



Electro Magnetism

When a charged particle travels or current flows, there is an **induced magnetic field**. The strength depends upon amount of charge and the speed of the particle. $\rightarrow v$

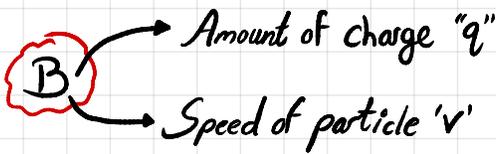
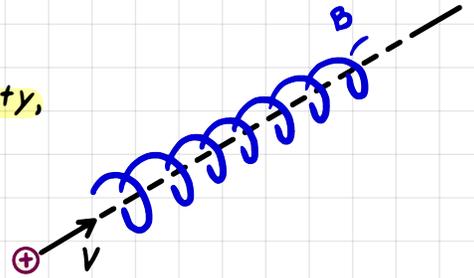
The strength of a magnetic field is called **magnetic flux density**, which is measured in **Tesla (T)**

The magnetic flux density of a current carrying conductor depends upon the amount of current.

Permeability of a medium is a property that determines the **degree of alignment of magnetic dipoles**

In a medium of high permeability, a strong magnetic field is developed.

If current travels in a circular loop. The **magnetic field induced is straight along the axis**.



$$I = nAqv$$

$$B \propto \frac{I}{d}$$

Mag Flux density of a current carrying conductor at distance "d"

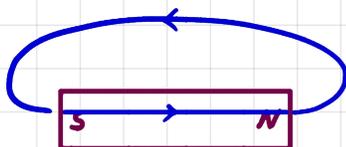
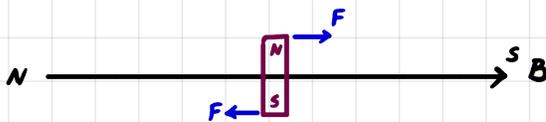
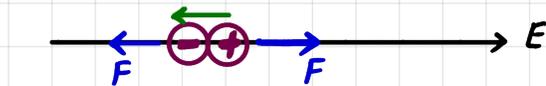
$$B = \frac{\mu}{2\pi} \cdot \frac{I}{d}$$

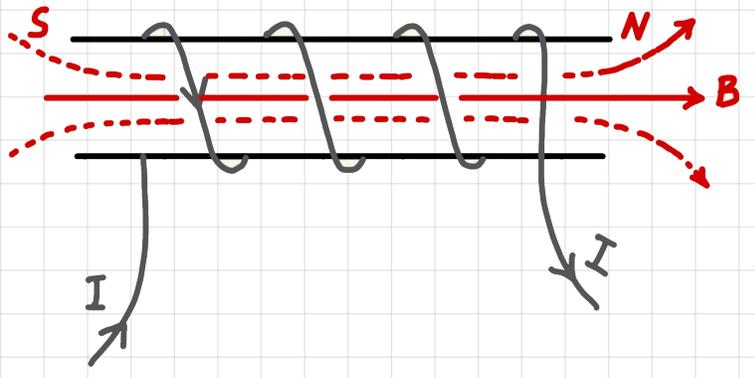
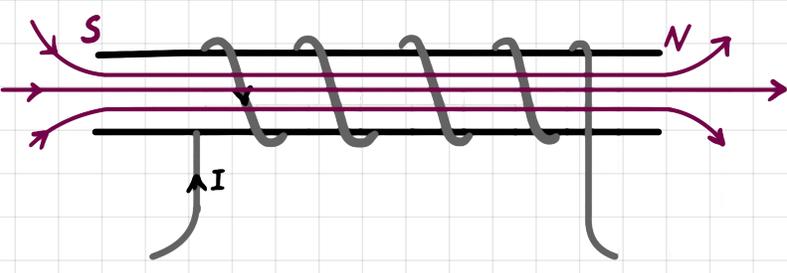
2×10^{-7}

μ \rightarrow Permeability of a medium
 μ_0 \rightarrow Permeability of vacuum/air
 $4\pi \times 10^{-7}$

Higher permeability \rightarrow Greater degree of dipolar alignment

Stronger the mag. field.

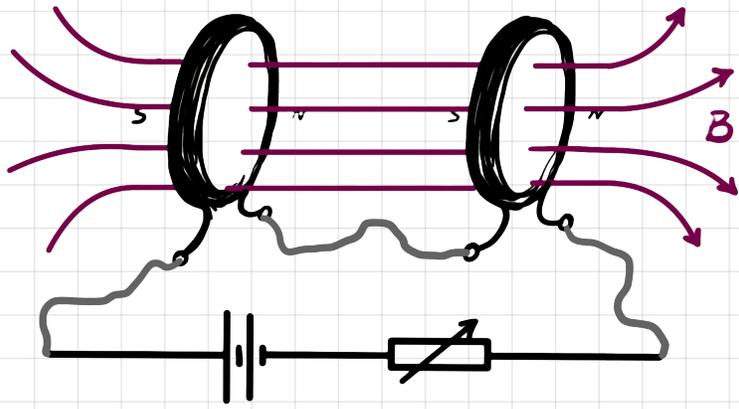




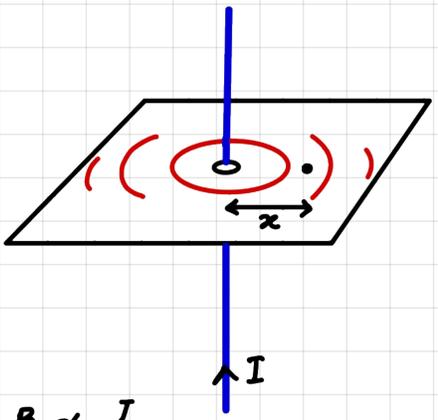
★ The magnetic flux density of induced magnetic field by a coil/solenoid depends upon amount of current and number of turns per unit length.

$$B = \mu_0 n I$$

↪ no of turns per unit length.



