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Term 2191

Welcome
to
PHYS 212: Physics

Chapter#28

Magnetic Fields

Topics

28-1 Magnetic Fields and the Definition of ***B***.

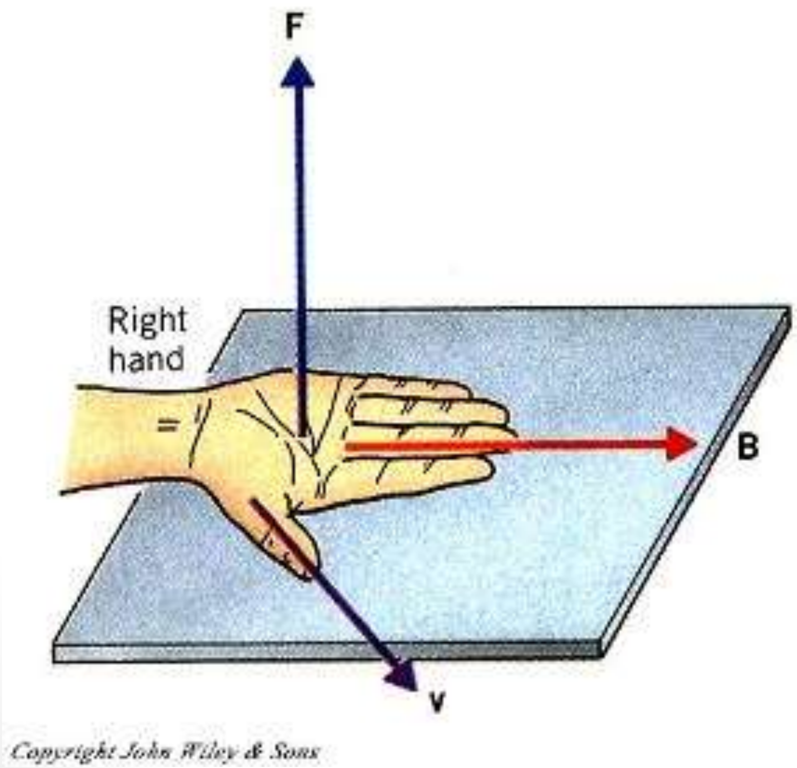
28-2 Crossed Fields: Discovery of The Electron.

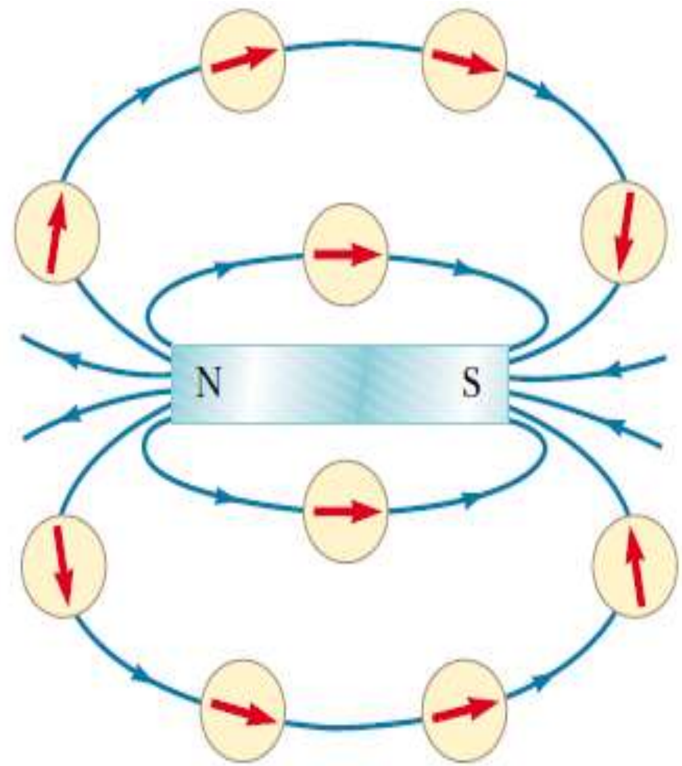
The oscilloscope.

