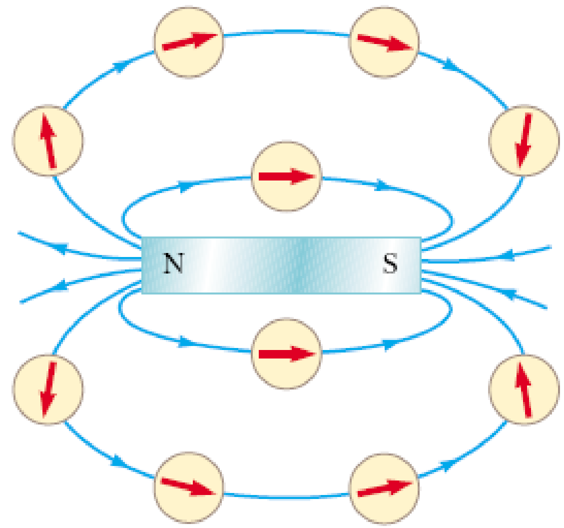
MAGNETIC FIELDS

Dr Muhammad Adeel

Magnetic Fields and Forces



We can define a magnetic field B at some point in space in terms of the magnetic force F_B that the field exerts on a charged particle moving with a velocity v, which we call the test object.

For the time being, let us assume that no electric or gravitational fields are present at the location of the test object. 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 **θ≠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**.

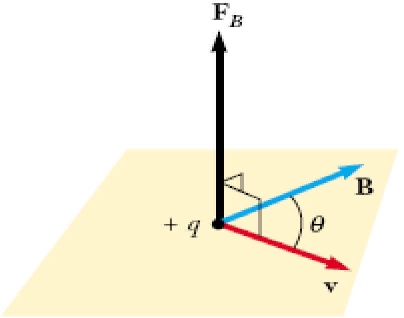
• The magnetic force exerted on a positive charge is in the direction opposite the direction of the magnetic force exerted on a negative charge moving in the same direction.

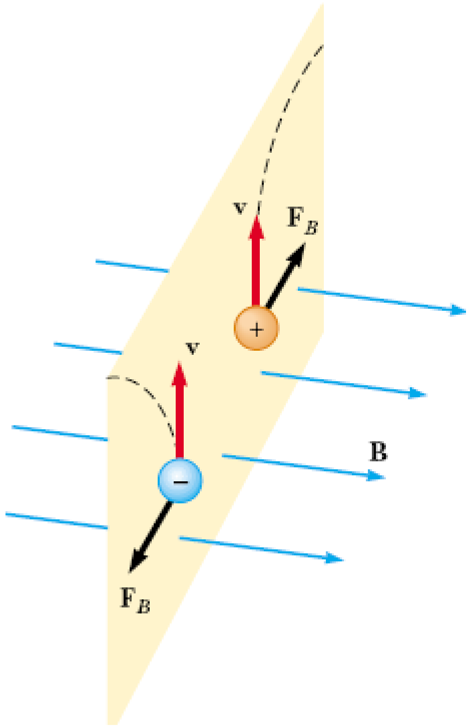
• The magnitude of the magnetic force exerted on the moving particle is proportional to **sinθ**, where **θ** is the angle the particle's velocity vector makes with the direction of **B**.

We can summarize these observations by writing the magnetic force in the form:

$$\mathbf{F}_B = q\mathbf{v} \times \mathbf{B}$$

$$F_B = |q| vB \sin\theta$$





There are several important differences between electric and magnetic forces:

- The electric force acts along 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 because the force is perpendicular to the displacement.

The SI unit of magnetic field is the newton per coulomb-meter per second, which is called the tesla (T):

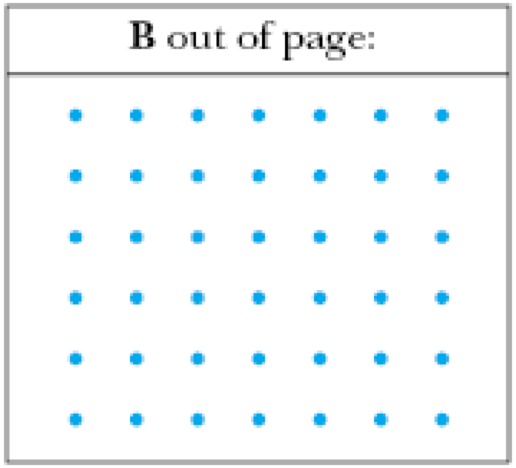
$$1\ \mathrm{T} = 1\ \frac{\mathrm{N}}{\mathrm{C}\cdot\mathrm{m/s}}$$

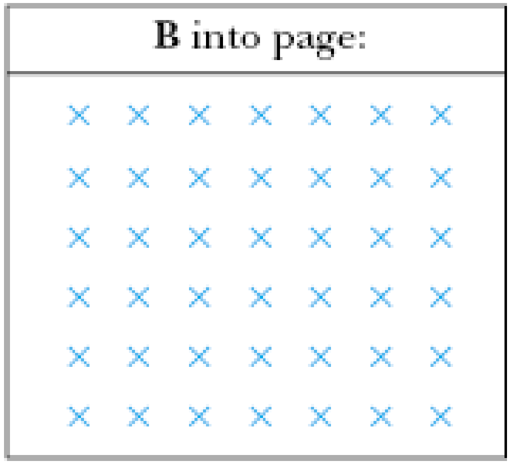
Because a coulomb per second is defined to be an ampere, we see that

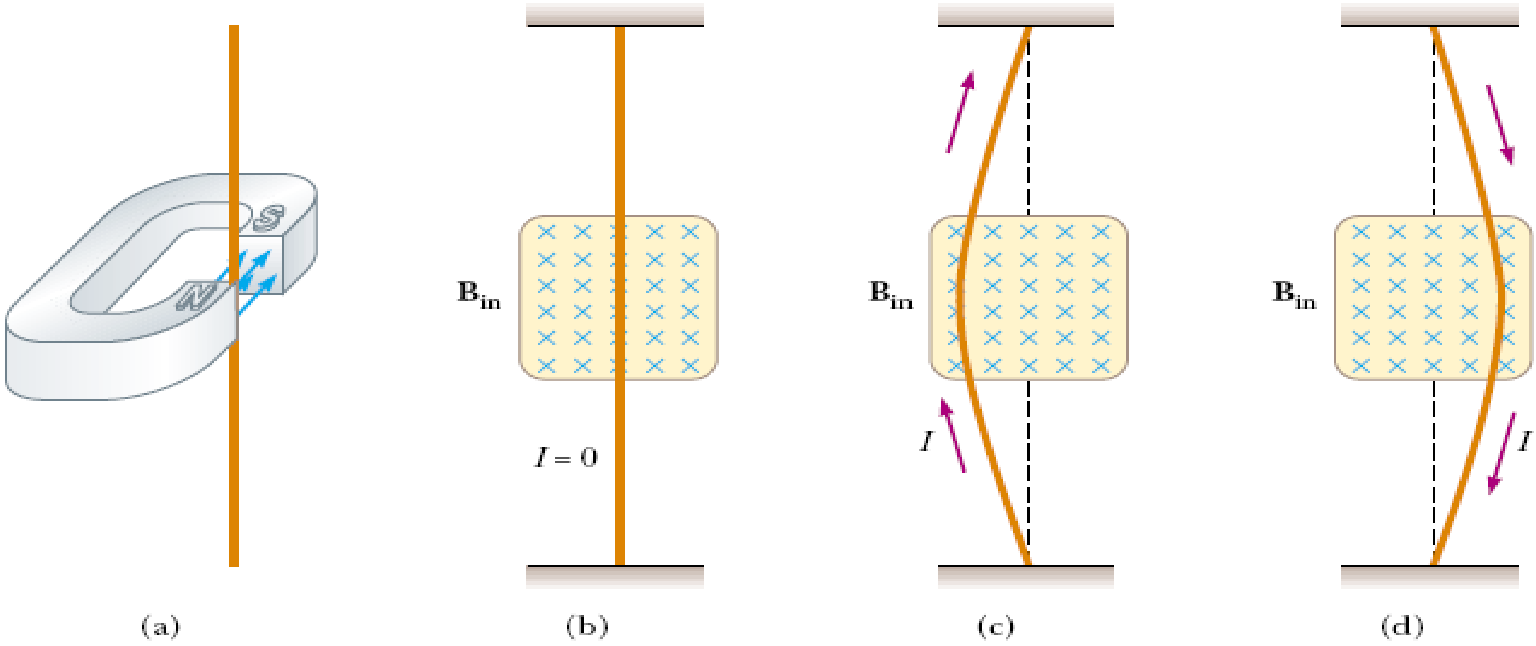
$$1\ \mathrm{T} = 1\ \frac{\mathrm{N}}{\mathrm{A}\cdot\mathrm{m}}$$

