MAGNETIC FIELD..

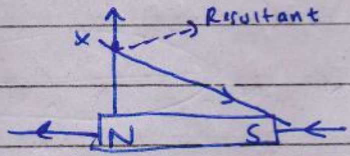
can be produced by:-

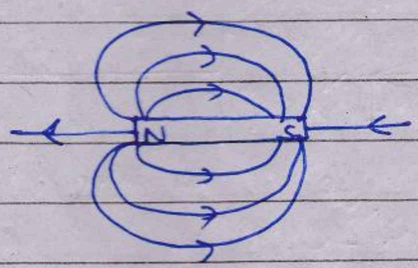
- Magnets
- Moving charge (current)

Naturally we find three ferromagnetic materials - materials strongly attracted by a magnet. Fe, Co, Ni

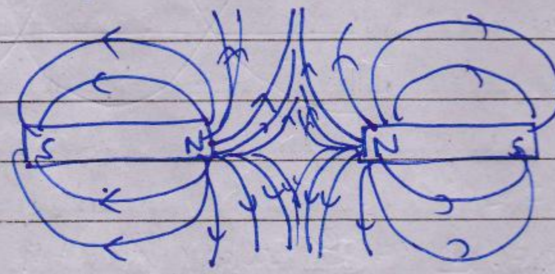
Magnetic monopoles are impossible

Direction of magnetic field is the same as the direction of force experienced by a north pole.



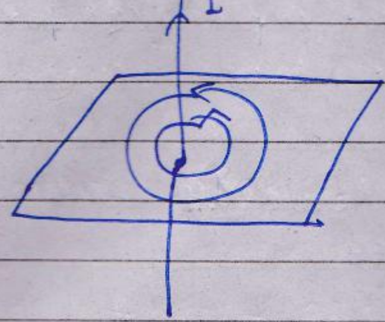


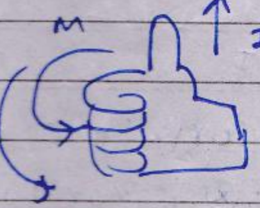
Two magnetic field lines never intersect each other.



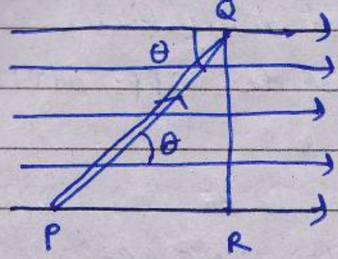
Current carrying conductor experiences force in magnetic field as it also produces magnetic field.

Right hand thumb rule.





where I = conventional directi
current and M is directi
of magnetic field.



Parallel line and equally spaced line of forces represent uniform magnetic field.

PQ is a current carrying conductor.

$PQ = l_1$ (length of PQ)

I = current in PQ

B = External magnetic field.

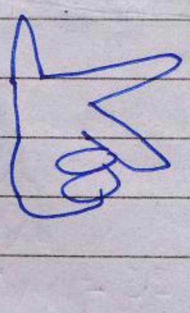
The conductor PQ experiences force given by.

$F = BIl\sin\theta$

So, F will be max when $\theta = 90°$ and min. when $\theta = 0°$

Here $QR = \frac{L\sin\theta}{PQ\sin\theta}$

Left hand rule

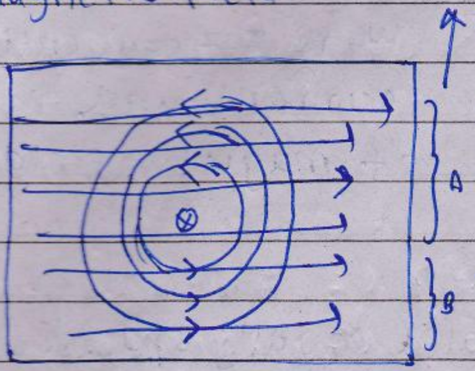


Middle finger → current

Index – field direction

Thumb – thrust

Why does a current carrying conductor experience force in a magnetic field.