28-6 Magnetic Force on Current-Carrying Wire.

28-1 Magnetic Fields and the Definition of *B*.

- We can define a magnetic field ***B*** to be a **vector quantity** that exists when it exerts a force $\boldsymbol{F_B}$ on a charge moving with velocity ***v***.

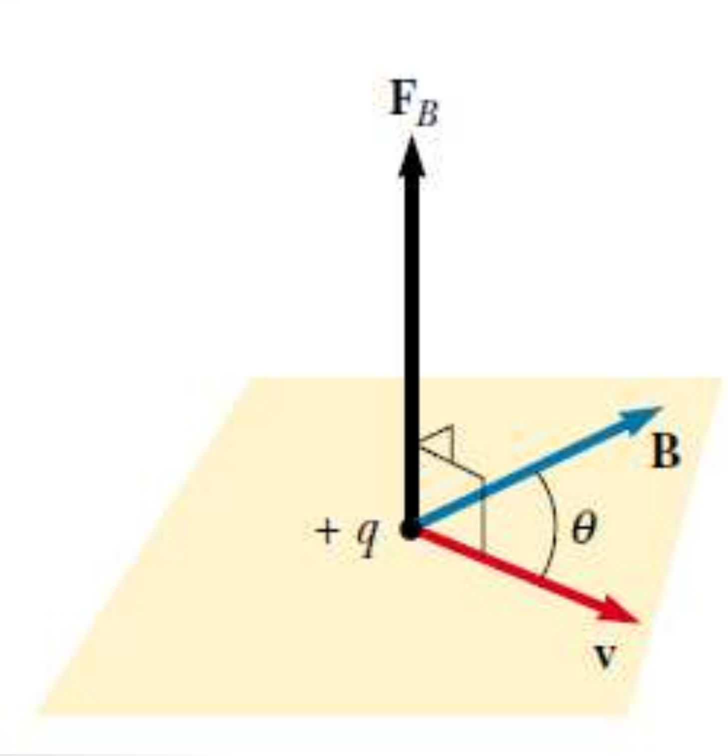


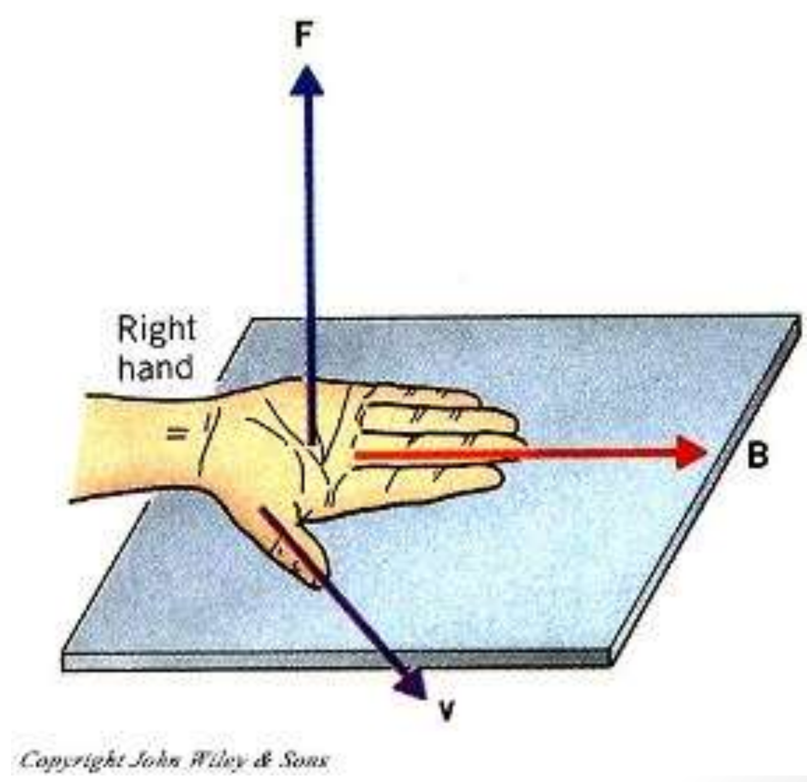


Experiments on various charged particles moving in a magnetic field give the following results:

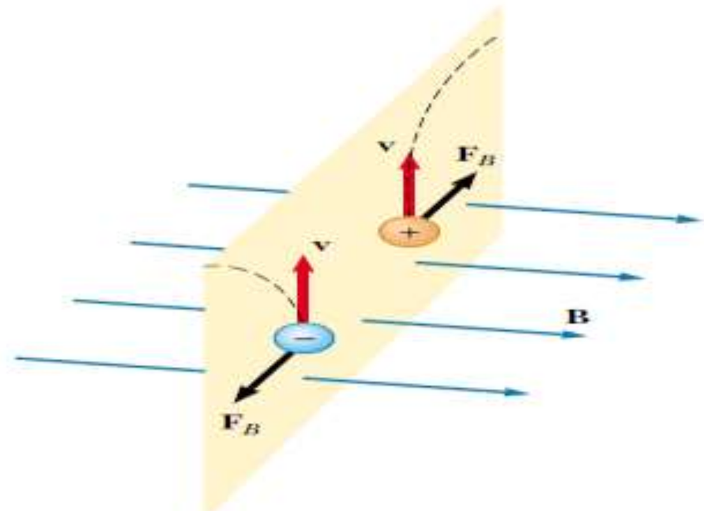
- The magnitude $\mathbf{F_B}$ of the magnetic force exerted on the particle is proportional to the charge **q** and to the speed **v** of the particle.
- The magnitude and direction of $\mathbf{F_B}$ depend on the velocity of the particle and on the magnitude and direction of the magnetic field **B**.
- When a charged particle moves parallel to the magnetic field vector, the magnetic force acting on the particle **is zero**.

- When the particle's velocity vector makes any angle $\theta \neq 0$ with the magnetic field, the magnetic force acts in a direction perpendicular to both **v** and **B**; that is, $\mathbf{F_B}$ is perpendicular to the plane formed by v and **B**.





- The magnetic force exerted on a positive charge is in the direction opposite the direction of the magnetic force exerted on a negative charge moving in the same direction.



- The magnitude of the magnetic force exerted on the moving particle is proportional to **sin**θ, where θ is the angle the particle's velocity vector makes with the direction of **B**.

Finding the Magnetic Force on a Particle

➢ We can summarize all these results with the following **vector equation:**

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

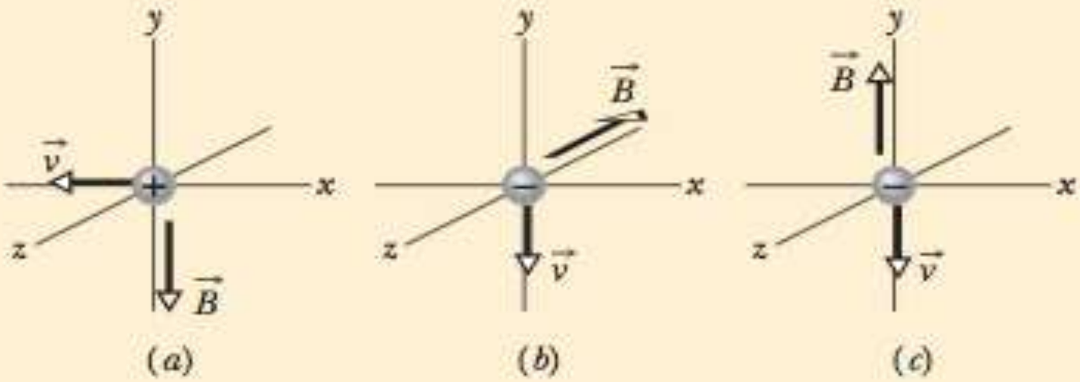
$$\boxed{F_B = |q| vB \sin\theta}$$

where θ is the smaller angle between **v** and **B**. From this expression, we see that F is zero when **v** is parallel or antiparallel to **B** ($\theta = 0$ or $180°$) and maximum ($F_{B,\max} = |q|vB$) when **v** is perpendicular to **B** ($\theta = 90°$).

