LIGHT

(A) Ray optics

1. Reflection
2. Refraction
3. Dispersion
4. Aberration
5. optical Instruments
6. Photometry

(B) WAVE OPTICS

1. Electromagnetic waves
2. Interference
3. Deffraction
4. Polarization

(यह Heat पर उत्सर्जित होता है)

"प्रकाश एक विकिरण ऊर्जा का भाग है जिसमें दृश्यता का गुण पाया जाता है।" अर्थात् यह मानव नेत्र में संवेदना उत्पन्न करता है जिससे हमें वस्तुएँ दिखाई पड़ती हैं।

its consisting different frequences and wave length of different colours, for energy

for All colours speed of light is equal in vacuum or in air (nearly equal)

> Light का Colour frequency के कारण होता है

VIBGYOR

(seven wave length in visible Light)

→ Increasing wave length

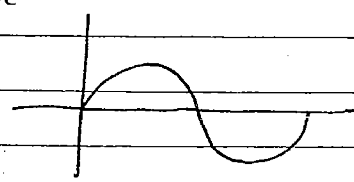
Properties of Light :

1- Properties of light as properties of E.M. waves. i.e, it's so that reflection, ~~or~~ refraction, Diffraction, polarization etc.

Nature of light :

① Wave nature (Transverse wave)

Like as sinusoidal

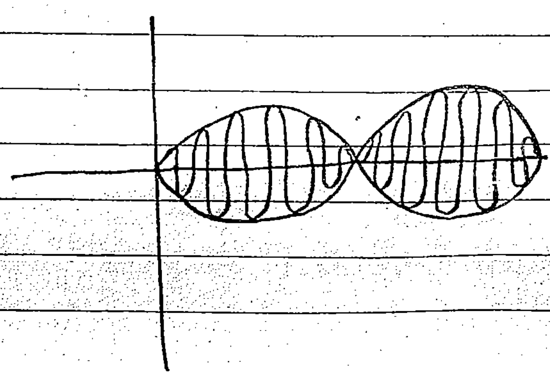


(ii) when light rays passing through vacuum its path represented as (followed as) straight line (High frequency)

(iii) Particle nature : wave packet के रूप में चलता है।

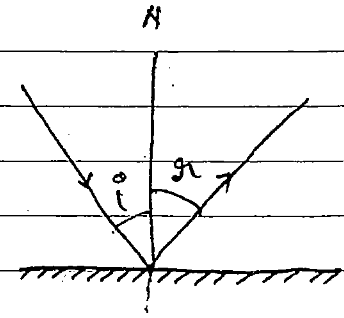
$V_g = \frac{d\omega}{dt}$ (group velocity), $V_{phase} = \frac{\omega}{k}$ (phase velocity / या wave velocity)

$V_{particle} = \frac{dy}{dt}$ (particle velocity)

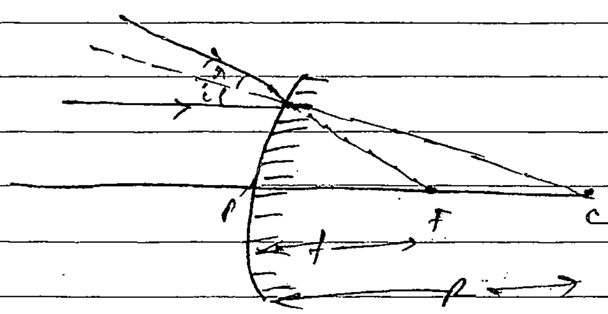


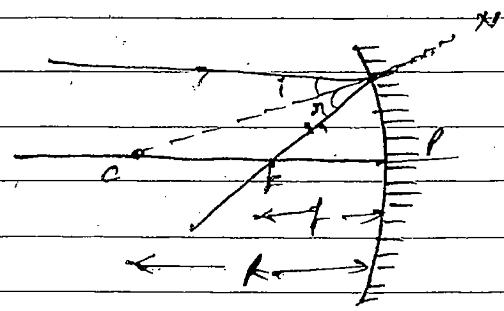
① Reflection (परावर्तन)

~~[illegible]~~



Daviation of light rays by on its pure reflecting surface is called reflection





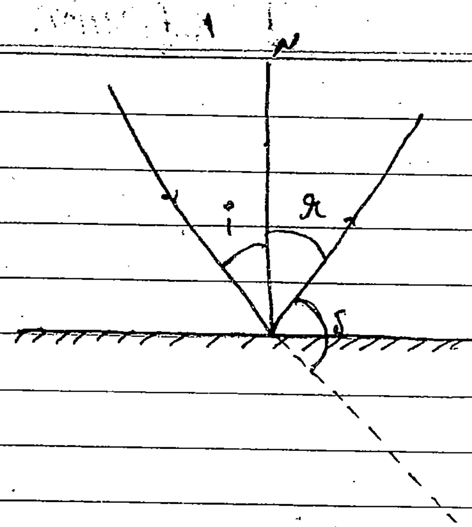
① Regular Reflection: $\angle i = \angle r$

(II) Iregular reflection: $\angle i \neq \angle r$

Law of reflection: ① Incident ray, N, reflected ray's, परावर्तक तल में स्थित होते हैं

(II) $\angle i = \angle r$

Reflection by plane mirror:



विचलन कोण:

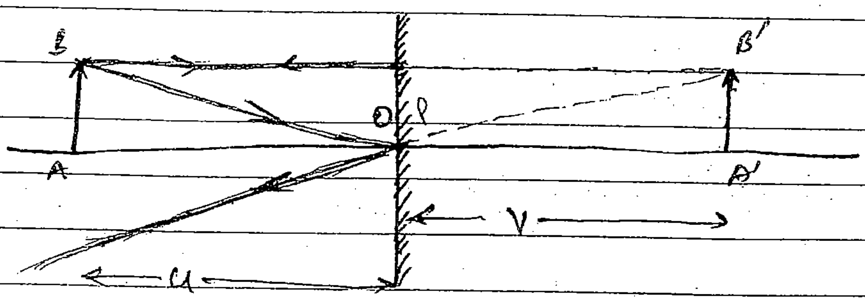
$$\delta + i + r = 180$$

$$\delta = 180 - (i + r)$$

$$\angle i = \angle r$$

$$\boxed{\delta = 180 - 2i = 180 - 2r}$$

Image formation by plane mirror:



$$\boxed{\begin{aligned} v &= +ve \\ u &= -ve \end{aligned}}$$

$$\boxed{v = |-u|}$$

Mirror formula: (u, v, f)