A pair of flat coils can be used to produce a uniform magnetic field of desired strength.



$$B \propto \frac{I}{x}$$

$$B = \frac{\mu_0}{2\pi} \cdot \frac{I}{x}$$

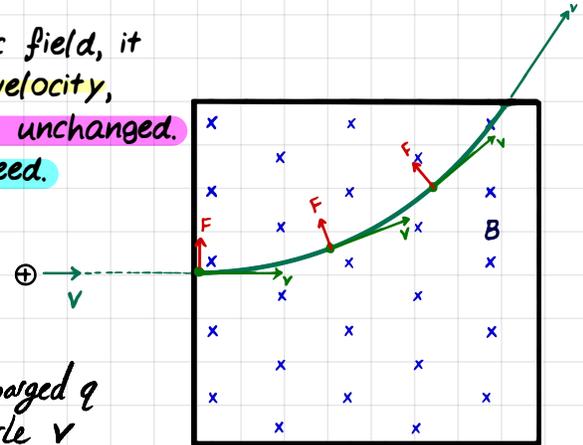
$\mu \rightarrow$ permeability

Electromagnetic FORCE

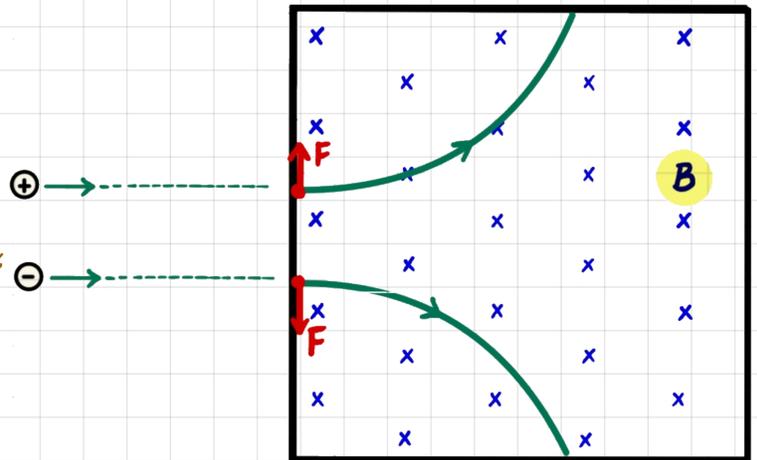
When a **charged particle enters an external magnetic field**, it experiences a force due to the interaction between the **external magnetic field**, and the **induced magnetic field** of the moving charge known as the **electromagnetic force**.

The electromagnetic force is **always directed Perpendicular to velocity**, therefore it cause **no changes of speed**, but affects direction only.

When a charged object travels through a uniform magnetic field, it experiences a **constant force directed perpendicular to its velocity**, causing a **uniform change in direction and leaving the speed unchanged**. Hence particles move on a **circular arc with a constant speed**.



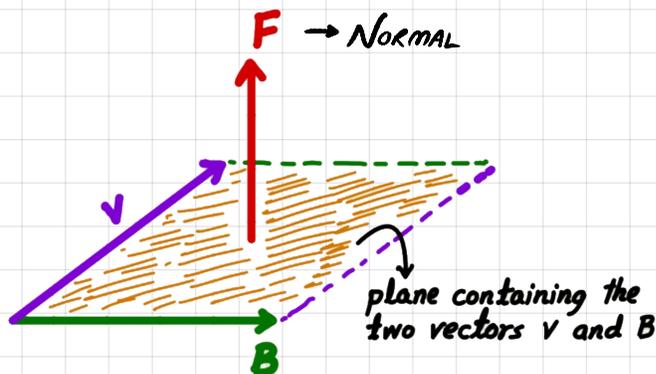
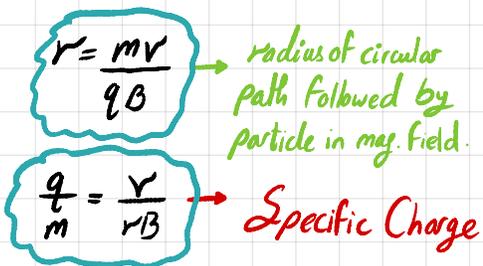
$$F = q v B \sin \theta$$

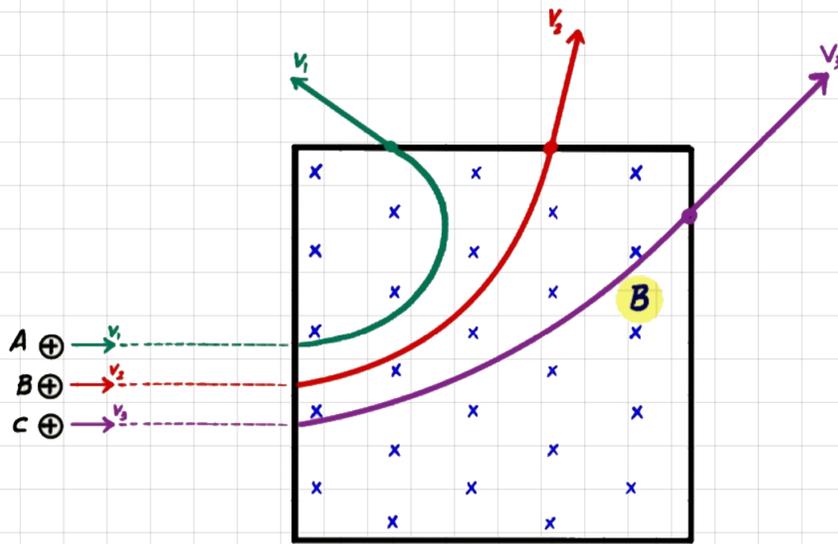


$$F_b = F_c$$

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

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





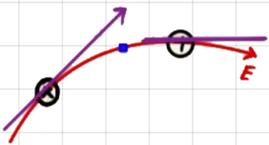
$$r = \frac{mv}{qB}$$

$$v_3 > v_2 > v_1$$

$$F = qvB$$

$$F \propto v$$

$$F_c > F_b > F_a$$



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

$$F \propto \frac{1}{r}$$

Incorrect as speed of particles can not be treated as constants.