The force $\vec{F}_B$ acting on a charged particle moving with velocity $\vec{v}$ through a magnetic field $\vec{B}$ is *always* perpendicular to $\vec{v}$ and $\vec{B}$.

Checkpoint 1

The figure shows three situations in which a charged particle with velocity $\vec{v}$ travels through a uniform magnetic field $\vec{B}$. In each situation, what is the direction of the magnetic force $\vec{F}_B$ on the particle?



Answer:

(a) towards the positive z-axis

(b) towards the negative x-axis

(c) none (cross product is zero)

➢ **Electric charges can be isolated (electron and proton), whereas a single magnetic pole has never been isolated. That is, magnetic poles are always found in pairs.**

There are several important differences between electric and magnetic forces:

- The electric force acts in the direction of the electric field, whereas the magnetic force acts perpendicular to the magnetic field.
- The electric force acts on a charged particle regardless of whether the particle is moving, whereas the magnetic force acts on a charged particle only when the particle is in motion.
- The electric force does work in displacing a charged particle, whereas the magnetic force associated with a steady magnetic field does no work when a particle is displaced.

when a charged particle moves with a velocity **v** through a magnetic field, the field can alter the direction of the velocity vector but cannot change the speed or kinetic energy of the particle.

we see that the SI unit of magnetic field is the newton

per coulomb-meter per second, which is called the **tesla** (T):

$$1\ \mathrm{T} = \frac{\mathrm{N}}{\mathrm{C}\cdot\mathrm{m/s}}$$

Because a coulomb per second is defined to be an ampere, we see that

$$1\ \mathrm{T} = 1\ \frac{\mathrm{N}}{\mathrm{A}\cdot\mathrm{m}}$$

A non-SI magnetic-field unit in common use, called the *gauss* (G), is related to the tesla through the conversion $1\ \mathrm{T} = 10^4\ \mathrm{G}$.

Problem-1

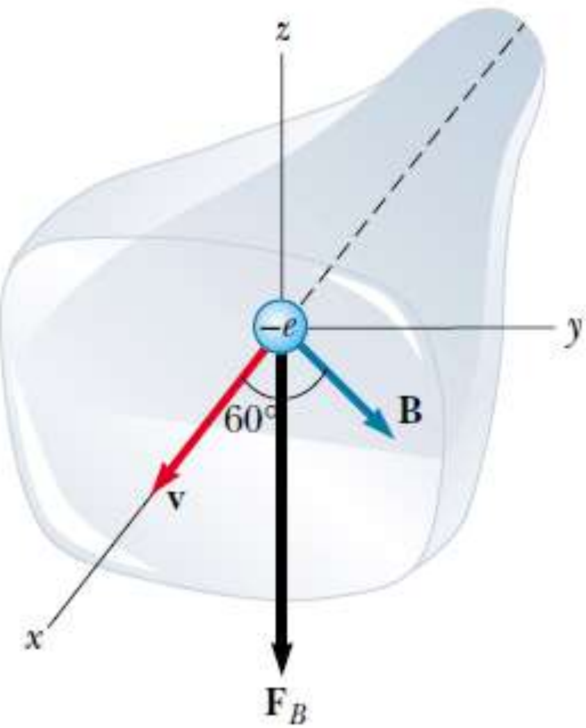
An electron in a television picture tube moves toward the front of the tube with a speed of 8.0×10^6 m/s along the x axis (Fig. 29.5). Surrounding the neck of the tube are coils of wire that create a magnetic field of magnitude 0.025 T, directed at an angle of 60° to the x axis and lying in the xy plane. Calculate the magnetic force on and acceleration of the electron.

