Chapter 22 Magnetism

Outline

22-1 The Magnetic Field

22-2 The Magnetic Force on Moving Charges
22-3 The Motion of Charges Particles in Magnetic Field

22-4 The Magnetic Force Exert on a Current-Carrying Wire

22-5 Loops of Current and Magnetic Torque

22-6 Electric Current, Magnetic Fields, and Ampère’s Law

22-7 Electric Loops and Solenoid

22-5 Loops of Current and Magnetic Torque

Rectangular Current Loops

A rectangle loop has height h and width w, and carries a current I, as shown. The loop is placed in a uniform magnetic field $\vec{B}$. The magnetic force on each *vertical side* (h height) is

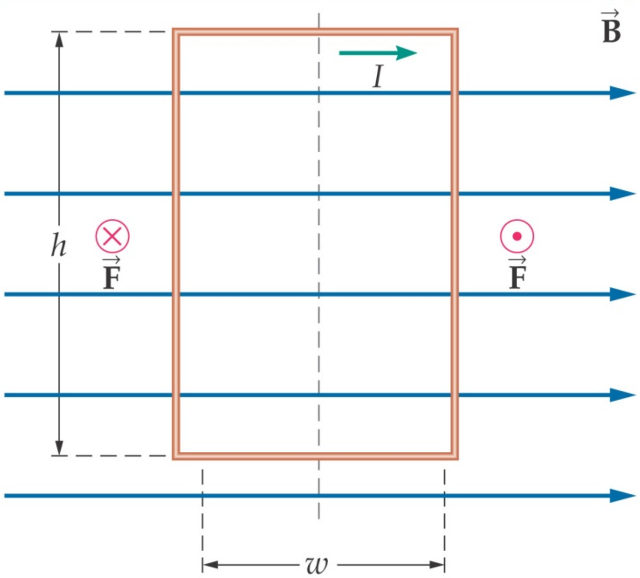
$$F = IhB$$

The loop is intend to rotate around its center. The torque τ is

$$\tau = (IhB)(\frac{w}{2}) + (IhB)(\frac{w}{2}) = IB(hw)$$

Since area A= hw, The torque τ is

$$\tau = IBA$$



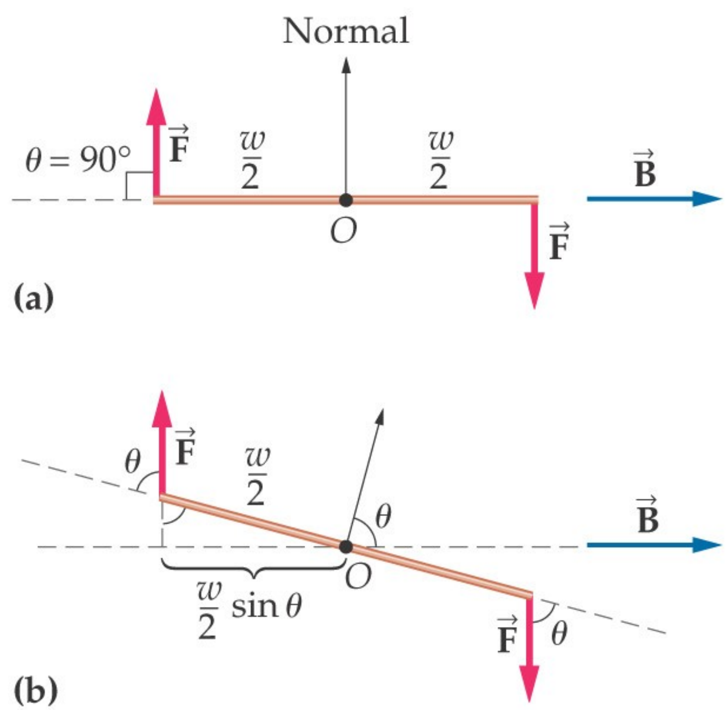
Torque applied on a rectangular Loop of Area A

$$\tau = IBA\sin\theta \qquad (22-5)$$

SI unit: N.m

Note:

the angle θ is the angle between the loop plane and the magnetic force on each side of the loop; This equation is suitable for any shape loop.



