

# 33 The Magnetic Field

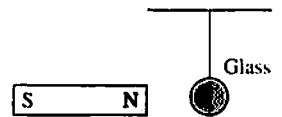
## 33.1 Magnetism

1. A lightweight glass sphere hangs by a thread. The north pole of a bar magnet is brought near the sphere.

a. Suppose the sphere is electrically neutral. How does it respond?

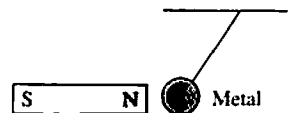
- i. It is strongly attracted to the magnet.
- ii. It is weakly attracted to the magnet.
- iii. It does not respond.
- iv. It is weakly repelled by the magnet.
- v. It is strongly repelled by the magnet.

Explain your choice.



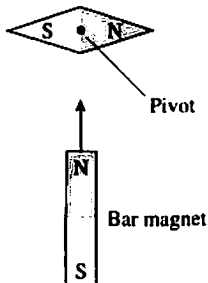
b. How does the sphere respond if it is positively charged? Explain.

2. A metal sphere hangs by a thread. When the north pole of a bar magnet is brought near, the sphere is strongly attracted to the magnet. Then the magnet is reversed and its south pole is brought near the sphere. How does the sphere respond? Explain.

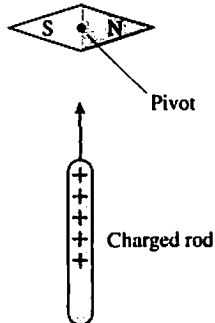


3. The compass needle below is free to rotate in the plane of the page. Either a bar magnet or a charged rod is brought toward the *center* of the compass. Does the compass rotate? If so, in which direction? If not, why not?

a.

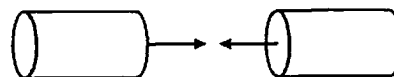


b.



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4. You have two electrically neutral metal cylinders that exert strong attractive forces on each other. You have no other metal objects. Can you determine if *both* of the cylinders are magnets, or if one is a magnet and the other just a piece of iron? If so, how? If not, why not?



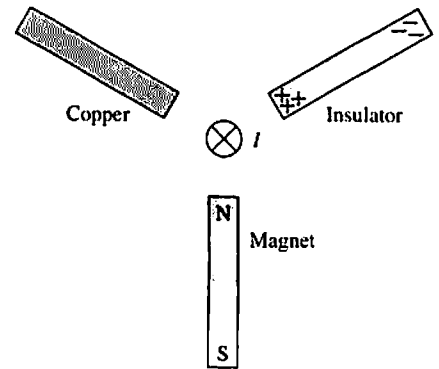
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5. Can you think of any kind of object that is repelled by *both* ends of a bar magnet? If so, what? If not, what prevents this from happening?

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### 33.2 The Discovery of the Magnetic Field

6. A neutral copper rod, a polarized insulator, and a bar magnet are arranged around a current-carrying wire as shown. For each, will it stay where it is? Move toward or away from the wire? Rotate clockwise or counterclockwise? Explain.



a. Neutral copper rod

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b. Polarized insulator

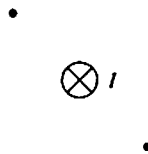
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c. Bar magnet

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7. For each of the current-carrying wires shown, draw a compass needle in its equilibrium position at the positions of the dots. Label the poles of the compass needle.

a.



b.



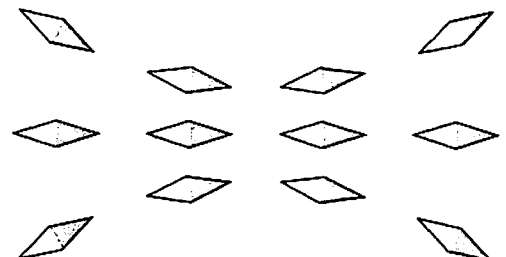
8. The figure shows a wire directed into the page and a nearby compass needle. Is the wire's current going into the page or coming out of the page? Explain.

