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Objectives

- For given situations, **predict** whether magnets will repel or attract each other.
- **Describe** the magnetic field around a permanent magnet.
- **Describe** the orientation of Earth's magnetic field.

Magnets

- ***Magnets*** *attract iron-containing objects.*
- Magnets have two distinct poles called the *north pole* and the *south pole*. *These names are derived from a magnet's behavior on Earth.*
- Like poles of magnets repel each other; unlike poles attract each other. *(Opposites attract!)*

End Of Slide

Magnetic Poles

End Of Slide

Magnetic Domains

- **Magnetic Domain**

  A region composed of a group of atoms whose magnetic fields are aligned in the same direction is called a **magnetic domain**.

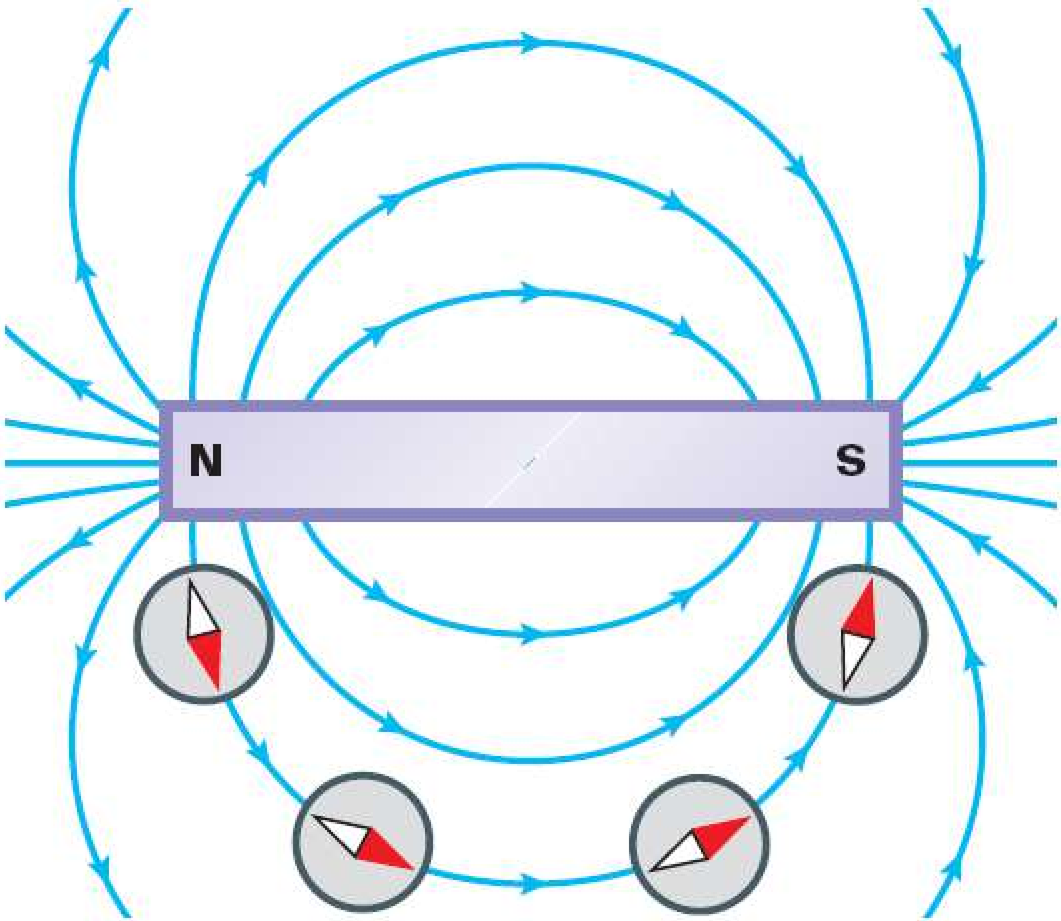
- Some materials can be made into permanent magnets.
  - Soft magnetic materials (*for example iron*) are easily magnetized but tend to lose their magnetism easily.
  - Hard magnetic materials (*for example nickel*) tend to retain their magnetism.

Magnetic Fields

- A **magnetic field** is a region in which a magnetic force can be detected.