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

$\because v = -u$

focal length → $\frac{1}{f} = +\frac{1}{v} - \frac{1}{u} = 0$

$$f = \infty$$

Hence focal length of plane mirror is Infinity

Power of mirror $\because P = \frac{1}{f} = \frac{1}{\infty} = 0 (D)$

$$P = 0 \; D$$

Image formed by plane mirror is erect
सीधा, आभासी, वस्तु के बराबर दूरी पर तथा ~~वस्तु~~ दर्पण के पीछे प्राप्त होता है।

आवर्धन :

$$m = \frac{A'B'}{AB} = 1$$

(1) $m = \frac{A'B'}{AB} = 1$

(2) $f = \infty$

(3) $P = 0$

(4) $v = |-u|$

Speed of Image and speed of object:

by any mirror

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

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

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

Speed of Object

$$\boxed{\frac{du}{dt} = \frac{d}{dt}\left(\frac{vf}{v-f}\right)}$$

$$\frac{du}{dt} = \frac{(v-f)\frac{d}{dt}(vf) - vf\frac{d}{dt}(v-f)}{(v-f)^2}$$

$$= \frac{(v-f)f\frac{d}{dt}v - vf\left(\frac{dv}{dt}\right)}{(v-f)^2}$$

$$\frac{du}{dt} = \frac{dv}{dt}\frac{(vf - f^2 - vf)}{(v-f)^2}$$

$$\boxed{\frac{du}{dt} = \frac{-f^2\left(\frac{dv}{dt}\right)}{(v-f)^2}}$$

$$\boxed{\text{speed of object} = \frac{-f^2}{(v-f)^2} \times (\text{speed of Image})}$$

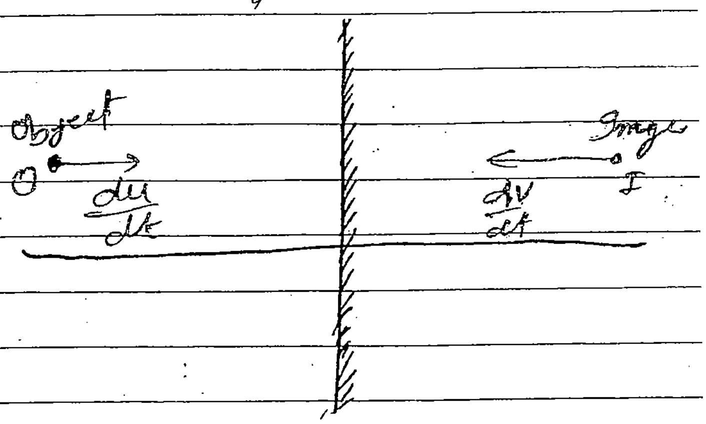
(*) Speed of Image and object by plane mirror: $f = \infty$

$\frac{du}{dt} = -\frac{dv}{dt}$ $\qquad \frac{f^2}{(v-f)^2} = 1$

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

$f = \infty$

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



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

$$\boxed{u = -v}$$

$$\boxed{\frac{du}{dt} = -\frac{dv}{dt}}$$

speed of object = -(Speed of Image)

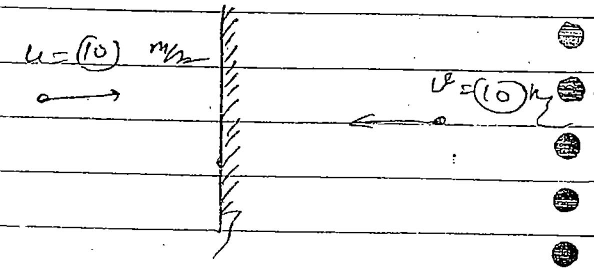
Que: एक व्यक्ति दर्पण के सामने 5 m/sec की चाल से गतिमान है। समतल दर्पण में उसके प्रतिबिम्ब की चाल उसे प्राप्त होगी।

Solⁿ: Relative speed = 2u (निरपेक्ष)

= 2×5

= 10 m/sec

(*) speed of observed by Moving mirror:

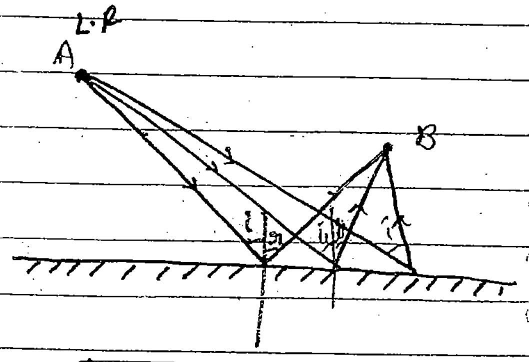


$$V_R = (v+u)$$

~~= 10 + 10 = 20 m/sec~~

प्रकाश का पथ:

(*) प्रकाश एक बिन्दु से दूसरे बिन्दु तक जाने में उस पथ से जाता है जहाँ से कम समय लेकर कम से कम दूरी तय करती है।



वह पथ $\boxed{\angle i = \angle r}$ होगा

$\boxed{i = r}$ ✓

$\boxed{i_1 \neq r_1 \quad i = 0}$ (x)

द्रव्यमान केन्द्र Centre of Mass and (Centriod)

द्रव्यमान केन्द्र: ↳ Centre of mass is a reference point where total mass of particle can be contientrated and motion of reference point alonge the St.line consider at motion of all particles of rigid body.

↳ किसी दृढ पिंड में द्रव्यमान का वितरण एक समान हो उस पिंड का द्रव्यमान केन्द्र तथा गुरुत्व केन्द्र एक ही बिन्दु पर स्थित होता है।

राशि : सदिश

द्रव्यमान केन्द्र की निर्भरता -

(I) द्रव्यमान के वितरण
(II) पिण्ड के आकार और आकृति
(III) position of refrence point (Co-ordinatsytem)

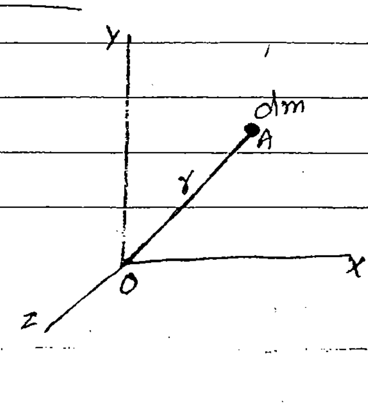
↳ यह वस्तु के Neature पर निर्भर नहीं करता है।
↳ यह internal forces पर निर्भर नहीं करता।

Read करता है:

- ↳ Position of centre of mass
- ↳ Velocity of centre of mass
- ↳ momentum " " "
- ↳ Accelaration " " "
- ↳ force on centre of mass.