Current I is towards reader

⊗ is conductor

In upper region A more field lines cancel out → F due to opp. direction

But region B has strong field.
Tendency to move from higher strength (potential) to lower strength (potential)
So direction of thrust is upwards.

A moving charge experiences force in magnetic field.

$F = BQv\sin\theta$

$F = BIl\sin\theta$

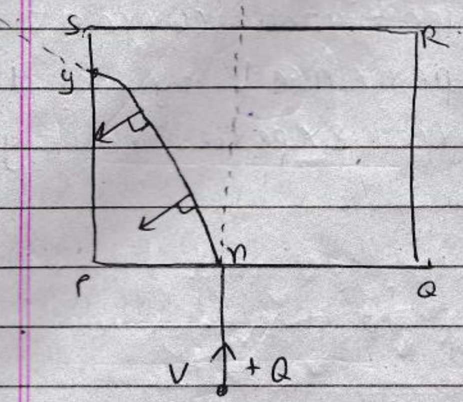
$\therefore B = \dfrac{F}{Il\sin\theta}$

if $\theta = 90°$

$\therefore B = \dfrac{F}{Il}$, where $l \perp B$.

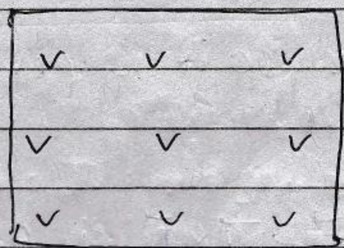
$\therefore$ Tesla is force per unit current length. Its SI unit is Tesla (T) where current must be in Ampere, and length must be in metre and $l \perp B$.

Magnetic field is circular

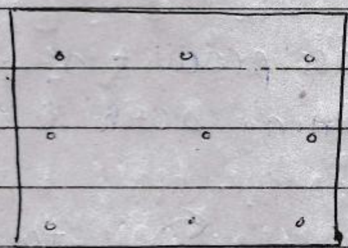


B is perpendicular and into plane PQRS.

The path is circular because the force that acts on particle is perpendicular to its velocity & magnetic flux density.



Magnetic field is perp. to plane and away from us



magnetic field is perpendicular to plane and towards us.

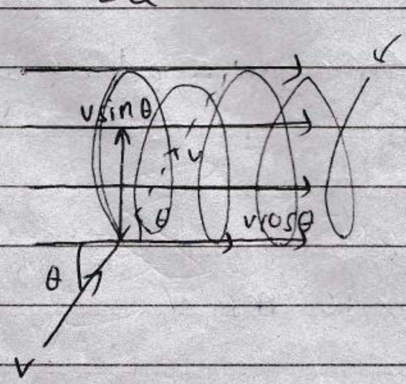
For the circular path,

$F = BQV$

$\frac{mv^2}{r} = BQ\cancel{V}$

$\therefore r = \frac{mv}{BQ}$ //.

BQV is responsible for centripetal force. Q is charge of particle sent into field. and V is velocity



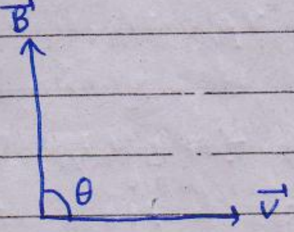
The distance between two successive rolls in the spiral/helix is equal to v cosθ.

In left hand thumb rule, if index is in direction of magnetic field, middle is direction of conventional current, then thumb is direction of force experienced by conductor, but is actually direction of force experienced by electrons.

$F = BIl \sin\theta \Rightarrow F = I(\vec{l} \times \vec{B})$

$F = Bqv \sin\theta \Rightarrow F = q(\vec{v} \times \vec{B})$

F is actually cross product of vectors, so it is perpendicular to plane containing both l and B.



screw

to find $\vec{F} = \vec{v} \times \vec{B} \sin\theta \cdot \hat{n}$
Going from $\vec{v}$ to $\vec{B}$, we use screw rule, so the direction of $\vec{F}$ (resultant) is towards us.