- *Magnetic field lines can be drawn with the aid of a compass.*

Magnetic Field of a Bar Magnet

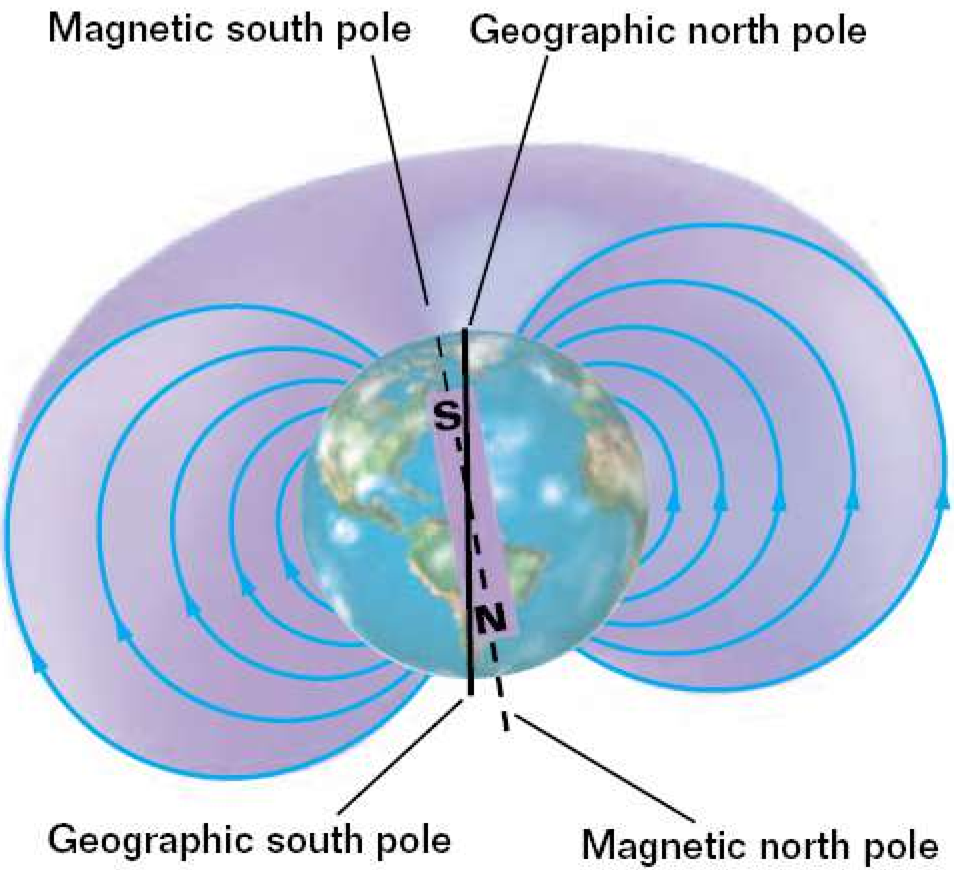


Representing the Direction of a Magnetic Field

Magnetic Fields, *continued*

- *Earth's magnetic field is similar to that of a bar magnet.*
- The *magnetic south pole* is near the Geographic North Pole. The *magnetic north pole* is near the Geographic South Pole.
- *Magnetic declination* is a measure of the difference between true north and north indicated by a compass.

Earth's Magnetic Field



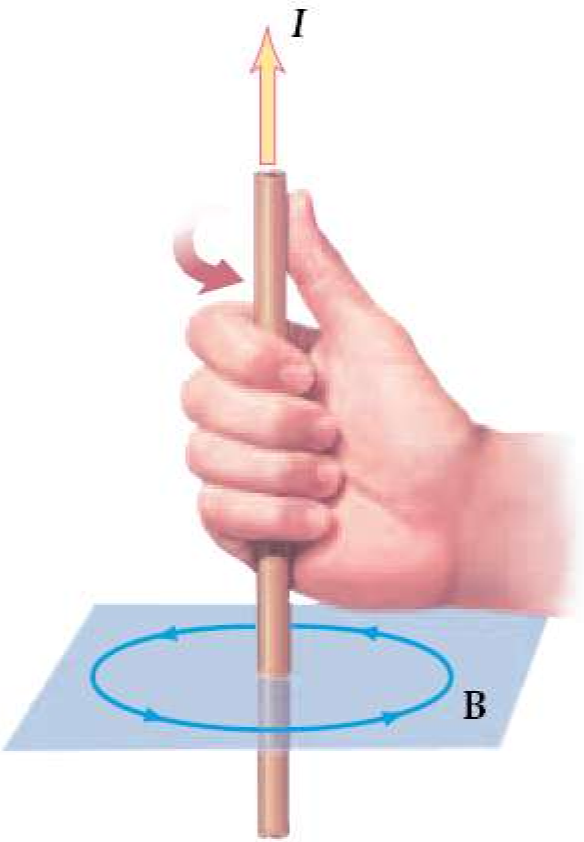
Objectives

- **Describe** the magnetic field produced by current in a straight conductor and in a solenoid.
- **Use** the right-hand rule to determine the direction of the magnetic field in a current-carrying wire.

Magnetic Field of a Current-Carrying Wire

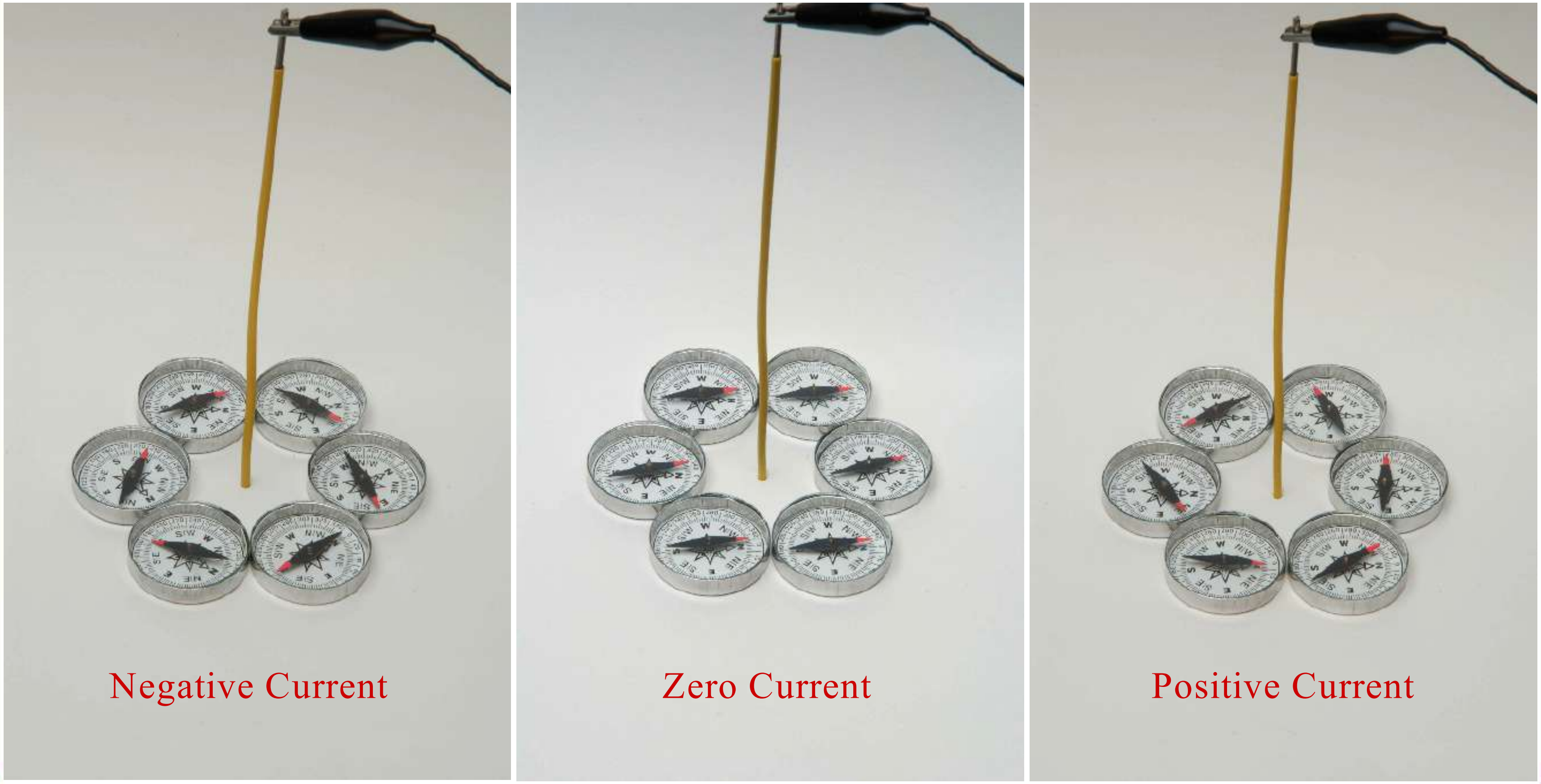
- A long, straight, current-carrying wire has a cylindrical magnetic field.
- *Compasses can be used to shown the direction of the magnetic field induced by the wire.*
- The right-hand rule can be used to determine the direction of the magnetic field in a current-carrying wire. (Thumb with current, fingers are magnetic field.)