① Position of Centre of mass: (i) Particle:

$$\bar{r} \text{ or } r_{cm} = \frac{1}{M}\int r\,dm$$



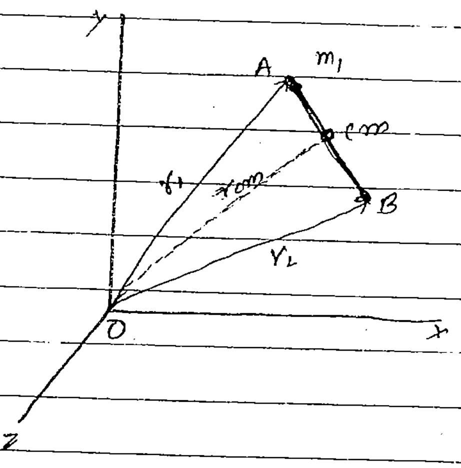
$$x_{cm} = \frac{1}{M}\int x\,dm$$

$$y_{cm} = \frac{1}{M}\int y\,dm$$

$$z_{cm} = \frac{1}{M}\int z\,dm$$

(ii) Position of centre of mass in two particle system :

$$r_{cm} = \frac{m_1 r_1 + m_2 r_2}{m_1 + m_2}$$



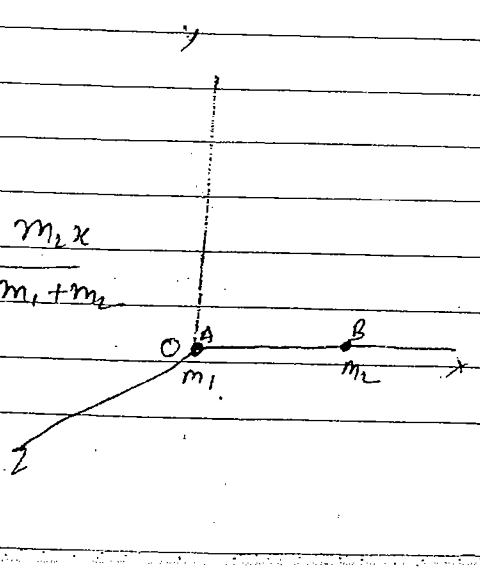
$$r_{cm} = \frac{\sum_{i=1}^{i=n} m_i r_i}{\sum_{i=1}^{i=n} m_i}$$

$n = 1, 2, 3 \ldots$

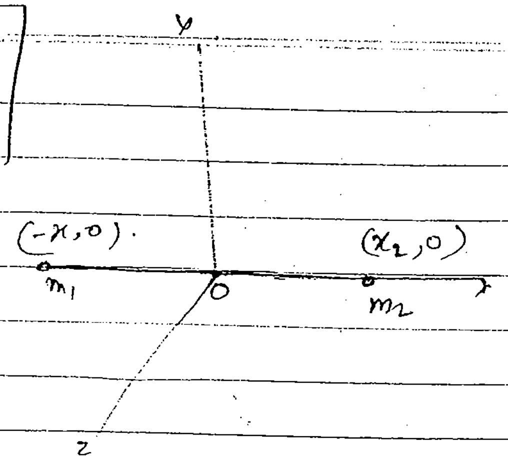
NOTE: (a)

$$x_{cm} = \frac{m_1 \times 0 + m_2 x}{m_1 + m_2} = \frac{m_2 x}{m_1 + m_2}$$

$$x_{cm} = \frac{m_2 x}{m_1 + m_2}$$



(b) $x_{cm} = \frac{m_1(-x_1) + m_2 x_2}{m_1 + m_2}$



$y_{cm} = 0$

$z_{cm} = 0$

m.c. position = $(x_{cm}, 0, 0)$

(13) Position of c.m of rigid body:

Let consider rigid body is consisting n particles and their masses simultaneously $m_1, m_2, m_3 --- m_n$ and there position, $r_1, r_2, r_3, --- r_n$

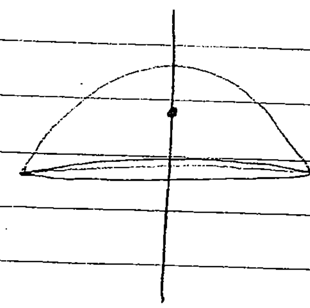
Then position of centre of mass

$$\bar{r} = \frac{m_1 r_1 + m_2 r_2 + m_3 r_3 + --- + m_n r_n}{m_1 + m_2 + m_3 + ---}$$

(14) Position of c.m for symmetrical distribution of any shape and size of rigid body:

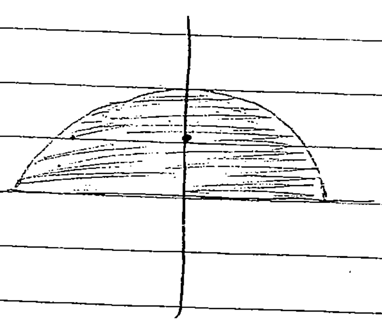
(i) वृत्त : केन्द्र बिन्दु पर

(ii) अर्द्ध Arc (खोखला आधा वृत्त)



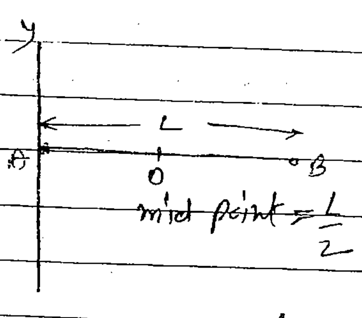
$y_{cm} = \frac{2R}{\pi}$

(iii) अर्द्ध वृत्त : (डिस्क) आधी :



$\bar{y} = \frac{4R}{3\pi}$

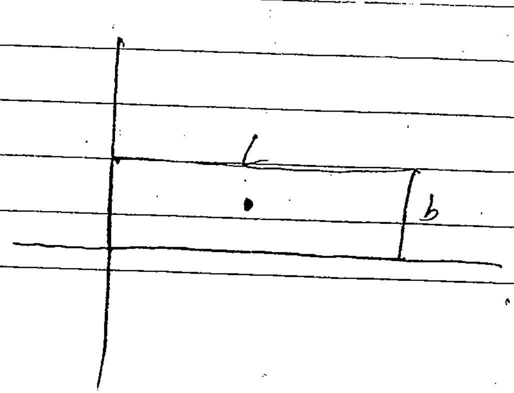
(iv) Thin wire : मध्य बिन्दु पर



$= \frac{L}{2}$

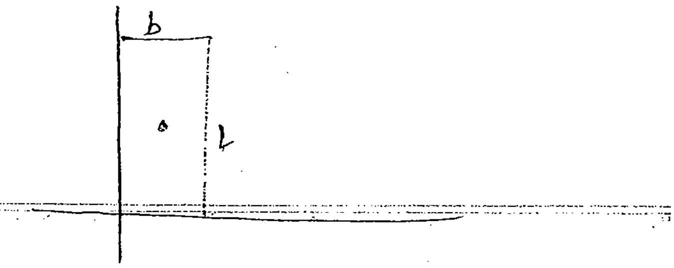
Let total mass = M

(v) आयत के लिए :