Force ON A CONDUCTOR

When a current carrying conductor is placed in an external magnetic field. It experiences a force due to the force on moving charge particles through the conductor.

The size of electromagnetic force on a conductor depends upon :-

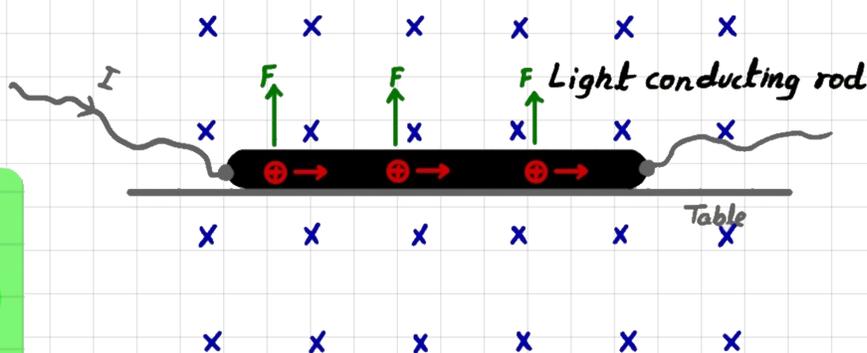
- 1 \rightarrow amount of current
- 2 \rightarrow current carrying length of conductor in magnetic field
- 3 \rightarrow magnetic flux density
- 4 \rightarrow angle b/w conductor's length and mag. field lines

Magnetic field can be defined as the region where a moving charge particle on a current carrying conductor experiences a force.

The strength of a magnetic field is called magnetic flux density is defined as force per unit length of a conductor per unit current when conductor is placed perpendicular to magnetic field lines

$$F = I l B \sin \theta$$

- $I \rightarrow$ Amount of current
- $l \rightarrow$ Current carrying length of conductor in mag. field
- $B \rightarrow$ Mag. flux density
- $\theta \rightarrow$ Angle b/w mag. field lines and conductor length/current.



$$F = q v B \sin \theta$$

$$= I t \cdot v B \sin \theta$$

$$= I v t B \sin \theta$$

$$F = I l B \sin \theta$$

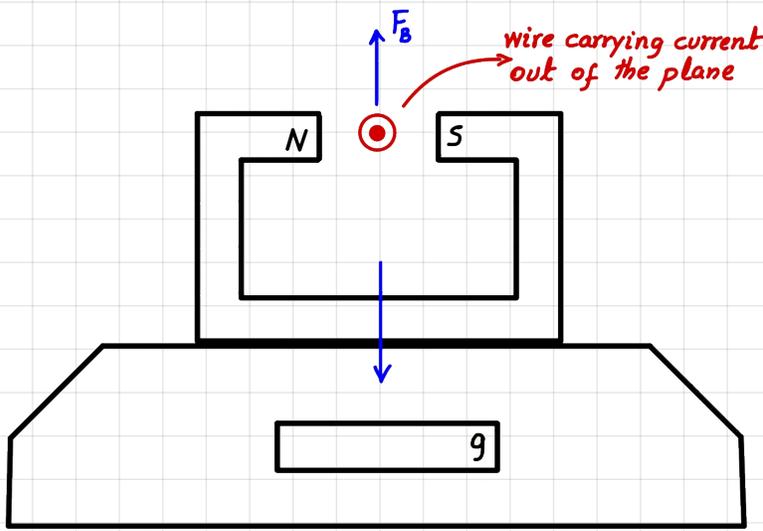
$$I = \frac{Q}{t}$$

$$s = vt$$

$$l = vt$$

$$I = nAev$$

$$F = BIL \sin \theta$$



Change in apparent weight = Electromagnetic Force on wire

$$\Delta m g = I l B \sin \theta \quad ; \theta = 90^\circ$$

$$\Delta m = \frac{l B}{g} I$$

$$\Delta m = \frac{l B}{g} I$$

Change in reading Δm (circled in red)

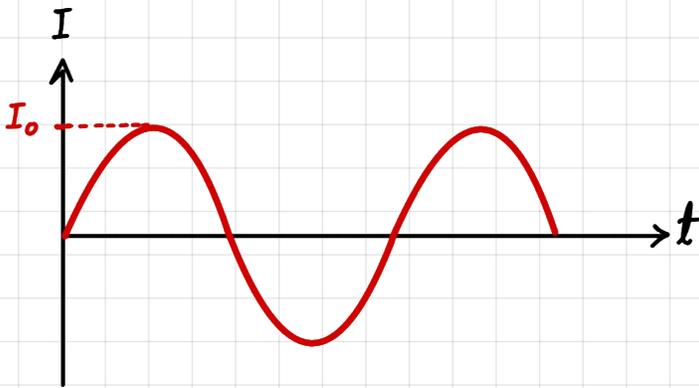
current in the wire I (circled in blue)

$$\Delta m_{\max} = \frac{l B}{g} I_0$$

Max. change in reading Δm_{\max} (circled in red)

Peak value of alternating current I_0 (circled in blue)