The Right-Hand Rule



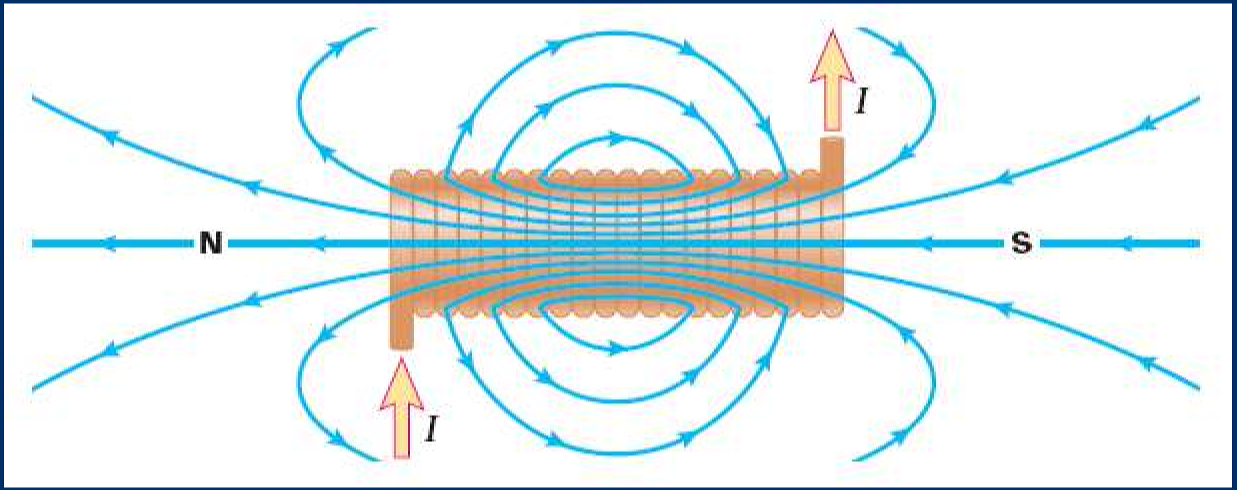
Magnetic Field of a Current-Carrying Wire

Magnetic Field of a Current-Carrying Wire



Magnetic Field of a Current Loop

- ***Solenoids*** *produce a strong magnetic field by combining several loops.*
- A **solenoid** is a long, helically wound coil of insulated wire.



Magnetic Field of a Current Loop

End Of Slide

Objectives

- Given the force on a charge in a magnetic field, **determine** the strength of the magnetic field.
- **Use** the right-hand rule to find the direction of the force on a charge moving through a magnetic field.
- **Determine** the magnitude and direction of the force on a wire carrying current in a magnetic field.

Charged Particles in a Magnetic Field

- A charge moving through a magnetic field experiences a force proportional to the charge, velocity, and the magnetic field.

$$B = \frac{F_{magnetic}}{qv}$$

$$\text{magnetic field} = \frac{\text{magnetic force on a charged particle}}{\text{(magnitude of charge)(speed of charge)}}$$

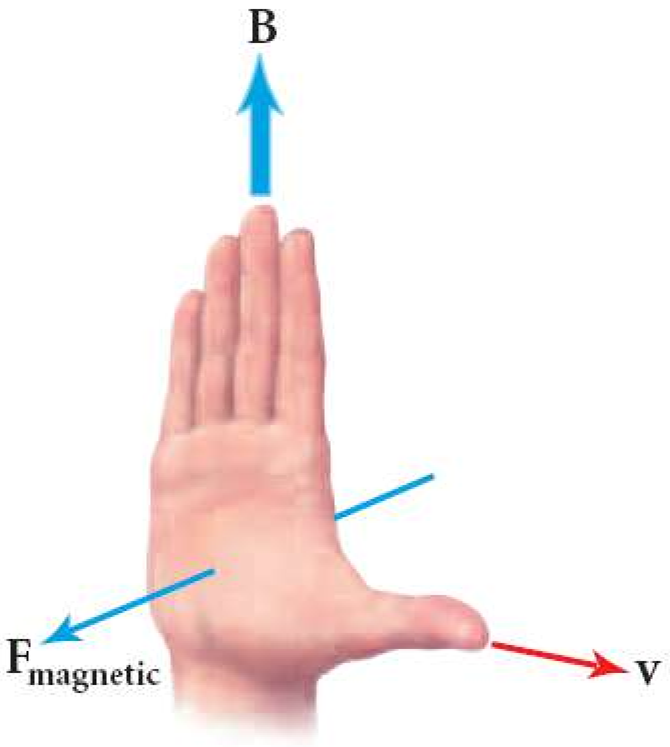
Force on a Charge Moving in a Magnetic Field

End Of Slide

Charged Particles in a Magnetic Field, *continued*

- The direction of the magnetic force on a moving charge is always perpendicular to both the magnetic field and the velocity of the charge.
- An alternative right-hand rule can be used to find the direction of the magnetic force.
- A charge moving through a magnetic field follows a circular path.

Alternative Right-Hand Rule: Force on a Moving Charge



Sample Problem

Particle in a Magnetic Field

A proton moving east experiences a force of 8.8×10^{-19} N upward due to the Earth's magnetic field.At this location, the field has a magnitude of 5.5×10^{-5} T to the north. Find the speed of the particle.

