Tutorial 11 Problems

A selection of the following problems were done:

Practice Final Exam

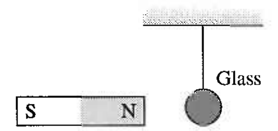
Workbook (2nd edition)
Chapter 33:
21–23

Textbook (2nd edition)
Chapter 33:
48, 64, 68, 73

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.

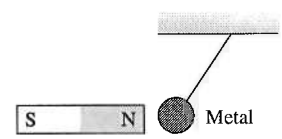
Explain your choice.

Glass experiences no force from a magnet.

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

It is weakly attracted to the magnet due to electrical polarization. There is simply a polarization of the charges in the magnet with negative charges nearest the positively charged sphere. other than polarization forces, charges have no effect on magnets.

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.

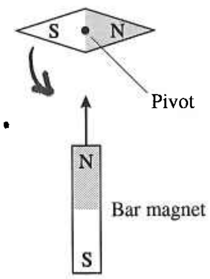


It is attracted. Magnetic materials are attracted to both poles of a magnet. This is analagous to how neutral objects are attracted to both positively and negatively charged rods by the polarization force.

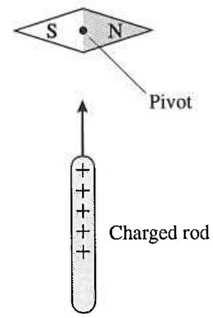
3. The compass needle below is free to rotate in the plane of the page. Either a bar magnet or a charged rod is brought toward the *center* of the compass. Does the compass rotate? If so, in which direction? If not, why not?

a.

It will rotate CCW.



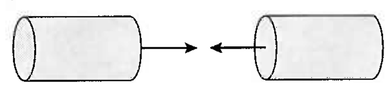
b.



The north pole of the bar magnet will attract the south pole of the compass needle.

Not at all. The charge exerts weak polarization forces on both ends of the compass needle. In this configuration, the forces will balance and have no effect.

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?



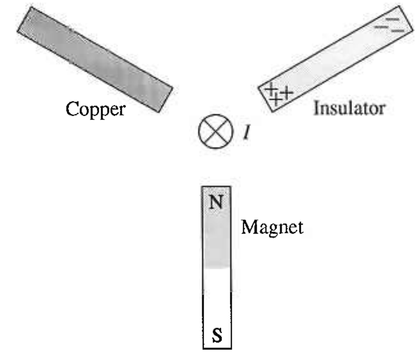
If both are magnets then one end of the first object will repel one end of the second object and attract the other end of the second object. If one is a magnet only, then the magnet will have both ends attract the iron.

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?

No. Magnets will be attracted to one end and repelled by the other. Magnetic materials will be attracted to both ends of a magnet. Non-magnetic materials experience no force.

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

It will stay where it is. The magnetic field will not exert a force on the copper rod.

b. Polarized insulator

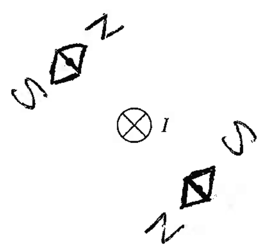
It will stay where it is. The magnetic field will not exert a force on the rod.

c. Bar magnet

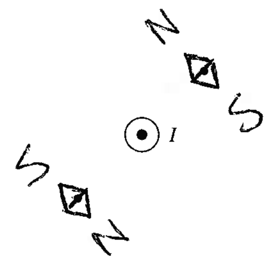
This will rotate counterclockwise to align along a tangent to a circle whose center is at the wire. North points in the direction of the magnetic field vector.

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.

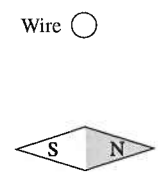
a.



b.

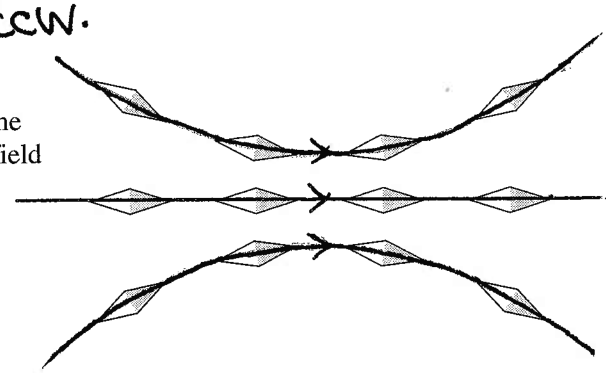


8. The figure shows a wire directed into the page and a nearby compass needle. Is the wire's current going into the page or coming out of the page? Explain.