Variation in reading = $2 \times \Delta m_{\max}$

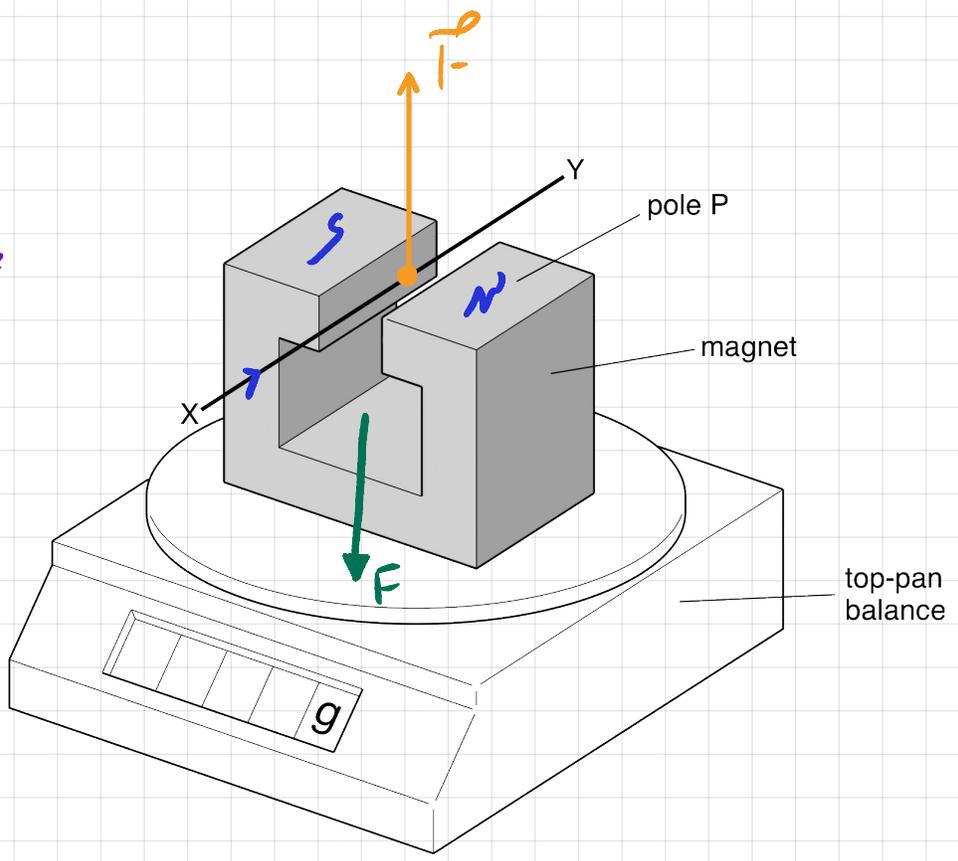


$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$$

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

Mean value of current I_{rms} (circled in blue)

Peak value of current I_0 (circled in purple)



VELOCITY SELECTOR

It is an arrangement of magnetic and electric field directed perpendicular to each other (crossed fields) in such a way that the electric field force on a moving charge object is oppositely directed to the electromagnetic force

The strength of the fields are adjusted in such a way that the net force on the moving charge particle is zero and the particle travels with no deflection.

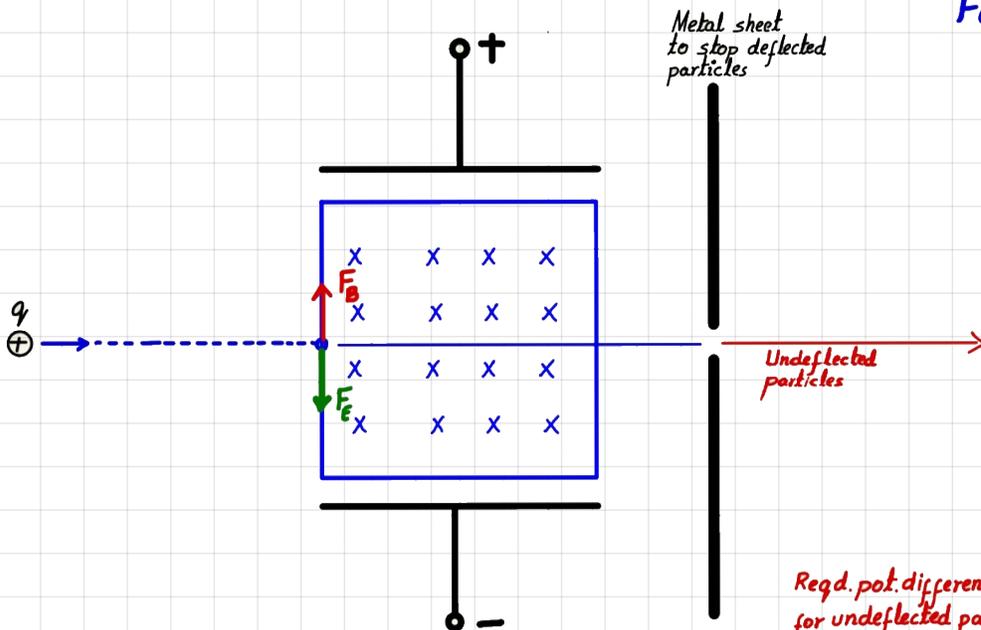
The gravitation effects are negligible.

The speed of undeflected particles is equal to the ratio of the two field strengths.

The arrangement can be used to select particles at a desired speed.

The selection of speed is independent of nature and amount of charge.

Velocity Selector



For an undeflected particle

$$F_E = F_B$$

~~$$qE = qvB \sin \theta$$~~

$$v = \frac{E}{B}$$

Determination of particles' speed.

$$E = vB$$

Finding electric field strength for undeflected particles at desired speed.

