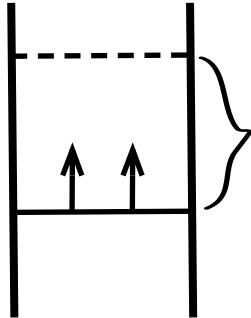


Lecture 27: Magnetic Force, Torque, Circular Motor and the Hall Effect

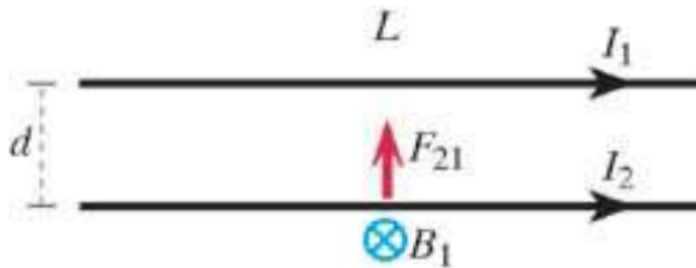
Magnetic Force: $\vec{B}$ field exerts a force on the source, $q\vec{v}$

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

$$\Delta\vec{F} = I\Delta\vec{l} \times \vec{B}$$


$$\Delta N q \frac{\Delta l}{\Delta t} = I \Delta l$$

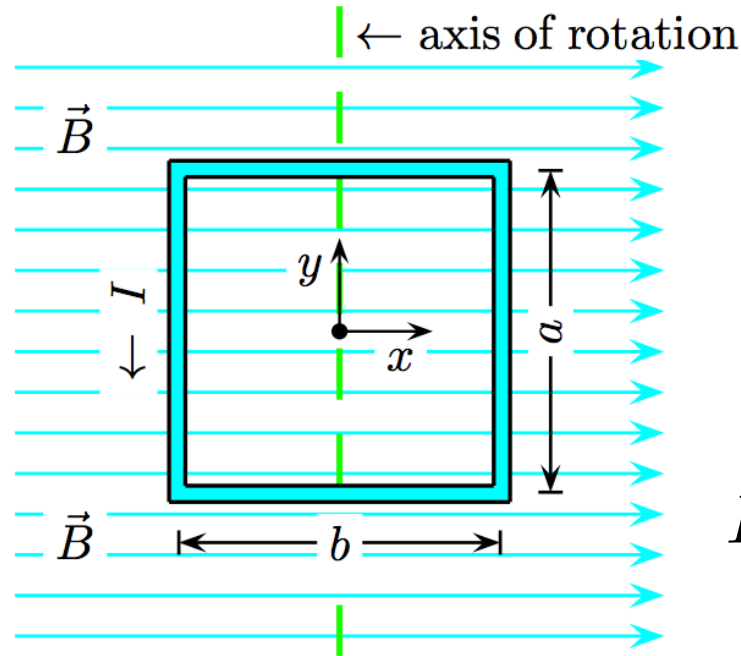
Magnetic force on parallel current segments



$$\Delta F_{I\Delta l}^B = I_2 \Delta l \times B_P^{I_1}$$

$$\Delta F = (I_2 \Delta l) \left(\frac{\mu_0 I_1}{2\pi a} \right) \quad (\text{attractive forces})$$

Current loop in a constant B field



$$F_1 = I a B \otimes$$

$$F_2 = F_4 = 0$$

$$F_3 = I a B \odot$$

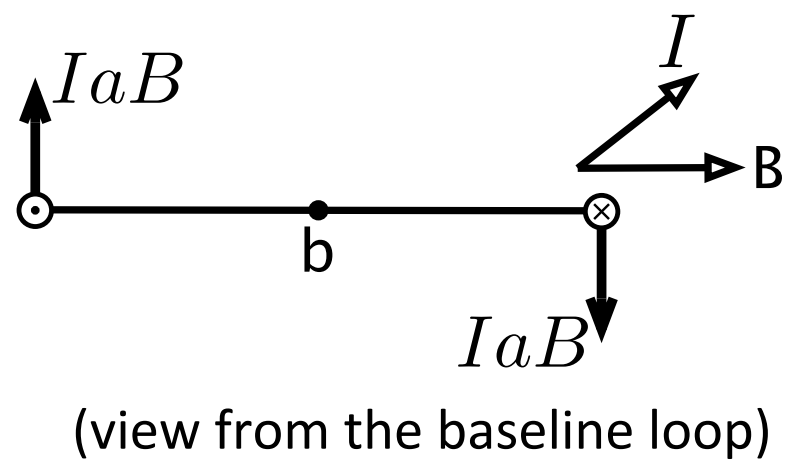
$$F_{\square} = F_1 + F_3 = I a B - I a B = 0$$