FB=qvB sin theta
F=ma
a = FB/m
M=1.67x10^-27

Answer:

$F_B = \boxed{2.8 \times 10^{-14}\ \text{N}}$

$a = \boxed{3.1 \times 10^{16}\ \text{m/s}^2}$



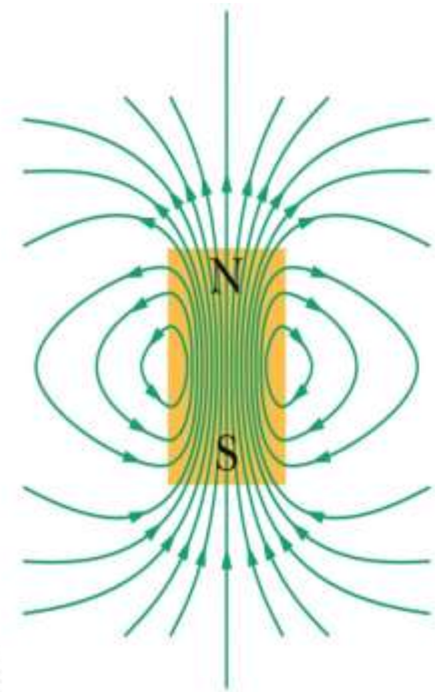
Magnetic Field Lines

We can represent magnetic fields with field lines, as we did for electric fields. Similar rules apply:

(1) the direction of the tangent to a magnetic field line at any point gives the direction of ***B*** at that point .

(2) the spacing of the lines represents the magnitude of ***B*** the magnetic field is stronger where the lines are closer together.

Opposite magnetic poles attract each other, and like magnetic poles repel each other.



(*a*)

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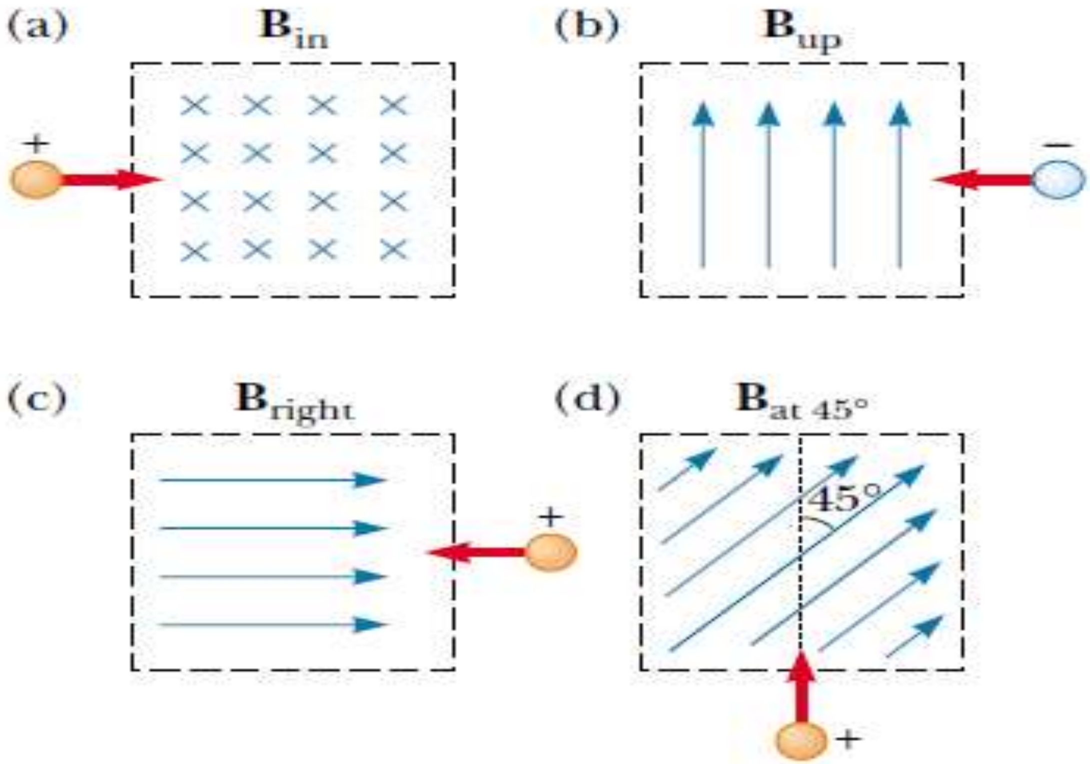
Problem-2