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

Magnetic Force Acting on a Current-Carrying Conductor

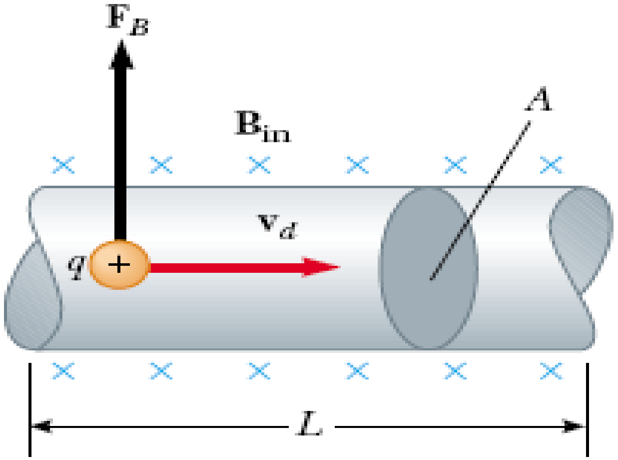






considering a straight segment of wire of length **L** and cross-sectional area **A**, carrying a current **I** in a uniform magnetic field **B**, as shown in Figure.
The magnetic force exerted on a charge q moving with a drift velocity $\mathbf{v}_d$,

$$\mathbf{F}_B = q\mathbf{v}_d \times \mathbf{B}$$



To find the total force acting on the wire, we multiply the force $\mathbf{q\ v_d \times B}$ exerted on one charge by the number of charges in the segment.

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 $I = nqv_dA$. Therefore,

$$\boxed{\mathbf{F}_B = I\mathbf{L} \times \mathbf{B}}$$

Now consider an arbitrarily shaped wire segment of uniform cross section in a magnetic field, as shown in Figure 29.9. It follows from Equation 29.3 that the magnetic force exerted on a small segment of vector length $d\mathbf{s}$ in the presence of a field $\mathbf{B}$ is

$$d\mathbf{F}_B = I\, d\mathbf{s} \times \mathbf{B}$$

where $d\mathbf{F}_B$ is directed out of the page for the directions of $\mathbf{B}$ and $d\mathbf{s}$ in Figure 29.9. We can consider Equation 29.4 as an alternative definition of $\mathbf{B}$. That is, we can define the magnetic field $\mathbf{B}$ in terms of a measurable force exerted on a current element, where the force is a maximum when $\mathbf{B}$ is perpendicular to the element and zero when $\mathbf{B}$ is parallel to the element.

To calculate the total force $\mathbf{F}_B$ acting on the wire shown in Figure 29.9,

$$\mathbf{F}_B = I \int_a^b d\mathbf{s} \times \mathbf{B}$$

where a and b represent the end points of the wire.

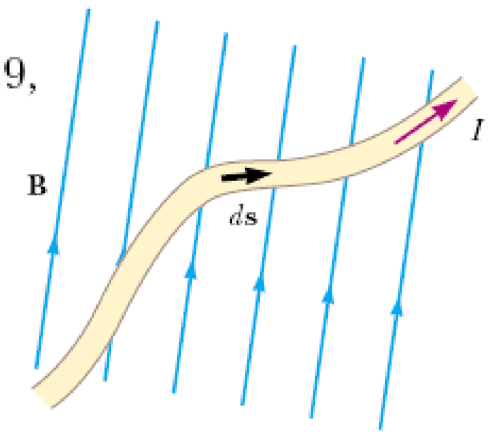
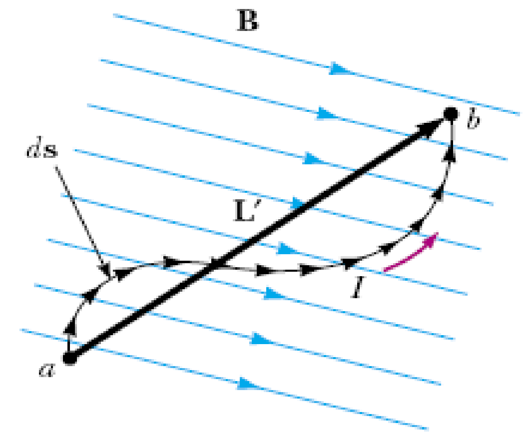


Figure 29.9

Case 1. A curved wire carries a current **I** and is located in a uniform magnetic field **B**, as shown in Figure. Because the field is uniform, we can take **B** outside the integral,



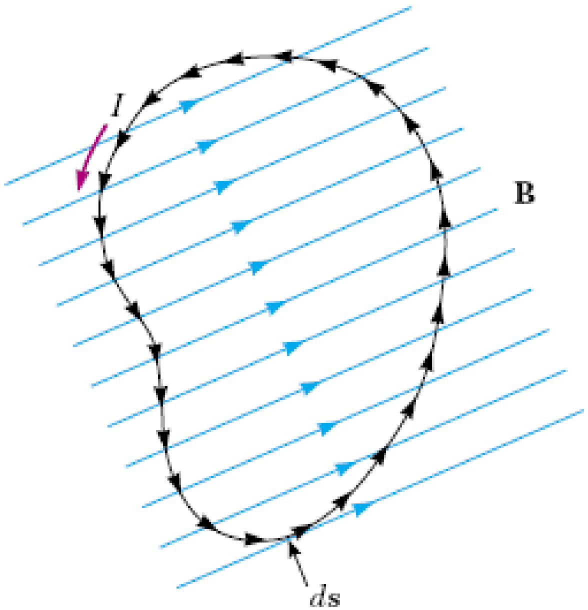
$$\mathbf{F}_B = I\left(\int_a^b d\mathbf{s}\right) \times \mathbf{B}$$

But the quantity $\int_a^b d\mathbf{s}$ represents the *vector sum* of all the length elements from a to b. From the law of vector addition, the sum equals the vector $\mathbf{L}'$, directed from a to b.

$$\mathbf{F}_B = I\,\mathbf{L}' \times \mathbf{B}$$

From this we conclude that **the magnetic force on a curved current-carrying wire in a uniform magnetic field is equal to that on a straight wire connecting the end points and carrying the same current.**

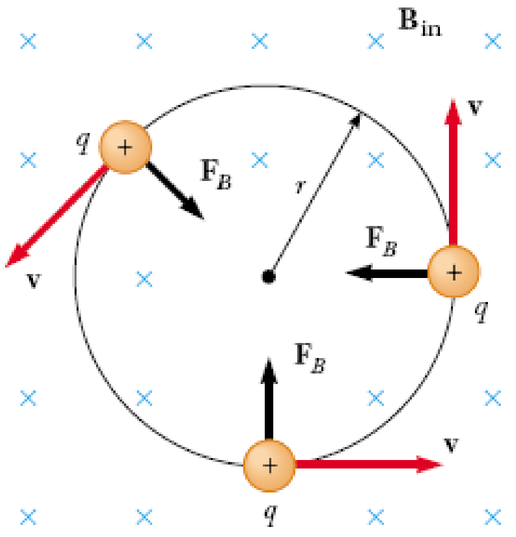
Case 2. An arbitrarily shaped closed loop carrying a current **I** is placed in a uniform magnetic field, as shown in Figure. We can again express the magnetic force acting on the loop, but this time we must take the vector sum of the length elements $\mathbf{d_s}$ over the entire loop:



$$\mathbf{F}_B = I\left(\oint d\mathbf{s}\right) \times \mathbf{B}$$

Because the set of length elements forms a closed polygon, the vector sum must be zero. This follows from the procedure for adding vectors by the graphical method. Because $\oint d\mathbf{s} = 0$, we conclude that $\mathbf{F}_B = 0$; that is, **the net magnetic force acting on any closed current loop in a uniform magnetic field is zero.**

Motion of a Charged Particle in a Uniform Magnetic Field



consider the special case of a positively charged particle moving in a uniform magnetic field with the initial velocity vector of the particle perpendicular to the field.

The particle moves in a circle because the magnetic force $\mathbf{F}_\mathbf{B}$ is perpendicular to **v** and **B** and has a constant magnitude **qvB**.