Torque about midline 00:

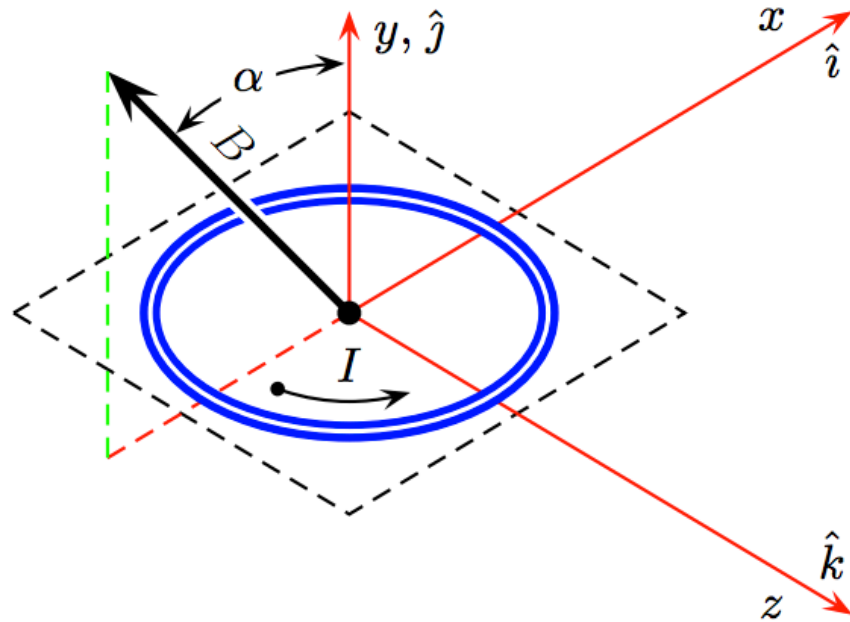
$$\tau = F b = (I a B) b = I a b B = I A B$$

$$\mu = I A = I a b$$

$$\vec{\tau} = \vec{\mu} \times \vec{B} \text{ (present case: } \tau = \mu B \text{)}$$



General Case:



$$\vec{\tau} = \vec{\mu} \times \vec{B} \quad \text{circular loop.}$$

$\vec{B}$ is in the xy plane, $\alpha < 90^\circ$

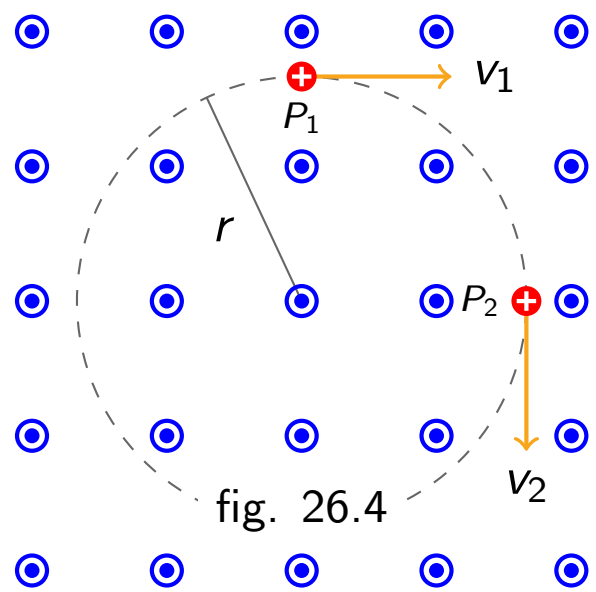
$$\text{So } \vec{B} = B \left(-\sin \alpha \hat{i} + \cos \alpha \hat{j} \right)$$

$$\vec{\mu} = \mu \hat{j}$$

$$\begin{aligned} \vec{\tau} = \vec{\mu} \times \vec{B} &= \mu B \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 1 & 0 \\ -\sin \alpha & \cos \alpha & 0 \end{vmatrix} \\ &= \mu B \sin \alpha \hat{k} \end{aligned}$$

