



2nd Year Physics

Chapter # 14

Electromagnetism

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Electromagnetism

The branch of physics that deals with the study of magnetic effects of current is called electromagnetism.

Magnetic field due to current in a long straight wire.

- A magnetic field is set up in the region surrounding a current carrying wire.
- The lines of the force is circular and their direction depends upon the direction of current.
- The magnetic field lasts only as long as the current is flowing through the wire.

Rule:

If the wire is grasped in first of right hand

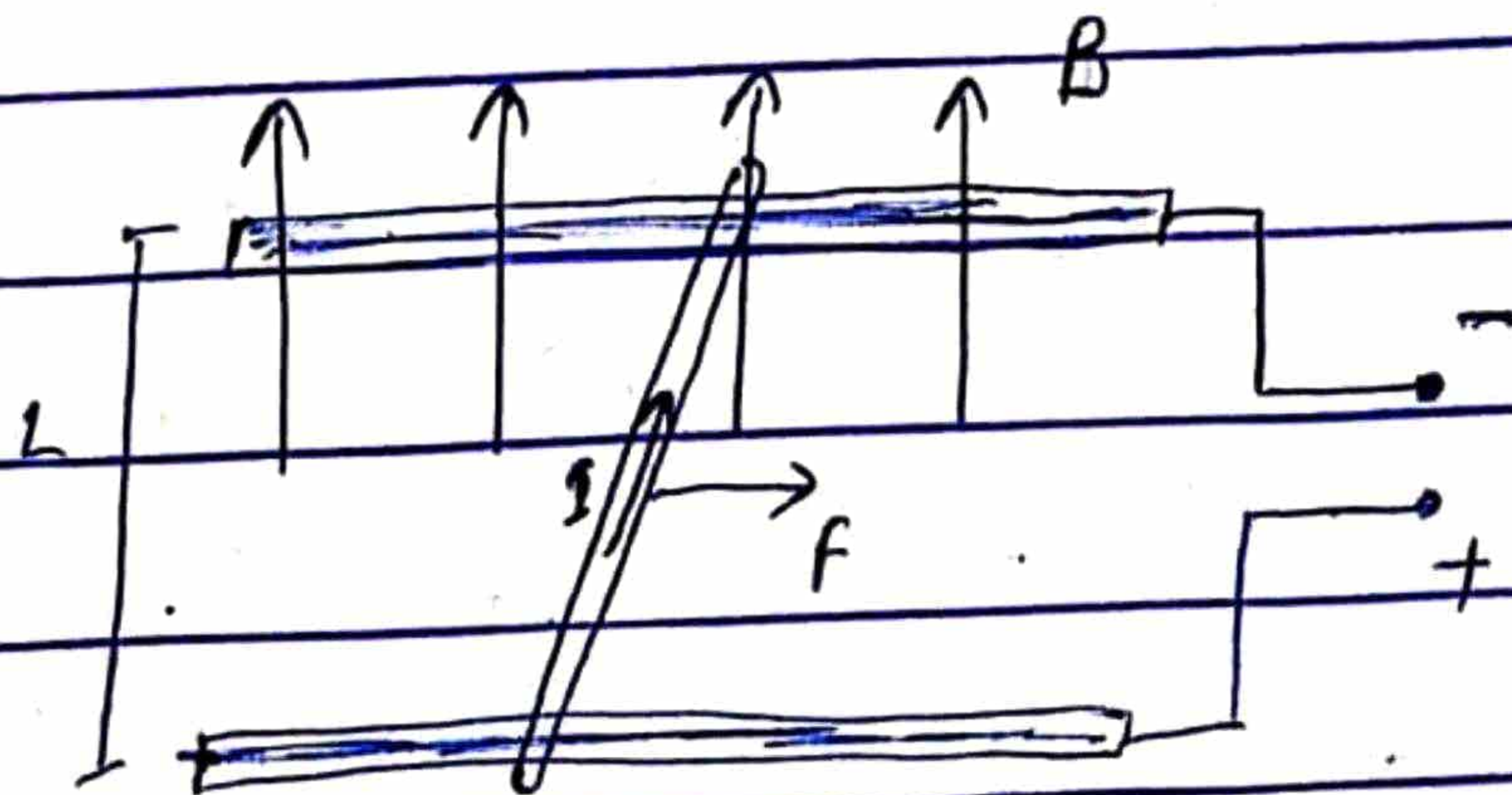
with the thumb pointing in the direction of current, the fingers of the hand will circle the wire in the direction of magnetic field.

Force On A Current Carrying Conductor In A Uniform Magnetic Field:

Reason of force:

Current Carrying Conductor sets up its own magnetic field. If such a conductor is placed in external magnetic field the M.F of the conductor will interact with the External magnetic field as a result of which the conductor may experience a force.

Construction:



Consider a rod of copper

capable of moving on a pair of copper rails. The whole arrangement is placed in between the pole pieces of a horseshoe magnet. so that the copper rod is subjected to the magnetic field directed vertically upward.

Dependence of force:

The force acting on the conductor depends upon the following factors.

i- The force is directly proportional to $\sin \alpha$. where α is the angle between magnetic field and rod.

$$F \propto \sin \alpha$$

ii- The force is directly proportional to the current flowing through the conducting rod.

$$F \propto I$$

iii- The force is directly proportional to the length of the rod.

$$F \propto L$$



iv- The force is directly proportional to the strength of magnetic field.

$$F \propto B$$

By combining the above factors.

$$F \propto BIL \sin \alpha$$

$$F = k BIL \sin \alpha$$

if we take the proportionality constant k as 1.

$$F = (1) BIL \sin \alpha$$

$$F = BIL \sin \alpha$$

Magnetic induction:

force acting on one meter length of conductor placed at right angle to the magnetic field when one Ampere current is passing through it.

Tesla: A magnetic field is said to have a strength of one tesla if it exert a force of one newton on one meter length of a conductor placed at right angle to the field when a current of one ampere passes through the conductor.
 $1T = 1NA^{-1}m$

vector form: As the force is a vector quantity. So, the vector form of magnetic force will be:

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

here vector $\vec{L}$ is in the direction of current.

Direction of force:

The direction of force is correctly given by right hand rule of cross product of vectors of L and B , i.e. rotate L to coincide with B through the smaller angle. curl the fingers.

of right hand rule in the direction of rotation. The thumb points in the direction of force.



Magnetic Flux and Flux Density.

Magnetic Flux: The number of magnetic field lines passing through a certain area is called magnetic flux.

OR

The dot product of magnetic intensity $\vec{B}$ and vector Area $\vec{A}$ is called magnetic flux. Mathematically:.

$$\phi = \vec{B} \cdot \vec{A}$$

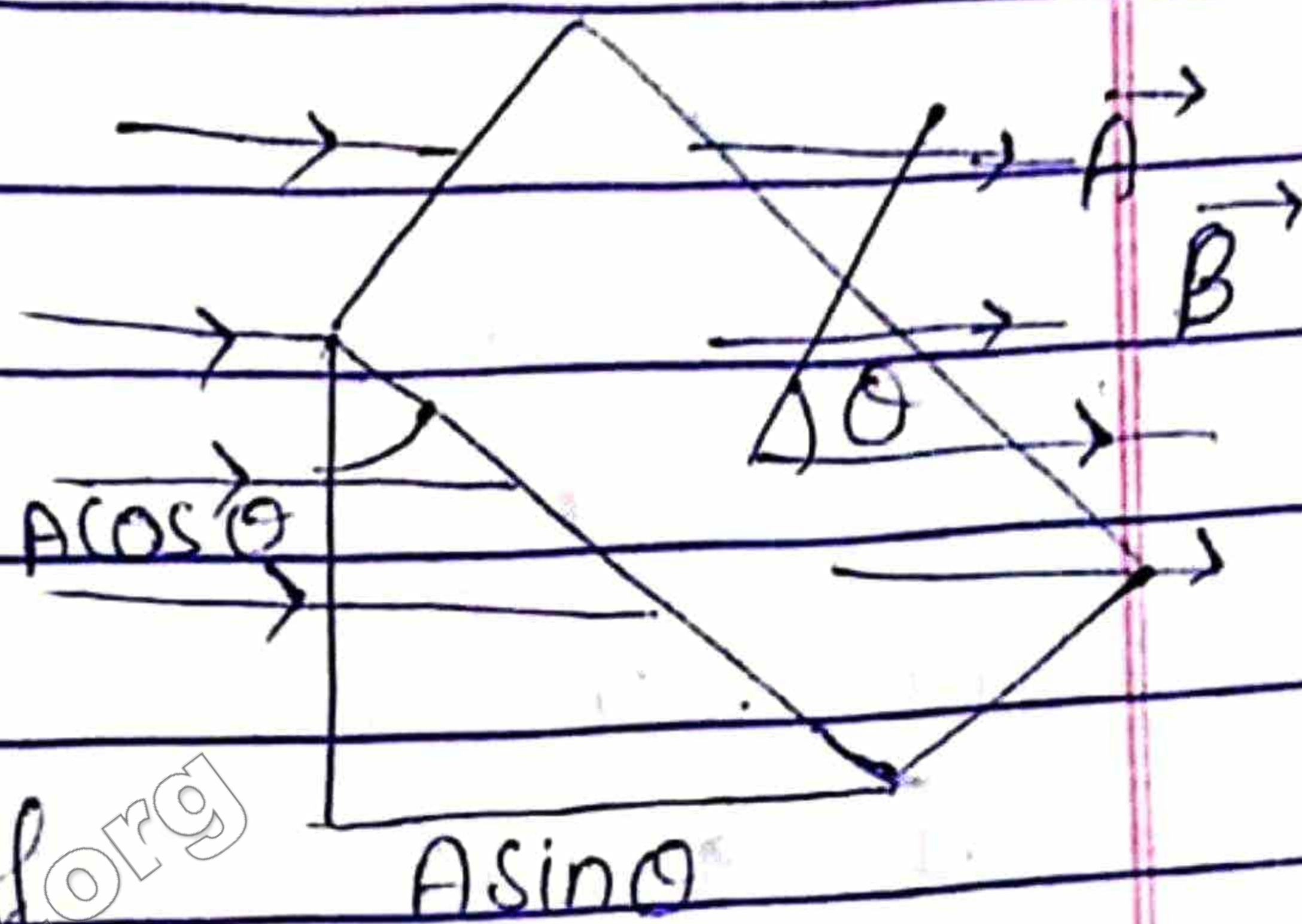
The magnetic flux is a scalar quantity.

Vector Area: The line normal to the surface is called vector Area. The magnitude of the vector area is the value of area of

the surface and direction perpendicular to the surface.

Explanation:

Consider a surface with vector area $\vec{A}$ placed in the path of



magnetic field lines. The angle between magnetic field lines and vector

Area is θ as shown in the figure. Then we resolve the vector area into

its components $A \sin \theta$ and $A \cos \theta$. The magnetic field lines are passing through the components $A \cos \theta$.

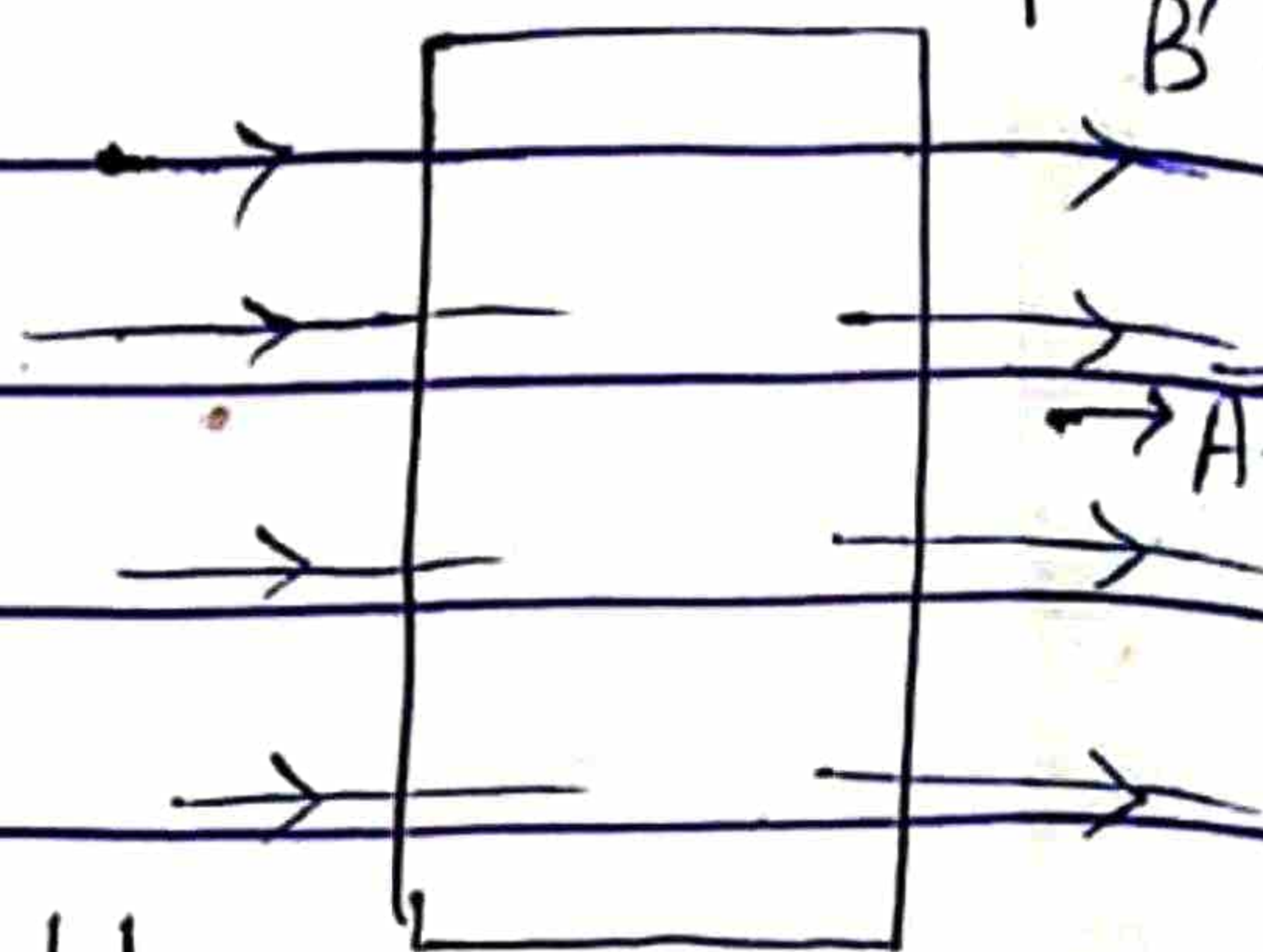
$$\phi = B(A \cos \theta)$$

$$\phi = BA \cos \theta$$

Maximum Flux:

The magnetic flux through the surface will be maximum when the surface is held

perpendicular to the magnetic field lines. In this



way magnetic field lines are perpendicular parallel to the vector area.

$$\phi = BA \cos \theta$$

$$\theta = 0^\circ$$

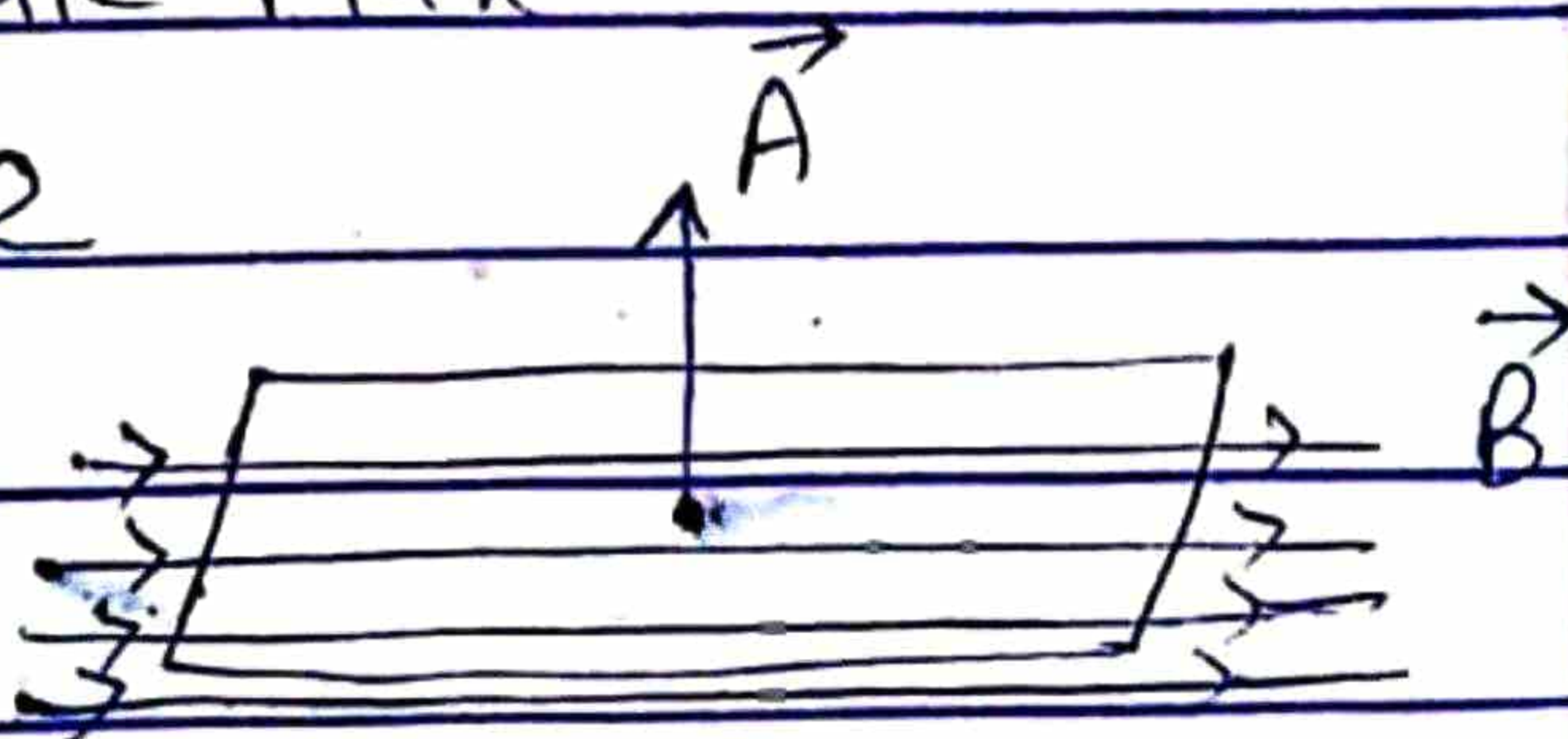
$$\phi = BA \cos(0^\circ)$$

$$\phi_{\text{max}} = BA$$



Minimum Flux:

The magnetic flux through the surface will be minimum



when surface is held parallel to the magnetic field lines. In this way

magnetic field lines are perpendicular to the Vector Area.

$$\phi = BA \cos \theta$$

$$\theta = 90^\circ$$

$$\phi = BA \cos(90^\circ)$$

$$\phi_{\min} = 0.$$



Flux density: The magnetic flux per unit area is called flux density. It is also known as magnetic induction (B). Its unit is tesla (T).

$$B = \frac{\phi}{A}$$

$$T = \frac{Wb}{m^2}$$

$$T = Wb m^{-2}$$

$$Wb = T m^2$$

Ampere's Law:

Statement:

Ampere stated that the sum of the quantities $(B \cdot \Delta L)$ for all paths element in to which the complete loop has been divided equal (μ_0) times the total current enclosed by the loop when μ_0 is constant known as permeability of free space.

