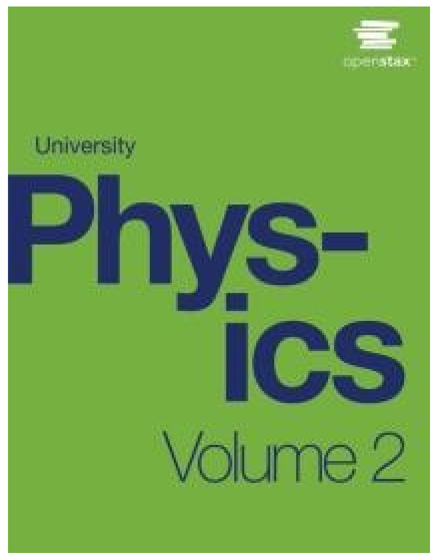
UNIVERSITY PHYSICS

Chapter 12 SOURCES OF MAGNETIC FIELDS

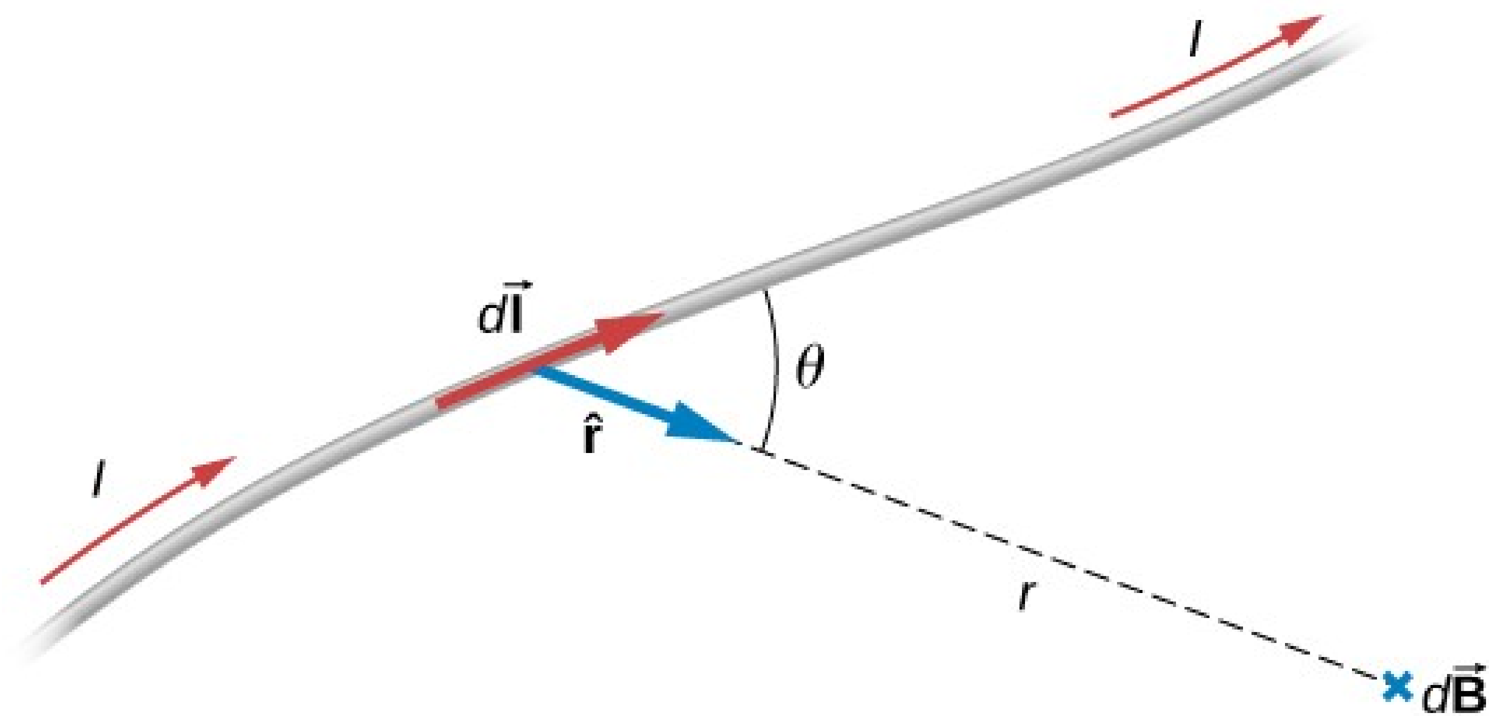
PowerPoint Image Slideshow



Biot-Savart Law

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{l} \times \hat{r}}{r^2}$$

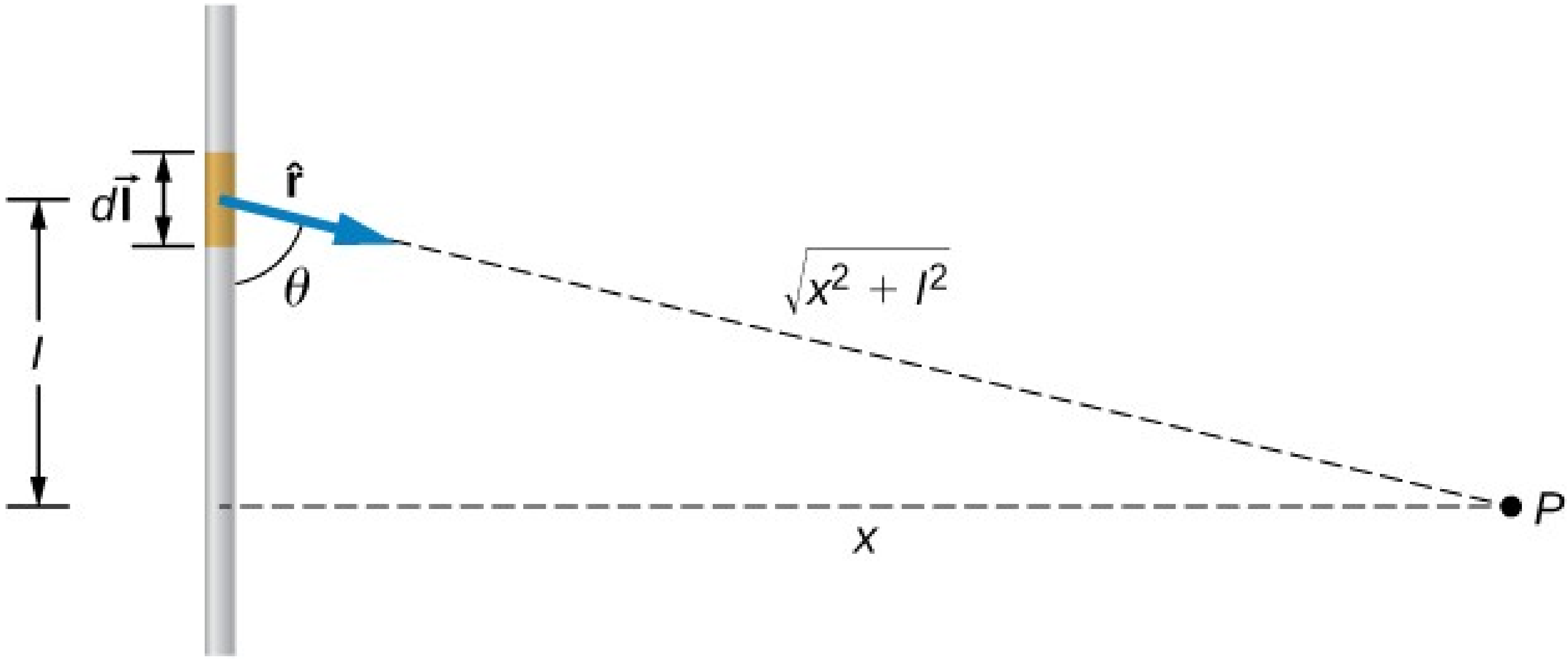
FIGURE 12.2



A current element *Id* produces a magnetic field at point *P* given by the Biot-Savart law.

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{l}\times\hat{r}}{r^2}$$

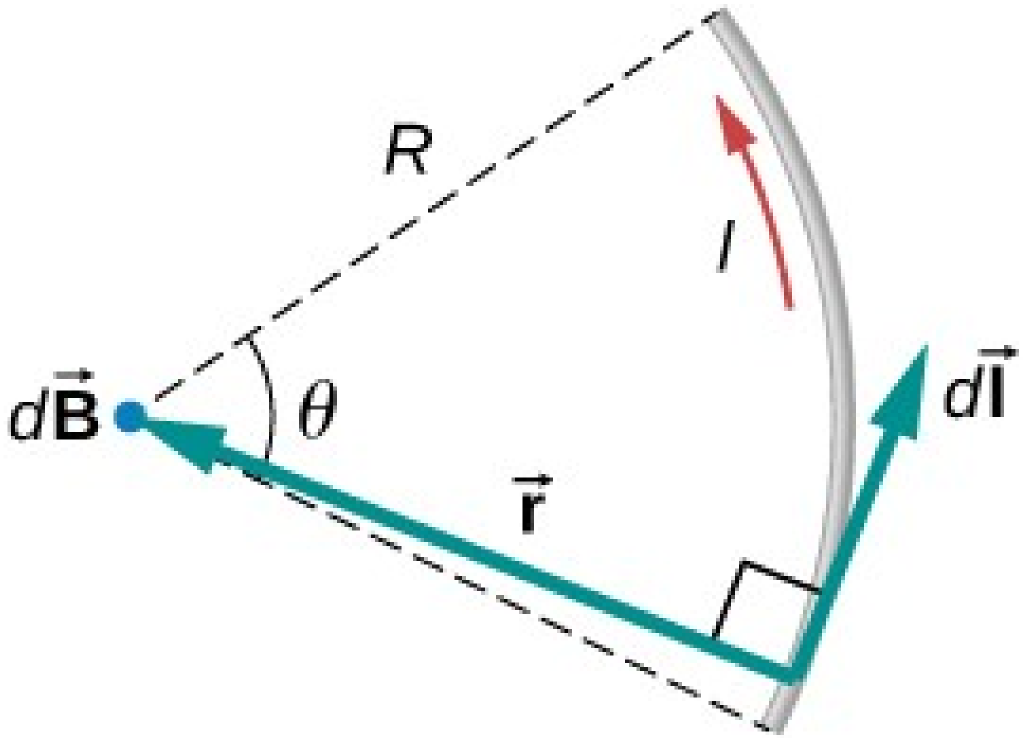
FIGURE 12.3



A small line segment carries a current *I* in the vertical direction. What is the magnetic field at a distance *x* from the segment?