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Wire ○

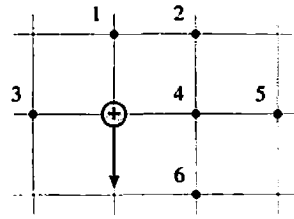


9. A compass is placed at 12 different positions and its orientation is recorded. Use this information to draw the magnetic field lines in this region of space. Draw the field lines on the figure.



### 33.3 The Source of the Magnetic Field: Moving Charges

10. A positively charged particle moves toward the bottom of the page.
- At each of the six number points, show the direction of the magnetic field or, if appropriate, write  $\vec{B} = \vec{0}$ .
  - Rank in order, from strongest to weakest, the magnetic field strengths  $B_1$  to  $B_6$  at these points.



Order:

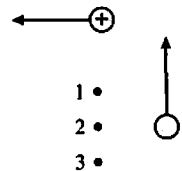
Explanation:

11. The negative charge is moving out of the page, coming toward you. Draw the magnetic field lines in the plane of the page.



12. Two charges are moving as shown. At this instant of time, the net magnetic field at point 2 is  $\vec{B}_2 = \vec{0}$ .

a. Is the unlabeled moving charge positive or negative? Explain.



b. What is the magnetic field direction at point 1? Explain.

c. What is the magnetic field direction at point 3?

### 33.4 The Magnetic Field of a Current

### 33.5 Magnetic Dipoles

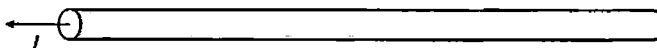
13. Each figure shows a current-carrying wire. Draw the magnetic field diagram:

a.



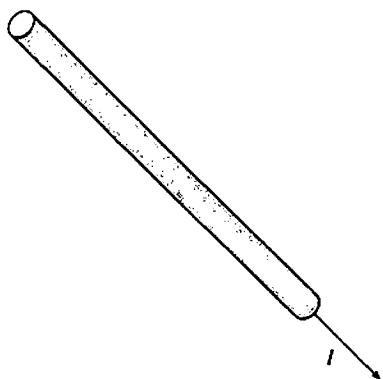
The wire is perpendicular to the page. Draw magnetic field *lines*, then show the magnetic field *vectors* at a few points around the wire.

b.

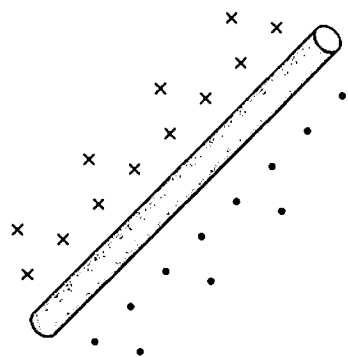


The wire is in the plane of the page. Show the magnetic field above and below the wire.

14. This current-carrying wire is in the plane of the page. Draw the magnetic field on both sides of the wire.



15. Use an arrow to show the current direction in this wire.



16. Each figure below shows two long straight wires carrying equal currents into and out of the page. At each of the dots, use a **black** pen or pencil to show and label the magnetic fields  $\vec{B}_1$  and  $\vec{B}_2$  of each wire. Then use a **red** pen or pencil to show the net magnetic field.

a.

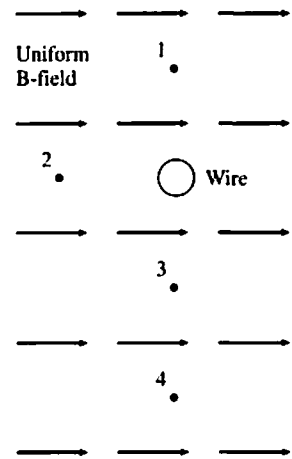


b.