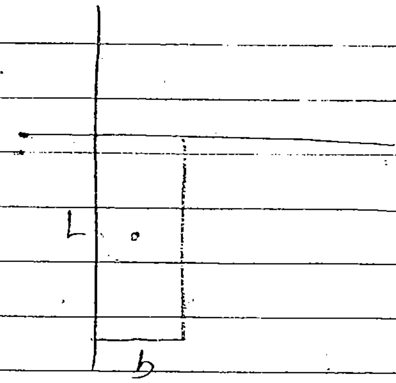


$r_{cm} = \left(\frac{L}{2}, \frac{b}{2}\right)$

$$r_{cm} = \left(\frac{b}{2}, \frac{L}{2}\right)$$



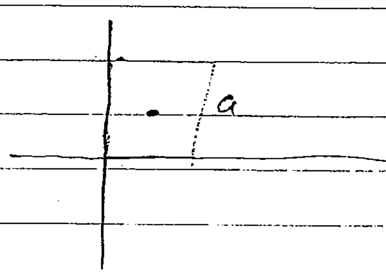
$$r_{cm} = \left(\frac{b}{2}, -\frac{L}{2}\right)$$



$$x_{cm} = \frac{b}{2}$$

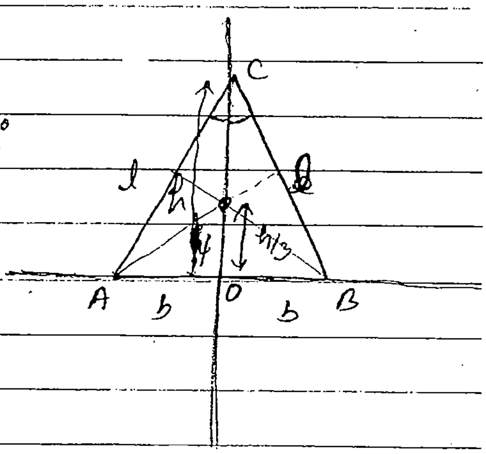
$$y_{cm} = -\frac{L}{2}$$

(vi) वर्ग का :



$$r_{cm} = \left(\frac{a}{2}, \frac{a}{2}\right)$$

(vii) समद्विबाहु Δ का तथा समबाहु Δ :



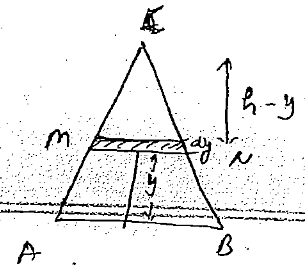
$OC = h$

$AB = 2b$

$AC = BC = l$

$$y_{cm} = \frac{h}{3}$$

Solve →



$\frac{CAB}{CMN}$

$$\frac{h}{h-y} = \frac{AB}{MN}$$

यदि समरूप हैं तो $AB = d$ and $MN = x$

$$\frac{h}{h-y} = \frac{d}{x}$$

$$x = \frac{d(h-y)}{h} \quad \text{— (1)}$$

we know

$$y_{cm} = \frac{1}{m}\int y \, dx$$

$$y_{cm} = \frac{1}{A\sigma}\int y \, dA \cdot \sigma$$

$$y_{cm} = \frac{1}{A}\int y \, dA$$

$$A \, y_{cm} = \int y \, dA$$

y Solve करने पर

$$\frac{h}{2} = y\int_0^h \frac{h-y}{h} \, dy$$

$$y_{cm} = \frac{h}{3}$$

$$\frac{1}{2} \text{ Base} \times \text{height} \times y_{cm} = \int y \, dA$$

let Base b

$$\frac{1}{2} b \times h = \int_0^h y \, x \, dy = \int_0^h \frac{y \cdot d(h-y)}{h} \cdot dy$$

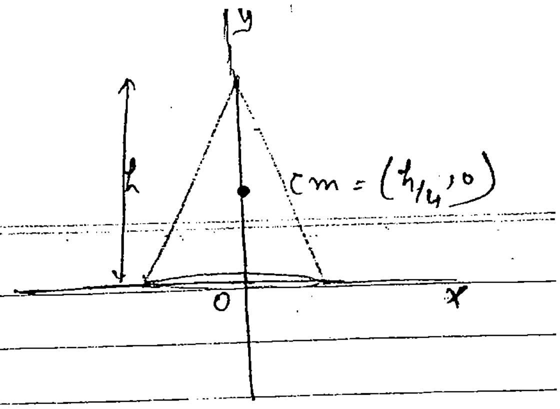
(1) से x का मान रखने पर

तो $b = d$

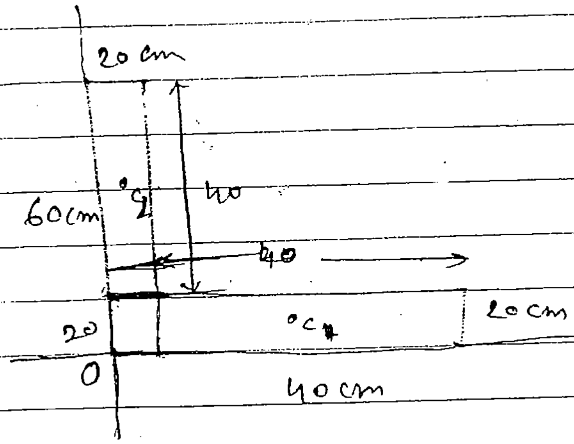
$$\frac{h}{2} = \int_0^h \frac{y(h-y)}{h} \, dy$$

2/2

(VIII) $y_{cm} = \left(\frac{h}{4}, 0\right)$



(IX) Centre of mass:



$A\bar{r} = \int r\,dA$

$\bar{r} = \frac{1}{A}\int r\,dA$

$$x_{cm} = \frac{x_1A_1 + x_2A_2}{A_1+A_2} \quad \text{—— (I)}$$

$A = A_1 + A_2$

$$y_{cm} = \frac{y_1A_1 + y_2A_2}{A_1+A_2} \quad \text{—— (II)}$$

Centroid $r_{cm} = (x_{cm}, y_{cm})$

(I) $A_1 = 20\times 40 = 800\ cm^2$

$(x_1, y_1) = (20, 10)$

(II) $A_2 = 40\times 20 = 800\ cm^2$

$x_2 y_2 = (10, 30)$

$r_{cm} = (15, 20)$

Put eqn (I) and (II)

