Applied Physics

BS Software Engineering/Information Technology

1st Semester

Lecture # 19

Magnetic fields

Presented By

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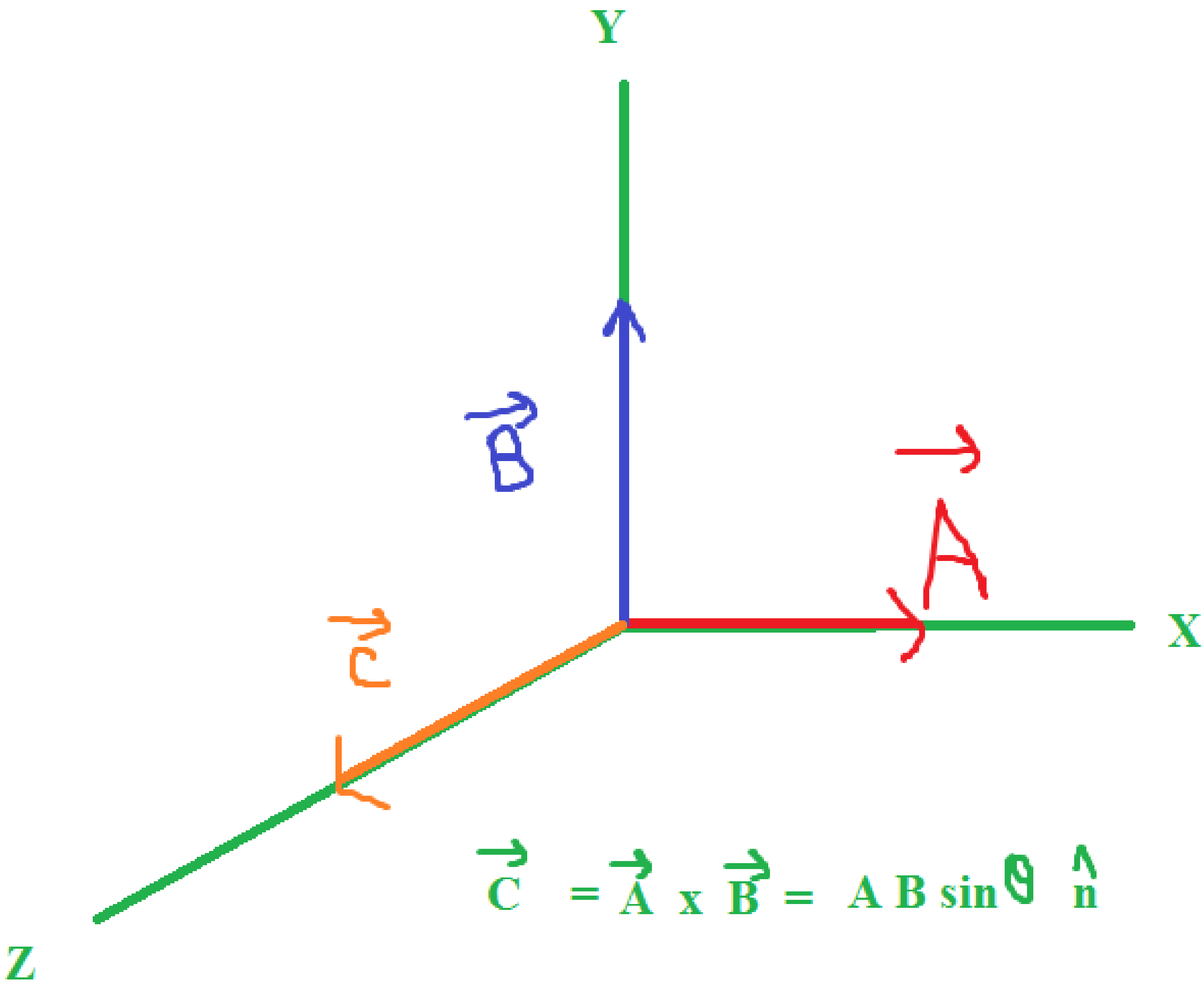
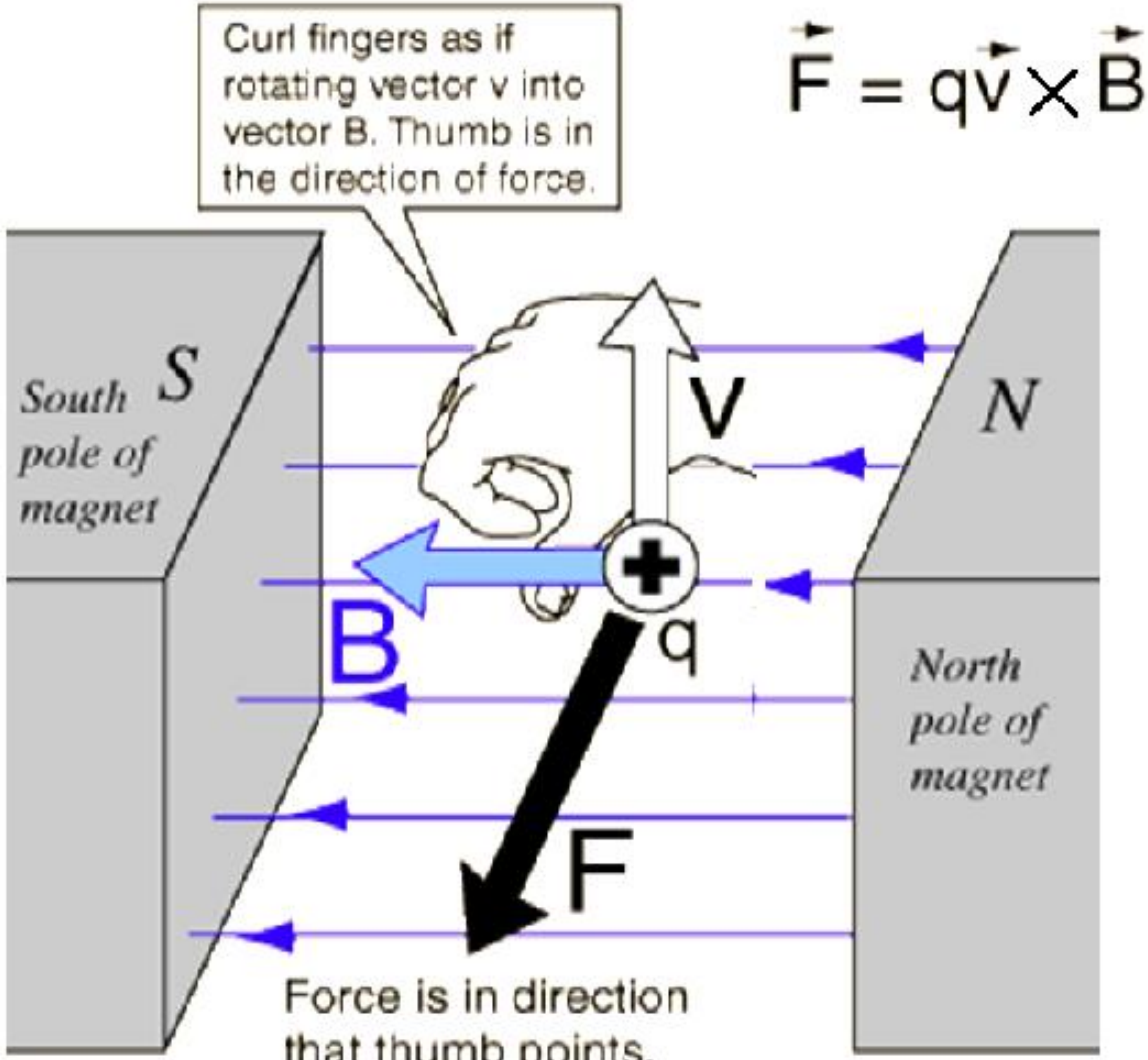
Lecture # 19