Sample Problem, *continued*

Particle in a Magnetic Field

Given:

$q = 1.60 \times 10^{-19}$ C

$B = 5.5 \times 10^{-5}$ T

$F_{magnetic} = 8.8 \times 10^{-19}$ N

Unknown:

$v = ?$

Sample Problem, *continued*

Particle in a Magnetic Field

Use the definition of magnetic field strength. Rearrange to solve for *v*.

$$B = \frac{F_{magnetic}}{qv}$$

$$v = \frac{F_{magnetic}}{qB} = \frac{8.8 \times 19^{19}\ \text{N}}{(1.60 \times 19^{19})(5.5 \times 10^{5})}$$

$$\boxed{v = 1.0 \times 10^{5}\ \text{m/s}}$$

Magnetic Force on a Current-Carrying Conductor

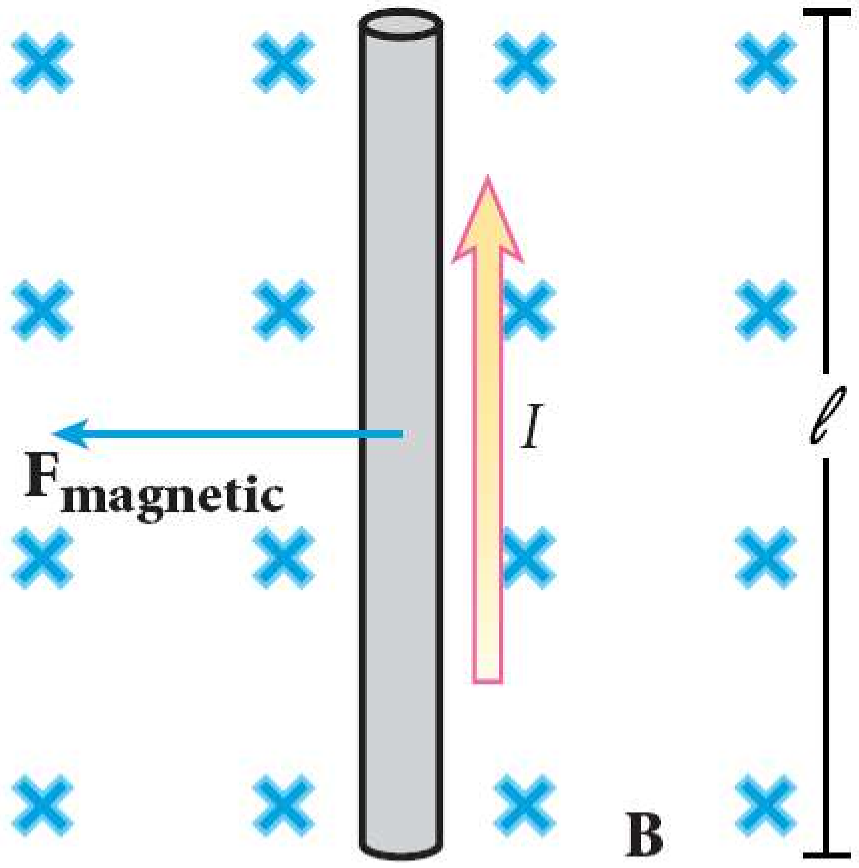
- A current-carrying wire in an external magnetic field undergoes a magnetic force.

- The force on a current-carrying conductor perpendicular to a magnetic field is given by:

$$F_{magnetic} = BI\ell$$

magnitude of magnetic force = (magnitude of magnetic field) × (current) × (length of conductor within B)

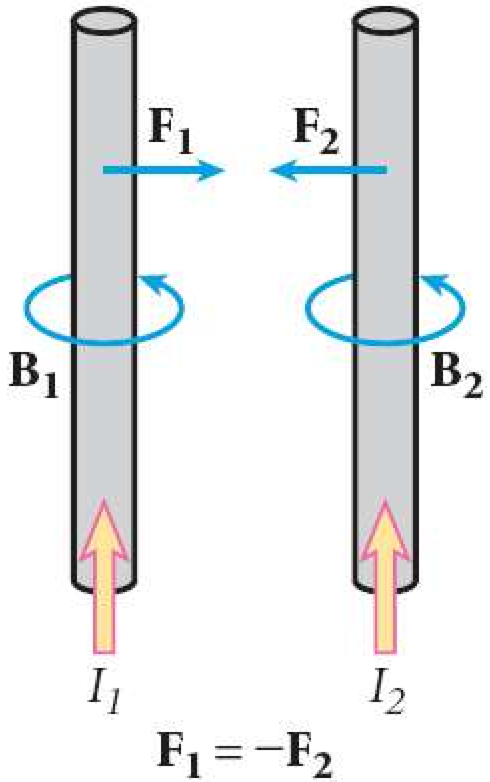
Force on a Current-Carrying Wire in a Magnetic Field

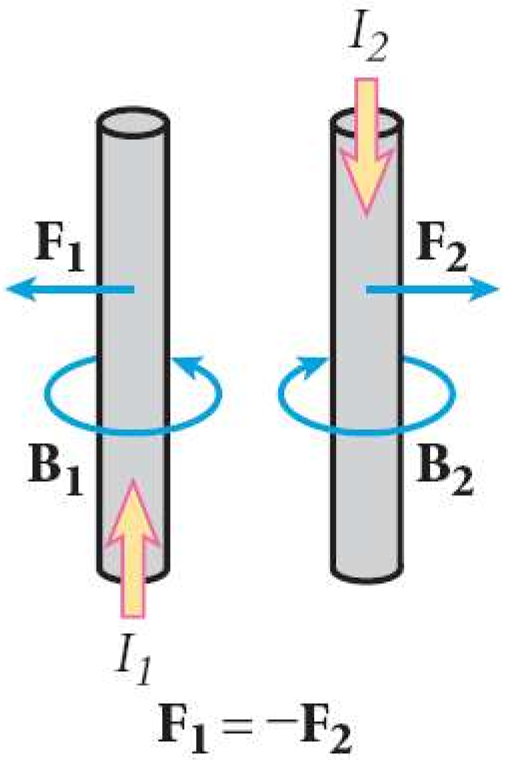


Magnetic Force on a Current-Carrying Conductor, *continued*

- Two parallel current-carrying wires exert a force on one another that are equal in magnitude and opposite in direction.
- If the currents are in the same direction, the two wires attract one another.
- If the currents are in opposite direction, the wires repel one another.
- Loudspeakers use magnetic force to produce sound.