Direction of resultant is given by direction screw moves.

The conditions to experience force are:

→ The charge must be moving.

→ The direction of its velocity mustn't be parallel or antiparallel to magnetic field.

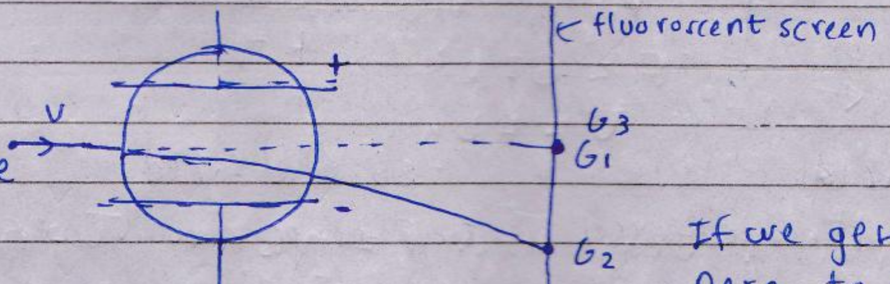
An electron is accelerated from rest through a pd of 10kV. What is KE it gains and its velocity.

$K_E = eV$ or, $mv^2 = 2eV$

or, $\frac{1}{2}mv^2 = eV$ or, $\therefore v = \sqrt{\frac{2eV}{m}} = 5.92 \times 10^7$ m/s

When a magnetic field is used to deflect a charged particle the velocity changes, but speed is always uniform, as force is perpendicular to velocity. Thus KE of a charged particle remains the same even throughout a magnetic field.

So, to deflect charged particles, magnetic field is considered the best during experiments.



First G_1 is a glow formed under no fields.

If we generate a magnetic field perp. to plate, we get a new glow G_2, where force on electron $F_e = BeV$

Now under magnetic field, we generate an electric field such that the electron deflecting towards G_2 due to magnetic field, the force from electric field cancels it and sends it back to G_1, to get a new glow G_3.

In $F = BIl$; B stands for magnetic flux density.

Here let force due to magnetic field be F_m and due to electric field be F_e.

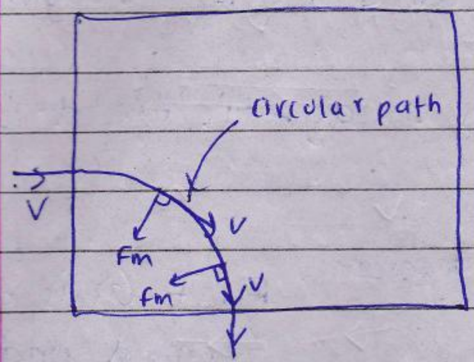
$F_m = BqV$, $F_e = q\mathcal{E}$

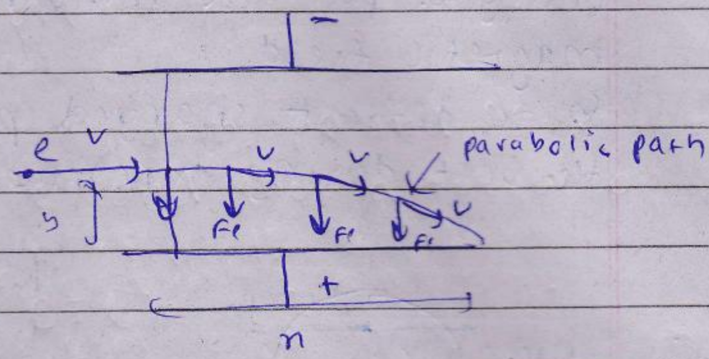
$BqV = q\mathcal{E}$

$\therefore V = \frac{\mathcal{E}}{B}$ " $v = \frac{\mathcal{E}}{B}$ "

This system is called velocity selector.

