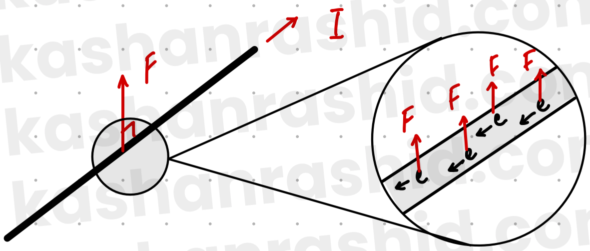
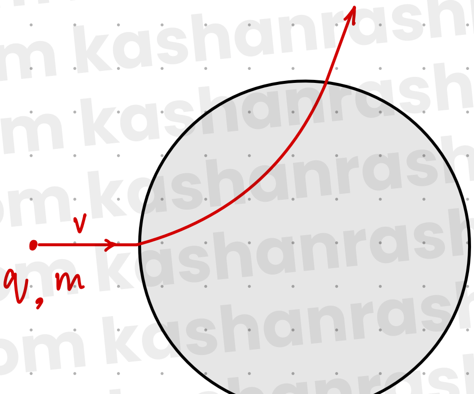


The force on the current carrying conductor is basically on the moving charges in that conductor!

Force on moving charges in a magnetic field



Magnetic field into the plane

$F = BIL$

as $I = \frac{q}{t}$ so

$F = B\left(\frac{q}{t}\right)L$

$F = B.q.v$

$$\boxed{F = Bvq}$$

F: magnetic force (N)
B: magnetic flux density (T)
v: velocity of charge particle (ms^{-1})
q: magnitude of charge (C)

- The force on the charged particle in magnetic field acts as a centripetal force
- Particle moves in a circular track in the magnetic field.

Magnetic force acts as centripetal force

$F_m = F_c$

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

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

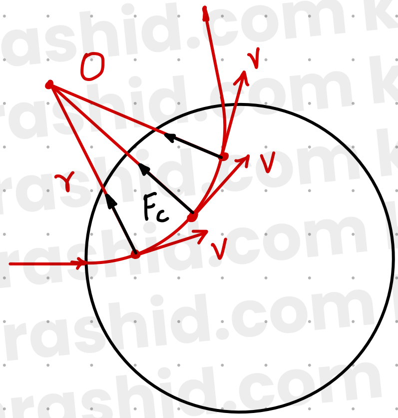
$$\boxed{r = \frac{mv}{Bq}}$$ ✓

as $p = mv$ so

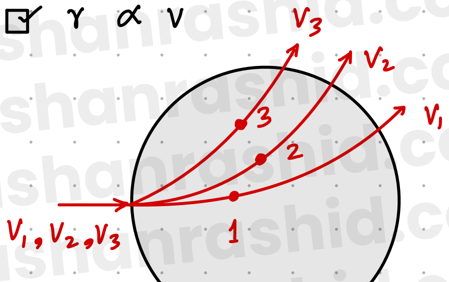
$r = \frac{p}{Bq}$

$\boxed{p = Bqr}$ or $\boxed{p = Ber}$

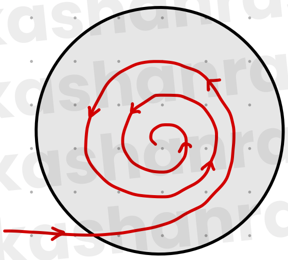
where e: elementary charge



☑ $r \propto v$



$V_1 > V_2 > V_3$ as $r_1 > r_2 > r_3$
the greater the speed, the greater is the radius and hence the lesser is the deflection



a constant decrease in radius shows that particle is slowing down!

☑ $r \propto \frac{1}{B}$

Stronger magnetic fields would bend charged particles more as they'd experience more force. thus they have a smaller radius.

$\frac{q}{m}$ for proton : 9.6×10^{6} C/kg

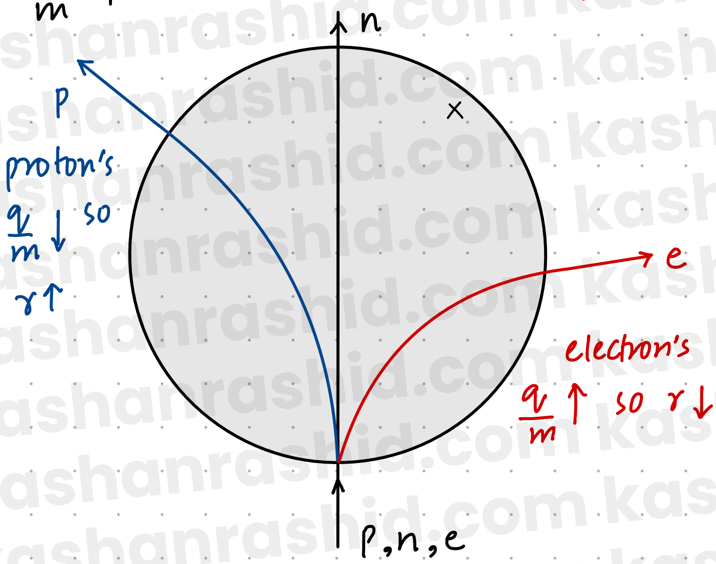
$\frac{q}{m}$ for electron : 1.76×10^{11} C/kg