- Combined electric and magnetic forces (Lorentz Force)
- The magnetic force on a current
- Hall Effect
- Problems



$$\vec{C} = \vec{A} \times \vec{B} = A\,B \sin\theta\ \hat{n}$$


Curl fingers as if rotating vector v into vector B. Thumb is in the direction of force.
$\vec{F} = q\vec{v} \times \vec{B}$
South pole of magnet
S
N
North pole of magnet
V
B
q
F
Force is in direction that thumb points.

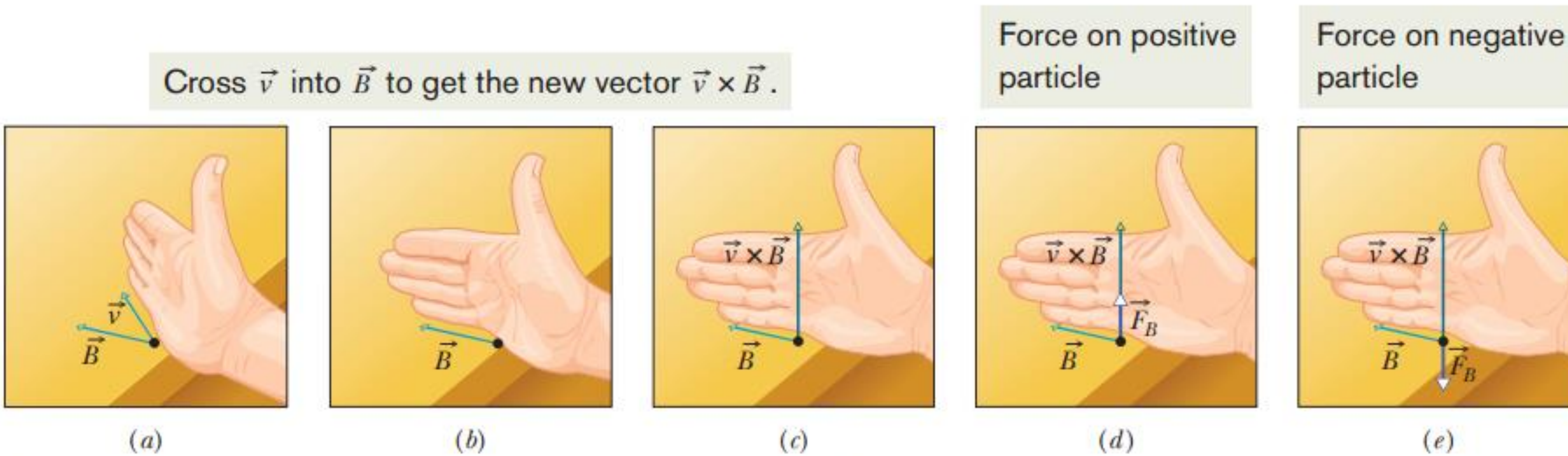


Figure (a)–(c) The right-hand rule (in which $\vec{v}$ is swept into $\vec{B}$ through the smaller angle ϕ between them) gives the direction of $\vec{v} \times \vec{B}$ as the direction of the thumb. (d) If q is positive, then the direction of $\vec{F}_B = q\vec{v} \times \vec{B}$ is in the direction of $\vec{v} \times \vec{B}$. (e) If q is negative, then the direction of $\vec{F}_B$ is opposite that of $\vec{v} \times \vec{B}$.

