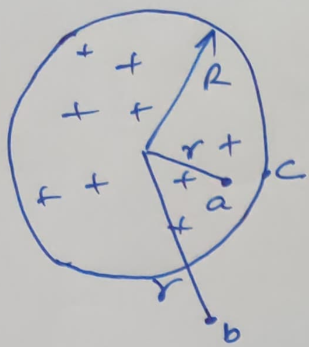
at a	at b	at c
$E = 0$	$E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$	$E = \frac{1}{4\pi\epsilon_0}\frac{Q}{R^2}$
$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{R}$	$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$	$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{R}$



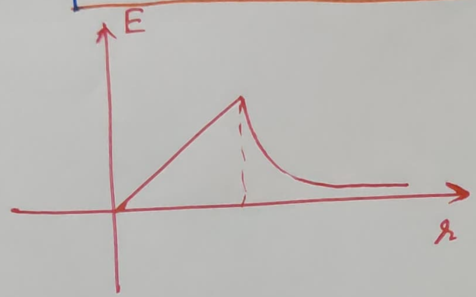


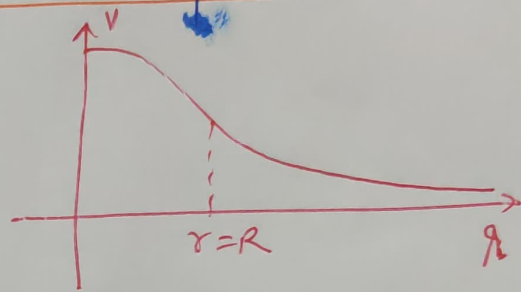
* Mark for → NOT for NEET Aspirants.

(VIII) Non-conducting sphere having charge inside its whole volume

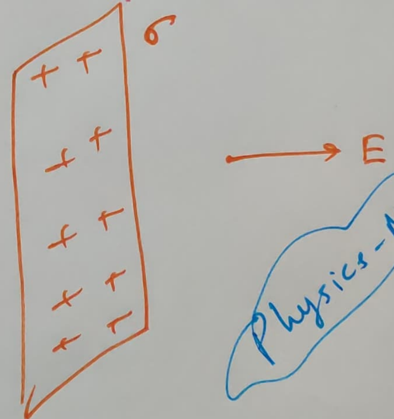


at a	at b	at c
$E = \frac{1}{4\pi\epsilon_0}\frac{Q}{R^3}r$ $\vec{E} = \frac{\rho}{3\epsilon_0}\vec{r}$	$E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$	$E = \frac{1}{4\pi\epsilon_0}\frac{Q}{R^2}$
$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{2R^3}(3R^2 - r^2)$	$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$	$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{R}$





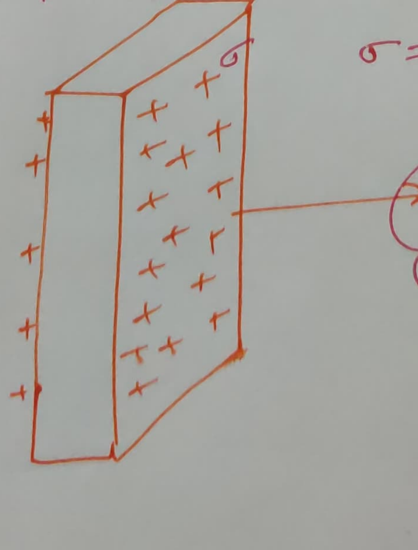
(IX) Electric field due to Large thin conducting sheet



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

(X) Electric field near thick conducting sheet or metallic surface →

σ = Surface charge density



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

Relation b/w Electric field & Potential ⇒

(I) $V_2 - V_1 = -\vec{E} \cdot \Delta\vec{r}$ (if $\vec{E}$ is constant)

(II) $V_2 - V_1 = -\int \vec{E} \cdot d\vec{r}$ (if $\vec{E}$ is variable)

where $d\vec{r} = dx\hat{i} + dy\hat{j} + dz\hat{k}$

Often use it

$$\boxed{V = \int_r^{\infty} \vec{E} \cdot d\vec{r}}$$

To find potential at a given point

(III) $E = -\dfrac{\Delta V}{\Delta r}$

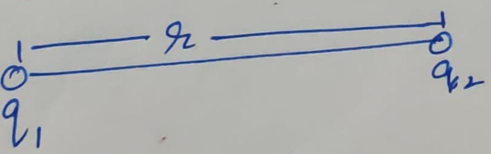
(IV) $\vec{E} = -\dfrac{\partial V}{\partial x}\hat{i} + \dfrac{\partial V}{\partial y}\hat{j} + \dfrac{\partial V}{\partial z}\hat{k}$

Work done to move a charge 'q_0' inside the field by external agent

$$W_{ab} = q_0 (V_b - V_a)$$

$$W_{field} = -W_{ab}$$

Electrostatic potential energy b/w Two point charge



$$U = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r}$$

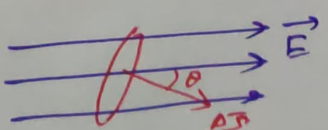
Total electrostatic potential energy of two point charge placed at points of potential of 'V_1' & 'V_2' resply –

$$U = q_1 V_1 + q_2 V_2 + \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r_{12}}$$

(r_{12} ⇒ distance b/w them)

Electric flux $(\phi) = \vec{E} \cdot \Delta\vec{S}$

$$\phi = \int \vec{E} \cdot d\vec{s}$$



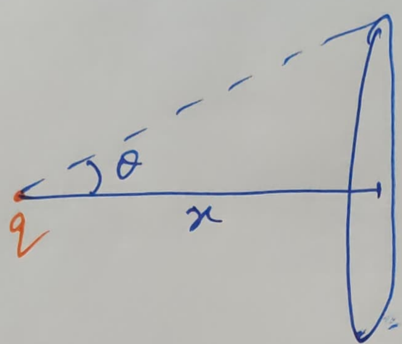
Gauss's theorem

$$\boxed{\phi = \oint \vec{E} \cdot \vec{ds} = \frac{q_{in}}{\epsilon_0}}$$

q_{in} = Charged enclosed by the surface

$\vec{E} \Rightarrow$ Net electric field due to both inside & outside charge.

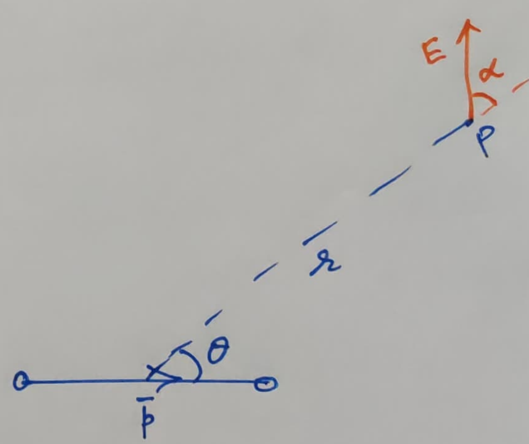
flux through a circular ~~parts~~ area, due to point charge * (Not for NEET)



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

Electric fild and Potential due to short dipole at angular point

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



$$E = \frac{1}{4\pi\epsilon_0}\frac{\sqrt{1+3\cos^2\theta}}{r^2}$$

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

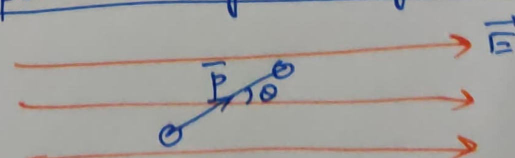
$\Rightarrow$ At axial point $\theta = 0$

$\Rightarrow$ At Bisectorial point $\theta = \pi/2$

$\Rightarrow$ Torque and Force on Dipole in uniform Magnetic field

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

$$\vec{F} = 0$$



Potential energy $(U) = -\vec{p} \cdot \vec{E} = -pE\cos\theta$

⇛ Time period of oscillation of Dipole

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

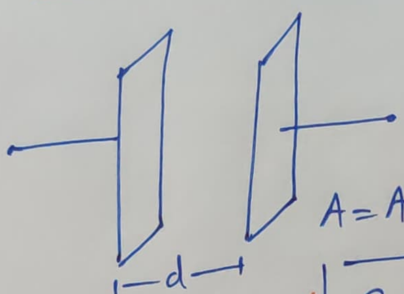
I = Moment of Inertia of Dipole
p = Dipole moment of Dipole
E = Electric field.