☑ $r \propto \frac{m}{q}$ or $r \propto \frac{1}{\frac{q}{m}}$

where $\frac{q}{m}$ is charge-to-mass ratio

proton: $q : 1.6 \times 10^{-19}$ C
$m : 1.67 \times 10^{-27}$ kg

electron: $q : 1.6 \times 10^{-19}$ C
$m : 9.11 \times 10^{-31}$ kg



Magnetic field into the page

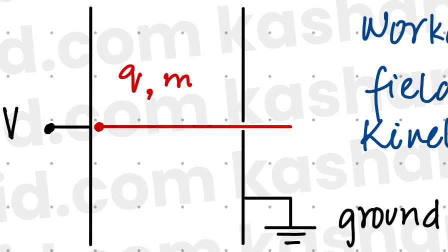
$\longrightarrow$ I $\longrightarrow$ + $\longrightarrow$ I $-\longleftarrow$

Determining charge-to-mass ratio

- When a moving charged particle enters a magnetic field it experiences a magnetic force which acts as a centripetal force.

$$F_m = F_c$$
$$Brq = \frac{mv^2}{r}$$
$$\frac{q}{m} = \frac{v}{Br}$$

to replace 'v' . . .



Workdone by Electric field = Gain in Kinetic energy

$$W.D = \Delta K.E$$

$V = \frac{W}{q}$ so $W = Vq$ and $\Delta K.E = \frac{1}{2}m(v^2 - u^2)$

$$Vq = \frac{1}{2}m(v^2 - u^2)$$

if particle is initially at rest, $u = 0$

$$2Vq = mv^2$$
$$v = \sqrt{\frac{2Vq}{m}}$$

where V is the accelerating voltage.

replacing v in previous equation

$$\frac{q}{m} = \sqrt{\frac{2Vq}{m}} \cdot \frac{1}{Br}$$

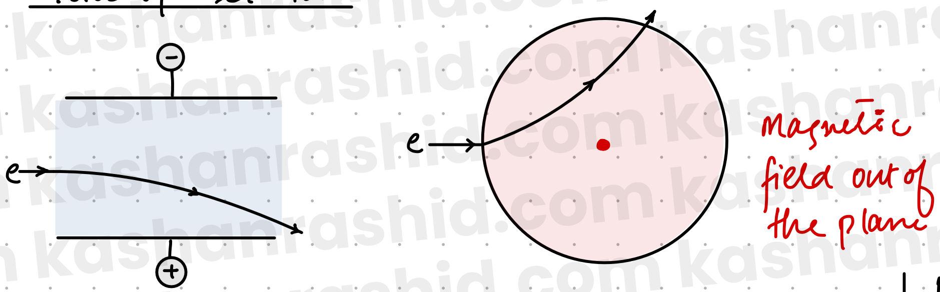
squaring both sides

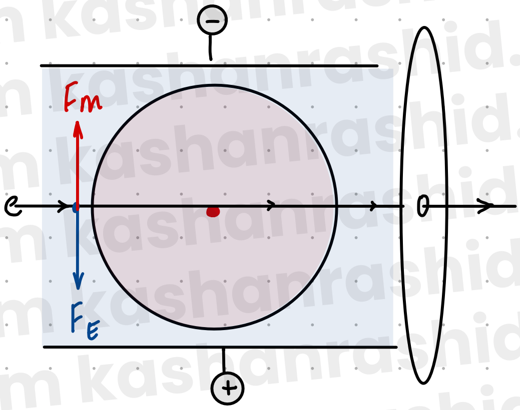
$$\left(\frac{q}{m}\right)^2 = \left(\sqrt{\frac{2Vq}{m}} \cdot \frac{1}{Br}\right)^2$$

$$\frac{q^{\cancel{2}}}{m^{\cancel{2}}} = \frac{2V\cancel{q}}{\cancel{m}} \cdot \frac{1}{B^2r^2}$$

$$\boxed{\frac{q}{m} = \frac{2V}{B^2r^2}}$$

Velocity Selector





A magnetic field and an electric field are placed perpendicular to one another. Their field strengths are adjusted such that the electric force is balanced by the magnetic force.