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{l} \times \hat{r}}{r^2}$$

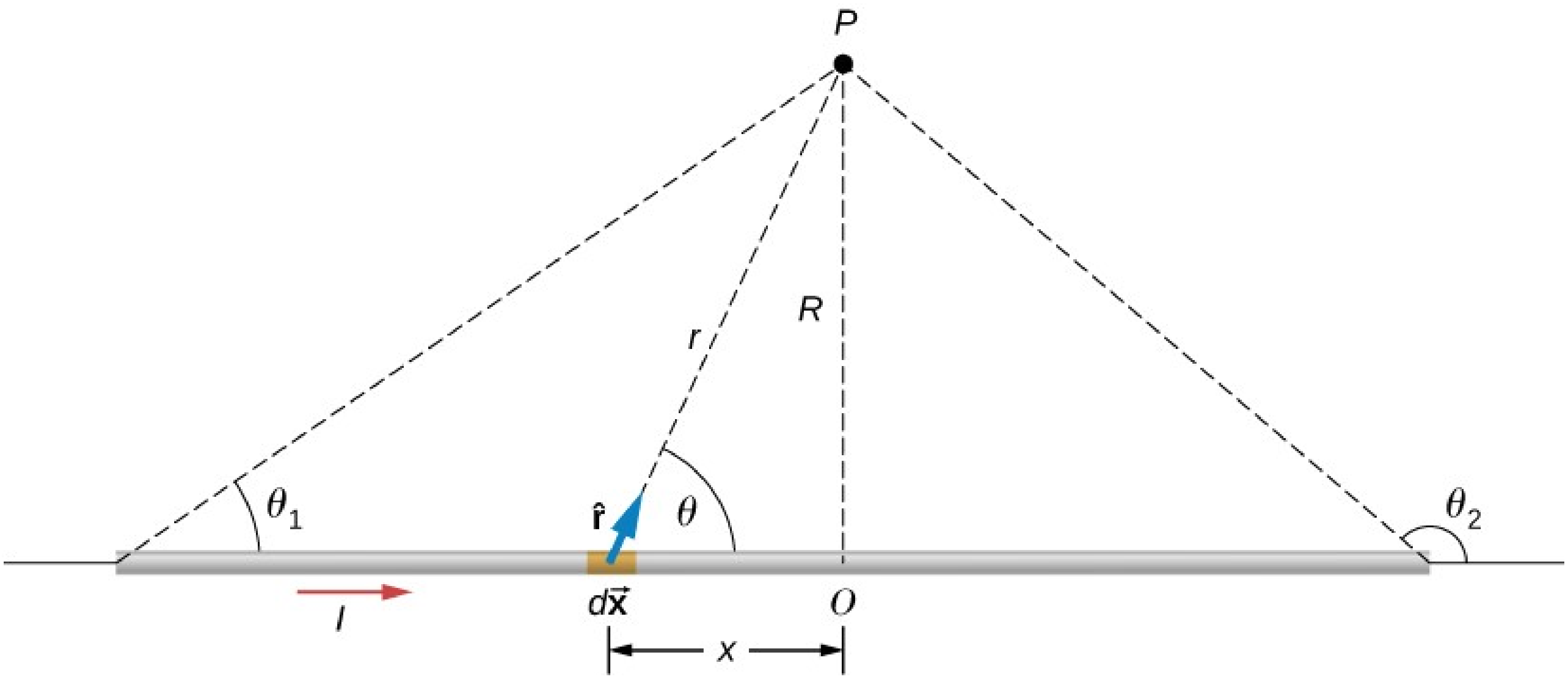
FIGURE 12.4



A wire segment carrying a current *I*. The path *d* and radial direction are indicated.

$$d\vec{B}=\frac{\mu_0}{4\pi}\frac{I\,d\vec{I}\times\hat{r}}{r^2}$$

FIGURE 12.5



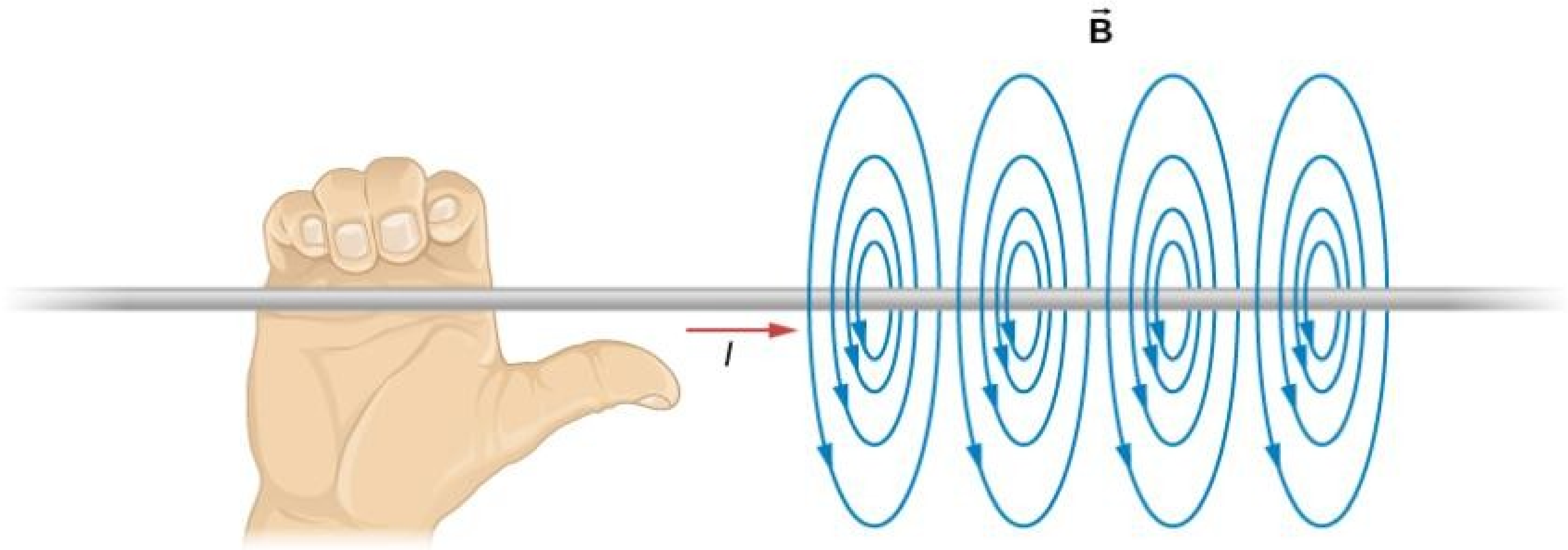
A section of a thin, straight current-carrying wire. The independent variable has the limits $_1$ and $_2$.

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{I} \times \hat{r}}{r^2}$$

Magnetic field around a wire

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

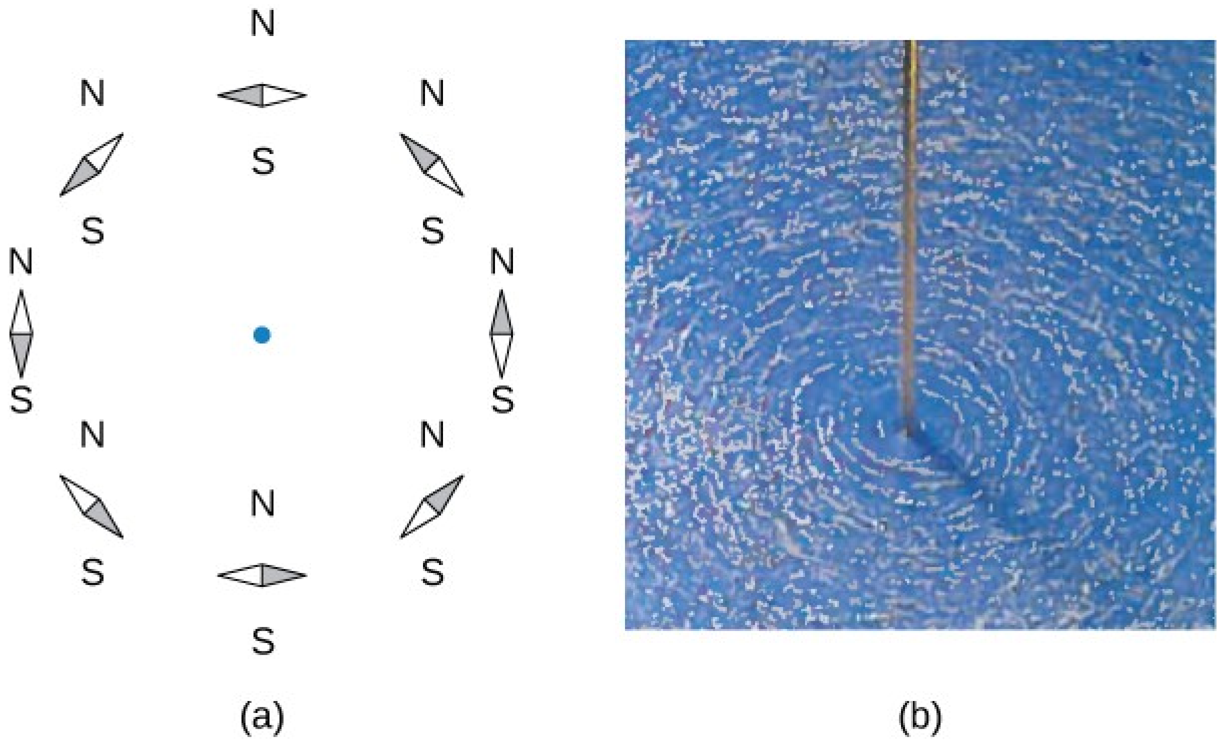
FIGURE 12.6



Some magnetic field lines of an infinite wire. The direction of can be found with a form of the right-hand rule.

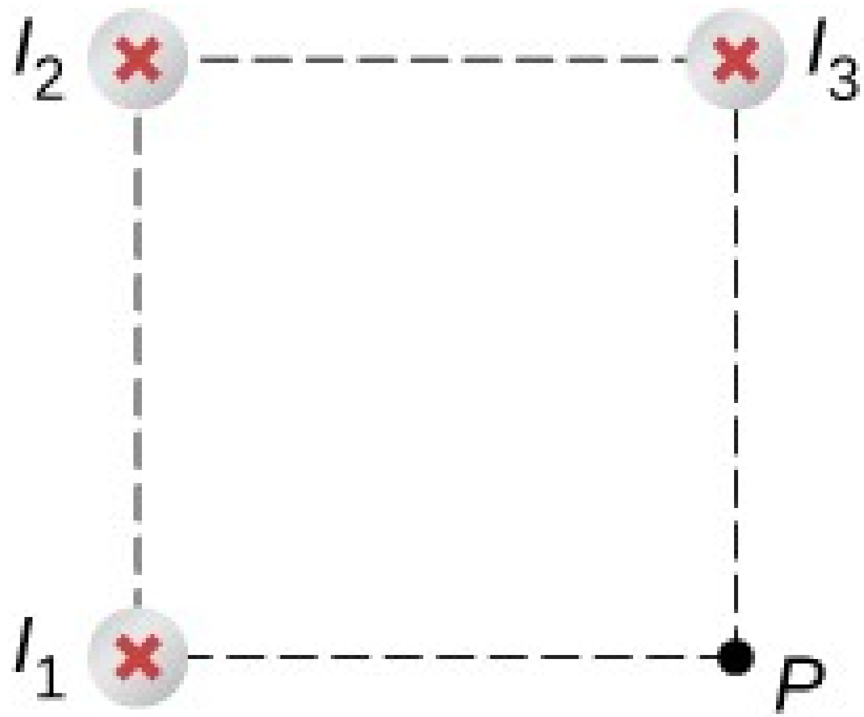
$$B = \frac{\mu_0 I}{2\pi R}$$

FIGURE 12.7



The shape of the magnetic field lines of a long wire can be seen using (a) small compass needles and (b) iron filings.

FIGURE 12.8



Three wires have current flowing into the page. The magnetic field is determined at the fourth corner of the square.

