Physics Notes

BY

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Class:10+2
Unit: III
Topic: Magnetic Effects of Current and Magnetism

__SYLLABUS__: UNIT-III-*B*

Concept of magnetic field, Oersted's experiment, Biot-Savart law, magnetic field due to an infinitely long current carrying straight wire and a circular loop; Ampere's circuit law and its applications to straight and toroidal solenoids; Force on a moving charge in uniform magnetic and electric fields, Cyclotron; Force on current – carrying conductor in a uniform magnetic field. Forces between two parallel current- carrying conductors- definition of ampere; Torque experienced by a current loop in a uniform magnetic field, moving coil galvanometer- its current sensitivity and conversion to ammeter and voltmeter.

Current loop as a magnetic dipole and its magnetic dipole moment; Magnetic dipole moment of a revolving electron; Magnetic field intensity due to magnetic dipole (bar magnet) along the axis and perpendicular to the axis; Torque on a magnetic dipole (bar magnet) in a uniform magnetic field; Bar magnet as an equivalent solenoid, Magnetic field lines' Earth's magnetic field and magnetic elements; Para-dia and ferro-magnetic substances with examples, Electromagnets and permanent magnets.

Q.1. Discuss motion of charged particle in Electric Field for

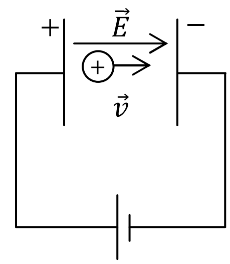
i) θ = 0^0

ii) θ = 180^0

iii) θ = 90^0

θ is the angle between $\vec{V}$ and $\vec{E}$.

Ans.**Case I**:- θ = 0^0



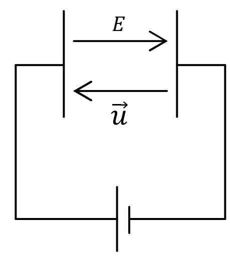
$\vec{V} = \vec{u} + \vec{a}t \qquad \left[acc, a = \frac{(q.\vec{E})}{m}\right]$

$= \vec{u} + \frac{(q\vec{E})}{m}.t$

$= \vec{u} + \frac{(q\vec{E})}{m}.t$

$= \vec{u} + \frac{qt}{m}.\vec{E}$ [speed increases, *K.E.* increases]

Case II:- θ = 180^0



$\vec{V} = \vec{u} + \vec{a}t$

$= \vec{u} + \frac{(q\vec{E})}{m}.t$

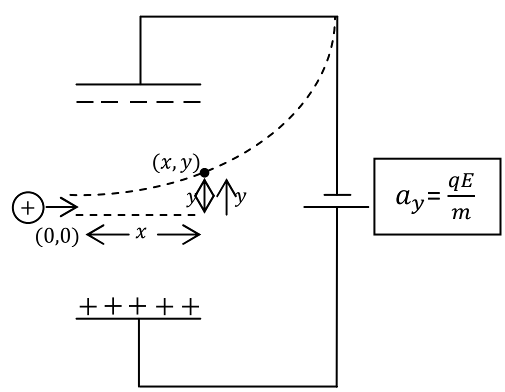
Speed decreases till the particles speed becomes zero and then increases.

Initial horizontal speed = *u*

$x = u_x.t + \frac{1}{2}a_x t^2$

$x = u_x.t$ ------------ (i)

$y = u_y.t + \frac{1}{2}.a_y.t^2$



$y = 0 + \frac{1}{2}.a_y.t^2$ $\boxed{t = \frac{x}{u}}$ from (i)

$y = 0 + \frac{1}{2}.a_y.\left(\frac{x}{u}\right)^2$

$y = \frac{1}{2}.\left(\frac{q.\vec{E}}{m}\right).\frac{x^2}{u^2}$

$y = (constant).x^2$

Q2. **Discuss motion of charged particle in magnetic field for**

i) **$\theta = 0^0$**

ii) **$\theta = 180^0$**

iii) **$\theta = 90^0$**

θ is the angle between $\vec{V}$ and $\vec{B}$.