In SI unit its value is $4\pi \times 10^{-7} \text{ WbA}^{-1}\text{m}^{-1}$ Mathematically.

$$(B \cdot \Delta L)_1 + (B \cdot \Delta L)_2 + \dots + (B \cdot \Delta L)_r + \dots +$$

$$(B \cdot \Delta L)_N = \mu_0 I$$

$$\sum_{r=1}^N (B \cdot \Delta L)_r = \mu_0 I$$

Where $(B \cdot \Delta L)_r$ is the value of $B \cdot \Delta L$ along the r th element and N is the total number of elements in to which the loop has been divided. This is known as Ampere's Circuital law.

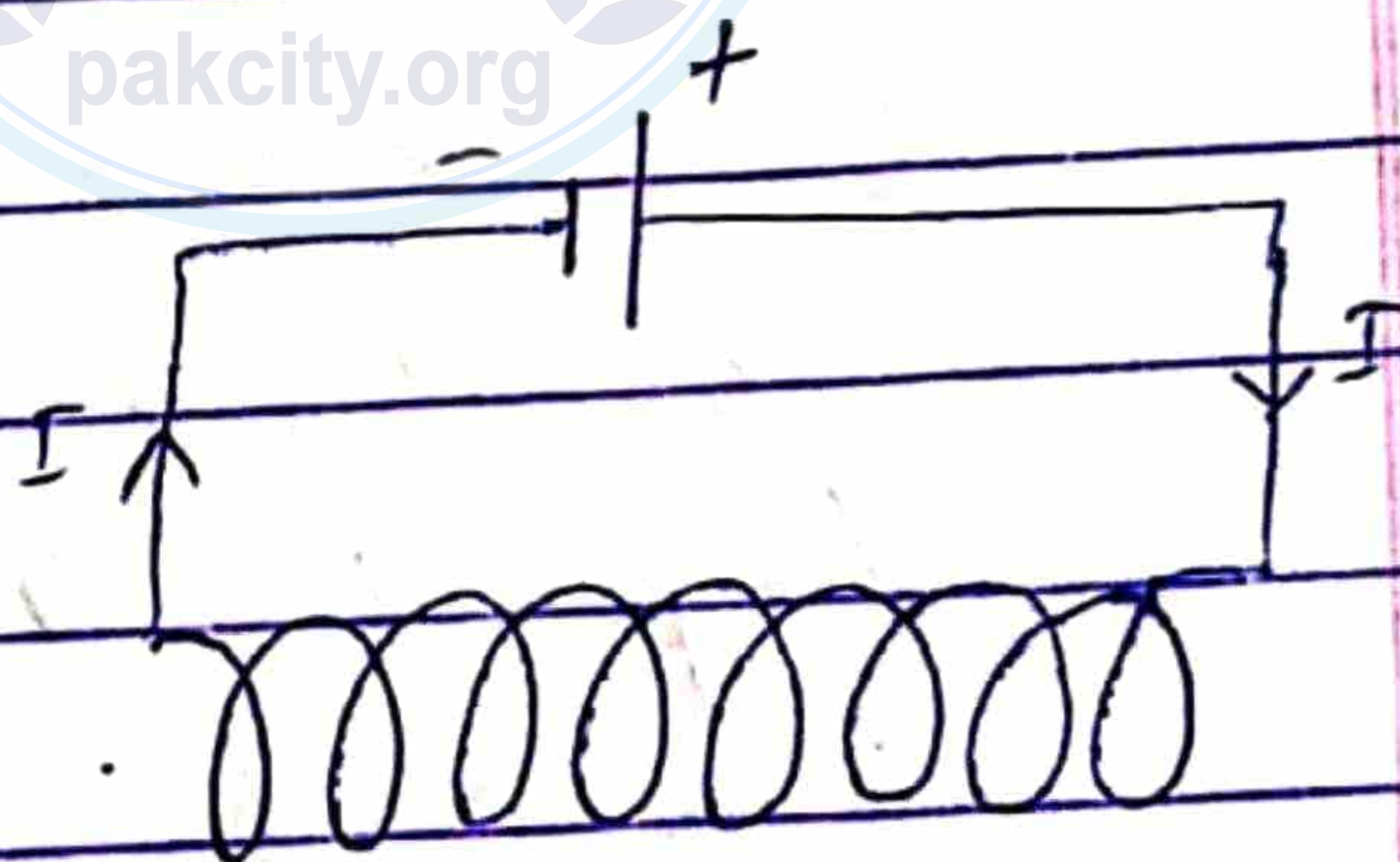
Field Due To A Current Carrying Solenoid:

Solenoid: A solenoid is a long tightly wound cylindrical coil of wire. A solenoid acts as a temporary magnet when current passes through it called electromagnet or bar magnet.

Now we will calculate an expression for the magnetic field through the solenoid.

Explanation:

Consider a solenoid having



" n " number

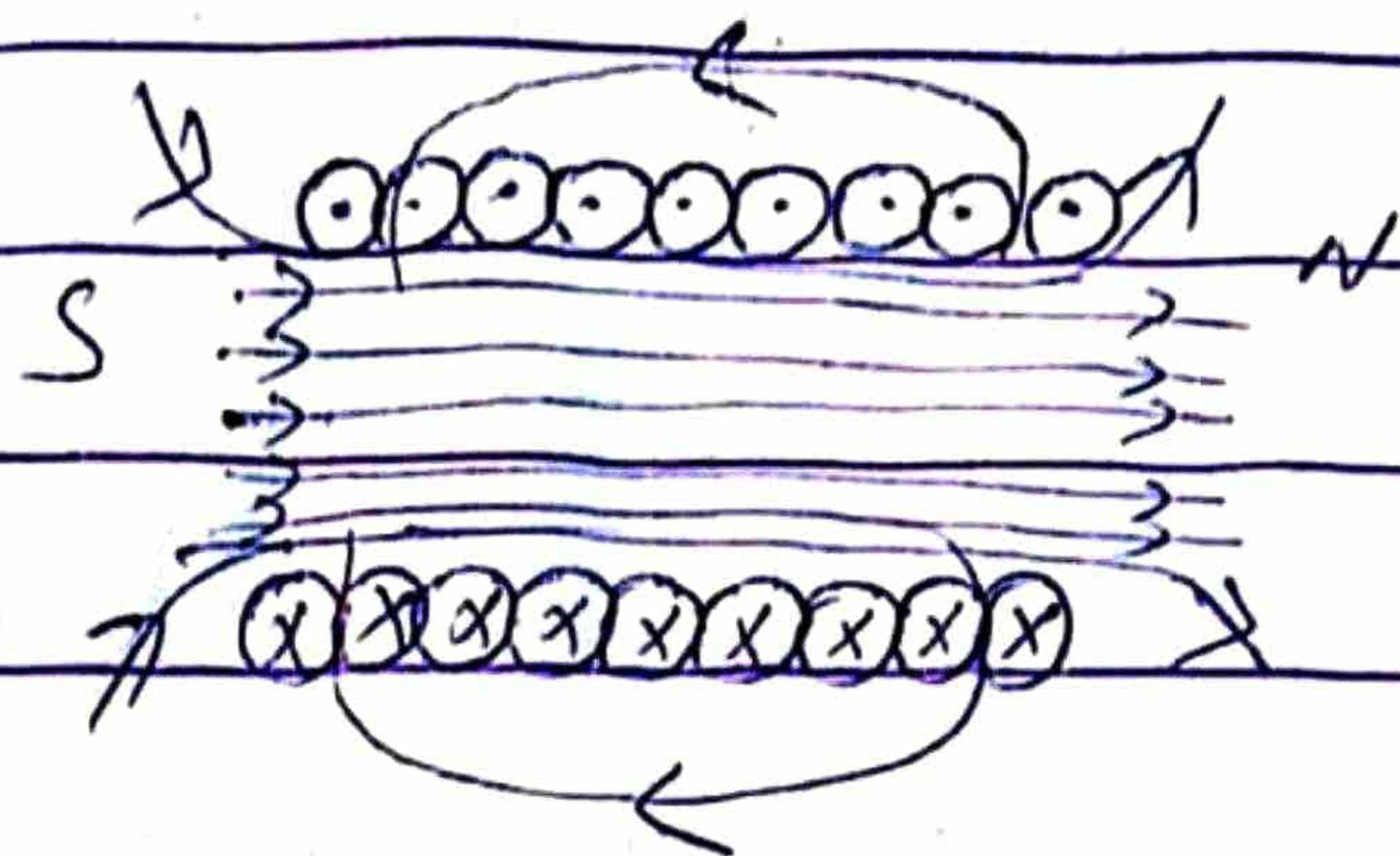
of turns per unit length.

When current passes through it, it behaves like a

bar magnet. The magnetic field inside the solenoid

is strong as compared to

the outside. The formation



of the magnetic field is shown in figure.

We consider

the

Amperean

surface

in the

form

of a rectangular box abcd

as shown in the figure

According to Ampere's law:

$$\sum_{n=1}^4 (\vec{B} \cdot \Delta \vec{L})_n = \mu_0 I$$

$$(\vec{B} \cdot \Delta \vec{L})_1 + (\vec{B} \cdot \Delta \vec{L})_2 + (\vec{B} \cdot \Delta \vec{L})_3$$

$$+ (\vec{B} \cdot \Delta \vec{L})_4 = \mu_0 (\text{current})$$

→ (1)

For side.1: For the side.1
magnetic field is parallel
to l_1 . $\theta = 0^\circ$

$$(\vec{B} \cdot d\vec{L})_1 = B l_1 \cos 0^\circ$$

$$= B l_1 (1)$$

$$(\vec{B} \cdot d\vec{L})_1 = B l_1$$



For side.2: For the side.2
magnetic field is perpendicular
to l_2 . $\theta = 90^\circ$

$$(\vec{B} \cdot d\vec{L})_2 = B l_2 \cos 90^\circ$$

$$= B l_2 (0)$$

$$(\vec{B} \cdot d\vec{L})_2 = 0$$

For side.3: The side.3 is
out of the magnetic
field. $B = 0$

$$(\vec{B} \cdot d\vec{L})_3 = B l_3 \cos \theta$$

$$= (0) l_3 \cos \theta$$

$$(\vec{B} \cdot d\vec{L})_3 = 0$$

For side.4: For the side.4 magnetic field is perpendicular to l_4 . $\theta = 90^\circ$

$$(\vec{B} \cdot \vec{dl})_4 = B l_4 \cos 90^\circ$$

$$= B l_4 (0)$$

$$(\vec{B} \cdot \vec{dl})_4 = 0$$

Now eq. (1) can be written as:

$$B l_1 + 0 + 0 + 0 = \mu_0 (\text{total current})$$

$$B l_1 = \mu_0 (\text{total current})$$

The total current passing through the solenoid having n number of turns per unit length.

$$B l_1 = \mu_0 (n l_1 I)$$

$$B = \mu_0 n I$$

Direction of $\vec{B}$:

Hold the solenoid in the right hand with fingers curling in the direction of the current, the thumb will point in the direction of the field.



Force On A Moving Charge In A Magnetic Field:

Introduction: We know that when a current carrying conductor is placed in an external magnetic field, a magnetic force acts on the conductor. This force is actually acting on the charges present in the conductor. Now we will calculate the force acting on a single charge.

Explanation: Consider a piece of conductor having length L and cross sectional area A as shown in the

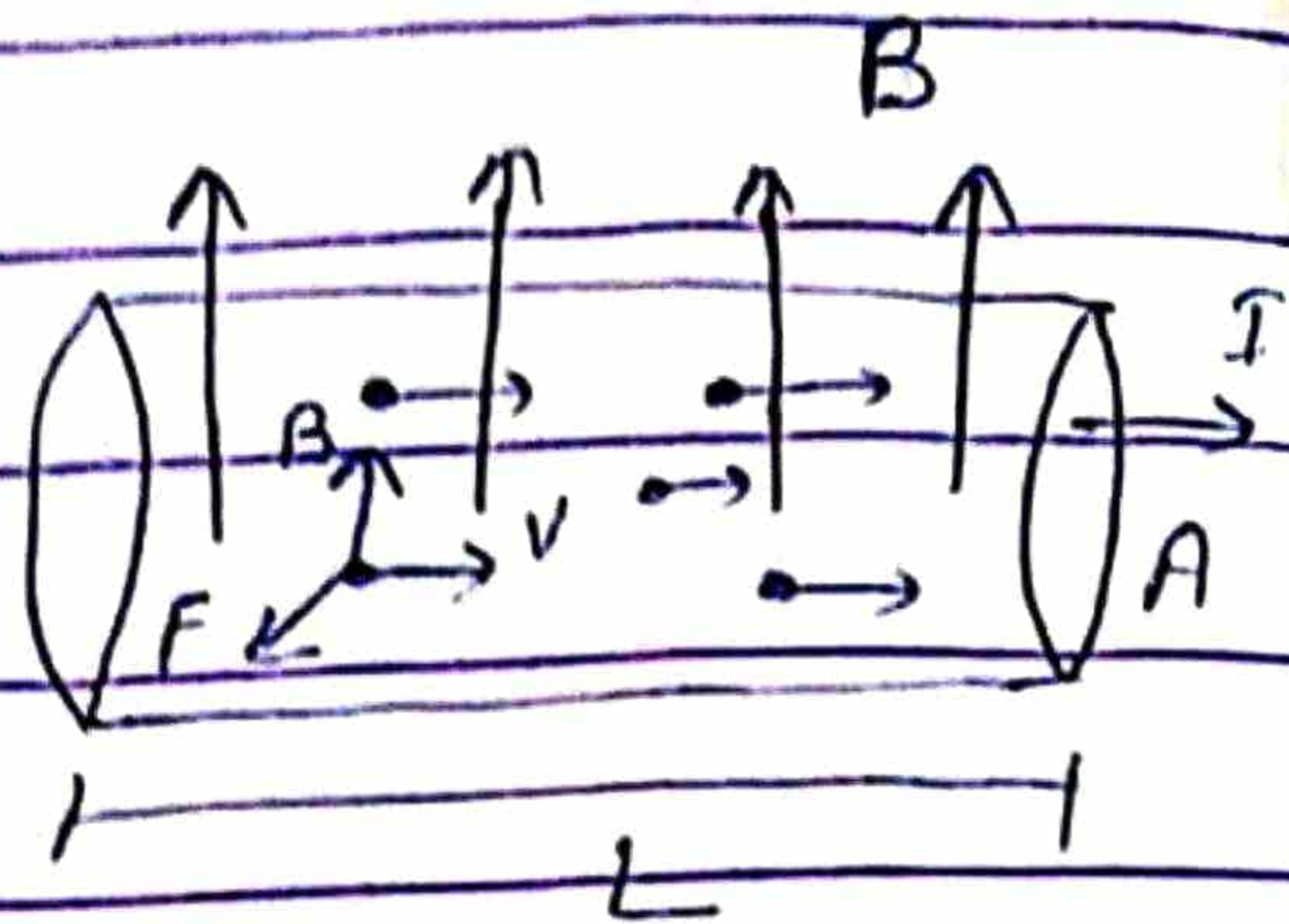


figure. This conductor is placed in an external magnetic field B , the current I is flowing due to n number of charges per unit volume. Let ΔQ be the total charge in this piece, while q is the charge on a single particle. Then

$$\Delta Q = nALq$$

If Δt is the time for the flow of ΔQ amount of charges. Then current will be:

$$I = \frac{\Delta Q}{\Delta t} \rightarrow (1)$$

we know that

$$S = vt$$

$$t = \frac{S}{v}$$

So,

$$\Delta t = \frac{L}{v}$$

Now eq. (1) can be written as:

$$I = \frac{nALv}{\frac{L}{v}}$$

$$I = nAqv$$

$$I = nAqv$$



The force acting on a current carrying conductor placed in the external magnetic field is:

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

$$\vec{F} = nAqv(\vec{L} \times \vec{B}) \rightarrow (2)$$

As the direction of length and velocity is same. we can conclude that

$$v \vec{L} = v L \hat{i} \quad (\because \hat{A} = \frac{\vec{A}}{A})$$

As $\hat{i} = \hat{v}$

So,

$$= v L \hat{v}$$

$$v \vec{L} = L \vec{v}$$

Now eq. (6) can be written as:

$$\vec{F}_L = n A q L (\vec{v} \times \vec{B})$$

This is the amount of magnetic force acting on the conductor of length L .
Now the force acting on a single charge will be:

$$\vec{F} = \frac{\vec{F}_L}{n A L}$$

$$\vec{F} = \frac{n A q L (\vec{v} \times \vec{B})}{n A L}$$

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

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

Here θ is the angle b/w $\vec{v}$ and $\vec{B}$

Direction of force:

The direction of force can be determined by the right hand rule.