EXAMPLE 12.3

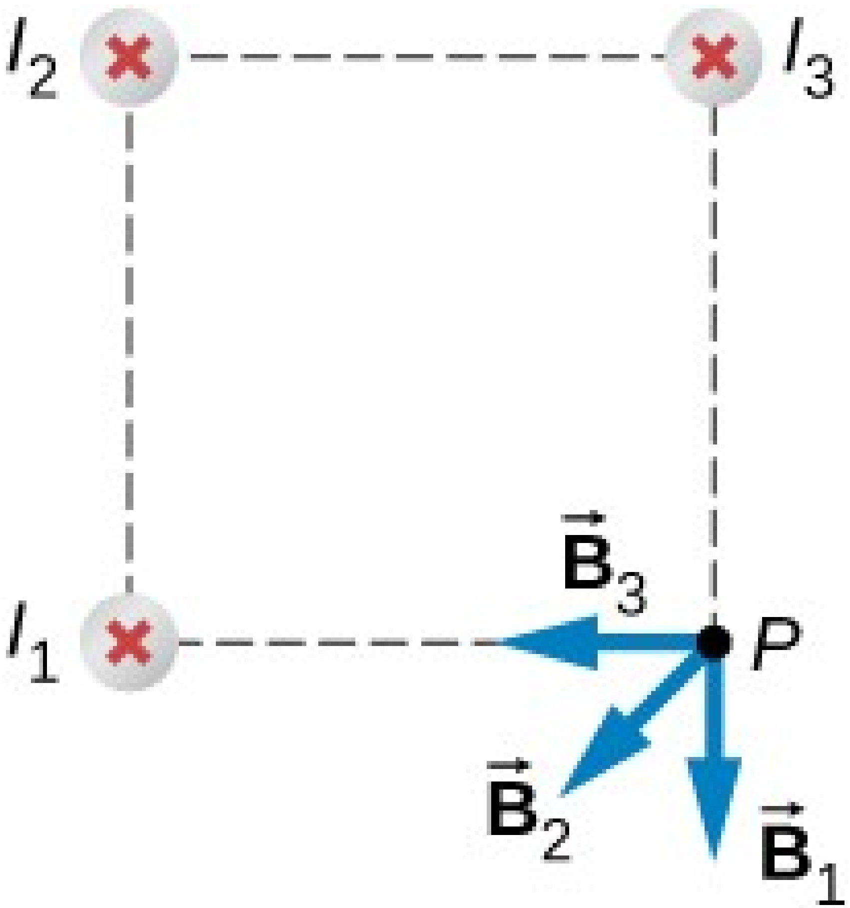
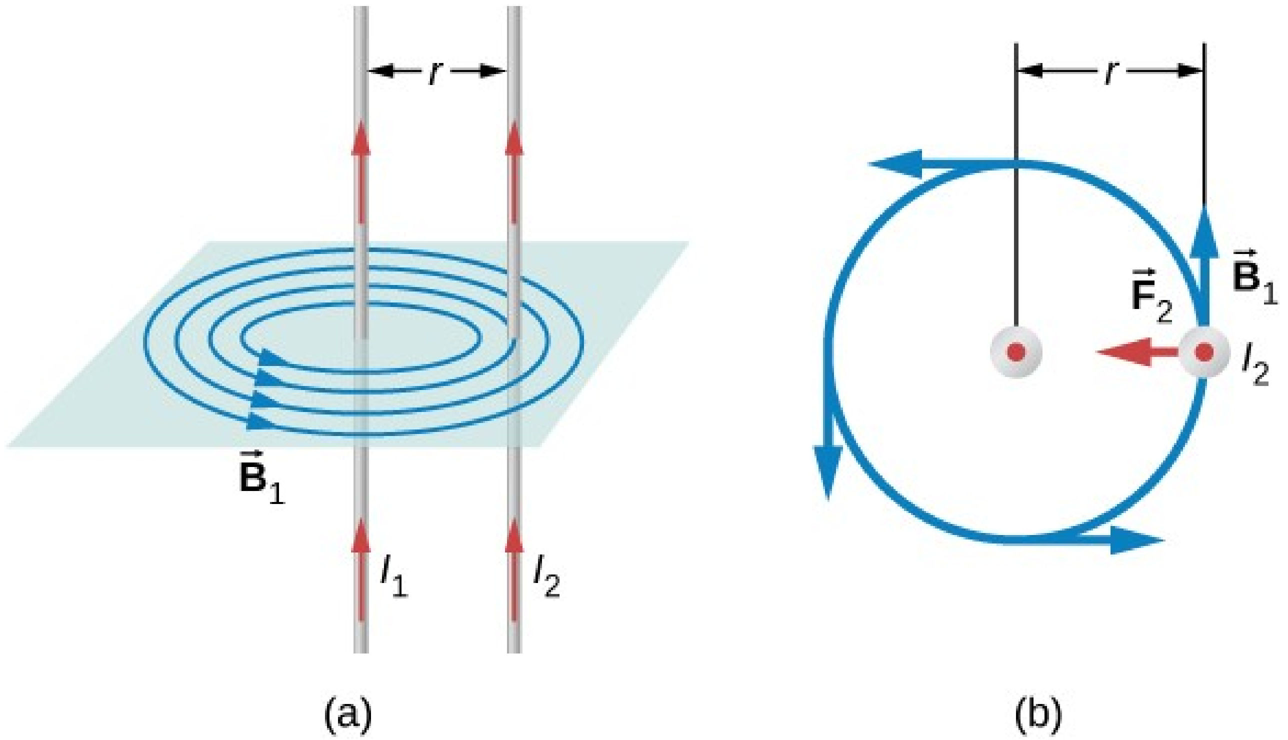


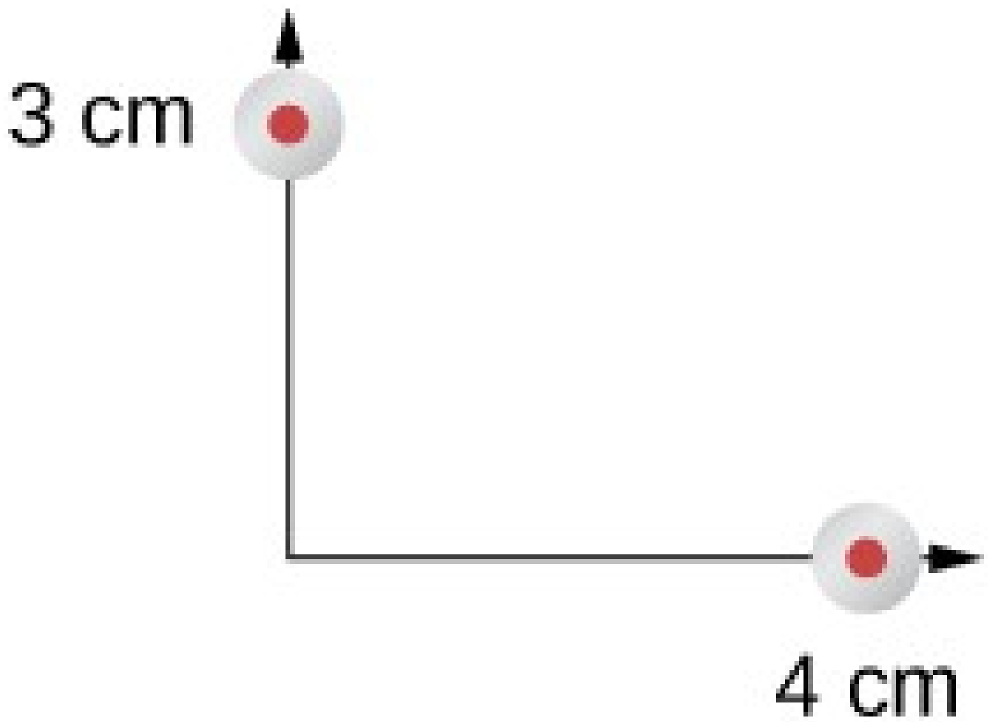
FIGURE 12.9



a) The magnetic field produced by a long straight conductor is perpendicular to a parallel conductor, as indicated by right-hand rule (RHR)-2.

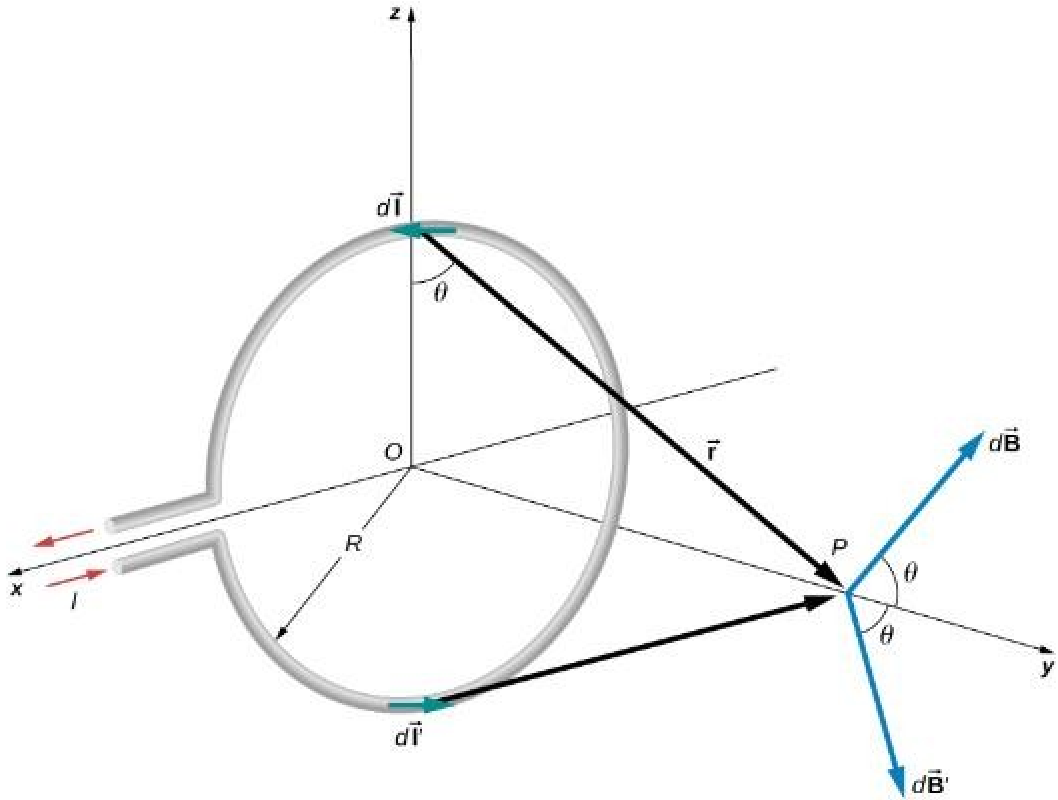
b) A view from above of the two wires shown in (a), with one magnetic field line shown for wire 1. RHR-1 shows that the force between the parallel conductors is attractive when the currents are in the same direction. A similar analysis shows that the force is repulsive between currents in opposite directions.

FIGURE 12.10



Two current-carrying wires at given locations with currents out of the page.

FIGURE 12.11



Determining the magnetic field at point *P* along the axis of a current-carrying loop of wire.

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FIGURE 12.12

Sketch of the magnetic field lines of a circular current loop.