Capacitance

Force on Dipole in non-uniform Field

$$F = p\frac{\Delta E}{\Delta r}$$

① Parallel Plate Capacitor

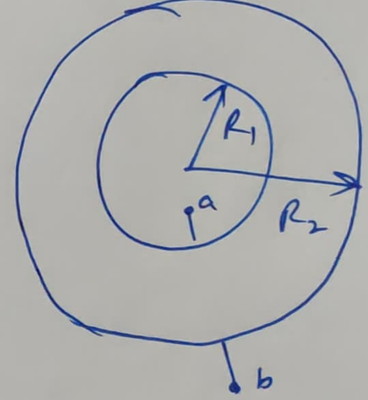


A = Area of plate

✓ $$\boxed{C = \frac{\epsilon_0 A}{d}}$$

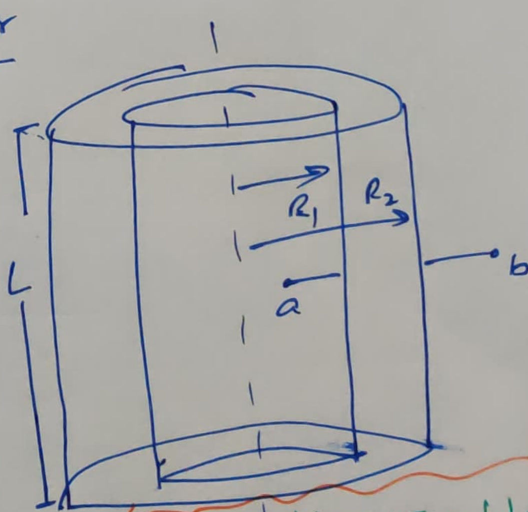
② Spherical Capacitor

✓ $$\boxed{C = \frac{4\pi\epsilon_0 R_1 R_2}{(R_2 - R_1)}}$$

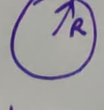


③ cylindrical Capacitor

✓ $$C = \frac{2\pi\epsilon_0 L}{\log_e(R_2/R_1)}$$



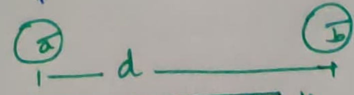
④ Capacitance of Isolated sphere



$$\boxed{C = 4\pi\epsilon_0 R}$$

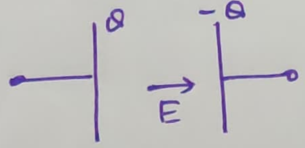
capacitance of earth = 711 μF

⑤ Two spheres placed at separation 'd' (> radius of sphere)



$$\boxed{C = \frac{4\pi\epsilon_0 ab}{(a+b)}}$$ *

Force between two plates



$$F = \frac{Q^2}{2\epsilon_0 A}$$

Electric field Inside capacitor

$$E = \frac{Q}{A\epsilon_0}$$

Energy stored inside capacitor →

$$U = \frac{1}{2}CV^2 = \frac{Q^2}{2C} = \frac{QV}{2}$$

$W_{ext} + W_{battery} = \Delta U + \Delta H$

W_{ext} → work done by external agent

$W_{battery}$ → work done by battery

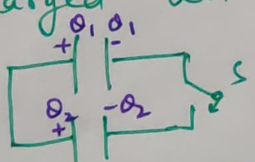
ΔH → Heat

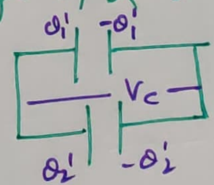
Energy density $\boxed{(\bar{U}) = \frac{1}{2}\epsilon_0 E^2}$ Joule/m^3

⇒ It is also electrostatic pressure in conductor or capacitor

Physics master ©

⇒ Sharing of charge b/w two capacitors having charged with voltage V_1 & V_2 respectively





V_c (common potential) after some time

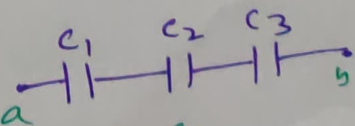
$$V_c = \frac{(C_1V_1 \pm C_2V_2)}{C_1 + C_2}$$

(-)ve sign indicate when (+)ve plate of one will be connected to (+)ve side of another

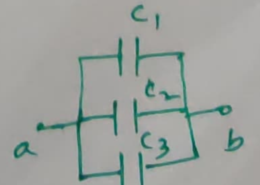
Heat Loss (ΔH) $\Delta H = \frac{1}{2}\frac{C_1C_2}{(C_1+C_2)}(V_1 \sim V_2)^2$

⇒ **Grouping of capacitors**

(I) series $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$



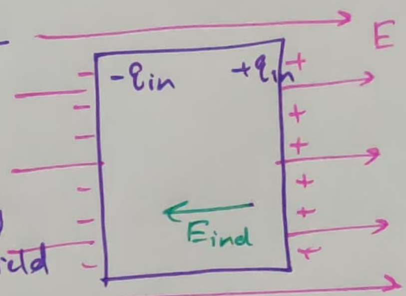
(II) Parallel $C = C_1 + C_2 + \cdots + C_n$



✓ Polarisation vector $\boxed{(\vec{P}) = \chi \vec{E}}$

χ = susceptiblity of material, $\vec{E}$ = Electric field

✓ Electric field in Dielectric



$$\vec{E}_{NET} = \vec{E} - \vec{E}_{ind}$$

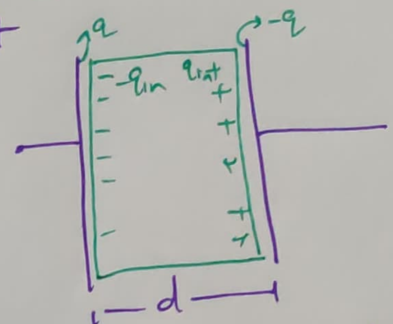
or

$$\vec{E}_{NET} = \frac{\vec{E}}{K}$$

$E_{ind} \rightarrow$ Induced electric field

K = Dielectric constant

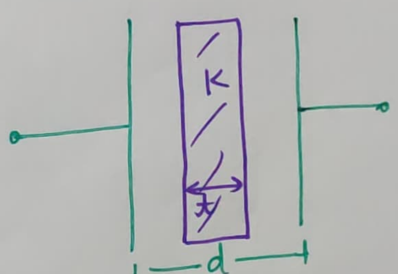
⇒ Dielectric inside capacitor



$$\boxed{q_{in} = q\left(1 - \frac{1}{K}\right)}$$

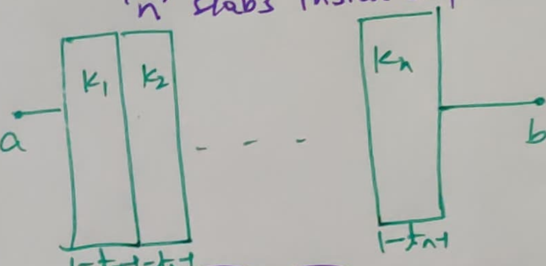
⇒

$$C = \frac{K\epsilon_0 A}{d} = K C_0$$



$$\boxed{C = \frac{\epsilon_0 A}{\left[d - t\left(1 - \frac{1}{K}\right)\right]}}$$

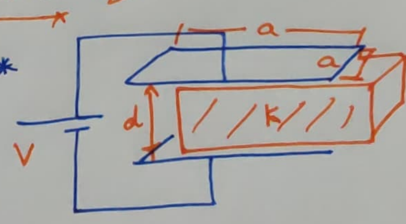
'n' slabs inside capacitors



$$C = \frac{\epsilon_0 A}{\left(\frac{t_1}{k_1} + \frac{t_2}{k_2} + \cdots + \frac{t_n}{k_n}\right)}$$