Curl the fingers of right hand from $\vec{v}$ to $\vec{B}$, then erect thumb will show the direction of force.



Magnetic force for electron and proton:

As there are two types of charges i.e. positive (protons) and negative (electrons) so, the magnetic force for both the charges will be different.

Force on proton;

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

Force on electron;

$$\vec{F} = -e (\vec{v} \times \vec{B})$$

When an electron and proton enter in the magnetic field, they will be deflected in

opposite direction due to magnetic forces. If electron moves in right side, then proton will move towards left.

Maximum Force:

The magnetic force acting on the charge will be maximum when it enters perpendicular to the magnetic field.

$$F = qvB \sin \theta$$

here $\theta = 90^\circ$

$$F = qvB \sin 90^\circ$$

$$F = qvB$$

Minimum Force:

The magnetic force acting on the charge will be minimum when it enters parallel or anti-parallel to the magnetic field.

$$F = qVB \sin 0^\circ$$

$$= qVB (0)$$

$$F = 0$$

$$F = qVB \sin 180^\circ$$

$$= qVB (0)$$

$$F = 0$$

Lorentz Force:



The sum of electric force and magnetic force acting on a charge is called Lorentz force.

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

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

It should be noted

that the work is done by the electric force while magnetic force is only a deflecting force. There is no work done by magnetic force.

✓ Determination Of e/m Of An Electron:

When a beam of electrons enters in the magnetic field, a magnetic force acts on the electrons that deflect them. The force is given by:

$$\vec{F} = -e (\vec{v} \times \vec{B})$$

Due to this magnetic force, the electron starts moving in the circle. The magnitude of

force is:

$$F_b = e v B \sin \theta$$

The angle between

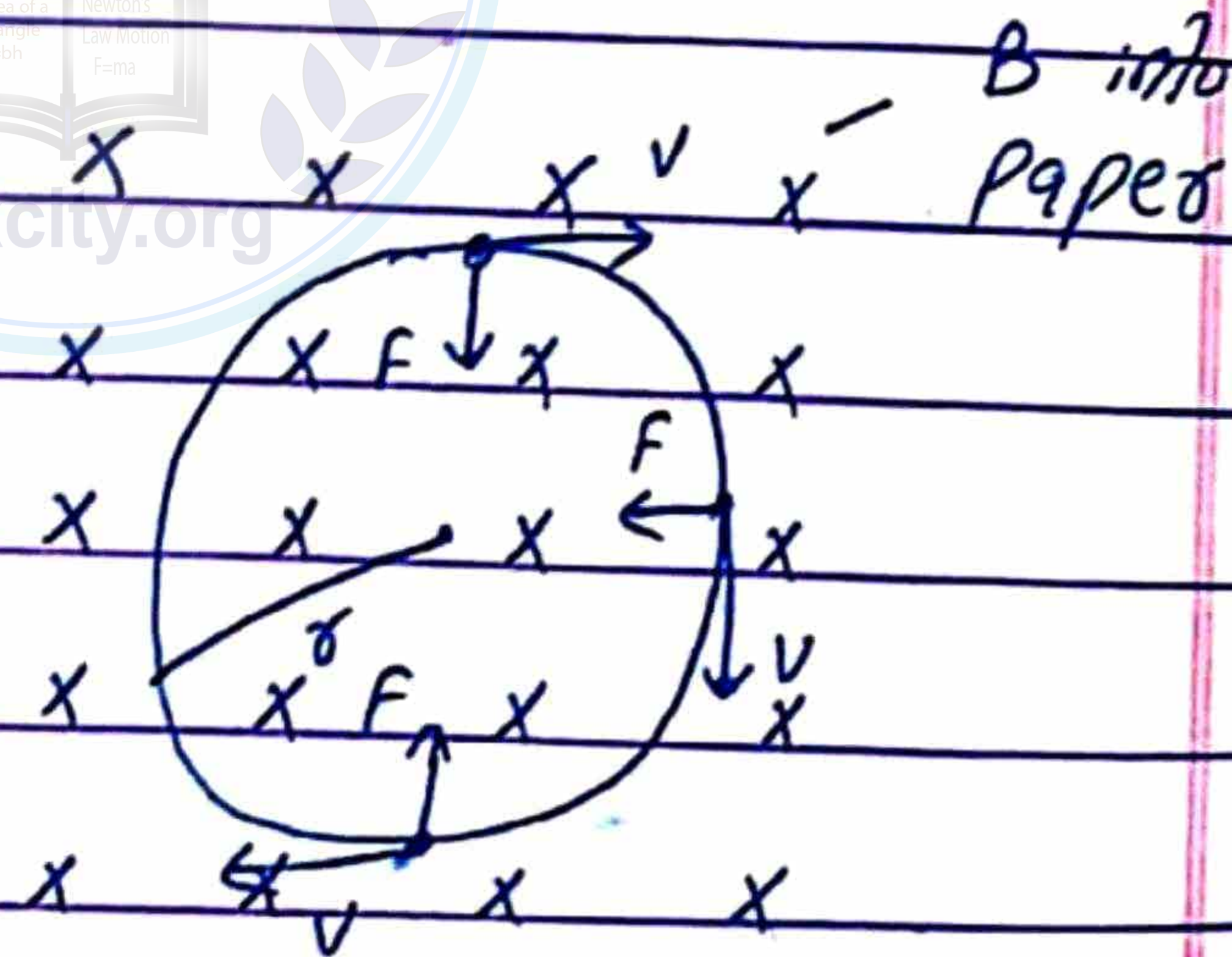
v and B is 90° . So,

$$F_b = e v B \sin 90^\circ$$

$$= e v B (1)$$

$$F_b = e v B$$

The centripetal force is provided by the magnetic



force to the electrons. so,

magnetic force = centripetal force

$$e v B = \frac{m v^2}{r}$$

$$\frac{e}{m} = \frac{v}{B r} \rightarrow (1)$$

By the above expression we can calculate the value of $\frac{e}{m}$ if we know the values of v , B and r .

The value of magnetic field intensity is known because it is externally provided.



Determination of " r ":

To determine the radius of the circle in which electrons are moving we fill the hydrogen gas in the tube where this experiment is being performed. When the electrons collide

with the atoms of hydrogen gas, they become excited and they emit light when comes back to the ground state. In this way, the trajectory of electrons becomes illuminated. We measure the diameter of the circle with the help of a scale and then calculate the radius of the circle.

Determination of "V":

When the electron is moving in the circle it has kinetic energy and it also possess electric energy due to the potential difference "V" now comparing these two energies:

$$K.E = \text{electric energy}$$

$$\frac{1}{2} m v^2 = eV$$

$$v^2 = \frac{2Ve}{m}$$

$$v = \sqrt{\frac{2Ve}{m}}$$

By putting this expression in eq. (1)

$$\frac{e}{m} = \frac{\sqrt{\frac{2Ve}{m}}}{B\lambda}$$

Taking square on both sides:



$$\frac{e^2}{m^2} = \frac{2Ve}{m B^2 \lambda^2}$$

$$\frac{e^2}{m^2} = \frac{2V\cancel{e}}{\cancel{m} B^2 \lambda^2}$$

$$\frac{e}{m} = \frac{2V}{B^2 \lambda^2}$$

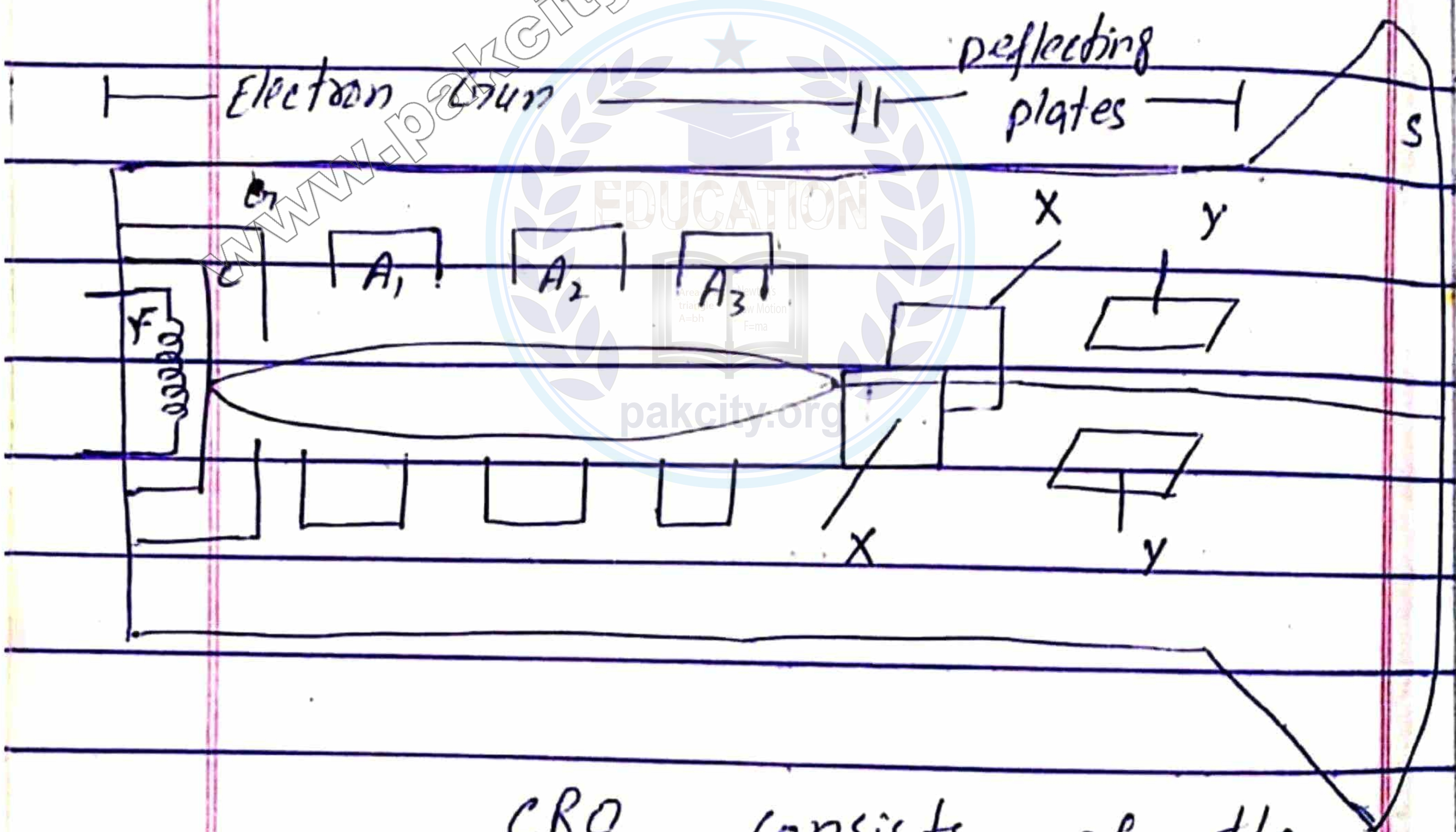
By this expression we can determine the value of $\frac{e}{m}$ of the electron.

Cathode Ray Oscilloscope:

Defination: CRO is very versatile electronic instrument which is, infact, a high speed graph plotting device.

Principle: It works by deflecting beam of electrons as they pass through uniform electric field between the two sets of parallel plates.

Construction:



CRO consists of the

following parts:

i- Filament (F)

ii- Cathode (C)

iii- Grid (G)

iv- Fluorescent screen (S)

v- Anodes (A_1, A_2, A_3)

- vi- Horizontal deflecting plates (X, X)
- vii- Vertical deflection plates (Y, Y)

Working:



The filament is heated with the help of applied potential difference.

In this way, electrons are emitted through the cathode.

These electrons pass through the anodes A_1 , A_2 and A_3

and are accelerated. Then electrons pass through the deflecting plates. Here the signal is provided according to which the waveform is produced.

Now electrons fall on the screen and illuminated spot is made.

Grid: The grid has negative potential and it controls the number of electrons moving through it. So, it

controls the brightness of the screen.

✓ Sweep or time base generator:

The voltage that is applied across the x plates is usually provided by the

circuit that is built.

the CRD. It is known as

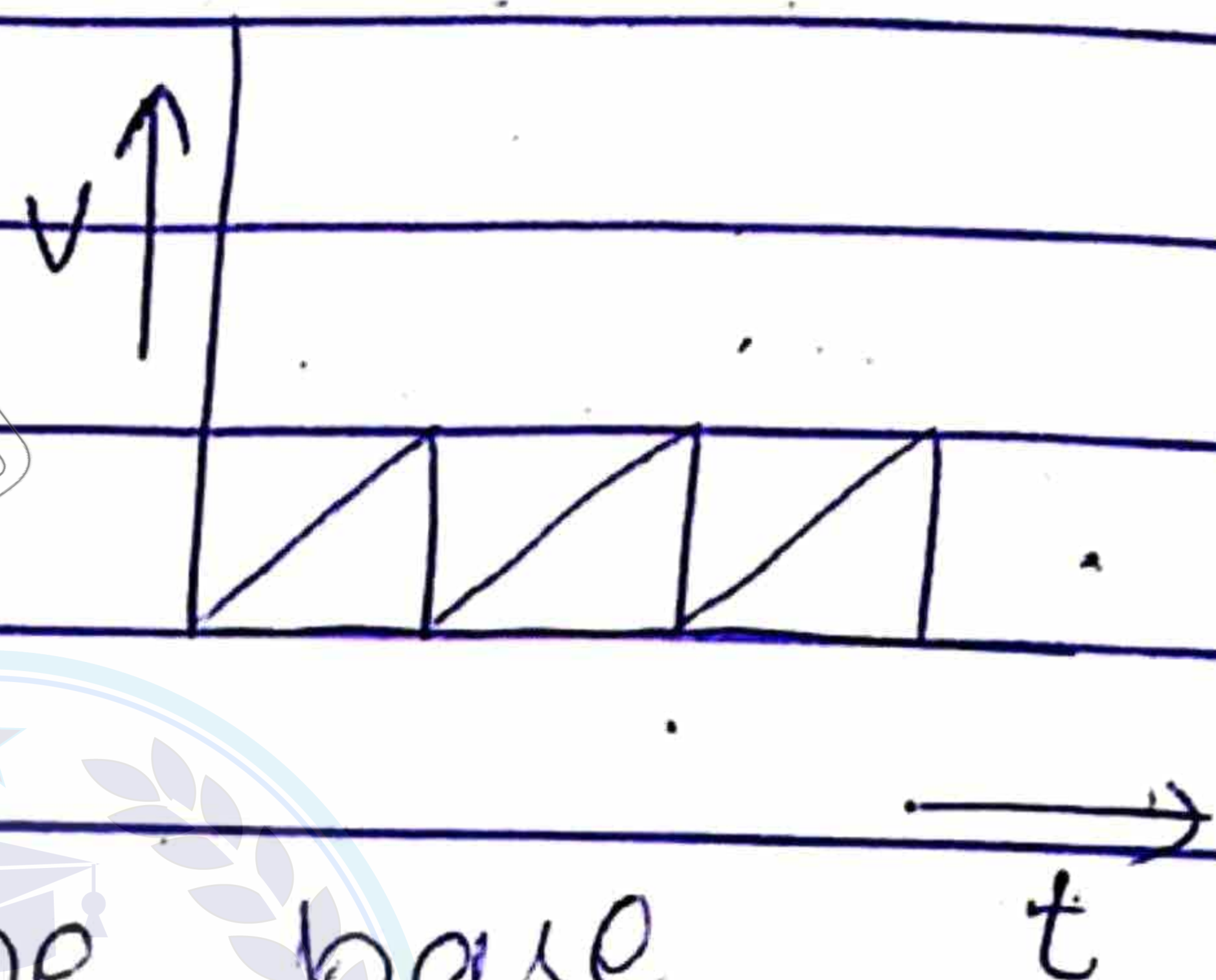
sweep or time base generator. Its output waveform

is a saw tooth voltage of period T . The voltage increases linearly with time for a period T and then drops to zero. As this

voltage is impressed across the x-plates, the spot is

deflected linearly with time along the x-axis for a time T . Then the

spot returns to its



starting point. on the screen very quickly because a saw tooth voltage rapidly falls to its initial value at the end of each period.