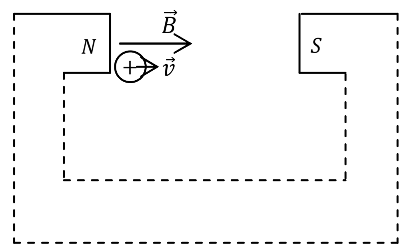
Ans. $\vec{F} = q(\vec{V} \times \vec{B})$

Case I:- $\theta = 0^0$

$F = qVB \sin\theta$

$= qVB \sin 0$

$$\boxed{F = 0}$$

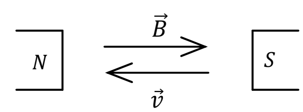


Case II:- $\theta = 180^0$

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

$\vec{F} = qVB \sin 180^0$

$$\boxed{F = 0}$$

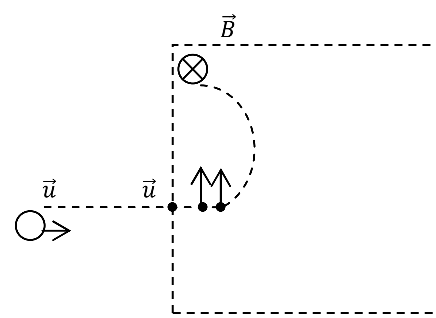


Case III:- $\vec{V} \perp \vec{B}$

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

$\vec{F} = qVB \sin 90^0$

$$\boxed{F = qVB}$$

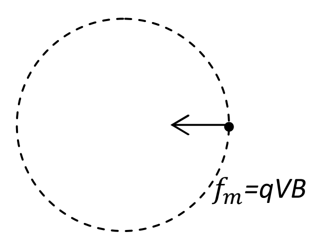


Towards centre of circle
$\perp$ to $\vec{V}$, $\perp$ to $\vec{B}$

$q\cancel{V}B = \frac{mV^{\cancel{2}}}{r}$

$\frac{qBr}{m} = V$

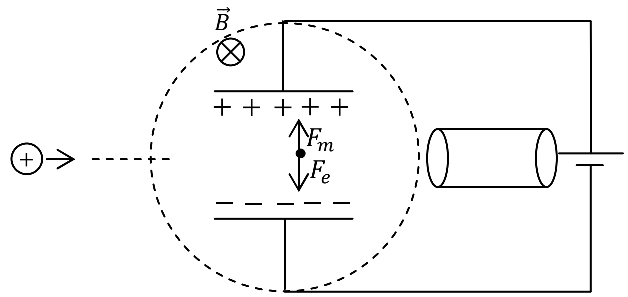
$T = \frac{2\pi r}{V} = \frac{2\pi \cancel{r}}{\frac{qB\cancel{r}}{m}} = \frac{2\pi m}{qB}$ $\boxed{T = \frac{2\pi m}{qB}}$



Q3. Working of '*Velocity Selector*' switch?

Ans. Electric Field causes downward deflection of a charged particle.
Magnetic Field causes upward deflection of a charged particle.

For no deflection of particle, upward force must be equal to downward force.



F_E = qE ------------- (1)

F_m = qVB ------------- (2)

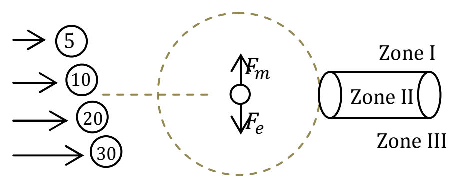
qE = qVB

E = VB

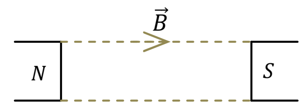
$$v = \frac{E}{B}$$

Example:- $= \frac{100}{5} = 20$m/sec

Particles moving with speed 20m/sec will enter the box. (Zone II)
Particles with speed less than 20 *i.e.* with 5 and 10 will get deflected towards Zone III.
Particles with speed 30 will enter Zone I.

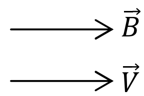


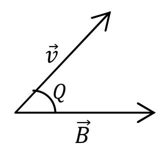
Q4. Find time period and pitch of helical path followed by a charged particle when it enters at angle θ with *B*.



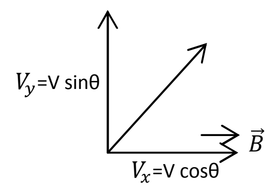
Ans.1. Horizontal component

V = V cosθ is parallel to $\vec{B}$



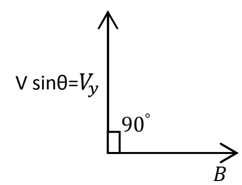


So, force acting due to V cosθ is zero.