Combined electric and magnetic forces (Lorentz Force)

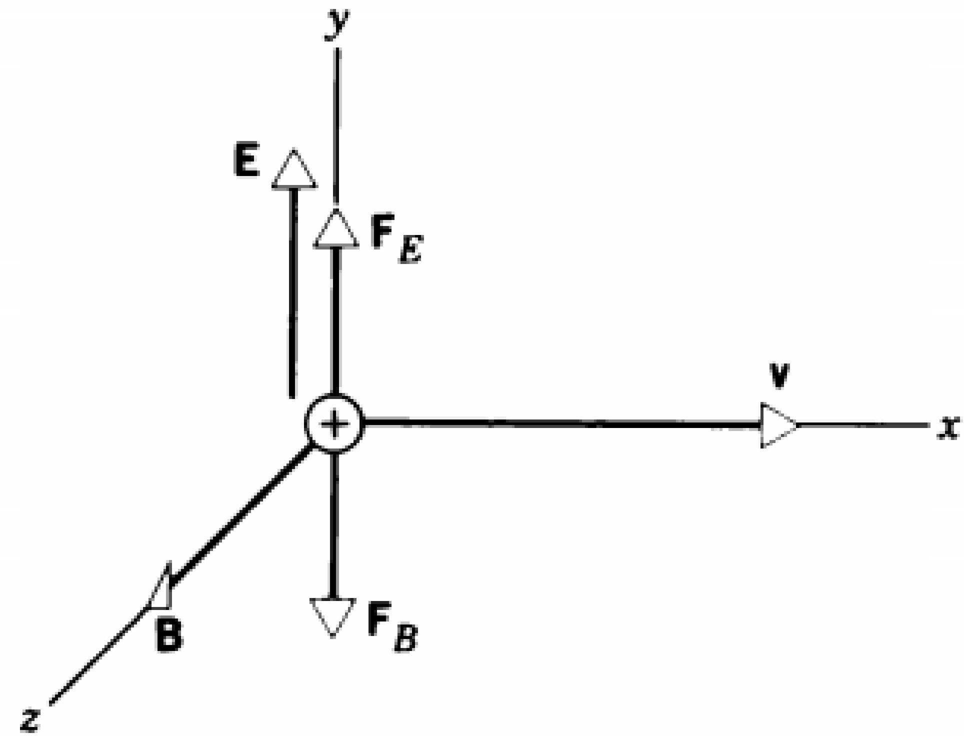
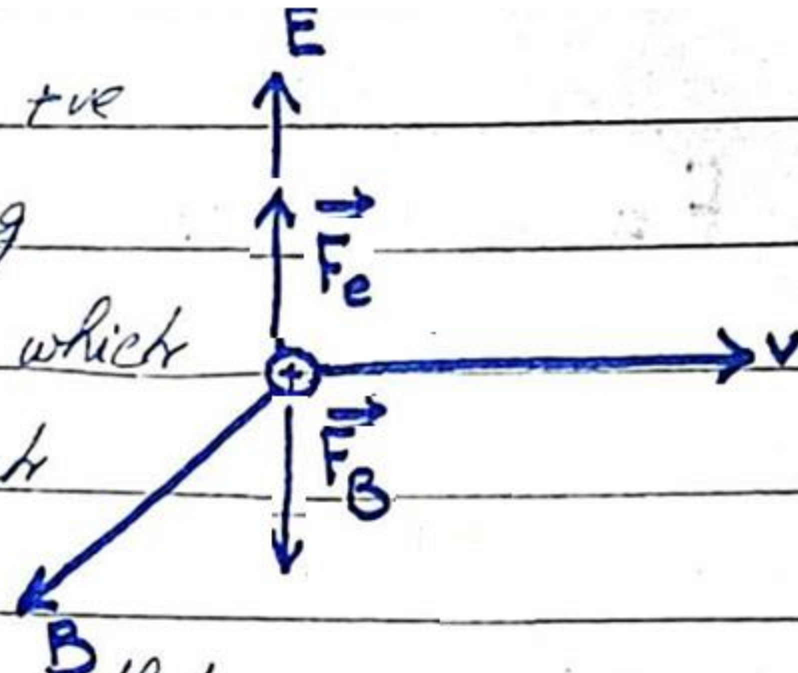


Figure 7 A positively charged particle, moving through a region in which there are electric and magnetic fields perpendicular to one another, experiences opposite electric and magnetic forces $\mathbf{F}_E$ and $\mathbf{F}_B$.

Consider, a +ve charge and the following $\vec{E}$, $\vec{B}$ & $\vec{v}$ acts on it which are perpendicular to each other.



From this, we get that F_e works in upward direction

The total force acting on the charge particle will be;

$$\vec{F} = \vec{F_e} + \vec{F_B} \quad \text{—— (i)}$$

result as;

$$F = qE + (-qvB\sin\theta) \quad \text{— (ii)}$$

This resultant force is known as Lorentz Force

If the Lorentz force become zero, then we have;

$$qE - qvB = 0$$

So, both the forces i.e electric force & magnetic force becomes equal, so;