~~Force b/w Plates of capacitors~~ ⇒

Force on Dielectric slab*



$$F = \frac{\epsilon_0 a V^2}{2d}(k-1)$$

* Not for NEET

Current Electricity

Instantaneous current

$i = \frac{dq}{dt}$ = slope of q, t graph

Avg current $I_{avg} = \frac{\Delta q}{\Delta t}$

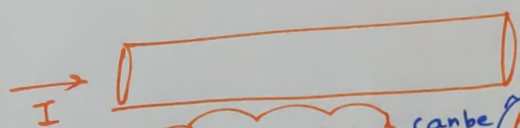
$$\Delta q = \int_{t_1}^{t_2} i\,dt$$

= Area of i, t graph

Drift velocity $\boxed{\vec{V}_d = -\frac{e\tau}{m}\vec{E}}$ τ = Relaxation time

$\tau \propto \frac{1}{\text{Temprature}}$

Current density $(\vec{J}) \Rightarrow$ $\boxed{I = \vec{J} \cdot \Delta\vec{A}}$ or $\boxed{I = \int \vec{J} \cdot d\vec{A}}$

$\Rightarrow$ 

A = Area of cross-section

$\boxed{I = neAV_d}$ $\xRightarrow{\text{canbe}}$ ☺ I = वीना = VenA

n = electron density (free electron carrier concentoration)

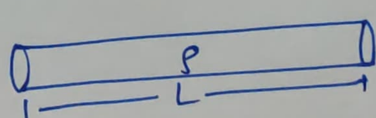
$\boxed{\vec{J} = \sigma\vec{E}}$

$\boxed{\text{Mobility } (\mu) = \frac{V_d}{E}}$

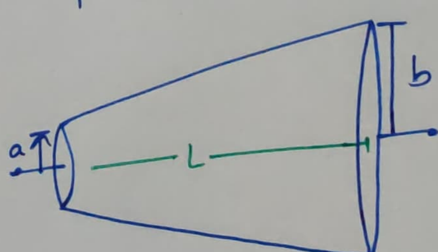
$\Rightarrow$ Ohm's law $\boxed{V = RI}$

where $\boxed{R = \int \rho \frac{dx}{A}}$ ρ = specific Resistance or Resistivity

uniform wire

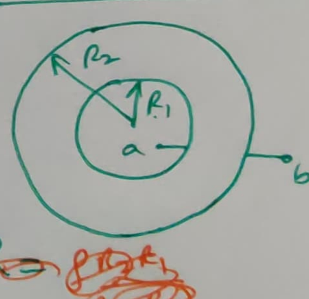


$\boxed{R = \rho\frac{L}{A}}$



$\boxed{R = \rho\frac{L}{\pi ab}}$ *

Thick shell



$\boxed{R = \frac{\rho(R_2 - R_1)}{R_1 R_2}}$ *

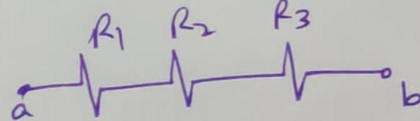
$$R_t = R_0(1 + \alpha t_c)$$
$$\rho_t = \rho_0(1 + \alpha t_c)$$

R_0 & ρ_0 are Resistance and Resistivity at $0°C$

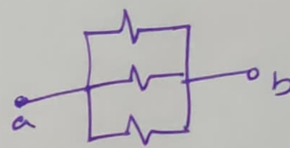
R_t & ρ_t are at $t°c$.

α = Thermal cofficient of Resistance or Resistivity.

⇒ Series grouping



$$\boxed{R = R_1 + R_2 + R_3}$$



⇒ Parallel grouping

$$\boxed{\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

⇒ KVL (Kirchhoff's voltage Law)

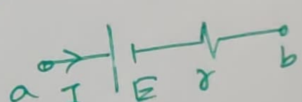
$\sum V_i = 0$ Conservation of energy

KCL (Kirchoff's current law)

$\sum I_i = 0$

Conservation of charge

⇒ Charging of Battery

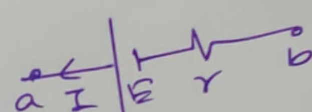


$V = E + Ir$

E = EMF

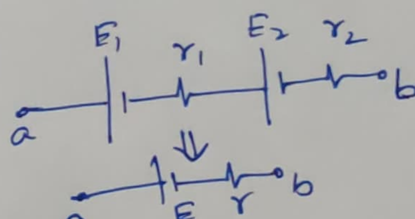
r = Internal Resistance.

Discharging of Battery



$V = E - Ir$

⇒ Battery in series

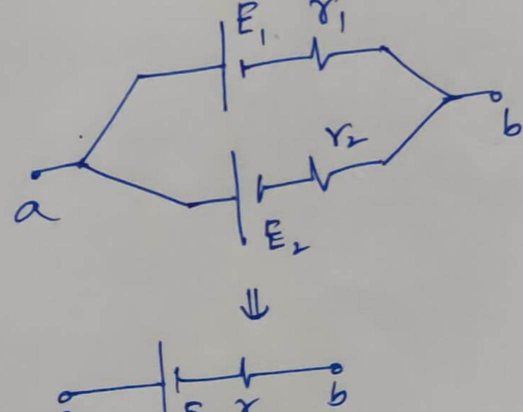


$$E = E_1 + E_2$$
$$r = r_1 + r_2$$

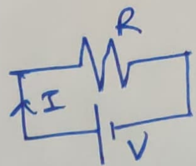
⇒ Batteries in parallel

$$E = \frac{E_1 r_2 + E_2 r_1}{(r_1 + r_2)}$$

$$r = \frac{r_1 r_2}{(r_1 + r_2)}$$



Power across a resistance



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

$$\text{Heat } (H) = Pt = \frac{V^2}{R}t = I^2Rt = VIt$$

NOTE: Resistance of bulb $= \frac{V^2}{P}$

NOTE: If 'i' is variable

Heat $\Delta H = \int_0^t i^2 R\, dt$

V = Rated voltage
P = " Power (wattage)

High wattage bulb has low Resistance

⇒ Equivalent power of bulb in

(i) series $\boxed{\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2}}$

(ii) Parallel $\boxed{P = P_1 + P_2}$

⇒ **Meter Bridge** ⇒ unknown Resistance (R_x) will be

⇒ $\boxed{R_x = \left(\frac{100 - l}{l}\right) R}$

R = standard Resistance
l = length of null point

If end correction consider the

$$R_x = \frac{(100 - l + \alpha)}{(l + \beta)} R$$

α and β are end correction at left and Right Part Respectively.

⇒ **Potentiometre**

$$\boxed{\text{Potential gradient } (K) = \frac{V}{L} = \frac{I\rho}{A} \propto \frac{1}{\text{Sensitivity}}}$$

(1) Comparing of EMFs

$$\frac{E_1}{E_2} = \frac{x_1}{x_2}$$

x_1 & x_2 are null points for E_1 & E_2 Respectively

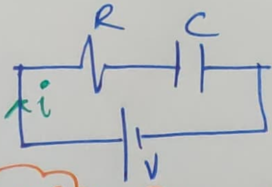
(2) Determination of internal resistance

$$r = R\left(\frac{l_1}{l_2} - 1\right)$$

R = standard Resistance
l_1 = null point without 'R'
l_2 = " " with 'R'

RC Transient circuit

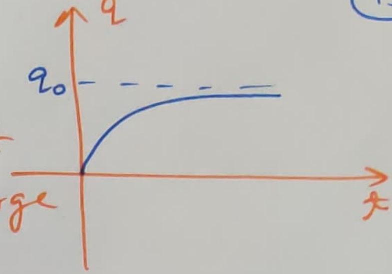
(a). Charging circuit



$$q = q_0(1 - e^{-t/\tau})$$

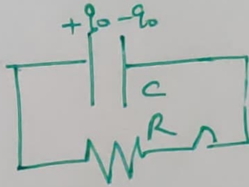
$\tau = CR$ = Time constant

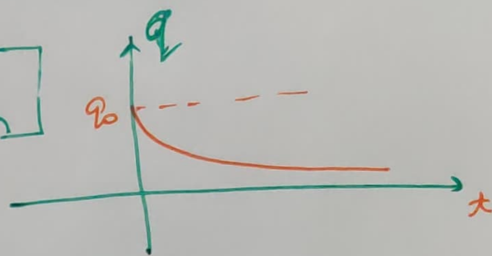
q_0 = Maximum charge



$$i = \frac{V}{R} e^{-t/\tau}$$

(b) Discharging circuit



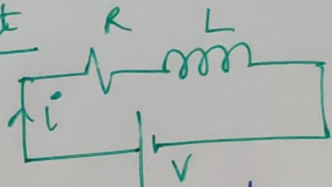


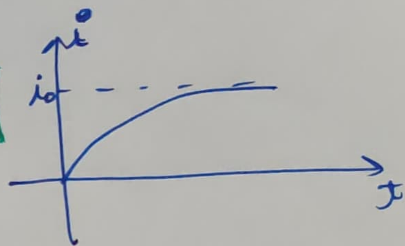
$$q = q_0 e^{-t/\tau}$$

(:) Same concept with 'LR' circuit
साथ साथ याद कर लो!