Circular Motion – Force due to B on qv

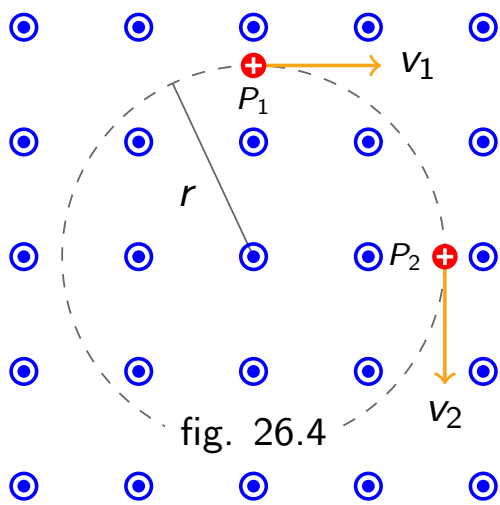
Motion of a charged particle in the plane perpendicular to the magnetic field



A proton is moving in a clockwise direction in a plane perpendicular to a uniform magnetic field B pointing out of the page. Determine the direction of the magnetic force at P_1 and at P_2 .

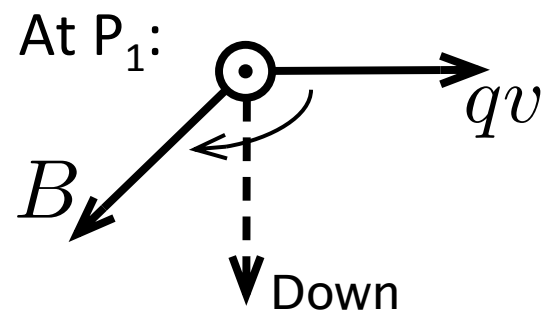
Choice	Direction of Force at P_1	Direction of Force at P_2
1	Up	Left
2	Down	Left
3	Up	Right
4	Down	Right

Circular Motion – Force due to B on qv



Given: $B = const.$, out of the paper

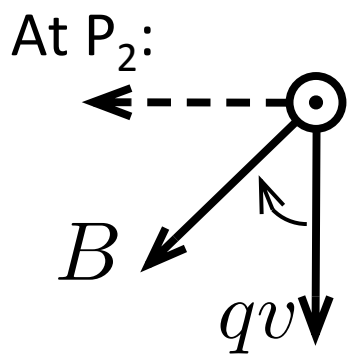
Find: The direction of the force at P_1 & at P_2



Period $T = \frac{2\pi r}{v}$
 $= \frac{2\pi m}{qB}$

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

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



$$\left(\omega = \frac{2\pi}{T} = \frac{qB}{m} \right)$$

Period is independent of v , r .

Circular motion in the plane perpendicular to a constant magnetic field

A proton of charge e and mass m is moving in a plane perpendicular to a uniform magnetic field. Investigate the radius and period of its circular motion.

Hint:

► $F_{cp} = \frac{mv^2}{r} = evB$

► $T = \frac{2\pi r}{v}$

Choice	R (radius of the circular motion)	T (period of circular motion)
1	mv/eB	As v increases, T increases
2	mv/eB	T is independent of v
3	eB/mv	As v increases, T increases
4	eB/mv	T is independent of v