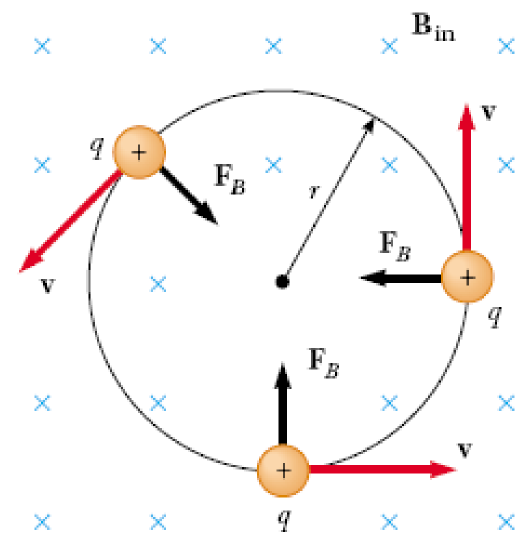
The rotation is counterclockwise for a positive charge. If q were negative, the rotation would be clockwise.

$$\sum F = ma_c$$

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

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

That is, the radius of the path is proportional to the linear momentum **mv** of the particle and inversely proportional to the magnitude of the charge on the particle and to the magnitude of the magnetic field. The angular speed of the particle is,



$$\omega = \frac{v}{r} = \frac{qB}{m}$$

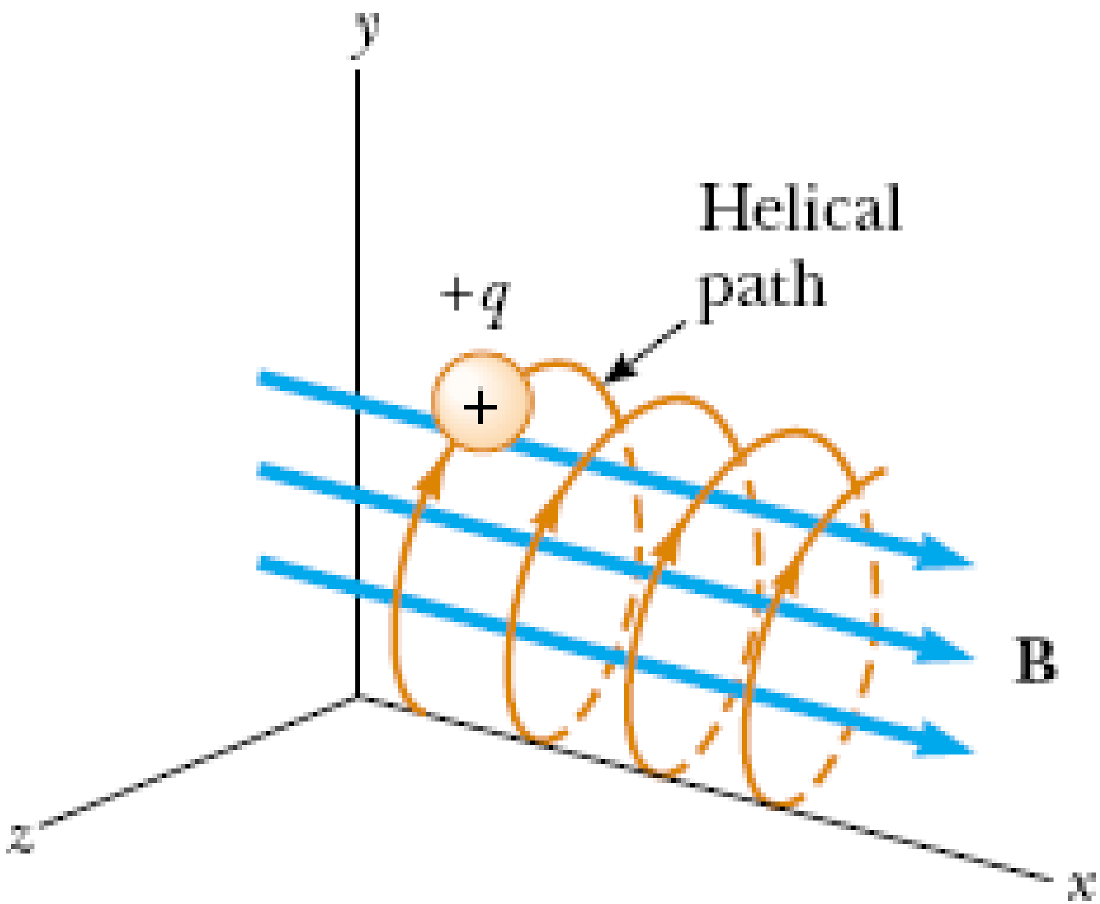
The period of the motion (the time interval the particle requires to complete one revolution) is equal to the circumference of the circle divided by the linear speed of the particle:

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

These results show that the angular speed of the particle and the period of the circular motion do not depend on the linear speed of the particle or on the radius of the orbit.

The angular speed . is often referred to as the cyclotron frequency because charged particles circulate at this angular frequency in the type of accelerator called a *cyclotron.*

If a charged particle moves in a uniform magnetic field with its velocity at some arbitrary angle with respect to B, its path is a helix.



Applications Involving Charged Particles Moving in a Magnetic Field

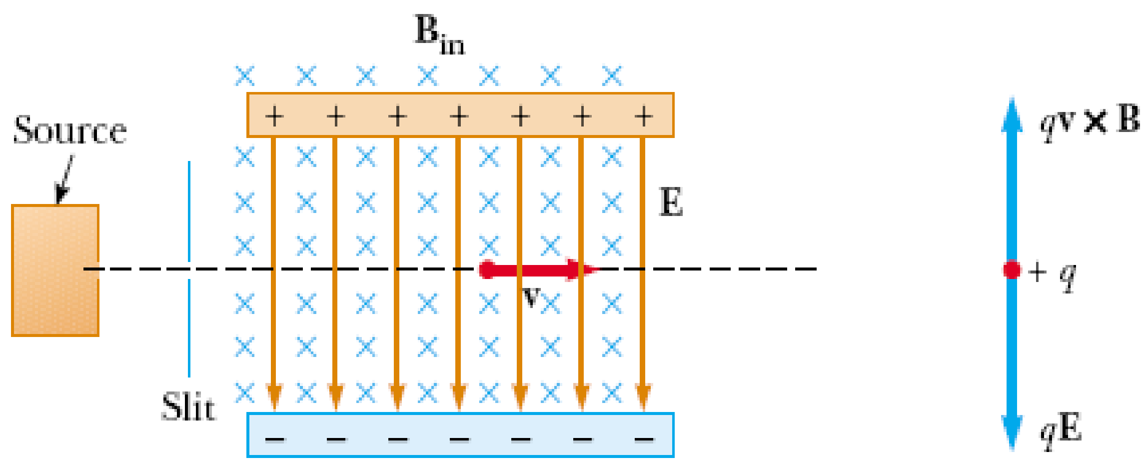
A charge moving with a velocity $\mathbf{v}$ in the presence of both an electric field $\mathbf{E}$ and a magnetic field $\mathbf{B}$ experiences both an electric force $q\mathbf{E}$ and a magnetic force $q\mathbf{v} \times \mathbf{B}$. The total force (called the Lorentz force) acting on the charge is

