CBSE Class 12 Physics (2026) - Derivations Practice Booklet

Unit I: Electrostatics - Formula Page

Coloumbs law :-

$$F = \frac{K q_1 q_2}{r^2}$$

$F \propto q_1 q_2$ $\quad$ $K = 9 \times 10^9 \, N m^2/C^2$

$F \propto \frac{1}{r^2}$ $\quad$ $K = \frac{1}{4\pi\varepsilon_0}$ $\quad$ $\varepsilon_0 \rightarrow$ Permitivity

$\varepsilon_0 = 8.85 \times 10^{-12} \, C^2 m^{-2} N^{-1}$

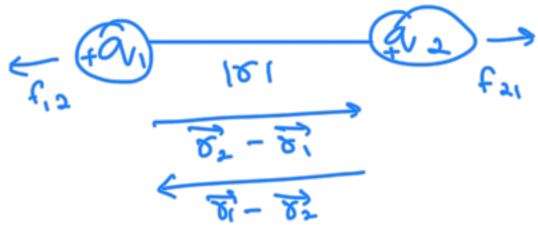
$$\varepsilon_r = \frac{\varepsilon_m}{\varepsilon_0} \qquad \boxed{\varepsilon_m = \varepsilon_0 \varepsilon_r}$$

Unit I: Electrostatics - Derivations

Derive Coulomb!s law in vector form.
Importance: ★★★★■ (4/5)

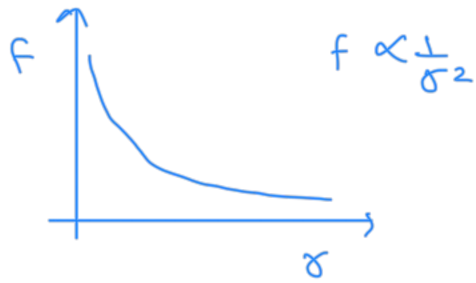
$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{|r|^2} \cdot \widehat{(\vec{r}_1 - \vec{r}_2)} \qquad \hat{a} = \frac{\vec{a}}{|a|}$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{|\vec{r}_1 - \vec{r}_2|^2} \cdot \frac{\vec{r}_1 - \vec{r}_2}{(\vec{r}_1 - \vec{r}_2)}$$



$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{|\vec{r}_1 - \vec{r}_2|^3} \cdot (\vec{r}_1 - \vec{r}_2)$$

$$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{|\vec{r}_2 - \vec{r}_1|^3} \cdot (\vec{r}_2 - \vec{r}_1)$$



Derive electric field due to a point charge.
Importance: ★★★★★ (5/5)

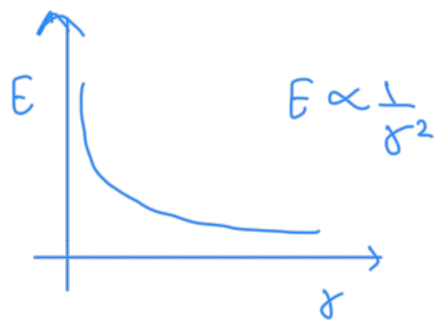
we know

$$\vec{E} = \frac{\vec{F}}{q_0} \quad \text{—— (1)}$$

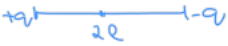
$$\vec{F}_{AB} = \frac{1}{4\pi\varepsilon_0} \frac{q\, q_0}{r^2} \quad \text{—— (2)}$$

Put (2) in (1)

$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r_2}$$



Dipole → Two equal and opposite charges separated by a distance of $2l$



$p = 2ql$

Derive electric field on axial line of dipole.
Importance: ★★★★★ (5/5)

$$E_{CA} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(x+l)^2}$$

$$E_{CB} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(x-l)^2}$$

Electric field at point P on axial line

$$\vec{E}_C = \vec{E}_{CB} - \vec{E}_{CA}$$

$$E_C = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{(x-l)^2} - \frac{1}{(x+l)^2}\right)$$

$$= \frac{q}{4\pi\varepsilon_0}\,\frac{x^2+l^2+2xl-x^2-l^2+2xl}{(x^2-l^2)^2}$$

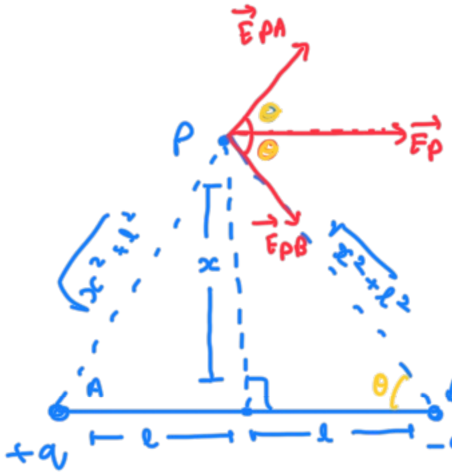
$$= \frac{q}{4\pi\varepsilon_0}\,\frac{4xl}{(x^2-l^2)^2} \qquad p = 2ql$$

$$E_C = \frac{2px}{4\pi\varepsilon_0(x^2-l^2)^2}$$

For $x >> l$ $\quad l = 0$

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

Derive electric field on equatorial line of dipole.
Importance: ★★★★★ (5/5)

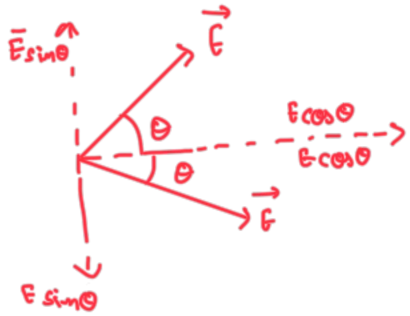


$$\cos\theta = \frac{l}{\sqrt{x^2+l^2}}$$

$$E_{PA} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(\sqrt{x^2+l^2})^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{x^2+l^2} = E$$

$$E_{PB} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(\sqrt{x^2+l^2})^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{x^2+l^2} = E$$

$$\vec{E}_P = \vec{E}_{PA} + \vec{E}_{PB}$$



$$E_{net} = 2E\cos\theta$$

$$E_{net} = 2\,\frac{1}{4\pi\varepsilon_0}\,\frac{q}{x^2+l^2}\cdot\cos\theta$$

$$E_{net} = 2\,\frac{1}{4\pi\varepsilon_0}\,\frac{q}{(x^2+l^2)}\cdot\frac{l}{(x^2+l^2)^{1/2}}$$

$$E_{net} = 2\,\frac{1}{4\pi\varepsilon_0}\,\frac{ql}{(x^2+l^2)^{3/2}}$$

$2ql = p$

$$E_{net} = \frac{1}{4\pi\varepsilon_0}\,\frac{p}{(x^2+l^2)^{3/2}}$$

For $x >>> l$ $\quad l = 0$

$$E_{net} = \frac{1}{4\pi\varepsilon_0}\,\frac{p}{x^3}$$

$$E_{equitorial} = \frac{kp}{x^3}$$

$$2E_{equitorial} = E_{axial}$$

State and prove Gauss!s theorem.
Importance: ★★★★★ (5/5)

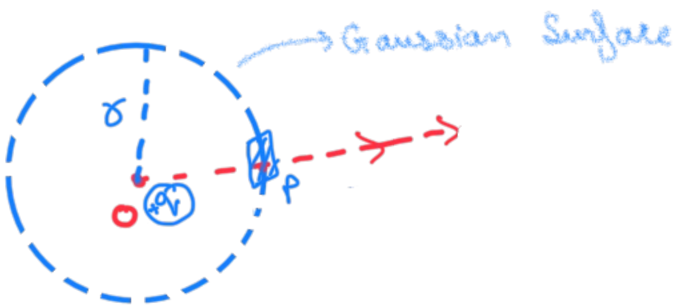
Electric Flux :- The no. of Electric field lines passing through a surface is called electric flux.

It is given by. $\boxed{\int E \cdot ds = \phi}$

Gauss Theorem :- The net flux passing through a closed surface is $\frac{1}{\varepsilon_0}$ time the net charge enclosed by the surface.

Proof.

Let $(+q)$ be the charge enclosed by a spherical gaussian surface and r be its Radius.



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

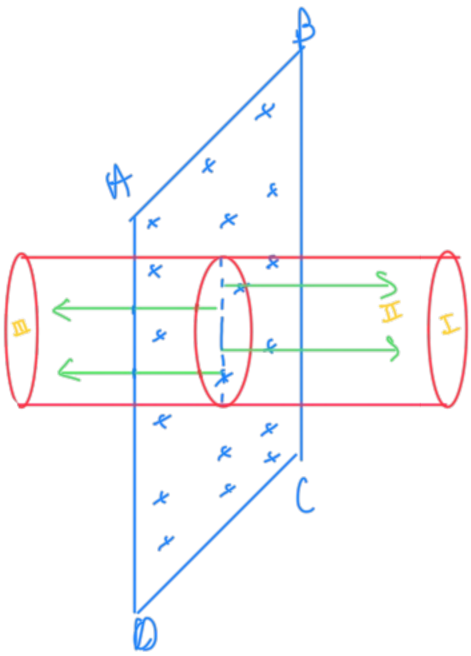
$$\phi = \int E \cdot ds$$

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

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

Hence Proved.

Using Gauss!s law derive field due to infinite plane sheet.
Importance: ★★★★■ (4/5)



Let, ABCD is an infinite positively charged plane sheet.

If we get a cylinderical gaussium surface through the charged plane sheet. and Q be the charge on whole sheet.

So,

$$\phi_{net} = \phi_{I} + \phi_{II} + \phi_{III}$$

$$\phi_{net} = \int E_I \, ds_I \cos\theta_I + \int E_{II} \, ds_{II} \cos\theta_{II} + \int E_{III} \, ds_{III} \cos\theta_{III}$$

$$\cos\theta_I = \cos\theta_{III} = 1 \qquad \cos\theta_{II} = 0$$

$$\phi_{net} = \int E_I \, ds_I \cos\theta_I + \cancel{\int E_{II} \, ds_{II} \cos\theta_{II}} \to 0 + \int E_{III} \, ds_{III} \cos\theta_{III}$$

$E_I = E_{III}$
$ds_I = ds_{III} = A$

$$\phi_{net} = 2EA$$

We know,

$$\sigma = \frac{Q}{A}$$

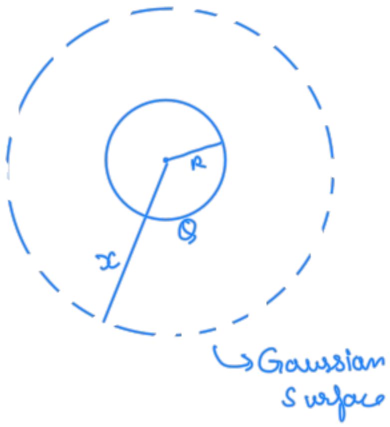
$$\phi_{net} = \frac{Q}{\varepsilon_0}$$

$$\boxed{\phi_{net} = \frac{\sigma A}{\varepsilon_0}}$$

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

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

Using Gauss!s law derive field due to spherical shell.
Importance: ★★★★■ (4/5)



Let Q be the charge on the spherical shell.
R be its radius.
Then, ϕ flux outside is.

$$\phi_{net} = \frac{Q_{inside}}{\varepsilon_0}$$

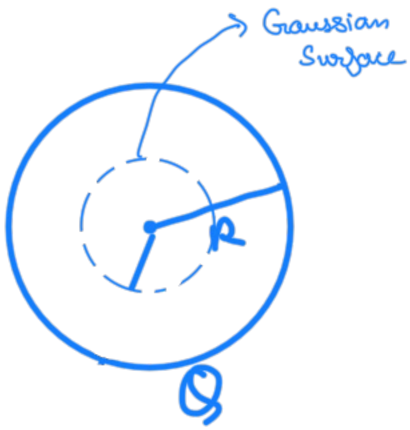
$$\phi_{net} = \frac{Q}{\varepsilon_0}$$

$$\phi_{net} = \int E \cdot ds$$

$$\phi_{net} = E\, 4\pi R^2$$

$$E\, 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

$$\boxed{E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{R^2}}$$



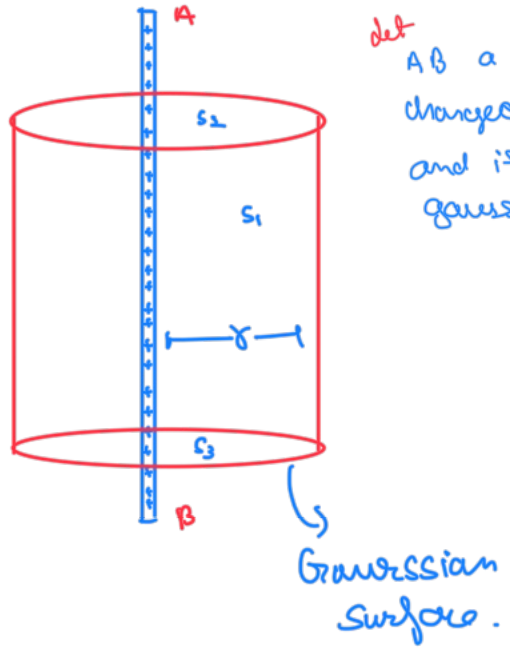
$$\phi_{net} = \frac{q_{inside}}{\varepsilon_0}$$

But $q_{inside} = 0$

$$\phi_{net} = 0$$

inside a spherical conductor.

Electric field due to a long straight charge conductor.