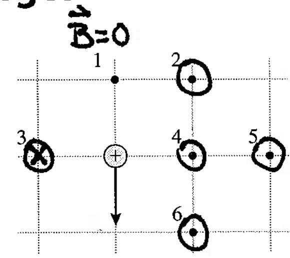
Out of the page. By the right hand rule the magnetic field vectors tangent to a circle centered on the wire point ccw.

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.



a. At each of the six number points, show the direction of the magnetic field or, if appropriate, write $\vec{B} = \vec{0}$.

b. Rank in order, from strongest to weakest, the magnetic field strengths B_1 to B_6 at these points.

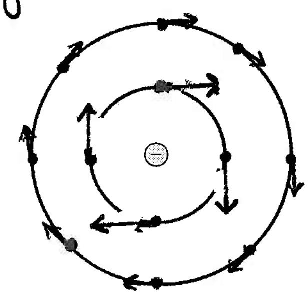
Order: $B_3 = B_4 > B_2 = B_6 > B_5 > B_1$

Explanation:

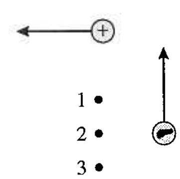
$B = \frac{\mu_0}{4\pi} \frac{qv\sin\theta}{r^2}$ For B_1, $\theta = 0°$ so $B_1 = 0$.

B_4 and B_3 are the shortest distance away and $\theta = 90°$ so they have the largest values. At points 2 and 6, r is larger and θ is smaller and at point 5 r is even larger.

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.

Negative. The field at point 2 due to the positive charge is out of the page so the field due to the second charge must be into the page.

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

The net field is out of the page. The field due to the positive charge is larger and the field due to the negative charge is smaller than those at point 2.

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

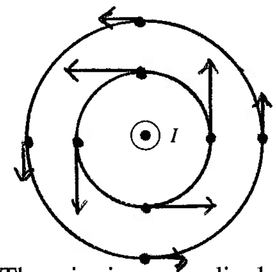
The net field is into the page.

33.4 The Magnetic Field of a Current

33.5 Magnetic Dipoles

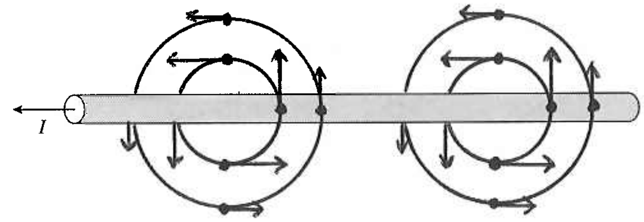
13. Each figure shows a current-carrying wire. Draw the magnetic field diagram:

a.



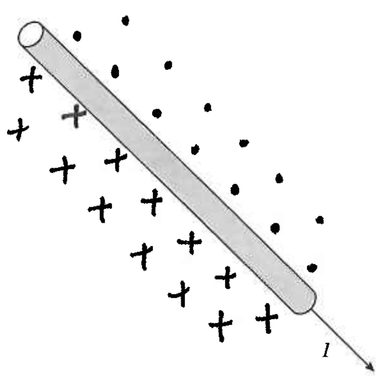
The wire is perpendicular to the page. Draw magnetic field *lines*, then show the magnetic field *vectors* at a few points around the wire.

b.

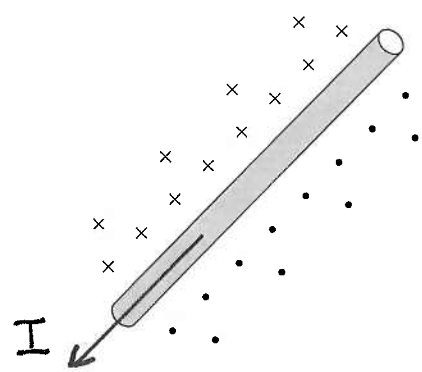


The wire is in the plane of the page. Show the magnetic field above and below the wire.