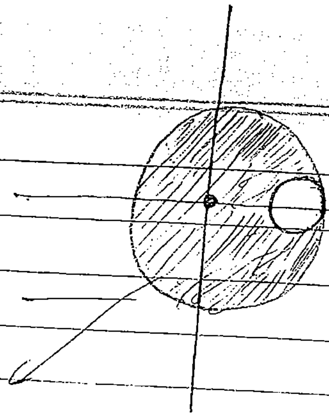
$$x_{cm} = \frac{20\times 800 + 800\times 10}{1600} = 15$$

= [illegible]

छोटे को cut करने पर

Ques: $D_b = 100 cm$

$D_s = 80 cm$



(i) बड़े का Area:

$$A_1 = 4\pi R_1^2$$

$$x_1, y_1 = (0, 0)$$

(ii) छोटे में

$$A_2 = \pi R_2^2$$

$$x_2 = R_1 - R_2 =$$

$$y_2 = 0$$

→ -ve क्योंकि इसे काट दिया गया है

$$x_{cm} = \frac{x_1 A_1 - x_2 A_2}{A_1 - A_2} = 0 \times 4\pi R_1^2 - R_1 - R_2$$

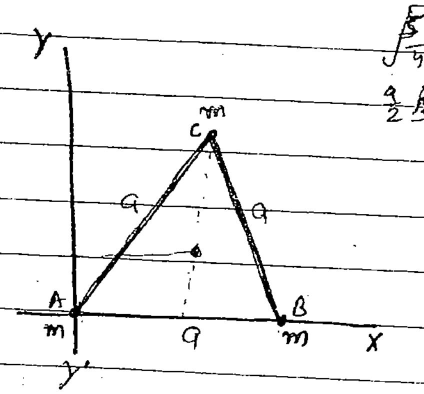
$$y_{cm} = 0$$

$\frac{a^2}{4} + a^2$

$\sqrt{\frac{5a^2}{4}}$

$\frac{a}{2}\sqrt{5}$

Example: find position of centre of mass about yy' axis.



हमें ज्ञात करना है (x_{cm}, y_{cm}, z_{cm})

m_A (x_1, y_1) $(0,0)$ m_B (x_2, y_2) $(a, 0)$ m_C (x_3, y_3) $\left(\frac{a}{2}, \frac{a\sqrt{3}}{2}\right)$

$$x_{cm} = \frac{m_1 x_1 + m_2 x_2 + m_3 x_3}{m_1 + m_2 + m_3}$$

$$x_{cm} = \frac{m}{3m}\left[0 + a + \frac{a}{2}\right] = \frac{3a}{6} = \frac{a}{2}$$

Magnet

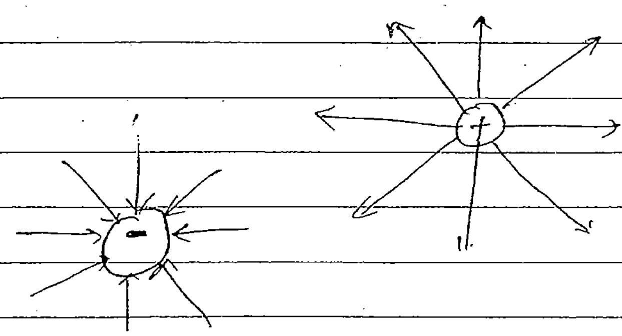
(I) Electromagnetism
(II) magnetic effect of current
(III) magnetic Induction
(IV) magnetic meterials and its properties
(V) (A.C)

Electromagnetism

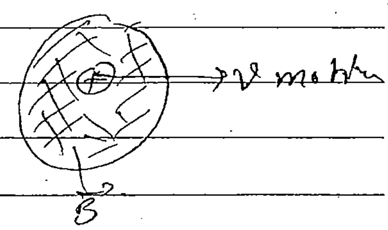
Electric charges at Rest Position produces only Electric field arround the space.

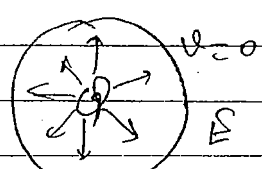
$\vec{\nabla} \times \vec{A} = 0$

$Div \cdot \vec{H} = 0$

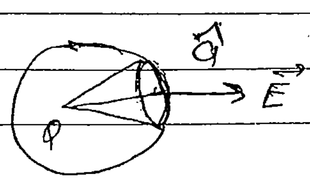


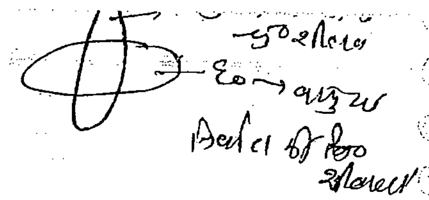
(II) A frelly moving charge produces magnetic field around the space





normal to the gaussian surface (outword or inword)

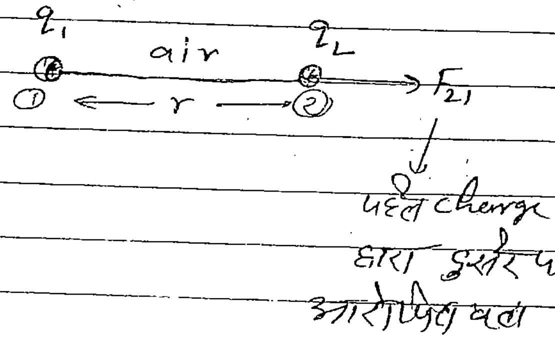




⇒ Electro magnetism is the properties of freely moving charge.

⇒ E, $\mathcal{E}$, V, U and Dipole } इस chapter में पढ़ा है इनका अध्ययन freely moving charge में पढ़ेंगे

② Electro Magnetic force in two freely moving charge where sepration is constant.