✓ Sinusoidal voltage:



If a sinusoidal voltage is applied across the y-plates when simultaneously, the time base voltage is impressed across the x-plates, the sinusoidal voltage, which itself gives rise to a vertical line, will now spread out and will appear as a sinusoidal trace on the screen. (graph from Book)

uses of CRO:



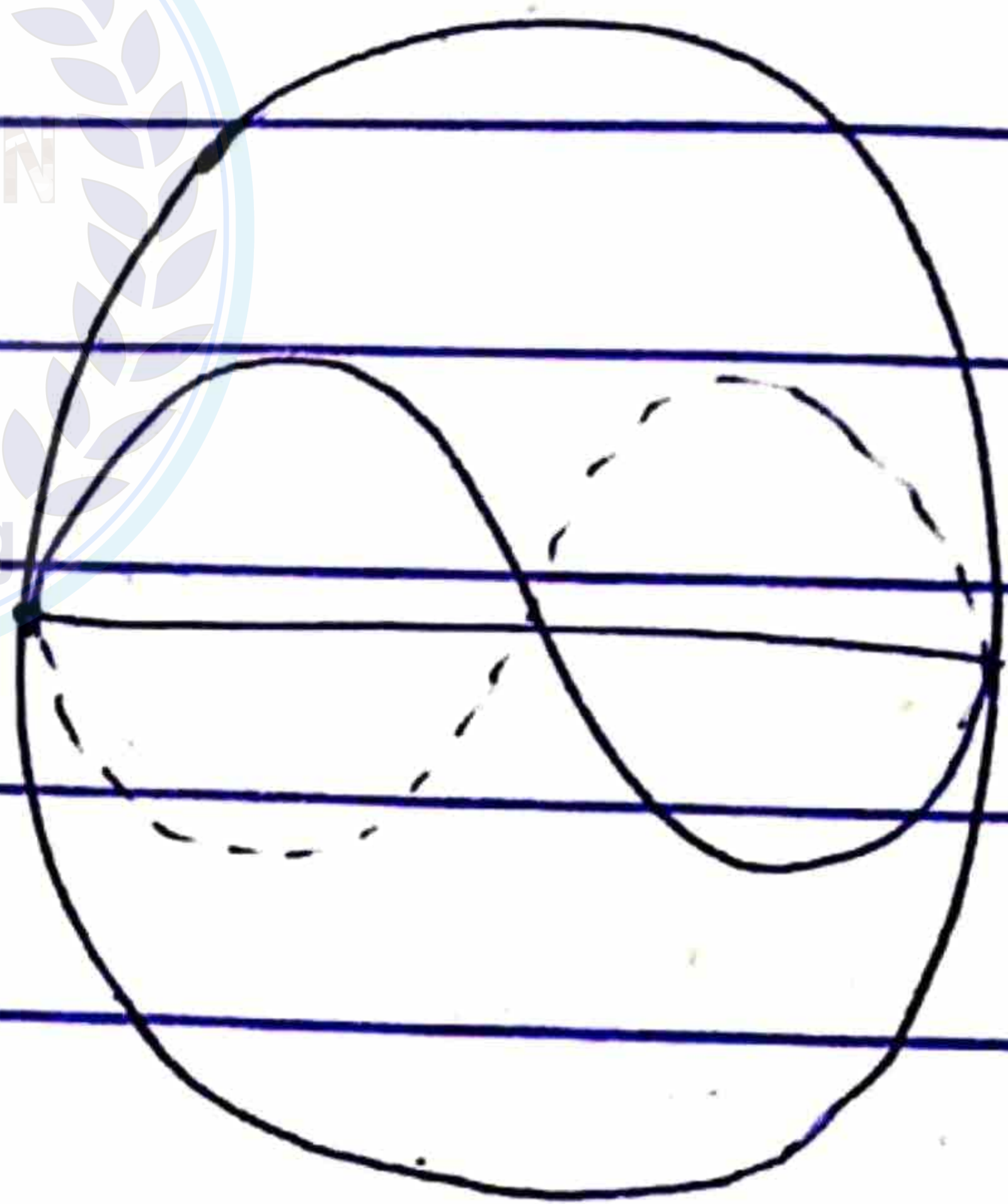
- 1- The CRO is used for displaying the waveform of a given voltage.
- 2- Once the waveform is displayed, we can measure the voltage, its frequency

and phases.

3- We can easily find the instantaneous value and peak value of the voltage.

4- The time period can also be determined by using the time calibration of x-axis.

5- Information about the phase difference between two voltages can be obtained simultaneously displaying their wave forms.



★ Forexample: The phase difference b/w these voltages is 180° .

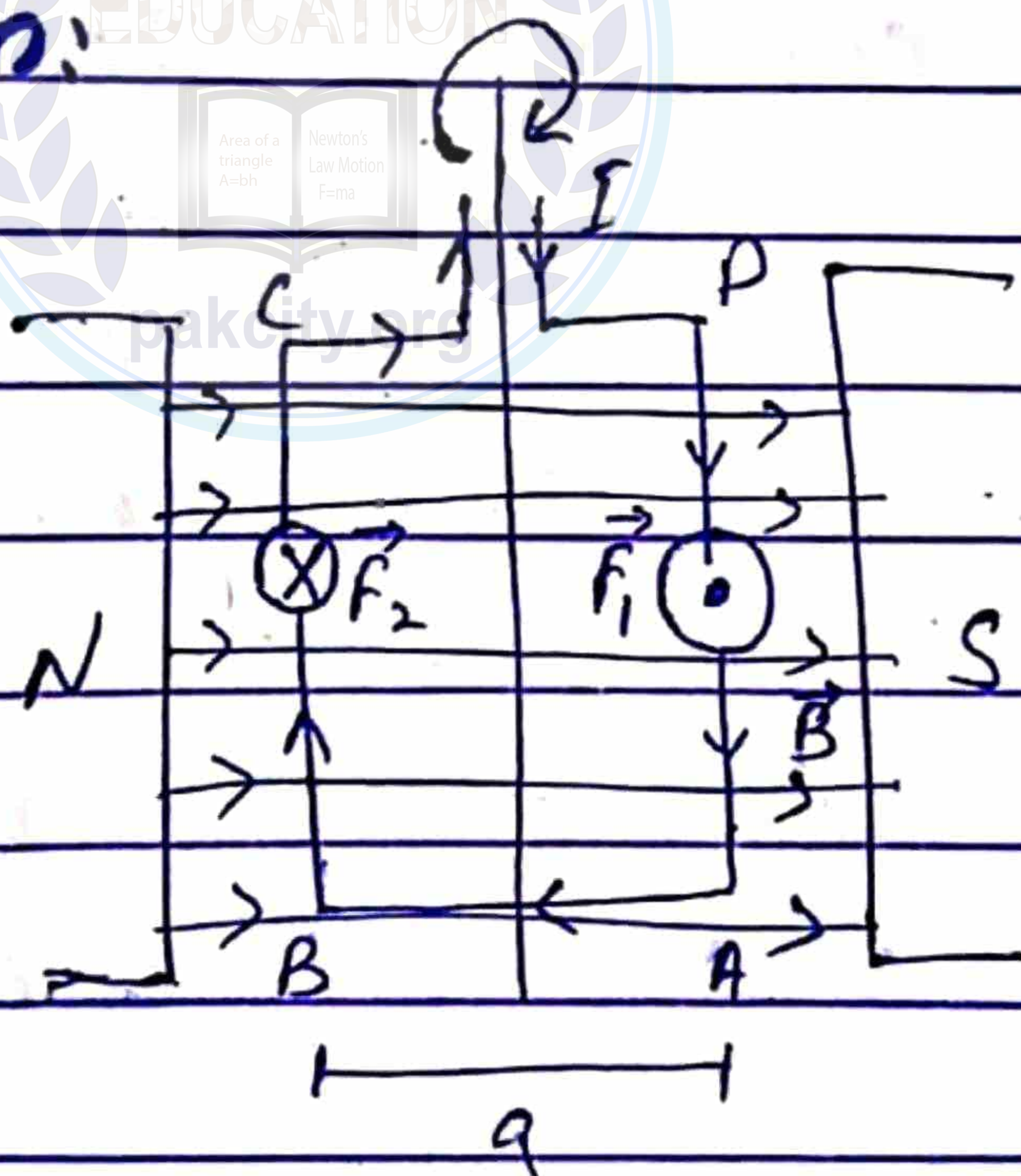
Torque On A Current Carrying Coil:



Defination: The turning effect of a force is called torque. When a current carrying coil is placed in the magnetic field, torque is produced in the coil due to forces acting on the sides of the coil.

Explanation:

Consider a coil ABCD of length l and width a placed in the magnetic field



as shown in the figure. The current I is flowing through the coil. The force acting on the sides of the

coil will be

$$F = BIL \sin \alpha$$

Forces along sides AB and CD:

For these two

sides AB and CD the angle α is either 180° or 0° . So, the magnetic force for these two sides will be zero.

$$F_{AB} = F_{CD} = 0$$



Forces along DA and BC:

For these two sides

DA and BC the angle α is 90° . So, magnetic force for these sides:

$$\begin{aligned} F_1 = F_2 &= BIL \sin 90^\circ \\ &= BIL (1) \end{aligned}$$

$$F_1 = F_2 = BIL$$

Direction of forces F_1 and F_2 :

we curl the

fingers of right hand from the direction of current to

magnetic field, then erect thumb will show the direction of force. So, $\vec{F}_1$ is acting outward while $\vec{F}_2$ is acting inward.



Torque / couple in the coil:

As the forces $\vec{F}_1$ and $\vec{F}_2$ are acting opposite. So, torque will be produced in the coil. The coil will move clock-wise.

$$\text{Torque} = \text{force} \times \text{moment arm}$$

$$\tau = (BIL)(a)$$

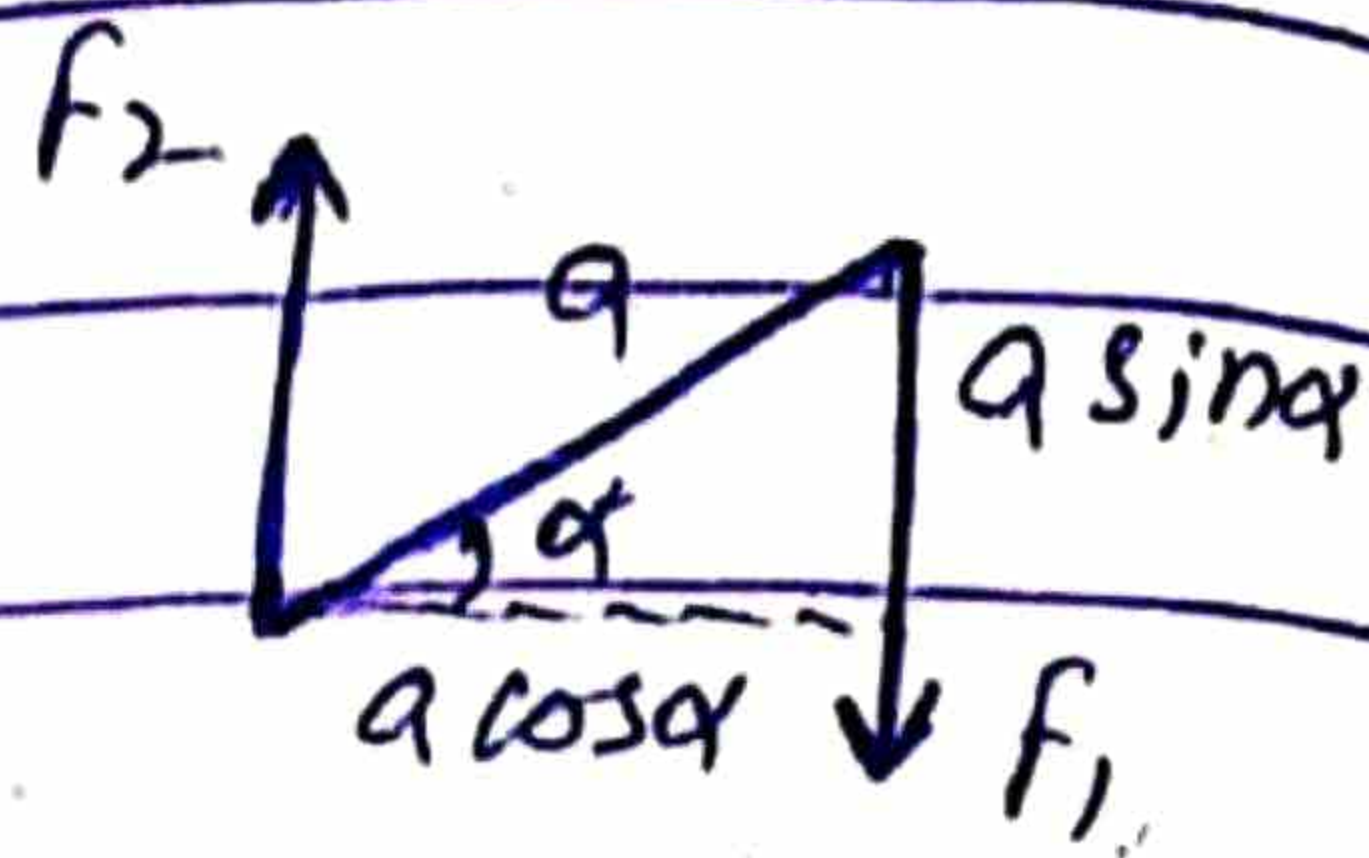
$$\tau = BI(La)$$



$$\tau = BIA$$

where A is the area of the coil.

If the coil makes an angle α with the magnetic field.



Then $a \cos \alpha$ will be the moment arm as shown in the figure.

$$\tau = (BIL)(a \cos \alpha)$$

$$\tau = BIA \cos \alpha$$

Maximum Torque:



For the maximum torque the angle α between magnetic field and coil should be 0° .

$$\tau = BIA \cos 0^\circ$$

$$= BIA (1)$$

$$\tau = BIA$$

Minimum Torque:

For the minimum torque the angle α between magnetic field and coil

should be 90°

$$\tau = BIA \cos(90)$$

$$\tau = BIA (0)$$

$$\tau = 0.$$

Galvanometer:

Defination: It is an electrical instrument which is used to detect the passage of current.

Working principle:

Its working depends upon the fact that when a conductor is placed in a magnetic field it experience a force. as soon as the current passes through it. Due to this force a torque act upon the conductor if it is in the form of a coil or loop.

$$\tau = NIAB \cos \alpha.$$

N is the number of turns in the coil, A is its area, I is the current passing through it. and B is the magnetic field in which the coil is placed such that it makes an angle α with the direction of B .

✓ Construction:

A rectangular coil is suspended between the concave

shaped poles N and S of a U-shaped magnet with the help of a fine metallic

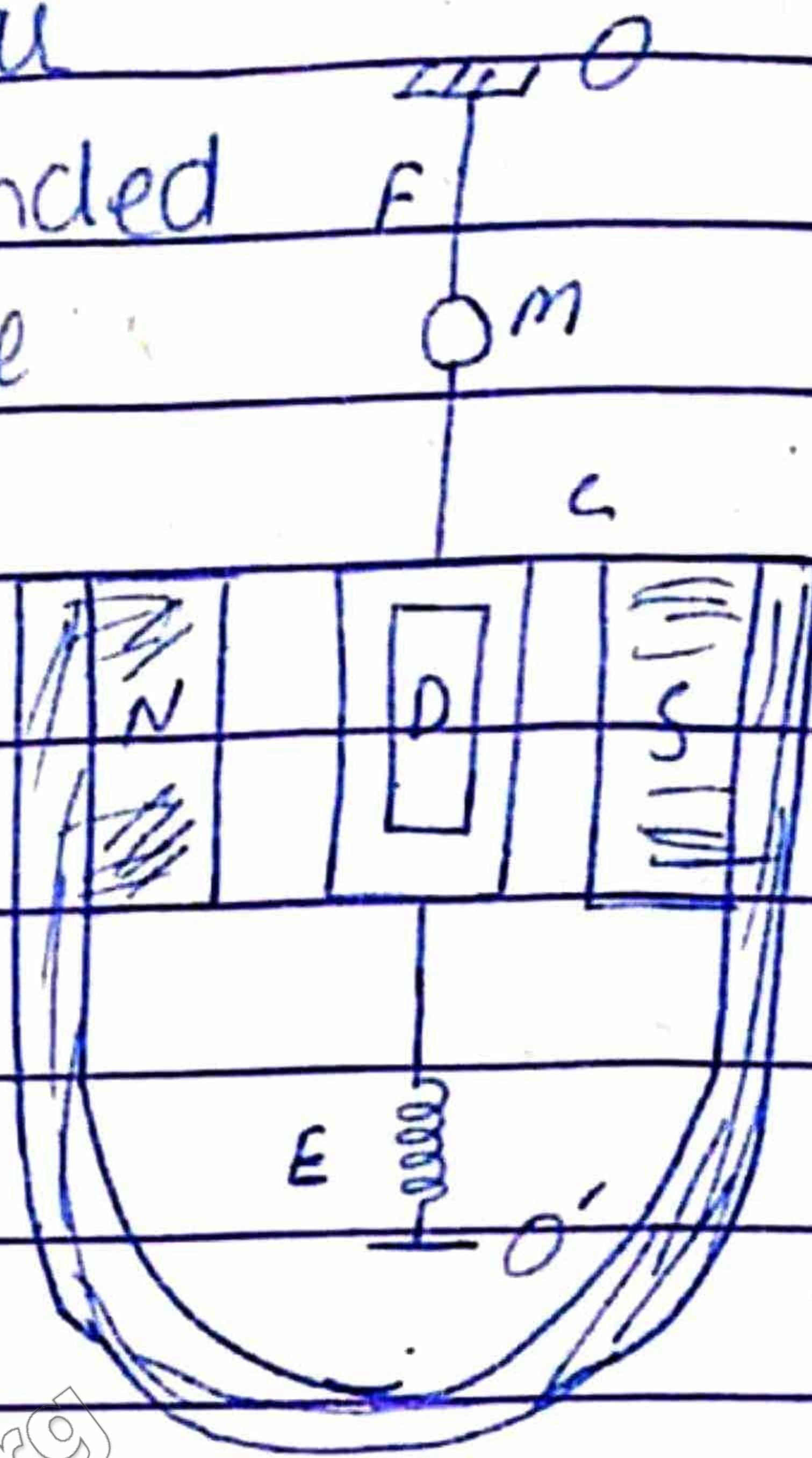
suspension wire. It is wound on a frame of non-magnetic material. The

suspension wire S is also used as one current leads

to the coil. The other terminal of the coil is connected to a loosely

wound spiral E which serve as the second current

lead. A soft iron cylinder D is placed inside the coil to make the field radial and stronger near the coil.



Deflecting couple:

When the current passes through the coil torque will be produced, this torque is called deflecting couple. Given by:

$$\tau = N A I B \cos \alpha$$

As the coil is placed parallel to the magnetic field. $\alpha = 0^\circ$

$$\text{deflecting couple} = N A I B \cos 0^\circ$$
$$= N A I B \quad (1)$$

$$\text{deflecting couple} = N A I B$$



Restoring torque:

Due to deflecting couple a twist will be produced in the spiral. After the current the spiral will untwist the coil, this torque is called restoring torque.

$$\text{restoring torque} = c \theta$$

Here c is the

proportionality constant called

torsional couple.