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

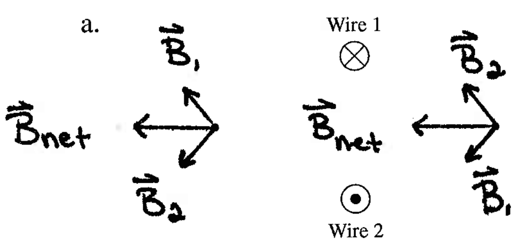


15. Use an arrow to show the current direction in this wire.

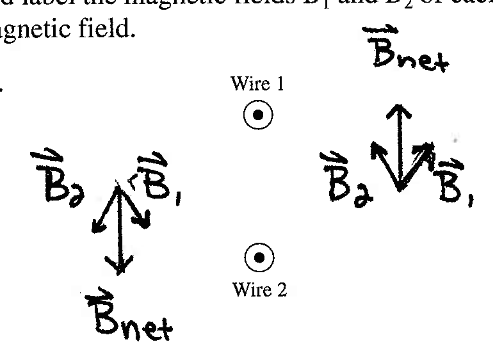


16. Each figure below shows two long straight wires carrying equal currents into and out of the page. At each of the dots, use a **black** pen or pencil to show and label the magnetic fields $\vec{B}_1$ and $\vec{B}_2$ of each wire. Then use a **red** pen or pencil to show the net magnetic field.

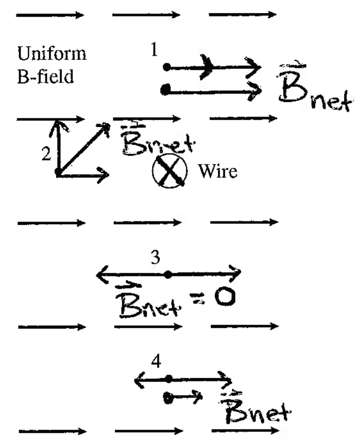
a.



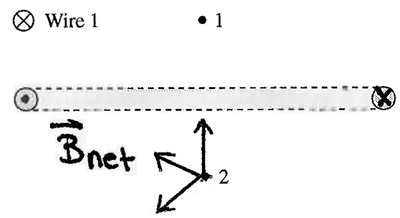
b.



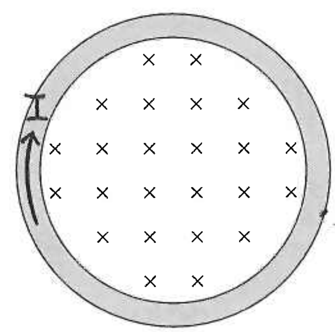
17. A long straight wire, perpendicular to the page, passes through a uniform magnetic field. The *net* magnetic field at point 3 is zero.
    a. On the figure, show the direction of the current in the wire.
    b. Points 1 and 2 are the same distance from the wire as point 3, and point 4 is twice as 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.
    a. On the figure, show the direction of the current in the loop.
    b. Use a vector diagram to determine the net magnetic field at point 2.

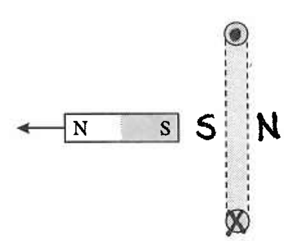


19. The figure shows the magnetic field seen when facing a current loop in the plane of the page.
    a. On the figure, show the direction of the current in the loop.
    b. Is the north pole of this loop at the upper surface of the page or the lower surface of the page? Explain.



The lower surface of the page. The north pole is the end from which the magnetic field emerges.

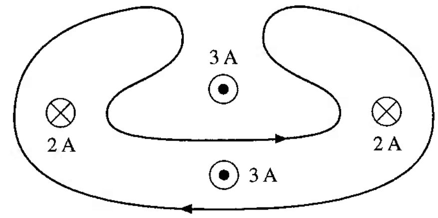
20. The current loop exerts a repulsive force on the bar magnet. On the figure, show the direction of the current in the loop. Explain.



With this current direction, the current loop creates a magnetic field going through the loop from left to right. This is a magnetic dipole with a south pole on the left. Like poles repel.