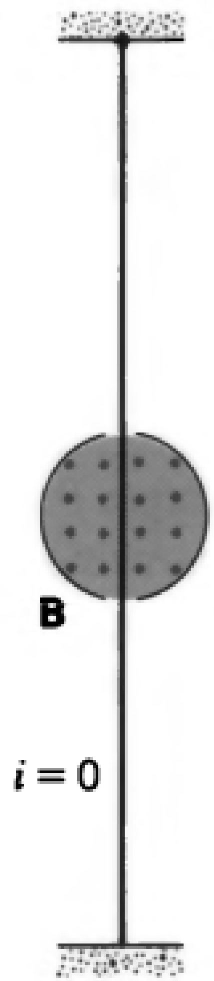
$$\cancel{q}vB = \cancel{q}E$$

The velocity of charge particle will be;

$$v = E/B \quad \text{——} \quad (iv)$$

The magnetic force on a current

When there is No Current

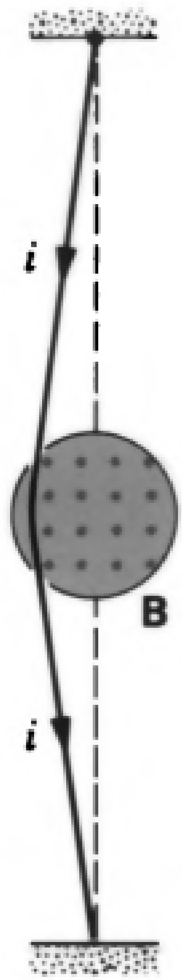


(a)

When there is Current in up word direction

(b)

When there is Current in downword direction



(c)

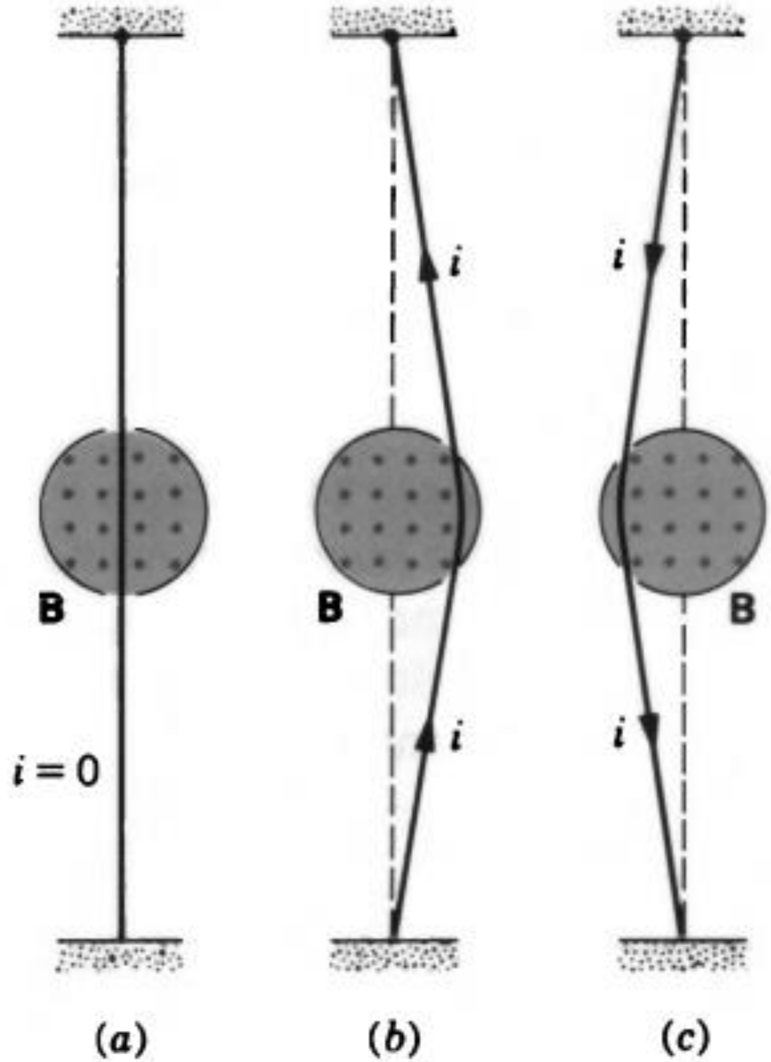


Figure 20 A flexible wire passes between the poles of a magnet. (*a*) There is no current in the wire. (*b*) A current is established in the wire. (*c*) The current is reversed.

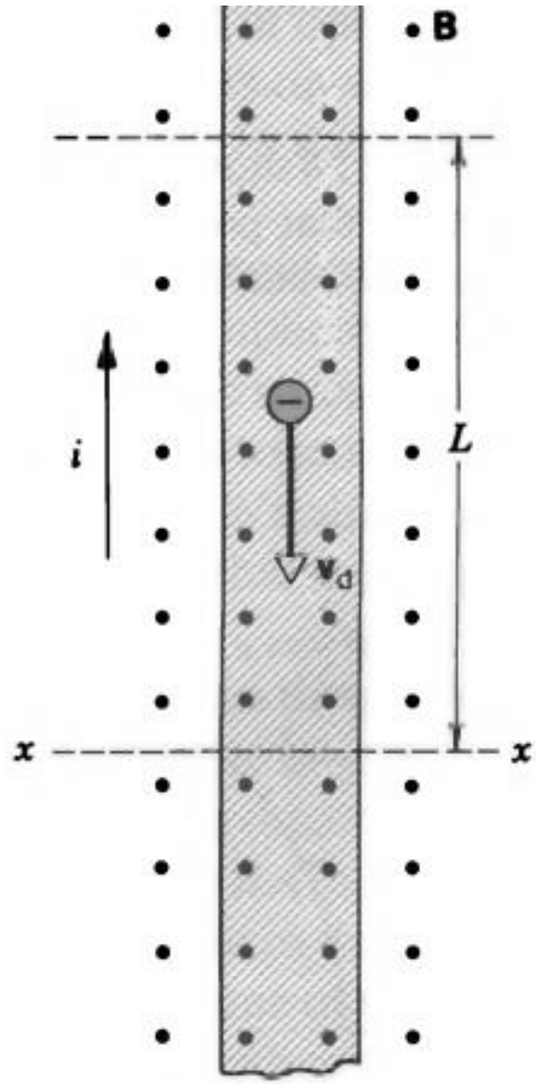


Figure 21 A close-up view of a length L of the wire of Fig. 20*b*. The current direction is upward, which means that electrons drift downward. A magnetic field emerges from the plane of the figure, so that the wire is deflected to the right.