Torsional couple:

The couple for unit twist is torsional couple. It is denoted by c .

As the coil comes back to its initial rest position, so,

deflecting couple = restoring torque

$$NAB = c\theta$$

$$I = \frac{c\theta}{NAB}$$

$$I = (\text{constant}) \theta$$

$$I \propto \theta$$

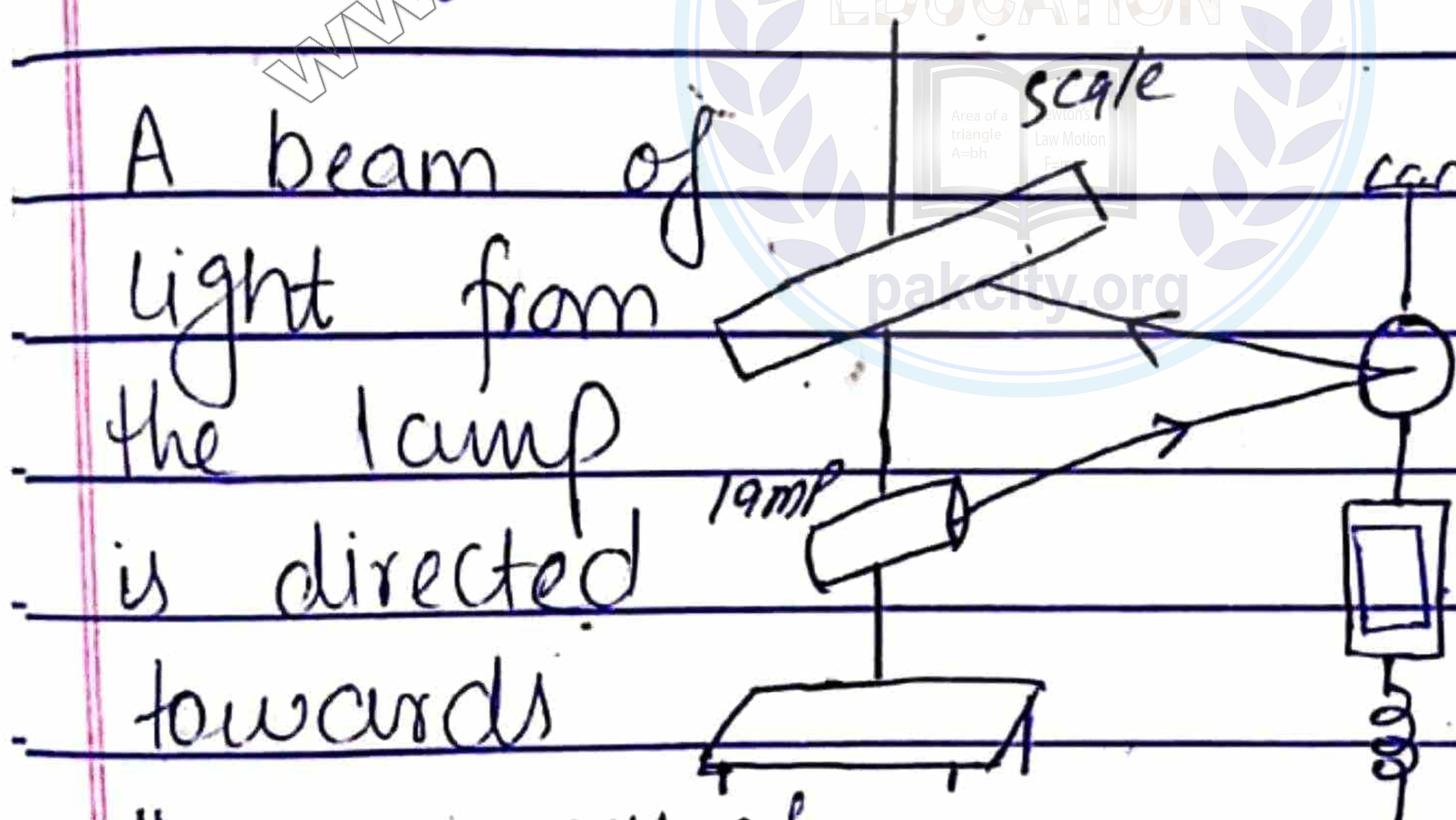
Above relation shows that the current flowing through the coil depends directly to the angle of deflection θ .

Measurement of angle of deflection (θ):

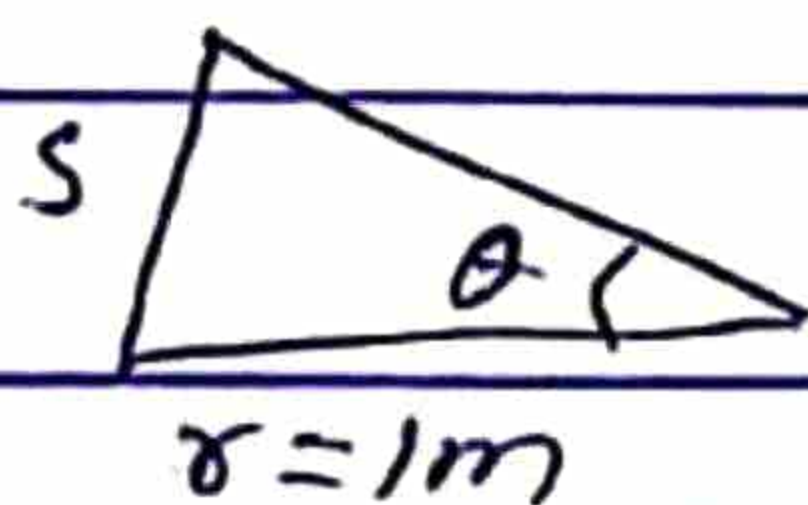
There are two methods to measure the angle of deflection.

- i- Lamp and scale arrangement
- ii- Pivoted type galvanometer

i- Lamp and scale arrangement:



A beam of light from the lamp is directed towards the mirror of the galvanometer. After reflection from the mirror it produces



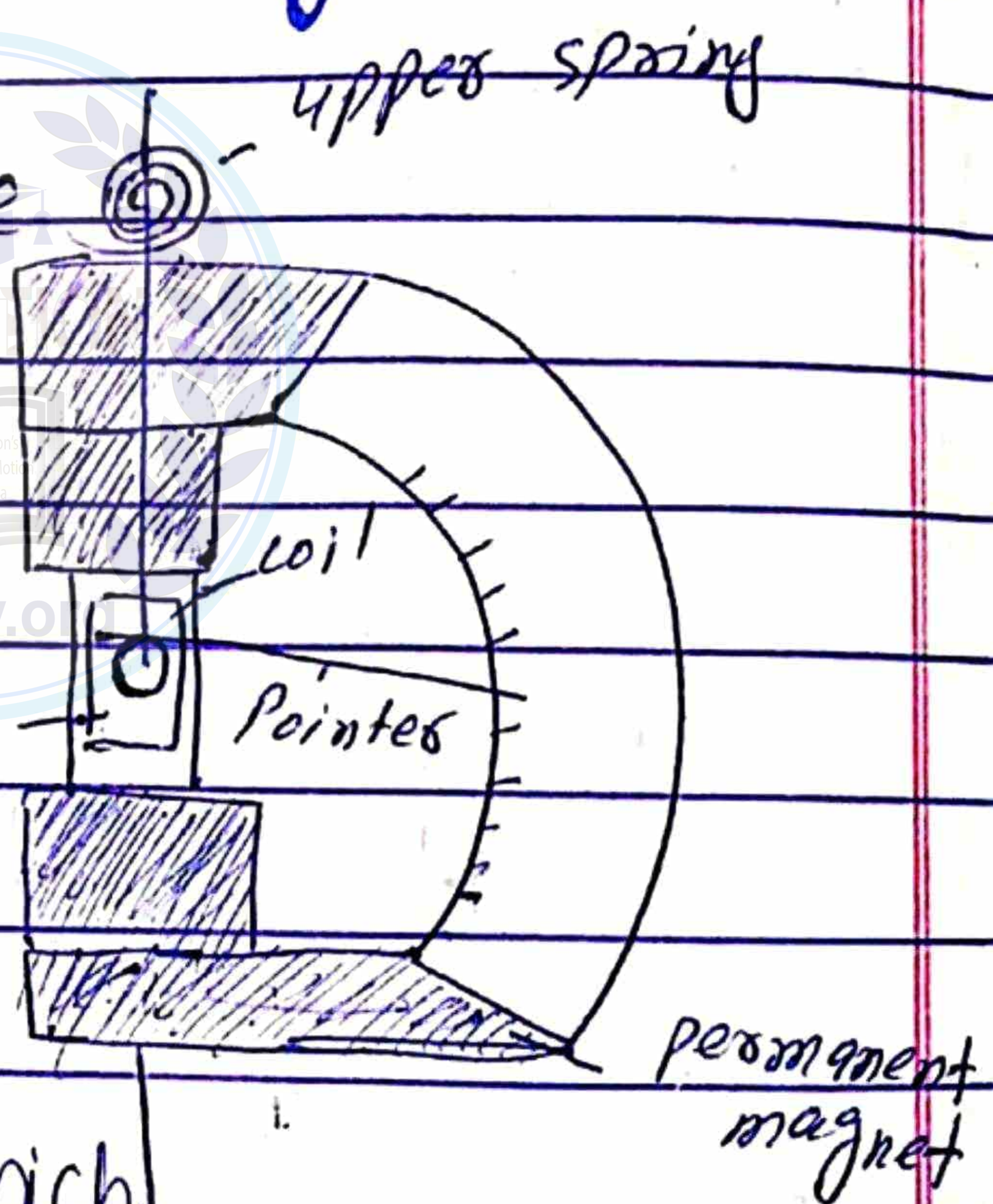
a spot on the translucent scale placed at a distance of one meter from the galvanometer. When the

coil rotate, mirror attached to the coil also rotates and spot light moves along the scale. The displacement of the spot of light on the scale is proportional to the angle of deflection.

ii- Pivoted type galvanometer:

In this type of galvanometer the coil is pivoted between two jewelled bearings.

The Restoring torque is provided by two hairs springs which also serve as



Current leads. A light aluminium pointer is attached to the coil which moves over a scale. It gives the angle of deflection of the coil.

Sensitivity of galvanometer:

The galvanometer will be more sensitive if it measures the small current. To make the galvanometer more sensitive the term $\frac{C}{BAN}$ should be small. Now we will discuss the terms individually.

i- To make the torsional couple (C) small the length the suspension wire should be large, it is not suitable.

ii- The greater number of turns (N) will make the coil more heavy and it is also not a suitable method.

iii- The greater coil will be more sensitive but it is also a not suitable method.

iv- For more sensitive galvanometer a strong magnet should be used and it is the only suitable method.

Types: There are two types of galvanometers.

i- Stable / Dead beat galvanometer:

Such galvanometer in which the coil comes to rest quickly after the current passed through it or the current is stopped from flowing through it. is called stable or dead beat galvanometer.

ii- Unstable galvanometer:

Such galvanometer in which the coil does not comes to rest quickly after the current passed through it or the current is stopped from flowing through it is called unstable galvanometer.

Ammeter:

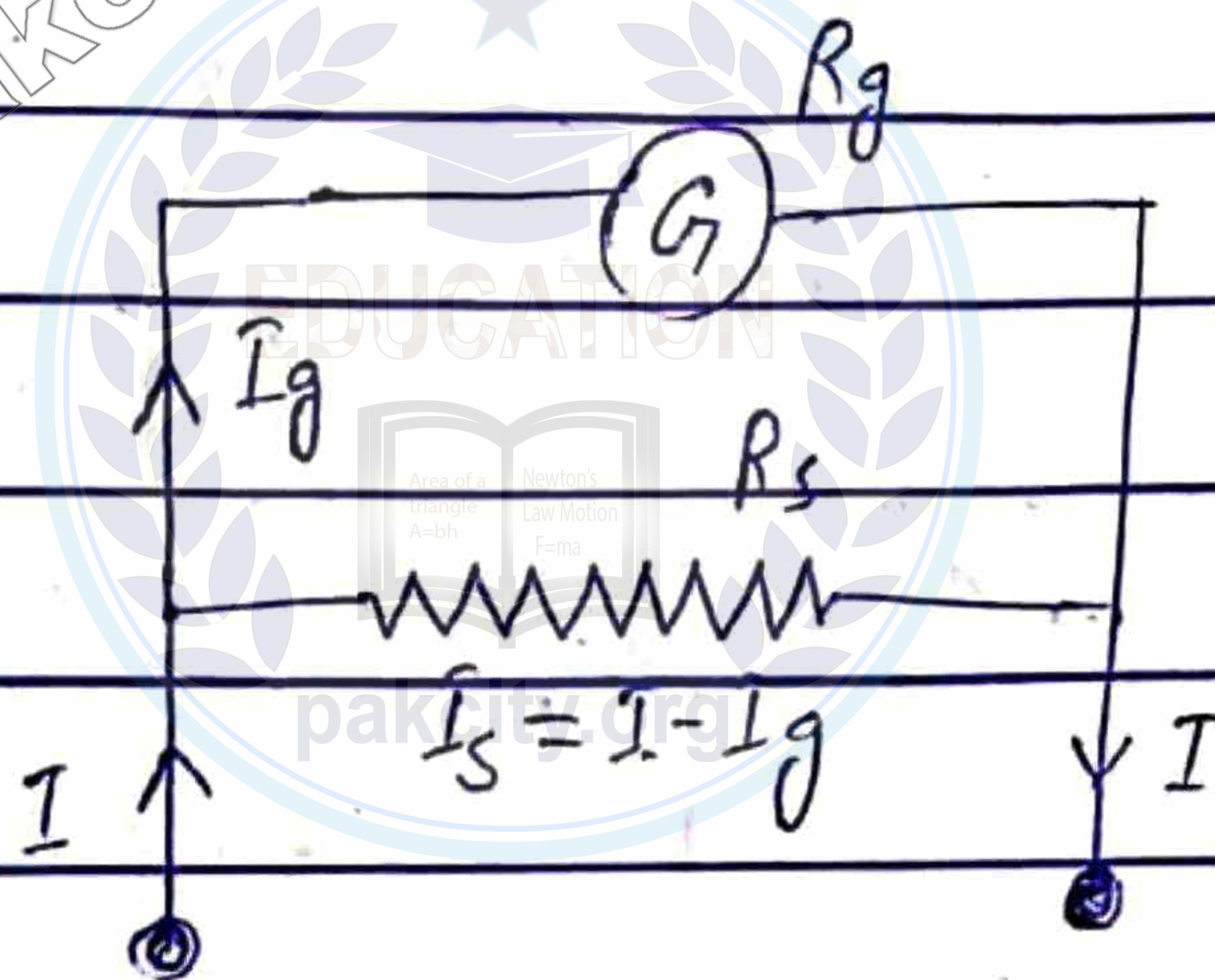
An ammeter is an electrical instrument which is used to measure current in amperes.

Construction:



To convert galvanometer into ammeter, a shunt resistance is connected parallel to it.

The circuit diagram is shown.



Calculation of shunt resistance

Consider the circuit in which shunt resistance R_s is connected parallel to the galvanometer of resistance R_g . The total current is I which is divided into I_g and I_s as shown in the figure. As

in the parallel combination potential difference remains same. So,

$$\begin{aligned} V_g &= V_s \\ I_g R_g &= I_s R_s \end{aligned}$$

$$I_g R_g = (I - I_g) R_s$$

$$\frac{I_g}{I - I_g} R_g = R_s$$

$$R_s = \left(\frac{I_g}{I - I_g} \right) R_g$$

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Use of shunt resistance:

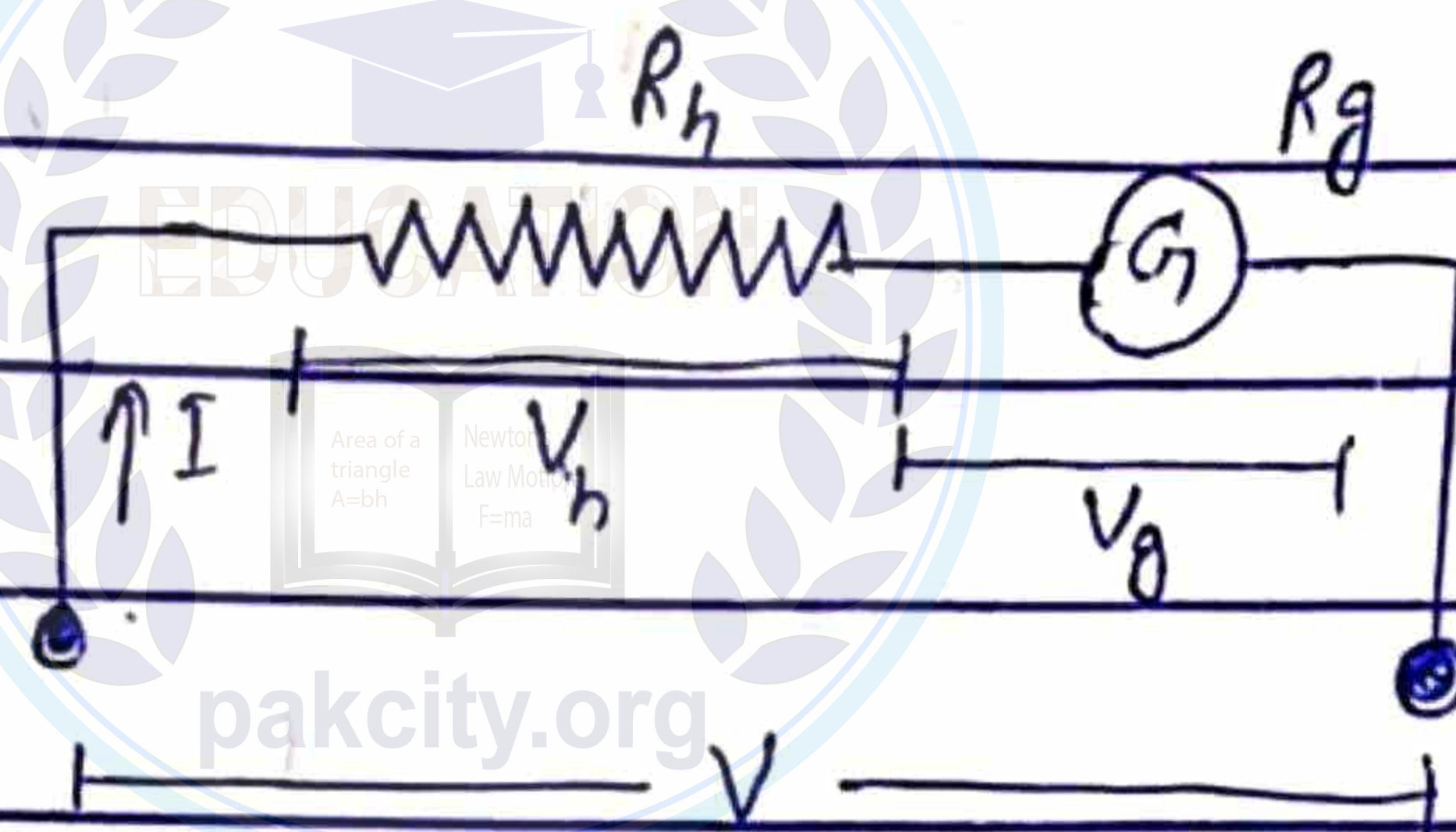
As ammeter is used to measure current. It is connected in series in the circuit because in series combination current remains same. The resistance of the ammeter should be small so that it does not disturb the current of the circuit.

volt meter:

A Voltmeter is an electrical instrument which is used to measure potential difference in volt.