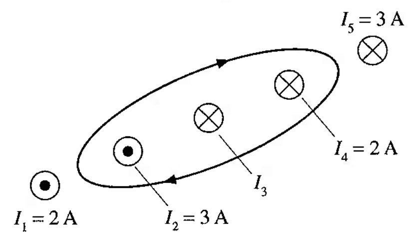
33.6 Ampère's Law and Solenoids

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



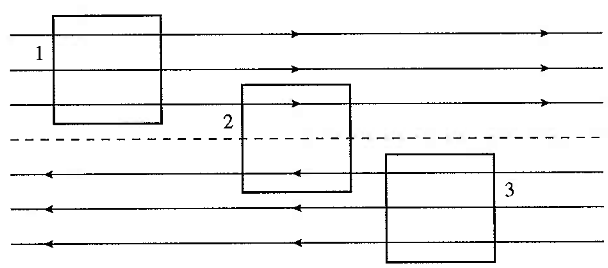
1A into the page.

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



I_3 = 3A into the page.

23. The magnetic field above the dotted line is $\vec{B}$ = (2 T, right). Below the dotted line the field is $\vec{B}$ = (2 T, left). Each closed loop is 1 m × 1 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.

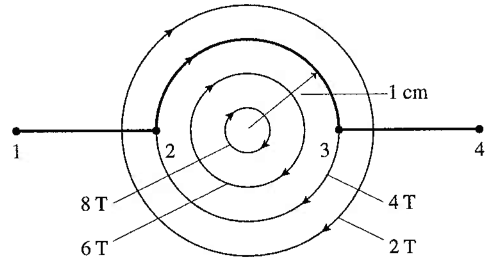


	Loop 1	Loop 2	Loop 3
$\int \vec{B} \cdot d\vec{s}$ along left edge	0	0	0
$\int \vec{B} \cdot d\vec{s}$ along top	+2T·m	+2T·m	−2T·m
$\int \vec{B} \cdot d\vec{s}$ along right edge	0	0	0
$\int \vec{B} \cdot d\vec{s}$ along bottom	−2T·m	+2T·m	+2T·m

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

	Loop 1	Loop 2	Loop 3
$\oint \vec{B} \cdot d\vec{s}$ around the loop	0	+4T·m	0

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



a. What is $\int_1^2 \vec{B} \cdot d\vec{s}$? 0

Explain or show your work.

$\vec{B}$ is perpendicular to the line everywhere from point 1 to point 2.

b. What is $\int_2^3 \vec{B} \cdot d\vec{s}$? 0.126 T·m Explain or show your work.

$\vec{B}$ is parallel to the line everywhere from point 2 to point 3.
$B \cdot L = B(\pi R) = (4T)\pi(0.01m)$ ($L = \frac{1}{2}$ circumference)

c. What is $\int_3^4 \vec{B} \cdot d\vec{s}$? 0 Explain or show your work.

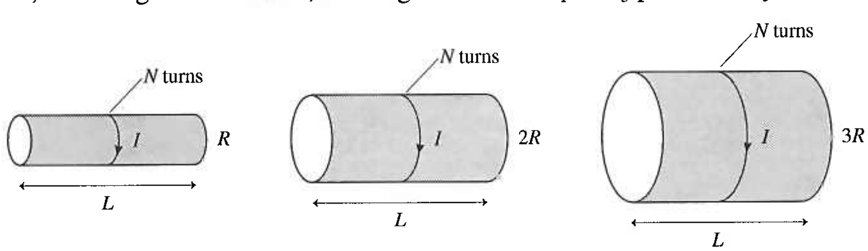
$\vec{B}$ is perpendicular to the line everywhere from point 3 to point 4.

d. Combining your answers to parts a to c, what is $\int_1^4 \vec{B} \cdot d\vec{s}$? 0. 126 T. m

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.

$B_{solenoid} = \mu_0 n I$
If I is decreased by a factor of 3, then n should be increased by a factor of 3.