$$\mathbf{F} = -Ne\mathbf{v}_d \times \mathbf{B}.$$

How many electrons are contained in that segment of wire? If n is the number density (number per unit volume) of electrons, then the total number N of electrons in the segment is nAL, where A is the cross-sectional area of the wire. Substituting into Eq. 25, we obtain

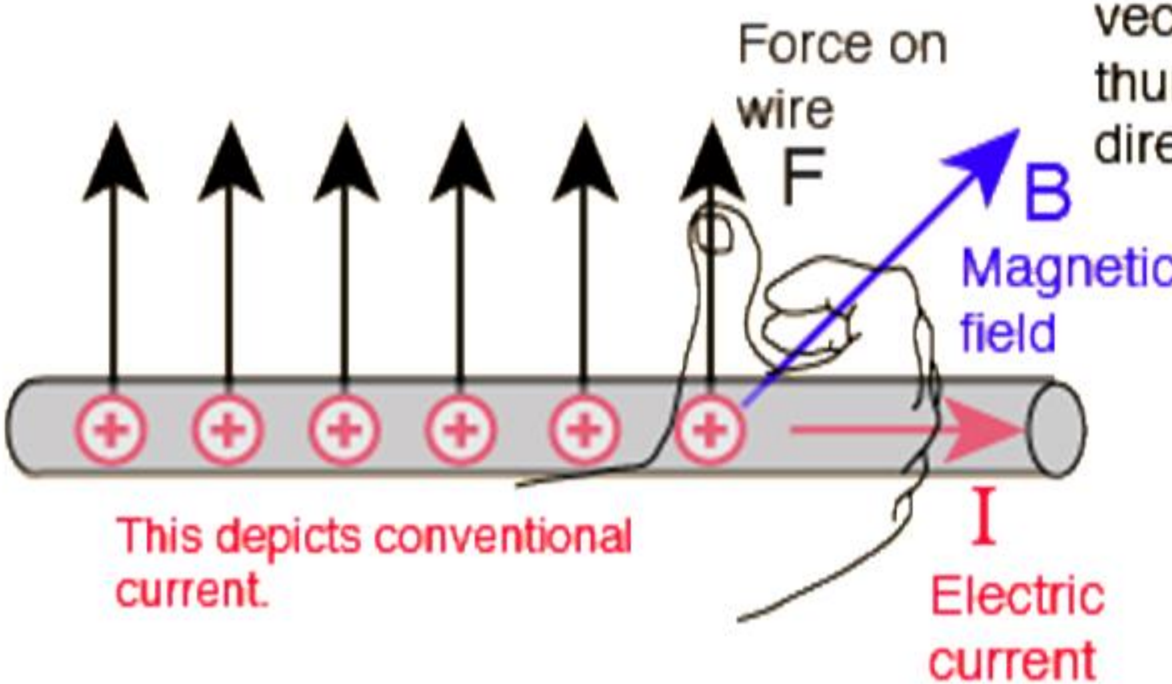
$$\mathbf{F} = -nALe\mathbf{v}_d \times \mathbf{B}.$$

Equation 6 of Chapter 32 ($v_d = i/nAe$) permits us to write Eq. 26 in terms of the current i. To preserve the vector relationship of Eq. 26, we define the vector $\mathbf{L}$ to be equal in magnitude to the length of the segment and to point in the direction of the current (opposite to the direction of electron flow). The vectors $\mathbf{v}_d$ and $\mathbf{L}$ have opposite directions, and we can write the scalar relationship $nALev_d = iL$ using vectors as

$$-nALe\mathbf{v}_d = i\mathbf{L}.$$

Substituting Eq. 27 into Eq. 26, we obtain an expression for the force on the segment:

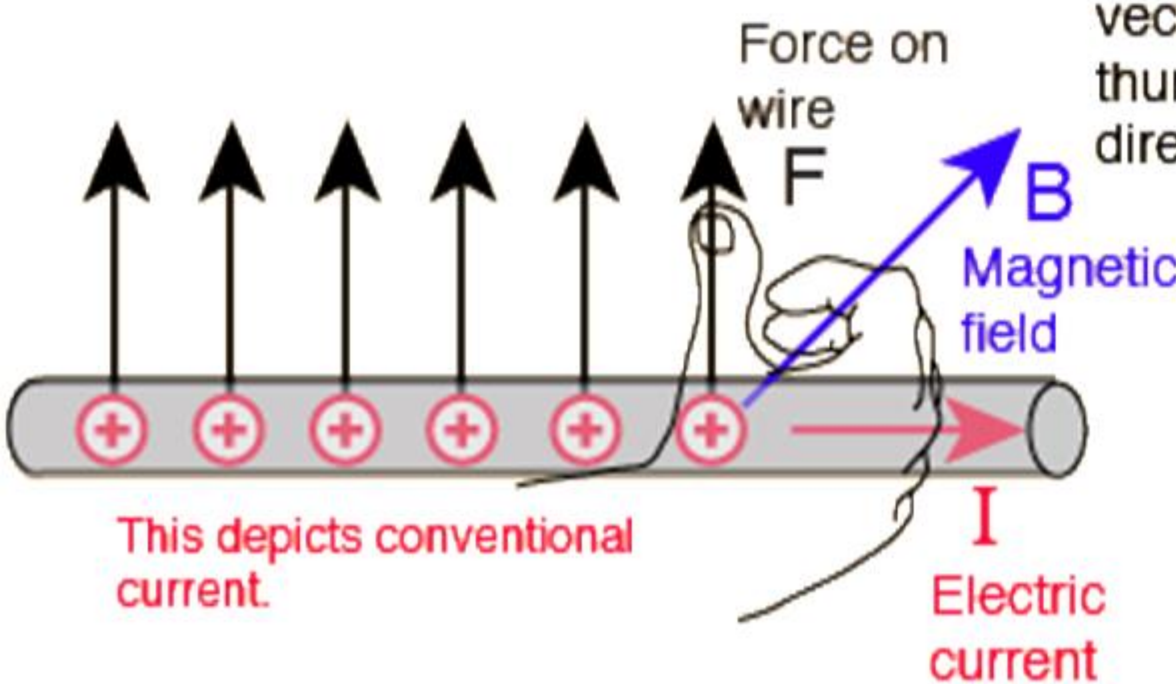
$$\mathbf{F} = i\mathbf{L} \times \mathbf{B}.$$