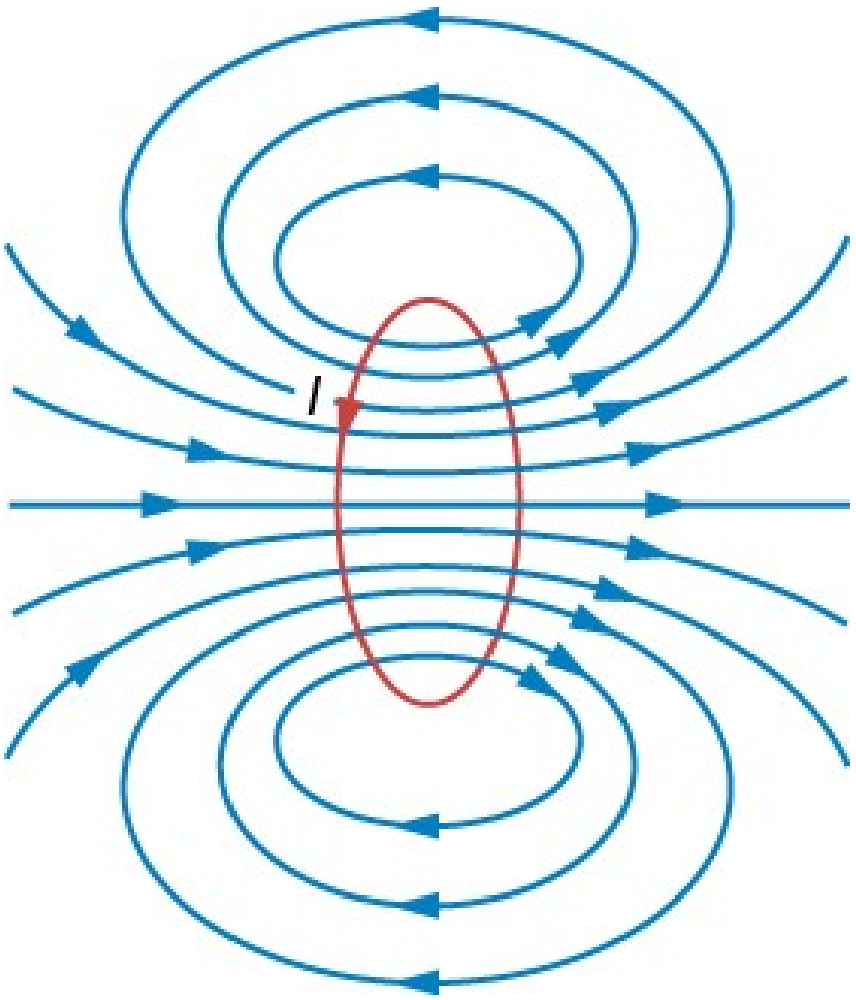
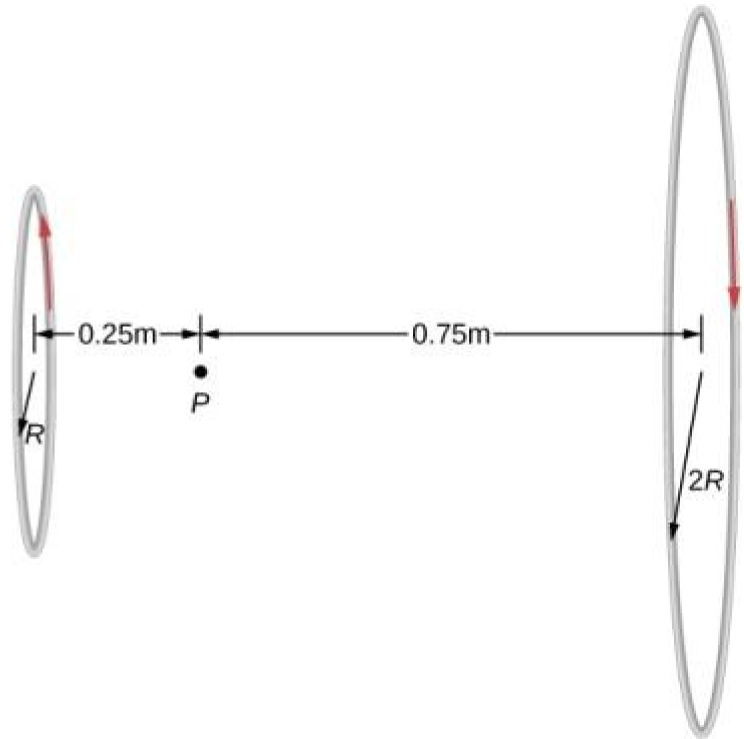


FIGURE 12.13

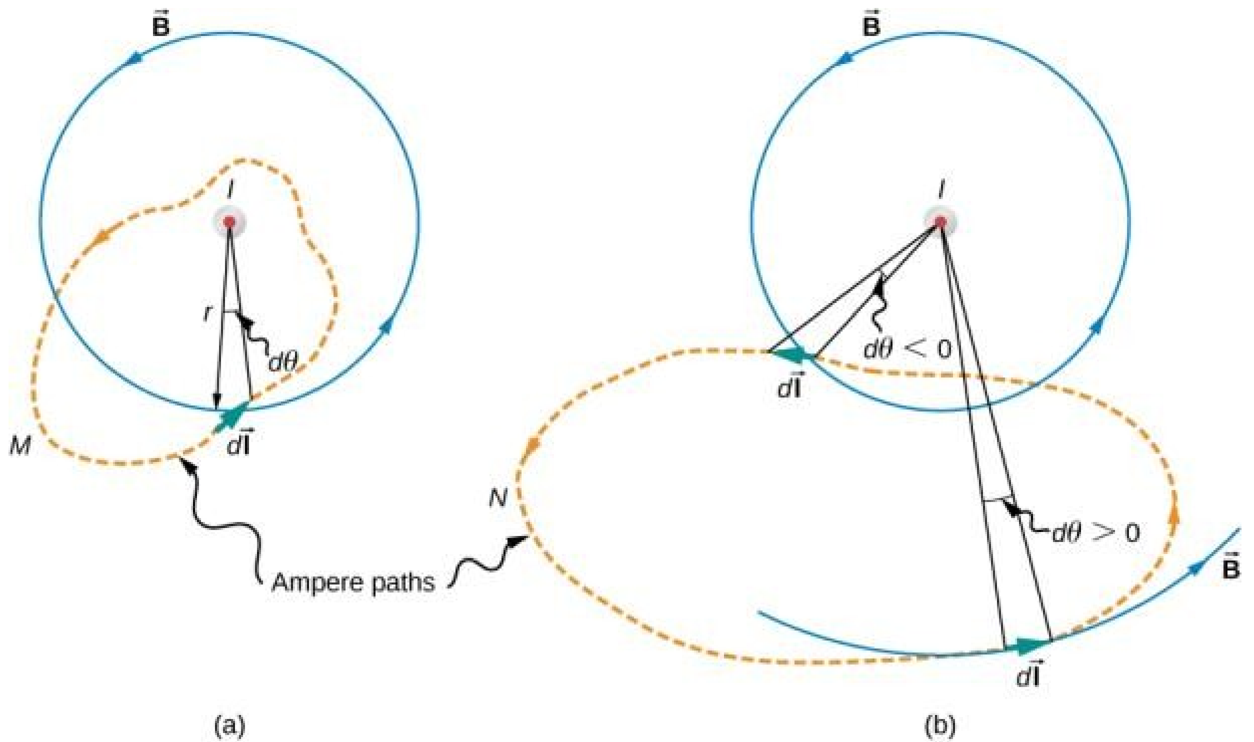


Two loops of different radii have the same current but flowing in opposite directions. The magnetic field at point *P* is measured to be zero.

Ampere's Law

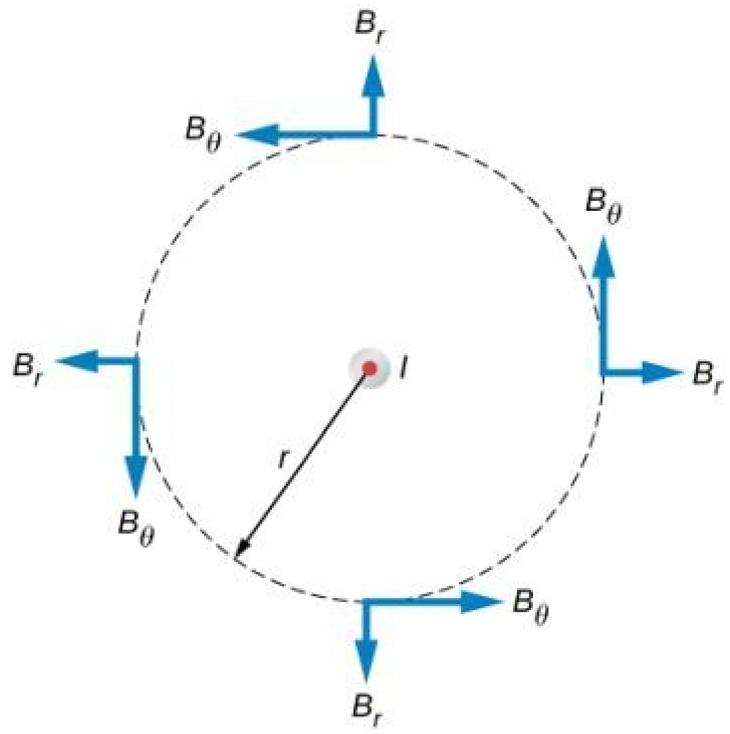
$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$$

FIGURE 12.14



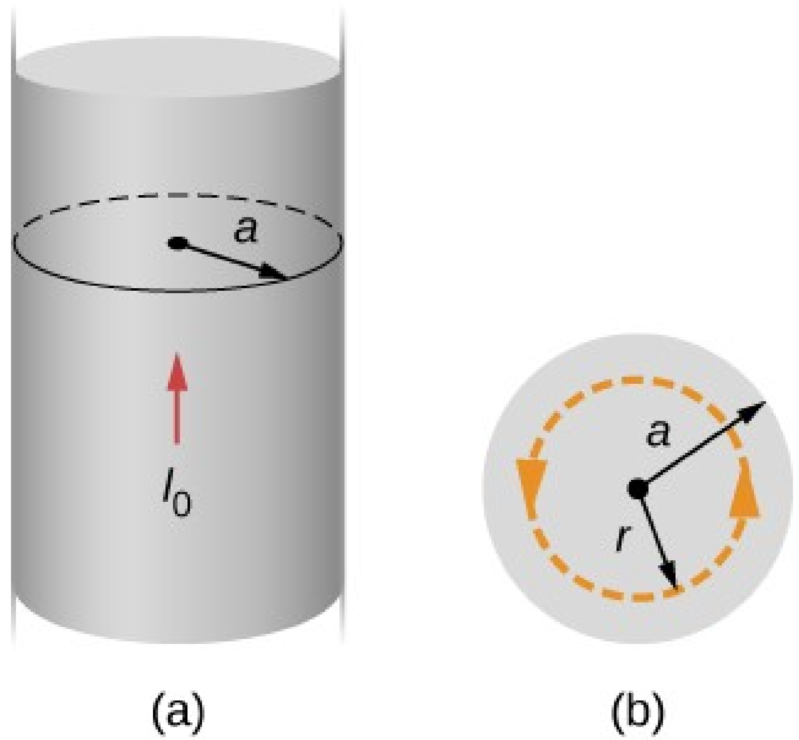
The current *I* of a long, straight wire is directed out of the page. The integral $\oint d\theta$ equals 2π and 0, respectively, for paths *M* and *N*.

FIGURE 12.15



The possible components of the magnetic field *B* due to a current *I*, which is directed out of the page. The radial component is zero because the angle between the magnetic field and the path is at a right angle.

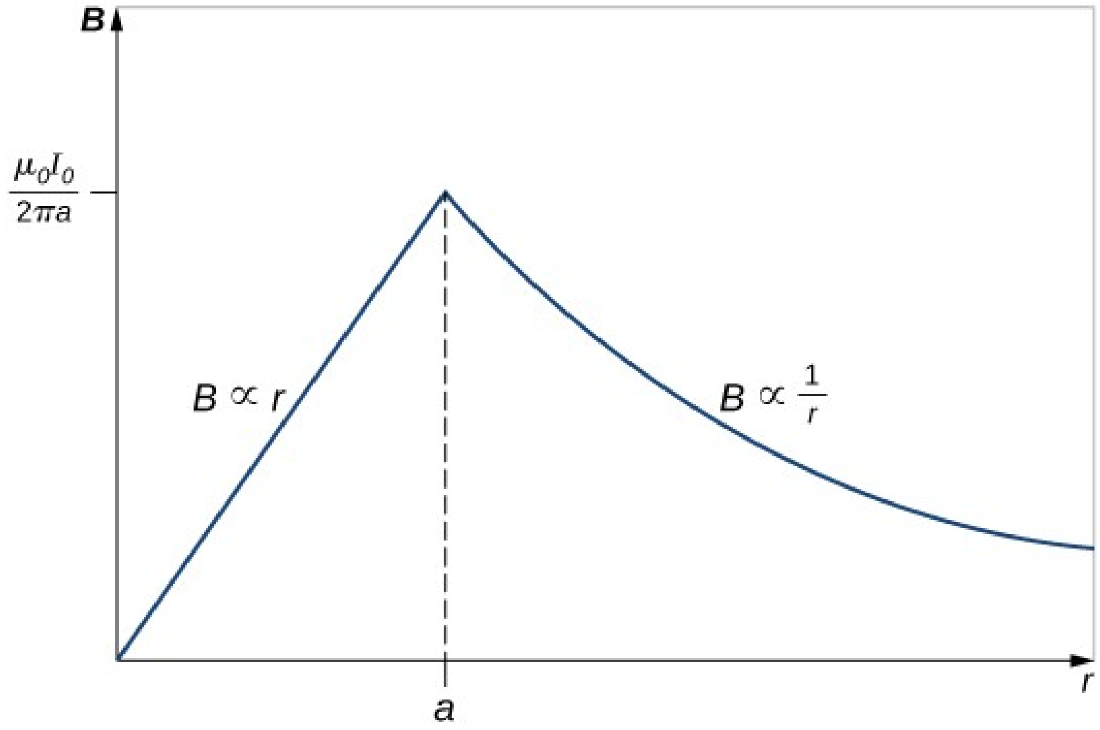
FIGURE 12.16



a) A model of a current-carrying wire of radius *a* and current I_0.