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



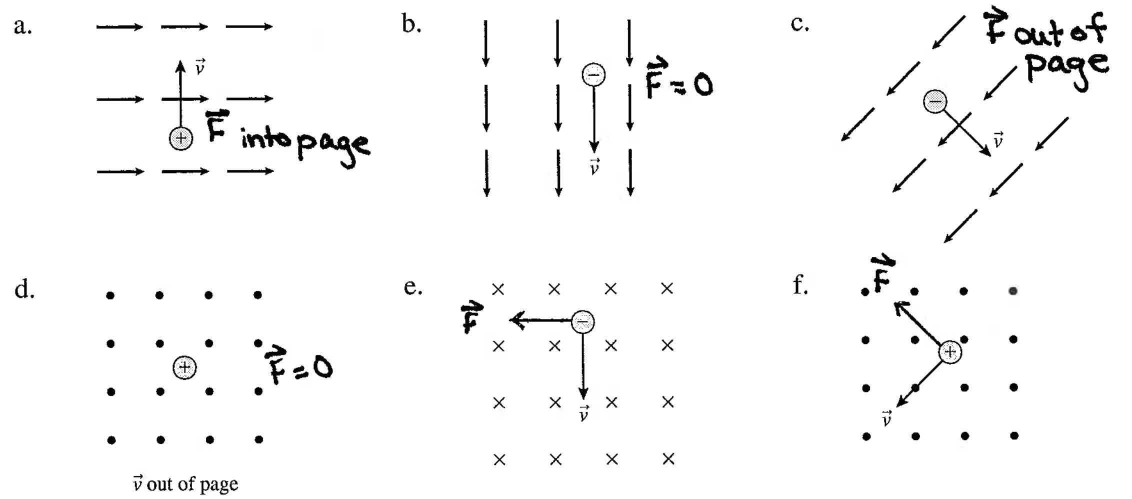
Order: $B_1 = B_2 = B_3$
Explanation:

$B = \frac{\mu_0 N I}{L}$ $N_1 = N_2 = N_3$
$I_1 = I_2 = I_3$
$L_1 = L_2 = L_3$

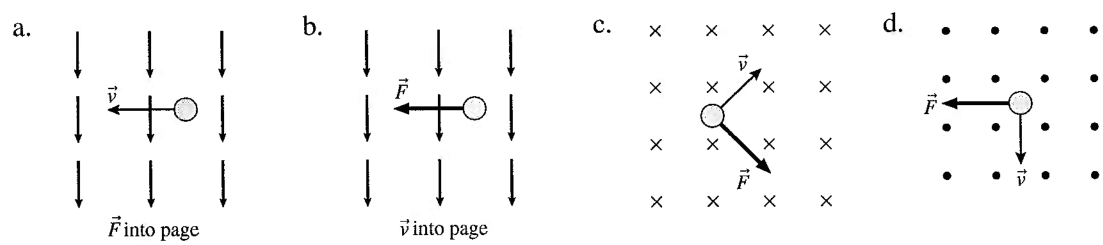
B is independent of R.

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 "$\vec{F} = \vec{0}$."

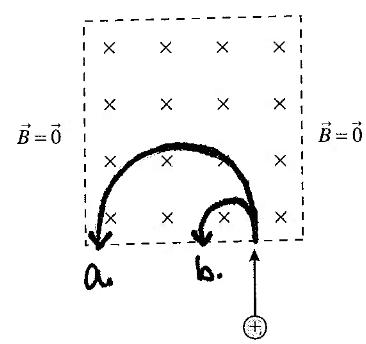


28. For each of the following, determine the sign of the charge (+ or −).

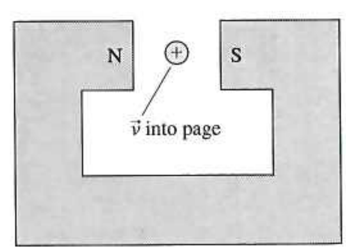


$q =$ − $q =$ + $q =$ − $q =$ +

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.

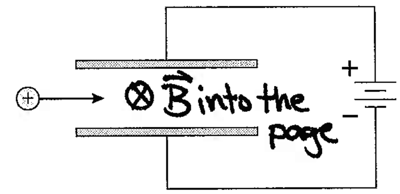


30. A positive ion, initially traveling into the page, is shot through the gap in a horseshoe magnet. Is the ion deflected up, down, left, or right? Explain.



Down. The magnetic field is left to right, from the north pole to the south pole.

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



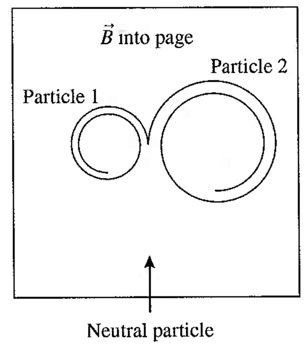
a. In what direction is the electric force on the ion?