The electron will pass straight, as fields tried to deflect it in opposite directions.

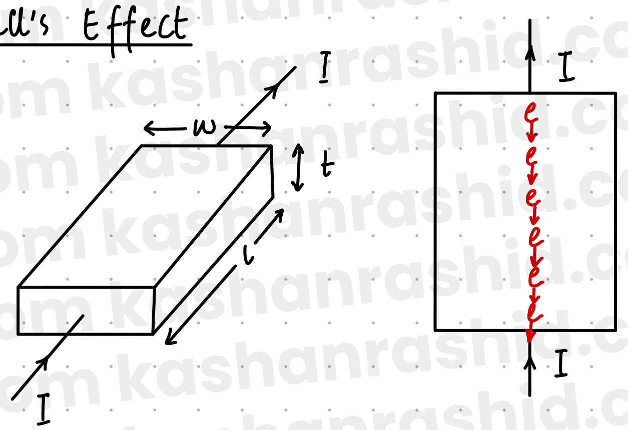
$F_E = F_m$

$E\cancel{q} = Bv\cancel{q}$

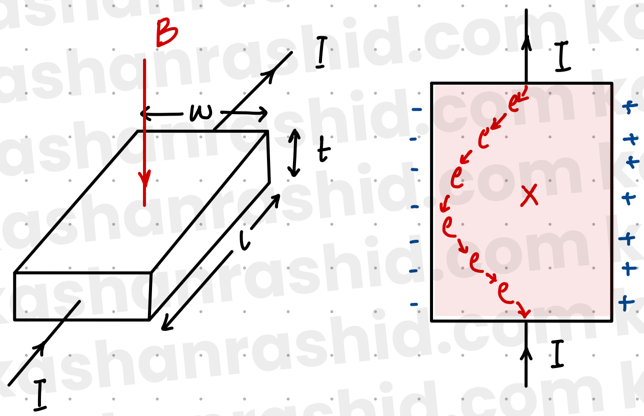
$E = Bv$ or $\boxed{v = \frac{E}{B}}$

using a specific value of E and B, a particular speed of charged particle is filtered out.

Hall's Effect

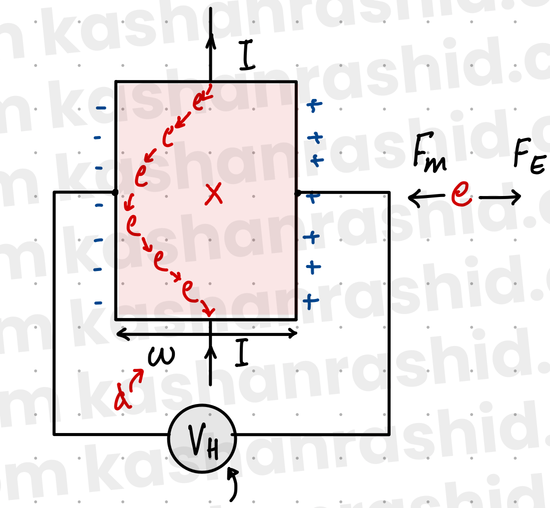


Before the application of magnetic field across the slice.



Due to the magnetic field into the conductor, the charges experienced a magnetic force and deflected to the left.

The segregation of electrons on one side induced an equal positive charge on the other. This induces a potential difference across that slice of conductor perpendicular to both direction of current and magnetic field. This induced voltage is called the Hall's Voltage.



$F_m = F_E$

$Bvq = Eq$

$Bv = E$

as $E = \frac{V}{d}$ so

$Bv = \frac{V_H}{w}$

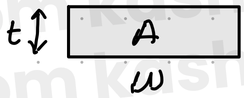
$V_H = Bvw$

as $I = nAve$ so $v = \frac{I}{nAe}$

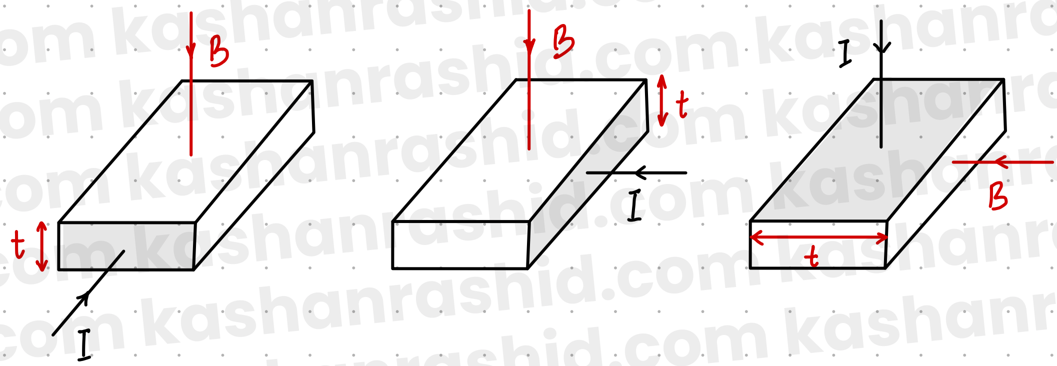
$V_H = B\left(\frac{I}{nAe}\right)w$

$V_H = \frac{BIw}{nAe}$

$V_H = \frac{BI\cancel{w}}{n(\cancel{w} \times t)e}$



$$\boxed{V_H = \frac{BI}{nte}}$$



"t" is that length of cross-sectional area which is parallel to the magnetic field.