Construction:

To convert galvanometer into voltmeter, a high resistance is connected in series with it.



Calculation of high resistance:

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Consider the circuit in which a high resistance R_h is connected with galvanometer in series as shown in the figure. In the series combination, current remains same but voltage divides according to the

resistance. If the total voltage provided is V , then

$$V = V_h + V_g$$

$$V = I_g R_h + I_g R_g$$

$$V = I_g (R_h + R_g)$$

$$\frac{V}{I_g} = R_h + R_g$$

$$\frac{V}{I_g} - R_g = R_h$$

$$R_h = \frac{V}{I_g} - R_g$$

This is the expression for the high resistance.

Use of high resistance:

As voltmeter is used to measure voltage. It is connected in parallel in the circuit because in parallel combination voltage remains same. The resistance of the voltmeter should be high so

that it does not allow any current to pass and measure the maximum voltage.

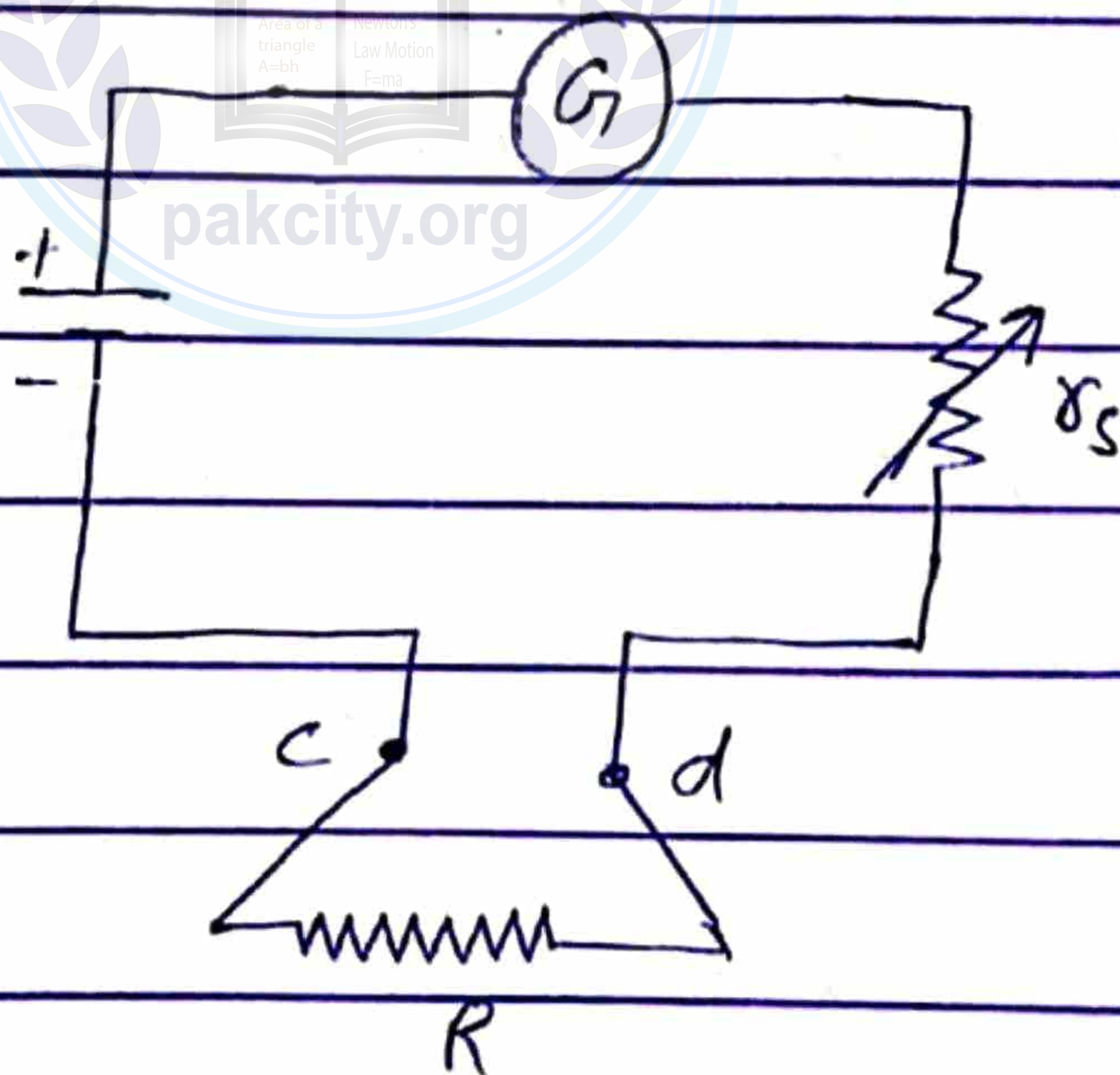
Ohm meter:

An ohm meter is an electrical instrument which is used to measure resistance in Ohm.

Construction:



To convert the galvanometer into ohm meter, a battery and a resistance adjustable

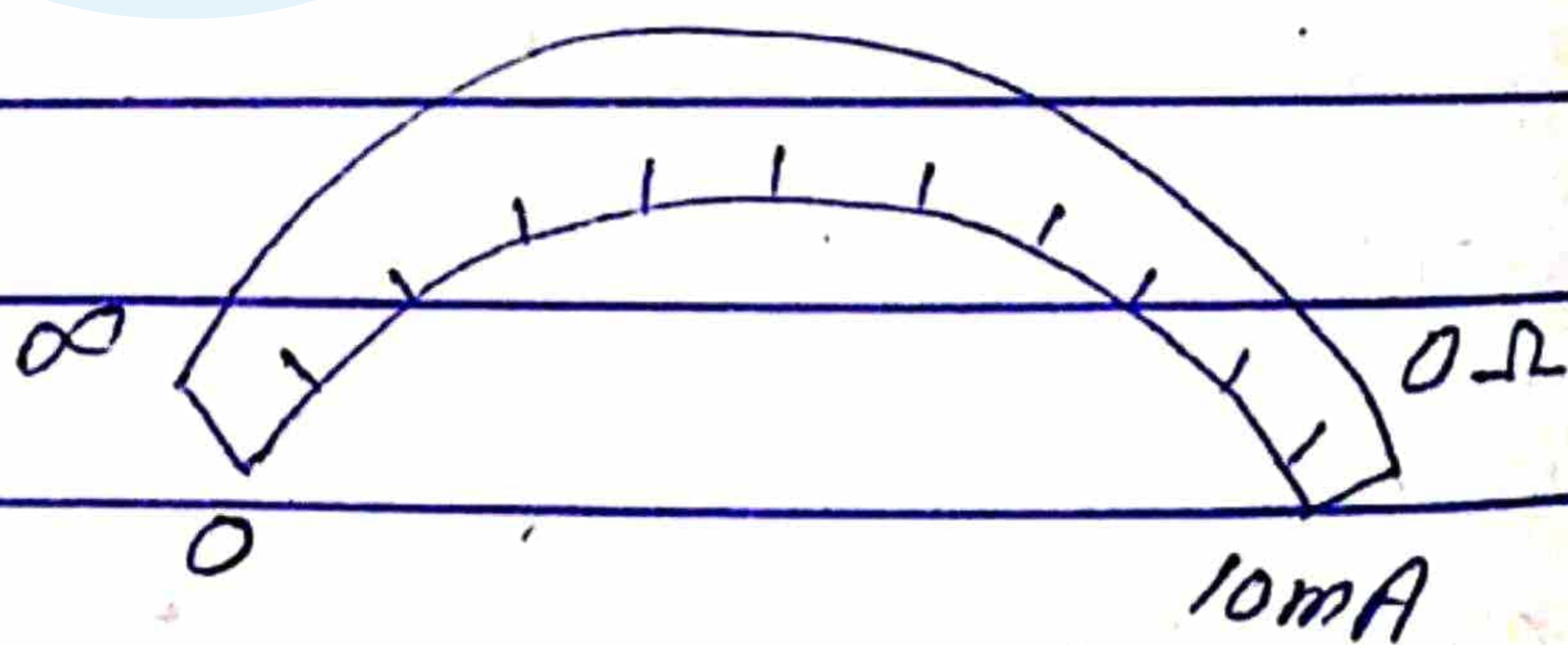


is connected in series with it. Then the resistance R is connected across the points c and d whose

value is to be measured.

Working: When the points c and d are connected together this situation is called short circuit. There will be zero resistance and maximum current in the circuit. When the points c and d are open, there will be infinite resistance and zero current. These two extremes are marked on the scale.

Now the unknown resistance R is



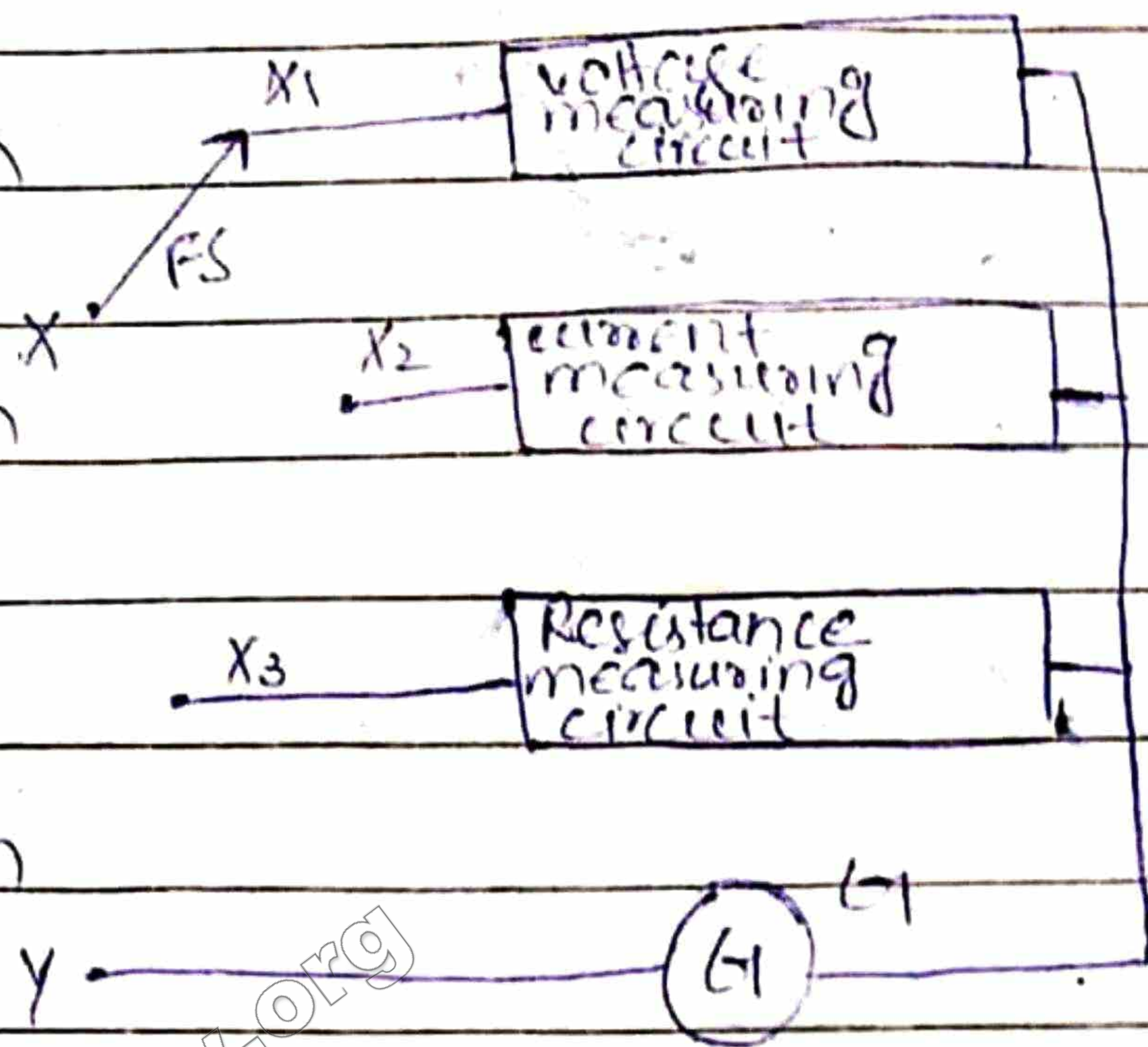
connected

between the points c and d. Then the deflection of needle shows the value of resistance.

AVOMETER:

Definition:

It is an instrument which can measure current in Amperes, potential difference in volts and resistance



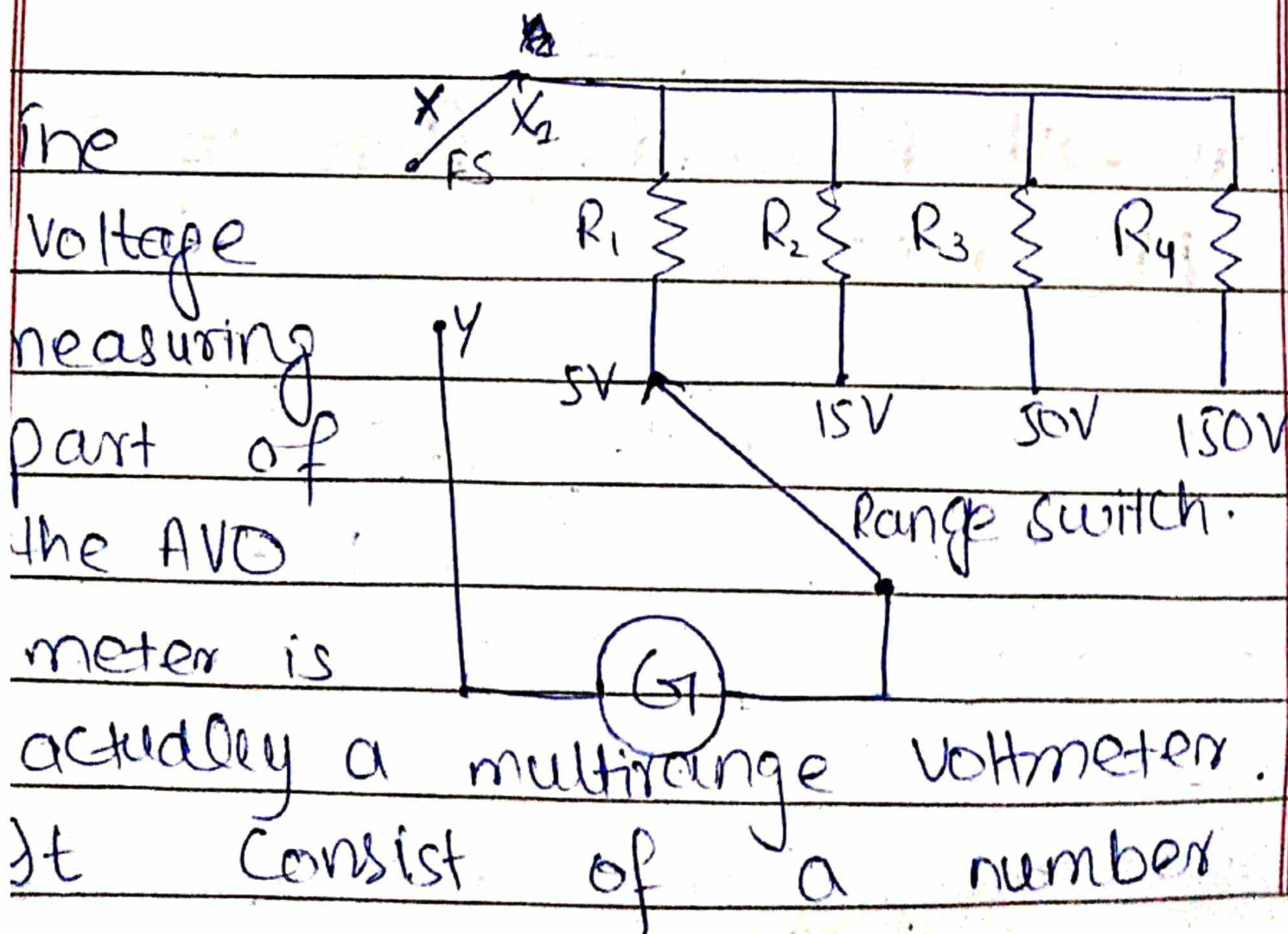
in ohms. It basically consist of sensitive moving coil galvanometer which is converted in to multirange ammeter, voltmeter or ohm meter accordingly as a current measuring circuit, or a Voltage measuring circuit or a resistance measuring circuit is connected with the galvanometer with the

help of switch known as function switch.