LR Transient circuit

(a) growing circuit

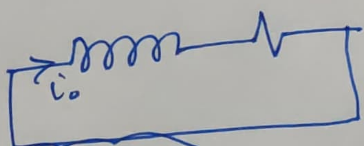


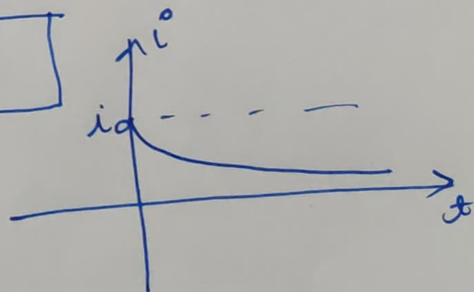


$$i = \frac{V}{R}(1 - e^{-t/\tau})$$

$\tau = \frac{L}{R}$ = Time constant

(b) Decaying circuit





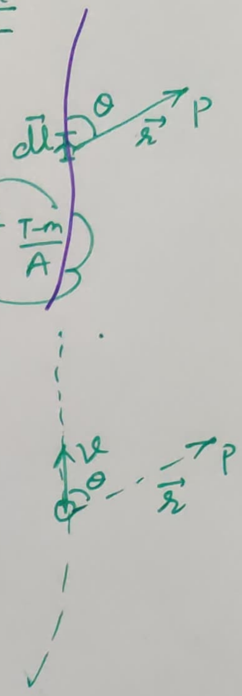
$$i = \frac{V}{R} e^{-t/\tau}$$ or $$i = i_0 e^{-t/\tau}$$

एक बार Notes बन्द करो, और फिर मन मे Revise करो!

Moving Charge & Magnetic field

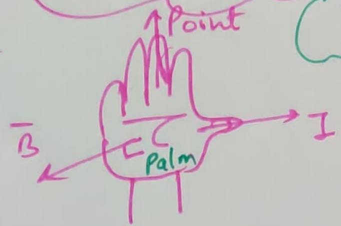
Biot-Savart Law

$$\vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{\vec{dl} \times \vec{r}}{r^3}$$



$$\frac{\mu_0}{4\pi} = 10^{-7} \frac{T\text{-}m}{A}$$

✓ Direction by Right Hand

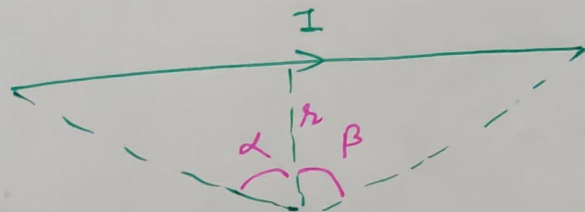


⇒ Magnetic field due to moving charge

$$\vec{B} = \frac{\mu_0 q}{4\pi} \frac{\vec{v} \times \vec{r}}{r^3}$$

$$\boxed{1\,T = 10^{-4}\,\text{Gauss}}$$

⇒ Due to straight wire

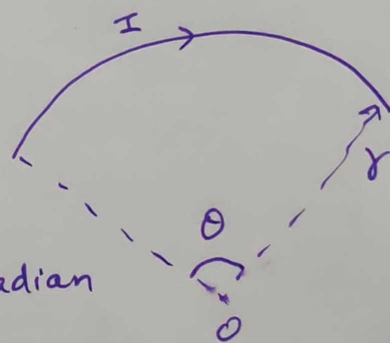


$$B = \frac{\mu_0 I}{4\pi r}(\sin\alpha + \sin\beta)$$

✓ for Long wire $\alpha = \pi/2$, $\beta = \pi/2$

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

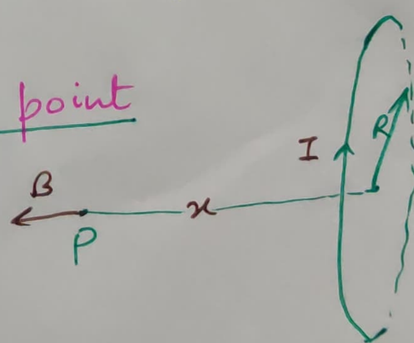
⇒ Due to circular Arc ⇒



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

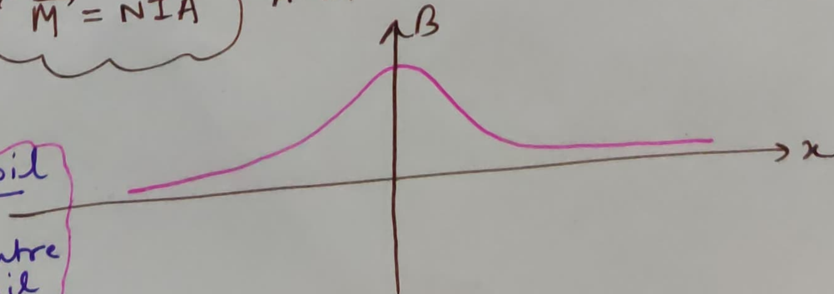
θ is in radian

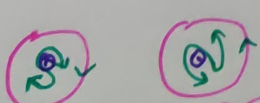
⇒ Due to circular coil at axial point



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

$$\vec{M} = N I \vec{A} \quad A\text{-}m^2$$

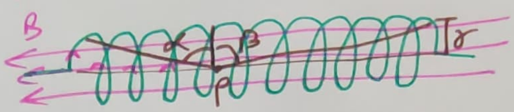




⇒ Due to circular coil

$$B = \frac{\mu_0 I}{2r}$$ at centre of coil

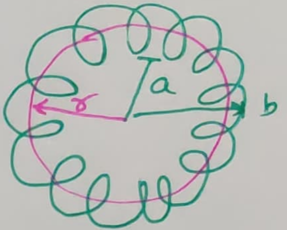
Magnetic field due to solenoid ⇒



$$\boxed{B = \frac{\mu_0 n i}{2}(\sin\alpha + \sin\beta)}$$

n = Turn density

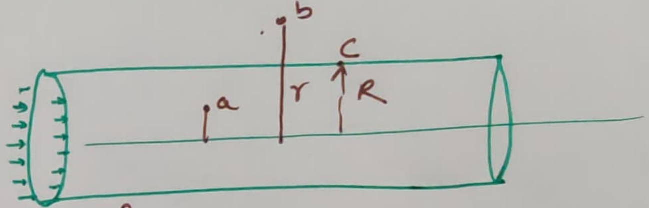
Long solenoid $(\alpha = \beta = \pi/2) \Rightarrow$ $B = \mu_0 n I$



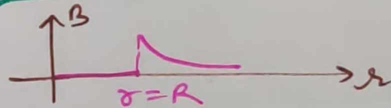
Due to Toroid ⇒ $B = \mu_0 n I$

$\Rightarrow \; n = \frac{N}{2\pi r}$ where $r = \frac{a+b}{2}$ = mean radius

⇒ Due to Long Hollow cylindrical wire ⇒



$$\boxed{B_a = 0, \quad B_b = \frac{\mu_0 I}{2\pi r}, \quad B_c = \frac{\mu_0 I}{2\pi R}}$$