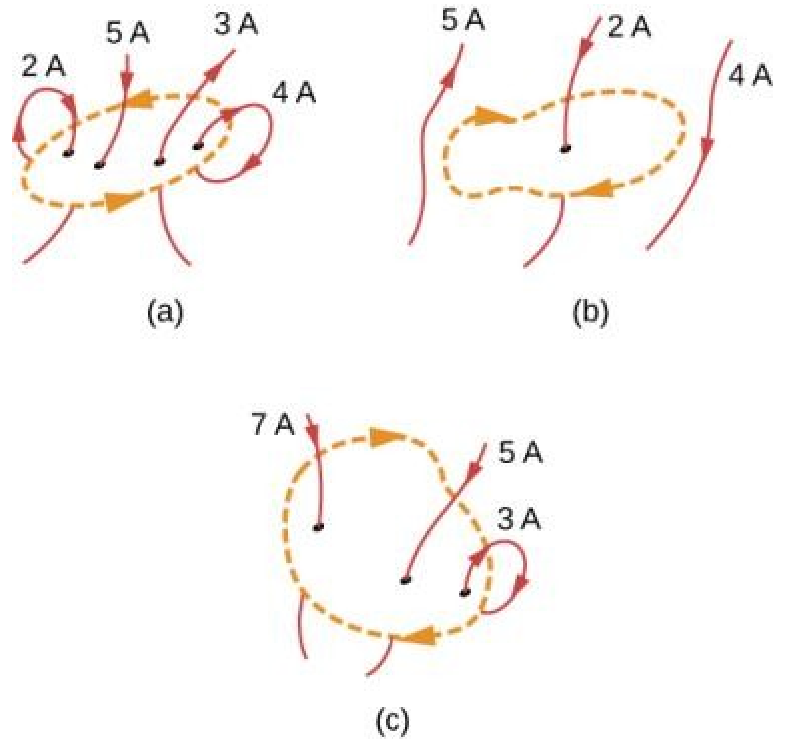
b) A cross-section of the same wire showing the radius a and the Ampère's loop of radius *r.*

FIGURE 12.17



Variation of the magnetic field produced by a current I_0 in a long, straight wire of radius *a*.

FIGURE 12.18

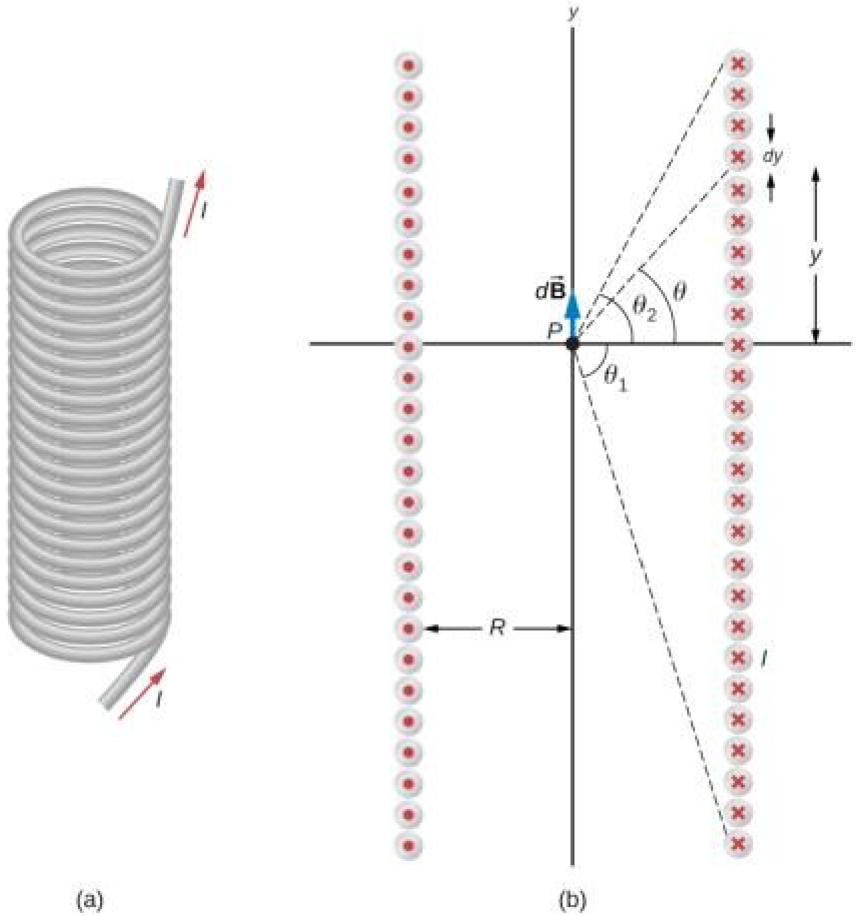


Current configurations and paths for Example 12.8.

Solenoids

$$B = n \mu_0 I$$

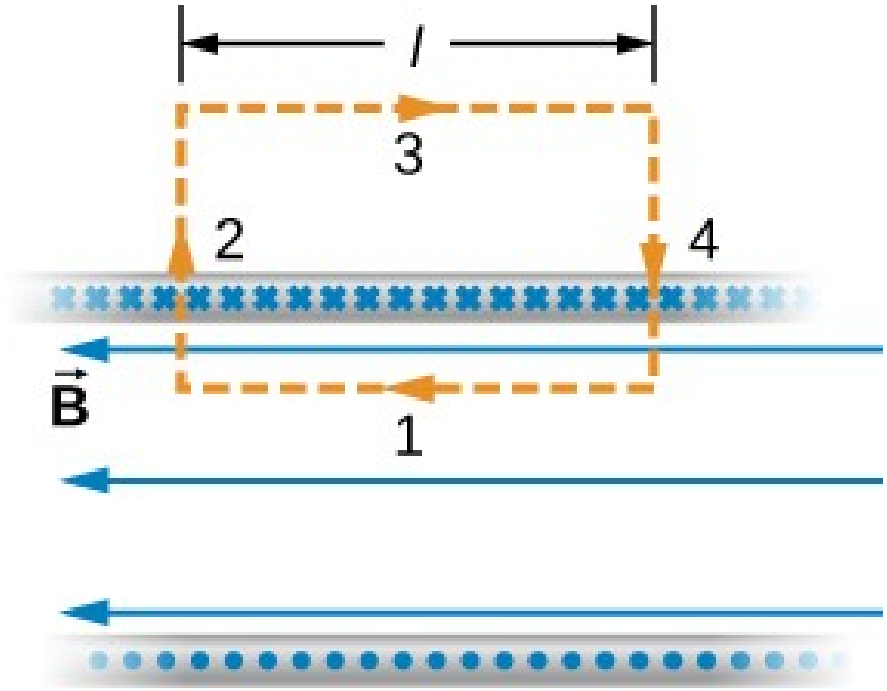
FIGURE 12.19



a) A solenoid is a long wire wound in the shape of a helix.

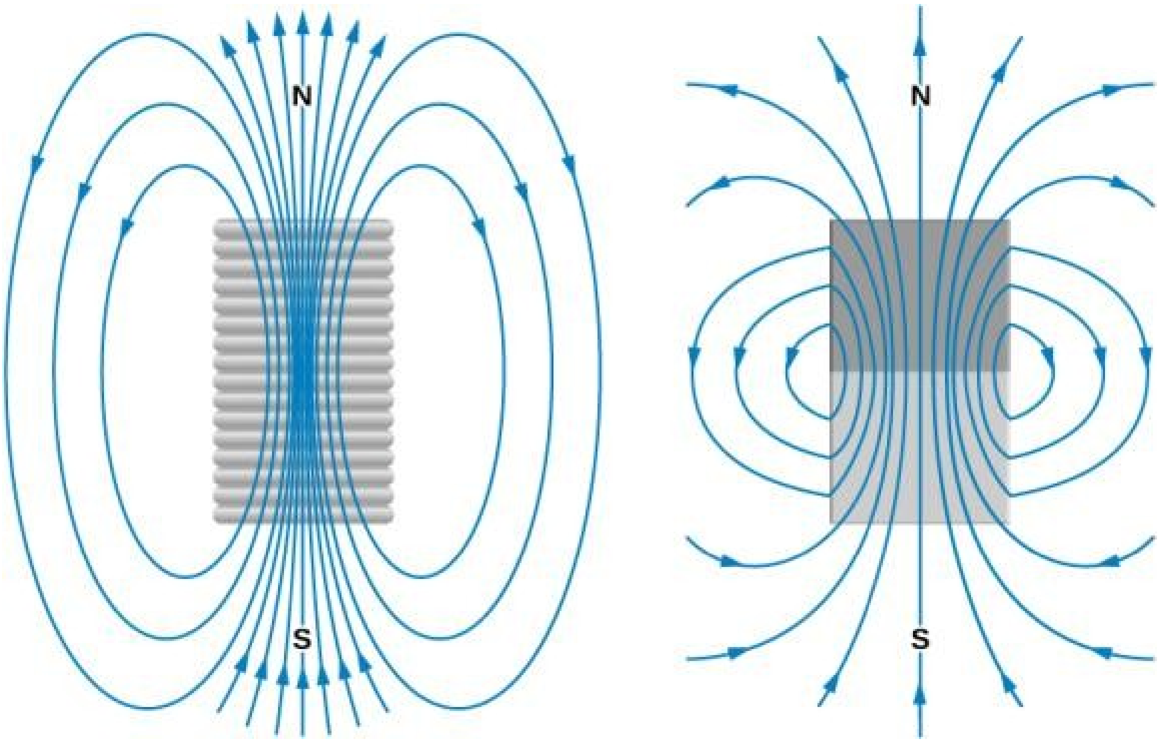
b) The magnetic field at the point *P* on the axis of the solenoid is the net field due to all of the current loops.

FIGURE 12.20



The path of integration used in Ampère’s law to evaluate the magnetic field of an infinite solenoid.

FIGURE 12.27



Comparison of the magnetic fields of a finite solenoid and a bar magnet.

Toroids

$$B = \frac{N \mu_0 I}{2 \pi R}$$

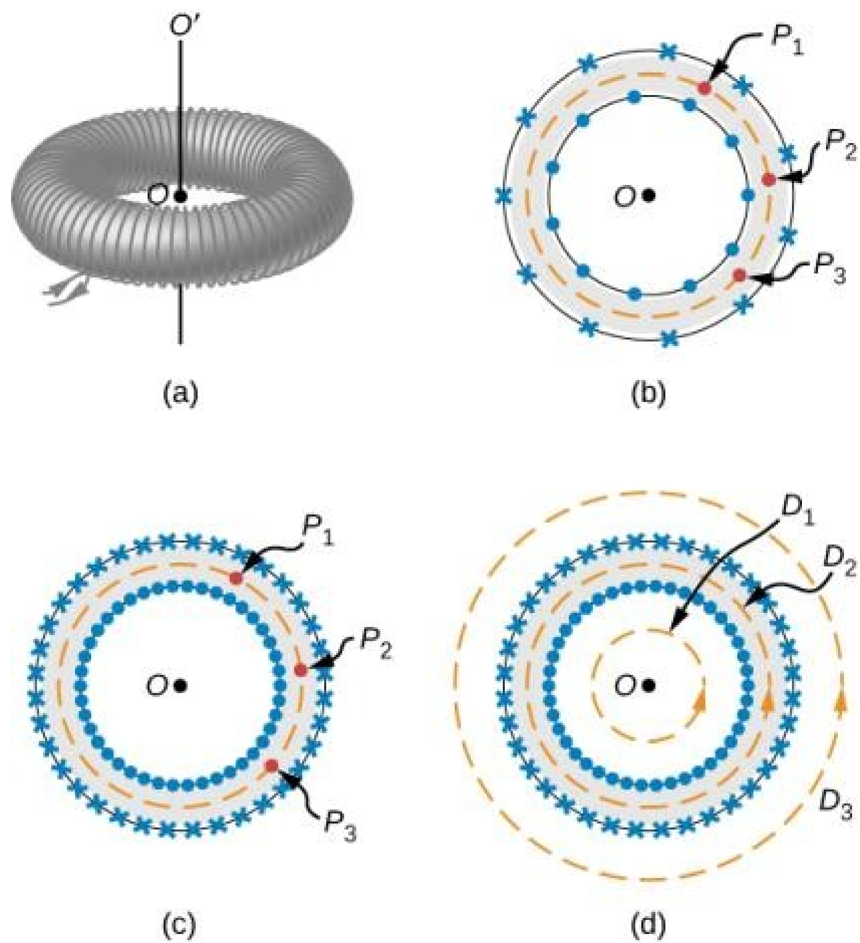
FIGURE 12.22

a) A toroid is a coil wound into a donut-shaped object.

b) A loosely wound toroid does not have cylindrical symmetry.