Let AB a long infinitely charged ~~con~~ straight conductor and it has a cyllinderical gaussian surface.

$$\phi_{net} = \frac{Q}{\epsilon_0}$$

$$\frac{Q}{l} = \lambda$$

$$Q = \lambda l$$

$$\phi_{net} = \frac{\lambda l}{\epsilon_0}$$

So,

$$\phi_{net} = \phi_{S_1} + \phi_{S_2} + \phi_{S_3}$$

$$\phi_{net} = \int E\, ds_1 \cos 0^\circ + \cancelto{0}{\int E\, ds_2 \cos 90^\circ} \quad \boxed{\because \cos 90 = 0}$$

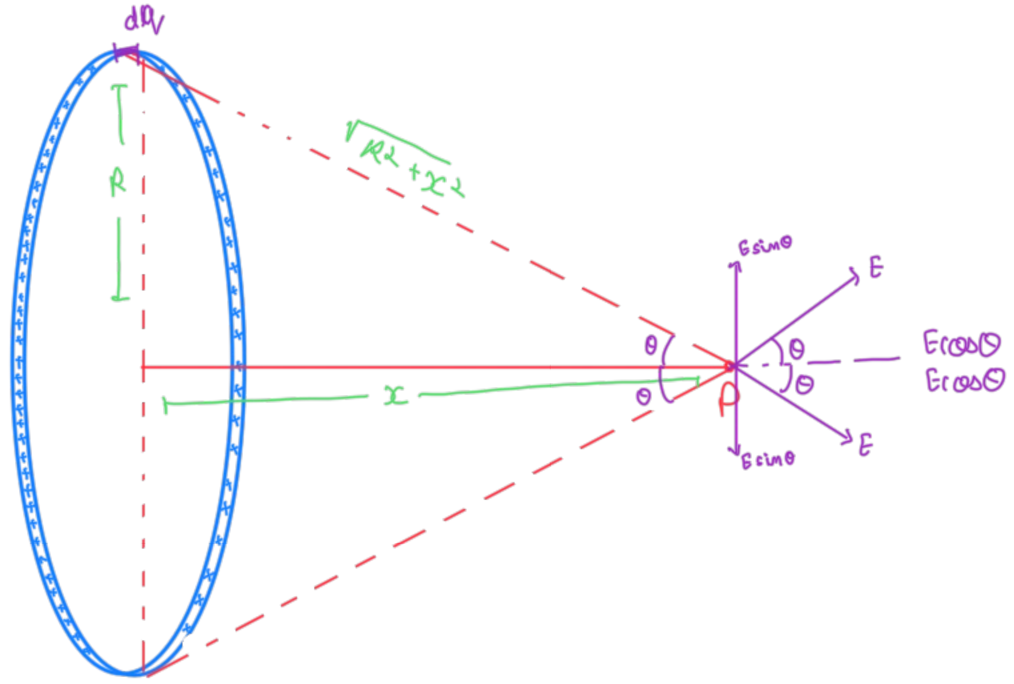
$$+ \cancelto{0}{\int E\, ds_3 \cos 90^\circ}$$

$$\phi_{net} = E \pi r l$$

$$\frac{\lambda \cancel{l}}{\epsilon_0} = E \pi r \cancel{l}$$

$$\boxed{\frac{\lambda}{\epsilon_0 \pi r} = E}$$

$\vec{E}$, Electric field due to Charged Ring. ★★



$$E_{net} = \int dE \cos\theta$$

$$E_{net} = \int \frac{1}{4\pi\varepsilon_0} \cdot \frac{dq}{(\sqrt{R^2+x^2})^2} \cdot \cos\theta$$

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

$$E_{net} = \int \frac{1}{4\pi\varepsilon_0} \cdot \frac{dq}{(R^2+x^2)} \cdot \frac{x}{\sqrt{R^2+x^2}}$$

$$E_{net} = \frac{1}{4\pi\varepsilon_0} \frac{x}{(R^2+x^2)^{3/2}} \cdot \int dq$$

$$E_{net} = \frac{1}{4\pi\varepsilon_0} \frac{x}{(R^2+x^2)^{3/2}} Q$$

at centre of ring

$\boxed{x = 0}$

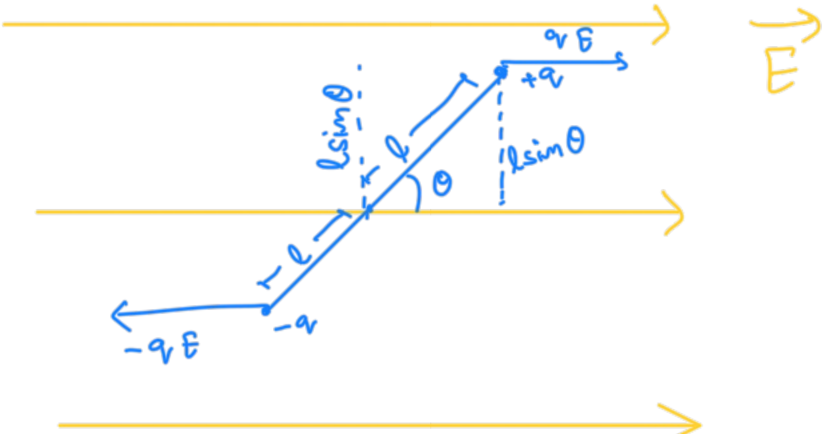
$\boxed{\therefore\ E_{net} = 0}$

when $R <<< x$
$R \simeq 0$

$$\boxed{E_{net} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{x^2}}$$

act as point charged.

Torque on a dipole in an uniform electric field.



$F = qE$

$\tau = F \times \perp d$

$\vec{\tau}_{net} = \vec{\tau}_1 + \vec{\tau}_2$

$\vec{\tau}_{net} = F_1 \perp d + F_2 \perp d$

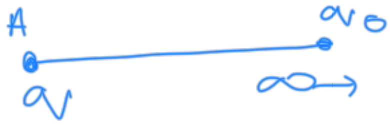
$= qE\, l\sin\theta + qE\, l\sin\theta$

$= 2ql\, E\sin\theta$

$= p\, E\sin\theta$

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

Derive electric potential due to point charge.
Importance: ★★★★■ (4/5)



$$V_A - \cancel{V_\infty}^{0} = V = \frac{W}{q} \qquad W = F \cdot r$$

$$V = \frac{F \cdot r}{q_0}$$

$$\boxed{V = \frac{kq}{r}}$$

$$V = \frac{K q q_0}{\cancel{q_0} r^{\cancel{2}}} \cdot \cancel{r}$$

Derive relation E = -dV/dr.
Importance: ★★★★■ (4/5)

" Potential decreases in the direction of $\vec{E}$ field "

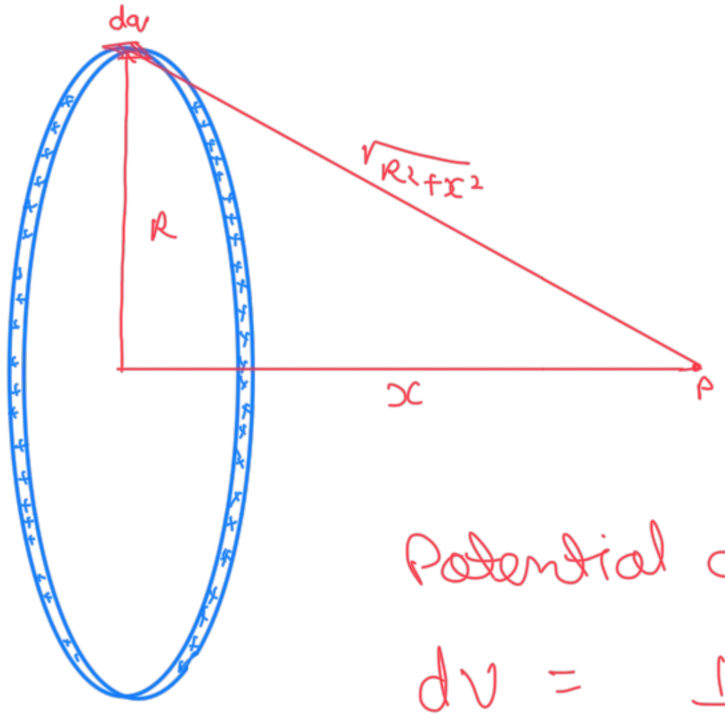
$$dV = -d\frac{W}{q}$$

$$dV = -d\frac{E\cancel{q} \cdot r}{\cancel{q}}$$

$$dV = -E \cdot dr$$

$$\boxed{E = \frac{-dV}{dr}}$$

Potential due to a charged ring at a point.



Potential at P

$$dV = \frac{1}{4\pi\varepsilon_0}\frac{1}{\sqrt{x^2+R^2}}\int dq$$

$$\int dV = \frac{1}{4\pi\varepsilon_0}\frac{Q}{\sqrt{x^2+R^2}}$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{\sqrt{x^2+R^2}}$$

At centre $x = 0$

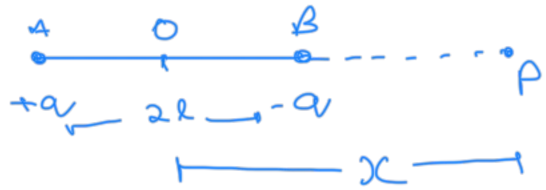
$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

A point $x >> R$ $R \simeq 0$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{x}$$

Act as point charge

Potential due to a dipole at its axis.



$$V_{PA} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{+q}{(x+l)}$$

$$V_{PB} = \frac{1}{4\pi\varepsilon_0} \frac{-q}{(x-l)}$$

Potential at point P

$$V_{net} = V_{PA} + V_{PB}$$

$$V_{net} = \frac{1}{4\pi\varepsilon_0} \frac{q}{x+l} - \frac{1}{4\pi\varepsilon_0} \frac{q}{x-l}$$

$$= \frac{q}{4\pi\varepsilon_0} \left(\frac{1}{x+l} - \frac{1}{x-l} \right)$$

$$= \frac{q}{4\pi\varepsilon_0} \left(\frac{\cancel{x} - l - \cancel{x} - l}{x^2 - l^2} \right)$$

$$V_{net} = \frac{q}{4\pi\varepsilon_0} \frac{-2l}{x^2 - l^2}$$

$$V_{net} = \frac{-p}{4\pi\varepsilon_0 (x^2 - l^2)}$$

At $x >>> l$

$$V_{net} = \frac{-p}{4\pi\varepsilon_0 x^2}$$

$$V_{net} = -\frac{p}{4\pi\varepsilon_0 x^2} = \frac{-kp}{x^2}$$

Potential due to a dipole at equitorial point.

$$V_{PA} = k \frac{q}{\sqrt{x^2 + l^2}}$$

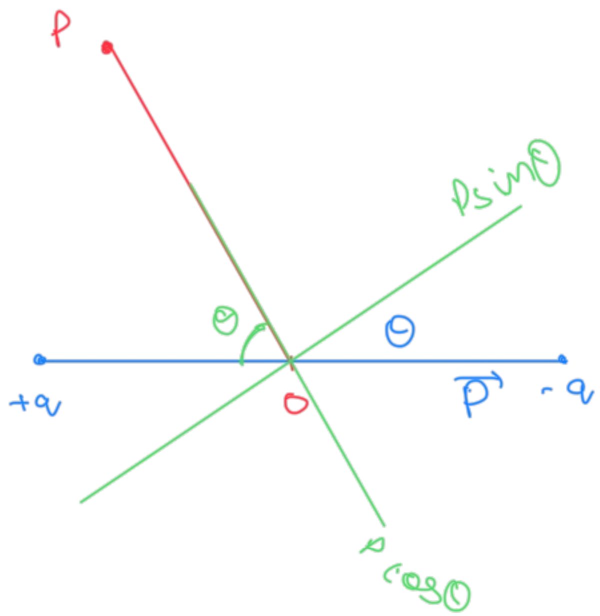
$$V_{PB} = k \frac{-q}{\sqrt{x^2 + l^2}}$$

$$V_{net} = V_{PA} + V_{PB}$$

$$= \frac{kq}{\sqrt{x^2 + l^2}} + \frac{-kq}{\sqrt{x^2 + l^2}}$$

$$\boxed{V_{net} = 0}$$

Potential due to a dipole at any point.



$$V_{net} = V_{P\cos\theta} + V_{P\sin\theta}$$

$V_{P\sin\theta}$ is at perpendicular ore equi forial point.