B can be measured using calibrated Hall Probe.
While a moving charge passes through a magnetic field, it gains no KE. but gains KE in electric field.





Magnetic field.
This is circular because force is always perpendicular to velocity of particle.

Electric field
This is parabolic because force is always perpendicular to the plate.

$Bq\cancel{v} = \frac{mv^{2}}{r}$ ← magnetic field provides necessary centripetal force

$Bq = mv/r$

$\frac{q}{m} = \frac{v}{rB}$ ← charge-to mass ratio.

$\frac{q}{m} = \frac{\varepsilon/B}{rB} = \frac{\varepsilon}{B^{2}r}$,,

$y = \frac{1}{2}at^{2}$, $F = ma$, $a = F/m = E\varepsilon/m$

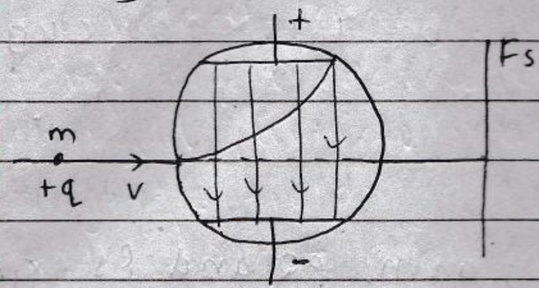
$y = \frac{E\varepsilon}{m} \cdot \frac{1}{2}t^{2}$

$q = n$

$q/m = y$

$\therefore m = n/y$,,

Velocity Selection



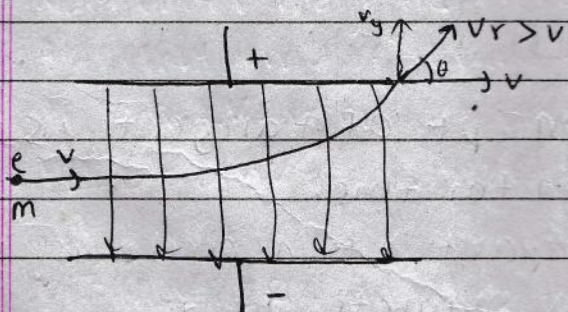
Here B is perpendicular to the plane of the board and into it. Electric field is such that deviation is nullified.

$B\cancel{q}v = \cancel{q}\mathcal{E}$ These fields are crossed fields, perpendicular to each other and along different planes.

$\therefore v = \frac{\mathcal{E}}{B}$.

The above arrangement is called velocity selector as it selects velocity and this process is called velocity selection.

Here in only magnetic field, there is no change in kinetic energy but in only electric field, there is.



$v_r = \sqrt{v_y^2 + v^2}$

$\therefore v_r > v$

There is gain in KE when deflection is done through electric field.

Magnetic field provides centripetal force in velocity selector

$Bqv = \frac{mv^2}{r}$

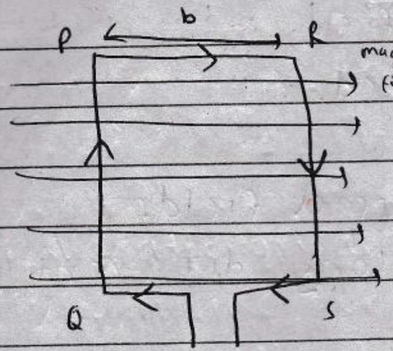
or, ~~$B\,e/m = Be = mv/r$~~ $Bq = mv/r$

or, ~~e/m~~ $= q/m = v/rB$

$\therefore q/m = \mathcal{E}/B^2r$ ← Here $\mathcal{E}$: B and r can be calculated and B can be measured using Hall Probe.

This allows us to find charge to mass ratio of electron.
e/m is experimentally found to be $1.78 \times 10^{11}\ C\,kg^{-1}$.