$$\frac{V}{d} = vB$$

Reqd. pot. difference for undeflected particles at a desired speed

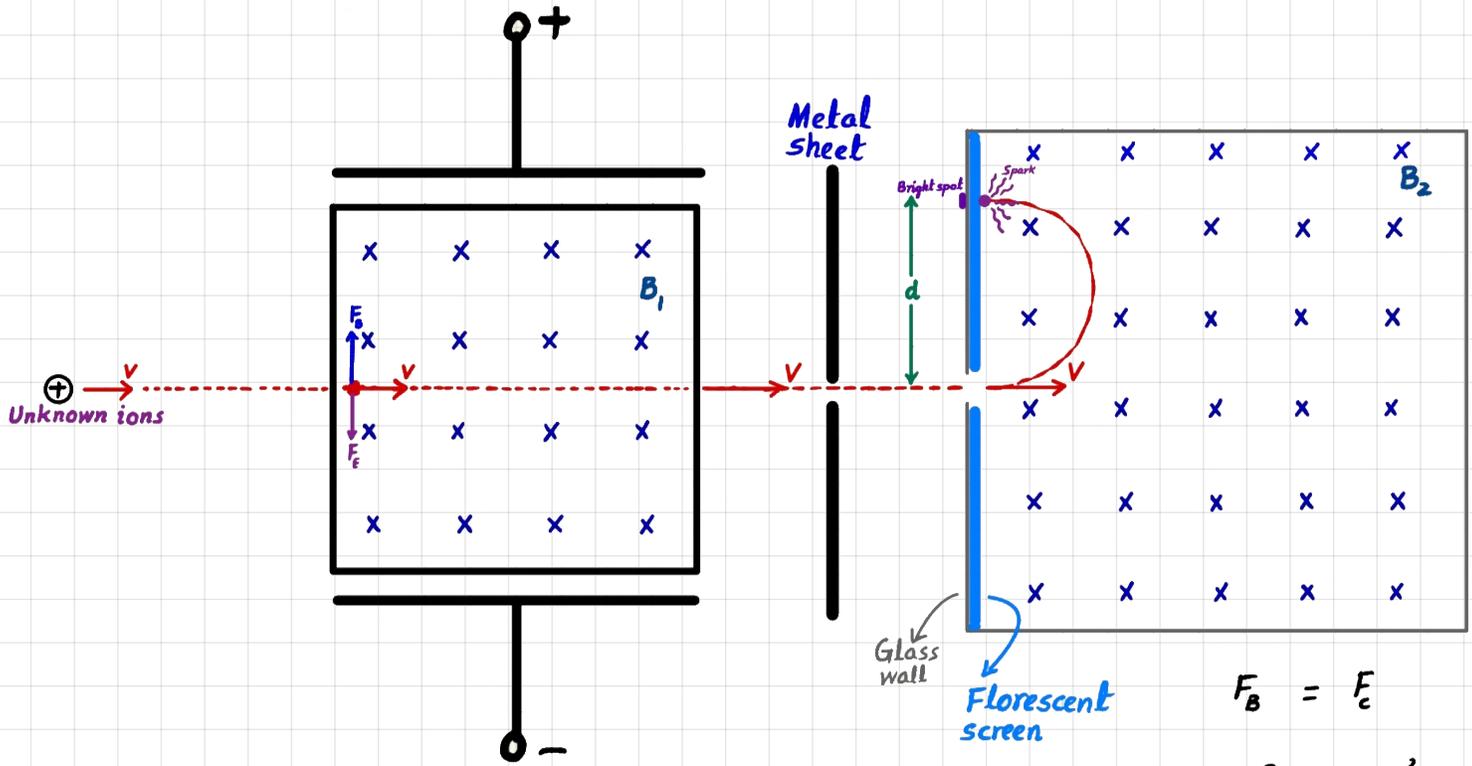
Separation b/w plates

Mag. Flux density

Desired speed

$$V = vdB$$

Determination of charge by mass (e/m) ratio



$$qvB_1 = qE$$

$$v = \frac{E}{B_1}$$

$$F_B = F_c$$

$$qvB_2 = \frac{mv^2}{r}$$

$$\frac{q}{m} = \frac{v}{rB_2}$$

$$\frac{q}{m} = \frac{E/B_1}{d/2 B_2}$$

CURRENT BALANCE METER

It is an instrument to measure magnetic flux density, it works on the principle of moments.

The turning affect caused by the electromagnetic force is balanced by the turning affect of a rider Weight

Current Balance Meter

For a balanced frame

Turning effect of electromag. force = Turning effect of the weight (mg).

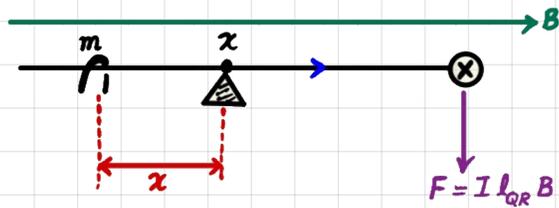
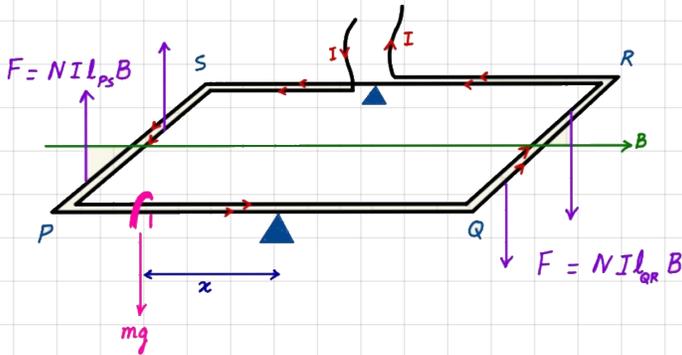
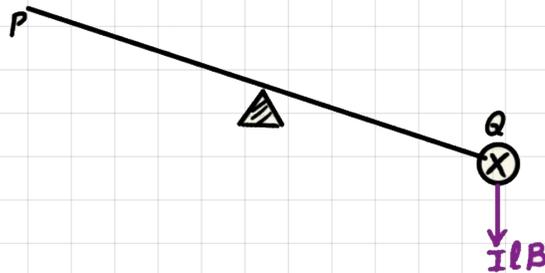
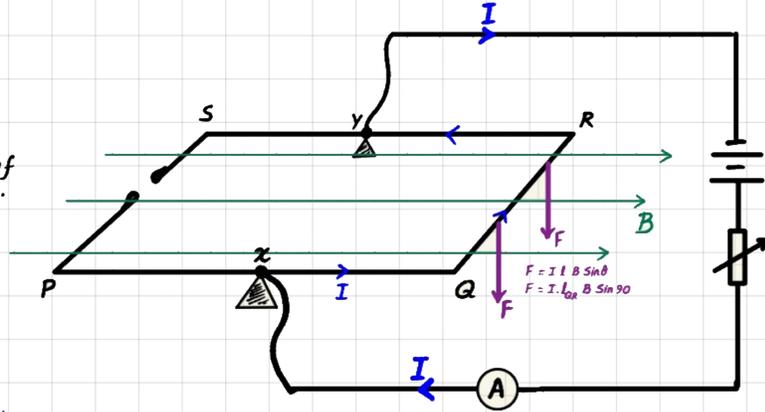
$$I l_{QR} B \times \frac{l_{PQ}}{2} = mg \times x$$