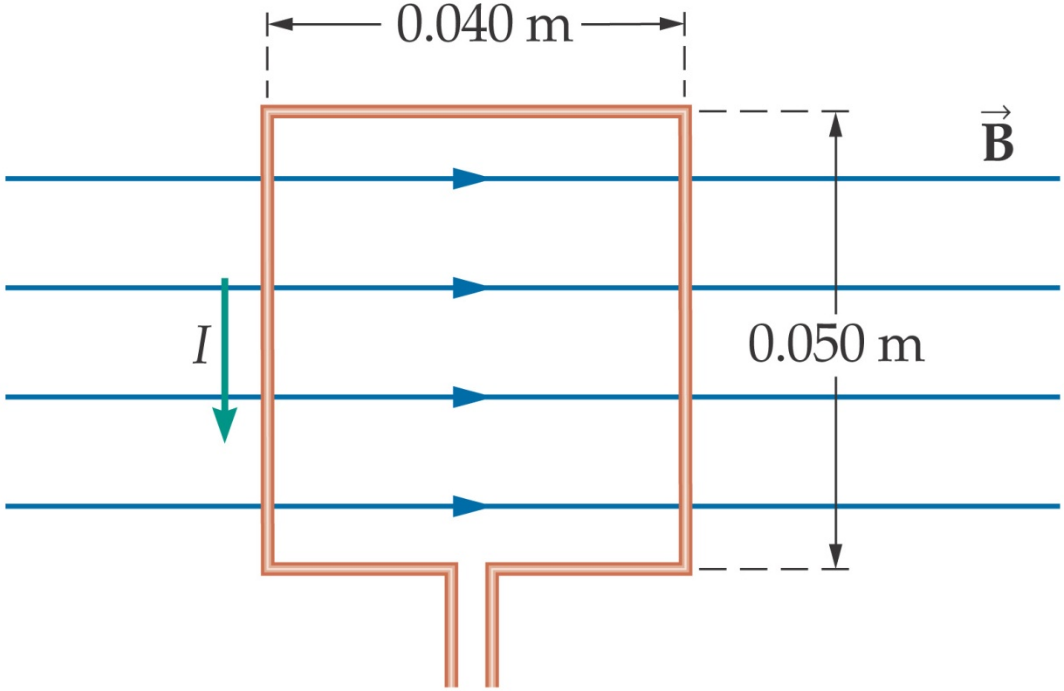
Torque applied on a rectangular Loop of Area A and N turns of loops

$$\tau = NIBA\sin\theta \qquad (22-6)$$

SI unit: N.m

Example 22-5 Torque on a Coil

A rectangular coil with 200 turns is 5.0 cm high and 4.0 cm wide. When the coil is placed in a magnetic field of 0.35 T, its maximum torque is 0.22 N.m. What is the current in the coil?



Example 22-5
Torque on a Coil

Solution:

1. For maximum torque, one has

$$\tau = NIBA$$

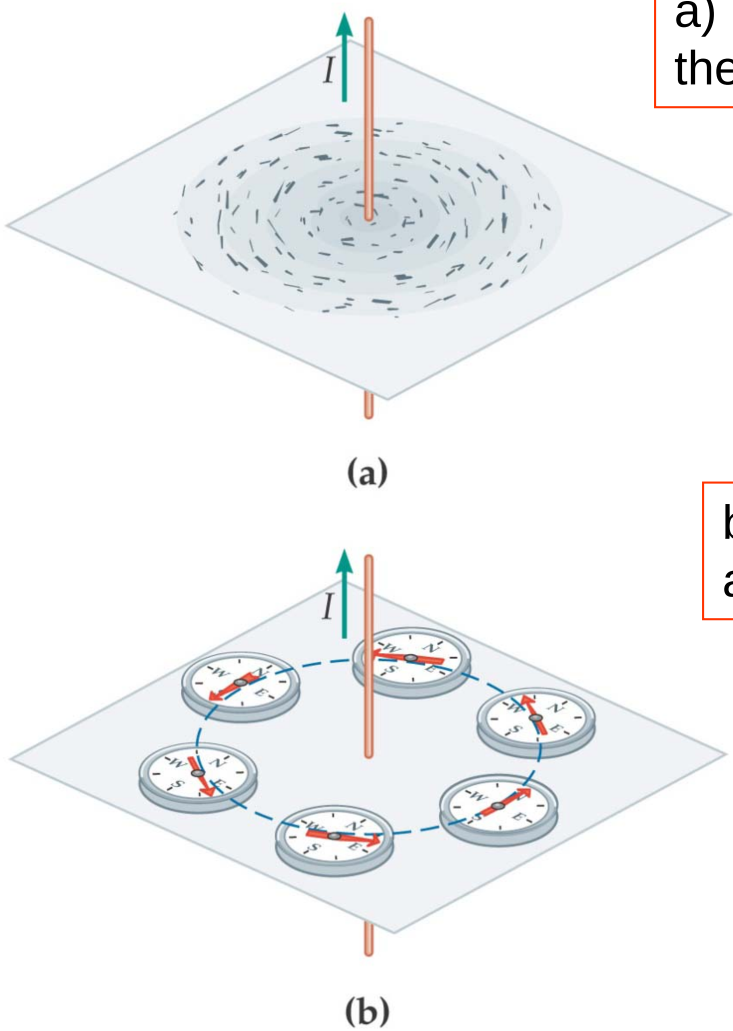
2. Solving for I,

$$I = \frac{\tau_{mas}}{NAB}$$

$$= \frac{0.22N.m}{(200)(0.050m)(0.040m)(0.35T)} = 1.6A$$

22-6 Electric Current, Magnetic Fields, and Ampère's Law

A Long, Straight Wire



a) Iron powder re-arranged when I go through the wire.

b) Compass point in same direction around a circle.

Figure 22-19
The Magnetic Field of a Current-Carrying Wire

Magnetic Field Right-Hand Rule

The direction of magnet field induced by a current-carrying wire can be found by: point the thumb of your right hand along the wire in the current direction I. Your fingers then will curl along the direction of the magnetic field.

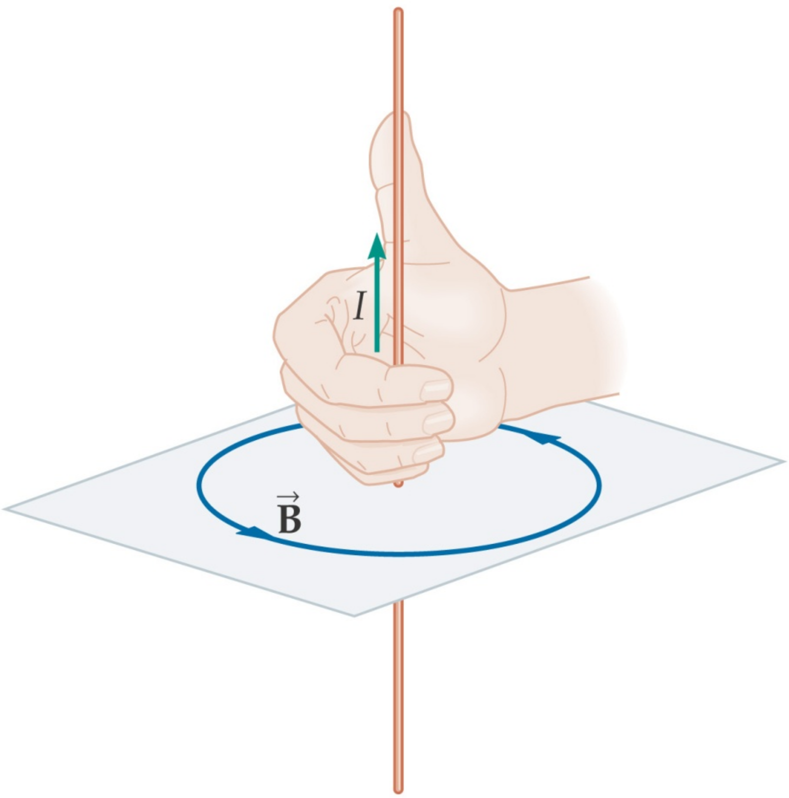
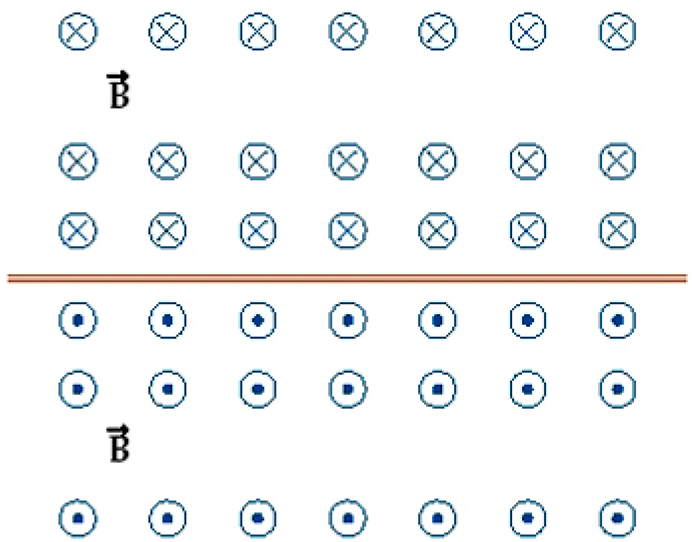