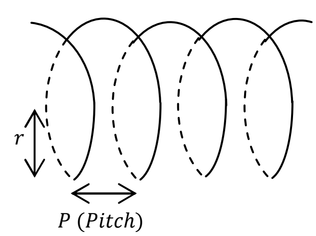


No acceleration along x-axis particle moves with constant speed V cosθ.

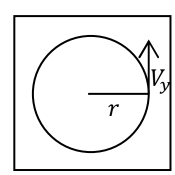
2. V_y = V sinθ causes circular motion.



3. T = $\frac{2\pi r}{V_y}$ = $\frac{2\pi r}{\text{V sin}\theta}$



4. Pitch: The distance between two identical points is called pitch.



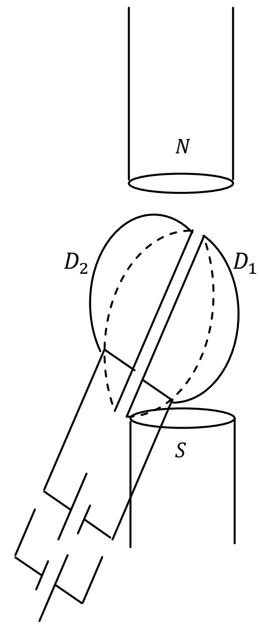
P = V_x x T

= $V_x\left(\frac{2\pi r}{\text{V sin}\theta}\right)$

P = $2\pi r\ \frac{\text{V cos}\theta}{\text{V sin}\theta}$ = $2\pi r\ cot\theta$

P = $2\pi r\ cot\theta$

Q5. Discuss construction and working of Cyclotron?



Ans.a) **Principle**:-

Cyclotron is a device used to increase speed/Kinetic Energy where

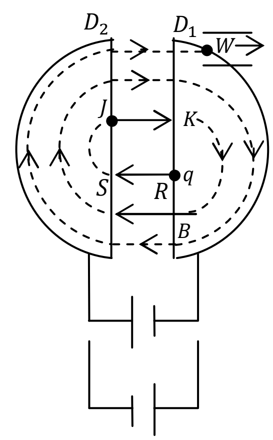
E is used to increase speed.
B is used to change direction.
(*E* → Electric Field, *B* → Magnetic Field).

b) **Construction**:-

Two magnets are used to create magnetic fields. *E* (alternating) is applied across the two D's as shown in figure.

Plane of D's is ⊥ to *B*.

c) **Working**:-



Particle is at *R* (say particle is –*ve* charged). Disc D_2 is made +*ve*. Particle moves to position *S* with increase speed. Particle moves from *S* to *J* with constant speed, but its direction changes due to magnetic field. Now D_1 becomes +*ve* when particle is at *J*, particle jumps to *K* with increase in speed due to *Electric Jerk*.

speed of particle increase with increase in radius, When radius of particle circle is almost equal to the disc radius, particle is taken out of the window *w*.

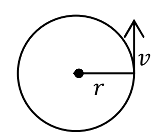
d) **Radius, Kinetic Energy**:-

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

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

$$\boxed{r = \frac{mv}{qB}} \quad , \quad v = \frac{rqB}{m}$$

As speed increase, radius also increase.



$$K.E_{max} = \frac{1}{2}mv_{max}^2$$

$$= \frac{1}{2}m\left(\frac{qB\,r_{max}}{m}\right)^2$$

$$= \frac{1}{2}m\left(\frac{q^2B^2r_{max}^2}{m^2}\right)$$

$$\boxed{K.E_{max} = \frac{1}{2}\left(\frac{q^2B^2r_{max}^2}{m}\right)}$$

$$K.E_{max} \propto r_{max}^2$$

$$T_{1/2} = \frac{\pi r}{v} = \frac{\pi \times m}{qB} \qquad \boxed{T_{1/2} = \frac{\pi m}{qB}}$$

$T_{1/2}$ → Time of stay of particle in one *D*

Q6. Derive an expression for force on a current carrying conductor placed in a magnetic field.