$V_H = \frac{BI}{nte}$ is used to calculate magnetic flux density "B".

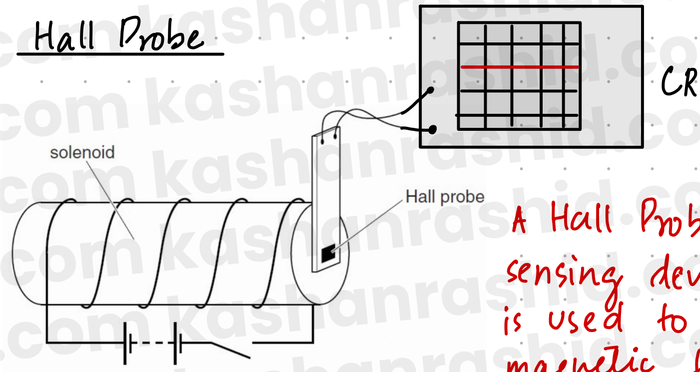
$V_H \propto B$

$\uparrow V_H \propto \frac{1}{n\downarrow}$ $\qquad \uparrow V_H \propto \frac{1}{t\downarrow}$

A conductor with a smaller value of 'n' and a thin slice is preferred so that measurable V_H is induced.

- Semi-conductors are used as they have smaller number density.

Hall Probe

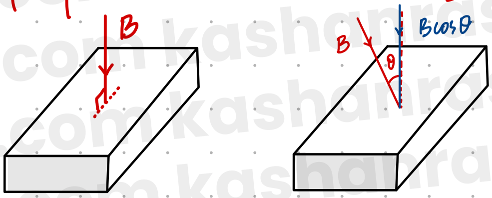


A Hall Probe is a sensing device that is used to measure magnetic flux density.

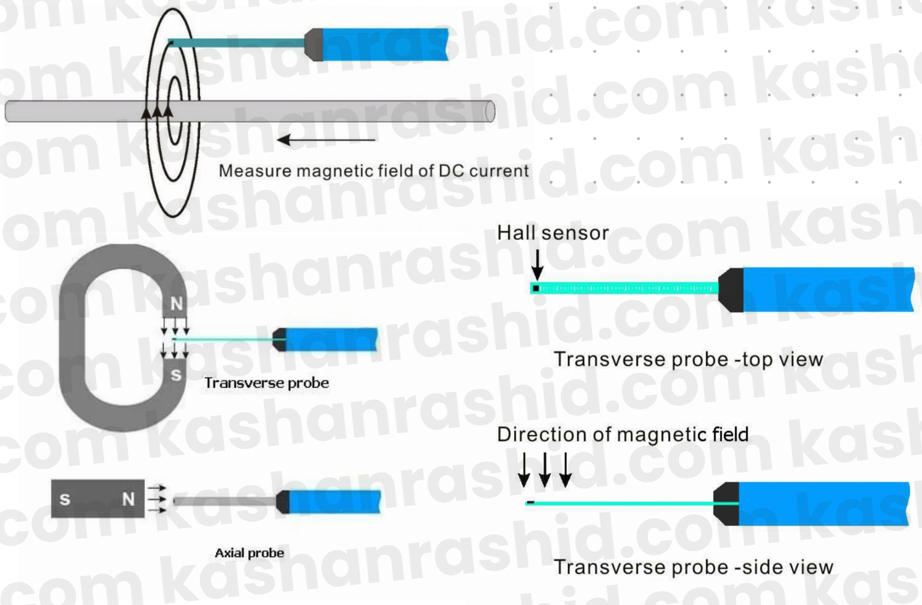
- It is connected to a CRO to show the Hall's voltage induced.

When using Hall Probe

☑ Make sure magnetic field lines are perpendicular to the slice of conductor.



If magnetic field is at an angle to the slice of conductor, the V_H induced will be less as a component of magnetic field will be exerting a force.



Hence to calibrate the Hall Probe, it is rotated about its axis such that the reading on CRO is max. At this orientation, magnetic field lines will be at 90° to slice of conductor.