Figure 22-20
The Magnetic-Field Right-Hand Rule

The direction of the magnetic field can be determined by using Magnetic Field Right-Hand Rule

CONCEPTUAL CHECKPOINT 22–5

The magnetic field shown in the sketch is due to the horizontal, current-carrying wire. Does the current in the wire flow to the left or to the right?



CONCEPTUAL CHECKPOINT 22–5

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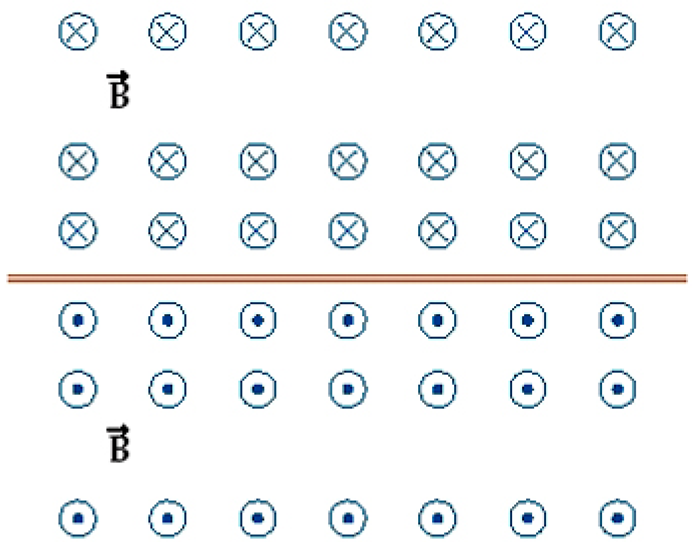


Reasoning and Discussion

If you point the thumb of your right hand along the wire to the left, your fingers curl into the page above the wire and out of the page below the wire, as shown in the figure. Thus, the current flows to the left.

Answer:

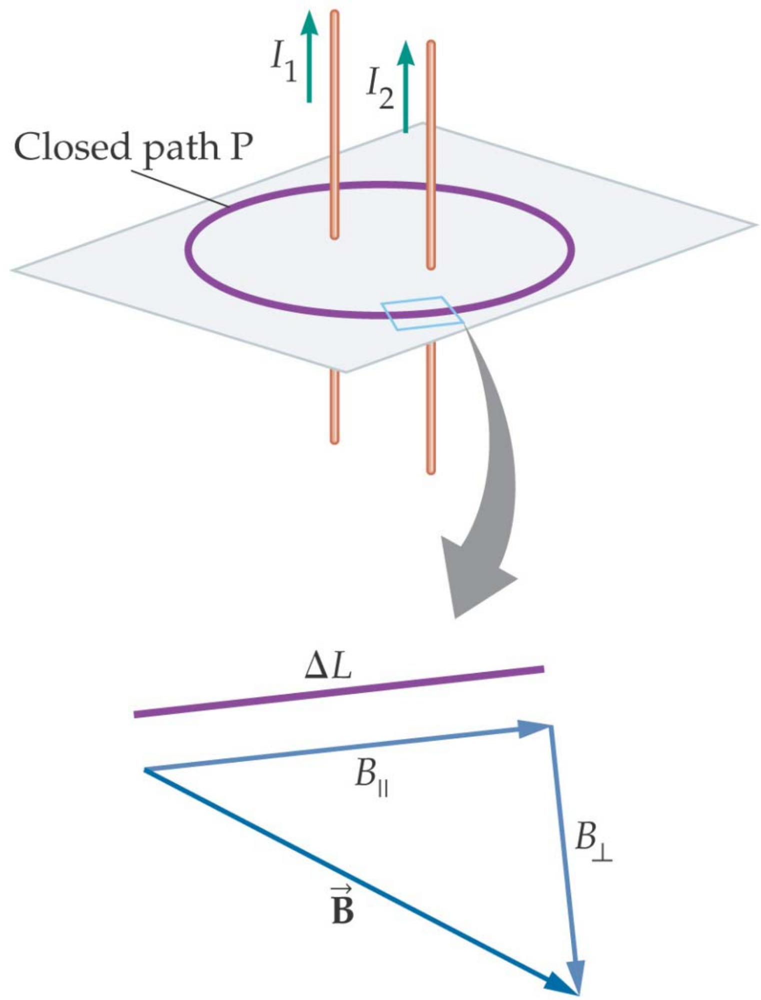
The current in the wire flows to the left.

Ampère’s Law

Ampère’s Law relates to the magnetic field along a closed path to the electric current. For a straight line segment ΔL, it can be expressed as (in the figure)

Ampère’s Law

$$\sum B_{||}\Delta L = \mu_0 I_{enclosed}$$



Where, $\mu_0 = 4\pi \times 10^{-7}$ T.m /A,

is a constant called Permeability of Free Space.

For a circular (see Figure), the circumference is 2πr.