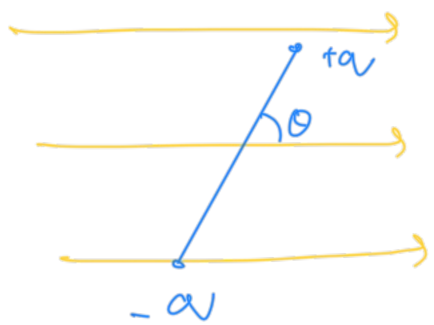
$$\therefore \quad V_{P\sin\theta} = 0$$

→ at axial point

$$V_{net} = 0 + V_{P\cos\theta}$$

$$V_{net} = \frac{K P\cos\theta}{x^2}$$

Energy stored in a dipole.



$$U = -\text{Work done}$$

$$U = -\int \tau \cdot d\theta$$

$$U = -\int P E \sin\theta \, d\theta$$

$$U = -PE\left[\cos\theta\right]_{90}^{\theta}$$

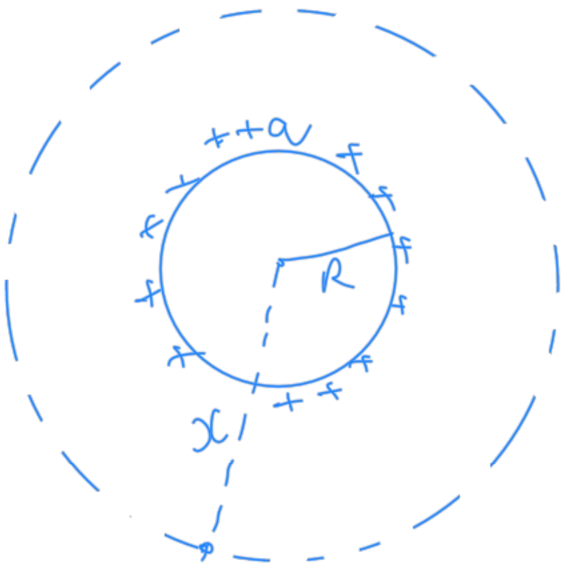
$$U = -PE(\cos\theta - 0)$$

$$U = -PE\cos\theta$$

$$U = -P \cdot E$$

$\boxed{F_{net} = 0}$ always

Potential due to a Spherical charged hollow conductor.



$$V = -\int E \cdot dl$$

$$V = -\int \frac{KQ}{l^2}\, dl$$

$$V = -KQ \int \frac{1}{l^2}\, dl$$

$$V = -KQ \left[-\frac{1}{l} \right]_{\infty}^{x}$$

$$\boxed{V = +\frac{KQ}{x}}$$

at $x = R$ $\quad V = \frac{KQ}{R}$

At point inside the Sphere.

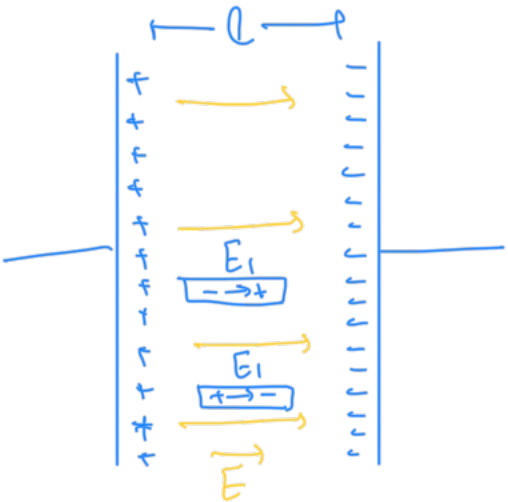
$$V_p - V_s = -\int \cancel{E} \cdot dl$$

0

$$V_p = V_s$$

$$\boxed{V_p = \frac{KQ}{R}}$$

Derive capacitance of parallel plate capacitor.
Importance: ★★★★★ (5/5)



we know

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

$$E = E_1 + E_2$$

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

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

$$\frac{V}{d} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$$

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

$$C = \frac{Q\,\varepsilon_0 A}{Qd}$$

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

Energy stored.

$$U = -\text{work done}$$

$$dU = -V\,dq$$

$$\int dU = \int -V\,dq$$

$$\int dU = -\int \frac{q}{C}\,dq$$

$$C = \frac{q}{V} \qquad V = \frac{q}{C}$$

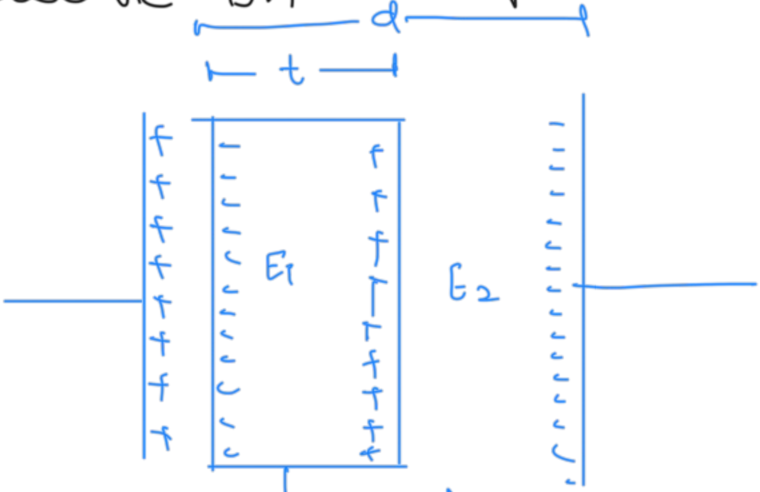
$$U = -\frac{1}{C}\frac{q^2}{2}$$

$$\boxed{U = -\frac{q^2}{C}\,\frac{1}{2}}$$

$$U = \frac{1}{2} QV$$

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

Dielectric in a capacitor.



Dielectric of constant K.

$$V = E_1 t + E_2 (d-t)$$

$$V = \frac{E}{K} t + E(d-t)$$

$$V = \frac{Q}{A\varepsilon_0}\left(\frac{t}{K} + d - t\right)$$

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

$$C = \frac{\cancel{Q} A\varepsilon_0}{\cancel{Q}\left(\frac{t}{K} + d - t\right)}$$

$$C = \frac{\varepsilon_0 A}{\left(\frac{t}{K} + d - t\right)}$$

For Spherical Conductor

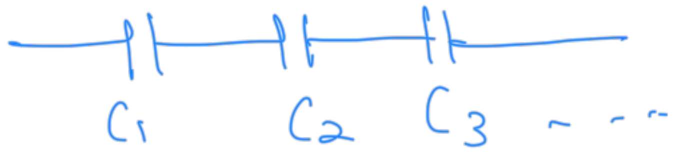
$$C = \frac{Q}{V}$$

$$V = \frac{KQ}{r}$$

$$C = \frac{\cancel{Q}}{K\cancel{Q}} r$$

$$\boxed{C = 4\pi\varepsilon_0 r}$$

Capacitator is series & Parallel

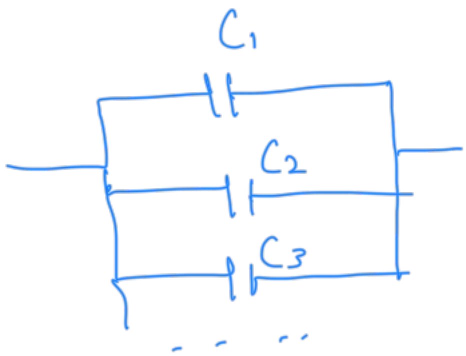


we know in series
charge on each capacitor remains same.
and potential is additive

$$V = V_1 + V_2 + V_3 \ldots$$

$$\frac{\cancel{Q}}{C} = \frac{\cancel{Q}}{C_1} + \frac{\cancel{Q}}{C_2} + \frac{\cancel{Q}}{C_3} \ldots$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \ldots$$



We know in parallel potential accross each capacitor is same and Q charge is additive

$$Q = Q_1 + Q_2 + Q_3$$

$$CV = C_1V_1 + C_2V_2 + C_3V_3 \ldots$$

$$C\cancel{V} = C_1\cancel{V} + C_2\cancel{V} + C_3\cancel{V} \ldots$$

$$C = C_1 + C_2 + C_3 \ldots$$

Unit II: Current Electricity - Formula Page

$$V_d = \frac{eEJ}{m}$$

Drift Velocity :- The velocity of electrons due to the presence of electric field.

$$\vec{J} = \frac{I}{A}$$ Current ensity.

$$V = IR$$

Electron Mobility

$$\mu = \frac{V_d}{E}$$

$$\sigma = \frac{1}{\rho}$$

Conductance ← σ, ρ ← Resistivity

KCL → Current is additive in general at the junctions.

KVL → Sum of all the potential across a loop is zero.

Unit II: Current Electricity - Derivations

Derive expression for drift velocity.
Importance: ★★★★★ (5/5)

$V_d = u_{avg} + at$

$V_{avg} = \frac{v_1 + v_2 + u_3 \dots}{n} = 0$

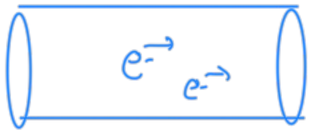
Initially velocity mean is zero.

$a = \frac{F}{m} = \frac{Ee}{m}$

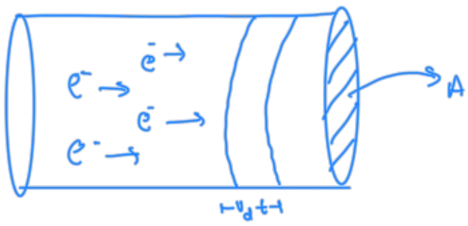
τ_{avg} = Avg relaxation time

Avg relaxation time btw two successive collisions

$V_d = \frac{Ee\tau}{m}$



Derive relation
Importance: ★★★★★ (5/5) $I = V_d e n A$



We know

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

n = no. of e⁻ per unit volume

N = No of e⁻

$N = nA.l = \underline{nA.V_d t}$

∵ l = length of conductor

$l = V_d t$

$N = nAV_d t$

$Ne = nAV_d te$

$\frac{q}{t} = nAV_d e$

$\boxed{I = V_d e n A}$

Ohms law derivation

$$I = V_d e n A$$

$$I = \frac{eE\tau}{m} e n A$$

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

$$I = e \frac{V\tau}{lm} e n A$$

$$\frac{I}{V} = \frac{e^2 \tau n A}{l m}$$

$$V = \frac{m l I}{e^2 \tau n A}$$

$$\boxed{R = \frac{ml}{e^2 \tau n A}} \qquad \rho = \frac{m}{n e^2 \tau}$$

Derive microscopic form of Ohm!s law. or Vector form of Ohm's law
Importance: ★★★★■ (4/5)

$$V = \frac{m l}{e^2 \tau n A} I$$

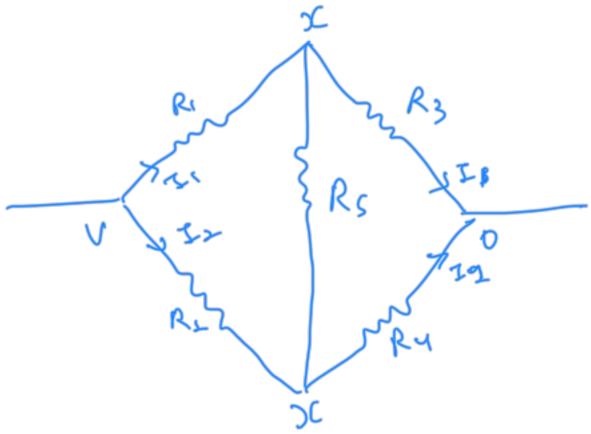
$$\vec{E} = \frac{m}{e^2 \tau n} \vec{J}$$

$$\frac{V}{l} = \frac{m}{e^2 \tau n} \frac{I}{A}$$

$$\vec{E} = \rho \vec{J}$$

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

Derive condition for Wheatstone bridge.
Importance: ★★★★■ (4/5)



Assume no current passes through the R_5

$$V - x = I_1 R_1 \quad (1)$$

$$x - 0 = R_3 I_\beta \quad (2)$$

$$V - x = I_2 R_2 \quad (3)$$

$$x - 0 = I_2 R_4 \quad (4)$$

(1)/(3) & (2)/(4)

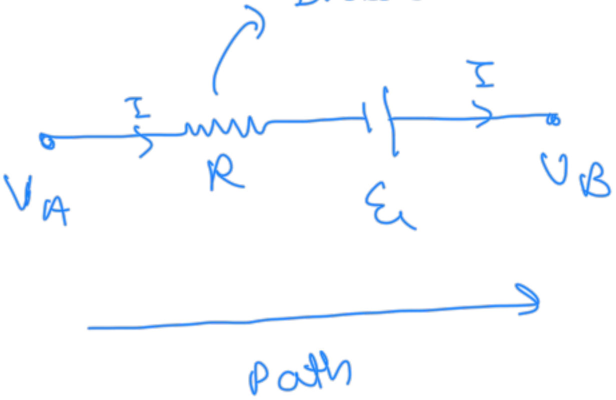
$$1 = \frac{I_1 R_1}{I_2 R_2} \qquad 1 = \frac{I_\beta R_3}{I_2 R_4}$$

$$\boxed{\frac{R_1}{R_2} = \frac{R_3}{R_4}}$$

Derive internal resistance of a cell.
Importance: ★★★★■ (4/5)

Terminal voltage → Potential diff accross the two ends of cell when current is ~~drawc~~ drawn from it.