(i) Rest में → electro static force

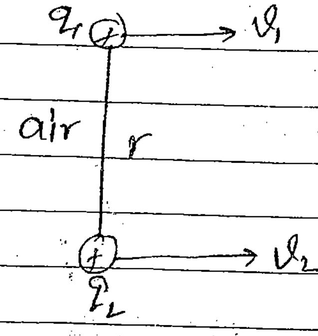
$$F_E = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$$

पहला charge द्वारा दूसरे पर आरोपित बल

$$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1q_2}{|\vec{r}_{12}^{\,3}|}\vec{r}_{12}$$

$$\frac{1}{4\pi\varepsilon_0} = 9\times10^9$$

(ii) in Motion → magnetic force

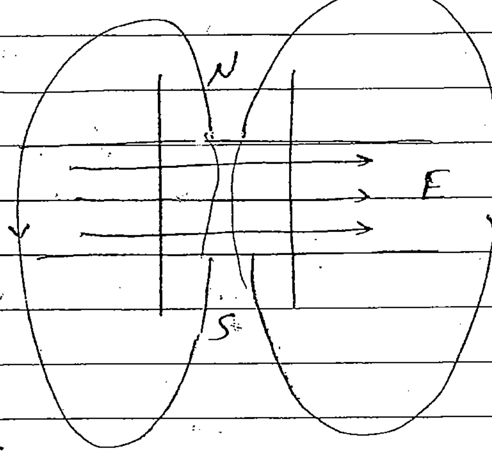


F_B.

$$F_B = \frac{\mu_0}{4\pi}\cdot\frac{q_1v_1q_2v_2}{r^2}$$

$$\left\{ \frac{\mu_0}{4\pi} = 10^{-7} \left(\frac{N}{amp^2}\right) \text{ or } \left(\frac{watt}{amp.\ metre}\right) \right.$$

~~A freely charge moves electric field~~



Electrostatic and magnetic force on a moving charge:

Let a freely charge perttel moves alonge the direction of oniform eleectric field and normal to the direction of magnetic field, then Net force on moving charg particle.

$$\vec{F}_{Net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots$$

Scalar form

$$F_{Net} = qE + qvB$$

$$F_{Net} = q(E + vB)$$

in vector form

$$\vec{F}_{Net} = q\left[\vec{E} + (\vec{v} \times \vec{B})\right] \quad (N)$$

v = m/sec

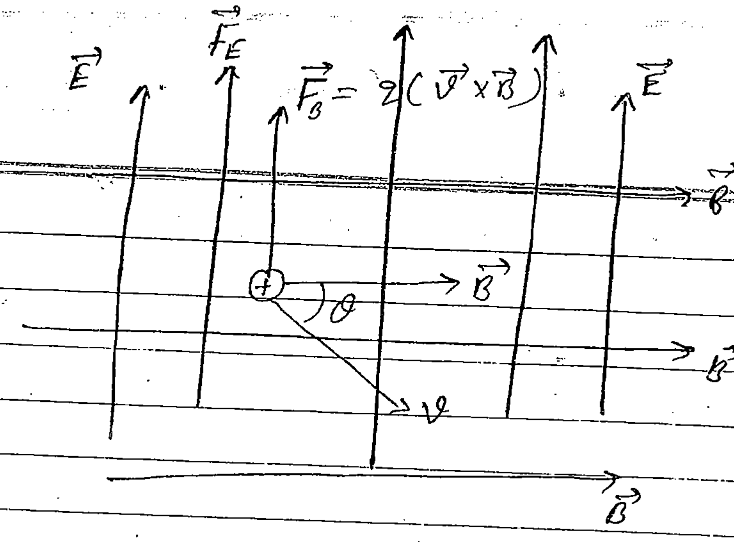
B = Tesla or $\left(\frac{N}{amp.\ metre}\right)$

E = N/C or V/m

q = C

(i) $\vec{F}_B \perp v$ and $\vec{B}$

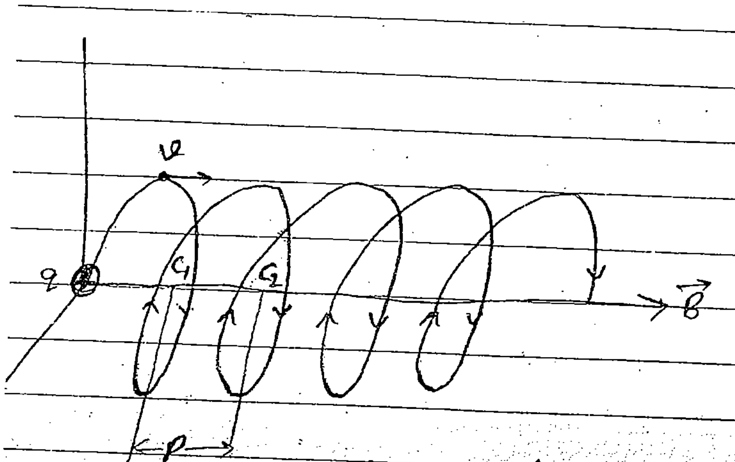
(ii) $\vec{F}_B \parallel \vec{E}$ or $\vec{F}_E$ or $(\vec{v} \times \vec{B})$

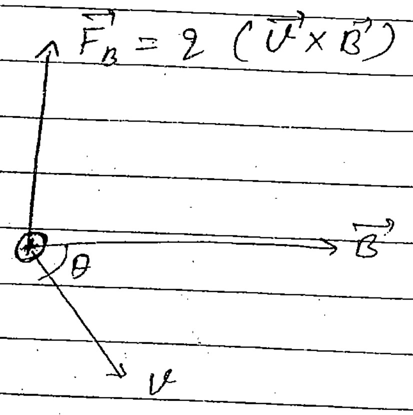


$$\vec{F}_{Net} = \vec{F}_E + \vec{F}_B$$

NOTE: इसका path ~~elliptical~~ helix होगा जब यह electric force and magnetic force से गति कर रहा हो

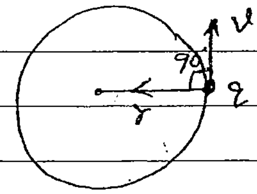
Magnetic force and Lorentz force of charge particle an Uniform magnetic field:





P → Pitch = Linear displacement of charge particle along magnetic field direction along complete one revolution on circular path

(1) if $\theta = 90$: i.e charge particle moves normal to the magnetic field direction then path of motion is circular.



$F_c = F_B$

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

त्रिज्या:

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

आवर्तकाल:

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

$$v = r\omega$$

(Charge particle close path पर चलता है तो उसके current effect उत्पन्न होता है)

current effect due to moving charge in a Close path:

(1) Let an electron from Hydrogen atom revolving around the neucleus of hydrogen atom, radius of orbit is r and no. of revolution per Time/second is $= \left(\frac{n}{t}\right)$ n = velocity of electron

$$i = \frac{n}{t} \cdot e$$

$$i = \frac{n}{t} \cdot e = fe$$

$$\omega = 2\pi \frac{n}{t}$$

$$\omega = 2\pi f$$

$v = r\omega$

$$i = \frac{\omega}{2\pi} \cdot e = \frac{ev}{2\pi r}$$

→ ① एक atom के लिए

Magnetic dipol effect of in circular loop:

$$M = niA$$

n = no. of revolution

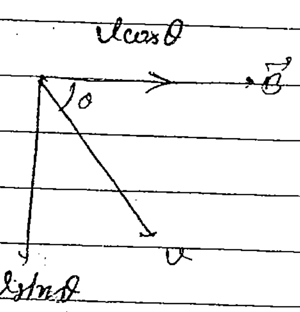
② if a charge particle moves at certain angle with magnetic field:

Path: ~~ellipes~~ helix

Pitich:

$P = v\cos\theta \times T$

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



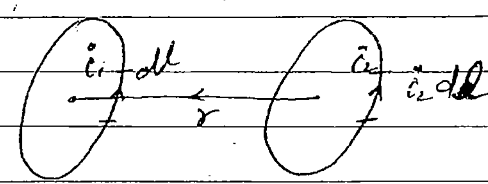
P → Pitch ⇒ Linear displacement of charge particle along magnetic field direction along complete on revolution on circular path.