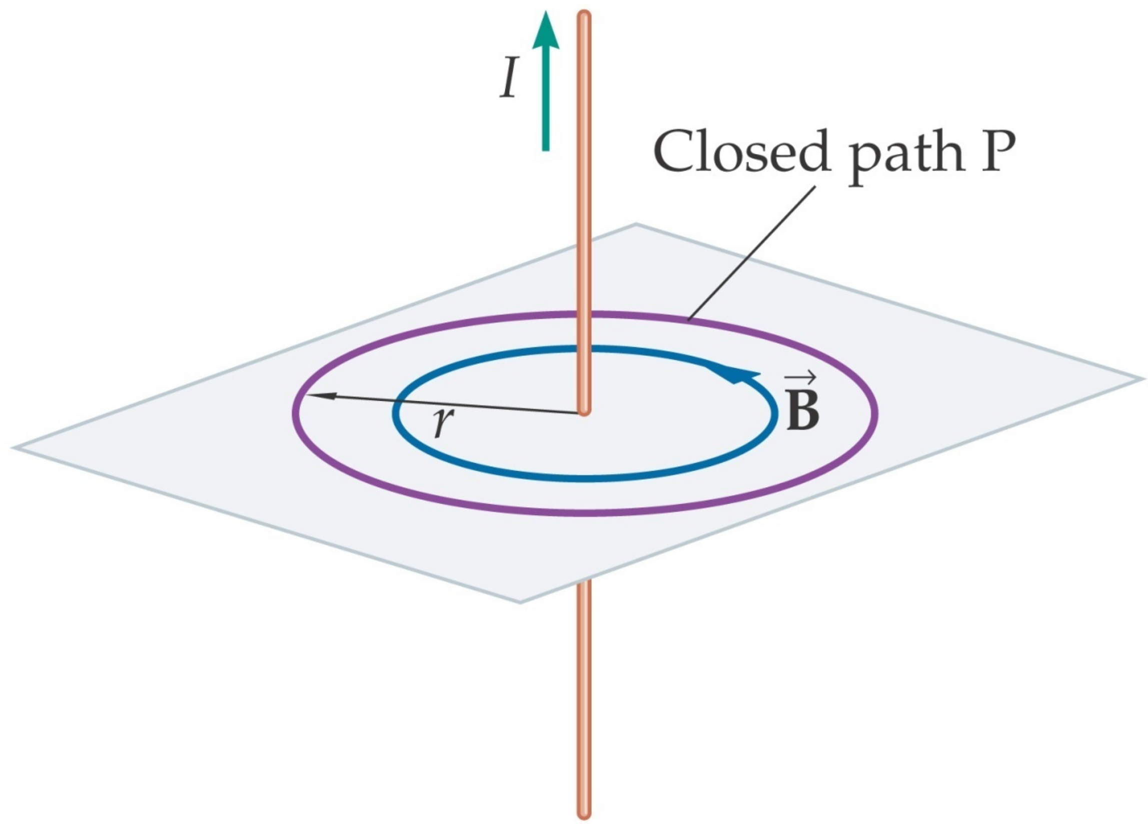
we have

$$\sum B_{\parallel}\Delta L = B\sum \Delta L = B(2\pi r)$$

Therefore, we have

$$B(2\pi r) = \mu_0 I$$

Figure 22-22
Applying Ampère's Law



Magnetic Field for a Long, Straight Wire

$$B = \frac{\mu_0 I}{2\pi r} \qquad (22-9)$$

SI unit: Tesla, T

Where, $\mu_0 = 4\pi \times 10^{-7}$ T.m /A,

is a constant called Permeability of Free Space.

Exercise 22-2

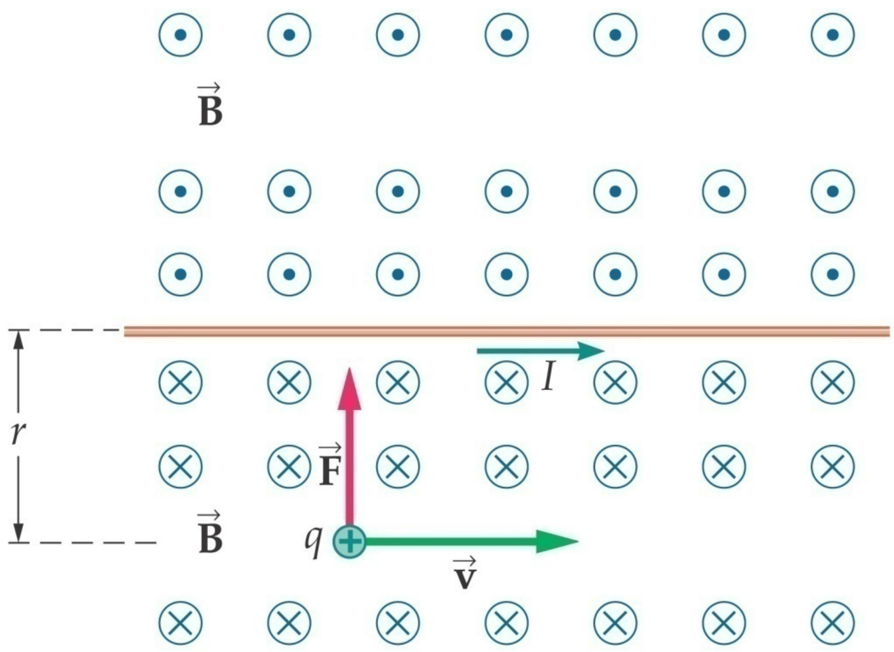
Find the magnitude of magnetic field 1 m away from a long straight wire carrying a current of 1 A.