Internal resistance of cell.



$$V_A - V_B = -IR + \varepsilon$$

$$V = \varepsilon - IR$$

$$V = I\, R_{external}$$

$$\varepsilon - IR = I R_{ext}$$

$$\varepsilon = I\,(R_{ext} + R)$$

$$\boxed{I = \frac{\varepsilon}{(R_{ext} + R)}}$$

Unit III: Moving Charges and Magnetism - Formula Page

$$\frac{\mu_0}{4\pi} = 10^{-7}$$

$$\mu_0 = 10^{-7} \times 4\pi$$

↳ permeability

Line integral of Magnetic field is equal to the μ_0 time the current flowing through conductor

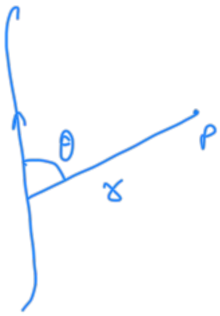
Ampere Circuital law. → $\int B.dl = \mu_0 i$

$$\text{Lorentz force} = q(\vec{V} \times \vec{B})$$

$$\text{Lorentz force} = qVB\sin\theta$$

Unit III: Moving Charges and Magnetism - Derivations

State and derive Biot–Savart law.
Importance: ★★★★★ (5/5)

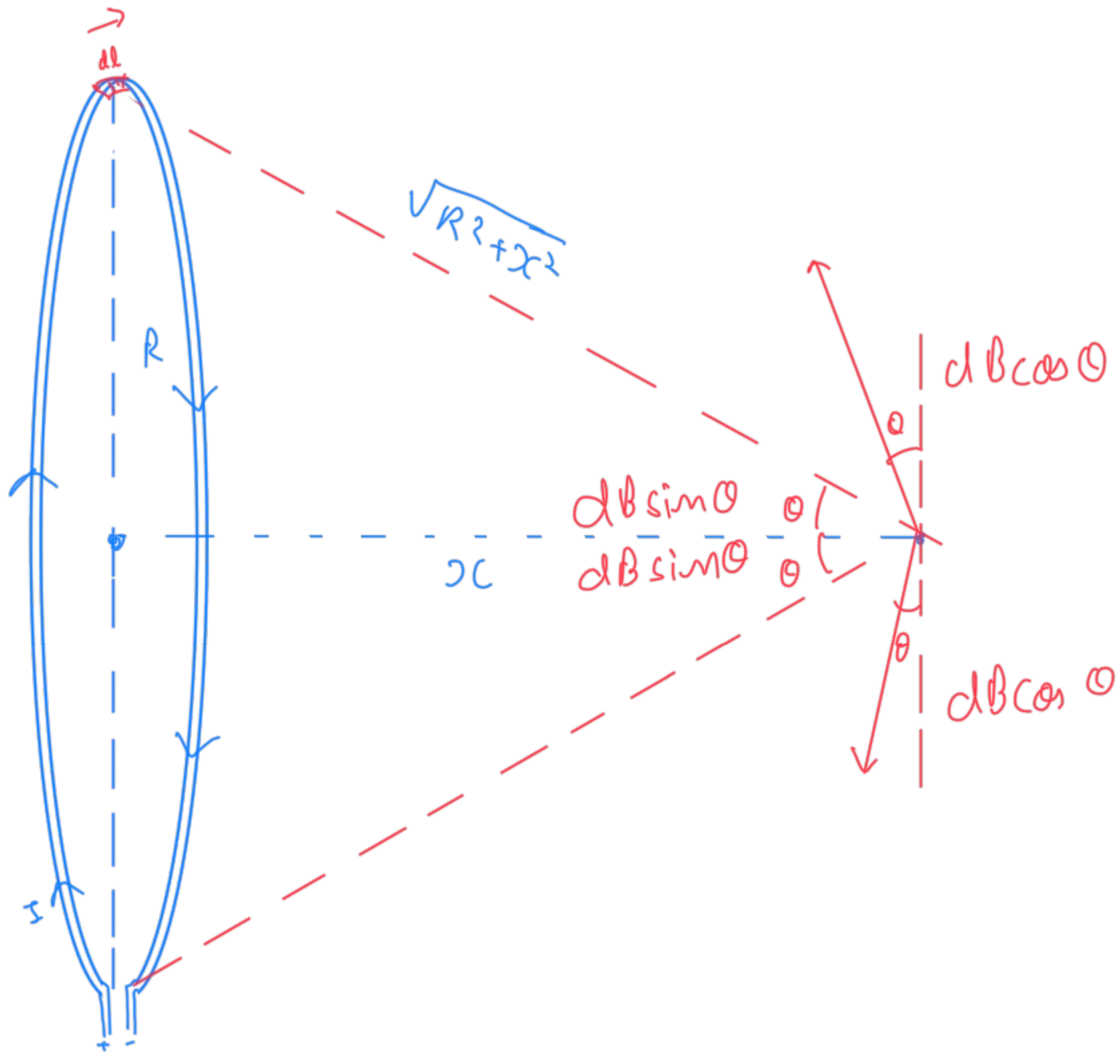


$$\vec{dB} = \frac{\mu_0}{4\pi} i \frac{\vec{dl} \times \vec{r}}{r^3}$$

$$dB = \frac{\mu_0}{4\pi} \frac{i\, dl \sin\theta}{r^2}$$

only for elemental current

Derive magnetic field on axis of circular loop.
Importance: ★★★★★ (5/5)



$$dB = \frac{\mu_0}{4\pi} \frac{i\,dl}{(R^2+x^2)}$$

$$B_{net} = \int dB \sin\theta$$

$$B_{net} = \int \frac{\mu_0}{4\pi} \frac{i\,dl \sin\theta}{R^2+x^2}$$

$$\sin\theta = \frac{R}{\sqrt{R^2+x^2}}$$

$$B_{net} = \int \frac{\mu_0}{4\pi} \frac{i\,dl}{(R^2+x^2)^{3/2}} R$$

$$B_{net} = \frac{\mu_0}{4\pi} \frac{i\,R}{(R^2+x^2)^{3/2}} \cdot 2\cancel{\pi}\cancel{R}$$

$$= \frac{\mu_0}{4\pi} \frac{i\,R^2\,2\pi}{R^2+x^2}$$

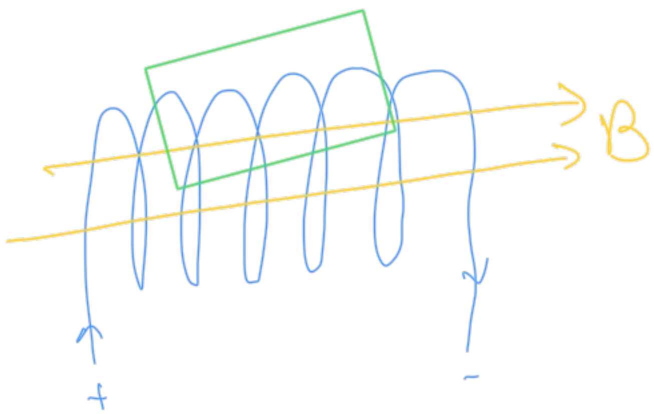
$$B_{net} = \frac{\mu_0 i R^2}{2(R^2+x^2)^{3/2}}$$

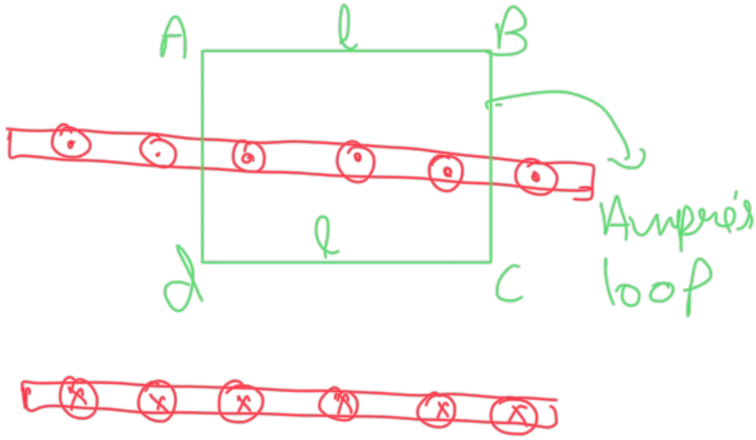
At centre $x = 0$

$$B_{net} = \frac{\mu_0 i \cancel{R^2}}{2 R^3}$$

$$\boxed{B_{net} = \frac{\mu_0}{2} \frac{i}{R}}$$

Magnetic field inside the solenoid using Ampere's Circuital Law.





$$\oint_{ABCD} B\cdot dl = \mu_0 i_{inside}$$

$$\oint_{AB} \overset{0}{\cancel{B\, dl}} + \oint_{BC} \overset{0}{\cancel{B\cdot dl \cos 90}} + \int_{Ad} \overset{0}{\cancel{B\cdot dl \cos 90}}$$

$$+ \oint_{CD} B\cdot dl = \mu_0 i_{inside}$$

$$-Bl = \mu_0 i_{inside}$$

1 → n turn

l → nl turns

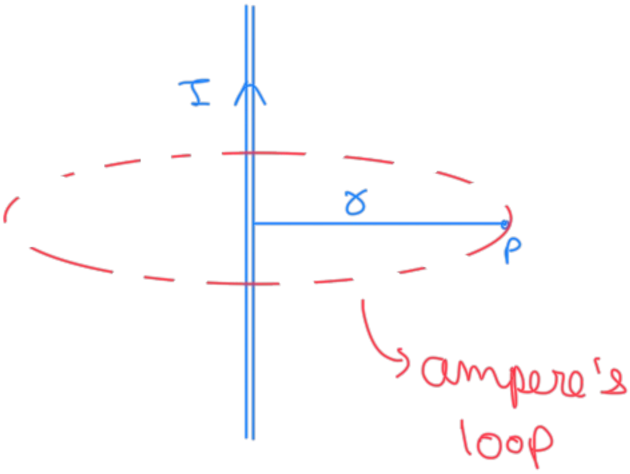
1 → i current

nl → nli current

$$Bl = \mu_0 n l i$$

$$\boxed{B = \mu_0 n i}$$

Using Ampere!s law derive field of long straight conductor.
Importance: ★★★★★ (5/5)



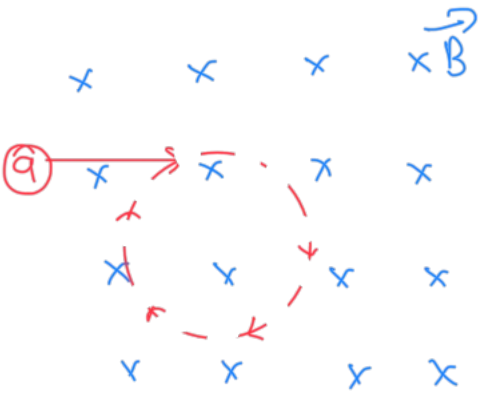
$$\oint B \cdot dl = \mu_0 i$$

$$B \oint dl = \mu_0 i$$

$$B \, 2\pi r = \mu_0 i$$

$$\boxed{B = \frac{\mu_0 i}{2\pi r}}$$

Derive radius & time period of charged particle in B field.
Importance: ★★★★★ (5/5)



Force due to magnetic field = Centripital force

$$q\cancel{v}B = \frac{mv^{\cancel{2}}}{r}$$

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

$P = mv$
momentum

$$r = \frac{P}{qB}$$

$$KE = \frac{1}{2}mv^2$$

$$P = \sqrt{2mKE}$$

$$\boxed{R = \frac{\sqrt{2mKE}}{qB}}$$

$$R = \sqrt{\frac{2mV}{qB^2}}$$ Potential.

$$T = \frac{\text{distance}}{\text{speed}}$$

$$= \frac{2\pi r}{v}$$

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

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

Force on a current carrying wire in a magnetic field

$f = IlB\sin\theta$

$f = qVB\sin\theta$

$f = e\,vB\sin\theta$

For all e^- in elemental region

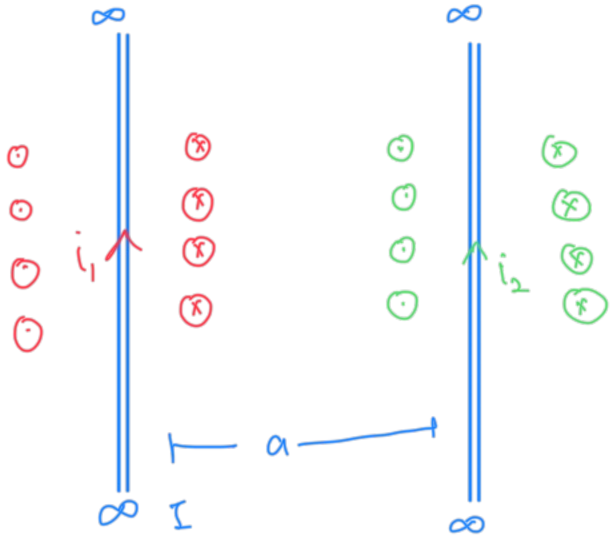
$df = Ne\,V_d B\sin\theta$

$df = n\,A\,dl\;e\,V_d\,B\sin\theta$

$\int df = \int I\,dl\,B\sin\theta$

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

Derive force between two parallel conductors.
Importance: ★★★★★ (5/5)



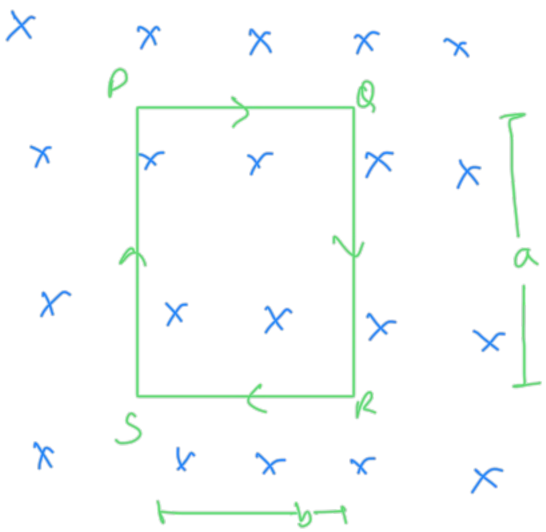
$$F_{12} = I_1\, l\, B_{12} \sin\theta$$

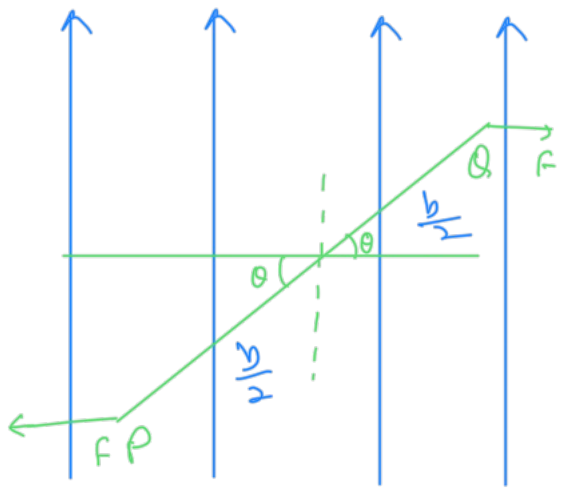
$$= I_1\, l\, \frac{\mu_0 I_2}{\pi 2 a}$$

$$F_{12} = \frac{\mu_0 I_1 I_2\, l}{2\pi a}$$

$$\boxed{\frac{F_{12}}{l} = \frac{\mu_0}{4\pi} \frac{I_1 I_2}{d} = \frac{F_{21}}{l}}$$