$$\frac{1}{2} I B l_{QR} l_{PQ} = mg x$$

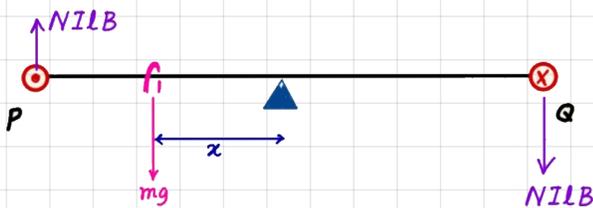
$$\frac{1}{2} I B A = mg x$$

Area of frame.
mass of rider weight
perp. distance b/w pivot and rider weight

$$B = \frac{2mgx}{IA}$$



$$N I l_{QR} B \times l_{PQ} = mg \times x$$



Torque of couple = Turning Effect of EM forces = Turning Effect of rider weight

$$N I l_{QR} B = mg x$$

$$N I QR = mg x$$

FORCE b/w Parallel Plate Conductor

If two conductors are placed parallel to each other, the magnetic field induced by one is perpendicular to the current of the other. Hence, the two wires exert electromagnetic force on each other.

The two wires attract each other, if they carry current in the same directions and repel if currents are opposite

The magnitude of force the two wires exert on each other depends upon :-

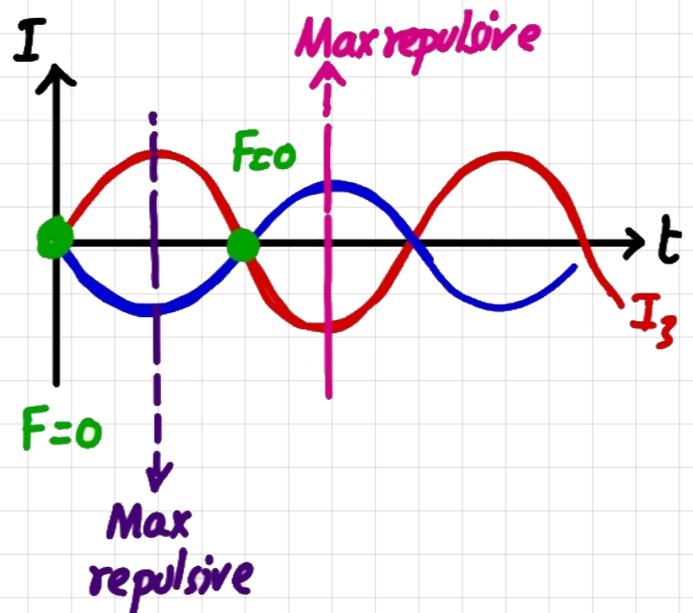
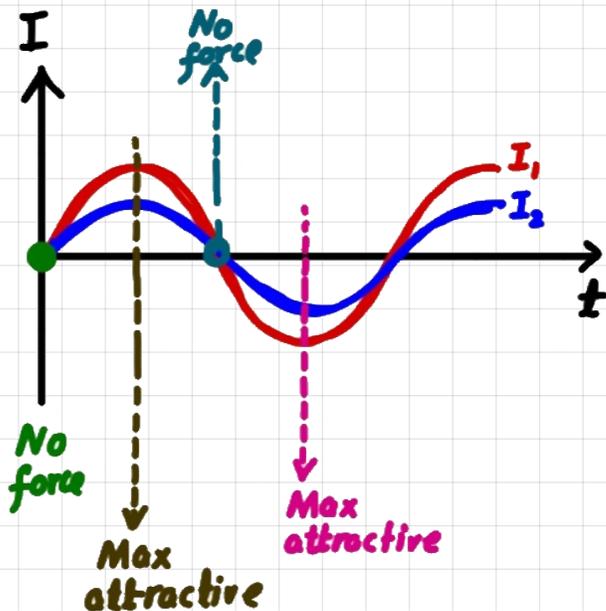
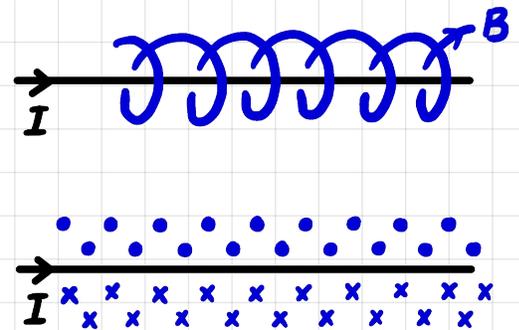
- ~> amount of current
- ~> Separation b/w wires
- ~> Parallel length of the wires