OR

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

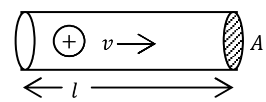
Ans. A charged particle *q* experiences a force $\vec{F} = q\,(\vec{V} \times \vec{B})$ when placed in a magnetic field.

A current is equivalent to number of charges in motion.

Force on each charge ⇒ F

$F = qVB$

No. of charges in conductor,



$N = (n)\,A\,l$

n→no. of e/volume

I= nAqVd

$F_{net} = NF$

$= (n\,A\,l)\,(qVB)$

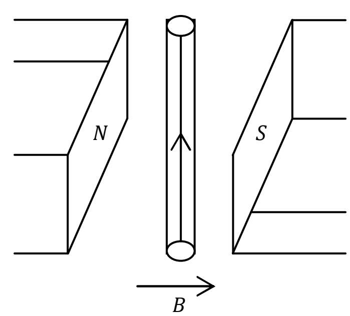
$= (nAqV)\,l\,B$

$F_{net} = I.\,l.B$

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

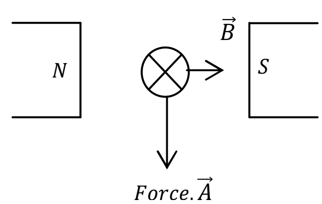
<u>Direction</u>:- Flemings **left hand** rule

First Finger → Field
Second Finger → Current
Thumb Finger → motion or Force



<u>Example</u>:- Downward Force (Left hand rule)

Current flows inwards, Magnetic Field towards right, Force downwards.



Q7. **Find $\frac{Force}{length}$ between two infinite conductor carrying I_1 and I_2 and separated by distance *d*.**

$$F/l = \frac{\mu_0 I_1 I_2}{2\pi d}$$

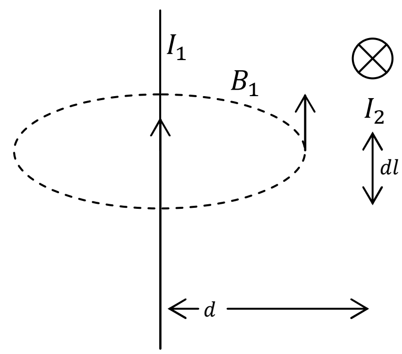
Ans.

Step 1. Current carried by conductor of length *dl* is I_2

dF $= I\,(\vec{dl} \times \vec{B})$

$dF_2 = I_2\,(\vec{dl} \times \vec{B})$

$$dF_2 = I_2\, dl\, B_1 \quad \text{——— (1)}$$



Step 2.

$$B_1 = \frac{\mu_0 I_1}{2\pi d} \quad \text{——— (2)}$$

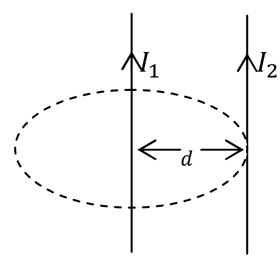
Step 3.

dF $= I_2.dl\, B_1$

$= I_2\, dl \left(\frac{\mu_0 I_1}{2\pi d}\right)$

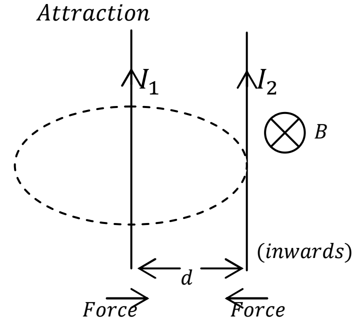
$\frac{dF}{dl} = \frac{I_2.\mu_0.I_1}{2.\pi.d}$

$$\frac{Force}{length} = \frac{\mu_0.I_1.I_2}{2.\pi.d}$$



They both attract each other. According to left hand Flemings rule, current is upwards, Magnetic Field inwards, force towards the conductor carrying current I_1(i.e. towards left).

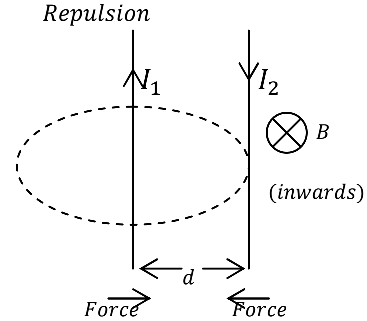
Attraction



Two possible cases:-

Case I:- If two currents $I_1$and I_2 are in same direction, two conductors will attract each other.