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

$$V_H = \frac{BI}{ntq}$$

" $V_H \propto B$ "

7 A solenoid is connected in series with a battery and a switch. A Hall probe is placed close to one end of the solenoid, as illustrated in Fig. 7.1.

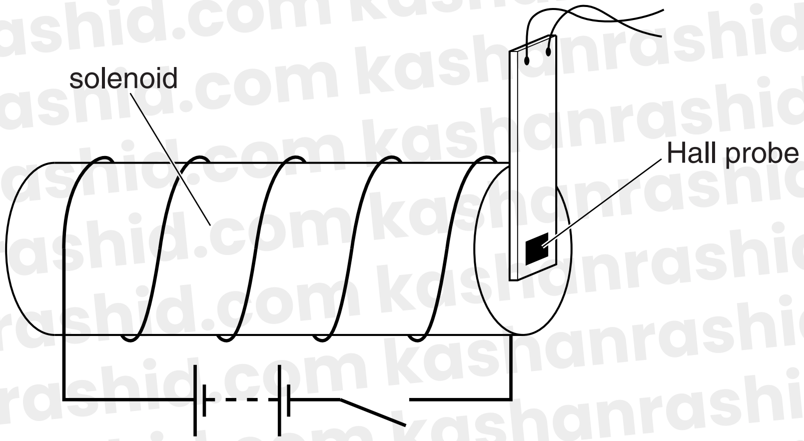


Fig. 7.1

The current in the solenoid is switched on. The Hall probe is adjusted in position to give the maximum reading. The current is then switched off.

(a) The current in the solenoid is now switched on again. Several seconds later, it is switched off. The Hall probe is not moved.

On the axes of Fig. 7.2, sketch a graph to show the variation with time t of the Hall voltage V_H.

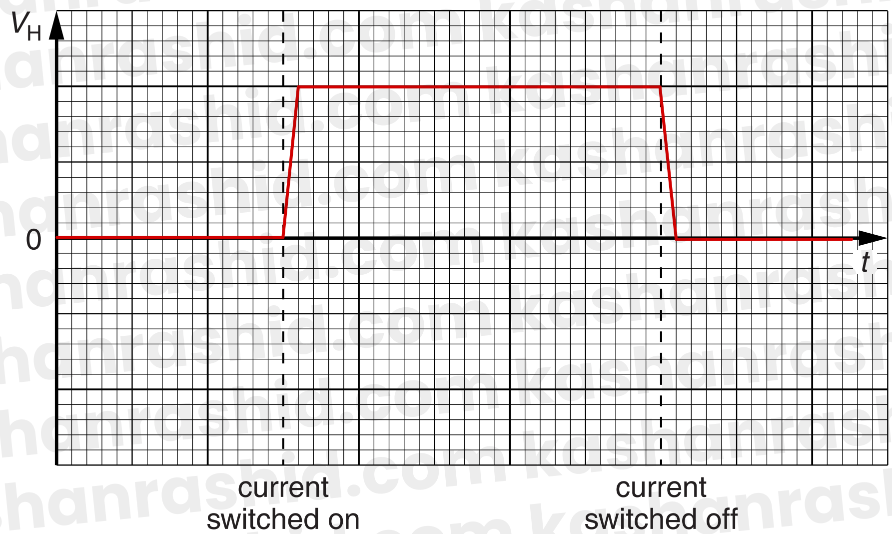


Fig. 7.2

[3]

5 A Hall probe is placed a distance d from a long straight current-carrying wire, as illustrated in Fig. 5.1.

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

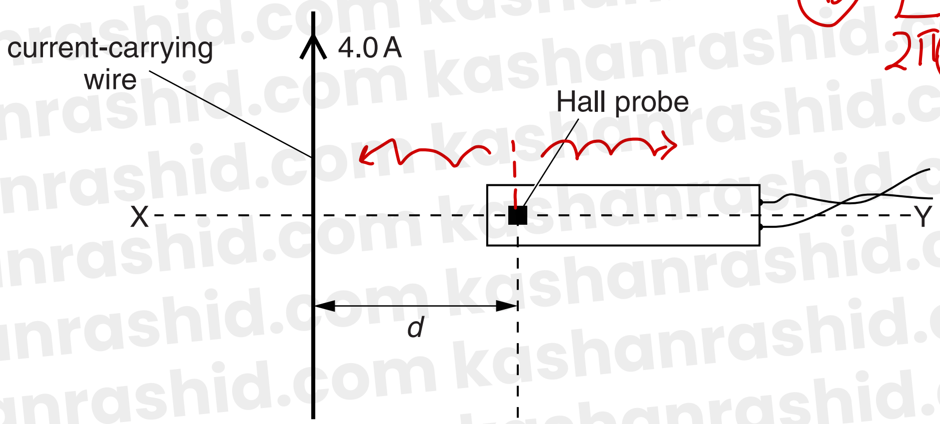


Fig. 5.1

The direct current in the wire is 4.0 A. Line XY is normal to the wire.