Derive torque on current loop.
Importance: ★★★★■ (4/5)





$$\vec{\tau} = F \times \perp d + F \times \perp d$$

$$= F \times \frac{b}{2} \sin\theta + F \times \frac{b}{2} \sin\theta$$

$\because F = IlB$ or IaB
$l = a$

$$= F\, b \sin\theta$$

$$= i\, a\, B\, b \sin\theta$$

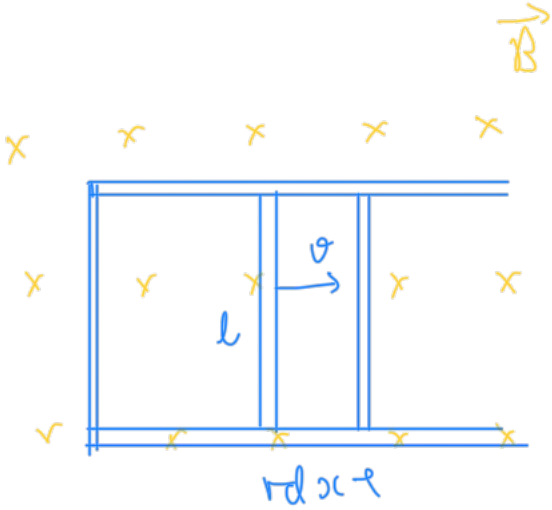
$$= i\, A\, B \sin\theta$$

$$\vec{\tau}_{net} = m B \sin\theta$$

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

Unit IV: EMI and AC - Formula Page

Motional EMF



$$\frac{d\phi}{dt} = \varepsilon_i$$

$$\varepsilon_i = \frac{d B.A}{dt}$$

$$\varepsilon_i = B\,\frac{d\,lx}{dt}$$

$$= B\,l\,\frac{dx}{dt}$$

$$\varepsilon_i = BlV$$

Unit IV: EMI and AC - Derivations

State Faraday!s laws and derive induced emf.
Importance: ★★★★★ (5/5)

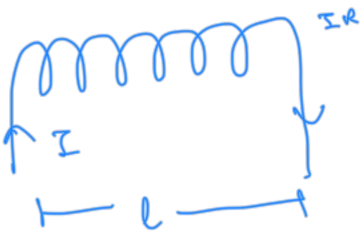
First Law, Whenever there is a change in magnetic flux linked with the conductor induced current is produced

Second Law, The induced current in conductor last as long as change in flux continue.

Third Law, The induced ε is directly proportional to rate of change in flux wrt time.

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

Derive self inductance of solenoid.
Importance: ★★★★★ (5/5)



$$\phi = B.A$$

$$\phi = \mu_0 n I . \pi R^2$$

$$\frac{L\cancel{I}}{N} = \mu_0 n \cancel{I} . \pi R^2$$

$$L = \mu_0 n^2 \, l \pi R^2$$

$$L = \mu_0 n^2 V$$

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

$$\phi \propto I$$

$$N\phi = LI \quad \boxed{N = nl}$$

$$\varepsilon = L \frac{dI}{dt}$$

Derive energy stored in inductor.
Importance: ★★★★■ (4/5)

$$\frac{dw}{dt} = (-\varepsilon_L) I$$

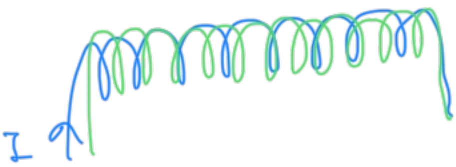
$$\int \frac{dw}{\cancel{dt}} = \int L \frac{dI}{\cancel{dt}} I$$

$$\varepsilon_L = L \frac{dI}{dt}$$

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

$$\boxed{U = \frac{L I^2}{2}}$$

Mutual Inductance



$l = l$

$n_2 \quad n_1 \quad I_1$

$$\phi = B \cdot A$$

$$\phi = \mu_0 n_1 I_1 \cdot \pi R^2$$

$$\phi \propto I_1$$

$$\phi_T = N \phi$$

$$N\phi = M I_1$$

$$\phi_T = n_2 l \mu_0 n_1 I_1 \pi R^2$$

$$M \cancel{I_1} = n_2 l \mu_0 n_1 \cancel{I_1} \pi R^2$$

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

$$M = n_1 n_2 \mu_0 l \pi R^2$$

$$\varepsilon = M \frac{dI}{dt}$$

Derive RMS value of AC.
Importance: ★★★★★ (5/5)

RMS value of alternate current is that value of current in which heat produced in given time is equal to the heat produced by a dC source through a particular load

$$\int dH_{ac} = \int I_0^2 \sin^2\omega t \, R \, dT$$

$$H_{ac} = I_0^2 R \frac{T}{2}$$

$$H_{dc} = H_{ac}$$

$$I^2 R \cancel{T} = I_{rms}^2 R \cancel{T}$$

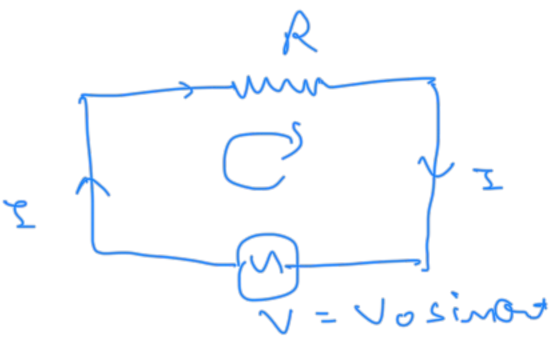
$$I = I_{rms}$$

$$I_{rms}^2 \cancel{RT} = I_0^2 \cancel{R} \frac{\cancel{T}}{2}$$

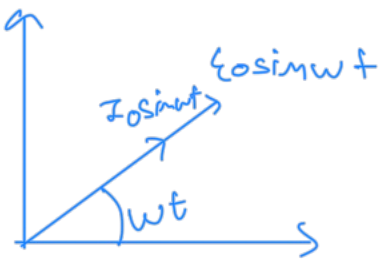
$$I_{rms}^2 = \frac{I_0^2}{2}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

Pure Resistive circuit.



Phasor diagram.



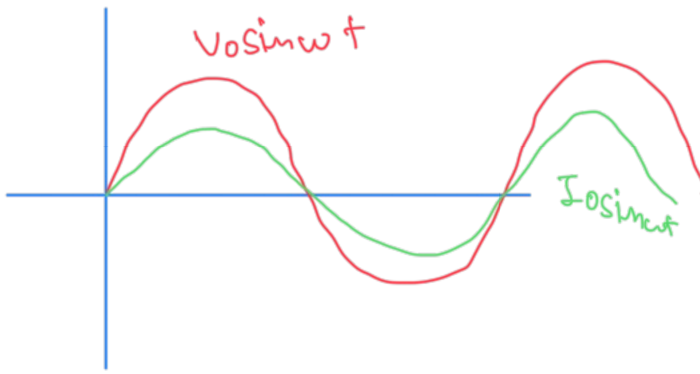
$$0 = V - IR$$

$$V = IR$$

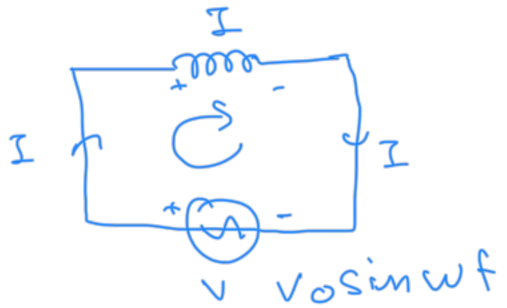
$$E_0 \sin\omega t = IR$$

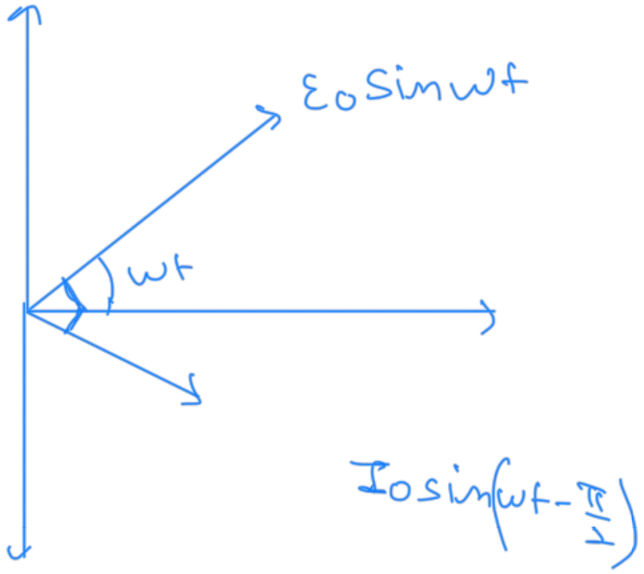
$$\frac{E_0}{R} \sin\omega t = I$$

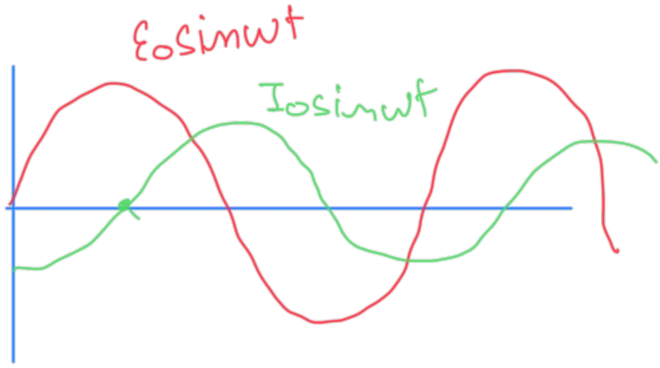
$$\boxed{I_0 \sin\omega t = I}$$



Pure Inductive circuit







$$V - \mathcal{E}_L = 0$$

$$V = \mathcal{E}_L$$

$$V = L \frac{dI}{dt}$$

$$\int \frac{V dt}{L} = \int dI$$

$$\int \frac{V_o \sin \omega t \, dt}{L} = \int dI$$

$$I = \frac{V_o}{L} \frac{-\cos \omega t}{\omega}$$

$$I = \frac{V_o}{\omega L} (-\cos \omega t)$$

$$I_o = \frac{V_o}{\omega L}$$

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

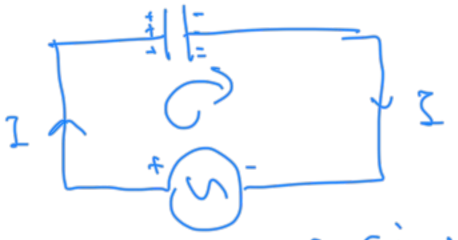
$$X_L = \omega L$$

↳ Reactance

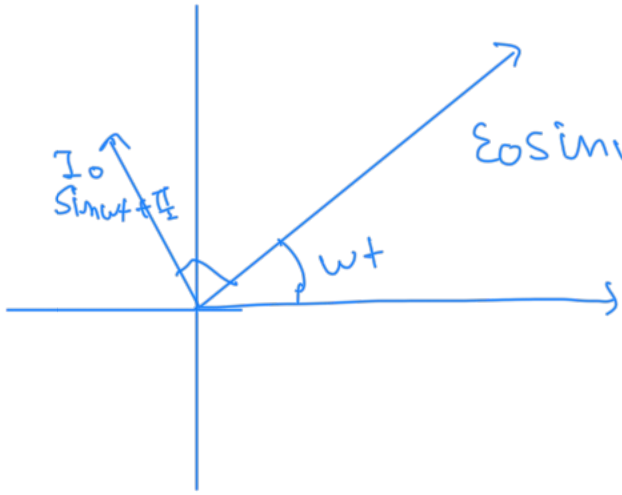
$$I = I_o \sin\left(\omega t - \frac{\pi}{2}\right)$$

Pure Capacitative circuit.