Repulsion



Case II:-If two currents $I_1$and I_2 are in opposite direction, two conductors will repel each other.

Q8. Derive an expression for Torque on a current carrying loop placed in a magnetic field?

OR

Prove $\vec{\tau} = \vec{M} \times \vec{B}$ where M = I $\vec{A}$

$= I\vec{A} \times \vec{B}$

Ans.

<u>Step 1.</u> Force on *PQ* and *RS*

F $= BIl$

$\vec{F}_{PQ}$ $= BIl$ (upwards)

$\vec{F}_{RS}$ $= BIl$ (downwards)

$|\vec{\tau}|$ $= 2\,|\vec{r} \times \vec{F}|$

= 2r F sinθ

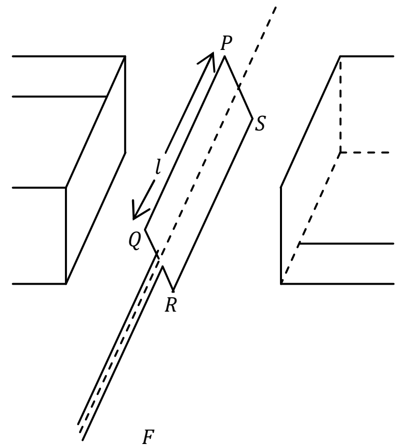
= 2r BIl sinθ [2r = breadth]

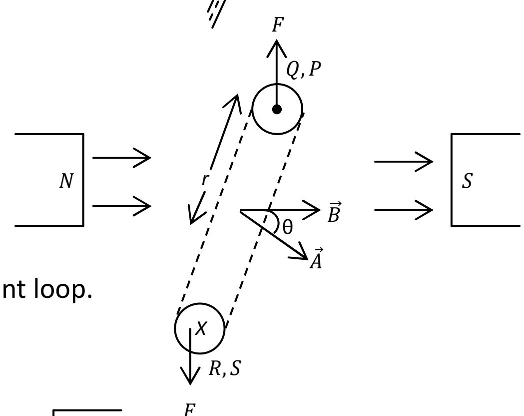
= b IBl sinθ

$\vec{\tau}$ = IAB sinθ

= MB sinθ

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





Where *M* = NIA is the magnet moment of current loop.

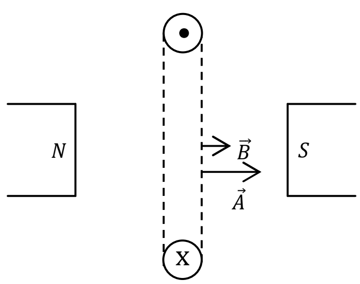
<u>Discussion</u>:-

<u>Case I</u>:-

θ $= 0^{\circ}$

τ $= MB$ sinθ

$$\boxed{\tau_{min} = 0}$$



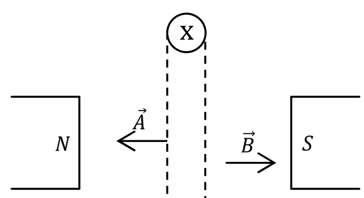
Stable equillibrium

<u>Case II</u>:-

θ $= 180^{\circ}$

τ $= MB$ sinθ

$$\boxed{\tau_{min} = 0}$$



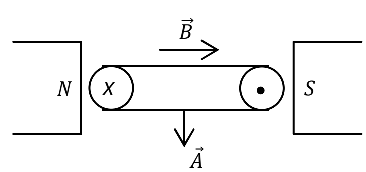
Unstable equil

<u>Case III</u>:-

θ $= 90^{\circ}$

τ $= MB$ sinθ

$$\boxed{\tau_{max} = MB}$$



Q9. Explain Principle, Construction and Working of moving coil galvanometer?

Ans.a) **<u>Principle</u>**:-

Galvanometer work on the principle that deflection produced in current carrying coil is proportional to current in coil.