The Hall probe is rotated about the line XY to the position where the reading V_H of the Hall probe is maximum.

(a) The Hall probe is now moved away from the wire, along the line XY.
On the axes of Fig. 5.2, sketch a graph to show the variation of the Hall voltage V_H with distance x of the probe from the wire. Numerical values are not required on your sketch.

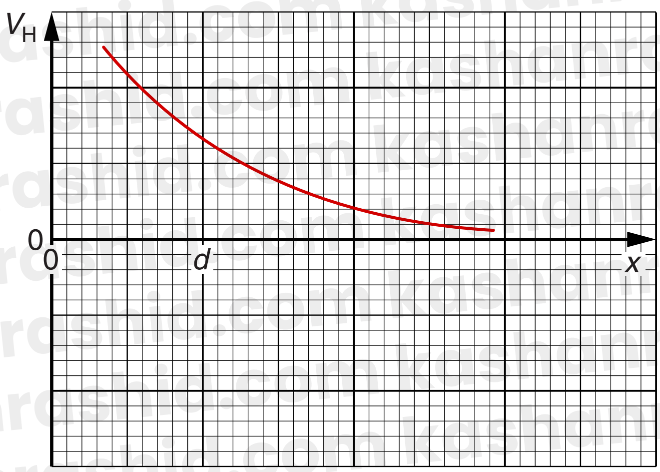
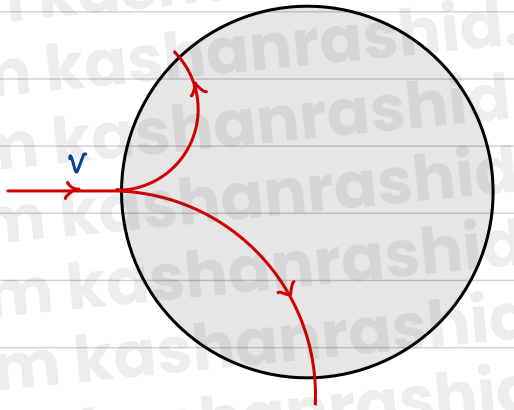


Fig. 5.2

[2]

Charge-to-mass ratio

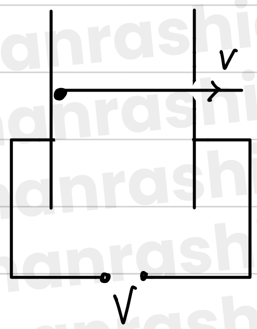


$F_m = F_c$

$B\cancel{v}q = \dfrac{mv^{\cancel{2}}}{r}$

$Bq = \dfrac{mv}{r}$

$\dfrac{q}{m} = \dfrac{v}{Br}$



Workdone = Gain in KE

$V \times q = \dfrac{1}{2}m(v^2 - \cancel{u^2})$, $u = 0$

$\dfrac{2Vq}{m} = v^2$

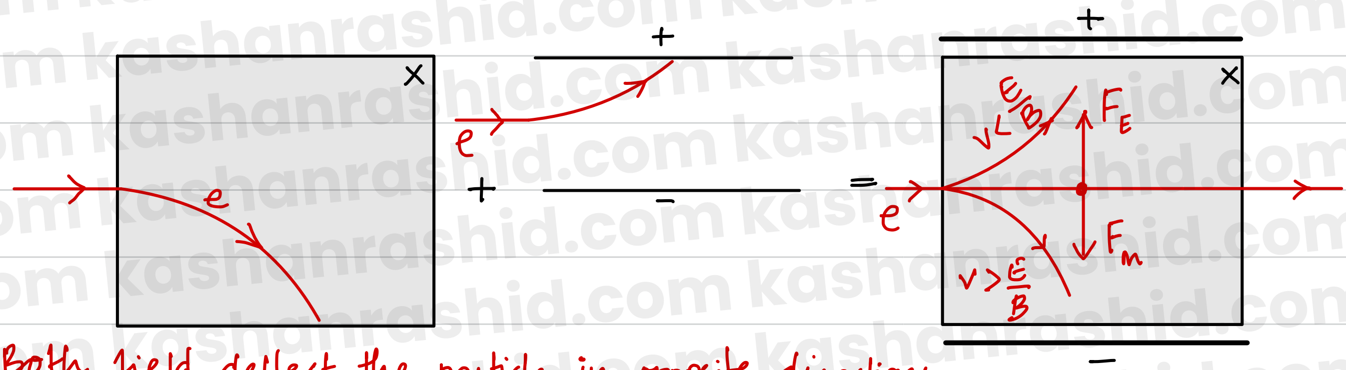
$v = \sqrt{\dfrac{2Vq}{m}}$

$\dfrac{q}{m} = \dfrac{1}{Br} \times \sqrt{\dfrac{2Vq}{m}}$

$\dfrac{q^{\cancel{2}}}{m^{\cancel{2}}} = \dfrac{1}{B^2 r^2} \times \dfrac{2V\cancel{q}}{\cancel{m}}$