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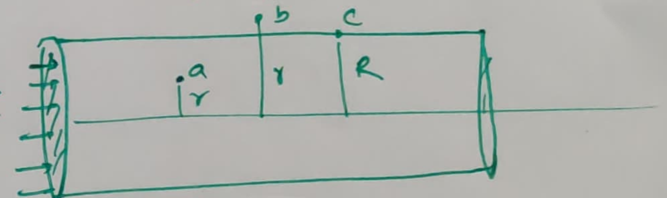
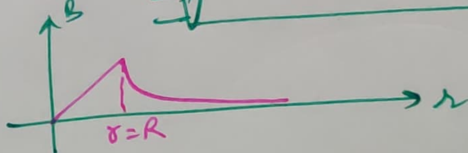
⇒ Due to Long solid cylidrical wire

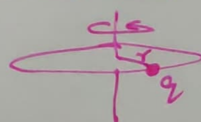


$$\boxed{B_a = \frac{\mu_0 I}{2\pi R^2} r = \frac{\mu_0 \vec{J} \times \vec{r}}{2}}$$

$$\boxed{B_b = \frac{\mu_0 I}{2\pi r}}, \quad \boxed{B_c = \frac{\mu_0 I}{2\pi R}}$$



⇒ Magnetic field due to revolving charge



Time period $T = 2\pi/\omega$

$$B = \frac{\mu_0 I_{eq}}{2a}$$

$$I_{eq} = \frac{q}{T}$$

⇒ Bohr magneton of Revolving electron

$$\boxed{\vec{\mu} = \frac{neh}{4\pi m}}$$

n = Principle Quantum Number $(n=1)$

h = planck constant.

$$\mu_0 = \frac{eh}{4\pi m}$$

$$\frac{\text{magnetic dipole moment}}{\text{Angular Momentum}} = \frac{\mu}{L} = \frac{q}{2m} = \text{gyromagnetic ratio}$$

⇒ Ampere's Circuital law ⇒

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I_{in}$$

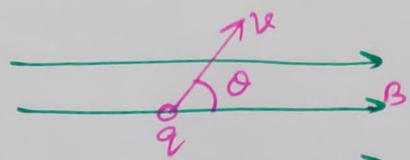
I_{in} = current enclosed by loop.

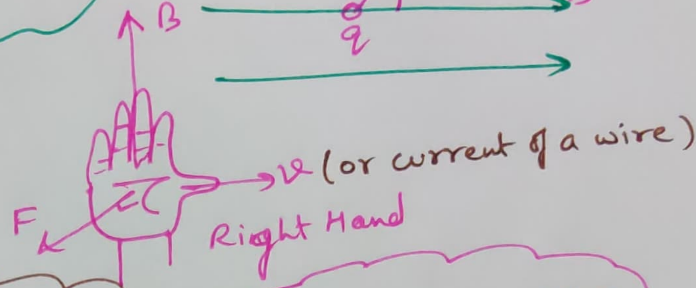
Lorentz force

$$\vec{F} = \vec{F}_m + \vec{F}_e$$

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

$$\boxed{\vec{F}_m = qvB\sin\theta\,\hat{n}}$$



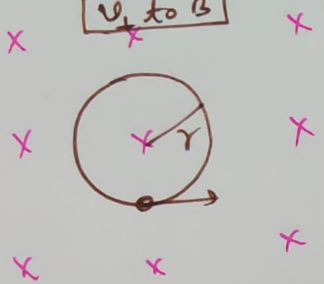


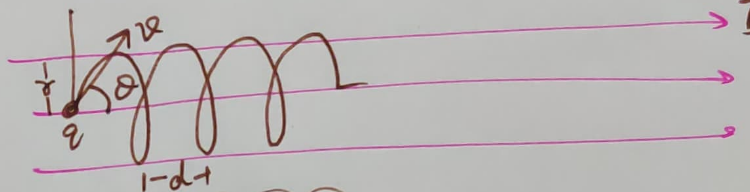
⇒ motion of charged particle inside field

$\boxed{v \perp \text{ to } B}$

radius of motion
$$r = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB}$$

$$\text{Time period}(T) = \frac{2\pi m}{qB}$$

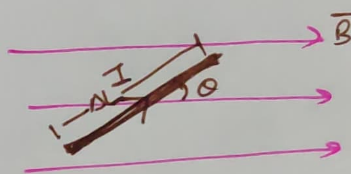




⇒ 'v' at angle 'θ'

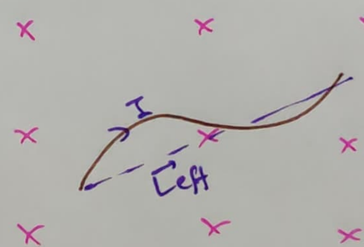
$$\boxed{r = \frac{mv\sin\theta}{qB}}$$

$$\text{pitch}(d) = \frac{2\pi mv\cos\theta}{qB}$$



⇒ Force on a current carrying wire

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

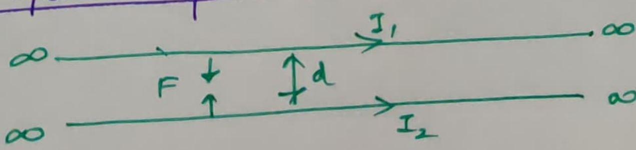


⇒ Force on a bent wire

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

⇒ Force per unit length b/w two parallel wire

$$\boxed{F = \frac{\mu_0 I_1 I_2}{2\pi d}}\ \text{N/m}$$

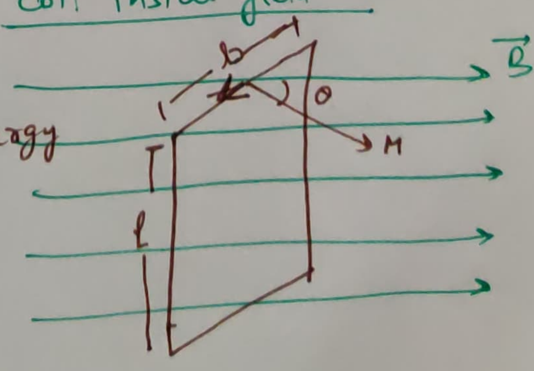


⇒ Torque on current carrying coil inside field

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

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

↓ Potential Energy



Time period of oscillation of coil

$$T = 2\pi\sqrt{\frac{I}{MB}}$$

Moving coil galvanometer

current (i) $\boxed{i = \left(\dfrac{K}{NAB}\right)\phi}$

K = Torsion constant
N = Number of turns
A = Area of coil
ϕ = deflection of coil

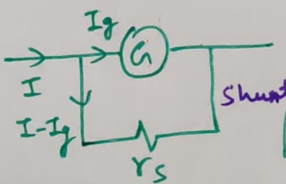
$\boxed{\dfrac{K}{NAB} = \text{Galvanometer constant}}$

Current sensitivity (CS) $= \dfrac{\phi}{i} = \dfrac{NAB}{K}$ (Degree/A or Rad/A or Number of Division/A)

Voltage sensitivity (VS) $= \dfrac{\phi}{V} = \dfrac{NAB}{K \cdot R} = \dfrac{CS}{R}$

$R \Rightarrow$ Resistance of coil

$\Rightarrow$ Ameter



$I_g G = (I - I_g) r_s$

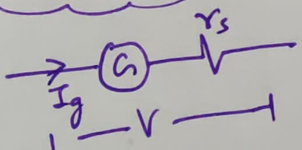
$\boxed{r_s = \dfrac{I_g G}{(I - I_g)}}$

G = Resistance of galvanometer
I = Range of current
I_g = full scale deflection current

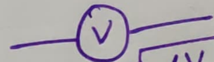
Range Increase
$I \to nI$

$r = \dfrac{r_A}{(n-1)}$

$\Rightarrow$ Voltmeter

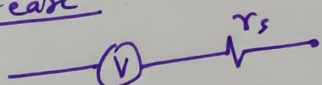


$\Rightarrow$



$\boxed{r_s = \left(\dfrac{V}{I_g} - G\right)}$

Range increase
$V \to nV$



$\boxed{r = r_s (n-1)}$

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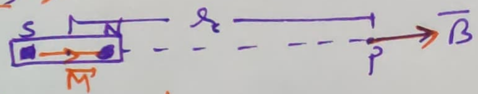
"एक बार लिख कर देख लो काका जी"