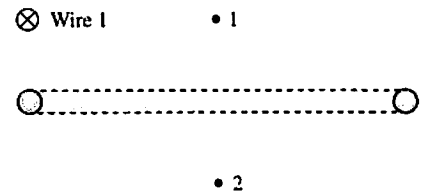
17. A long straight wire, perpendicular to the page, passes through a uniform magnetic field. The *net* magnetic field at point 3 is zero.

- On the figure, show the direction of the current in the wire.
- Points 1 and 2 are the same distance from the wire as point 3, and point 4 is twice as distant. Construct vector diagrams at points 1, 2, and 4 to determine the net magnetic field at each point.



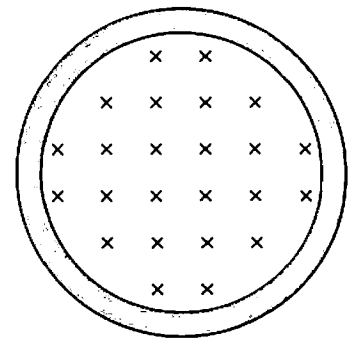
18. A long straight wire passes above one edge of a current loop. Both are perpendicular to the page.  $\vec{B}_1 = \vec{0}$  at point 1.

- On the figure, show the direction of the current in the loop.
- Use a vector diagram to determine the net magnetic field at point 2.

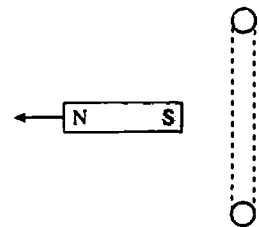


19. The figure shows the magnetic field seen when facing a current loop in the plane of the page.

- On the figure, show the direction of the current in the loop.
- Is the north pole of this loop at the upper surface of the page or the lower surface of the page? Explain.

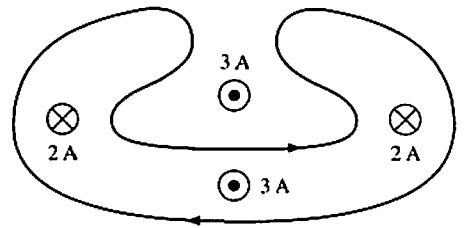


20. The current loop exerts a repulsive force on the bar magnet. On the figure, show the direction of the current in the loop. Explain.

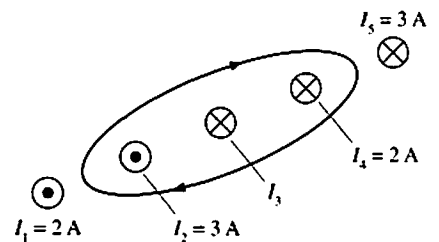


### 33.6 Ampère's Law and Solenoids

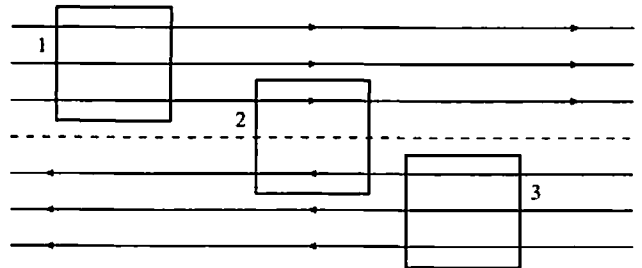
21. What is the total current through the area bounded by the closed curve?



22. The total current through the area bounded by the closed curve is 2 A. What are the size and direction of  $I_3$ ?



23. The magnetic field above the dotted line is  $\vec{B} = (2 \text{ T, right})$ . Below the dotted line the field is  $\vec{B} = (2 \text{ T, left})$ . Each closed loop is  $1 \text{ m} \times 1 \text{ m}$ . Let's evaluate the line integral of  $\vec{B}$  around each of these closed loops by breaking the integration into four steps. We'll go around the loop in a *clockwise* direction. Pay careful attention to signs.