$$\boxed{\dfrac{q}{m} = \dfrac{2V}{B^2 r^2}}$$

Velocity Selector



- Both field deflect the particle in opposite directions
- The particle with speed $v = \dfrac{E}{B}$ travels straight as magnetic force = electric force on it.
- All other particles are filtered out.

$F_m = F_E$

$B v \cancel{q} = E \cancel{q}$

$$\boxed{v = \dfrac{E}{B}}$$

if $F_m > F_E$ then $v > \dfrac{E}{B}$ deflects downwards

if $F_m < F_E$ then $v < \dfrac{E}{B}$ deflect upwards

$$F_m = F_c$$

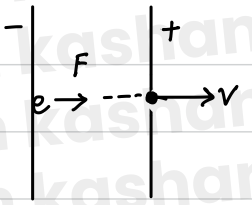
$$B\cancel{v}q = \frac{mv^{\cancel{2}}}{r}$$

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

$$\frac{q}{m} = \sqrt{\frac{2Vq}{m}} \times \frac{1}{Br}$$

$$\frac{q^2}{m^{\cancel{2}}} = \frac{2V\cancel{q}}{\cancel{m}} \times \frac{1}{B^2 r^2}$$

$$\boxed{\frac{q}{m} = \frac{2V}{B^2 r^2}}$$



$V = \frac{\text{Work}}{\text{charge}}$

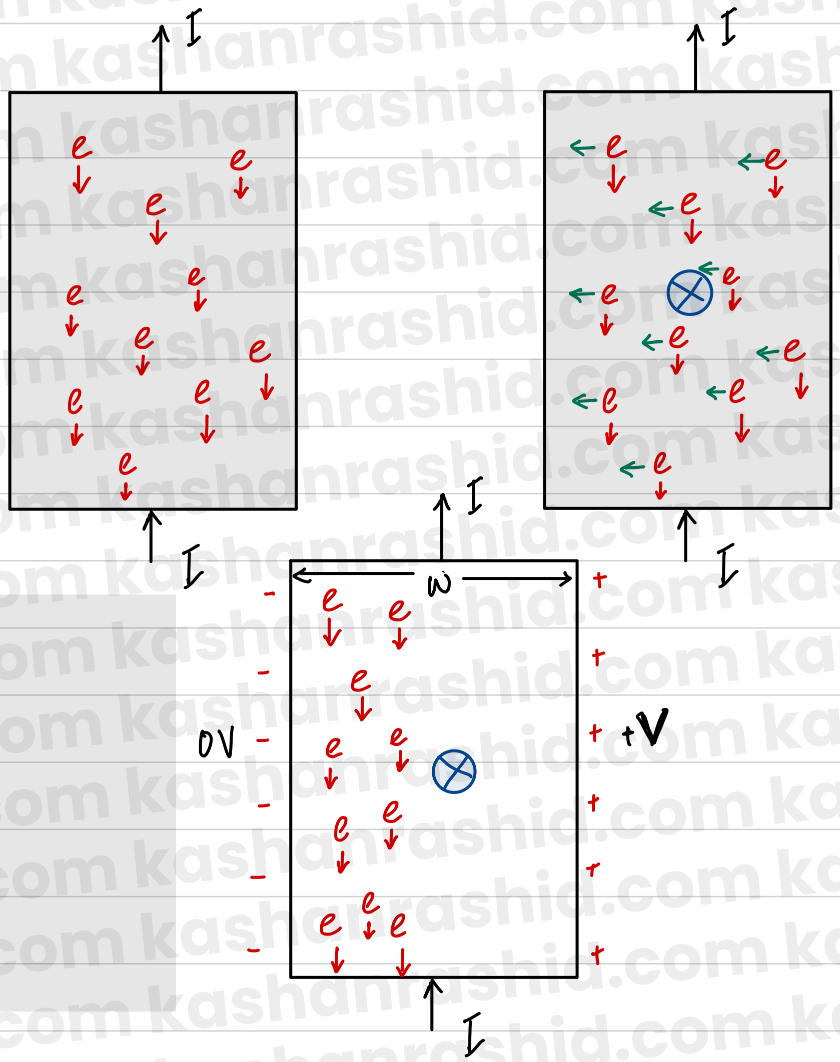
$Vq = \text{Work}$

Workdone = Gain in KE

$$V \times q = \frac{1}{2} m(v^2 - 0)$$

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

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



magnetic field into the page

$$F_m = F_E$$

$$Bv\cancel{q} = E\cancel{q}$$

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

$$Bv = \frac{V_H}{w}$$

$$V_H = Bvw$$

$$V_H = B\left(\frac{I}{nAe}\right)w$$

$$V_H = \frac{BIw}{nAe}$$

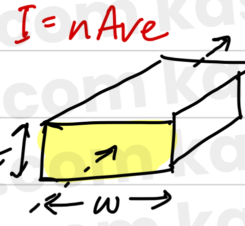