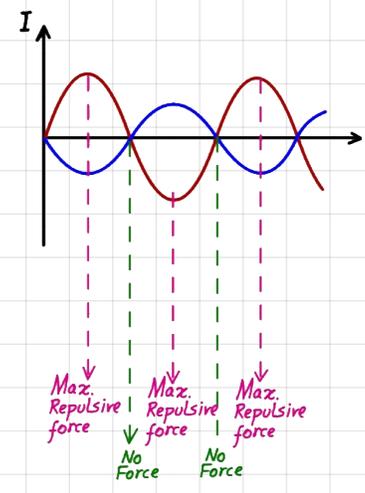
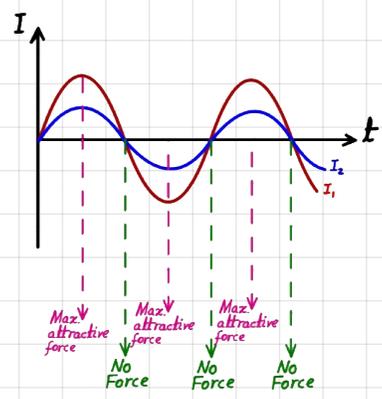
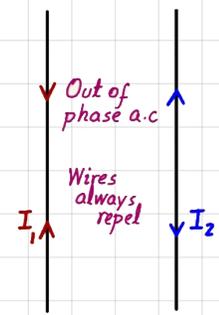
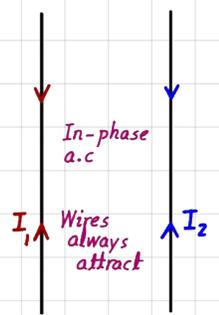
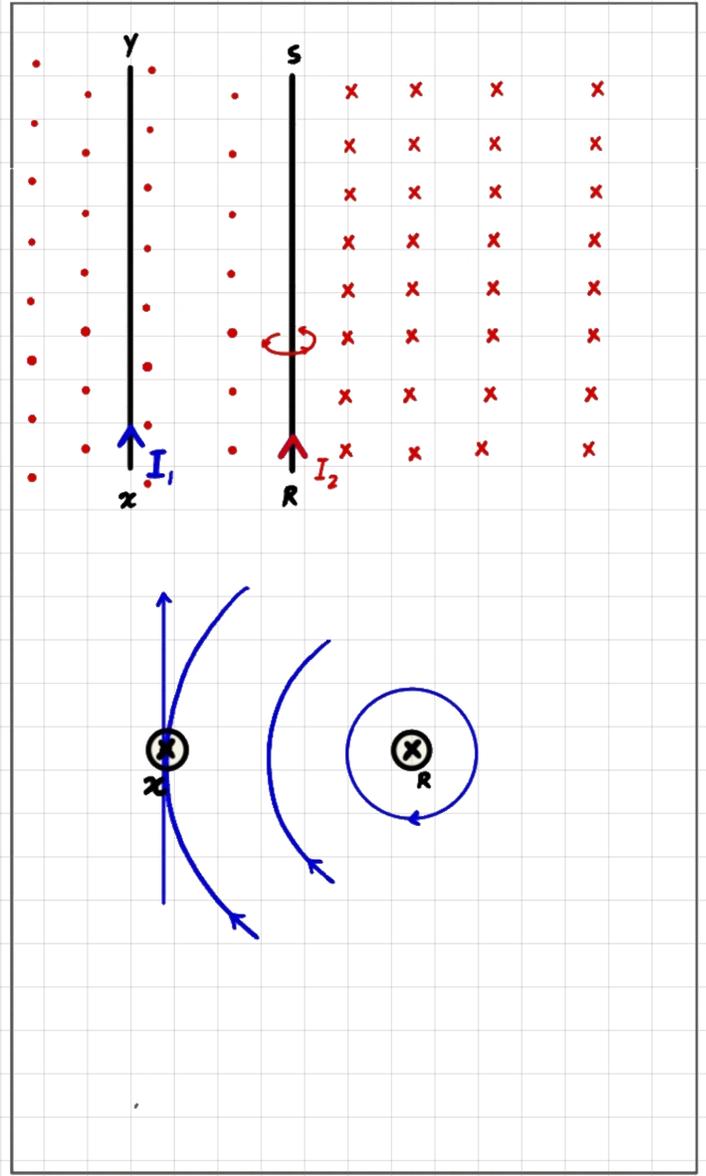
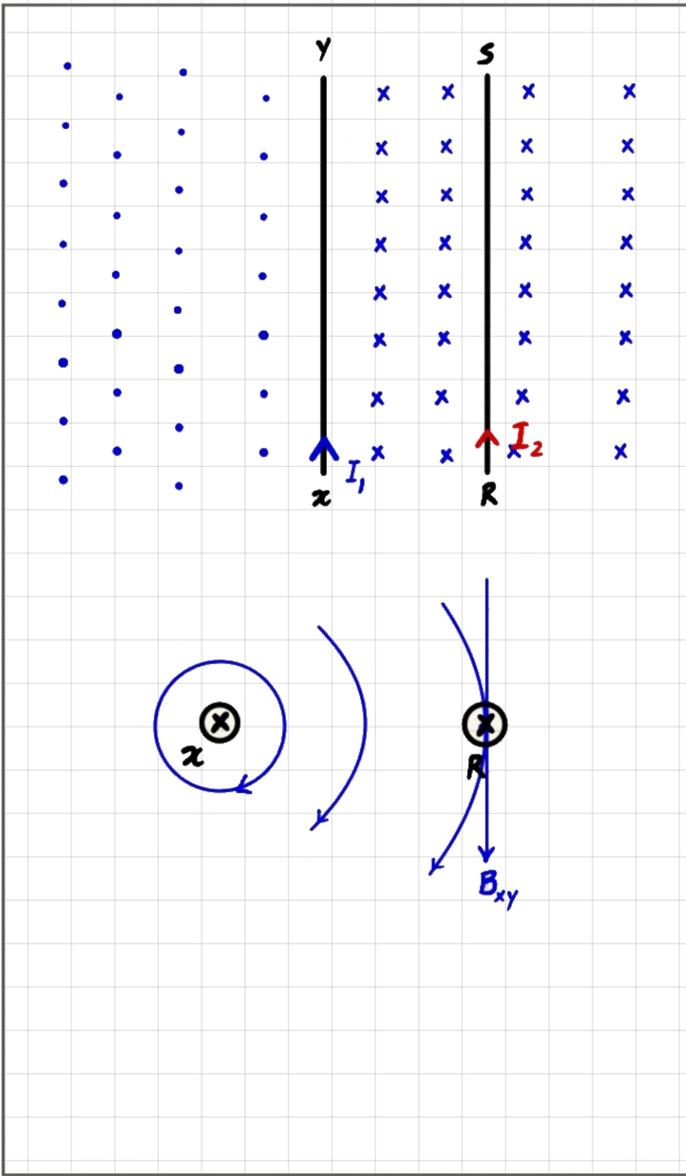
If parallel wires carry alternating currents, the magnitude of force changes between maximum and minimum frequency. Causing the wire to vibrate with the frequency twice of the frequency of alternating currents.

$$F = I_1 B \sin \theta$$

$$F_{RS} = I_2 l \cdot \frac{\mu_0}{2\pi} \frac{I_1}{d} \sin 90$$

$$F_{RS} = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{d} l \quad \rightsquigarrow \quad F = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{d} l$$





The Hall Probe

Hall probe is an instrument to measure magnetic flux density. Through a calibrated voltmeter connected across the width of a conducting sheet.