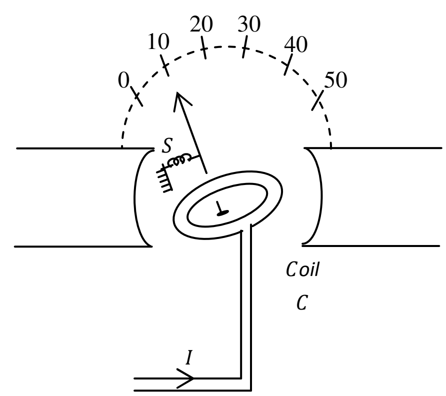
i.e. $\theta \propto I$

b) **<u>Construction</u>**:-

Magnets of the given shape are used to produce <u>radial magnetic field</u>. For radial magnetic field $\vec{A} \perp \vec{B}$ for all positions of the coil plane.

$\tau = MB \sin 90^\circ$

$\tau = MB$



Coil *C* carries current *I*. Any deflection produced in coil is measured by "*needle*" on the scale.

Spring *S* provides necessary torque in opposite direction to make the needle stable.

c) **<u>Working</u>**:-

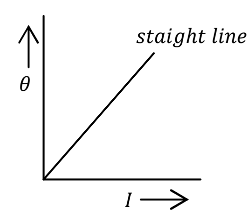
Current in the coil develops clockwise torque (say)

$\tau_c = MB \sin 90^\circ$

$\tau_c = (NIA)\, B \times I$ ——— (1)

Spring provides anticlockwise torque (say)

$\tau_{ac} = K\theta$ ——— (2)

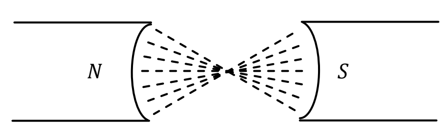


Needle is stable when

$\tau_{ac} = \tau_c$ [Anticlockwise torque = clockwise torque]

$K\theta = nIAB$

$\theta = \left(\frac{nAB}{K}\right) . I$



<u>Sensitivity</u>

a) sensitivity : $\frac{\Delta\, output}{\Delta\, input}$

b) Current sensitivity: $\frac{\Delta \theta}{\Delta I}$

Current sensitivity = $\frac{nAB}{K}$

c) Voltage sensitivity = $\frac{\Delta \theta}{\Delta V} = \frac{\Delta \theta}{R\, \Delta I}$

$= \frac{1}{R} \left(\frac{nAB}{K}\right)$

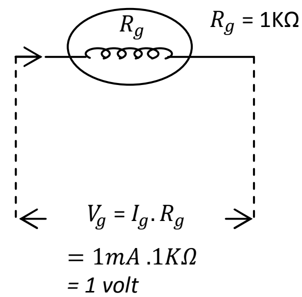
Voltage sensitivity = $\frac{current\ sensivity}{R}$

Q10. Convert a galvanometer of 1mA, 1KΩ to

a) Ammeter of (0-1) Amp.

b) Voltmeter of (0-100) volt

Ans. Galvanometer



So, given galvanometer can act as ammeter of **1 m A**

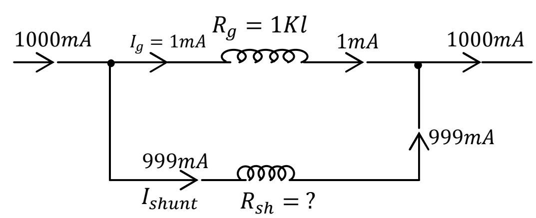
OR

Can act as voltmeter of **1 volt**

a) In parallel, voltage is same.

$I_g . R_g \quad = I_{sh} . R_{sh}$

$R_{sh} \quad = \frac{1mA.1K\Omega}{999} = \frac{1000}{999} = 1\Omega$

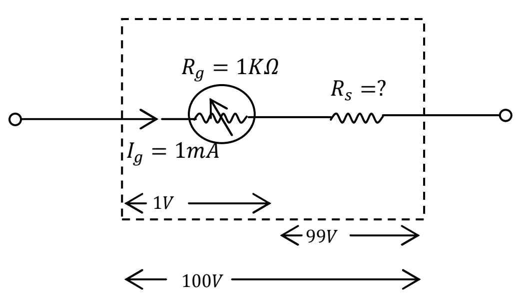


b) In series current is same

99V $\quad = R_s$ X 1mA

$R_s \quad = \frac{99V}{1mA}$

$R_s \quad$ = 99KΩ Which can bear 100V



New device can measure 100 volt.