Alternative $\Delta V \Rightarrow E > 0, E < 0$

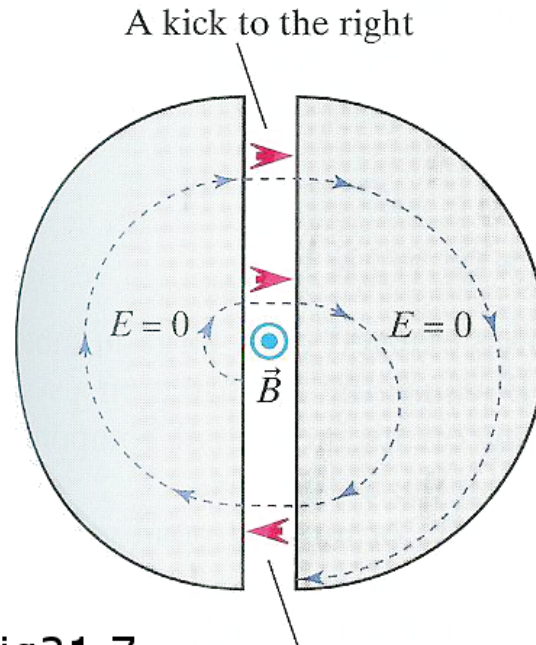
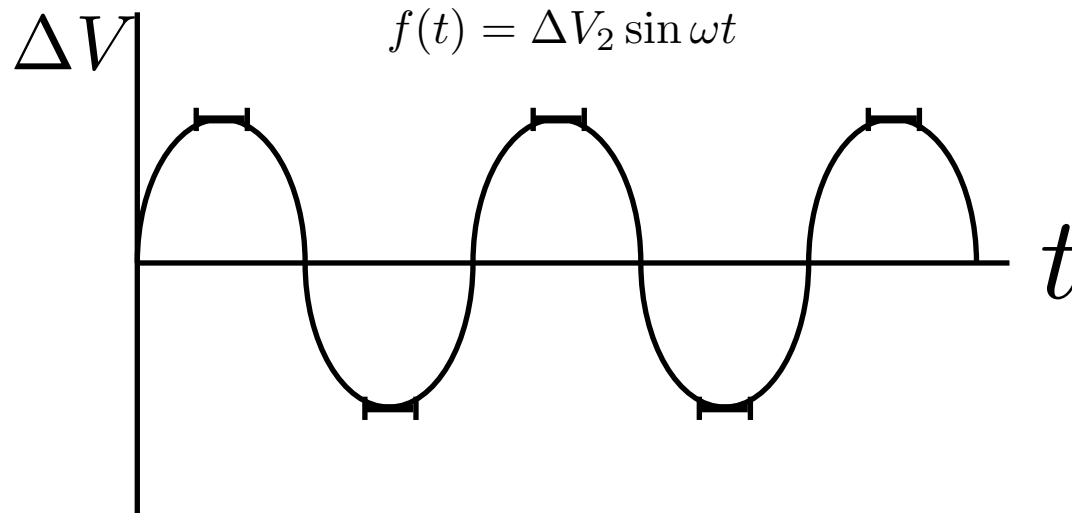
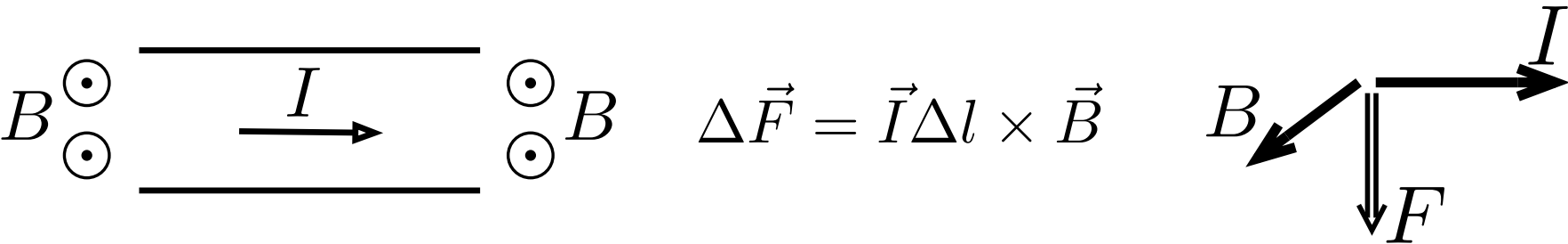


Fig21.7 A kick to the left

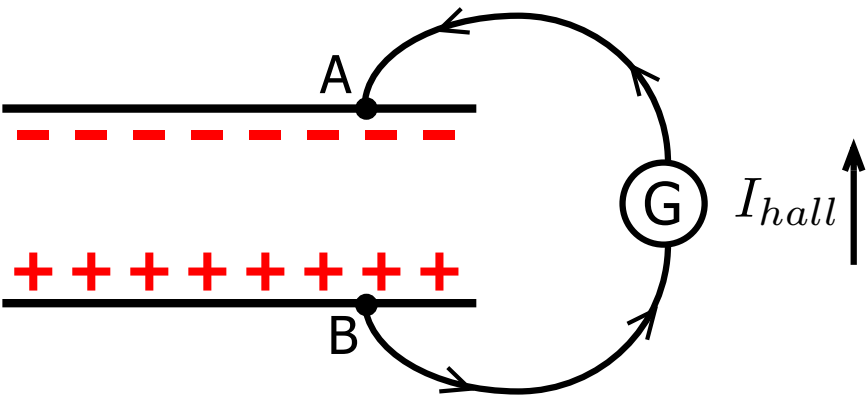


▮ = successive acceleration of charged particle

Hall Effect: Determine the sign of charge carriers



If carriers have + charges:



For case 1: Static polarized charge creates $E \uparrow$
 $\therefore$ Potential at B is higher. Take a test charge to be pushed by $F = qvB$ to raise it's potential from A to B .