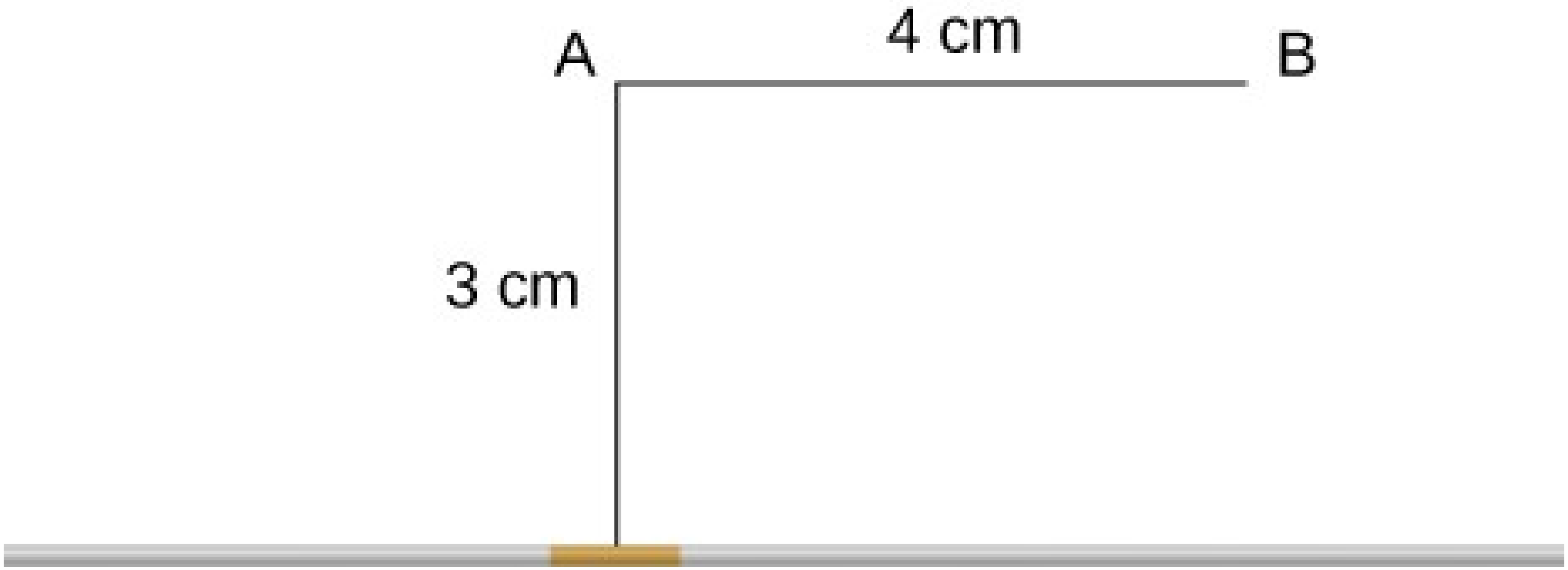
c) In a tightly wound toroid, cylindrical symmetry is a very good approximation.

d) Several paths of integration for Ampère's law.



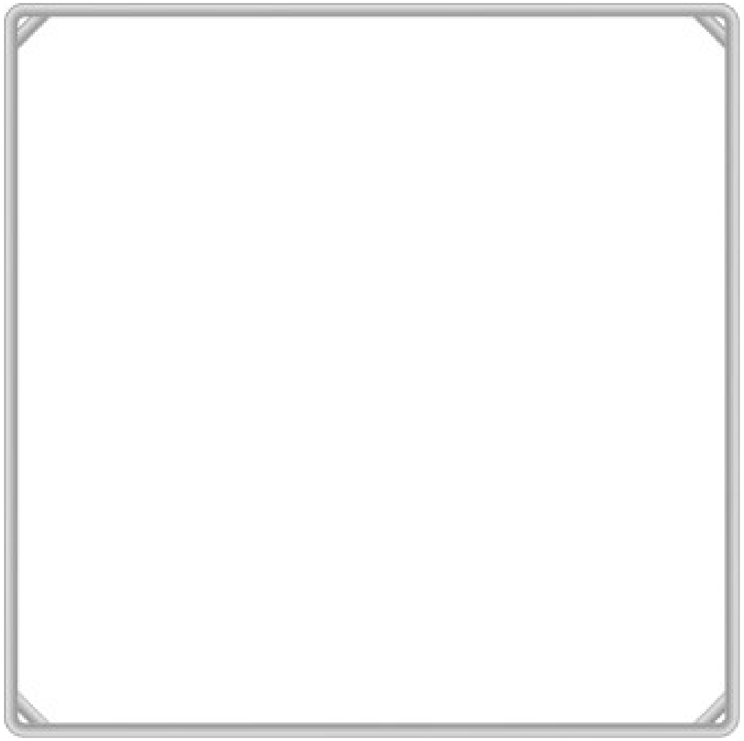
Examples

EXERCISE 16



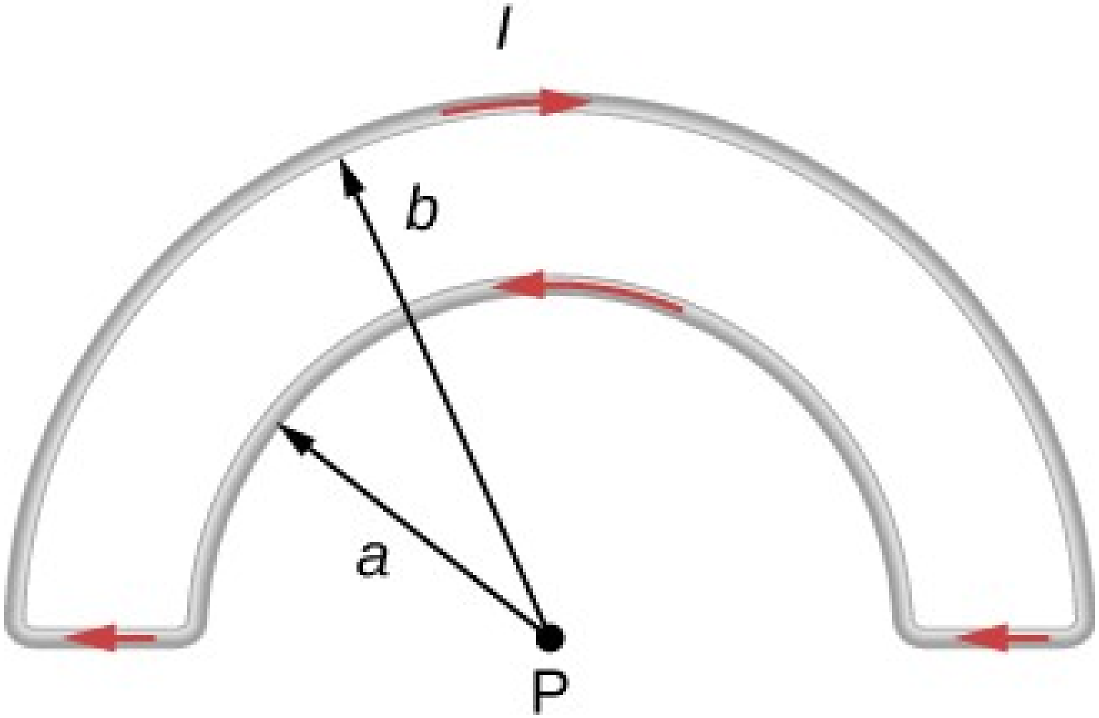
1. A 10-A current flows through the wire shown. What is the magnitude of the magnetic
0.5-mm segment of wire as measured at (a) point A and (b) point B?

EXERCISE 17



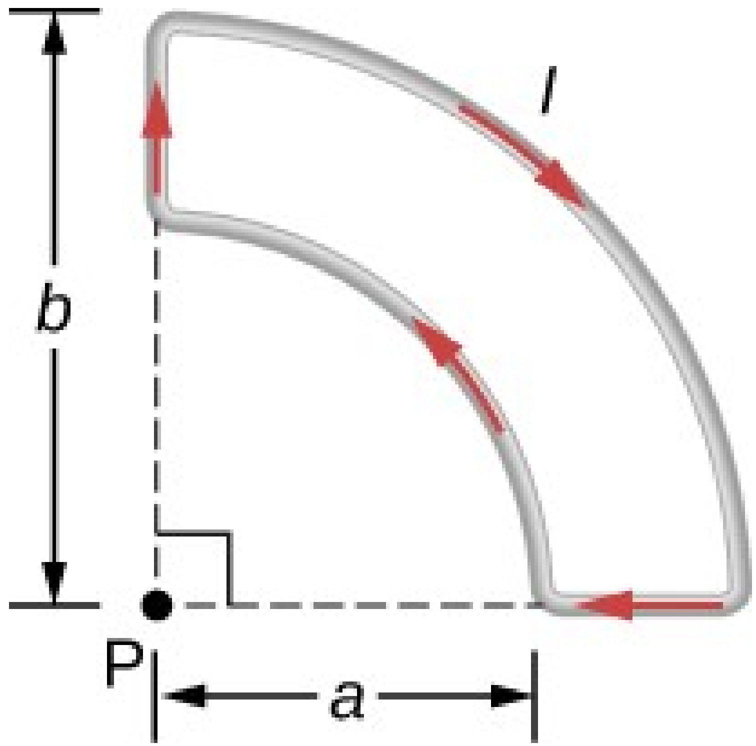
Ten amps flow through a square loop where each side is 20 cm in length. At each corner of the loop is a 0.01-cm segment that connects the longer wires as shown. Calculate the magnitude of the magnetic field at the center of the loop.