Loop 1

Loop 2

Loop 3

$\int \vec{B} \cdot d\vec{s}$  along left edge      \_\_\_\_\_

$\int \vec{B} \cdot d\vec{s}$  along top      \_\_\_\_\_

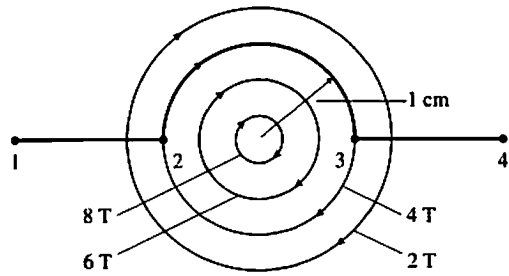
$\int \vec{B} \cdot d\vec{s}$  along right edge      \_\_\_\_\_

$\int \vec{B} \cdot d\vec{s}$  along bottom      \_\_\_\_\_

The line integral *around* the loop is simply the sum of these four separate integrals:

$\oint \vec{B} \cdot d\vec{s}$  around the loop      \_\_\_\_\_

24. The strength of a circular magnetic field decreases with increasing radius as shown.



a. What is  $\int_1^2 \vec{B} \cdot d\vec{s}$ ? \_\_\_\_\_  
 Explain or show your work.

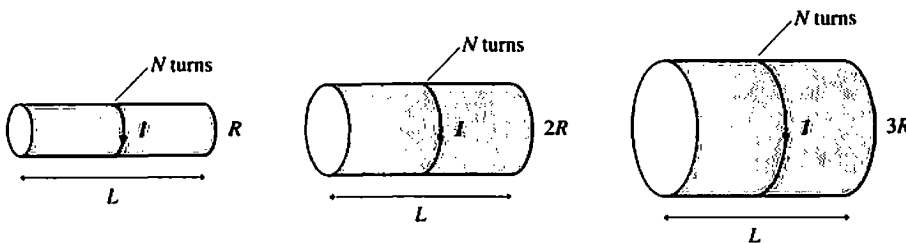
b. What is  $\int_2^3 \vec{B} \cdot d\vec{s}$ ? \_\_\_\_\_ Explain or show your work.

c. What is  $\int_3^4 \vec{B} \cdot d\vec{s}$ ? \_\_\_\_\_ Explain or show your work.

d. Combining your answers to parts a to c, what is  $\int_1^4 \vec{B} \cdot d\vec{s}$ ? \_\_\_\_\_

25. A solenoid with one layer of turns produces the magnetic field strength you need for an experiment when the current in the coil is 3 A. Unfortunately, this amount of current overheats the coil. You've determined that a current of 1 A would be more appropriate. How many additional layers of turns must you add to the solenoid to maintain the magnetic field strength? Explain.

26. Rank in order, from largest to smallest, the magnetic fields  $B_1$  to  $B_3$  produced by these three solenoids.



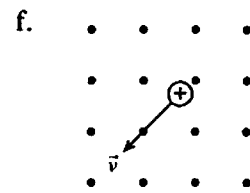
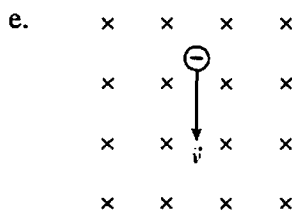
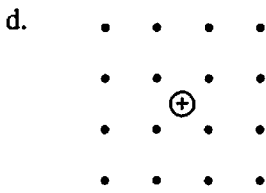
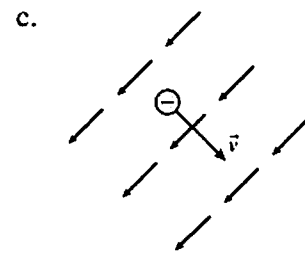
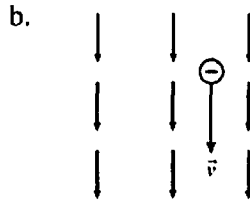
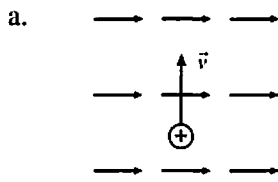
Order:

Explanation:



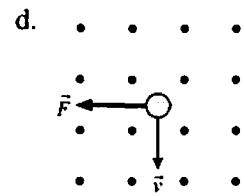
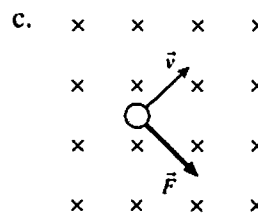
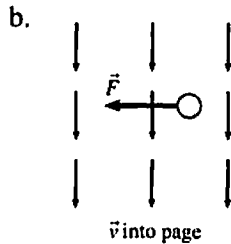
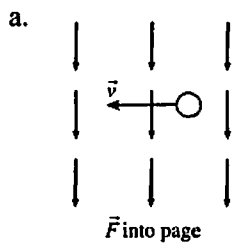
### 33.7 The Magnetic Force on a Moving Charge

27. For each of the following, draw the magnetic force vector on the charge or, if appropriate, write " $\vec{F}$  into page," " $\vec{F}$  out of page," or " $\vec{F} = \vec{0}$ ."



$\vec{v}$  out of page

28. For each of the following, determine the sign of the charge (+ or -).



$q = \text{_____}$

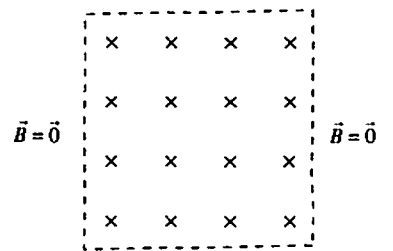
$q = \text{_____}$

$q = \text{_____}$

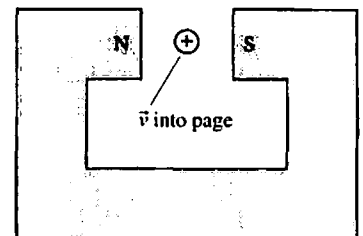
$q = \text{_____}$

29. The magnetic field is constant magnitude inside the dashed lines and zero outside. Sketch and label the trajectory of the charge for

- a. A weak field.
- b. A strong field.



30. A positive ion, initially traveling into the page, is shot through the gap in a horseshoe magnet. Is the ion deflected up, down, left, or right? Explain.




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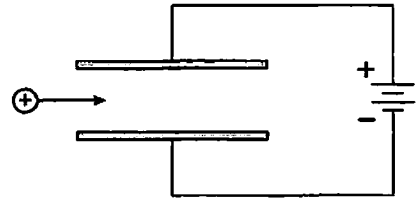


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31. A positive ion is shot between the plates of a parallel-plate capacitor.

a. In what direction is the electric force on the ion?

b. Could a magnetic field exert a magnetic force on the ion that is opposite in direction to the electric force? If so, show the magnetic field on the figure.

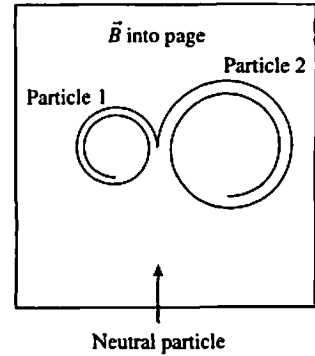


32. In a high-energy physics experiment, a neutral particle enters a bubble chamber in which a magnetic field points into the page. The neutral particle undergoes a collision inside the bubble chamber, creating two charged particles. The subsequent trajectories of the charged particles are shown.

a. What is the sign (+ or -) of particle 1? \_\_\_\_\_

What is the sign (+ or -) of particle 2? \_\_\_\_\_

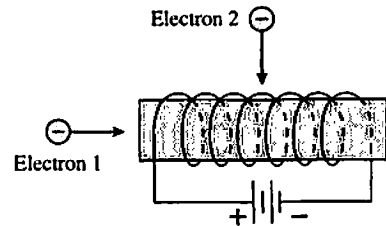
b. Which charged particle leaves the collision with a larger momentum? Explain. (Assume that  $|q| = e$  for both particles.)