Curl fingers as if rotating vector I into vector B. The thumb is then in the direction of the force F

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

Force on straight wire of length L

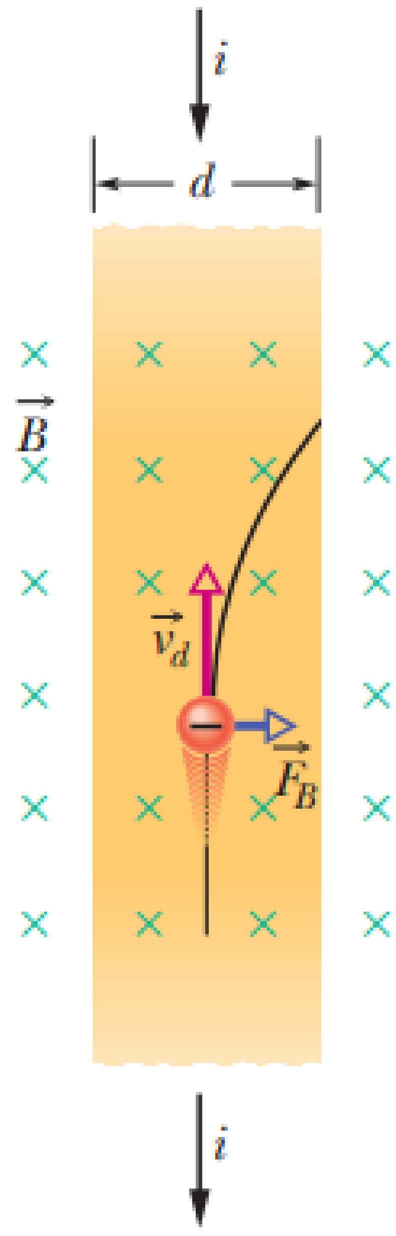


Curl fingers as if rotating vector I into vector B. The thumb is then in the direction of the force F