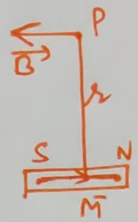
Magnetism & Matter

✓ Magnetic field due to Bar Magnet (Short) ⇒



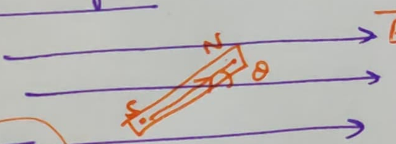
(a) axial point – $\vec{B}_a = \frac{\mu_0}{4\pi}\frac{2\vec{M}}{r^3}$

$\vec{M}$ - Dipole moment



(b) Bisectorial point – $\vec{B}_b = -\frac{\mu_0}{4\pi}\frac{\vec{M}}{r^3}$

✓ Short Bar Inside uniform magnetic field ⇒



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

Potential energy $(U) = -\vec{M}\cdot\vec{B}$

Time period of oscillation $(T) = 2\pi\sqrt{\frac{I}{MB}}$ I = M.O.I. (as of rod about centre of Rod)

✓ Earth Magnetism

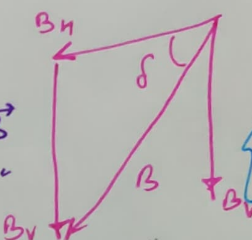
$\tan\delta = \frac{B_V}{B_H}$

δ → Angle of Dip

B_V → vertical comp. of $\vec{B}$

B_H → Horizontal " " "

$B = \sqrt{B_V^2 + B_H^2}$



✓ Magnetic Material

Magnetic Intensity or Magnetic field strength (H)

$\boxed{H = \frac{B}{\mu_m}}$ μ_m = magnetic permeability of medium

✓ Intensity of Magnetisation $(\vec{M}) = \frac{\mu\ (Am^2)}{V\ (m^3)}$

✓ Magnetic Susceptiblity $(\chi) = \frac{M}{H}$

✓ magnetic permeablity $(\mu_m) = \frac{B}{H}$

$\vec{B} = \mu_0\vec{H} + \mu_0\vec{I}$

$\vec{B} = \mu_m\vec{H}$

$\mu_r = (1+\chi)$

⇒ Curie's law for paramagnetic

$M = \frac{C B_0}{T}$ or $\chi = \frac{C\mu_0}{T}$

C = curie's constant

T = absolute Temp (K)

⇒ Curie's law for Ferro

$\chi = \frac{C}{T - T_C}$ $T \neq T_c$

T_c = Curie's Temp at which Ferro convert into diamagnetic

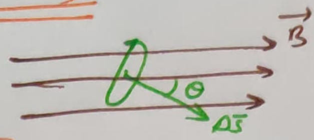
Dia	Para	Ferro
$\mu_r < 1$	$\mu_r > 1$	$\mu_r >> 1$
$-1 \le \chi < 0$	$0 < \chi \le \epsilon$	$\chi >> 1$

ε → It is a small (+)ve number

Electro-Magnetic Induction (EMI)

✓ **Magnetic flux (ϕ)** $= \vec{B}\cdot\Delta\vec{S} = B\Delta S\cos\theta$

$$\phi = \int \vec{B}\cdot d\vec{s}$$



✓ **Gauss Law in Magnetism** $\Rightarrow$ $\oint \vec{B}\cdot d\vec{s} = 0$

✓ **Faraday's law of EMI** $\Rightarrow$ $\varepsilon = -N\dfrac{d\phi}{dt}$

ϕ = flux link in each turn
N = Number of turn

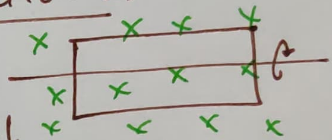
✓ **Amount of charge that will flow in coil** $\Rightarrow$

$$\Delta q = \frac{|\phi|}{R}$$

$|\Delta\phi|$ = change in flux
R = Resistance of coil.

Induced EMF in a coil due to Rotation $\Rightarrow$

✓ $\varepsilon = NWAB\sin\omega t$



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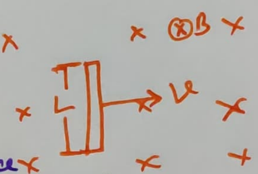
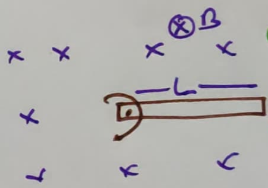
N = Number of turns, A = Area of coil
ω = angular speed, B = Magnetic field,

Motional EMF in a wire

✓ $\varepsilon = Bv L_{eff}$

L_{eff} = distance b/w open end



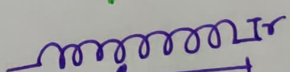


✓ $\varepsilon = \dfrac{B\omega L^2}{2}$

✓ **Self Induction** $\phi = Li$

L = Cofficient of self Induction (H)

✓ **Induced EMf** $\varepsilon = -L\dfrac{di}{dt}$



for solenoid

✓ $L = \mu_0 n^2 \pi r^2 l$ henry

n = Turn density, r = radius of coil
l = length

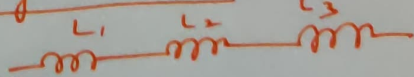
✓ Energy stored

$$U = \frac{1}{2}Li^2 \ (J)$$

Energy density $(\bar{U}) = \dfrac{B^2}{2\mu_0}$

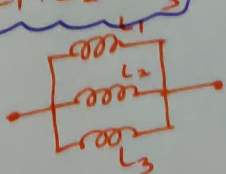
$\Rightarrow$ **grouping of Inductor**

(i) Series



$L = L_1 + L_2 + L_3$

(ii) Parallel



$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}$$

Mutual Inductance

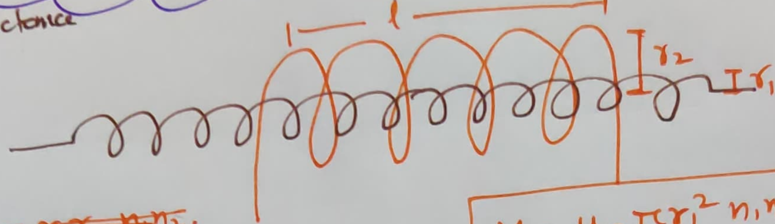
$$\phi_{12} = M_{12}\, i_2 \qquad \phi_{21} = M_{21}\, i_1$$

ϕ_{12} = flux in 'C_1' due to 'C_2'
ϕ_{21} = " " 'C_2' " " 'C_1'

$M_{12} = M_{21} = M$ (Cofficient of Mutual Inductance

Induced EMF by Mutual Inductance

$$\mathcal{E} = -M_{12}\frac{di_1}{dt} \qquad \mathcal{E} = -M_{21}\frac{di_2}{dt}$$



$M = \cancel{\mu_0 \pi r_1 r_2 n_1 n_2}$.

$$\boxed{M = \mu_0 \pi r_1^2 n_1 n_2 l}$$

⇒ Induced Electric field ⇒ $\boxed{\oint \vec{E}\cdot d\vec{l} = -\frac{d\phi_B}{dt}}$

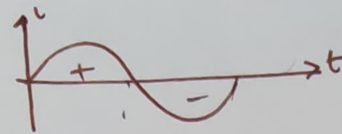
ϕ_B = Magnetic flux
E → Induced ~~of~~ Electric field.