$$\mathbf{F} = q\mathbf{E} + q\mathbf{v} \times \mathbf{B}$$

Velocity Selector

$$qE = qvB$$

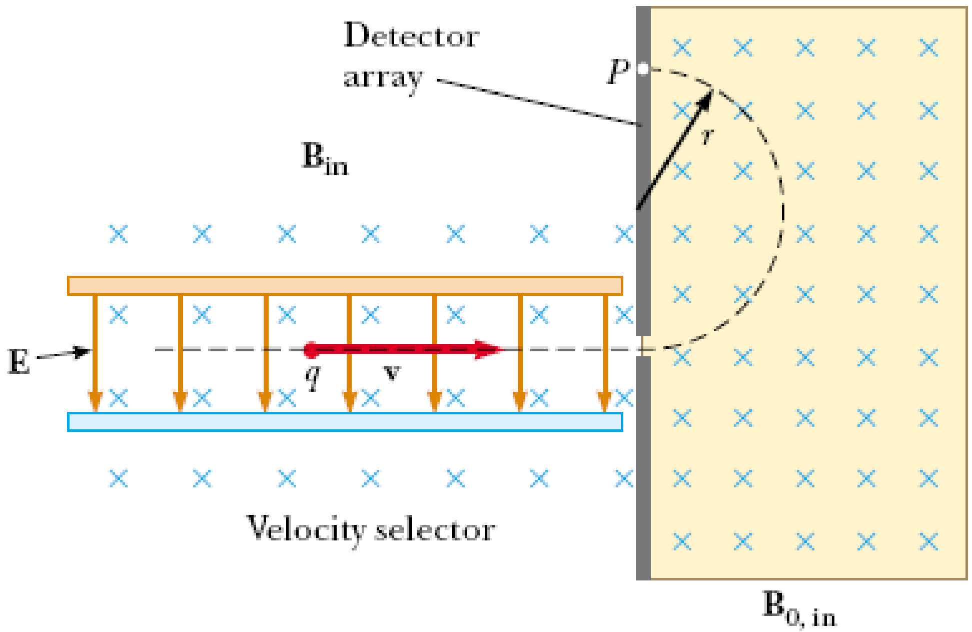
$$v = \frac{E}{B}$$



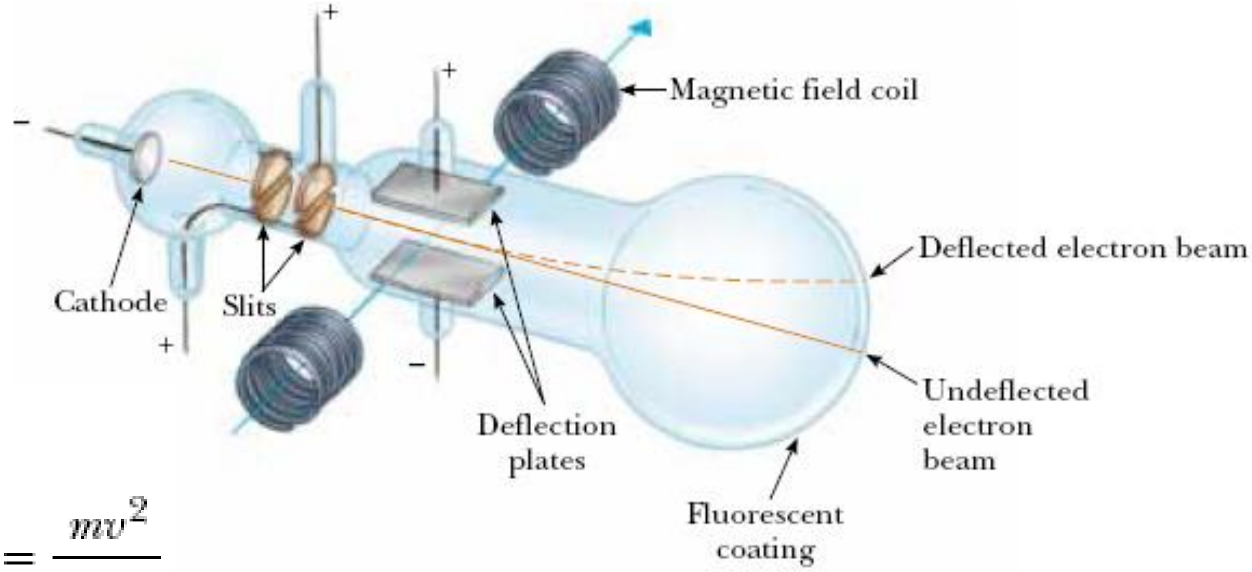
Only those particles having speed v pass undeflected through the mutually perpendicular electric and magnetic fields. The magnetic force exerted on particles moving at speeds greater than this is stronger than the electric force, and the particles are deflected upward. Those moving at speeds less than this are deflected downward.

The Mass Spectrometer

A mass spectrometer separates ions according to their mass-to-charge ratio.
In one version of this device, known as the Bainbridge mass spectrometer, a beam of ions first passes through a velocity selector and then enters a second uniform magnetic field $\mathbf{B_0}$ that has the same direction as the magnetic field in the selector.



Upon entering the second magnetic field, the ions move in a semicircle of radius r before striking a detector array at P. If the ions are positively charged, the beam deflects upward. If the ions are negatively charged, the beam deflects downward.



$$\sum F = ma_c$$

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

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

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

$$\frac{m}{q} = \frac{rB_0}{v}$$

$$\frac{m}{q} = \frac{rB_0 B}{E}$$

The Cyclotron

A cyclotron is a device that can accelerate charged particles to very high speeds. The energetic particles produced are used to bombard atomic nuclei and thereby produce nuclear reactions of interest to researchers.
A number of hospitals use cyclotron facilities to produce radioactive substances for diagnosis and treatment.

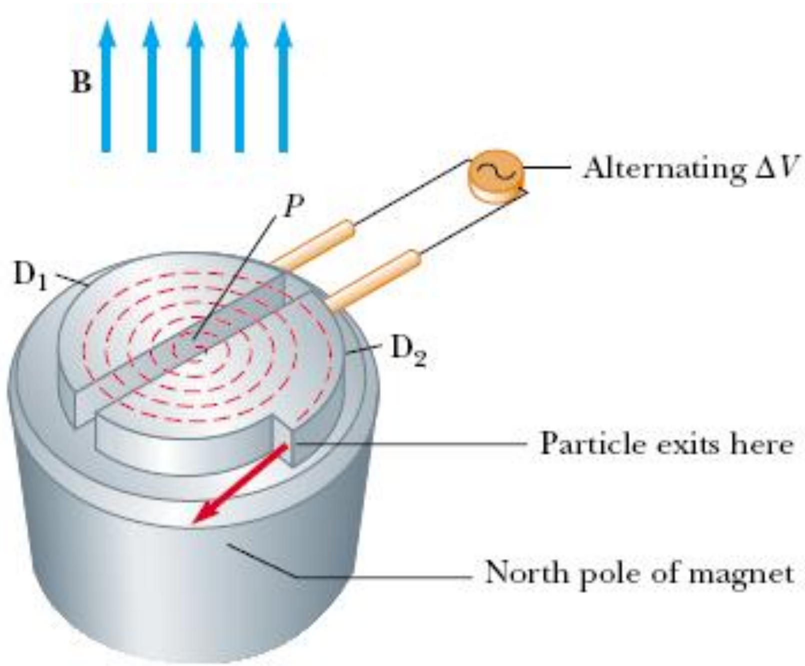
$$\sum F = ma_c$$

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

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

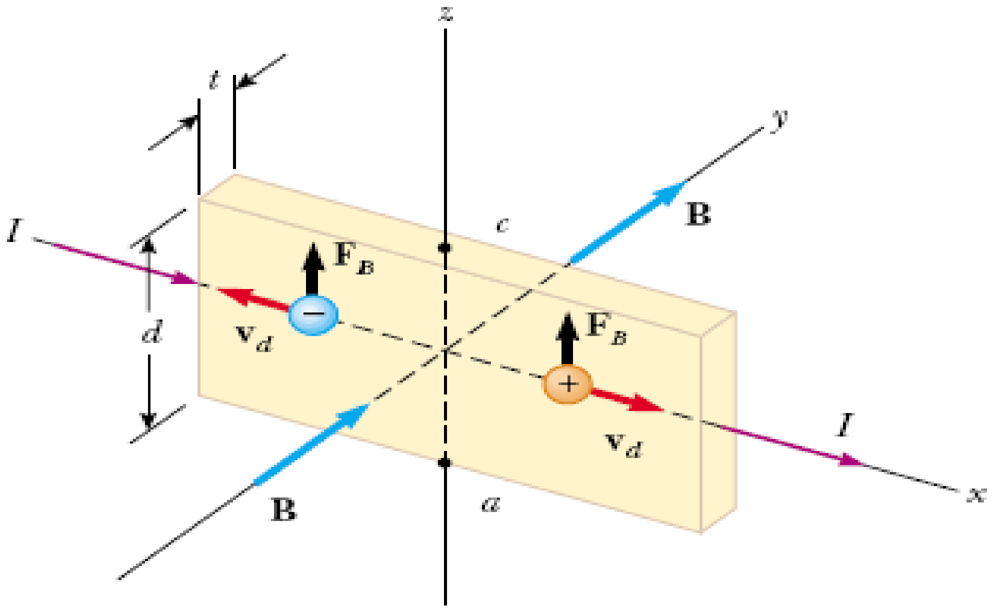
$$v = qBR/m$$

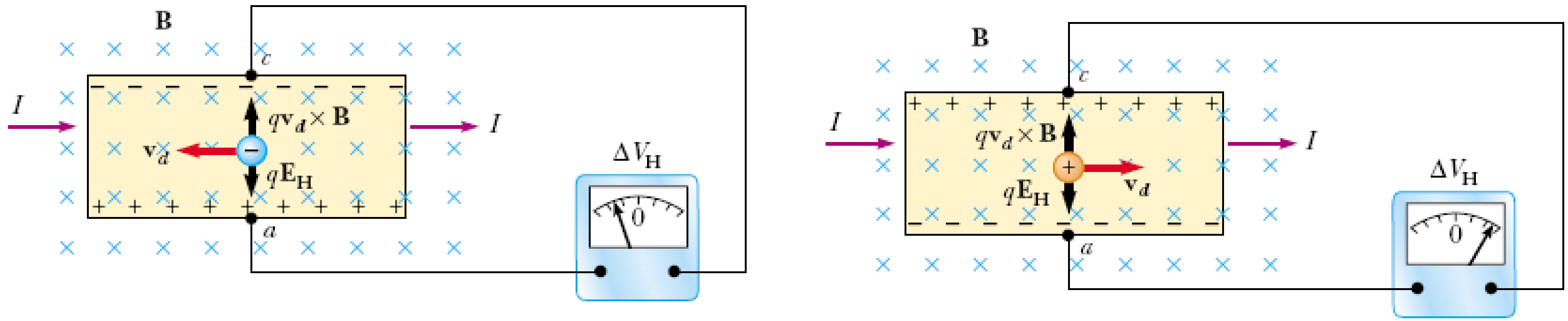
$$K = \frac{1}{2}mv^2 = \frac{q^2B^2R^2}{2m}$$



The Hall Effect

When a current-carrying conductor is placed in a magnetic field, a potential difference is generated in a direction perpendicular to both the current and the magnetic field. This phenomenon, first observed by Edwin Hall (1855–1938) in 1879, is known as the *Hall effect*. It arises from the deflection of charge carriers to one side of the conductor as a result of the magnetic force they experience. The Hall effect gives information regarding the sign of the charge carriers and their density; it can also be used to measure the magnitude of magnetic fields.