1. Determine the initial direction of the deflection of charged particles as they enter the magnetic fields, as shown in Figure P29.1.



Answer:

(a) up

(b) out of the page, since the charge is negative.

(c) no deflection

(d) into the page

Problem-3

An electron moving along the positive x axis perpendicular to a magnetic field experiences a magnetic deflection in the negative y direction. What is the direction of the magnetic field?

Answer:

negative z direction

Problem-4

A proton travels with a speed of 3.00×10^6 m/s at an angle of 37.0° with the direction of a magnetic field of 0.300 T in the $+y$ direction. What are (a) the magnitude of the magnetic force on the proton and (b) its acceleration?

Answer:

(a) $F_B = \boxed{8.67 \times 10^{-14}\ \text{N}}$

(b) $a = \boxed{5.19 \times 10^{13}\ \text{m/s}^2}$

Problem-5

A proton moves in a direction perpendicular to a uniform magnetic field **B** at 1.00×10^{7} m/s and experiences an acceleration of 2.00×10^{13} m/s^2 in the $+x$ direction when its velocity is in the $+z$ direction. Determine the magnitude and direction of the field.

F= qvbsintheta
B= F/qvsintehta F= ma
B= ma/qvsintheta z and y axis
make angle of 90 degree

Answer:

$B = \boxed{2.09 \times 10^{-2}\ \mathrm{T}}$

The right-hand rule shows that B must be in the $-y$ direction to yield a force in the $+x$ direction when v is in the z direction.