The charge particle travelling through the conductive sheet deflect across the width due to electromagnetic force. An electric field force with a gradually increasing magnitude, eventually balances the electromagnetic force.

The Voltmeter reading reaches a constant value called Hall Voltage

For consistent observation of a Hall Probe, the current must remain constant so that all voltage remains directly proportional to magnetic flux density.

In most of the cases, magnetic flux density has a very small value there for a high sensitivity Hall Probe is required for the measurement.

For high sensitivity of the meter, the current must be kept as large as possible, the thickness must be kept as small as possible. The conducting sheet must be made up of semiconducting material.

In order to measure the flux density Hall probe is rotated in magnetic field until the Voltmeter reading increases to maximum.

Hall Probe

Hall probe is an instrument to measure mag. flux density. In order to measure, the probe is placed in mag. fields, and rotated until the voltmeter reading increases to maximum for mag. field directed normal to the surface of conducting sheet.

A thin sheet of a conducting material is connected to an external circuit with a voltmeter across the width. When placed in a mag. field, moving charged particles deflect across width due to electromagnetic force and a electric field of gradually increasing strength builds up across width, the voltmeter reading also increases. The electric field force on moving charge carriers increases and eventually balances electromagnetic force

with voltmeter's reading increasing to maximum called Hall voltage V_H .

The voltmeter can be calibrated to measure magnetic flux density.

For an undeflected stream of particles / For maximum reading on voltmeter

$$F_E = F_B$$

$$qE = qvB \sin \theta$$

$$\frac{V_H}{d} = vB$$

$$\frac{V_H}{x} = \frac{I}{ntxq} B$$

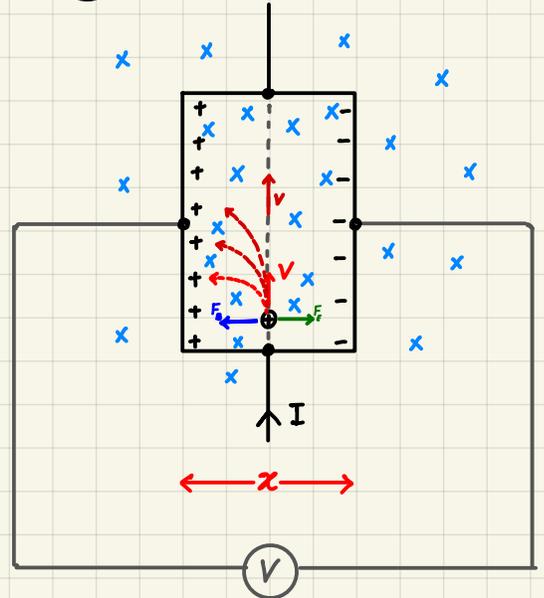
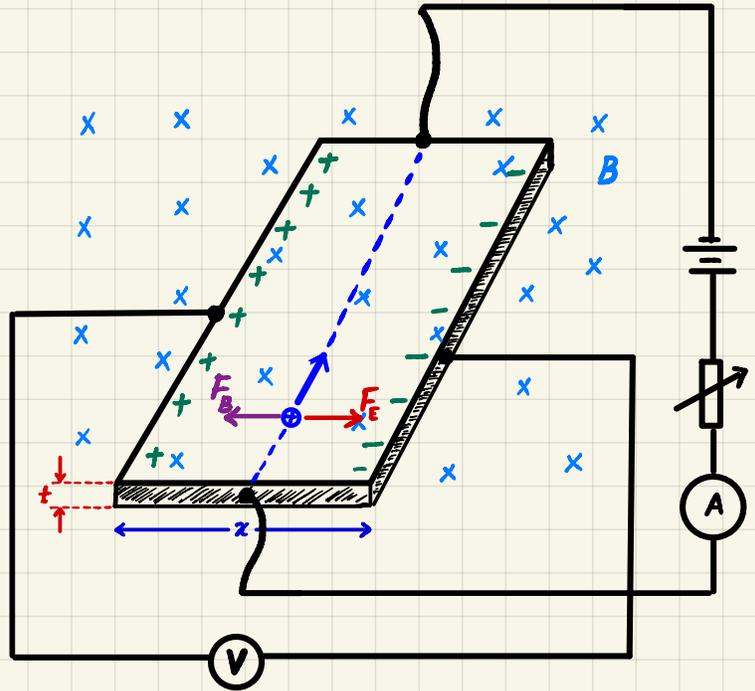
$$V_H = \frac{I}{ntq} \times B$$

$$V_H \propto B$$

$$V_H = \frac{I}{ntq} \times B$$

has to be large for high sensitivity
Very small

Max. possible I; Min. possible n;
Thickness must be as small as possible
Very thin sheet.



If mag. lines are normal to the plane of conducting sheet, the voltmeter's reading increases to maximum therefore the probe is rotated gently before taking observation.

For consistent measurement/linearity, the size of current must be constant.

For higher sensitivity of measurement:

- * maximum safe current must flow.
- * smallest possible thickness of sheet must be used. (small t)
- * a semi-conducting material's sheet should be used. (small n)