In deriving an expression for the Hall voltage, we first note that the magnetic force exerted on the carriers has magnitude qv_dB. In equilibrium, this force is balanced by the electric force qE_H, where E_H is the magnitude of the electric field due to the charge separation (sometimes referred to as the *Hall field*). Therefore,

$$qv_dB = qE_H$$
$$E_H = v_dB$$

If d is the width of the conductor, the Hall voltage is

$$\Delta V_H = E_H d = v_d B d$$

Thus, the measured Hall voltage gives a value for the drift speed of the charge carriers if d and B are known.

We can obtain the charge carrier density n by measuring the current in the sample.

$$v_d = \frac{I}{nqA}$$

$$\Delta V_{\mathrm{H}} = \frac{IBd}{nqA}$$

Because $A = td$, where t is the thickness of the conductor,

$$\Delta V_{\mathrm{H}} = \frac{IB}{nqt} = \frac{R_{\mathrm{H}} IB}{t}$$

where $R_{\mathrm{H}} = 1/nq$ is the **Hall coefficient.**

$$v_d = \frac{\Delta V_{\mathrm{H}}}{Bd}$$

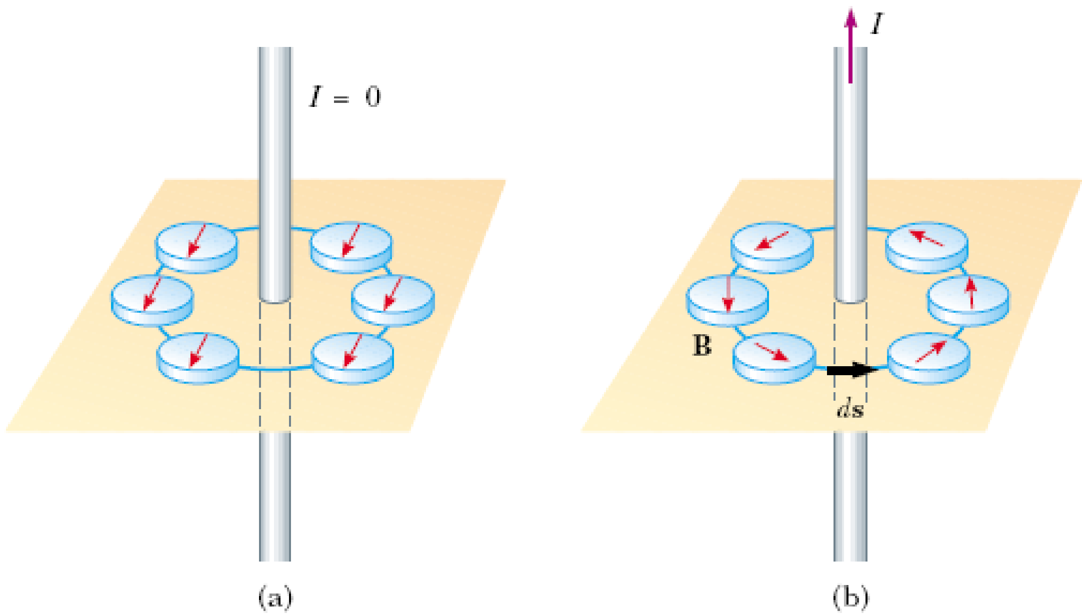
Thus, by measuring the voltage across the artery, the diameter of the artery, and the applied magnetic field, the speed of the blood can be calculated.

Example:

A rectangular copper strip 2.4cm wide and 0.2 cm thick carries a current of 5A. Find the Hall voltage for a 1.5T magnetic field applied in a direction perpendicular to the strip.

$$\Delta V_{\mathrm{H}} = \frac{IB}{nqt}$$

Ampere's Law

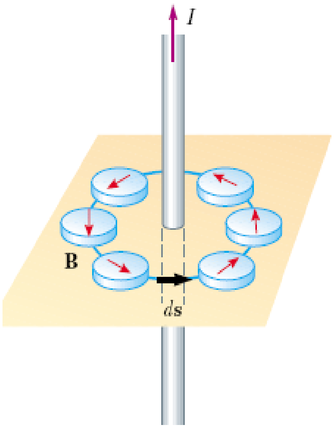


Because the compass needles point in the direction of **B**, we conclude that the lines of **B** form circles around the wire, as discussed in the preceding section. By symmetry, the magnitude of **B** is the same everywhere on a circular path centered on the wire and lying in a plane perpendicular to the wire. By varying the current and distance a from the wire, we find that B is proportional to the current and inversely proportional to the distance from the wire, as Equation 30.5 describes.

$$B = \boxed{\frac{\mu_0 I}{2\pi a}}$$

Now let us evaluate the product $\mathbf{B} \cdot d\mathbf{s}$ for a small length element $d\mathbf{s}$ on the circular path defined by the compass needles, and sum the products for all elements over the closed circular path.[2] Along this path, the vectors $d\mathbf{s}$ and $\mathbf{B}$ are parallel at each point (see Fig. 30.9b), so $\mathbf{B} \cdot d\mathbf{s} = B\,ds$. Furthermore, the magnitude of $\mathbf{B}$ is constant on this circle and is given by Equation 30.5. Therefore, the sum of the products $B\,ds$ over the closed path, which is equivalent to the line integral of $\mathbf{B} \cdot d\mathbf{s}$, is

$$\oint \mathbf{B} \cdot d\mathbf{s} = B \oint ds = \frac{\mu_0 I}{2\pi r}(2\pi r) = \mu_0 I$$



(b)

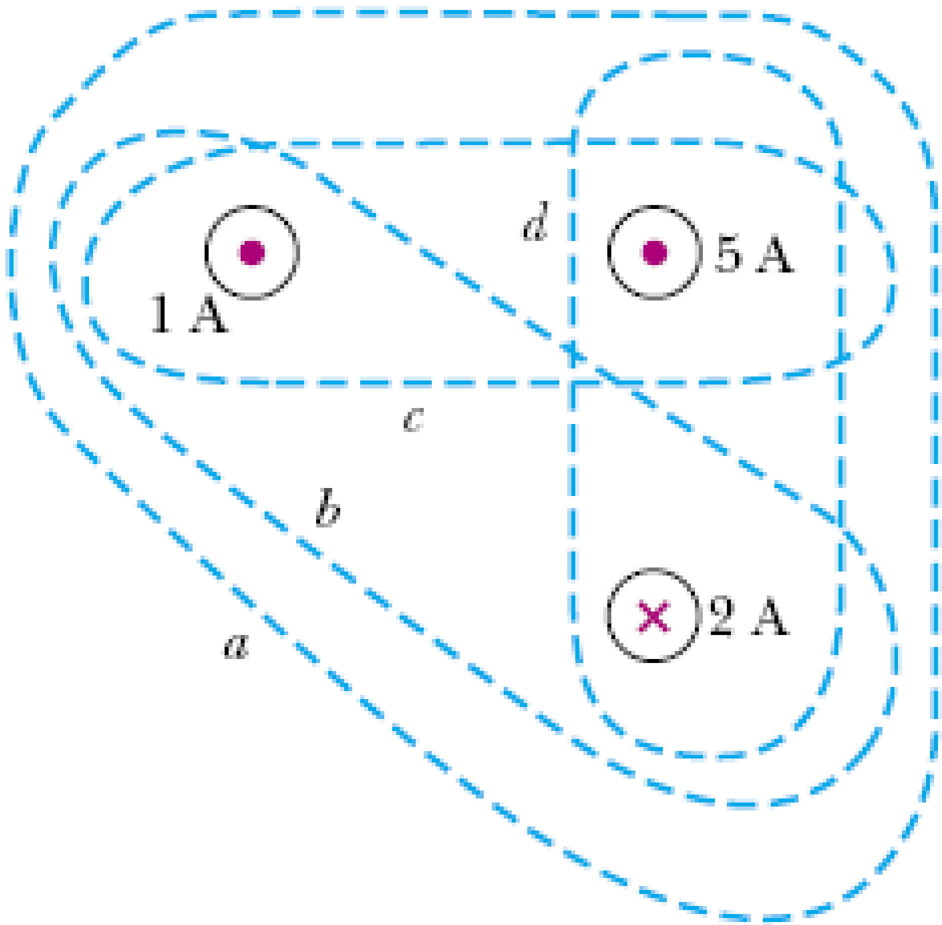
where $\oint ds = 2\pi r$ is the circumference of the circular path.

The line integral of $\mathbf{B} \cdot d\mathbf{s}$ around any closed path equals $\mu_0 I$, where I is the total steady current passing through any surface bounded by the closed path.