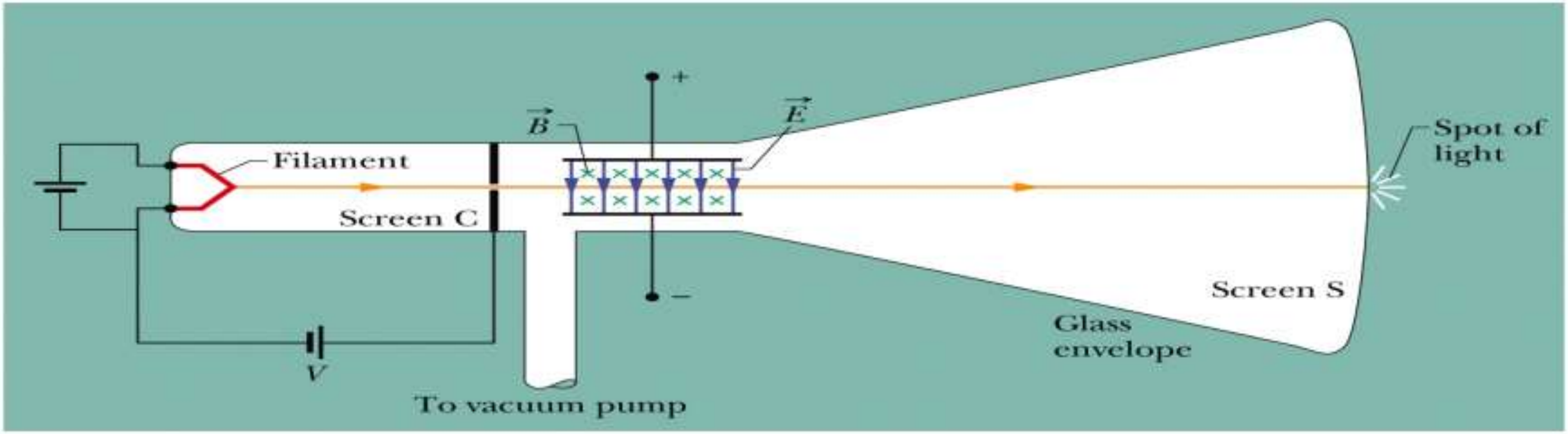
Problem-6

A proton moving at 4.00×10^6 m/s through a magnetic field of 1.70 T experiences a magnetic force of magnitude 8.20×10^{-13} N. What is the angle between the proton's velocity and the field?

Answer:

$$\theta = \boxed{48.9^\circ \text{ or } 131^\circ}$$

28-2 Crossed fields: Discovery of the electron



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➤ **A modern version of Thomson's apparatus for measuring the ratio of mass to charge for the electron.**

➤ If a charged particle moves through a region containing both an electric field and a magnetic field, it can be affected by both an electric force and a magnetic force.

➤ When the two fields are perpendicular to each other, they are said to be **crossed fields.**

➤ If the forces are in opposite directions, one particular speed will result in no deflection of the particle.