33. A solenoid is wound as shown and attached to a battery. Two electrons are fired into the solenoid, one from the end and one through a very small hole in the side.

a. In what direction does the magnetic field inside the solenoid point? Show it on the figure.

b. Is electron 1 deflected as it moves through the solenoid? If so, in which direction? If not, why not?

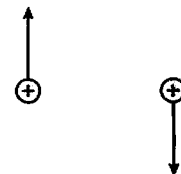


c. Is electron 2 deflected as it moves through the solenoid? If so, in which direction? If not, why not?

34. Two protons are traveling in the directions shown.

a. Draw and label the electric force on each proton due to the other proton.

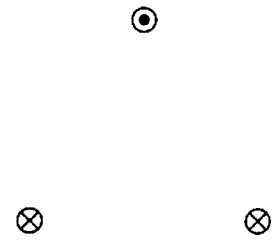
b. Draw and label the magnetic force on each proton due to the other proton. Explain how you determined the directions.



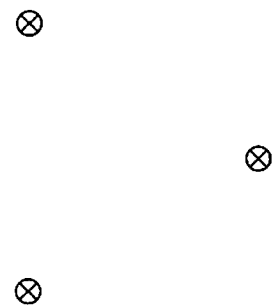
### 33.8 Magnetic Forces on Current-Carrying Wires

### 33.9 Forces and Torques on Current Loops

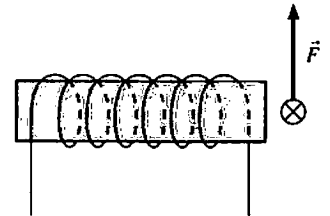
35. Three current-carrying wires are perpendicular to the page. Construct a force vector diagram on the figure to find the net force on the upper wire due to the two lower wires.



36. Three current-carrying wires are perpendicular to the page.  
 a. Construct a force vector diagram on each wire to determine the direction of the net force on each wire.  
 b. Can three *charges* be placed in a triangular pattern so that their force diagram looks like this? If so, draw it below. If not, why not?



37. A current-carrying wire passes in front of a solenoid that is wound as shown. The wire experiences an upward force. Use arrows to show the direction in which the current enters and leaves the solenoid. Explain your choice.

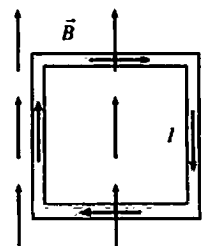


38. A current loop is placed between two bar magnets. Does the loop move to the right, move to the left, rotate clockwise, rotate counterclockwise, some combination of these, or none of these? Explain.



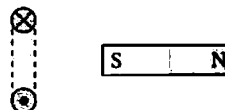
39. A square current loop is placed in a magnetic field as shown.

a. Does the loop undergo a displacement? If so, is it up, down, left, or right? If not, why not?



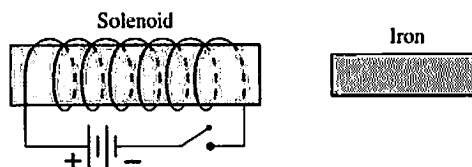
b. Does the loop rotate? If so, which edge rotates out of the page and which edge into the page? If not, why not?

40. The south pole of a bar magnet is brought toward the current loop. Does the bar magnet attract the loop, repel the loop, or have no effect on the loop? Explain.



### 33.10 Magnetic Properties of Matter

41. A solenoid, wound as shown, is placed next to an unmagnetized piece of iron. Then the switch is closed.



a. Identify on the figure the north and south poles of the solenoid.

b. What is the direction of the solenoid's magnetic field as it passes through the iron?

c. What is the direction of the induced magnetic dipole in the iron?

d. Identify on the figure the north and south poles of the induced magnetic dipole in the iron.

e. When the switch is closed, does the iron move left or right? Does it rotate? Explain.