Solution

$$B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7} T \cdot m / A)(1A)}{2\pi (1m)} = 2 \times 10^{-7} \quad T$$

Example 22-6 An Attractive Wire

A 52 uC charged particle parallel to a long wire with a speed of 720 m/s. The separation between the particle and the wire is 13 cm, and the magnitude of a force exerted on the particle is 1.4×10^{-7} N. Find (a) the magnitude of the magnetic field B at the location of the particle, and (b) the current I in the wire.



Picture the problem

Solution

Part (a) Since F=qvB

$$B = \frac{F}{qv} = \frac{1.4\times10^{-7}\,N}{(5.2\times10^{-5}\,C)(720\,m/s)}$$
$$= 3.7\times10^{-6} \quad T$$

Part (b) Since

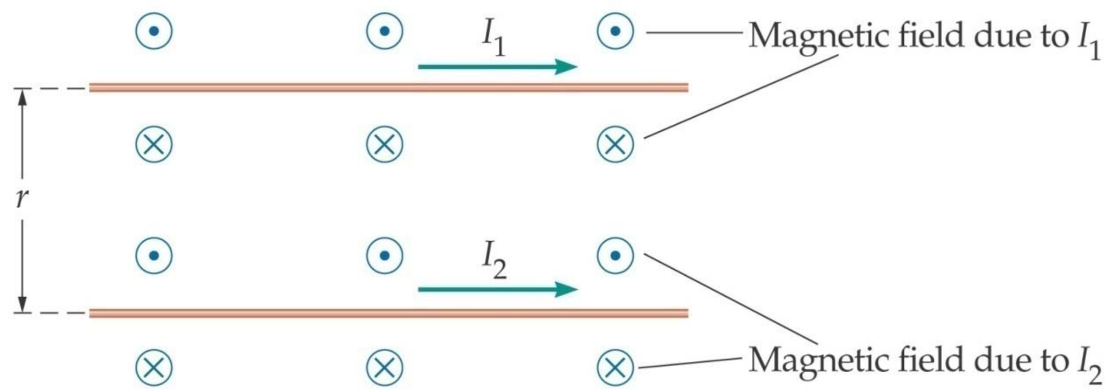
$$B = \frac{\mu_0 I}{2\pi r}$$

Solving for I, we have

$$I = \frac{2\pi r B}{\mu_0} = \frac{2\pi(0.13m)(3.7\times10^{-6}T)}{4\pi\times10^{-7}\,T\cdot m/A} = 2.4 \quad A$$

Active Example 22-2   Find the magnetic Field

Two wires separated by a distance of 22 cm carry currents in the same direction. The current in one wire is 1.5 A, and the current in the other is 4.5 A. Find the magnitude of the magnetic field halfway between the wires.



Active Example 22-2
Find the Magnetic Field

Solution:

1) Find the magnitude of the magnetic field of wire 1

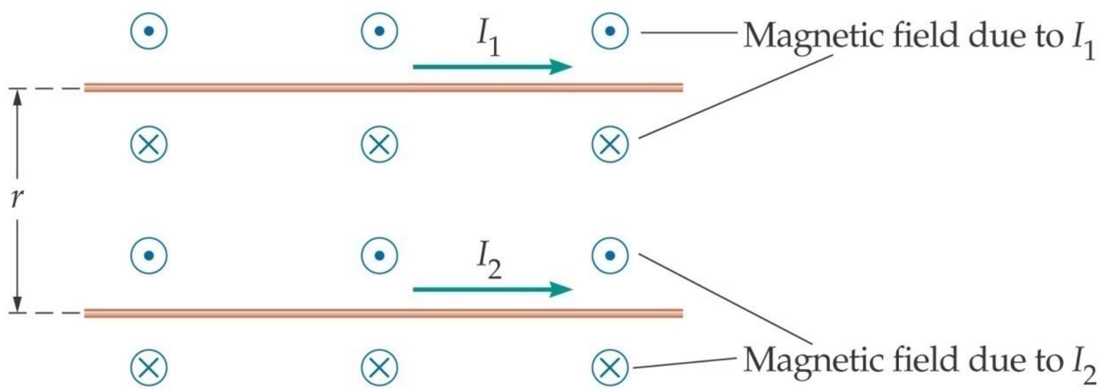
$B1 = 2.7 \times 10^{-6}$ T, *into page*