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



$\varepsilon_i = \varepsilon_0 \sin \omega t$



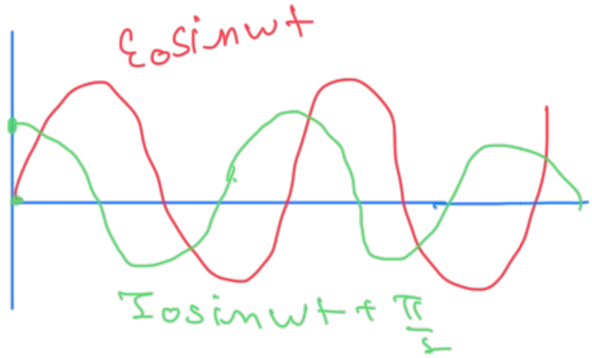
$\varepsilon_i - V = 0$

$$\frac{d\, \varepsilon_0 \sin \omega t}{dt} = \frac{d\frac{q}{C}}{dt}$$

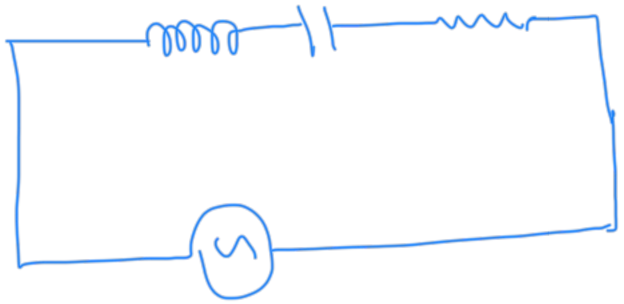
$$\varepsilon_0 \cos \omega t \cdot \omega = \frac{I}{C}$$

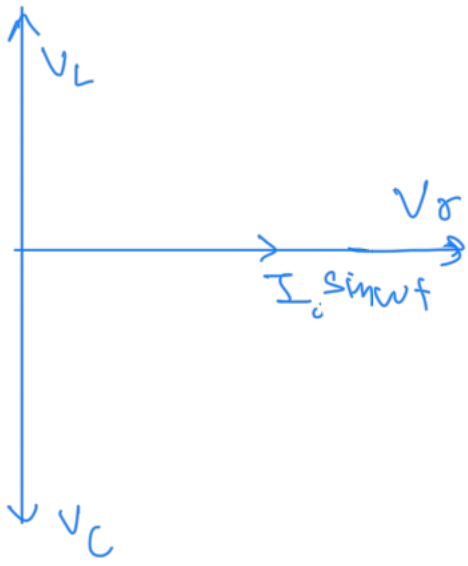
$$\frac{\varepsilon_0}{\frac{1}{\omega C}} \cos \omega t = I$$

$$I_0 \sin \omega t + \frac{\pi}{2} = I$$



Series LCR Circuit.





$v_r = iR \qquad V_r = V_0 \sin \omega t$

$v_L = i X_L \qquad V_L = V_0 \sin \omega t + \frac{\pi}{2}$

$v_C = i X_C \qquad V_C = V_0 \sin \omega t - \frac{\pi}{2}$

$$V_0^2 = V_r^2 + (V_L - V_C)^2$$

$$V_0^2 = i^2 R^2 + (i X_L - i X_C)^2$$

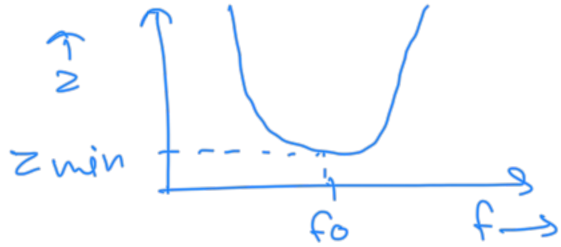
$$V_0^2 = i^2 (R^2 + (X_L - X_C)^2)$$

$$V_0 = i \sqrt{R^2 + (X_L - X_C)^2}$$

$$V_0 = i Z$$

Z = impedence

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



Derive condition for resonance.
Importance: ★★★★■ (4/5)

For resonance condition. the impedence is minim.

$X_L = X_C$

$$\boxed{Z = R}$$

$$(i_0)_{max} = \frac{V_0}{R}$$

$$X_L = X_C$$
$$\omega L = \frac{1}{\omega C}$$
$$\omega^2 = \frac{1}{LC}$$
$$\omega = \frac{1}{\sqrt{LC}}$$
$$2\pi f = \frac{1}{\sqrt{LC}}$$
$$f = \frac{1}{2\pi\sqrt{LC}}$$

Q factor = $\frac{\text{Resonant frequency}}{\text{Bandwidth}}$

$$= \frac{\frac{1}{\sqrt{LC}}}{\frac{R}{L}}$$
$$= \frac{L}{R}\frac{1}{\sqrt{LC}}$$

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

Derive power in AC circuit.
Importance: ★★★★■ (4/5)

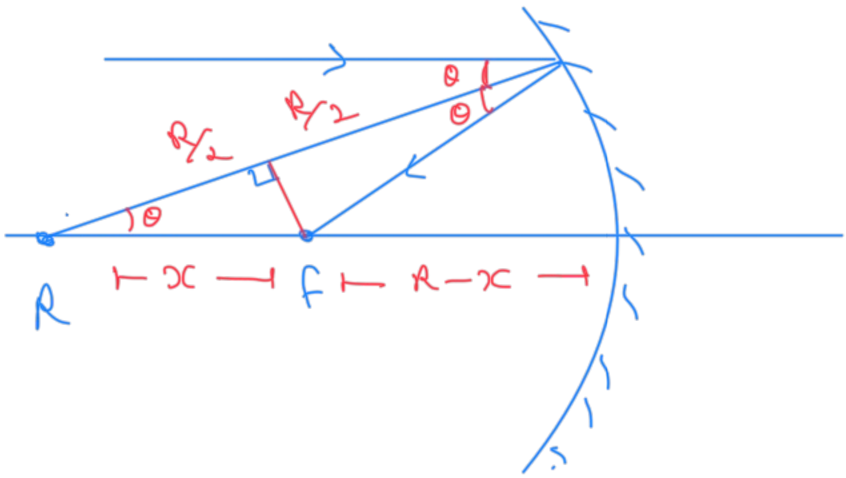
$$P = V I$$
$$P = V_0 \sin\omega t \quad I_0 \sin\omega t + \phi$$
$$P = V_0 I_0 (\sin\omega t + \sin\omega t + \phi)$$
$$= V_0 I_0 \frac{\cos\phi}{2} \text{ (for complete cycle)}$$
$$= \frac{V_0}{\sqrt{2}} \frac{I_0}{\sqrt{2}} \cos\phi$$
$$\boxed{P = V_{rms} I_{rms} \cos\phi}$$

Unit VI: Optics - Formula Page

$$\mu_2^1 = \frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{\nu_1}{\nu_2}$$

$$V_m = \frac{V_i + V_0}{2}$$

Proof of $R = \frac{f}{2}$



$$\cos\theta = \frac{R}{2x}$$

$$x = \frac{R}{2}\sec\theta$$

$$f = R - x$$

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

$$f = R\left(1 - \frac{\sec\theta}{2}\right)$$

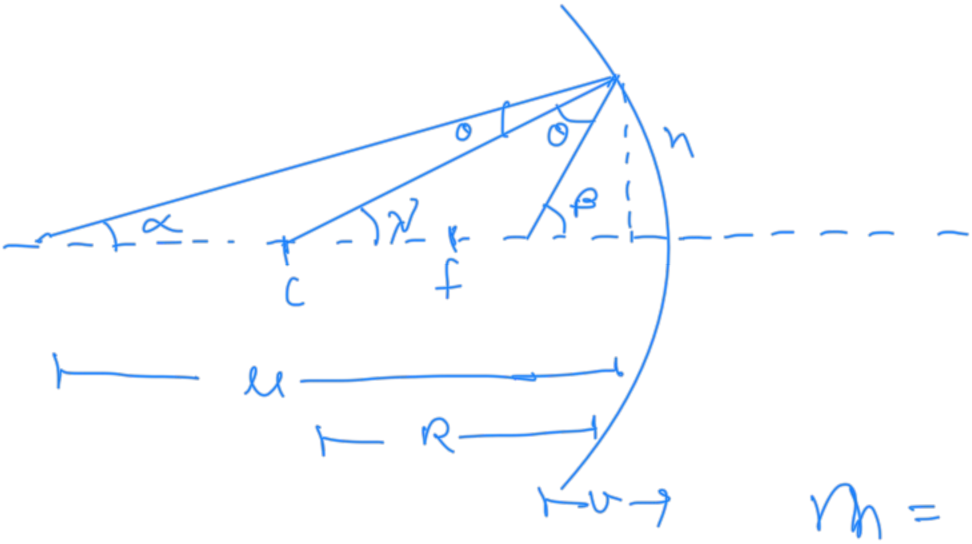
$\theta \simeq$ small

$\sec\theta \simeq 1$

$$f = \frac{R}{2}$$

Unit VI: Optics - Derivations

Derive mirror formula.
Importance: ★★★★★ (5/5)



$$\alpha = \tan\alpha = \frac{h}{u}$$

$$\beta = \tan\beta = \frac{h}{v}$$

$$\gamma = \tan\gamma = \frac{h}{R}$$

$$\alpha + \theta = \gamma$$

$$\gamma + \theta = \beta$$

$$\alpha + \beta - \gamma = \gamma$$

$$\alpha + \beta = 2\gamma$$

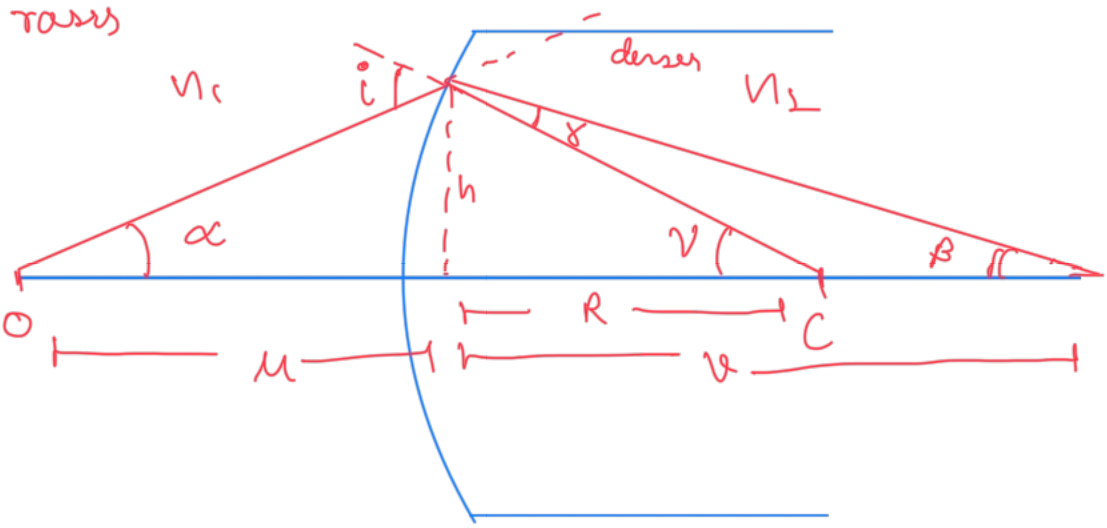
$$\frac{\cancel{h}}{u} + \frac{\cancel{h}}{v} = \frac{2\cancel{h}}{R}$$

$$\frac{1}{u} + \frac{1}{v} = \frac{\cancel{2}}{\cancel{2}f}$$

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$m = \frac{-v}{u} = \frac{h_i}{h_o}$$

Derive refraction at spherical surface.
Importance: ★★★★★ (5/5)



$$i = \alpha + \gamma \qquad \gamma = r + \beta$$

$$\alpha = \frac{h}{u} \qquad \gamma = \frac{h}{R}$$

$$\beta = \frac{h}{v}$$

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{i}{r} \qquad i \simeq r \simeq \sin i \simeq \sin r$$

$$\frac{i}{r} = \frac{\frac{h}{u} + \frac{h}{R}}{\frac{h}{R} - \frac{h}{v}} = \frac{n_2}{n_1}$$

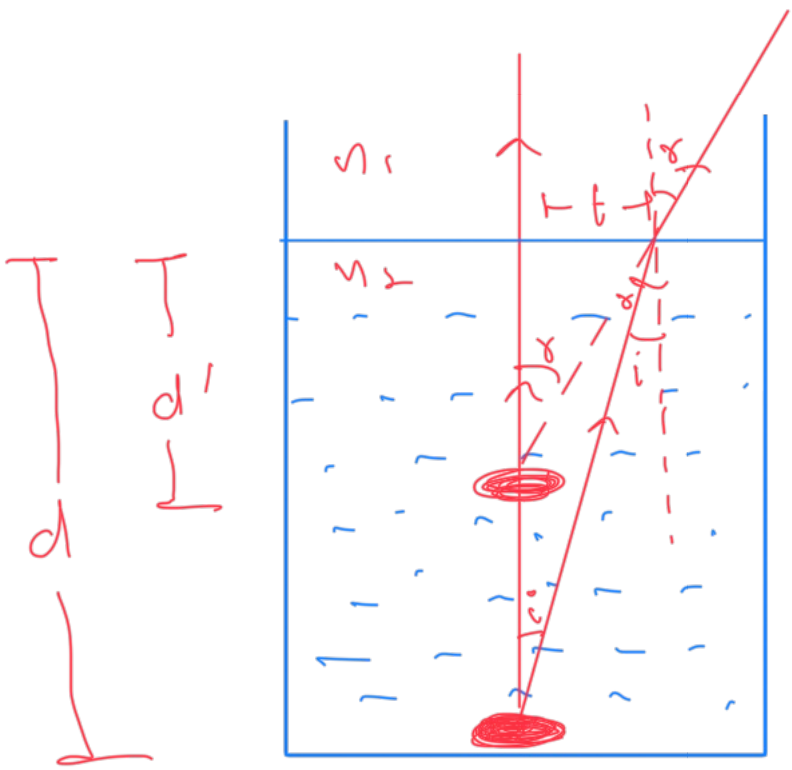
$$\frac{n_1}{-u} + \frac{n_1}{R} = \frac{n_2}{R} - \frac{n_2}{v}$$