Force Between Parallel Conducting Wires





Sample Problem

Force on a Current-Carrying Conductor

A wire 36 m long carries a current of 22 A from east to west. If the magnetic force on the wire due to Earth's magnetic field is downward (toward Earth) and has a magnitude of 4.0×10^{-2} *N, find the magnitude and direction of the magnetic field at this location.*

End of Slide

Sample Problem, *continued*

Force on a Current-Carrying Conductor

Given:

$\ell = 36$ m

$I = 22$ A

$F_{magnetic} = 4.0 \times 10^{-2}$ N

Unknown:

$B = ?$

End Of Slide

Sample Problem, *continued*

Force on a Current-Carrying Conductor

Use the equation for the force on a current-carrying conductor perpendicular to a magnetic field.

$$F_{magnetic} = BI\ell$$

Rearrange to solve for *B*.

$$B = \frac{F_{magnetic}}{I\ell} = \frac{4.0 \times 10^{-2}\ \text{N}}{(22\ \text{A})(36\ \text{m})}$$

$$\boxed{B = 5.0 \times 10^{-5}\ \text{T}}$$

End Of Slide

Sample Problem, *continued*

Force on a Current-Carrying Conductor

Using the right-hand rule to find the direction of **B,** face north with your thumb pointing to the west (in the direction of the current) and the palm of your hand down (in the direction of the force). Your fingers point north. Thus, Earth's magnetic field is from south to north.

Galvanometers

Multiple Choice

1. Which of the following statements best describes the domains in unmagnetized iron?

A. There are no domains.

B. There are domains, but the domains are smaller than in magnetized iron.

C. There are domains, but the domains are oriented randomly.

D. There are domains, but the domains are not magnetized.

Multiple Choice, *continued*

1. Which of the following statements best describes the domains in unmagnetized iron?

A. There are no domains.

B. There are domains, but the domains are smaller than in magnetized iron.

C. There are domains, but the domains are oriented randomly.

D. There are domains, but the domains are not magnetized.

Multiple Choice, *continued*

2. Which of the following statements is most correct?

F. The north pole of a freely rotating magnet points north because the magnetic pole near the geographic North Pole is like the north pole of a magnet.

G. The north pole of a freely rotating magnet points north because the magnetic pole near the geographic North Pole is like the south pole of a magnet.

H. The north pole of a freely rotating magnet points south because the magnetic pole near the geographic South Pole is like the north pole of a magnet.

J. The north pole of a freely rotating magnet points south because the magnetic pole near the geographic South Pole is like the south pole of a magnet.

Multiple Choice, *continued*

2. Which of the following statements is most correct?

F. The north pole of a freely rotating magnet points north because the magnetic pole near the geographic North Pole is like the north pole of a magnet.

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J. The north pole of a freely rotating magnet points south because the magnetic pole near the geographic South Pole is like the south pole of a magnet.

Multiple Choice, *continued*

3. If you are standing at Earth's magnetic north pole and holding a bar magnet that is free to rotate in three dimensions, which direction will the south pole of the magnet point?

A. straight up

B. straight down

C. parallel to the ground, toward the north

D. parallel to the ground, toward the south

Multiple Choice, *continued*

3. If you are standing at Earth's magnetic north pole and holding a bar magnet that is free to rotate in three dimensions, which direction will the south pole of the magnet point?

A. straight up

B. straight down

C. parallel to the ground, toward the north

D. parallel to the ground, toward the south

Multiple Choice, *continued*

4. How can you increase the strength of a magnetic field inside a solenoid?

F. increase the number of coils per unit length

G. increase the current

H. place an iron rod inside the solenoid

J. all of the above

Multiple Choice, *continued*

4. How can you increase the strength of a magnetic field inside a solenoid?

F. increase the number of coils per unit length

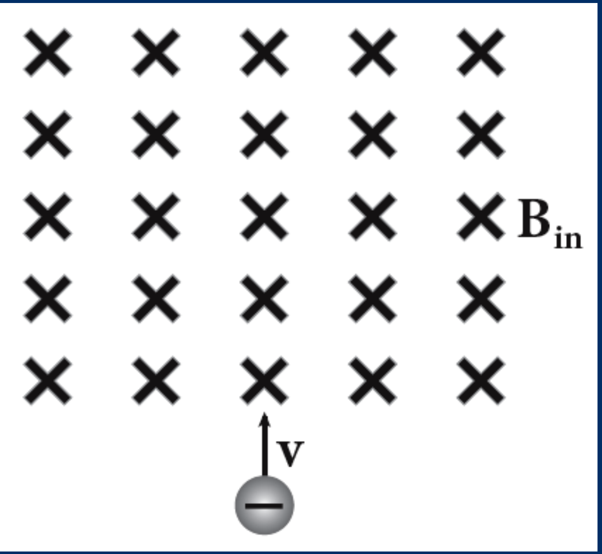
G. increase the current

H. place an iron rod inside the solenoid

J. all of the above

Multiple Choice, *continued*

5. How will the electron move once it passes into the magnetic field?



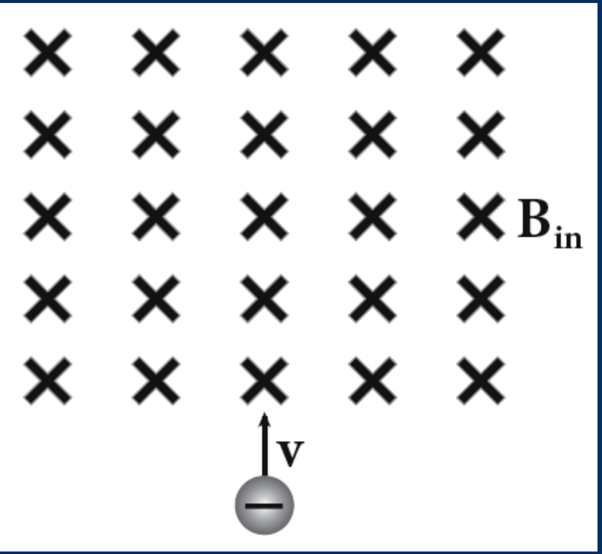
A. It will curve to the right and then continue moving in a straight line to the right.