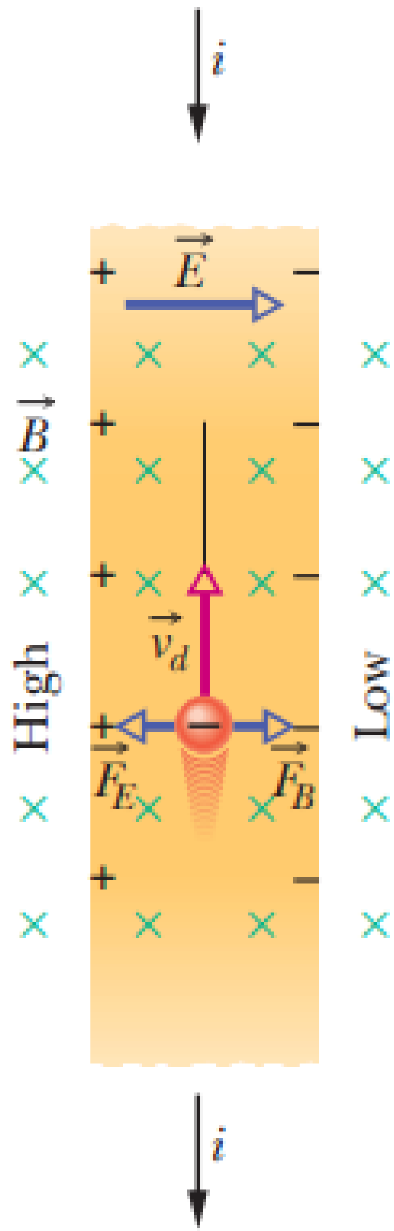
$$\vec{F} = I\vec{L} \times \vec{B}$$

Force on straight wire of length L

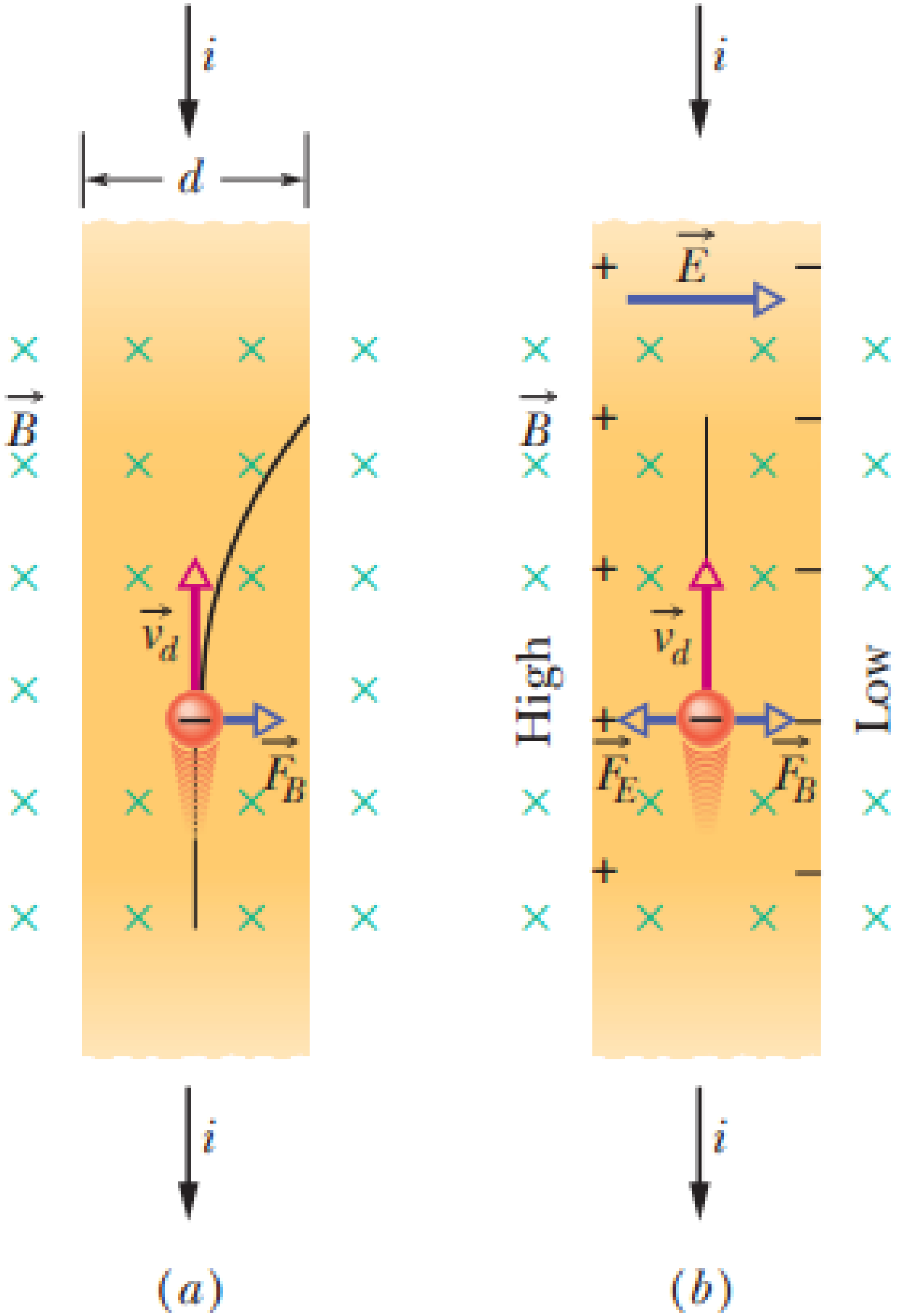
The Hall Effect



(a)



(b)



i
d
B
v_d
F_B
(a)
E
High
Low
F_E
(b)

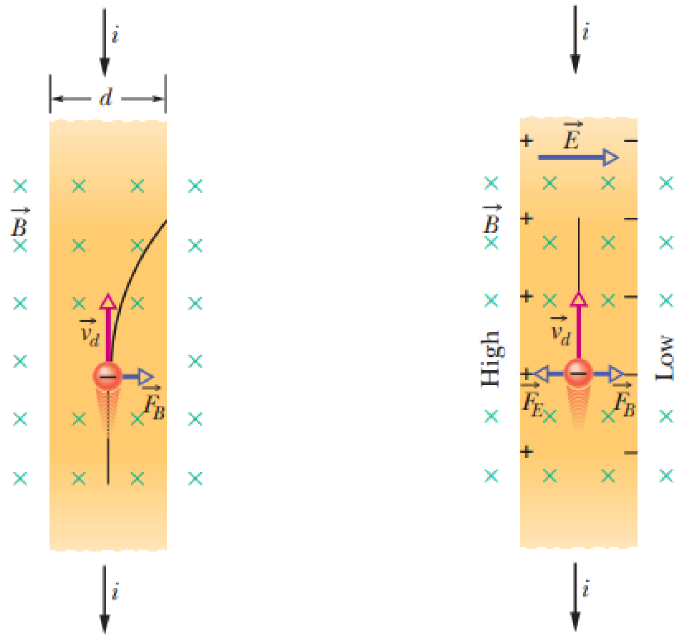
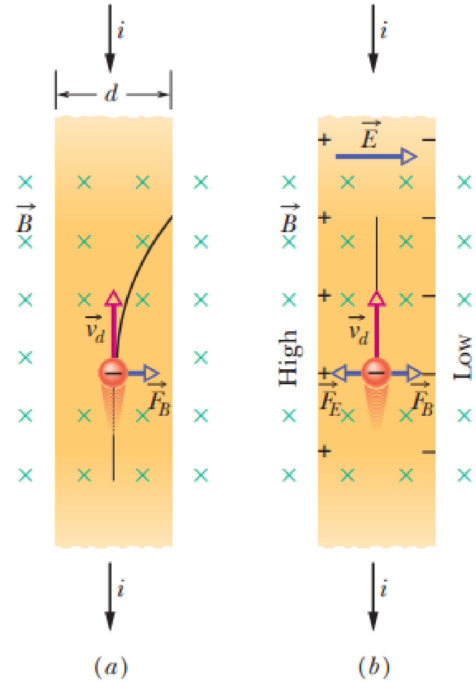


Figure 28-8*a* shows a copper strip of width d, carrying a current i whose conventional direction is from the top of the figure to the bottom. The charge carriers are electrons and, as we know, they drift (with drift speed v_d) in the opposite direction, from bottom to top. At the instant shown in Fig. 28-8*a*, an external magnetic field $\vec{B}$, pointing into the plane of the figure, has just been turned on. From Eq. 28-2 we see that a magnetic deflecting force $\vec{F}_B$ will act on each drifting electron, pushing it toward the right edge of the strip.