$v = +v$
$u = -v$

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

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

Real depth and apparent depth



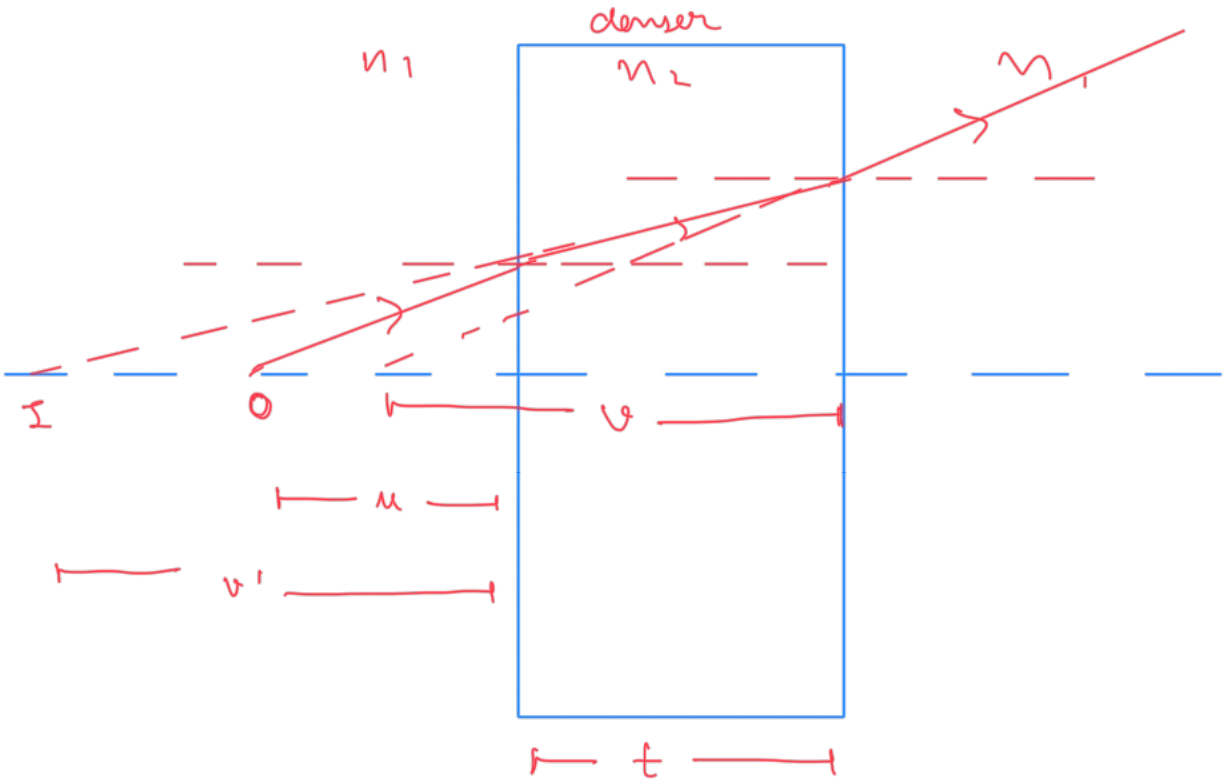
$$\sin i \, n_2 = \sin r \, n_1$$

$$\frac{n_2}{n_1} = \frac{r}{i} = \frac{\frac{t}{d'}}{\frac{t}{d}}$$

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

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

Shift (S) through a glass slab.



$$\frac{n_1}{n_2} = \frac{u}{v'} = \frac{1}{n_2}$$

$$v' = u\,\mu$$

$$\frac{n_2}{n_1} = \frac{v'+t}{v} = \mu$$

$$\frac{v'+t}{\mu} = v$$

$$\frac{u\cancel{\mu}}{\cancel{\mu}} + \frac{t}{\mu} = v$$

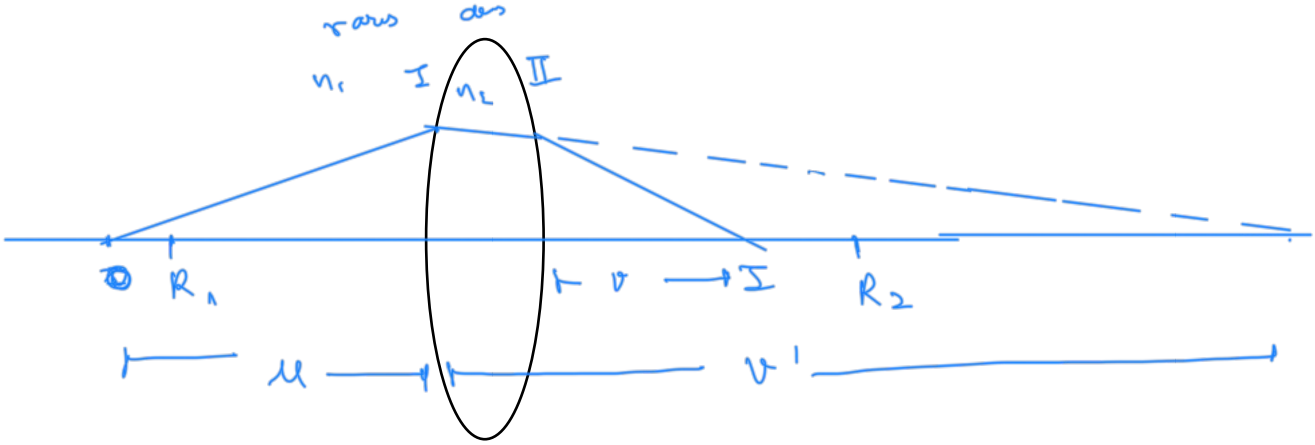
$$u + \frac{t}{\mu} = v$$

$$S = u + t - v$$

$$S = \cancel{u} + t - \cancel{u} - \frac{t}{\mu}$$

$$S = t\left(1 - \frac{1}{\mu}\right)$$

Derive lens maker!s formula.
Importance: ★★★★★ (5/5)



for surface I

$$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \quad \text{--- (i)}$$

for surface II

$$\frac{n_1}{v} - \frac{n_2}{v'} = \frac{n_1 - n_2}{R_2} \quad \text{--- (ii)}$$

add (i) & (ii)

$$\cancel{\frac{n_2}{v'}} - \frac{n_1}{u} + \frac{n_1}{v} - \cancel{\frac{n_2}{v'}} = \frac{n_2 - n_1}{R_1} + \frac{n_1 - n_2}{R_2}$$

$$\frac{n_1}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} + \frac{n_1 - n_2}{R_2}$$

$$n_1\left(\frac{1}{v} - \frac{1}{u}\right) = n_2 - n_1 \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

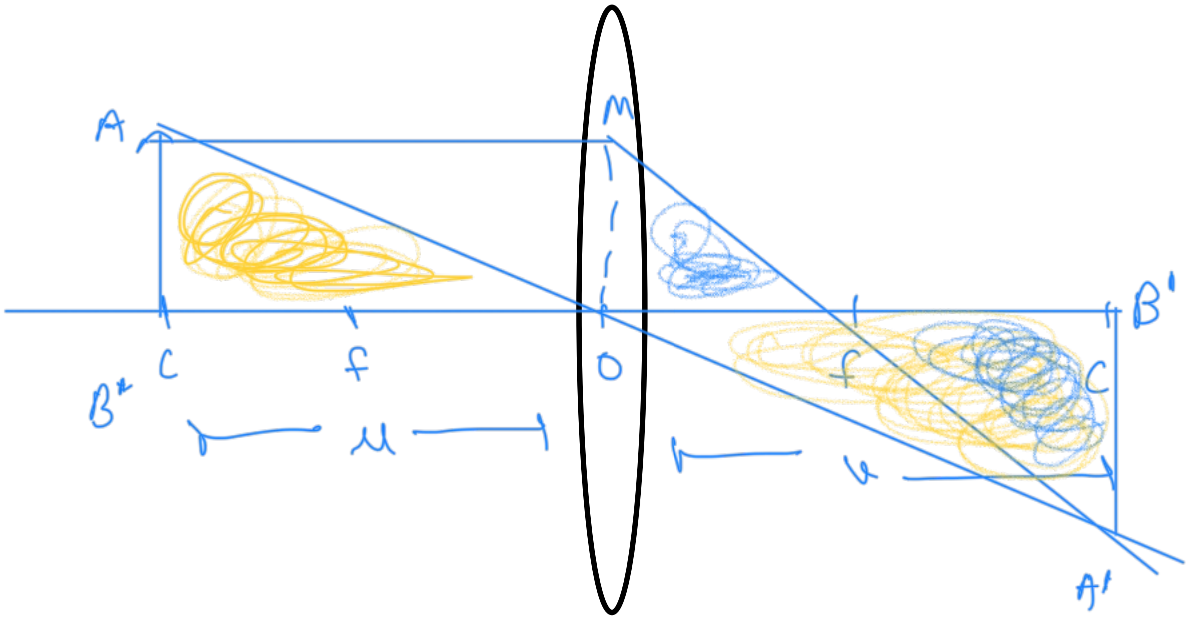
If object is at infinity

$u = \infty \qquad v = f$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} - \frac{1}{\infty} = \frac{1}{f}$$

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Thin lens formula.



$$\frac{AB}{A'B'} = \frac{BO}{B'O} \qquad ABO \sim A'B'O$$

$$\frac{A'B'}{MO} = \frac{B'F}{FO} \qquad \Delta A'B'F \sim MOF$$

$$\frac{A'B'}{AB} = \frac{B'F}{FO} \qquad MO = AB$$

$$\frac{BO}{B'O} = \frac{FO}{B'F}$$

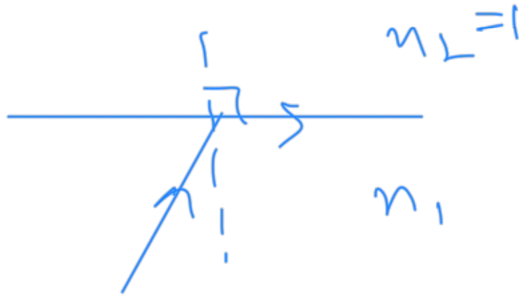
$$\frac{-u}{v} = \frac{f}{v-f}$$

$$\frac{v}{-u} = \frac{v}{f} - 1$$

$$\frac{1}{-u} = \frac{1}{f} - \frac{1}{v}$$

$$\boxed{\frac{1}{v} - \frac{1}{u} = \frac{1}{f}}$$

Critical angle



$r = 90^\circ$

$\sin i \, n_1 = \sin r \, n_2$

$\sin i \, n_1 = 1$

$\sin i = \frac{1}{n_1}$

$\sin C = \frac{1}{n}$

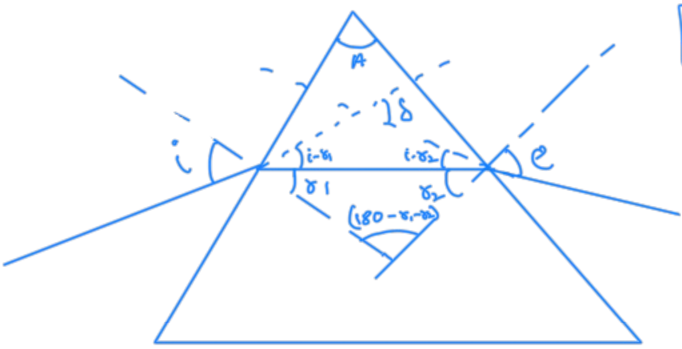
$$\delta = i - r_1 + e - r_2$$
$$\delta = i + e - r_1 - r_2$$
$$\delta = i + e - (r_1 + r_2)$$

Derive deviation by prism.
Importance: ★★★★■ (4/5)

$$360^\circ = \cancel{90+90} + A + \cancel{180} - (r_1 + r_2)$$

$$\boxed{A = r_1 + r_2}$$

$$\boxed{\delta = i + e - A}$$



$\delta_{min} \Rightarrow i = e$ $\quad r_1 = r_2$

$\delta_{min} = 2i + A$ $\quad A = r2$

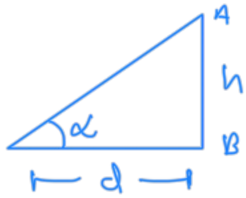
$r = \frac{A}{2}$

$$\boxed{\frac{\sin \frac{\delta_{min} - A}{2}}{\sin \frac{A}{2}} = \mu}$$

Derive magnifying power of microscope.
Importance: ★★★★■ (4/5)