Force on a rectangular coil



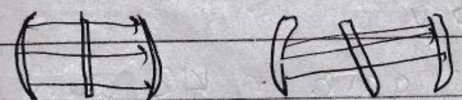
Here only arms PQ and RS experience force, and thus a torque on the coil is created.

$F = BIl$

$\therefore \tau = Fb$

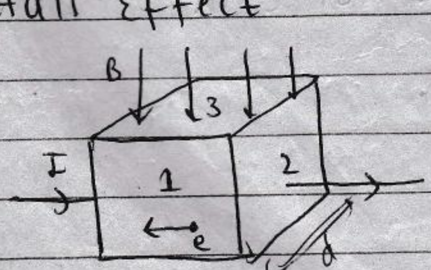
If the coil had n turns then $F = nBIl$, $\tau = nFb$.

The magnetic poles in dc motor are concave so that when the coil is spinning, it is always parallel to the magnetic lines of force and thus experience the same linear torque.



The concept of tangents is the reason for this.
The concept that a small part of a circle is a straight line creates such a magnetic flux.

Hall Effect

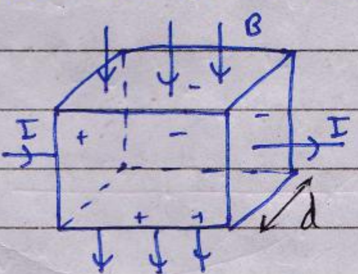


Let face 4 be opposite to face 1, face 5 opp. to face 2, and face 6 opp. to face 3.

The electron experiences force towards face Y.
Now as electrons move towards face Y, face Y becomes negative and face 1 becomes relatively positive.
Thus a pd is induced between face 1 and Y.
This pd is called Hall pd.
Thus an electric field is induced, where let's say V_H is pd induced due to Hall effect

$$\mathcal{E} = \frac{V_H}{d}$$

The metallic cuboid must be solid not hollow.
Here V_H is hall voltage which is induced due to magnetic field.
Thus an electric field is induced because of a magnetic field.
Now we still have incoming electrons due to current I.



Force experienced by electron in magnetic field, $F_m = BeV$
Force experienced by electron in electric field $\mathcal{E}$, $F_e = e\mathcal{E}$

The two forces must be equal at steady state.
Steady state is a condition when let's say boiling water. The water gains no heat and all heat goes into converting water at 100°C to steam at 100°C.

$F_m = F_e$

or $BeV = e\mathcal{E}$

or $BV = V_H/d$

$\therefore V_H = BVd$

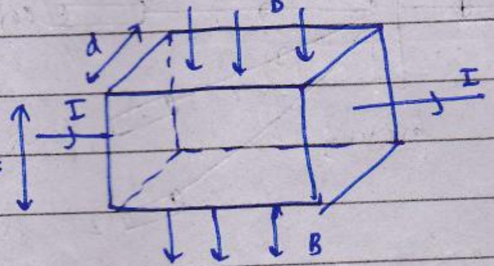
MAGNETIC FIELD....

Hall effect

Hall pd V_H can be given by,

$V_H = Bvd$ -- (i)

where B is magnetic flux density, v is drift speed of electrons and d is separation between plates.



$I = nevA$

$\Rightarrow v = \frac{I}{neA}$ -- (ii)

Using (ii) in (i)

$\therefore V_H = \frac{BId}{neA}$

$V_H = \frac{BI\cancel{d}}{ne\cancel{d}t}$ $\therefore V_H = \frac{BI}{net}$

Hall voltage is negligible for conductors.