EXERCISE 18



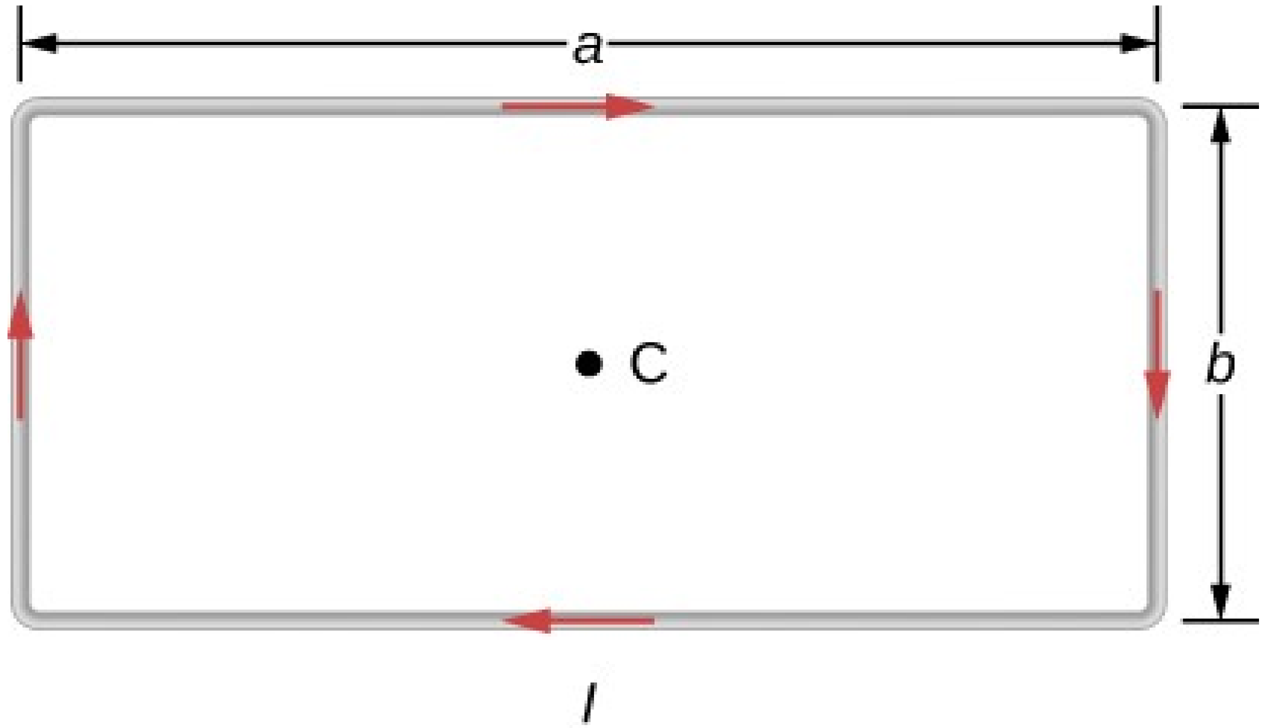
What is the magnetic field at P due to the current I in the wire shown?

EXERCISE 19



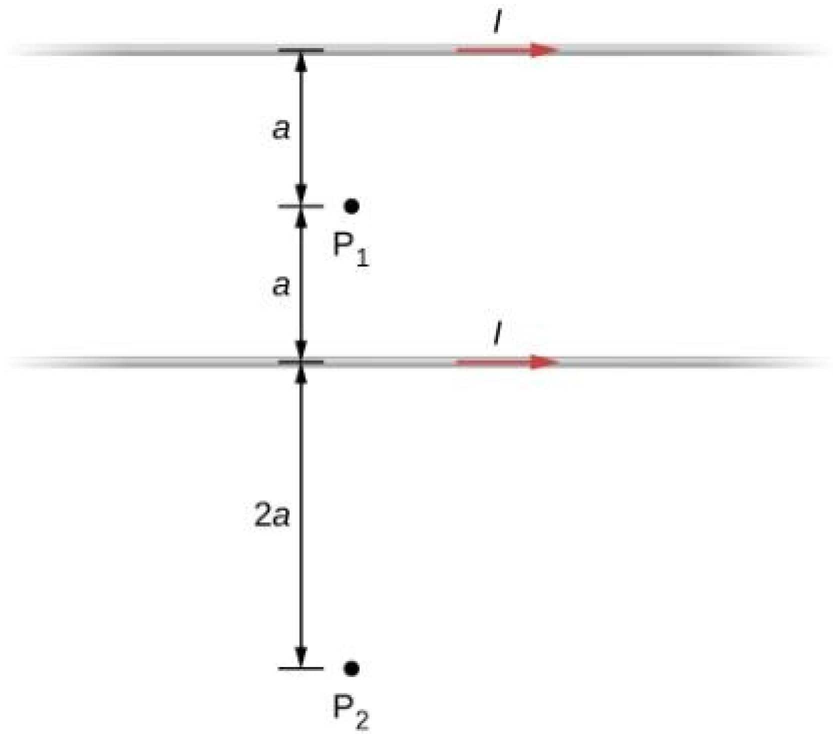
The accompanying figure shows a current loop consisting of two concentric circular arcs perpendicular radial lines. Determine the magnetic field at point P.

EXERCISE 20



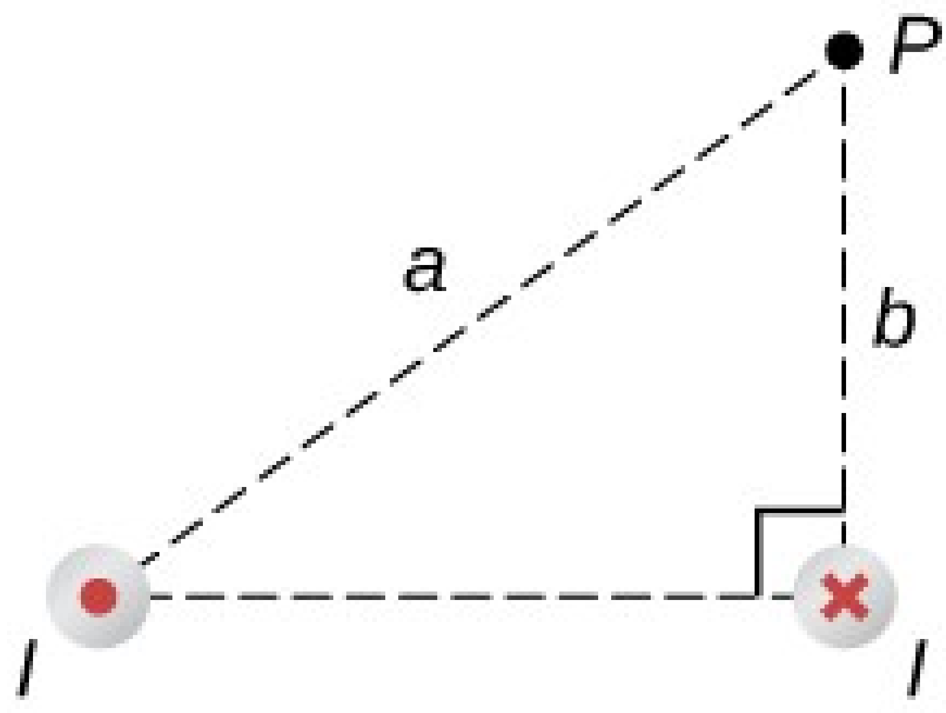
Find the magnetic field at the center C of the rectangular loop of wire shown in the accompanying figure.

EXERCISE 27



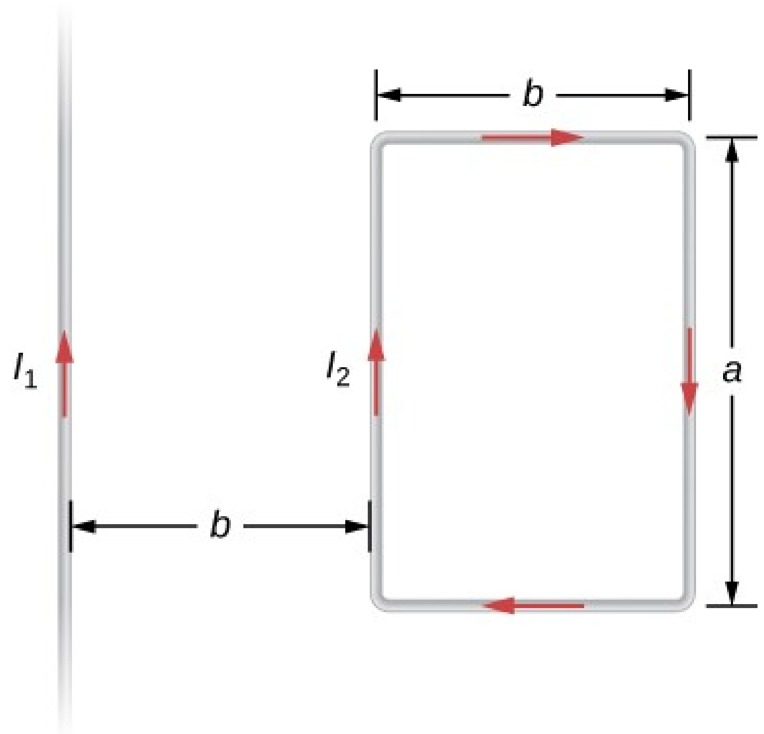
The accompanying figure shows two long, straight, horizontal wires that are parallel and a distance $2a$ apart. If both wires carry current I in the same direction, (a) what is the magnetic field at ? (b)?

EXERCISE 33



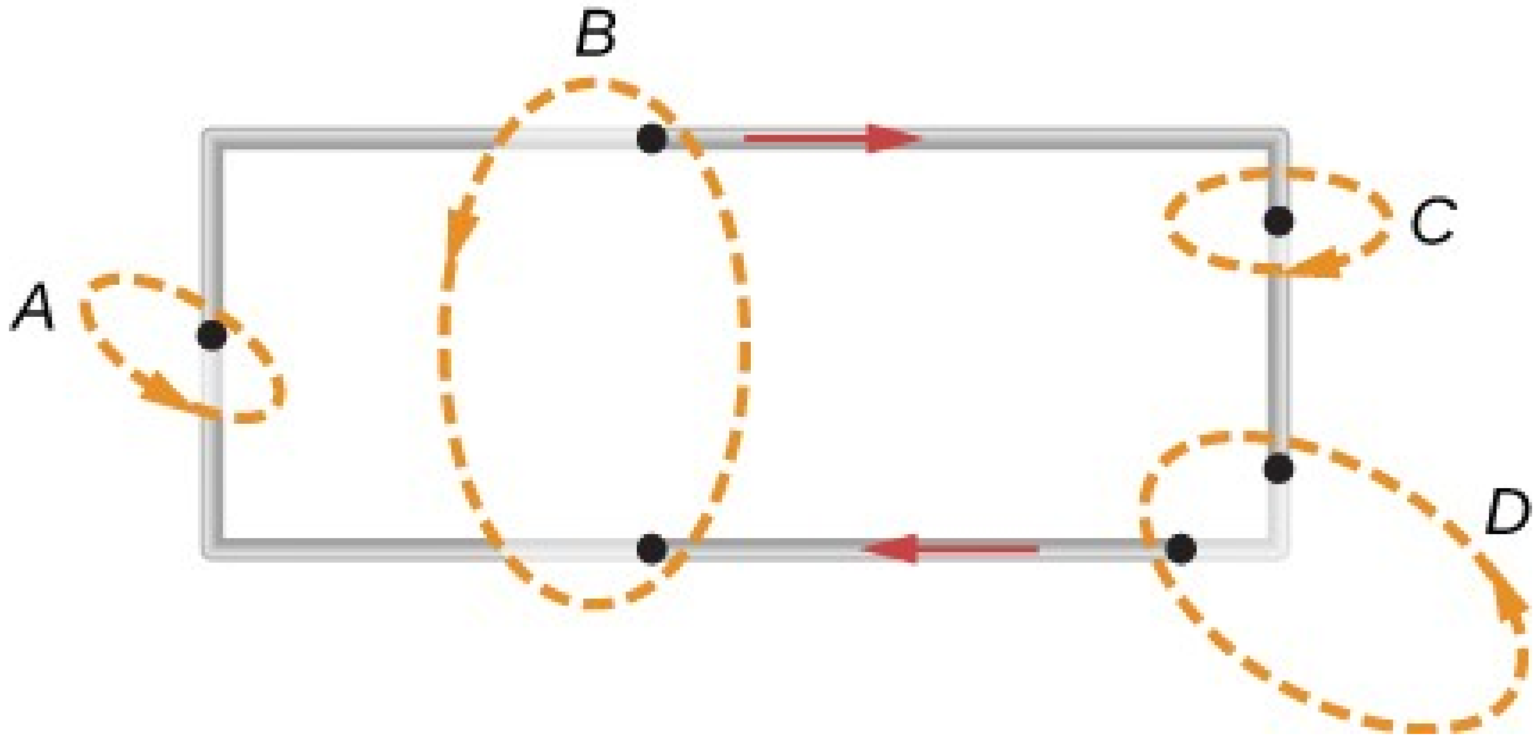
A circuit with current I has two long parallel wire sections that carry current in opposite directions. Find magnetic field at a point P near these wires that is a distance a from one wire and b from the other wire as shown in the figure.