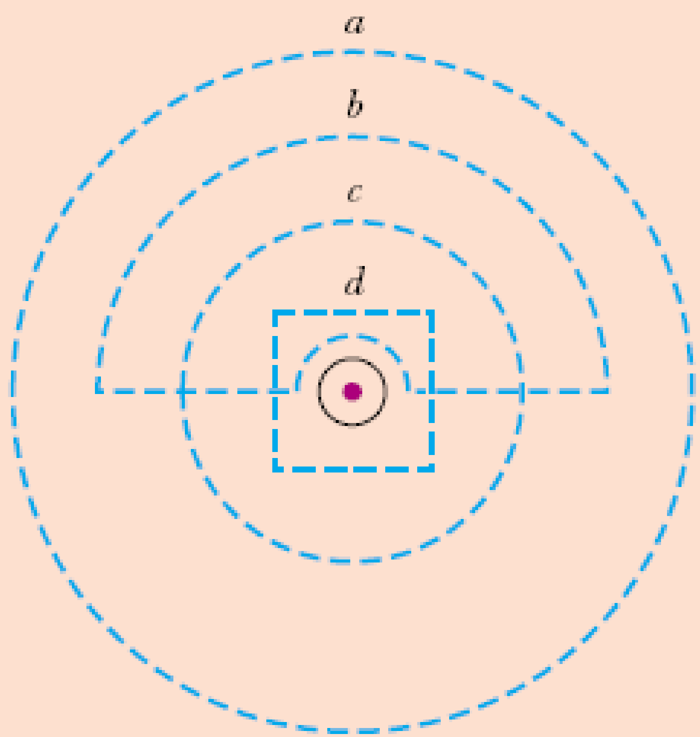
$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I$$

Ampère's law describes the creation of magnetic fields by all continuous current configurations, but at our mathematical level it is useful only for calculating the magnetic field of current configurations having a high degree of symmetry. Its use is similar to that of Gauss's law in calculating electric fields for highly symmetric charge distributions.

Quick Quiz 30.4 Rank the magnitudes of $\oint \mathbf{B} \cdot d\mathbf{s}$ for the closed paths in Figure 30.10, from least to greatest.

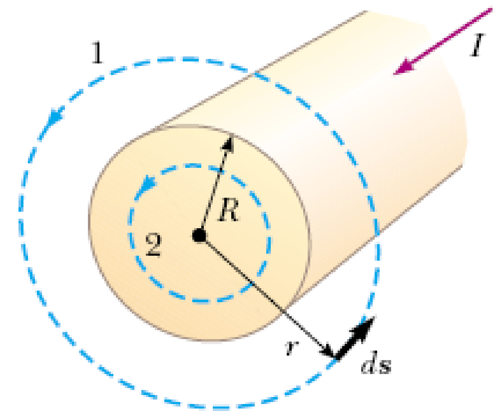


Quick Quiz 30.5 Rank the magnitudes of $\oint \mathbf{B} \cdot d\mathbf{s}$ for the closed paths in Figure 30.11, from least to greatest.



The Magnetic Field Created by a Long Current-Carrying Wire

A long, straight wire of radius R carries a steady current I that is uniformly distributed through the cross section of the wire (Fig. 30.12). Calculate the magnetic field a distance r from the center of the wire in the regions $r \geq R$ and $r < R$.

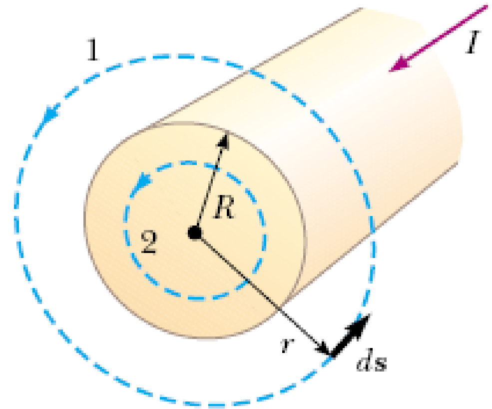


Solution Figure 30.12 helps us to conceptualize the wire and the current. Because the wire has a high degree of symmetry, we categorize this as an Ampère's law problem. For the $r \geq R$ case, we should arrive at the same result we obtained in Example 30.1, in which we applied the Biot–Savart law to the same situation. To analyze the problem, let us choose for our path of integration circle 1 in Figure 30.12. From symmetry, $\mathbf{B}$ must be constant in magnitude and parallel to $d\mathbf{s}$ at every point on this circle. Because the total current passing through the plane of the circle is I, Ampère's law gives

$$\oint \mathbf{B} \cdot d\mathbf{s} = B \oint ds = B(2\pi r) = \mu_0 I$$

$$B = \boxed{\frac{\mu_0 I}{2\pi r}} \qquad (\text{for } r \geq R)$$

Now consider the interior of the wire, where $r < R$. Here the current I' passing through the plane of circle 2 is less than the total current I. Because the current is uniform over the cross section of the wire, the fraction of the current enclosed by circle 2 must equal the ratio of the area πr^2 enclosed by circle 2 to the cross-sectional area πR^2 of the wire:[3]



$$\frac{I'}{I} = \frac{\pi r^2}{\pi R^2}$$

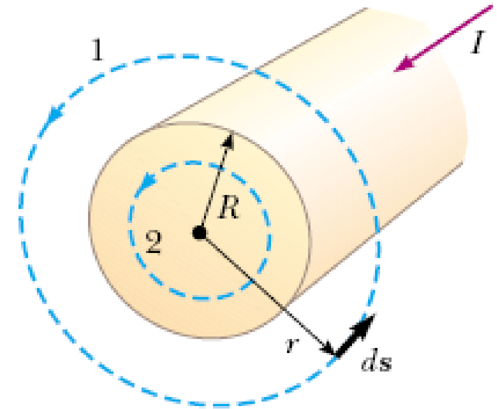
$$I' = \frac{r^2}{R^2} I$$

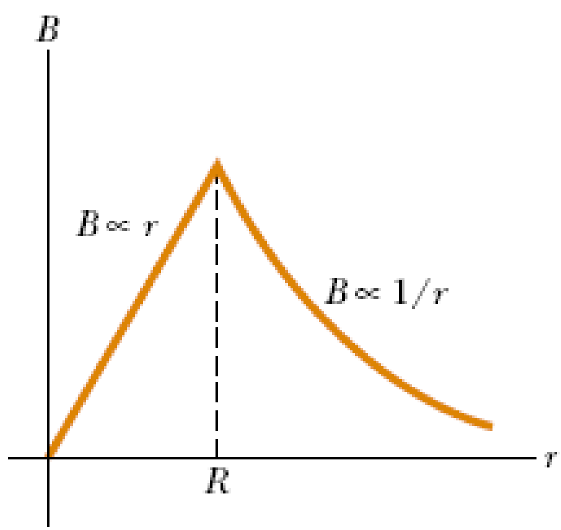
Following the same procedure as for circle 1, we apply Ampère's law to circle 2:

$$\oint \mathbf{B} \cdot d\mathbf{s} = B(2\pi r) = \mu_0 I' = \mu_0 \left(\frac{r^2}{R^2} I \right)$$

$$B = \boxed{\left(\frac{\mu_0 I}{2\pi R^2} \right) r} \qquad (\text{for } r < R)$$

To finalize this problem, note that this result is similar in form to the expression for the electric field inside a uniformly charged sphere (see Example 24.5). The magnitude of the magnetic field versus r for this configuration is plotted in Figure 30.13. Note that inside the wire, $B \rightarrow 0$ as $r \rightarrow 0$. Furthermore, we see that Equations 30.14 and 30.15 give the same value of the magnetic field at $r = R$, demonstrating that the magnetic field is continuous at the surface of the wire.



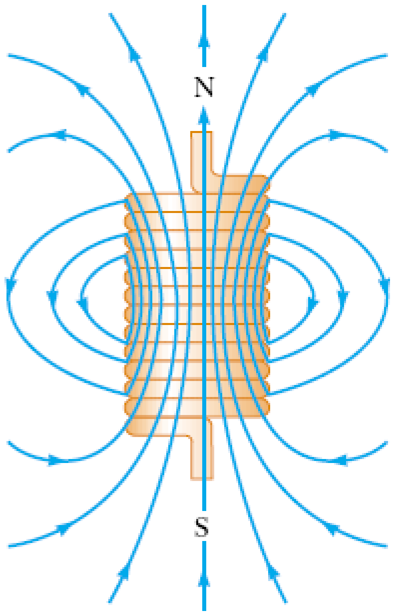


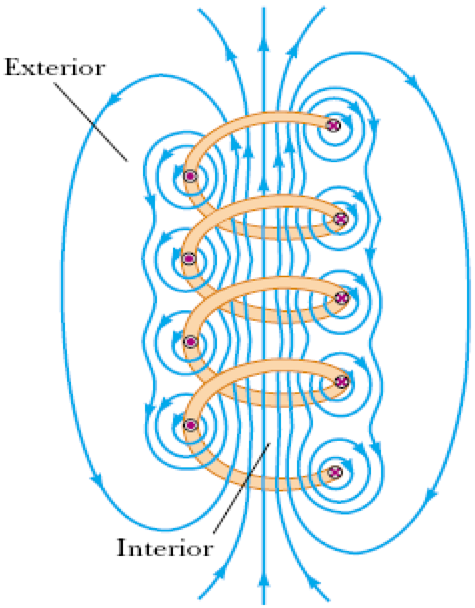
The Magnetic Field of a Solenoid

A solenoid is a long wire wound in the form of a helix. With this configuration, a reasonably uniform magnetic field can be produced in the space surrounded by the turns of wire, which we shall call the interior of the solenoid, when the solenoid carries a current.