28-6 Magnetic force on current carrying wire

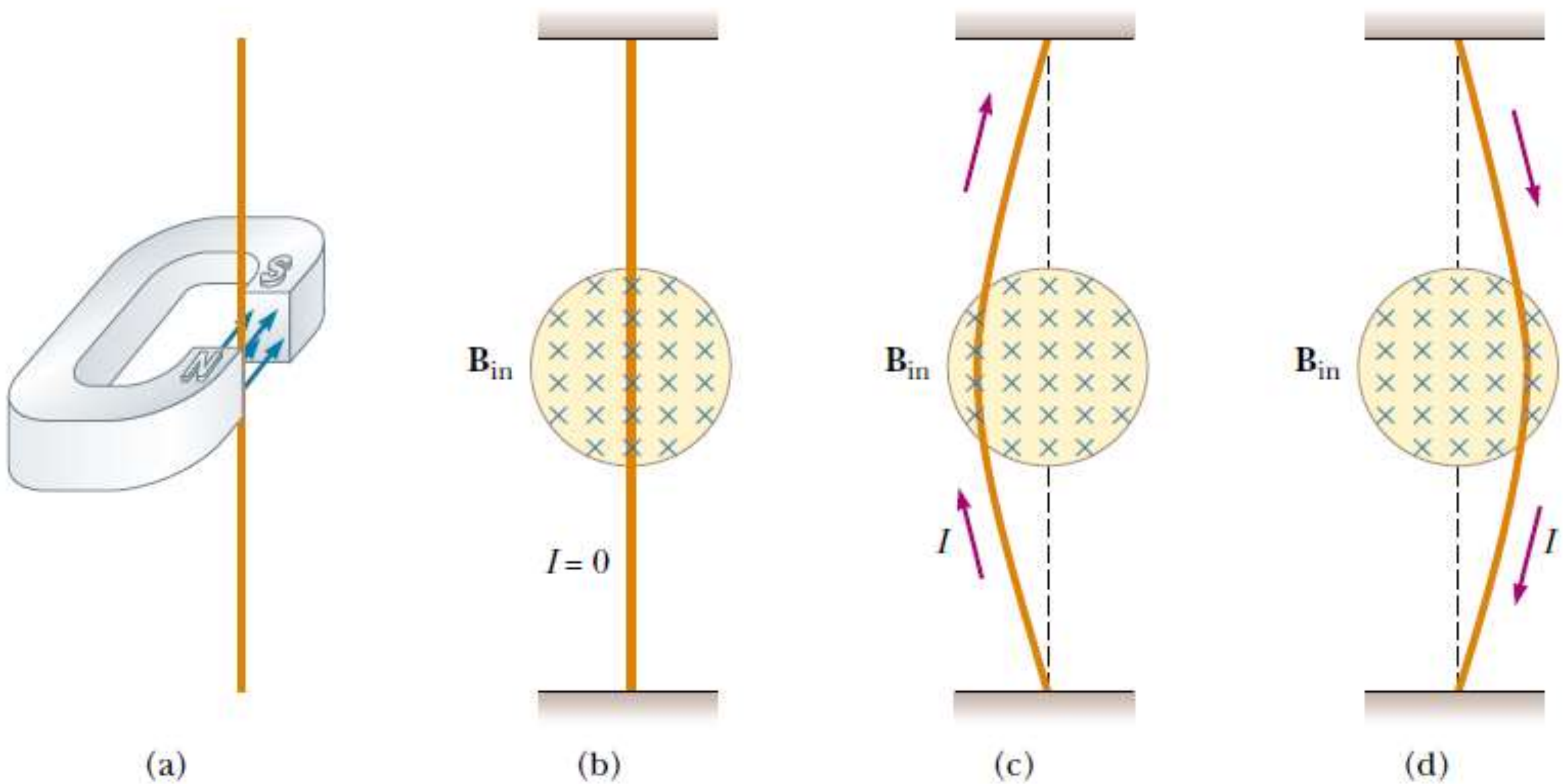


Figure 29.6 (a) A wire suspended vertically between the poles of a magnet. (b) The setup shown in part (a) as seen looking at the south pole of the magnet, so that the magnetic field (blue crosses) is directed into the page. When there is no current in the wire, it remains vertical. (c) When the current is upward, the wire deflects to the left. (d) When the current is downward, the wire deflects to the right.

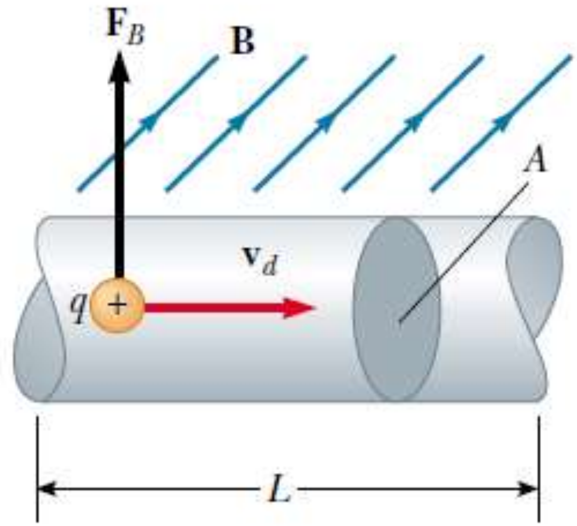
Because the volume of the segment is AL,

the number of charges in the segment is nAL,

where n is the number of charges per unit volume.

Hence, the total magnetic force on the wire of length L is

$$\mathbf{F}_B = (q\mathbf{v}_d \times \mathbf{B})\,nAL$$



the current in the wire is $I = nqv_dA$.

$$\vec{F}_B = i\vec{L} \times \vec{B} \quad \text{(force on a current).}$$

Problem-7

A wire carries a steady current of 2.40 A. A straight section of the wire is 0.750 m long and lies along the x axis within a uniform magnetic field of magnitude $B = 1.60$ T in the positive z direction. If the current is in the $+x$ direction, what is the magnetic force on the section of wire?

Answer:

$F_B = 2.88$ N

Problem-8

A wire 2.80 m in length carries a current of 5.00 A in a region where a uniform magnetic field has a magnitude of 0.390 T. Calculate the magnitude of the magnetic force on the wire if the angle between the magnetic field and the current is (a) 60.0°, (b) 90.0°.

Answer:

(a) $F_B = \boxed{4.73\ \text{N}}$

(b) $F_B = \boxed{5.46\ \text{N}}$ ***Max. Force***