$$V_B - V_A = \frac{W_{A \rightarrow B}}{q} = \frac{qvBl}{q} = vBl$$

Hall Experiment

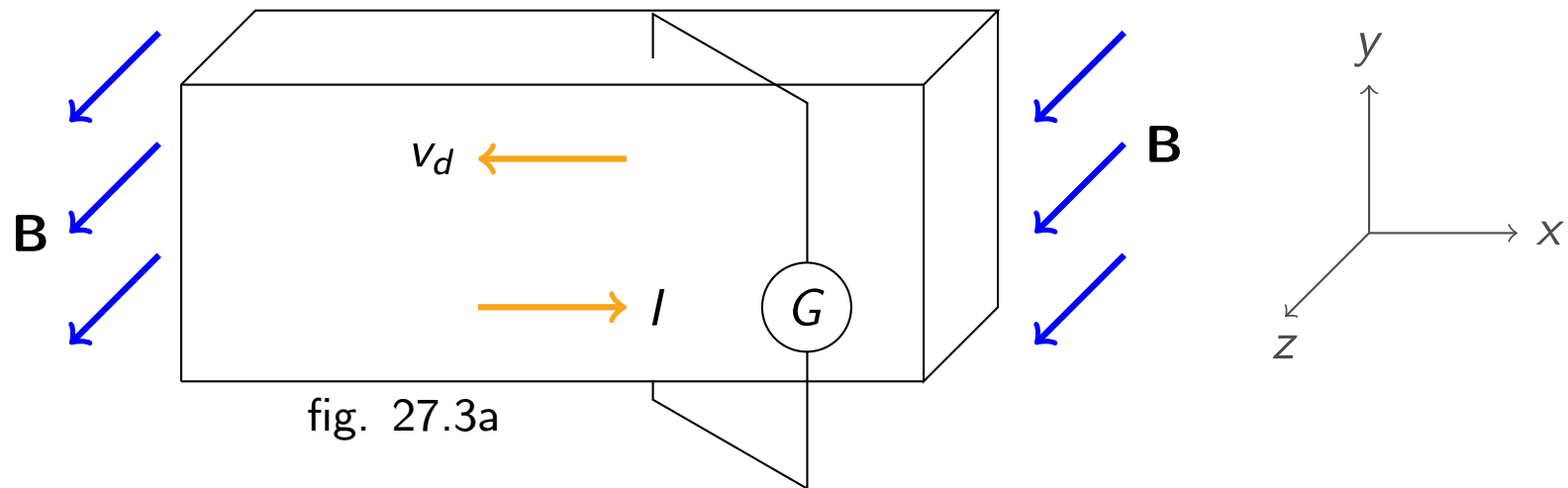
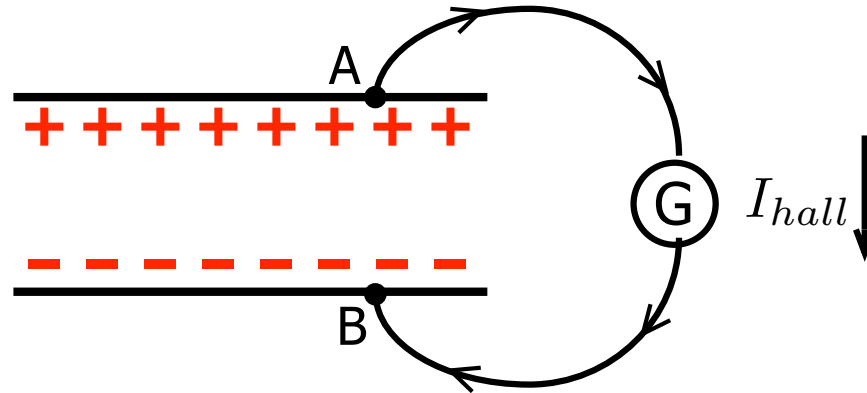


fig. 27.3a

Fig. 27.3a shows a portion of a metal strip in a region of uniform magnetic field. A galvanometer is connected to the upper and lower surfaces of the strip. A current I flows to the right (so the electron drift velocity v_d is to the left) and $\mathbf{B} = B\hat{z}$. Determine the direction of the magnetic force experienced by the drifting electrons and the direction of the (conventional) Hall current through the galvanometer.

Choice	F_B	Direction of Hall current through the galvanometer
1	Up	Up
2	Up	Down
3	Down	Up
4	Down	Down

If carriers have – charges:



For case 2: $E \downarrow$ $V_A - V_B = vBl$

Determination of v :

$$I = |q|i = |q|nAv, \quad v = \frac{I}{|q|nA}$$

$$n = \frac{\# \text{ of electrons}}{\text{volume}} \xrightarrow{2 \text{ valence}} \frac{2N_A (\# \text{ of moles})}{\text{volume}}$$