• Function switch:

Here X, Y are the main terminals of the AVO meter which are connected with the circuit in which measurement is required. F.S is the function selector switch which connects the galvanometer with relevant measuring circuit.

Voltage measuring part of AVO meter.



of resistances each of which can be connected in series with the moving coil galvanometer with the help of a switch called range switch. The value of each resistance depends upon the range of the voltmeter which it controls.

⇒ Alternating voltages are also measured by AVO meter. AC voltage is first converted into DC voltage by using diode as rectifier and then measured as usual.

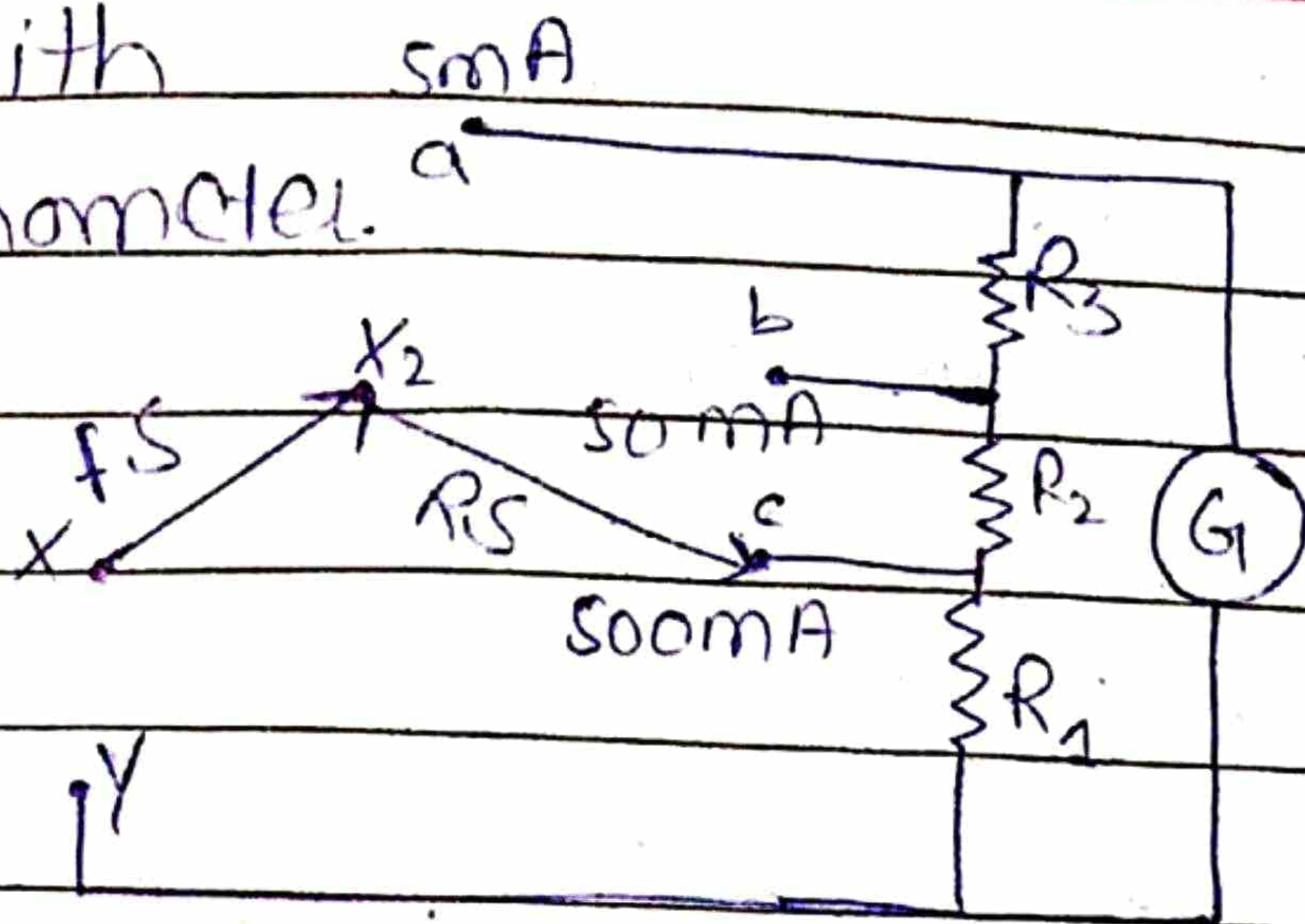
• Current Measuring Part of AVO meter.

The current measuring part of the AVO meter is actually a multirange ammeter. It consists of a number of low resistances connected in

parallel with the galvanometer.

The values of these resistances depend

upon the range of the ammeter.

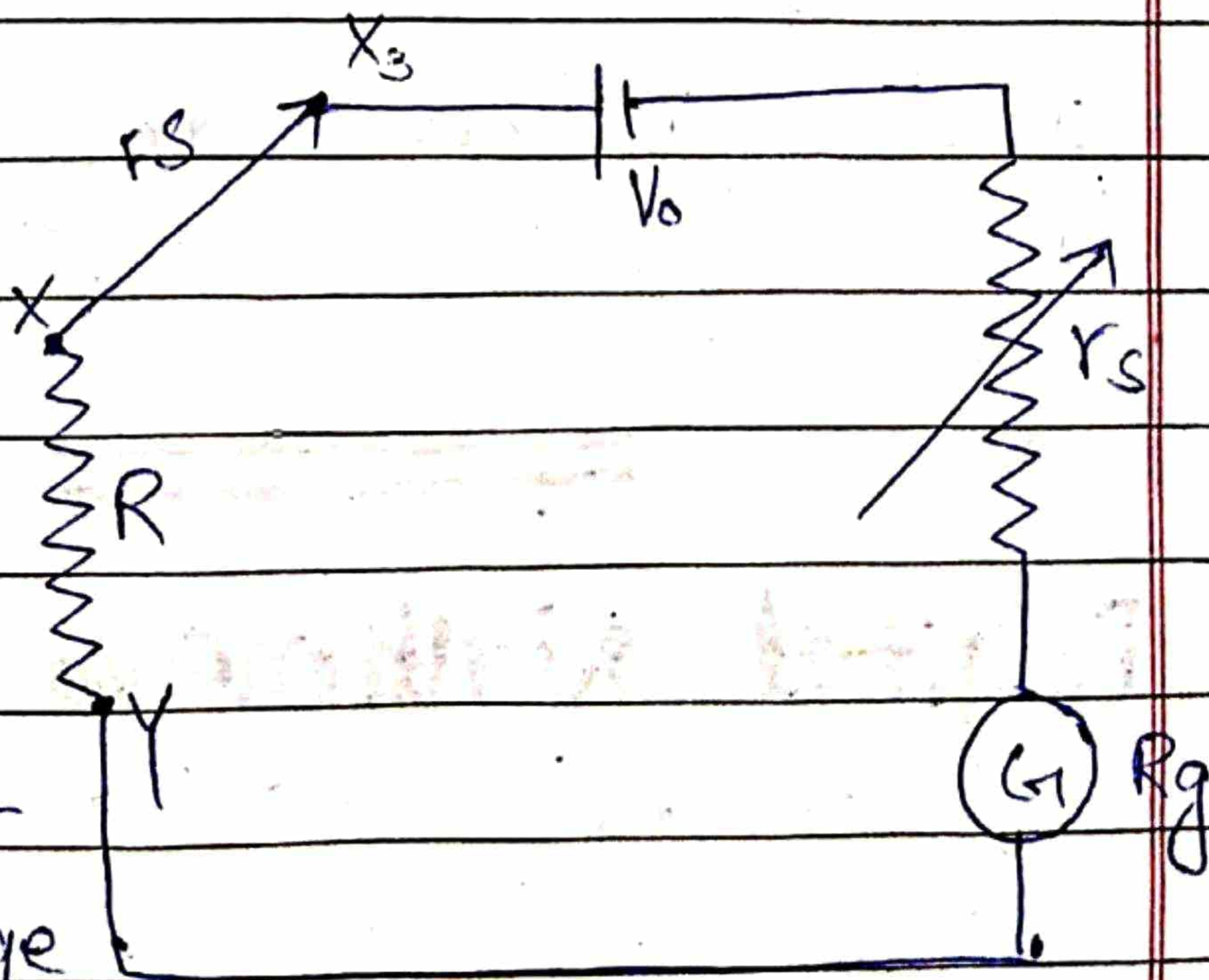


⇒ The circuit also has a range selection switch R_S which is used to select a particular range of the current.

• Resistance Measuring part of AVO meter:

The resistance measuring part of AVO meter is in fact a multirange

ohmmeter. Circuit for each range of this



meter consist of battery of emf V_0 and a variable resistance r_s connected in series with galvanometer of resistance R_g . When a function switch is switched to position X_2 , this circuit is connected with the terminals X, Y of the AVO meter.

⇒ Before measuring an unknown resistance by an ohmmeter it is first zeroed which means that we short circuit the terminals X, Y and adjust r_s to produce full scale deflection.

Digital Multimeter (DMM):

A useful device to measure resistance, current and voltage is an electronic instrument

called digital multimeter. It is digital version of AVO meter. It has become a very popular testing device because the digital value displayed automatically with decimal point, polarity and the unit for A, V or Ω . These meters are generally easier to use because they eliminate the human error that often occurs in reading the dial of an ordinary AVO meter.

Short Questions

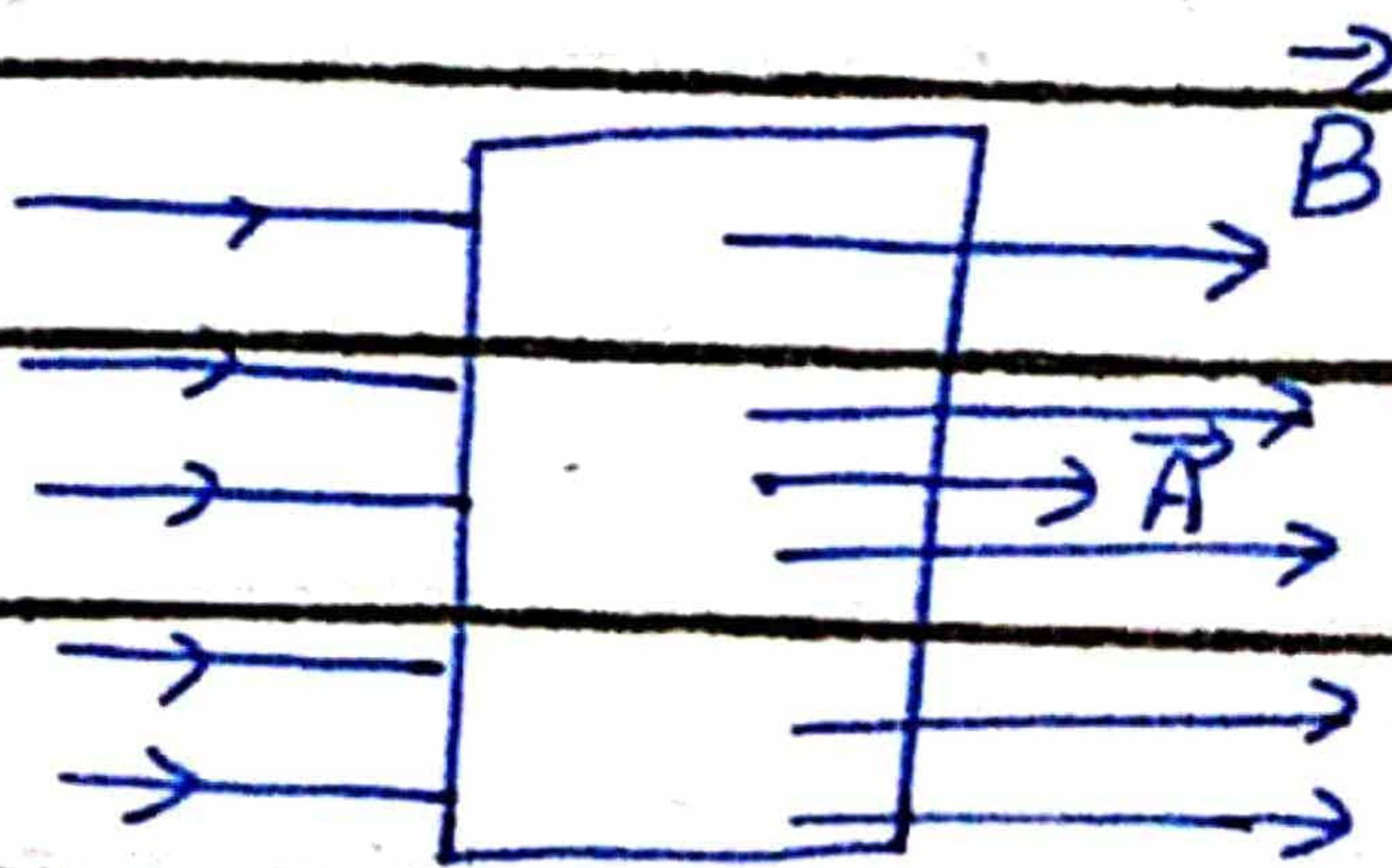
14.1



Maximum flux:

The magnetic flux through the surface will be maximum when the surface is held perpendicular to the magnetic field lines. Now magnetic field and vector area will be parallel.

$$\begin{aligned}\phi &= BA \cos \theta \\ &= BA \cos 0^\circ \\ &= BA(1)\end{aligned}$$



$$\phi_{\text{max}} = BA$$

Minimum flux:

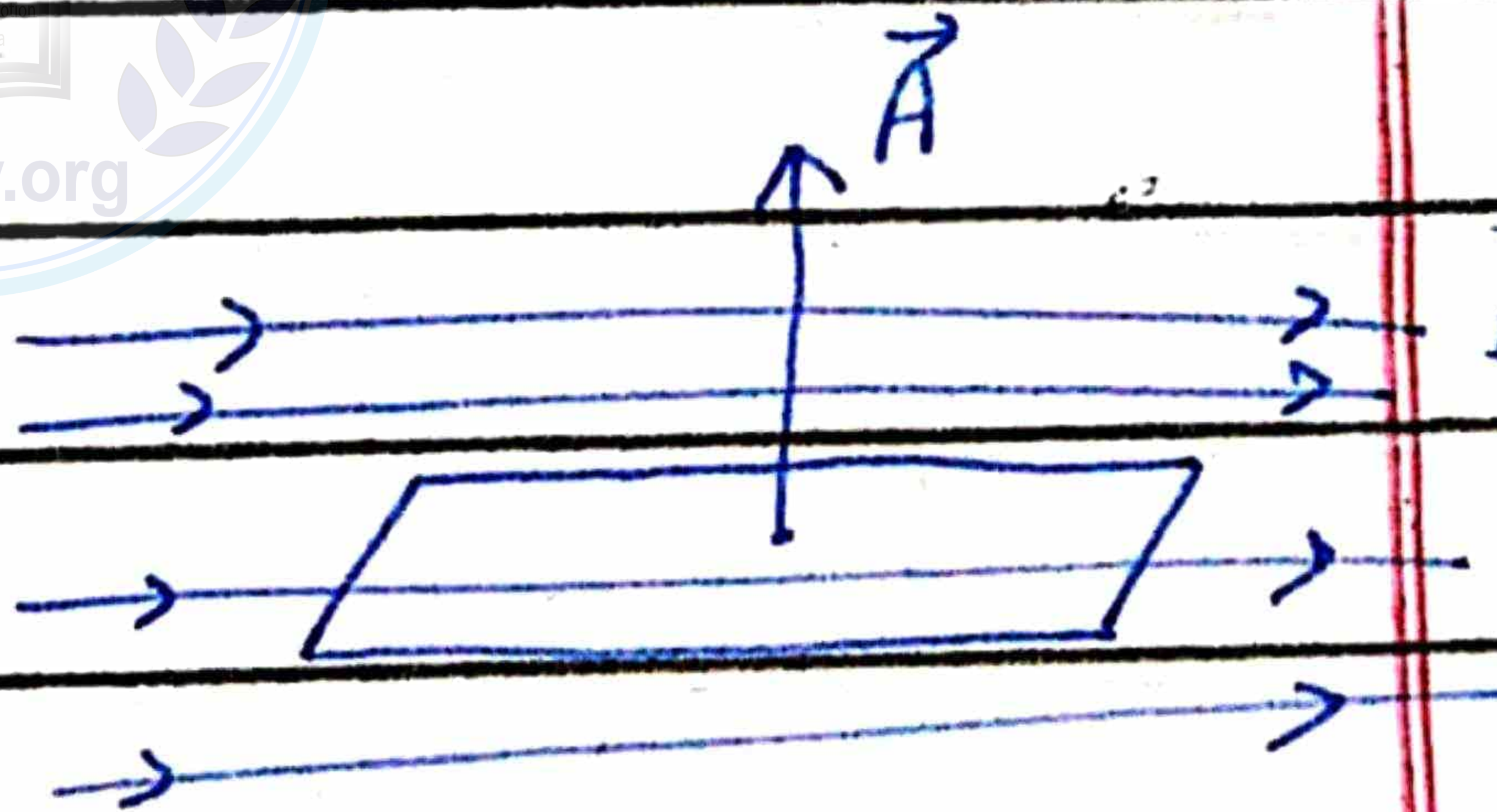
The magnetic flux through the surface will be minimum when the surface is held parallel to magnetic field lines. Now magnetic field and vector area will be perpendicular.

$$\phi = BA \cos \theta$$

$$= BA \cos 90^\circ$$

$$= BA (0)$$

$$\phi_{\min} = 0$$



14.2 There will be no magnetic field due to stationary charges. Stationary charges have electric field around them.

Moving charges will have magnetic field. Because a current carrying conductor have magnetic field.