⇒ वृत्ताकार पथ पर गति करते समय ion, वै० क्षेत्र तथा चुम्बकीय क्षेत्र उत्पन्न करता है

⇒ पृथ्वी के ionospare में उपस्थित ions के कारण केवल चु० क्षेत्र उत्पन्न होता है।

Electro magnetic force b/w two current loop due to elementry current $i_1 dl$ and $i_2 dl$:

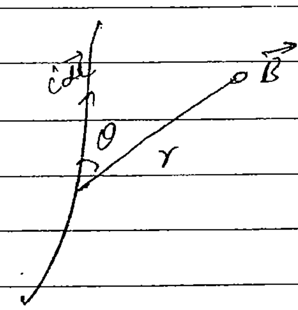
$$F_B = \frac{\mu_0}{4\pi} \frac{i_1 dl \, i_2 dl}{r^2}$$



$$\boxed{\vec{F}_B = \frac{\mu_0}{4\pi} \frac{i_1 i_2 \, d\vec{l} \times (d\vec{l} \times \vec{r})}{|\vec{r}|^3}}$$

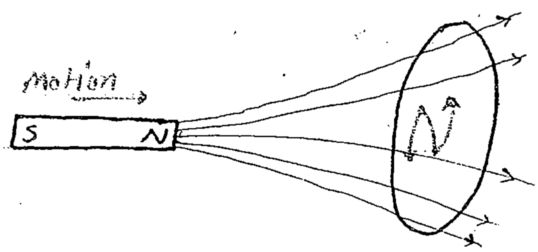
⊛ Lorentz force deu to current element

$$\boxed{F_B = iB l \sin\theta}$$



Lenz Low: Direction of Induce current in coil represnted as its always opposess. becouse of it produced.

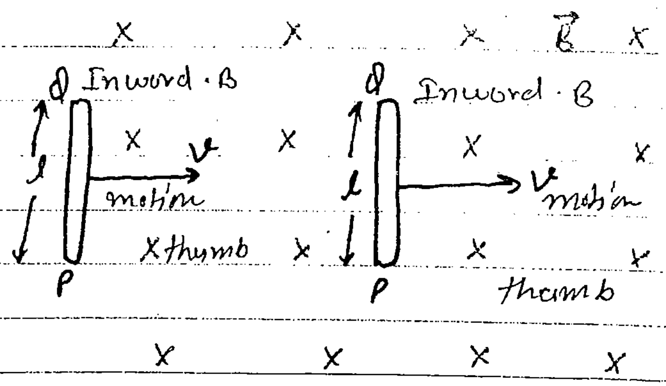
Principle of Lenz low:



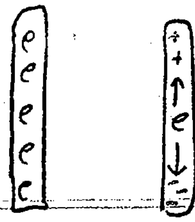
Lenz Low based on conservation on energy according to this rule magnetic potiantial energy induced in a coil is equal to machanical energy which losees by work done again repalsion force.

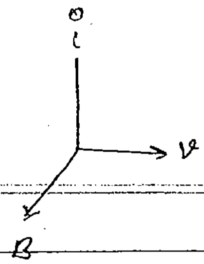
Potaintial difference b/w two end of any condector of uniform thikness-

Let mag field Intensity represented in word on plane of paper and a uniform then rod moves Horizentuly with constant velocity from left to Right direction



$F_E = F_B$





$qE = qBv$

$\frac{e}{l} = Bv$

$$\boxed{e = Bvl}$$

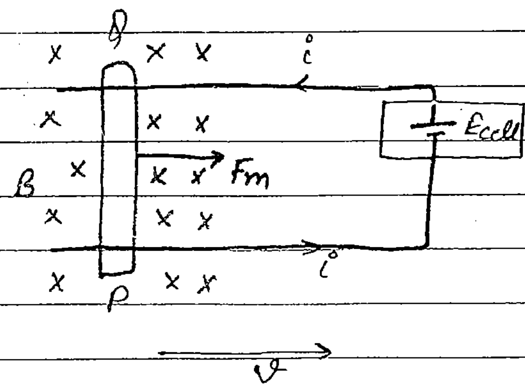
e = induced emf
l = length of rod
v = velocity of rod

Left Hand Rule
main current

Right Hand Rule
Induce current

<u>Qus:</u> किधर गति करेगा?

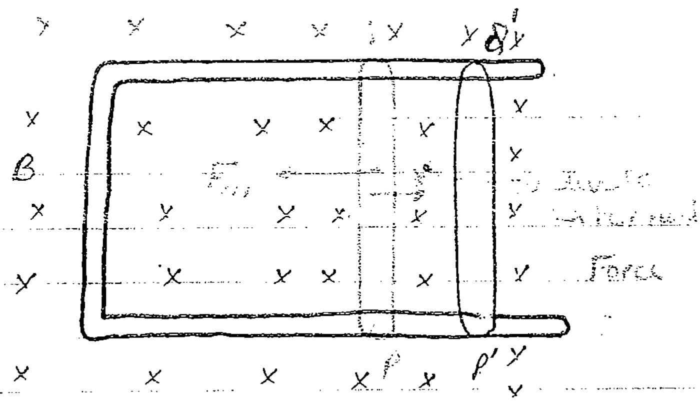
by Left ~~Rel~~ hand Rule



$$\boxed{F_m = iBl}$$

$$\boxed{i = \frac{E_{cell}}{R_{(wire\ or\ rod)}}}$$

Force and direction of current



Induce current upword ↑

magnetic field direction

← Left

external force

Right →

$\phi_1 = B \cdot A_1$

$\phi_2 = B \cdot A_2$

$A_2 > A_1$

change in flux

$$\boxed{\frac{d\phi}{dt} = B \cdot \frac{dA}{dt}}$$

अतः magnetic force, flux को बढ़ने नहीं देगा अतः यह left hand direction में होगा।

F_m ← → F_{ext}, v →

$F_{ext} - F_m = m(0)$

$F_{ext} = F_m$

$W = F_{ext} \times x$

$W = |F_m| \times x$

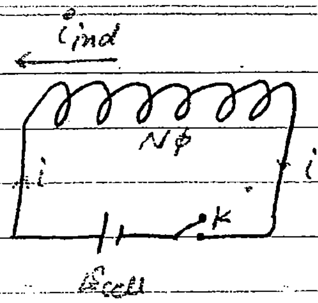
$W = iBl \times x$ $\quad dA = l \times x$