Equilibrium. An equilibrium quickly develops in which the electric force on each electron has increased enough to match the magnetic force. When this happens, as Fig. 28-8*b* shows, the force due to $\vec{B}$ and the force due to $\vec{E}$ are in balance. The drifting electrons then move along the strip toward the top of the page at velocity $\vec{v}_d$ with no further collection of electrons on the right edge of the strip and thus no further increase in the electric field $\vec{E}$.

A *Hall potential difference V* is associated with the electric field across strip width d. From Eq. 24-21, the magnitude of that potential difference is

$$V = Ed. \tag{28-9}$$

By connecting a voltmeter across the width, we can measure the potential difference between the two edges of the strip. Moreover, the voltmeter can tell us which edge is at higher potential. For the situation of Fig. 28-8*b*, we would find that the left edge is at higher potential, which is consistent with our assumption that the charge carriers are negatively charged.

Number Density. Now for the quantitative part. When the electric and magnetic forces are in balance (Fig. 28-8*b*), Eqs. 28-1 and 28-3 give us

$$eE = ev_d B. \tag{28-10}$$

From Eq. 26-7, the drift speed v_d is

$$v_d = \frac{J}{ne} = \frac{i}{neA}, \tag{28-11}$$

in which J $(= i/A)$ is the current density in the strip, A is the cross-sectional area of the strip, and n is the *number density* of charge carriers (number per unit volume).

In Eq. 28-10, substituting for E with Eq. 28-9 and substituting for v_d with Eq. 28-11, we obtain

$$n = \frac{Bi}{Vle}, \tag{28-12}$$

HOME WORK # 2

PROBLEMS

Section 34-2 The Magnetic Force on a Moving Charge

1. Four particles follow the paths shown in Fig. 29 as they pass through the magnetic field there. What can one conclude about the charge of each particle?
2. An electron in a TV camera tube is moving at 7.2×10^6 m/s in a magnetic field of strength 83 mT. (*a*) Without knowing the direction of the field, what could be the greatest and least magnitudes of the force the electron could feel due to the field? (*b*) At one point the acceleration of the electron is 4.9×10^{16} m/s^2. What is the angle between the electron's velocity and the magnetic field?
3. An electric field of 1.5 kV/m and a magnetic field of 0.44 T act on a moving electron to produce no force. (*a*) Calculate

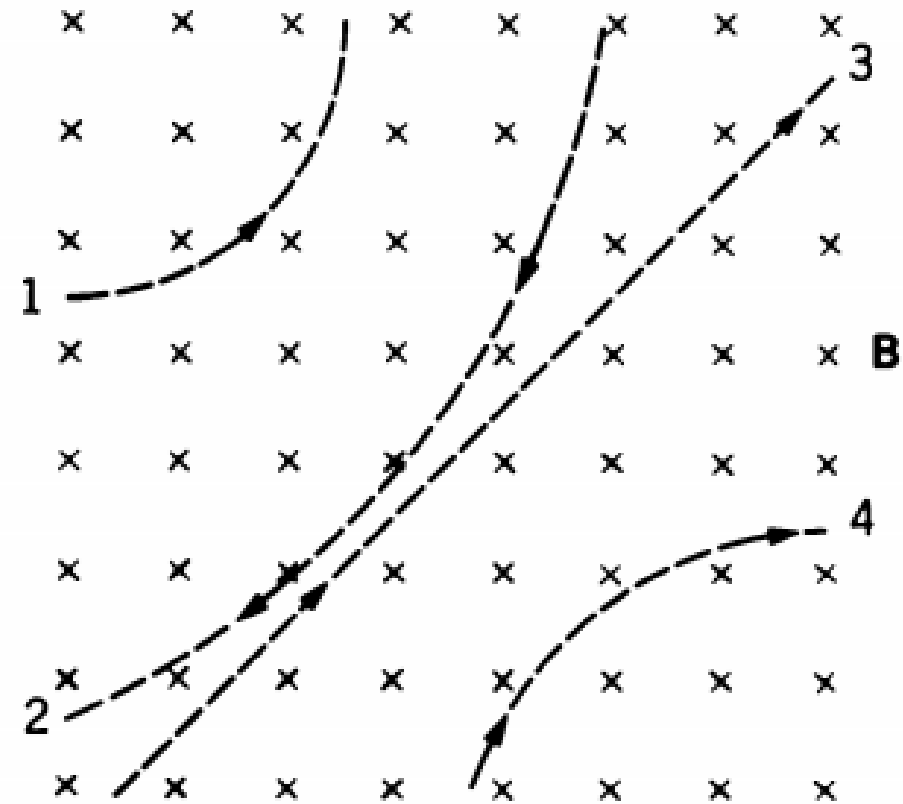


Figure 29 Problem 1.

the minimum electron speed v. (b) Draw the vectors **E**, **B**, and **v**.

4. A proton traveling at 23.0° with respect to a magnetic field of strength 2.63 mT experiences a magnetic force of 6.48×10^{-17} N. Calculate (a) the speed and (b) the kinetic energy in eV of the proton.
5. A cosmic ray proton impinges on the Earth near the equator with a vertical velocity of 2.8×10^7 m/s. Assume that the horizontal component of the Earth's magnetic field at the equator is 30 μT. Calculate the ratio of the magnetic force on the proton to the gravitational force on it.
6. An electron is accelerated through a potential difference of 1.0 kV and directed into a region between two parallel plates separated by 20 mm with a potential difference of 100 V between them. If the electron enters moving perpendicular to the electric field between the plates, what magnetic field is necessary perpendicular to both the electron path and the electric field so that the electron travels in a straight line?