Let's suppose an extreme case,

$B = 1T$ (very large) $I = 5A$ (very large)

$t = 1 \times 10^{-3}$ m (very small) $n = 1.53 \times 10^{29} m^{-3}$

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

$V_H = \frac{BI}{ntq} \approx 2.04 \times 10^{-7} V \approx 0.204 \mu V$

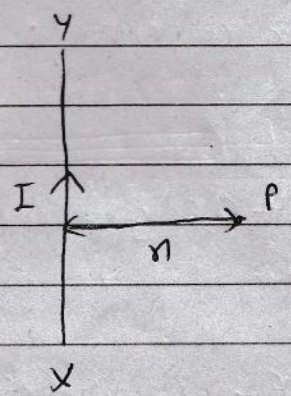
Even in such an extreme case Hall voltage is negligible. But in semiconductors, as n is less, V_H is high and more prominent. It is measurable

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

where μ_0 = permeability of free space.

$\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1} (Henry/metre)

Force between current carrying conductors.



Magnetic flux density at P due to current in XY is given by:

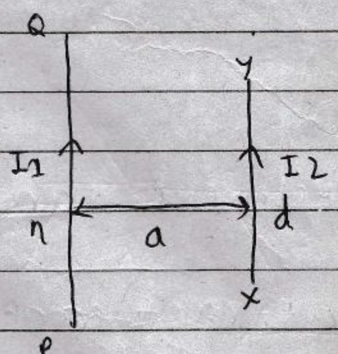
$$B = \frac{\mu_0 I}{2\pi r}$$

where μ_0 = permeability of free space

$\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1}.

$\therefore B = (2\times 10^{-7})(I/r)$

Direction of B at P is perp. to the plane of the paper and into it.



$PQ = l_1$, $XY = l_2$

a = Distance betn PQ and XY (perp.)

Conductor XY is in magnetic field of PQ.

Magnetic flux density at d due to current in PQ is $B_1 = (2\times 10^{-7}) \times I_1/a$

Direction of B_1 at D is perp to board and into it.

In this magnetic field, conductor XY experiences force F_1 given by:

$F_1 = B_1 I_2 l_2$.

$$F_1 = \cancel{\frac{\mu_0 I_1 l_2}{}} \rightarrow \frac{\mu_0 I_1 I_2 l_2}{2\pi a}$$

Force per unit length is,

$$\therefore \frac{F_1}{l_2} = \frac{\mu_0 I_1 I_2}{2\pi a}$$

Magnetic flux density ~~at~~ B_2 at n due to current I_1 in vs

$$B_p = \cancel{\frac{\mu_0 I_x}{2\pi a}}, \quad B_2 = \frac{\mu_0 I_2}{2\pi a}$$

B_2 is perp. to board and outside it as given by right hand rule.

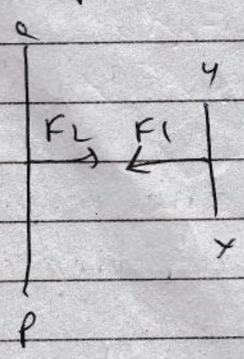
Conductor ~~PQ~~ PQ experiences force F_2 in this field B_2 given by $F_2 = B_2 I_1 l_2$

$$F_2 = \frac{\mu_0 I_1 . I_2 . l_1}{2\pi a}$$

Force per unit length is,

$$\therefore \frac{F_2}{l_1} = \frac{\mu_0 . I_1 . I_2}{2\pi a}$$

$\therefore$ Force per unit length of both conductors is same.

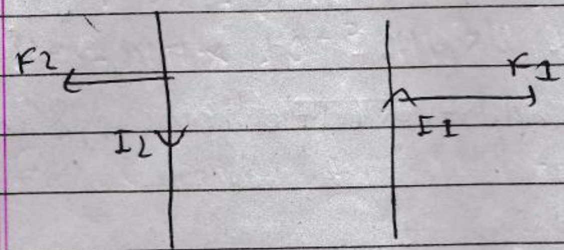


Thus these conductors attract each other.