2) Find the magnitude of the magnetic field of wire 2

$B2 = 8.2 \times 10^{-6}$ T, *out of page*

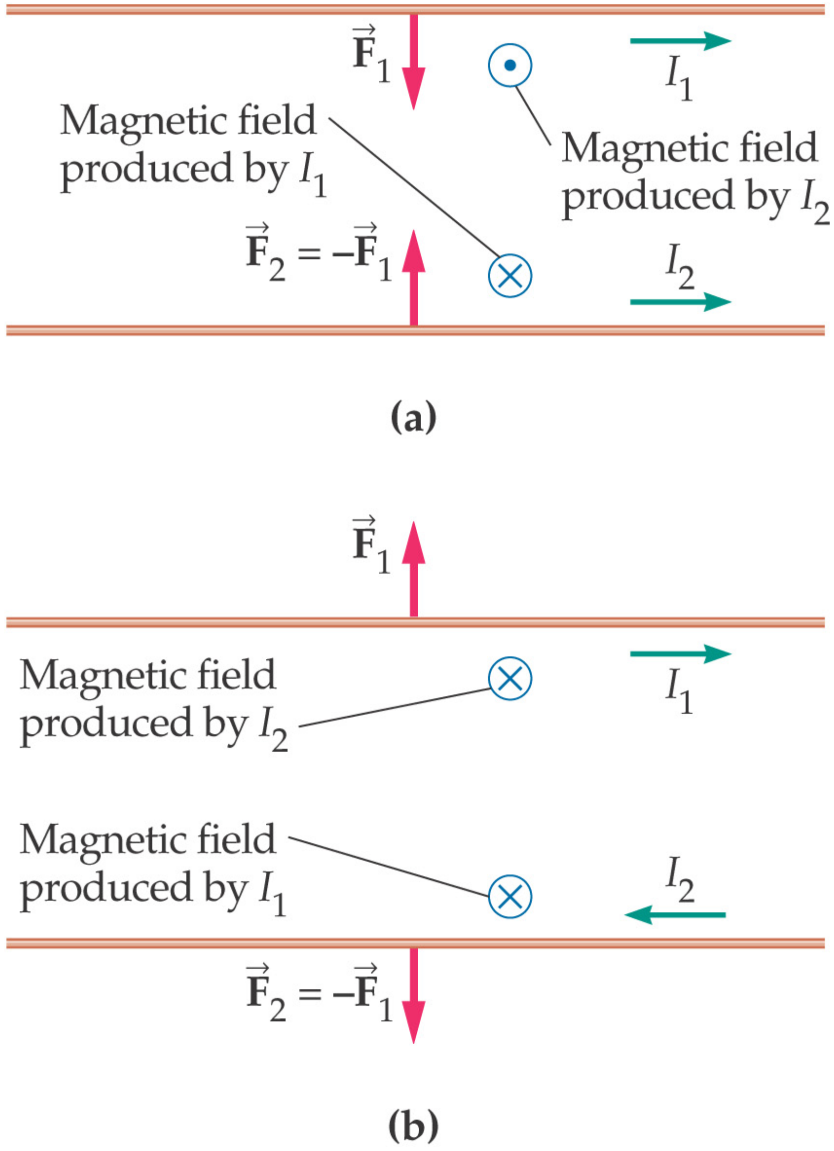
3) The net magnetic field

$B = B2 - B1 = 5.5 \times 10^{-6}$ T



Active Example 22-2
Find the Magnetic Field

Forces between Current-Carrying Wires



How large the force is?

Figure 22-24
The Direction of the Magnetic Force
Between Current-Carrying Wires

Summary

1. Torque Exert on a rectangular Loop of Area A and N turns

$$\tau = NIBA\sin\theta \qquad (22-6)$$

2. Magnetic Field for a Long, Straight Wire

$$B = \frac{\mu_0 I}{2\pi r} \qquad (22-9)$$