EXERCISE 34



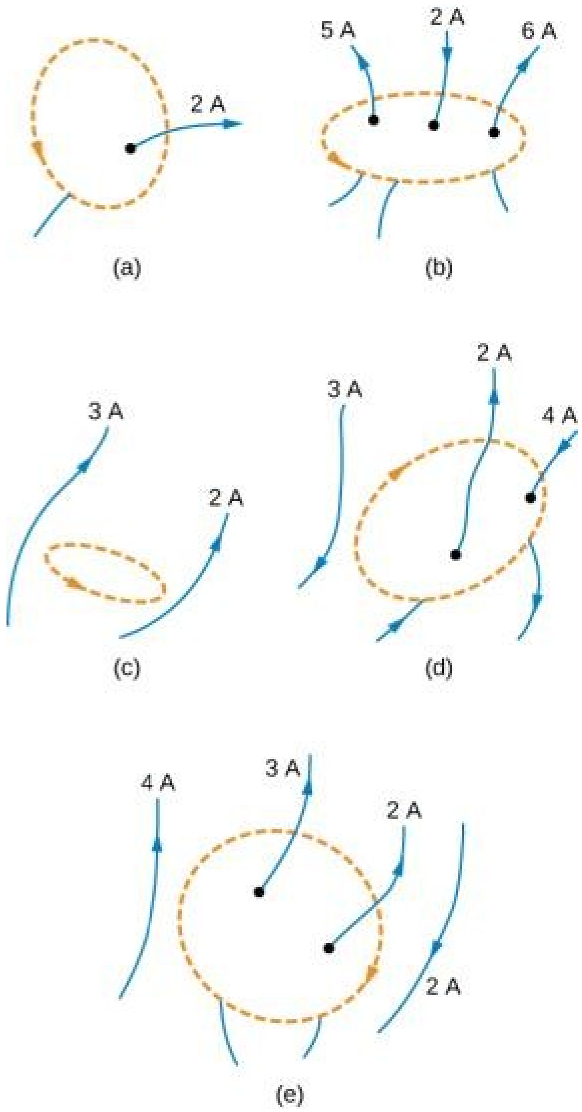
The infinite, straight wire shown in the accompanying figure carries a current I_1. The rectangular loop, whose long sides are parallel to the wire, carries a current I_2. What are the magnitude and direction of the force on the rectangular loop due to the magnetic field of the wire?

EXERCISE 41



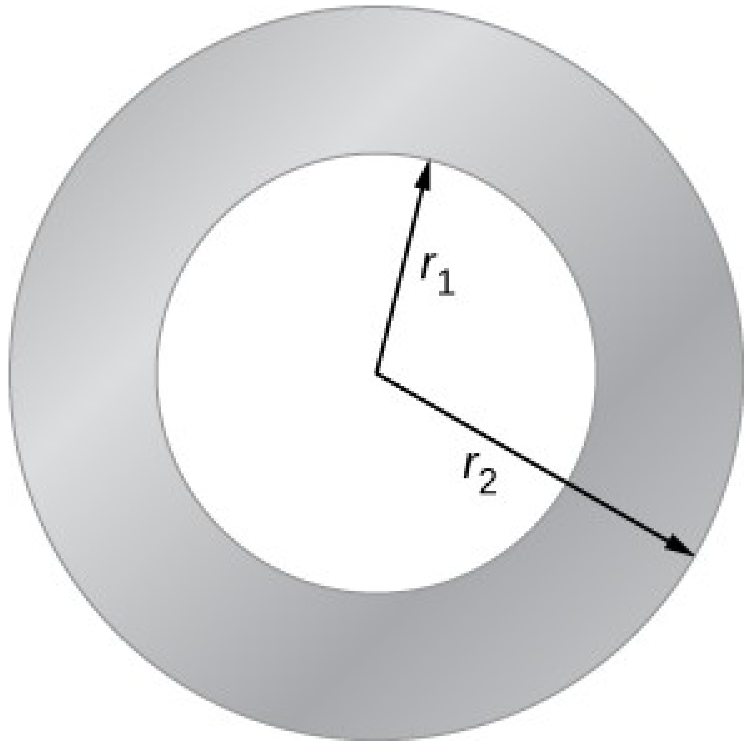
A current I flows around the rectangular loop shown in the accompanying figure. Evaluate $\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{l}}$ for the paths *A*, *B*, *C*, and *D*.

EXERCISE 42



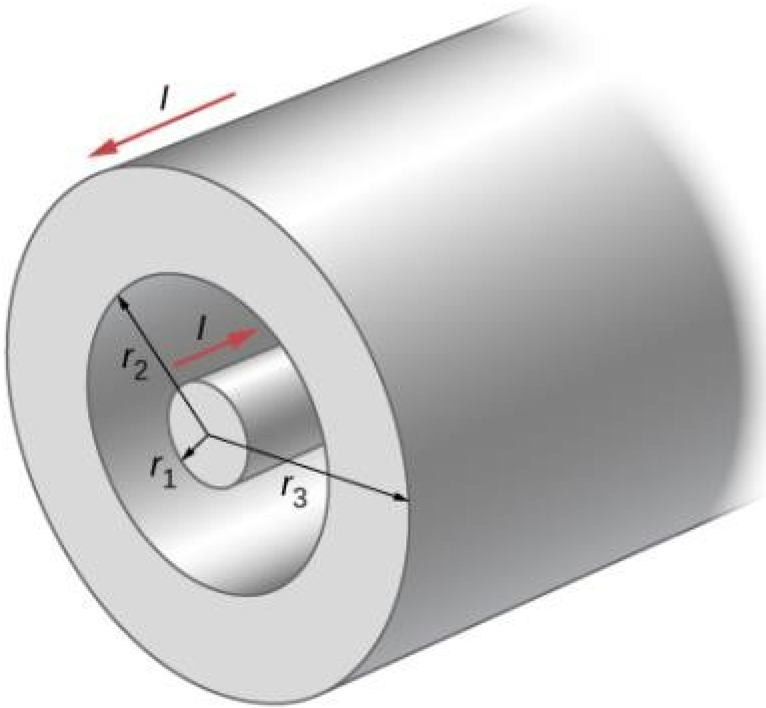
Evaluate $\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{l}}$ for each of the cases shown in the accompanying figure.

EXERCISE 46



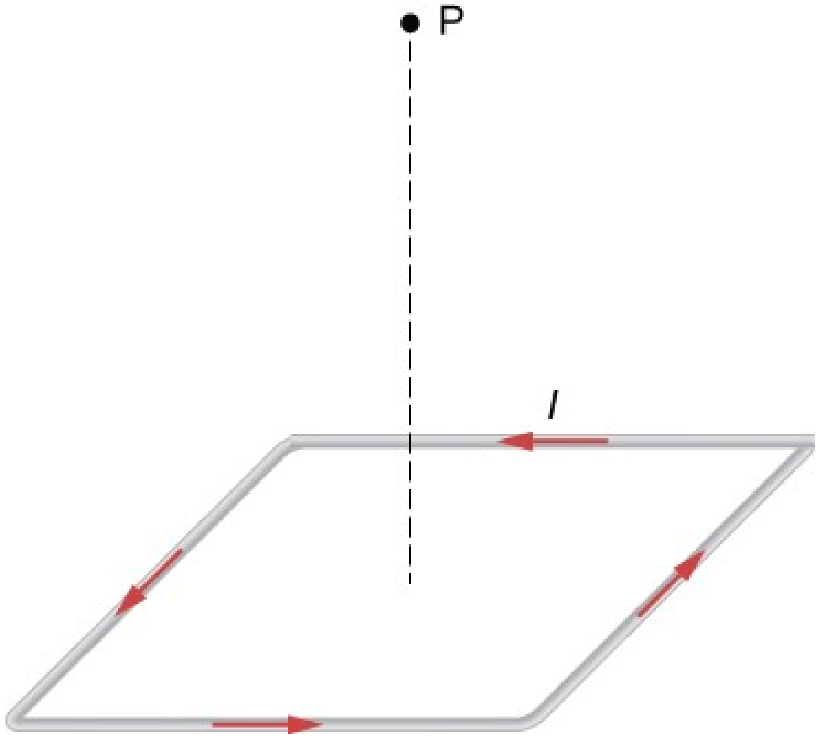
The accompanying figure shows a cross-section of a long, hollow, cylindrical conductor of inner radius $r_1 = 3.0\ \text{cm}$ and outer radius $r_2 = 5.0\ \text{cm}$. A 50-A current distributed uniformly over the cross-section flows into the page. Calculate the magnetic field at $r = 2.0\ \text{cm}$, $r = 4.0\ \text{cm}$, and $r = 6.0\ \text{cm}$.

EXERCISE 48



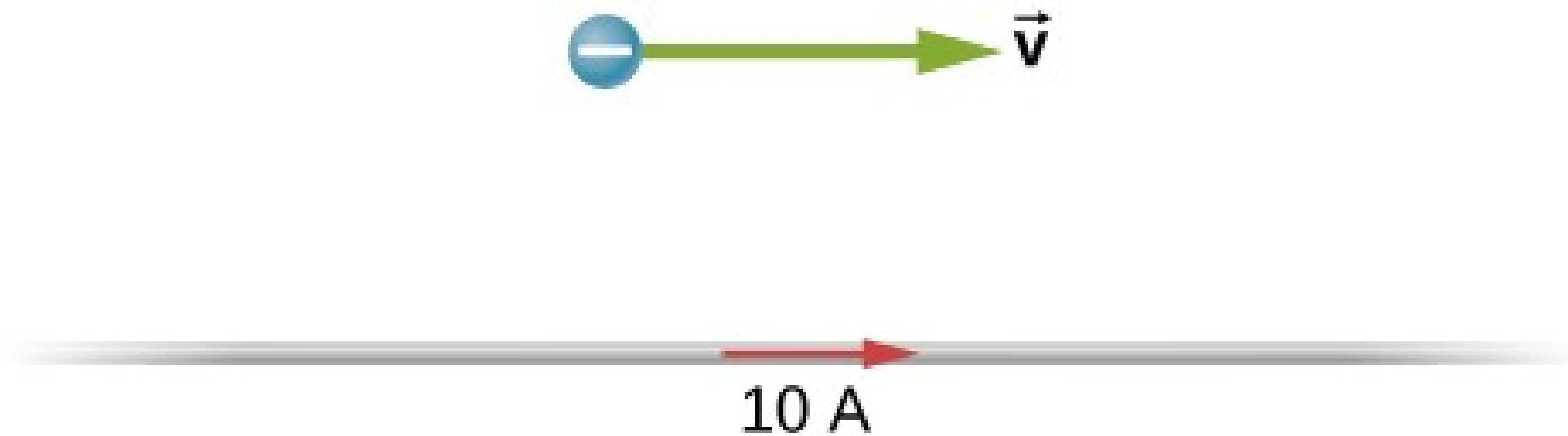
A portion of a long, cylindrical coaxial cable is shown in the accompanying figure. A current *I* flows down the center conductor, and this current is returned in the outer conductor. Determine the magnetic field in the regions (a) $r \leq r_1$, (b) $r_2 \geq r \geq r_1$, (c) $r_3 \geq r \geq r_2$, and (d) $r \geq r_3$. Assume that the current is distributed uniformly over the cross sections of the two parts of the cable.

EXERCISE 66



A current I flows around a wire bent into the shape of a square of side a. What is the magnetic field at the point P that is a distance z above the center of the square (see the accompanying figure)?

EXERCISE 67



The accompanying figure shows a long, straight wire carrying a current of 10 A. What is force on an electron at the instant it is 20 cm from the wire, traveling parallel to the wire of 2.0×10^5 m/s ? Describe qualitatively the subsequent motion of the electron.