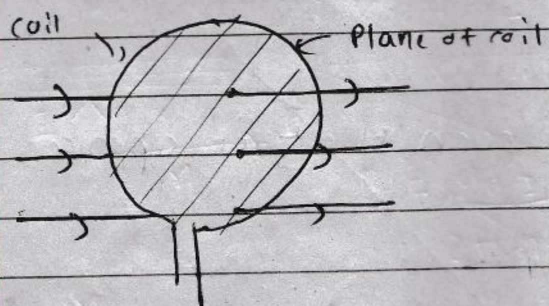
This model assumes that at every point of these conductors, magnetic field is constant. For this, these conductors must be infinitely long.

$$F/l \propto I_1 . I_2$$

F_1 and F_2 are ~~same~~ equal when both ~~long~~ conductors are of uniform length.

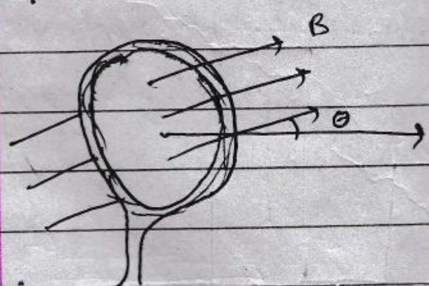


Repel each other when currents are in opposite direction.



At every point in the plane of coil, value of magnetic flux density is B. (B is perp. to the plane of coil.)
flux linked with coil, $\phi = BA$
where A is area of plane of coil.

If coil has n turns, flux linked with coil is,
$\phi_n = nBA$.



Direction of B makes an angle θ with direction of normals to the plane of coil, then flux linked with the coil is.

$\phi_n = nBA\cos\theta$.

Force between two magnetic poles (magnetostatic force) also varies ~~with the~~ inversely with square of distance

/ / /

Faraday's Law

$$\varepsilon \propto \frac{d\phi}{dt} \Rightarrow \varepsilon = -\frac{d\phi}{dt}$$

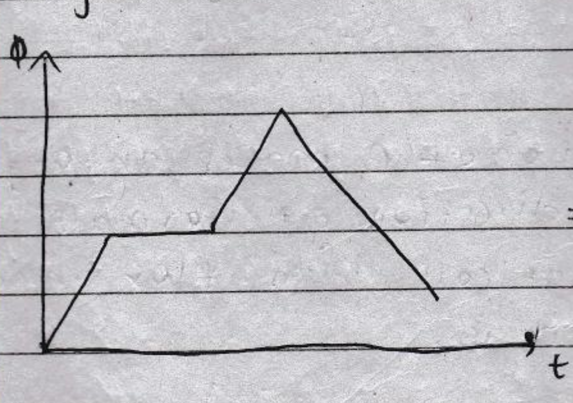
Induced emf is directly proportional to change in flux per unit time.

Lenz's law

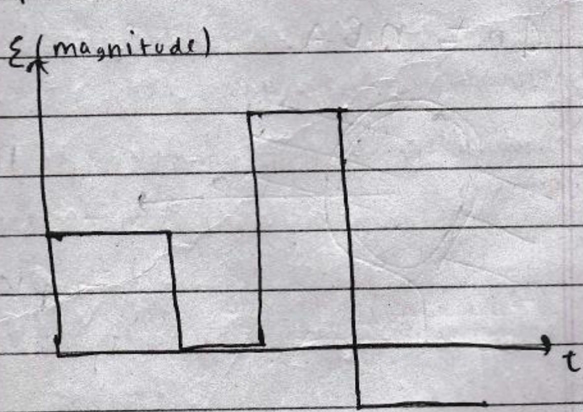
Direction of induced emf is such that it opposes the cause which produces it.