Alternating current

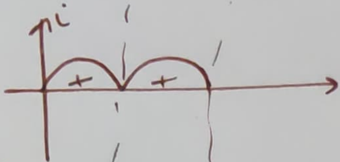
$\boxed{i = i_0 \sin(\omega t \pm \phi) \\ v = v_0 \sin(\omega t \pm \phi)}$, $\boxed{i = i_0 \cos(\omega t \pm \phi) \\ v = v_0 \cos(\omega t \pm \phi)}$

Avg. current $(i_{avg}) = \frac{2 i_0}{\pi}$

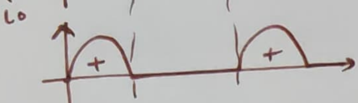
RMS. current $= \frac{i_0}{\sqrt{2}}$



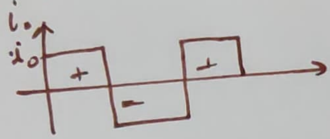
$i_{rms} = \frac{i_0}{\sqrt{2}}$



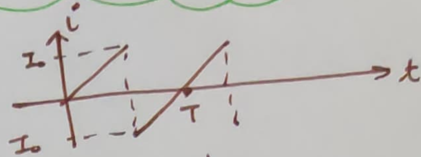
$i_{rms} = \frac{i_0}{\sqrt{2}}$



$i_{rms} = \frac{i_0}{2}$



$i_{rms} = i_0$

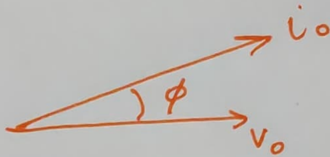


$i_{rms} = \frac{i_0}{\sqrt{3}}$

$i = i_1 \sin\omega t + i_2 \cos\omega t$

$i_{rms} = \sqrt{\frac{i_1^2 + i_2^2}{2}}$

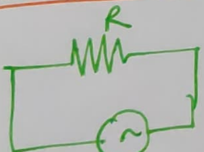
Average Power



$P_{avg} = \frac{v_0 i_0 \cos\phi}{2}$

$P_{avg} = v_{rms}\, i_{rms} \cos\phi$

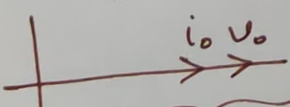
Resistive circuit



$v = v_0 \sin\omega t$

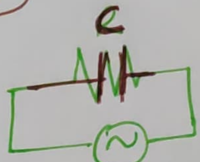
$i_{rms} = \frac{v_{rms}}{R}$

$\phi = 0$



$P_{avg} = i_{rms}^2 R$

capacitive circuit



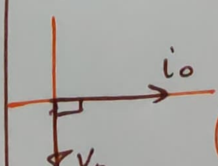
$v = v_0 \sin\omega t$

$i_{rms} = \frac{v_{rms}}{X_c}$

X_c = capacitive Reactance

$X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C}$ (Ω)

$\boxed{\phi = \pi/2}$



$P_{avg} = 0$

CIVIL

C → 'i_0' leads 'v_0'

L → 'v_0' Leads 'i_0'

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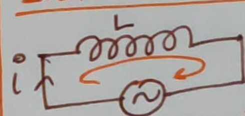
Inductive circuit

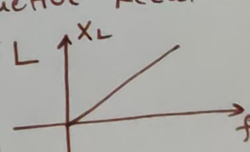


$v = v_0 \sin\omega t$

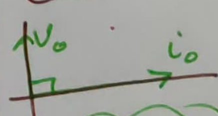
$i_{rms} = \frac{v_{rms}}{X_L}$

X_L = Inductive Recatance (Ω)

$X_L = 2\pi f L$

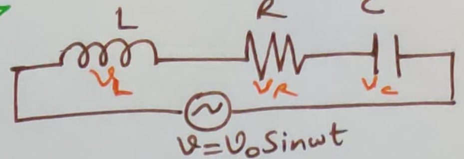


$\phi = \pi/2$



$P_{avg} = 0$

Series LCR circuit



Peak values of voltage

$$\boxed{v_0 = \sqrt{v_R^2 + (v_L \sim v_c)^2}}$$

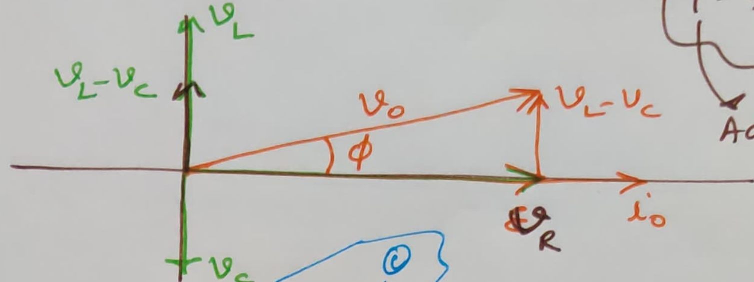
$v_R, v_L, v_c \rightarrow$ are peak value of voltage across R, L, C respectively

$Z = \sqrt{R^2 + (X_L \sim X_c)^2}\ \Omega$ where Z = Impedence

$$Y = \frac{1}{Z}$$

Admittance

$$i_{rms} = \frac{v_{rms}}{Z}$$



$$\cos\phi = \frac{v_R}{v_0} = \frac{R}{Z}$$

$$P_{avg} = i_{rms}^2 R$$

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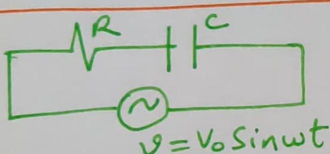
R-C circuit

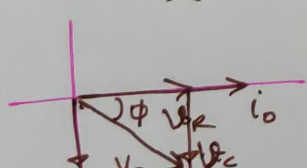


$Z = \sqrt{R^2 + X_c^2}$

~~$v_0 = \sqrt{R^2 + X_c^2}$~~

$v_0 = \sqrt{v_R^2 + v_c^2}$

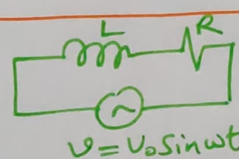
$i_{rms} = \frac{v_{rms}}{Z}$



$\boxed{\cos\phi = R/Z}$

$P_{avg} = i_{rms}^2 R$

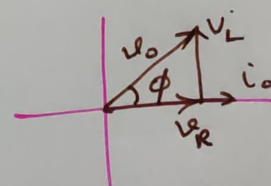
LR circuit (choke coil)



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

$v_0 = \sqrt{v_R^2 + v_L^2}$

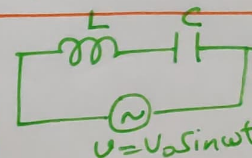
$i_{rms} = \frac{v_{rms}}{Z}$



$\boxed{\cos\phi = R/Z}$

$P_{avg} = i_{rms}^2 R$

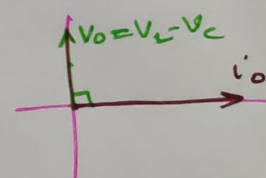
LC circuit



$Z = X_L \sim X_c$

$v_0 = v_L \sim v_c$

$i_{rms} = \frac{v_{rms}}{Z}$



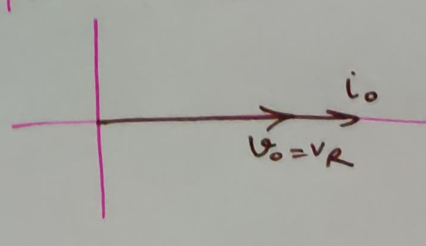
$\boxed{\cos \pi/2 = 0}$

$P_{avg} = 0$

Resonance in LCR circuit (Acceptor circuit)

$X_L = X_c$

$$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$ Resonance frequency



$v_0 = v_R$

$Z_{min} = R$

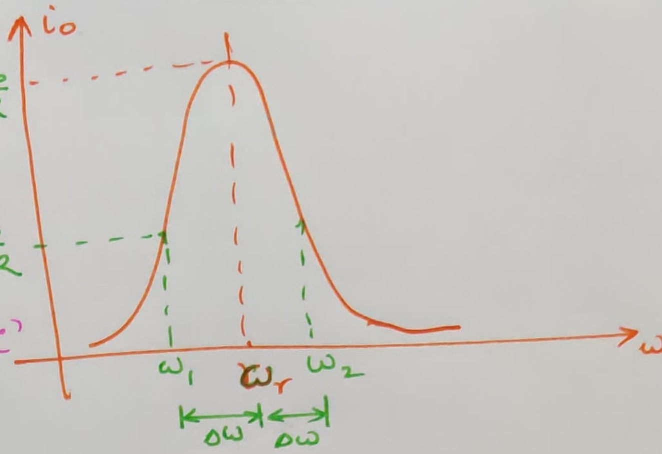
$(i_0)_{max} = \frac{v_0}{R}$

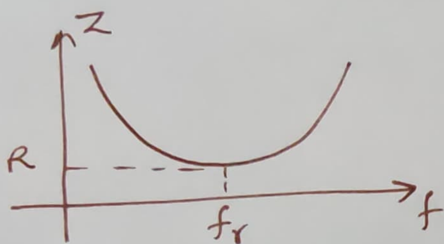
$$Q\text{-factor} = \frac{\omega_r}{\omega_2-\omega_1} = \frac{\omega_r}{2\Delta\omega}$$