14.3 The magnetic field inside a solenoid carrying a steady current I having n number of turns per unit length is:

$$B = \mu_0 n I$$

$$B = \mu_0 \frac{N}{l} I$$

a) If the length of the solenoid is doubled

$$B' = \mu_0 \frac{N}{2l} I$$

$$= \frac{1}{2} \left(\mu_0 \frac{N}{l} I \right)$$

$$B' = \frac{1}{2} B$$

So, the magnetic field will become half.

b) If the number of turns becomes doubled.

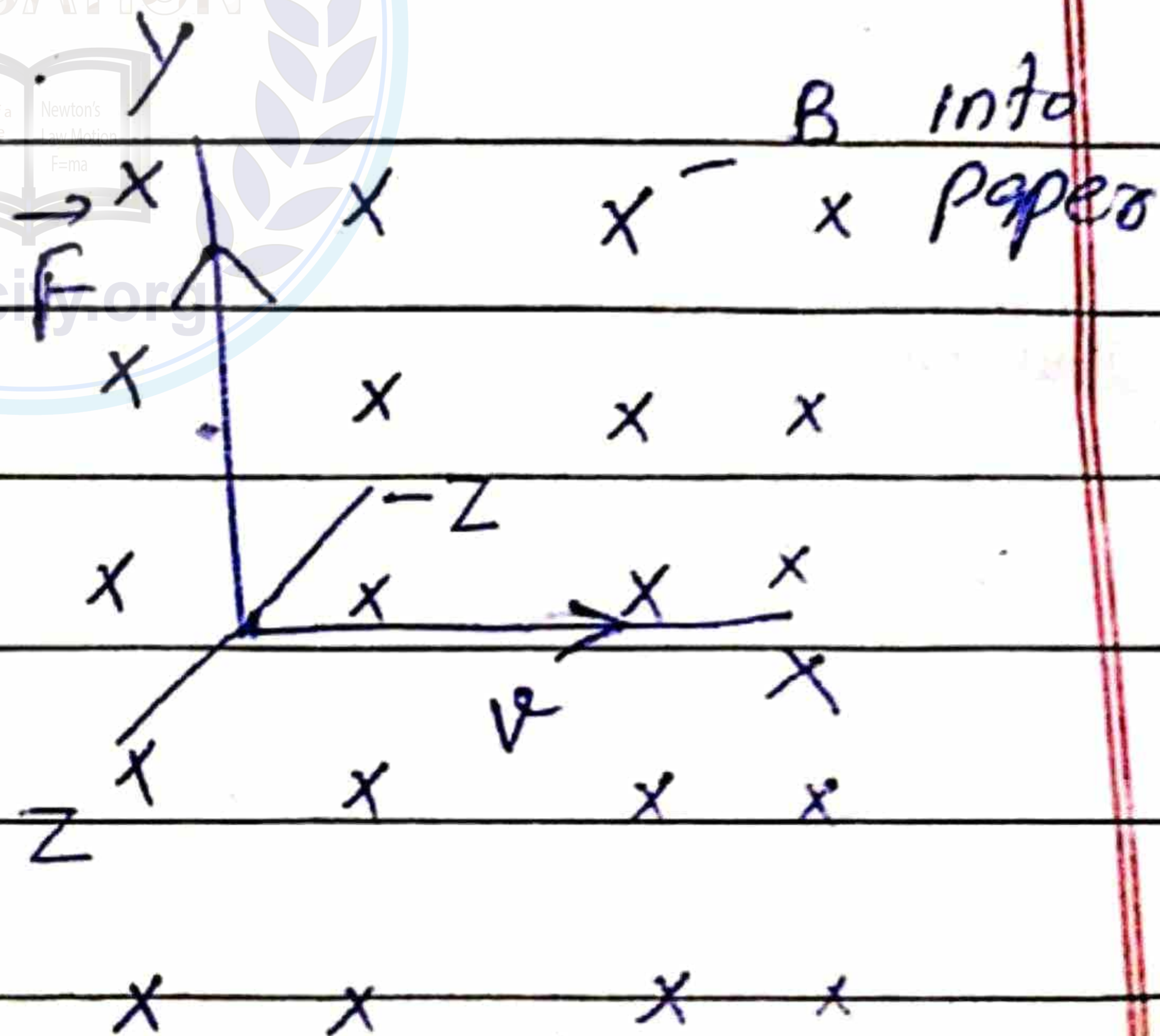
$$B' = \mu_0 \frac{2N}{l} I$$

$$= 2 \left(\mu_0 \frac{N}{l} I \right)$$

$$B' = 2B$$

So, the magnetic field will also become doubled.

14.4 The magnetic force on the moving proton is:



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

The magnetic force is acting along y-axis that can be found by right hand rule. Curl the fingers

of right hand from $\vec{v}$ to $\vec{B}$, then erect thumb will show the direction of magnetic force.

No, the proton will not continue to move in the positive x direction. It will start moving in circle due to the magnetic force.

14.5 Two charged particles are projected into a region where there is a magnetic field perpendicular to their velocities. If the charges are deflected in opposite directions it shows that both the particles have opposite charges. One is positive charge and other is negative charge.

$$\vec{F} = e (\vec{v} \times \vec{B})$$

$$\vec{F} = -e (\vec{v} \times \vec{B})$$

14.6: A charge q is moving in a uniform magnetic field with a velocity $\vec{v}$. There will be zero work done due to magnetic field because it deflects the charge into a circle. The magnetic force will act as centripetal force acting towards the centre of the circle and displacement is along the tangent and $\theta = 90^\circ$.

$$W = Fd \cos \theta$$

$$= Fd \cos 90^\circ$$

$$= Fd(0)$$

$$W = 0$$



14.7 If a charged particle moves in a straight line through some region of space. May be the magnetic field in the region is zero.

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

if $B = 0$

Then $F = 0$

Moreover, the magnetic force will be zero if the charged particle enters parallel or anti-parallel to the magnetic field.

$$F = qvB \sin 0^\circ$$

$$F = qvB \sin 180^\circ$$

$$= qvB (0)$$

$$= qvB (0)$$

$$F = 0$$

$$F = 0$$

14.8 The picture formed on the TV screen is due to the

electrons falling on the screen

In this way, there is a magnetic field present near

the TV screen due to these

electrons. When a magnet is

brought near the screen its

magnetic field disturbs the

magnetic field due to moving

electrons. So, the electrons are

dislocated from their exact positions

and TV screen become distorted.

14.9 Yes, it is possible to orient a current loop in a magnetic field such that the loop will not tend to rotate. The torque produced in the loop

is: $\tau = BIA \cos \alpha$

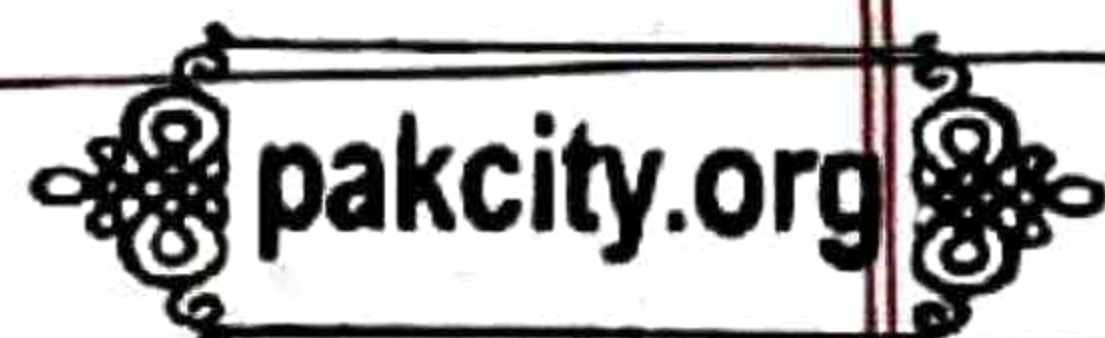
when the loop is held perpendicular to the magnetic field, then it will not rotate.

$$\alpha = 90^\circ$$

$$\tau = BIA \cos 90^\circ$$

$$= BIA (0)$$

$$\tau = 0$$



14.10 When a current loop is brought in the region of magnetic field, torque will be produced in it, given by:

$$\tau = BIA \cos \alpha$$

Therefore, the torque produced in the loop will

show the presence of magnetic field.

14.11 Isotopes are the atoms of a chemical element having same atomic number but different atomic mass. So when they enter into magnetic field, they will continue to rotate in circle with different radius due to having different masses. mathematically

$$\frac{e}{m} = \frac{v}{Br}$$

$$eBr = vm$$

$$r \propto m$$

14.12

Maximum Torque:

The torque will be maximum if the loop is held parallel to the magnetic field.

$$\alpha = 0^\circ$$

$$\tau = BIA \cos \alpha$$

$$\tau = BIA \cos(0)$$

$$\tau = BIA$$

Minimum Torque: The Torque will be minimum if the loop is perpendicular to the magnetic field.

$$\alpha = 90^\circ$$

$$\tau = BIA \cos \alpha$$

$$\tau = BIA \cos(90)$$

$$\tau = 0$$

14.13 A loop of wire is suspended between the poles of a magnet with its plane parallel to the pole faces. If direct current is passed through the coil it will rotate at 90° and stop. Because the magnetic forces on the sides will become now opposite and cancel each other. If an alternating current is passed through coil, it will rotate continuously.

14-4 As ammeter is used to measure current. It is connected in series in the circuit because in series combination current remains same. The resistance of the ammeter should be small so that it does not disturb the current of the circuit.

14-5

As the voltmeter is used to measure voltage. It is connected in parallel in the circuit because in parallel combination voltage remains same. The resistance of the voltmeter should be high so that it does not allow any current to pass and measure the maximum voltage.

14.1 Datamagnetic field = $B = ?$ magnetic force = $F = 7 \times 10^{-3} \text{ N}$ length of wire = $L = 20 \text{ cm}$

$$= \frac{20}{100} \text{ m} = 0.2 \text{ m}$$

current = $I = 10 \text{ A}$ Solution:

$$F = BIL$$

$$\frac{F}{IL} = B$$

$$B = \frac{7 \times 10^{-3}}{10 \times 0.2}$$

$$B = 3.5 \times 10^{-3} \text{ T}$$

14.2 Dataspeed of proton = $v = ?$ magnetic field = $B = 2.5 \times 10^{-3} \text{ T}$

magnetic force = weight

mass of proton = $m = 1.67 \times 10^{-27} \text{ kg}$, $g = 9.8 \text{ m/s}^2$ Solution: charge of proton = $q = 1.6 \times 10^{-19} \text{ C}$

magnetic force = weight

$$qvB = mg$$

$$v = \frac{mg}{qB}$$

$$= \frac{1.67 \times 10^{-27} \times 9.8}{1.6 \times 10^{-19} \times 2.5 \times 10^{-3}}$$

$$v = 4.09 \times 10^{-5} \text{ m s}^{-1}$$

14.3 Data



magnetic field = $B = 0.3 \text{ T}$

electric field = $E = 10000 \text{ V m}^{-1}$

speed of particle = $v = ?$

Solution: For the selector

electric force = magnetic force

$$qE = qvB$$

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

$$v = \frac{10000}{0.3}$$

$$v = 3.3 \times 10^4 \text{ m s}^{-1}$$

14.4 Data

Area of coil = $A = 0.1 \text{ m} \times 0.1 \text{ m}$

$$A = 0.01 \text{ m}^2$$

number of turns = $N = 200$

current = $I = 1 \text{ mA} = 10^{-3} \text{ A}$

magnetic field = $B = 0.1 \text{ T}$

maximum torque = $\tau = ?$



Solution:

$$\tau = N A I B$$

$$= (200)(0.01)(10^{-3})(0.1)$$

$$\tau = 2 \times 10^{-4} \text{ Nm}$$

14.5 Data

height of power line = $R = 10 \text{ m}$

current = $I = 200 \text{ A}$

magnetic field = $B = ?$

$$\mu_0 = 4\pi \times 10^{-7} \text{ Wb A}^{-1} \text{ m}^{-1}$$

Solution:

$$B(2\pi R) = \mu_0 I$$

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

$$= \frac{4\pi \times 10^{-7} \times 200}{2\pi (10)}$$

$$[B = 4 \times 10^{-6} \text{ T}]$$

14.6 Data

magnetic field = $B = 0.10 \text{ T}$

current = $I = 10 \text{ A}$

number of turns = $N = ?$

per unit length

$$\mu_0 = 4\pi \times 10^{-7} \text{ Wb A}^{-1} \text{ m}^{-1}$$

Solution:

$$B = \mu_0 n I$$

$$\frac{B}{\mu_0 I} = n$$

$$n = \frac{0.10}{4\pi \times 10^{-7} \times 10}$$

$$[n = 7.96 \times 10^3]$$

14.7 Data

current = $I = ?$

length = $L = 0.5 \text{ m}$

number of turns = $N = 10000$

magnetic field = $B = 0.4 \text{ T}$

$$\mu_0 = 4\pi \times 10^{-7} \text{ Wb A}^{-1} \text{ m}^{-1}$$

Solution:

$$B = \mu_0 N I$$

$$B = \mu_0 \frac{N}{L} I$$

$$BL = \mu_0 N I$$

$$\frac{BL}{\mu_0 N} = I$$

$$I = \frac{(0.4)(0.5)}{(4\pi \times 10^{-7})(10000)}$$

$$I = 16 \text{ A}$$

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14.8 Data

resistance of galvanometer = $R_g = 15 \Omega$

$$I_g = 20 \text{ mA} = 20 \times 10^{-3} \text{ A}$$

$$I_g = 0.02 \text{ A}$$

current = $I = 10 \text{ A}$

shunt resistance = $R_s = ?$

Solution:

$$R_s = \frac{I_g R_g}{I - I_g}$$

$$= \frac{(0.02)(15)}{(10 - 0.02)}$$

$$R_s = 0.03 \Omega$$

14.9 Data

resistance of galvanometer = $R_g = 50 \Omega$

current = $I_g = 2 \text{ mA}$

$$I_g = 2 \times 10^{-3} \text{ A}$$

voltage = $V = 200 \text{ V}$

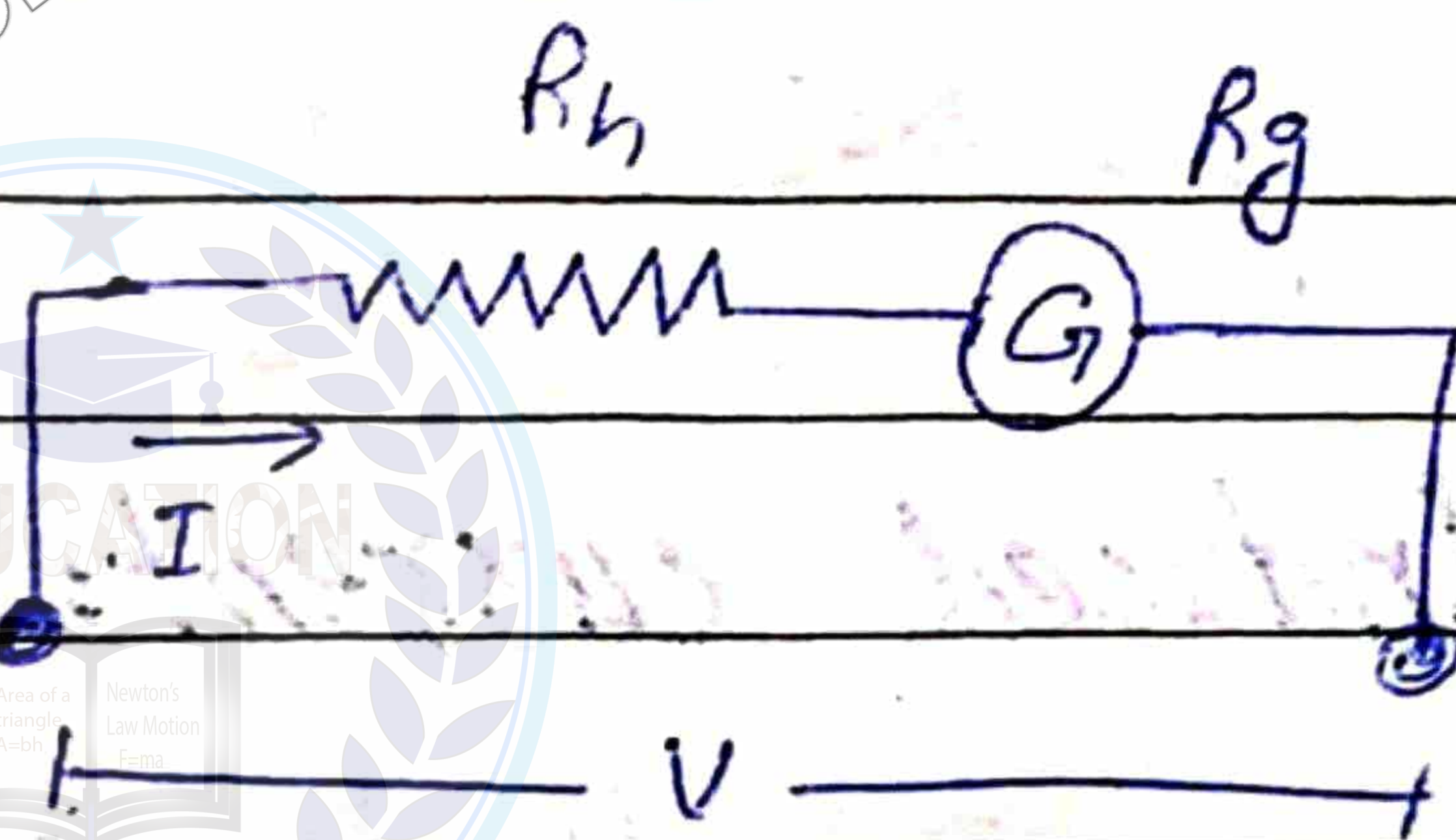
high resistance = $R_h = ?$

Solution:

To convert
galvanometer
into

voltmeter,

a high resistance is
connected in series with it.



$$R_h = \frac{V}{I_g} - R_g$$

$$= \frac{200}{2 \times 10^{-3}} - 50$$

$$R_h = 99950 \Omega$$