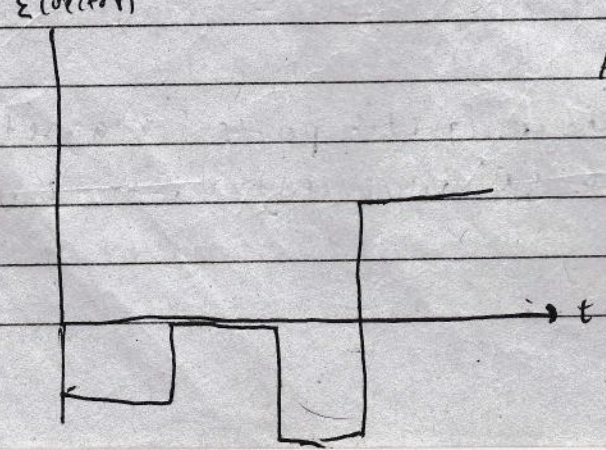
ϕ-t (flux-time graph) $\phi \propto I$

Gradient of ϕ-t graph is $d\phi/dt$, which gives the magnitude of induced emf.



$\Rightarrow$





As $\varepsilon = -d\phi/dt$, the vector ε is actually negative.

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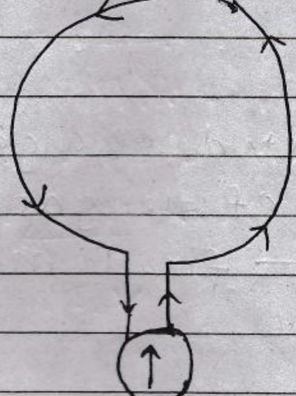
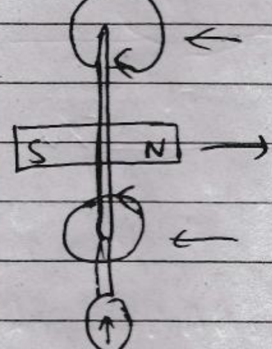
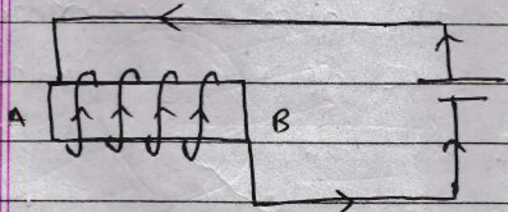


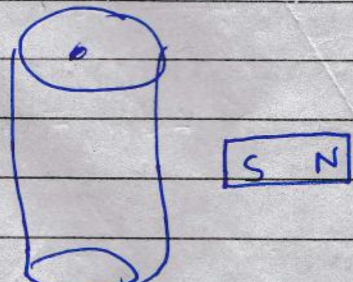
Suppose a magnet's north pole is going ~~into~~ perp. to plane of paper and into it. Now this changes flux linkage. From Lenz's law the magnetic field of magnet is cause for emf and thus another field must oppose it. So the direction of induced current's field is towards us, as then it would oppose the magnet. From right hand rule, we can find direction of current.

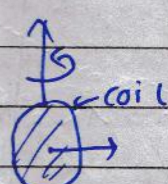


The circular field lines are tangent and try to oppose the magnet from entering inside the coil.



Here pole A becomes north pole as due to right hand thumb's rule magnetic field is towards A, and it becomes north pole.





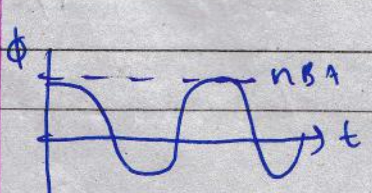
$\theta = \omega t$

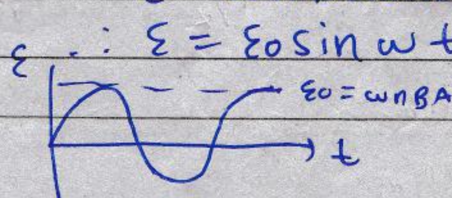
$\phi = nBA\cos\omega t$

$\varepsilon = -\frac{d}{dt} nBA\cos\omega t$

$\therefore \varepsilon = \omega nBA\sin\omega t$

$\therefore \varepsilon = \varepsilon_0 \sin\omega t$





phase diff = $\pi/2$