When the turns are closely spaced, each can be approximated as a circular loop, and the net magnetic field is the vector sum of the fields resulting from all the turns.

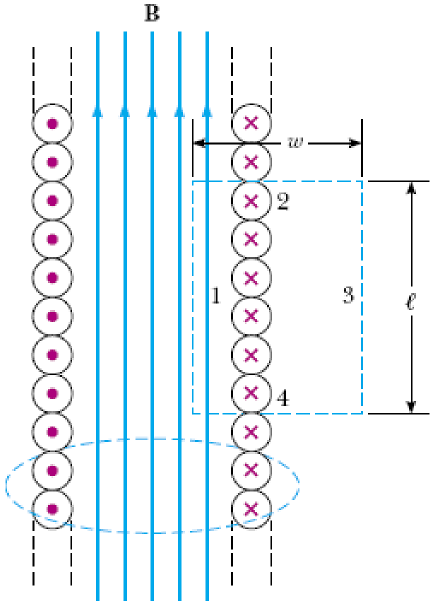
Note that the field lines in the interior are nearly parallel to one another, are uniformly distributed, and are close together, indicating that the field in this space is strong and almost uniform.

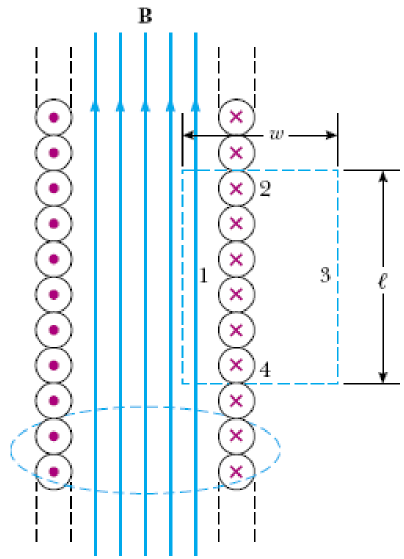




We can use Ampère's law to obtain a quantitative expression for the interior magnetic field in an ideal solenoid. Because the solenoid is ideal, **B** in the interior space is uniform and parallel to the axis, and the magnetic field lines in the exterior space form circles around the solenoid. The planes of these circles are perpendicular to the page. Consider the rectangular path of length ℓ and width w shown in Figure 30.19. We can apply Ampère's law to this path by evaluating the integral of $\mathbf{B} \cdot d\mathbf{s}$ over each side of the rectangle. The contribution along side 3 is zero because the magnetic field lines are perpendicular to the path in this region. The contributions from sides 2 and 4 are both zero, again because **B** is perpendicular to $d\mathbf{s}$ along these paths, both inside and outside the solenoid. Side 1 gives a contribution to the integral because along this path **B** is uniform and parallel to $d\mathbf{s}$. The integral over the closed rectangular path is therefore

$$\oint \mathbf{B} \cdot d\mathbf{s} = \int_{\text{path 1}} \mathbf{B} \cdot d\mathbf{s} = B \int_{\text{path 1}} ds = B\ell$$





The right side of Ampère's law involves the total current I through the area bounded by the path of integration. In this case, the total current through the rectangular path equals the current through each turn multiplied by the number of turns. If N is the number of turns in the length ℓ, the total current through the rectangle is NI. Therefore, Ampère's law applied to this path gives

$$\oint \mathbf{B} \cdot d\mathbf{s} = B\ell = \mu_0 NI$$

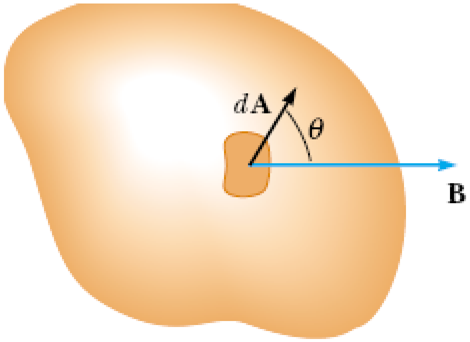
$$\boxed{B = \mu_0 \frac{N}{\ell} I = \mu_0 nI} \qquad (30.17)$$

where $n = N/\ell$ is the number of turns per unit length.

Magnetic Flux

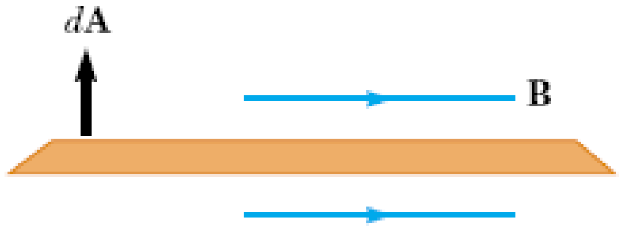
Consider an element of area dA on an arbitrarily shaped surface, as shown in Figure 30.20. If the magnetic field at this element is $\mathbf{B}$, the magnetic flux through the element is $\mathbf{B} \cdot d\mathbf{A}$, where $d\mathbf{A}$ is a vector that is perpendicular to the surface and has a magnitude equal to the area dA. Therefore, the total magnetic flux Φ_B through the surface is

$$\Phi_B = \int \mathbf{B} \cdot d\mathbf{A}$$

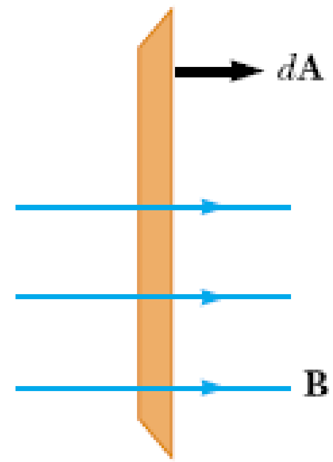


Consider the special case of a plane of area A in a uniform field $\mathbf{B}$ that makes an angle θ with $d\mathbf{A}$. The magnetic flux through the plane in this case is

$$\Phi_B = BA \cos \theta$$



(a)

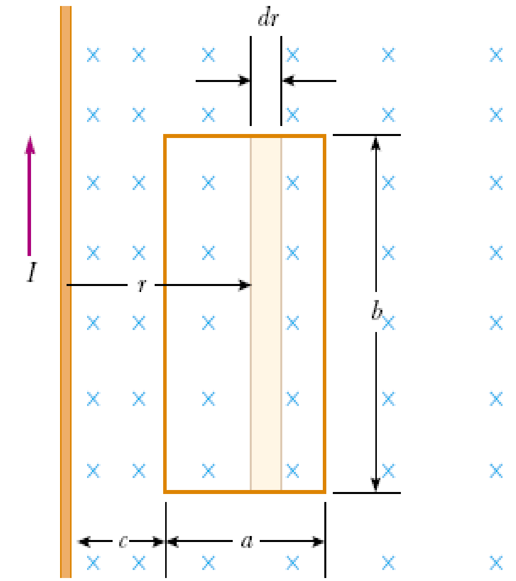


If the magnetic field is parallel to the plane, as in Figure 30.21a, then $\theta = 90°$ and the flux through the plane is zero. If the field is perpendicular to the plane, as in Figure 30.21b, then $\theta = 0$ and the flux through the plane is BA (the maximum value).

The unit of magnetic flux is $\mathrm{T \cdot m^2}$, which is defined as a *weber* (Wb); $1\ \mathrm{Wb} = 1\ \mathrm{T \cdot m^2}$.

Magnetic Flux Through a Rectangular Loop

A rectangular loop of width a and length b is located near a long wire carrying a current I (Fig. 30.22). The distance between the wire and the closest side of the loop is c. The wire is parallel to the long side of the loop. Find the total magnetic flux through the loop due to the current in the wire.