B. It will curve to the left and then continue moving in a straight line to the left.

C. It will move in a clockwise circle.

D. It will move in a counterclockwise circle.

Multiple Choice, *continued*



5. How will the electron move once it passes into the magnetic field?

A. It will curve to the right and then continue moving in a straight line to the right.

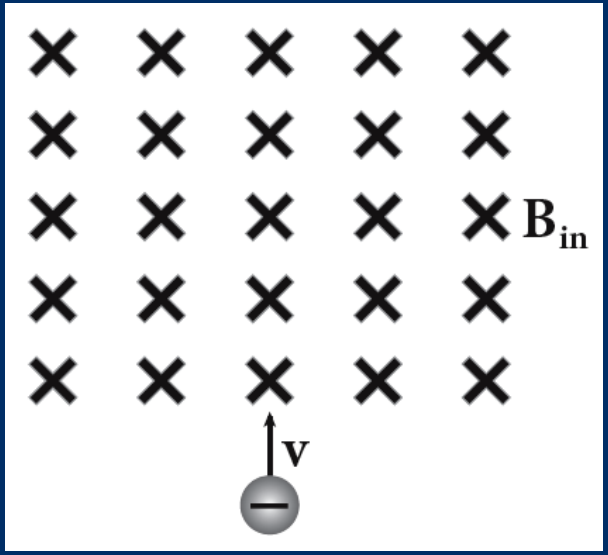
B. It will curve to the left and then continue moving in a straight line to the left.

C. It will move in a clockwise circle.

D. It will move in a counterclockwise circle.

Multiple Choice, *continued*

6. What will be the magnitude of the force on the electron once it passes into the magnetic field?



F. *qvB*

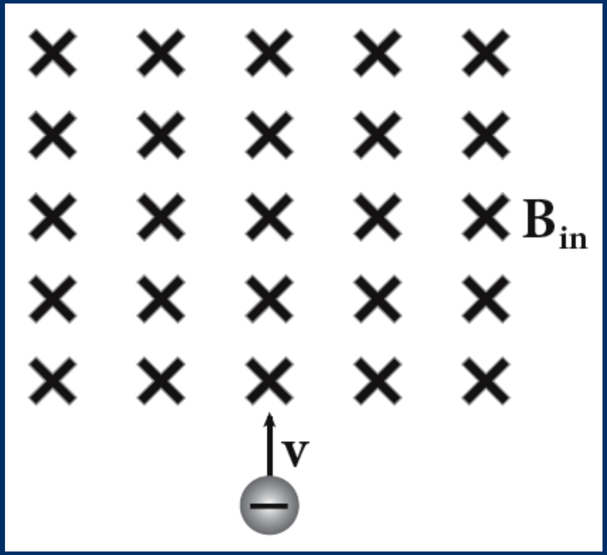
G. –*qvB*

H. *qB/v*

J. $BI\ell$

Multiple Choice, *continued*

6. What will be the magnitude of the force on the electron once it passes into the magnetic field?



F. qvB

G. $-qvB$

H. qB/v

J. $BI\ell$

Multiple Choice, *continued*

7. An alpha particle ($q = 3.2 \times 10^{-19}$ C) moves at a speed of 2.5×10^{6} m/s perpendicular to a magnetic field of strength 2.0×10^{-4} T. What is the magnitude of the magnetic force on the particle?

A. 1.6×10^{-16} N

B. -1.6×10^{-16} N

C. 4.0×10^{-9} N

D. zero

Multiple Choice, *continued*

7. An alpha particle ($q = 3.2 \times 10^{-19}$ C) moves at a speed of 2.5×10^6 m/s perpendicular to a magnetic field of strength 2.0×10^{-4} T. What is the magnitude of the magnetic force on the particle?

A. 1.6×10^{-16} N

B. -1.6×10^{-16} N

C. 4.0×10^{-9} N

D. zero

Multiple Choice, *continued*

Use the passage below to answer questions 8–9.

A wire 25 cm long carries a 12 A current from east to west. Earth's magnetic field at the wire's location has a magnitude of 4.8×10^{-5} T and is directed from south to north.

8. What is the magnitude of the magnetic force on the wire?

F. 2.3×10^{-5} N

G. 1.4×10^{-4} N

H. 2.3×10^{-3} N

J. 1.4×10^{-2} N

Multiple Choice, *continued*

Use the passage below to answer questions 8–9.

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Multiple Choice, *continued*

Use the passage below to answer questions 8–9.

A wire 25 cm long carries a 12 A current from east to west. Earth's magnetic field at the wire's location has a magnitude of 4.8×10^{-5} T and is directed from south to north.

9. What is the direction of the magnetic force on the wire?

A. north

B. south

C. up, away from Earth

D. down, toward Earth

Multiple Choice, *continued*

Use the passage below to answer questions 8–9.

A wire 25 cm long carries a 12 A current from east to west. Earth's magnetic field at the wire's location has a magnitude of 4.8×10^{-5} T and is directed from south to north.

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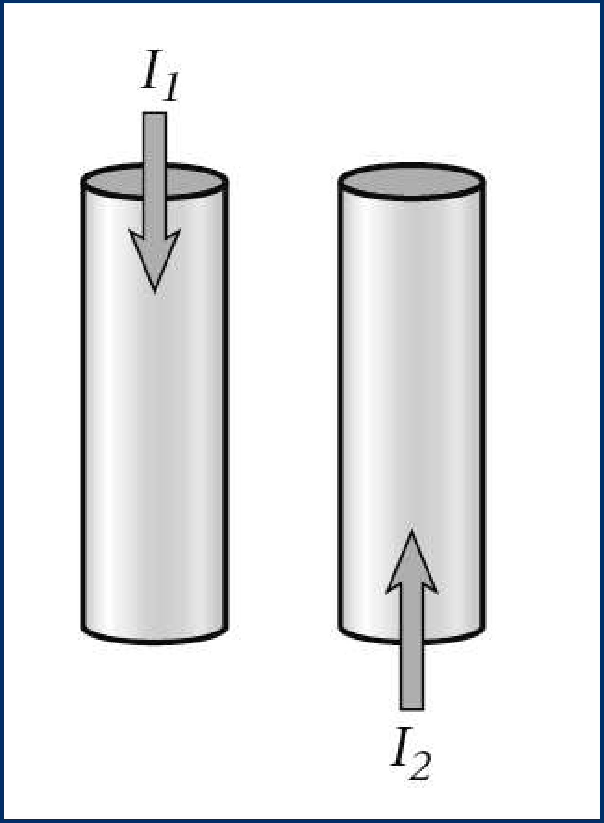
Multiple Choice, *continued*



- *Wire 1 carries current I_1 and creates magnetic field B_1.*
- *Wire 2 carries current I_2 and creates magnetic field B_2.*