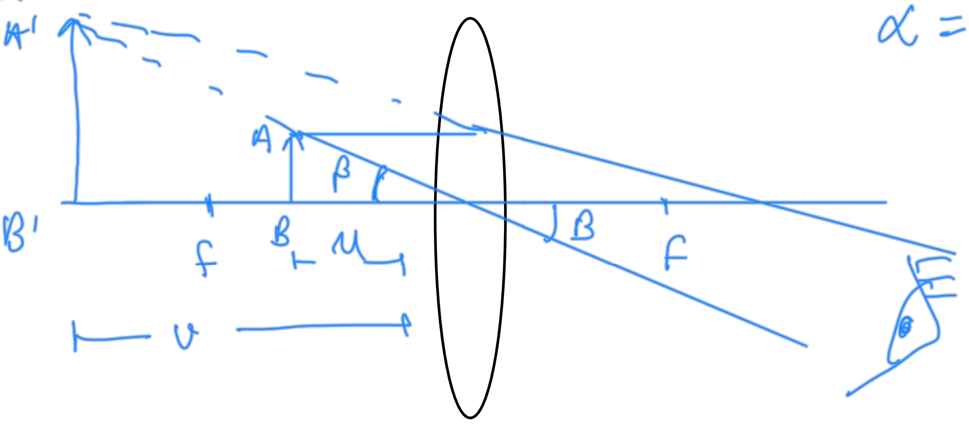
Simple Microscope

M = Magnifying power $= \frac{\beta}{\alpha} \rightarrow$



$\alpha = \frac{h}{d}$

$\alpha = \frac{h}{d}$



$$\beta = \frac{h}{u}$$

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

at $v = d$

$$M = \frac{\frac{\cancel{h}}{u}}{\frac{\cancel{h}}{d}} = \frac{d}{u}$$

$$\frac{1}{f} - \frac{1}{d} = +\frac{1}{u}$$

$$+\frac{1}{u} = \frac{1}{d} + \frac{1}{f}$$

$$m = d\left(\frac{1}{d} + \frac{1}{f}\right) = 1 + \frac{d}{f}$$

for max magnification

For relaxed eyes :→

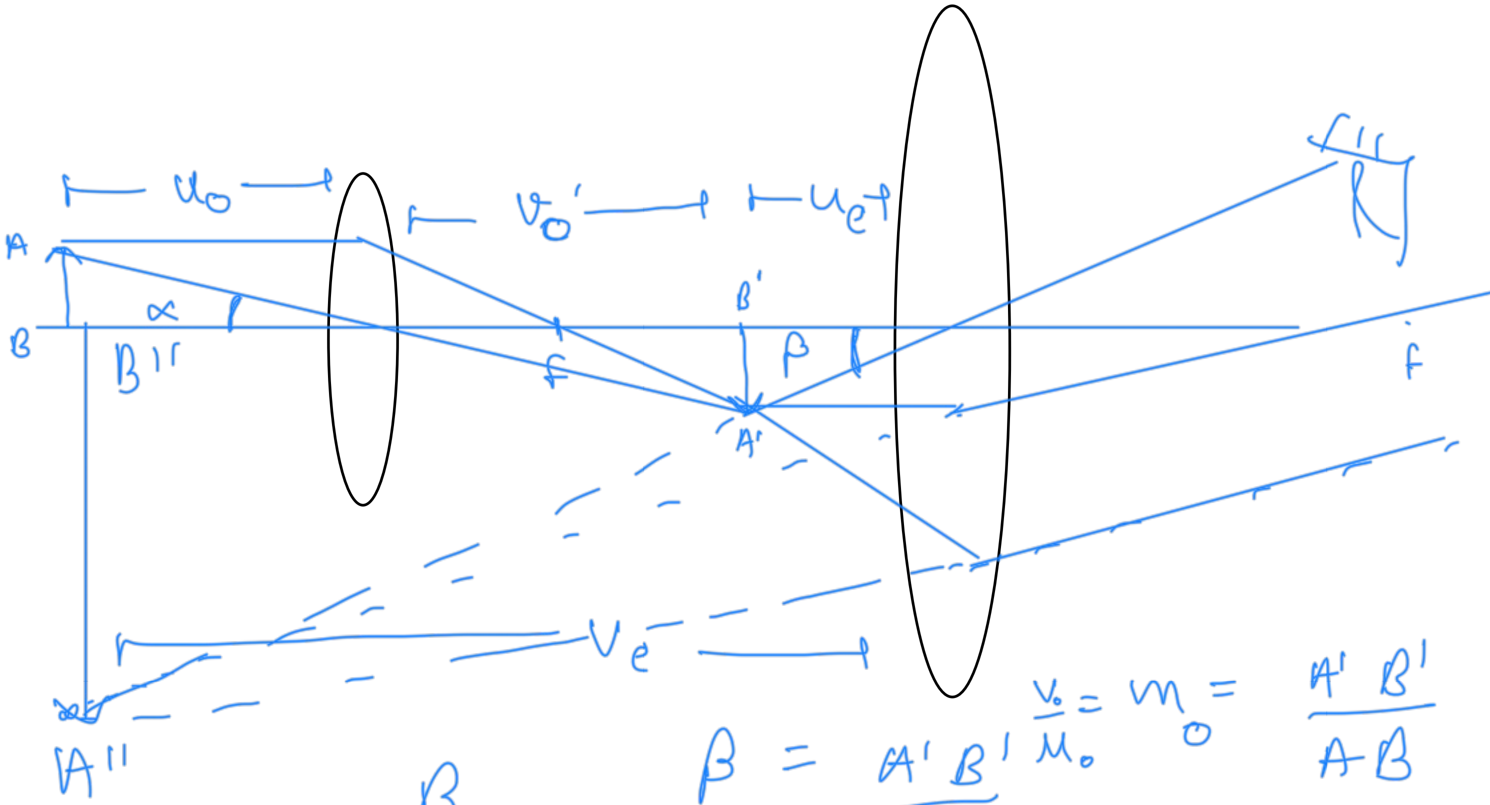
$$v = \infty$$

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{f} = \frac{1}{\infty} + \frac{1}{+u} = \frac{1}{u}$$

$$\boxed{m = \frac{d}{f}}$$

Complex Microscope.



$$\frac{v_o}{u_o} = m_o = \frac{A'B'}{AB}$$

$$\beta = \frac{A'B'}{u_e}$$

$$M = \frac{\beta}{\alpha}$$

$$\beta = \frac{AB}{u_e}\,\frac{m_o}{\alpha} \qquad \alpha = \frac{AB}{d}$$

$$M = m_o \cdot m_e$$

$$M = \frac{\cancel{AB}}{u_e}\,\frac{m_o}{\cancel{AB}} \cdot d$$

Max magnification

$$v = d$$

$$M = \frac{v_o}{u_o}\,\frac{d}{u_e}$$

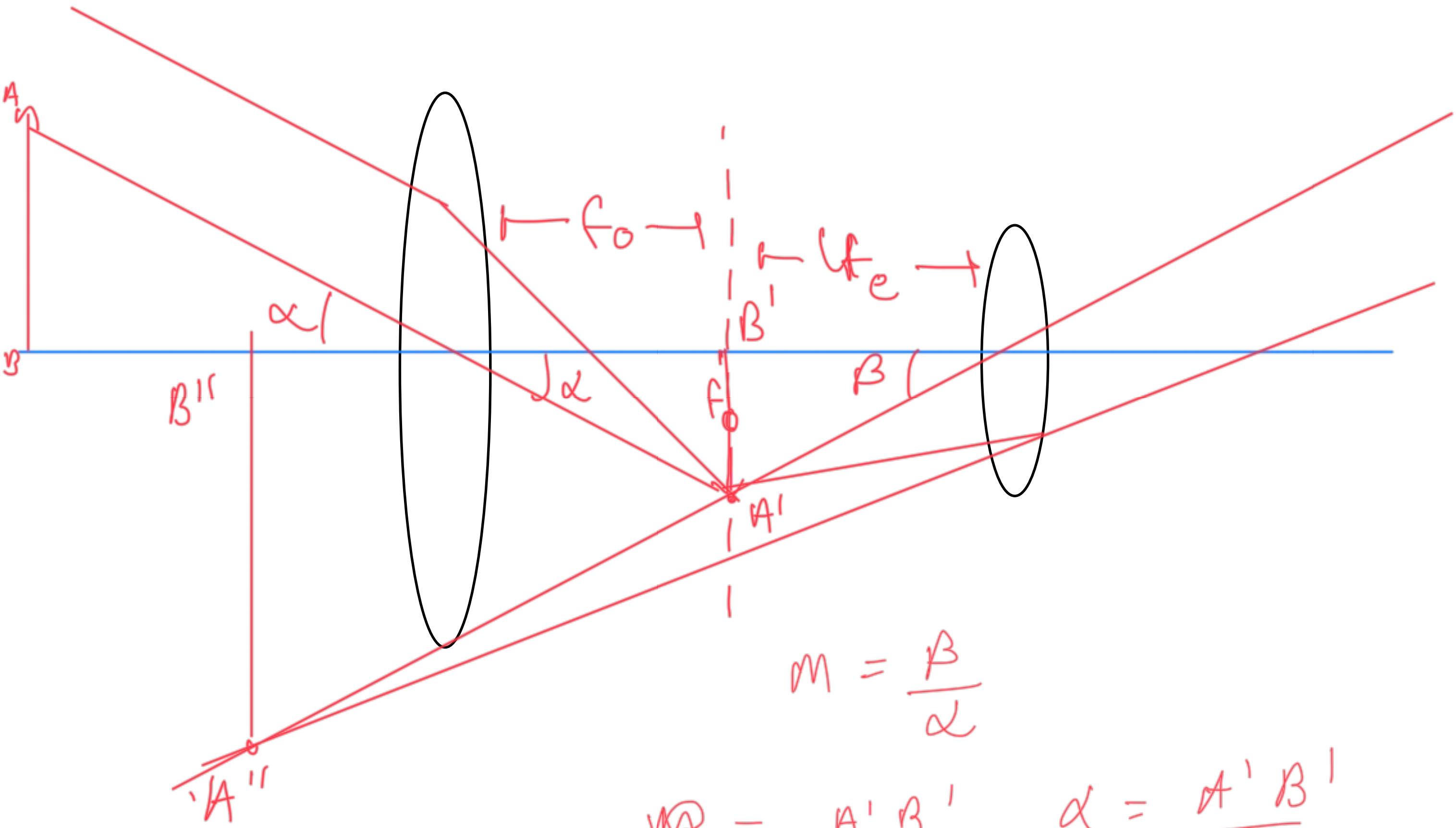
$$M = m_o \cdot \frac{d}{u_e}$$

$$\boxed{m = \frac{v_o}{u_o}\left(1 + \frac{d}{f_e}\right)}$$

Relaxed eyes

$$\boxed{M = \frac{v_o}{u_o}\frac{d}{f_e}}$$

Derive magnifying power of telescope.
Importance: ★★★★■ (4/5)



$$m = \frac{\beta}{\alpha}$$

$$\beta = \frac{A'B'}{u_e} \qquad \alpha = \frac{A'B'}{f_o}$$

$$\boxed{m = \frac{f_o}{u_e}}$$

for relaxed eyes

$$v_e = \infty \qquad \frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{-u_e}$$

$$\frac{1}{f_e} = \frac{1}{u_e}$$

$$\boxed{m = \frac{f_o}{f_e}}$$

For max magnification

$$d = v$$

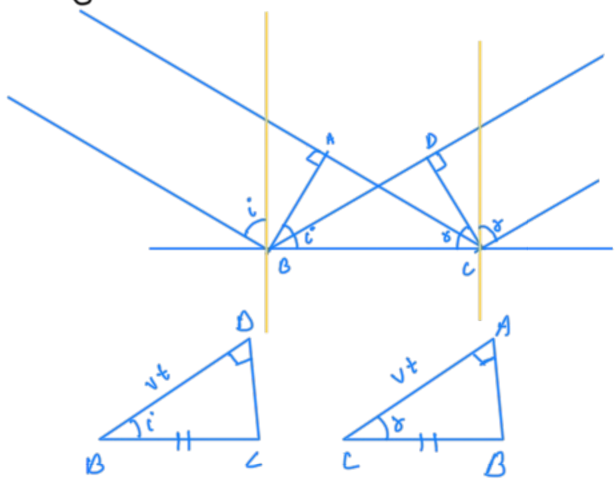
$$\frac{1}{+f_e} = \frac{1}{-d} - \frac{1}{-u}$$

$$\frac{1}{f_e} + \frac{1}{d} = \frac{1}{u}$$

$$m = f_o\left(\frac{1}{f_e} + \frac{1}{d}\right)$$

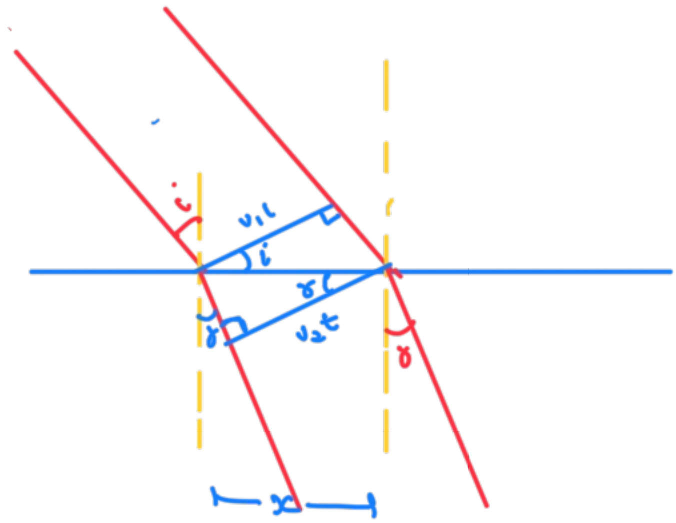
Wave Optics

Proof of Reflection



$\boxed{i = r}$ By SSS

Proof of Refraction



$$\sin i = \frac{v_1 t}{x}$$

$$\sin r = \frac{v_2 t}{x}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$$

Hence this is snells law.

Unit VII: Dual Nature - Formula Page

Unit VII: Dual Nature - Derivations

Derive Einstein!s photoelectric equation.
Importance: ★★★★★ (5/5)

$$E = \phi + \frac{1}{2}mv^2max$$

$$h\nu = \phi + KE$$

$$h\nu = h\nu_0 + KE$$

$$KE = h\nu - h\nu_0$$

Derive de Broglie wavelength.
Importance: ★★★★★ (5/5)

$$\lambda = \frac{h}{p}$$

Unit VIII: Atoms and Nuclei - Formula Page

Unit VIII: Atoms and Nuclei - Derivations

Derive radius of nth orbit in Bohr!s model.
Importance: ★★★★★ (5/5)

Derive velocity of electron in nth orbit.
Importance: ★★★★■ (4/5)

Derive energy of electron in nth orbit.
Importance: ★★★★★ (5/5)

Derive radioactive decay law.
Importance: ★★★★★ (5/5)

Derive relation between half-life and decay constant.
Importance: ★★★★★ (5/5)

Derive mass-energy relation & binding energy.
Importance: ★★★★■ (4/5)