Solution From Equation 30.14, we know that the magnitude of the magnetic field created by the wire at a distance r from the wire is

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

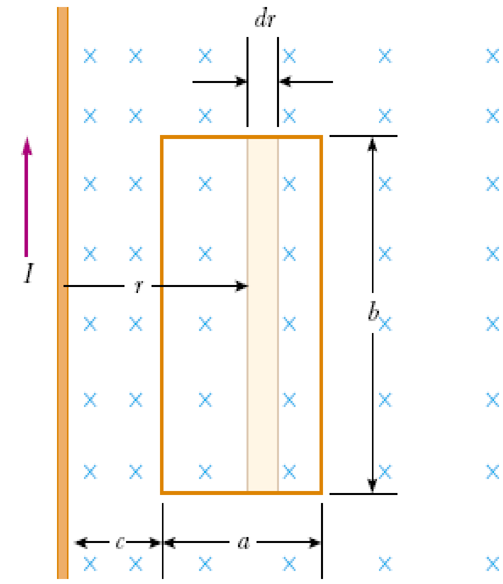
The factor $1/r$ indicates that the field varies over the loop, and Figure 30.22 shows that the field is directed into the page at the location of the loop. Because $\mathbf{B}$ is parallel to $d\mathbf{A}$ at any point within the loop, the magnetic flux through an area element dA is

$$\Phi_B = \int B\, dA = \int \frac{\mu_0 I}{2\pi r}\, dA$$

To integrate, we first express the area element (the tan region in Fig. 30.22) as $dA = b\,dr$. Because r is now the only variable in the integral, we have

$$\Phi_B = \frac{\mu_0 I b}{2\pi}\int_c^{a+c}\frac{dr}{r} = \frac{\mu_0 I b}{2\pi}\ln r\,\Big]_c^{a+c}$$

$$(1) \qquad = \frac{\mu_0 I b}{2\pi}\ln\left(\frac{a+c}{c}\right) = \boxed{\frac{\mu_0 I b}{2\pi}\ln\left(1+\frac{a}{c}\right)}$$



What If? **Suppose we move the loop in Figure 30.22 very far away from the wire. What happens to the magnetic flux?**

Answer The flux should become smaller as the loop moves into weaker and weaker fields.

As the loop moves far away, the value of c is much larger than that of a, so that $a/c \rightarrow 0$. Thus, the natural logarithm in Equation (1) approaches the limit

$$\ln\left(1+\frac{a}{c}\right) \longrightarrow \ln(1+0) = \ln(1) = 0$$

and we find that $\Phi_B \rightarrow 0$ as we expected.

GAUSS'S LAW IN MAGNETISM

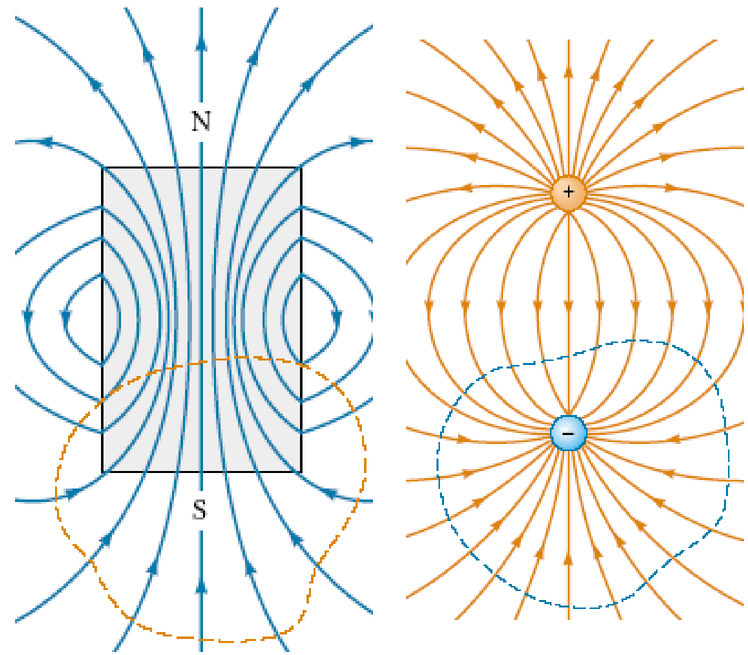
Gauss's law in magnetism states that

the net magnetic flux through any closed surface is always zero:

$$\oint \mathbf{B} \cdot d\mathbf{A} = 0$$

An isolated magnetic pole (monopole) has never been detected and may not exist.

The magnetic field lines of a bar magnet form closed loops.
The net magnetic flux through the closed surface (dashed red line) surrounding one of the poles (or any other closed surface) is zero.
The electric field lines surrounding an electric dipole begin on the positive charge and terminate on the negative charge. The electric flux through a closed surface surrounding one of the charges is not zero.



Classification of Magnetic Substances

Substances can be classified as belonging to one of three categories, depending on their magnetic properties. Paramagnetic and ferromagnetic materials are those made of atoms that have permanent magnetic moments.
Diamagnetic materials are those made of atoms that do not have permanent magnetic moments.

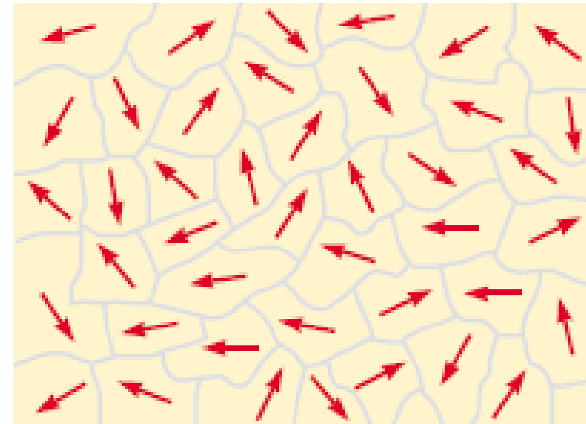
Substances may be classified in terms of how their magnetic permeability μ_m compares with μ_0 (the permeability of free space), as follows:

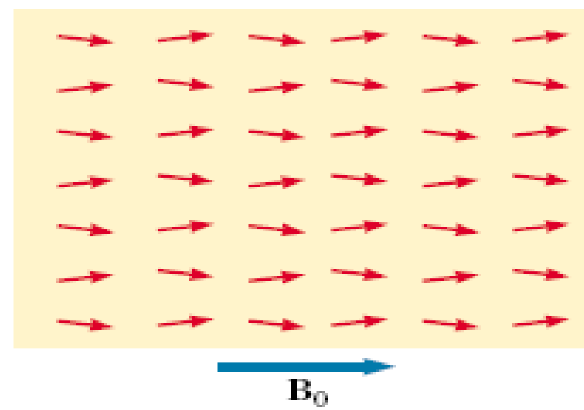
Paramagnetic	$\mu_m > \mu_0$
Diamagnetic	$\mu_m < \mu_0$

Because χ is very small for paramagnetic and diamagnetic substances (see Table 30.2), μ_m is nearly equal to μ_0 for these substances. For ferromagnetic substances, however, μ_m is typically several thousand times greater than μ_0 (meaning that χ is very great for ferromagnetic substances).

Ferromagnetism

A small number of crystalline substances in which the atoms have permanent magnetic moments exhibit strong magnetic effects called ferromagnetism.
Some examples of ferromagnetic substances are iron, cobalt, nickel, gadolinium, and dysprosium.
All ferromagnetic materials are made up of microscopic regions called **domains**, regions within which all magnetic moments are aligned. These domains have volumes of about 10^{12} to 10^{8} m^3 and contain 10^{17} to 10^{21} atoms. The boundaries between the various domains having different orientations are called **domain walls**.





Paramagnetism

Paramagnetic substances have a small but positive magnetic susceptibility ($0 < \chi \ll 1$) resulting from the presence of atoms (or ions) that have permanent magnetic moments. These moments interact only weakly with each other and are randomly oriented in the absence of an external magnetic field. When a paramagnetic substance is placed in an external magnetic field, its atomic moments tend to line up with the field. However, this alignment process must compete with thermal motion, which tends to randomize the magnetic moment orientations.

Diamagnetism

When an external magnetic field is applied to a diamagnetic substance, a weak magnetic moment is induced in the direction opposite the applied field. This causes diamagnetic substances to be weakly repelled by a magnet. Although diamagnetism is present in all matter, its effects are much smaller than those of paramagnetism or ferromagnetism, and are evident only when those other effects do not exist.

Magnetic Field

Q1. An electron that has velocity v = (2.0*10^6 m/s)i + (3.0*10^6 m/s)j moves with the uniform magnetic field (b =0.030t)I – (0.15t)j (a)Find the force on the electron due to magnetic field.(b)Repeat your calculation for proton having same velocity.

Q2. An alpha particle travel at velocity of magnitude 550m/s through uniform magnetic field of magnitude 0.045t (an alpha particle has the charge of + 3.2 * 10^-19C and mass of 6.6*10^-27 kg). the angle between v and B is 52 degree. What is the magnitude of (a)Force F b acting on the particle due to filed(b)Acceleration of particle due to Fb(c)Does the speed of particle increase, decrease or remain same.

Q3) a particle of mass 10 g and charge 80µC move through uniform magnetic field in a region where the free fall acceleration is -9.8j m/s^2.the velocity of particle is constant 20i km/s which is perpendicular to magnetic field. what then, is magnetic field?

Q4) an electron moves through uniform magnetic field given by B= Bxi + (3.0Bx)j. At a particular instant, the electron has velocity v = (2.0i + 4.0j)m/s and the magnetic force acting on it is (6.4 * 10^-19N)k. find Bx.

Q5) an electron has initial velocity of (12.0j + 15.0k) km/s and the constant acceleration of (2.00*10^12 m/s^2)i in a region in which uniform electric and magnetic field are present. If B = (400µT)i. find the electric field E