10. What is the direction of the magnetic field B_1 at the location of wire 2?

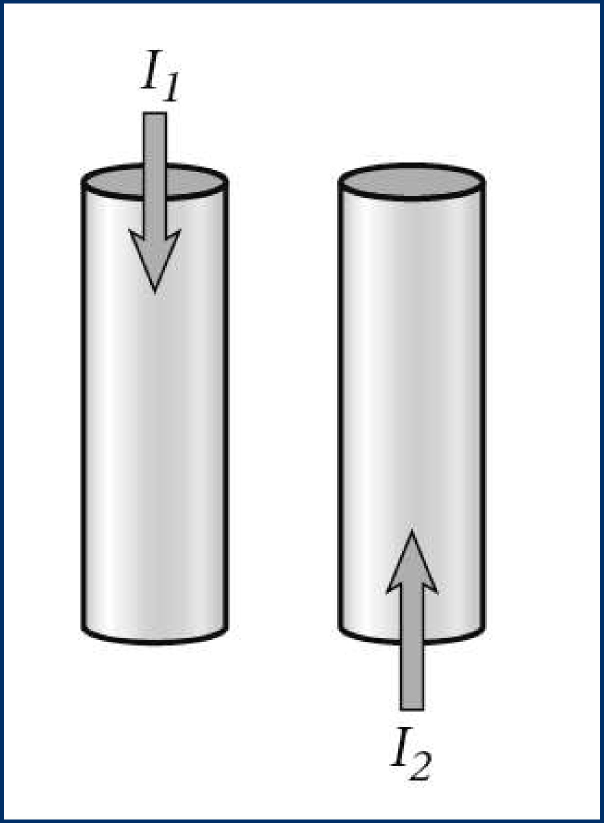
F. to the left

G. to the right

H. into the page

J. out of the page

Multiple Choice, *continued*



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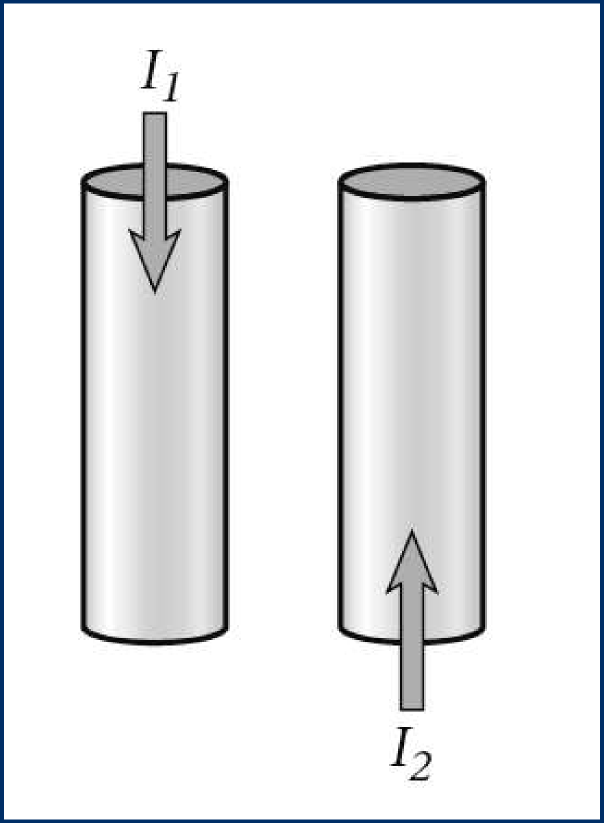
F. to the left

G. to the right

H. into the page

J. out of the page

Multiple Choice, *continued*



- *Wire 1 carries current I_1 and creates magnetic field B_1.*
- *Wire 2 carries current I_2 and creates magnetic field B_2.*

11. What is the direction of the force on wire 2 as a result of B_1?

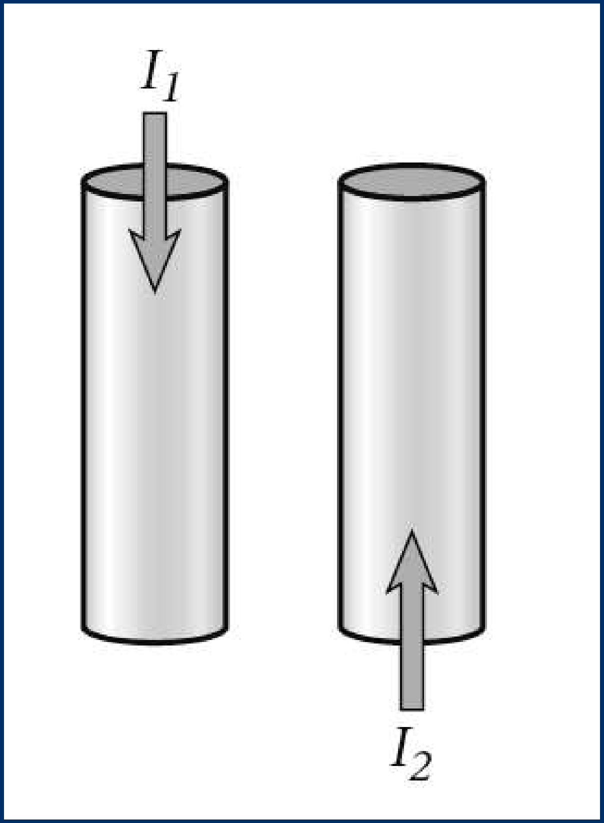
A. to the left

B. to the right

C. into the page

D. out of the page

Multiple Choice, *continued*



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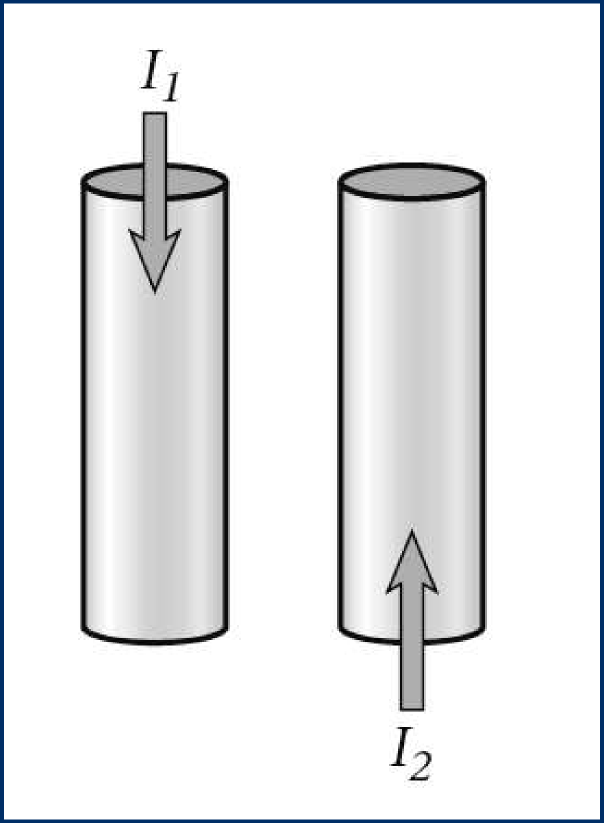
A. to the left