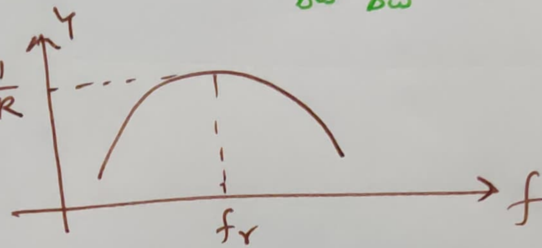
$$\Delta\omega = R/L$$

$$Q\text{-factor} = \frac{\omega_r L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

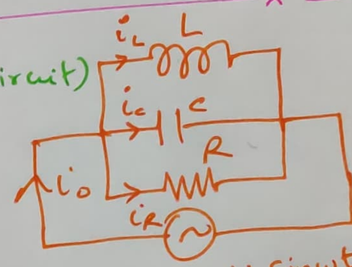
$$Q\text{-factor} = \frac{\text{Voltage across 'L' or 'C'}}{\text{'' \quad '' \quad 'R'}}$$







Parallel LCR circuit (Rejector circuit)



$$\frac{1}{Z} = \sqrt{\frac{1}{R^2}+\left(\frac{1}{X_L}-\frac{1}{X_C}\right)^2}$$

$$i_0 = \sqrt{i_R^2+(i_L-i_C)^2}$$

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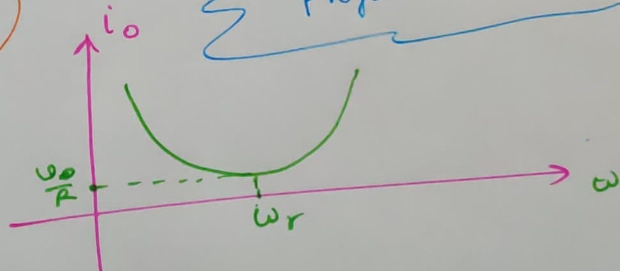
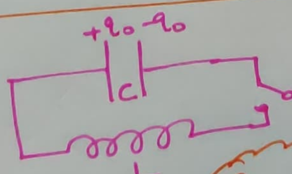


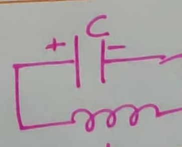
Resonance $(X_L = X_C)$

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

$$Z_{max} = R$$

LC oscillation





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

~~$q = q_0 \sin\omega t$~~

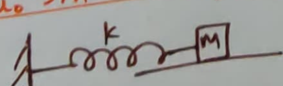
~~$i = i_0 \cos\omega t$~~

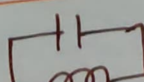
$$q = q_0 \cos\omega t$$
$$i = i_0 \sin\omega t$$

$$i_0 = q_0\omega$$

$U_e = \frac{q_0^2}{2C}\cos^2\omega t$ [across 'C']

$U_m = \frac{1}{2}L i_0^2 \sin^2\omega t$ [across 'L']



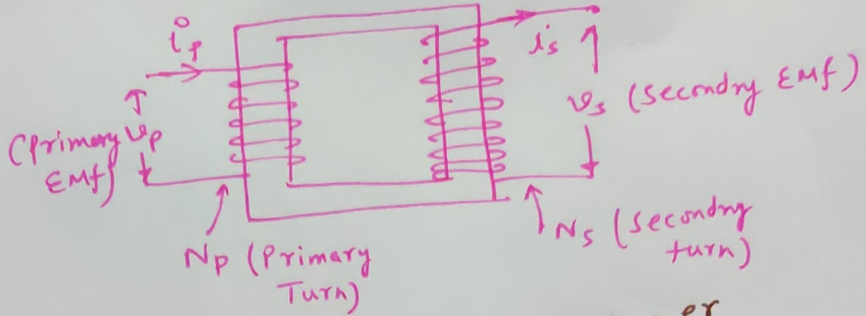


Similarity b/w 'LC' and spring

LC oscillation	Spring pendulum
L	m (mass)
C	$\frac{1}{k}$
R	b (damping const)
q	x (displacement)
i	v (velocity)

विद्यार्थियो, आप SHM chapter ka "Damping oscillation" जरूर पढ़े!

Transformer



$$\frac{i_p}{i_s} = \frac{v_s}{v_p} = \frac{N_s}{N_p}$$

$$v_s = \frac{N_s}{N_p} v_p$$

$\frac{N_s}{N_p}$ = Turn ratio , $N_s > N_p \rightarrow$ step up X^{er}

$N_s < N_p \rightarrow$ step down X^{er}

Efficiency of X^{er} = $\frac{\text{Output power}}{\text{Input power}}$

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Electromagnetic Wave

Maxwell's Amper's Law

$$\boxed{\oint \vec{B} \cdot \vec{dl} = \mu_0 (i_c + i_D)}$$

where i_D = Displacement current

$i_D = \epsilon_0 \frac{d\phi}{dt}$, ϕ = magnetic flux

i_c = conduction current

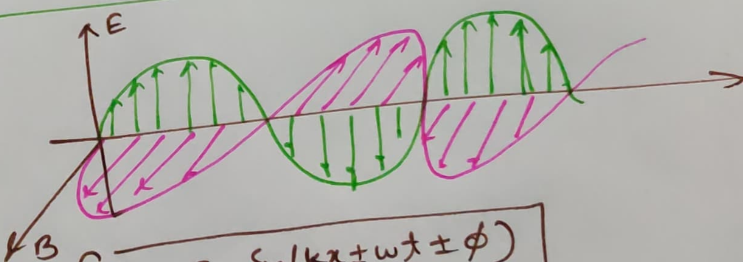
Maxwell's Equation

① $\oint \vec{E} \cdot \vec{ds} = \frac{Q}{\epsilon_0}$

② $\oint \vec{B} \cdot \vec{ds} = 0$

③ $\oint \vec{E} \cdot \vec{dl} = -\frac{d\phi}{dt}$

④ $\oint \vec{B} \cdot \vec{dl} = \mu_0 (i_c + i_D)$



$$E = E_0 \sin(kx \pm \omega t \pm \phi)$$
$$B = B_0 \sin(kx \pm \omega t + \phi)$$

NOTE → Both sine & Cos function can represent an EMW

where $E_0 = cB_0$ —ⓐ] amplitude

$B_0 = c\mu_0\epsilon_0 E_0$ —ⓑ]

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

k = propagation constant $= \frac{2\pi}{\lambda}$

λ = wave length

$\omega = 2\pi\nu = \frac{2\pi}{T}$, ν = frequency

ϕ = Initial phase

Direction of wave along $\vec{E} \times \vec{B}$

Avarege Energy density

of Electric field

$$U_E = \frac{1}{2} \epsilon_0 E_0^2$$

magnetic field

$$U_M = \frac{B_0^2}{2\mu_0}$$

Intensity of EMW ⇒

$$I = \frac{1}{2} \epsilon_0 E_0^2 c = \frac{B_0^2}{2\mu_0} c$$

c = speed of Light.

EMW spectrum

EMW	wavelength
Radio	$> 0.1\,m$
Microwave	$0.1\,m$ to $1\,mm$
Infra Red	$1\,mm$ to $700\,nm$
Visible light	$700\,nm$ to $400\,nm$
Ultra-Voilet	$400\,nm$ to $1\,nm$
X Rays	$1\,nm$ to $10^{-3}\,nm$
Gamma Rays	$< 10^{-3}\,nm$

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