$$V_H = \frac{BI\cancel{w}}{n(\cancel{w} \times t)e}$$

$$\boxed{V_H = \frac{BI}{nte}}$$

$F_m \leftarrow e \rightarrow F_E$

$E = \frac{F}{q}$ $\quad E = \frac{V}{d}$

$I = nAve$



9 A thin rectangular slice of aluminium has sides of length 65 mm, 50 mm and 0.10 mm, as shown in Fig. 9.1.

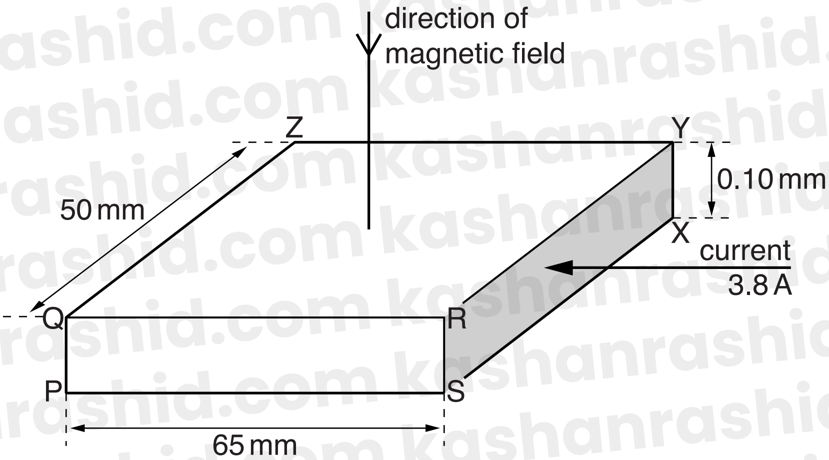


Fig. 9.1 (not to scale)

Some of the corners of the slice are labelled.

A current I of 3.8 A is normal to face RSXY of the slice.

In aluminium, the number of free electrons per unit volume is $6.0 \times 10^{28}\,m^{-3}$.

A uniform magnetic field of magnetic flux density B equal to 0.13 T is normal to face QRYZ of the aluminium slice in the direction from Q to P.

A Hall voltage V_H is developed across the slice and is given by the expression

$$V_H = \frac{BI}{ntq}.$$

(a) Use Fig. 9.1 to state the magnitude of the distance t.

t = ...0.10.... mm [1]

(b) Calculate the magnitude of the Hall voltage V_H.

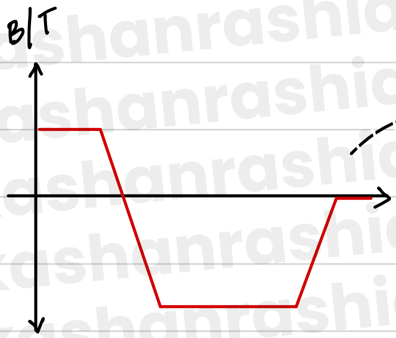
$V_H = \frac{BI}{ntq}$ $V_H = \frac{0.13 \times 3.8}{6 \times 10^{28} \times 0.1 \times 10^{-3} \times 1.6 \times 10^{-19}}$

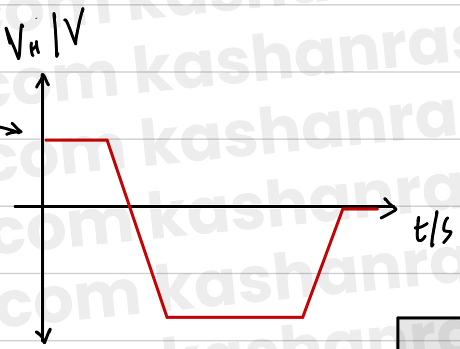
$V_H = 5.15 \times 10^{-7}$ V

V_H = ...5.2×10^{-7}.... V [2]

[Total: 3]

$$V_H = \frac{BI}{ntq}$$





$V_H \propto B$

- similar shape
- different values

$$\boxed{V_H \propto B \propto I}$$

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