B. to the right

C. into the page

D. out of the page

Multiple Choice, *continued*



- *Wire 1 carries current I_1 and creates magnetic field B_1.*
- *Wire 2 carries current I_2 and creates magnetic field B_2.*

12. What is the magnitude of the magnetic force on wire 2?

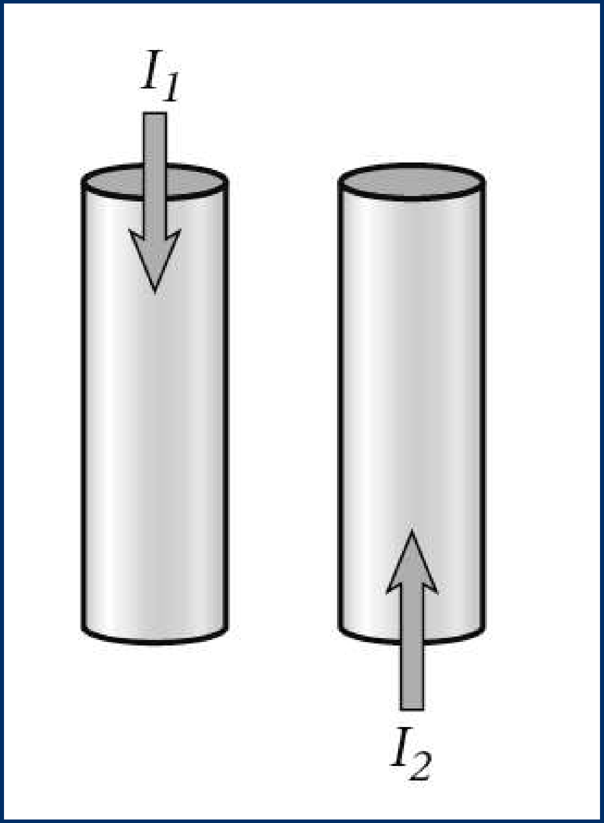
F. $B_1 I_1 \ell_1$

G. $B_1 I_1 \ell_2$

H. $B_1 I_2 \ell_2$

J. $B_2 I_2 \ell_2$

Multiple Choice, *continued*



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H. $B_1 I_2 \ell_2$

J. $B_2 I_2 \ell_2$

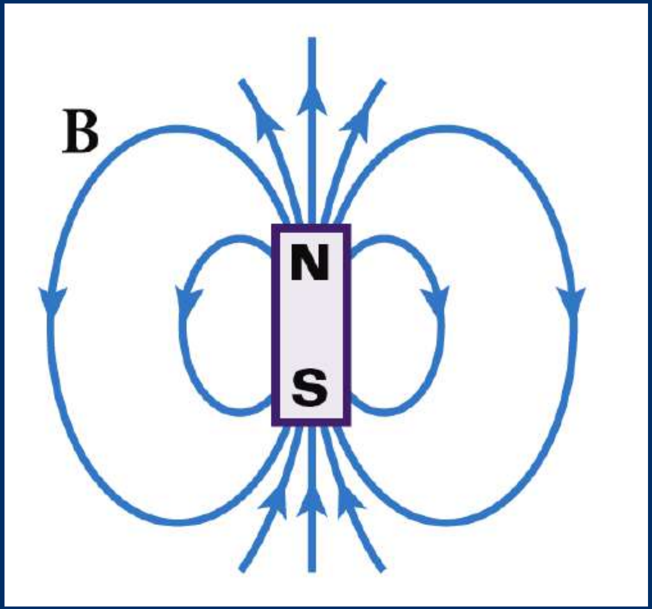
Short Response

13. Sketch the magnetic field lines around a bar magnet.

Short Response, *continued*

13. Sketch the magnetic field lines around a bar magnet.

Answer:



Short Response, *continued*

14. Describe how to use the right-hand rule to determine the direction of a magnetic field around a current-carrying wire.

Short Response, *continued*

14. Describe how to use the right-hand rule to determine the direction of a magnetic field around a current-carrying wire.

Answer: Imagine wrapping the fingers of your right hand around the wire and pointing your thumb in the direction of the current. The magnetic field lines form concentric circles that are centered on the wire and curve in the same direction as your fingers.

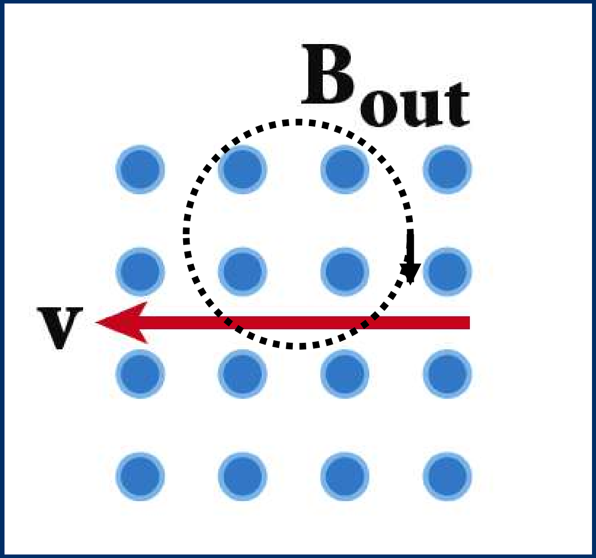
Short Response, *continued*

15. Draw a diagram showing the path of a positively charged particle moving in the plane of a piece of paper if a uniform magnetic field is coming out of the page.

Short Response, *continued*

15. Draw a diagram showing the path of a positively charged particle moving in the plane of a piece of paper if a uniform magnetic field is coming out of the page.

Answer:



Magnetic Field of a Current Loop