A = Area of $(PP'Q'Q)$ $= l \times x$

$dW = |-iB\,dA|$

$$\boxed{W = iBA}$$

Self Induction :
(स्वप्रेरण गुणांक)



① If key is on:

$\phi_i = 0$, if K is off

$\phi_f = B \cdot A$, if K is on

$\Delta\phi = \phi_f - \phi_i$

$\boxed{\Delta\phi = B \cdot A}$ magnetic current increses

$N\phi \propto i$

$\boxed{N\phi = Li}$

where L is self induction coefficent

स्वप्रेरण गुणांक $\boxed{L = \frac{N\phi}{i}}$

L का मात्रक – $L = \frac{N\phi}{i} = \frac{B \cdot A}{i} = \frac{\frac{N}{amp \cdot m} m^2}{amp} = \frac{N \cdot m}{amp^2}$

$\boxed{L = \frac{weber}{amp} = \frac{Joule}{amp^2}}$

L की विमा – $[ML^2T^{-2}A^{-2}]$

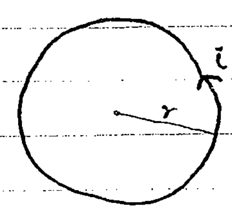
"magnetic flux linked with coil for unit current passing through them is equal to self Induction coefficient"

$$emf = -\frac{N\phi}{t} = -\frac{Li}{t}$$

$$L = -\frac{emf\ t}{i}$$

$$L = -\frac{et}{i} = \frac{\text{Volt sec}}{\text{amp}}$$

self induction cofficent of the coil:



$$L = \frac{N\phi}{i} = \frac{NBA}{i}$$

$$L = \frac{N \mu_0 i}{i\, 2r} \times \pi r^2 \qquad B = \frac{\mu_0 i}{2r}$$

$$L = \frac{\mu_0 N \pi r}{2}$$

$$L = \frac{\mu_0 N A}{2r}$$

if no. of Coil is N

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

$$L = \frac{NBA}{i} = \frac{N \cdot \mu_0 N i}{i \, 2r} \times \pi r^2$$

$$\boxed{L = \frac{\mu_0 N^2 \pi r}{2}}$$

$$\boxed{L = \frac{\mu_0 N^2 \times A}{r}}$$

Self induction of Solenoid "or" Toeriod:

B At Centre of Solenide

$$B = \mu_0 n i = \frac{\mu_0 N}{l} i$$

$$L = N\left(\frac{\mu_0 N i}{l}\right) \pi r^2$$

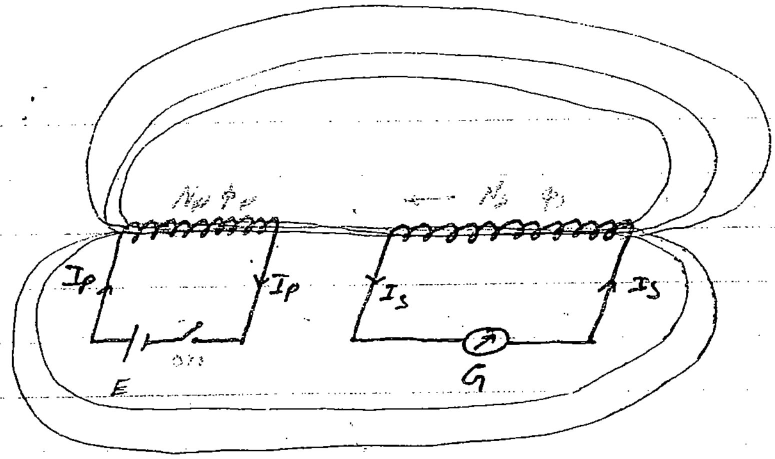
$$\boxed{L = \left(\frac{\mu_0 N^2 \pi r^2}{l}\right) = \mu_0 n N \pi r^2}$$

$$n = \frac{N}{l}$$

Self induction energy:

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

Mutual Inductive Effect :



$N_s \phi_s \propto i_p$

$N_s \phi_s = M i_p$

M = Mutual Inductive cofficient

$$\boxed{M = \frac{N_s \phi_s}{i_p}}$$

$\boxed{\phi_p \geq \phi_s}$ or $\phi_p = \phi_s$ → Qus Solve करते समय

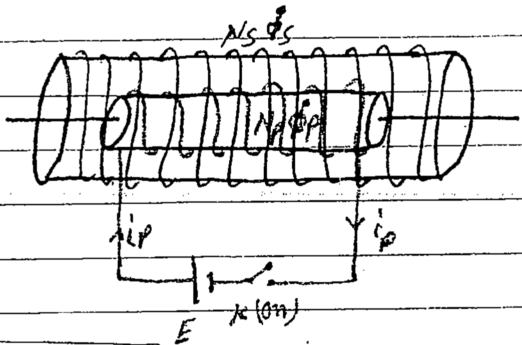
when two conducting coils placed closed to each other and ones of them is ~~contact~~ conected by cell and key. and other is coneted by galvometer. when current passing through first coil by cell then Induce current also produced secondry coil as well as primary coil thus finomindm is called Mutual Inductive effect

Cofficient of mutual Inductive effecte :

$$\boxed{M = \frac{N_s \phi_s}{i_p}}$$

Measurment of Mutual Induction effect Cofficient:

Mutual Induction Cofficent by two coaxial solenoid:



$$M = \frac{N_s \phi_s}{i_p}$$

$$\phi_s = B_p \cdot A_s$$

$$B_p = \mu_0 n_p i_p$$

$$N_s \cdot \phi_s = N_s B_p A_s$$

$$n_p = \frac{N_p}{l}$$

$$N_s \cdot \phi_s = N_s \left(\frac{\mu_0 N_p i_p}{l} \right) A_s$$

$$\frac{N_s \cdot \phi_s}{i_p} = \frac{\mu_0 N_p N_s A_s}{l}$$

$$M = \frac{\mu_0 N_p N_s \pi r_s^2}{l}$$

Examples of Mutual Induction effect:

Transformer. based on mutual Induction effect