Down.

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.

Yes.

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? +

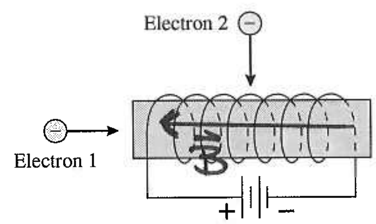
What is the sign (+ or −) of particle 2? −

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

Particle 2.

$r = \frac{mv}{qB}$ $\quad mv = rqB$ the larger radius particle had the greater momentum.

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.

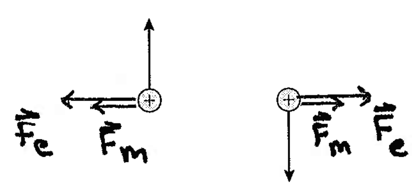
b. Is electron 1 deflected as it moves through the solenoid? If so, in which direction? If not, why not?

No. $\vec{F} = q\vec{v} \times \vec{B}$ There is no force on a charge moving antiparallel to a field because $\vec{v} \times \vec{B} = 0$.

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

Yes. Out of the page.

34. Two protons are traveling in the directions shown.



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

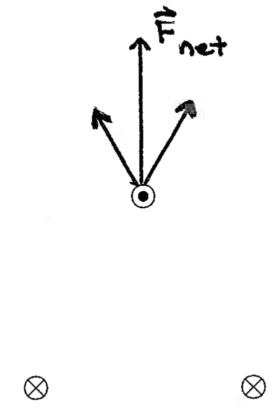
b. Draw and label the magnetic force on each proton due to the other proton. Explain how you determined the directions.

The moving charge on the left creates a magnetic field in the region between the charges that is into the page. This field exerts a magnetic force on the charge on the right that is to the right.

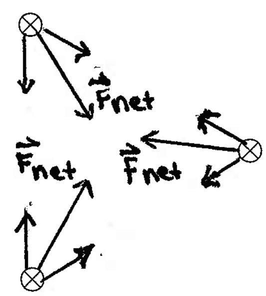
33.8 Magnetic Forces on Current-Carrying Wires

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.

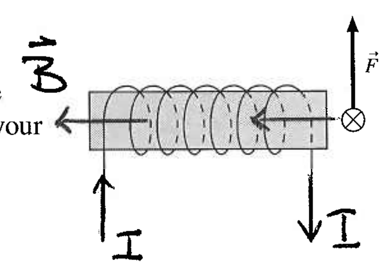


36. Three current-carrying wires are perpendicular to the page.
   a. Construct a force vector diagram on each wire to determine the direction of the net force on each wire.
   b. Can three *charges* be placed in a triangular pattern so that their force diagram looks like this? If so, draw it below.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



No. Charges must be unlike to exert attractive forces on each other. There are not 3 different unlike charges to be able to achieve this.

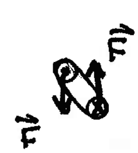
37. A current-carrying wire passes in front of a solenoid that is wound as shown. The wire experiences an upward force. Use arrows to show the direction in which the current enters and leaves the solenoid. Explain your choice.



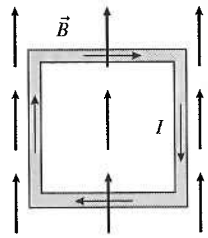
To experience an upward force, the wire must be in a field that points to the left.

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.

It rotates counterclockwise. The magnetic field created by the magnets points to the left. Forces on the loop, as shown, tend to rotate the loop ccw.



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



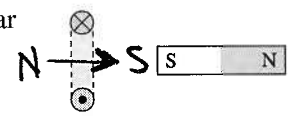
a. Does the loop undergo a displacement? If so, is it up, down, left, or right? If not, why not?

It will rotate but it will not undergo translational displacement because the sum of the forces equals zero.

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

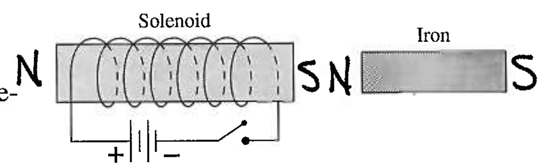
Yes. The top edge rotates out of the page and the bottom edge rotates into the page.

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.



Repel. The south magnet pole of the current loop faces the south pole of the magnet.

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?

Right to left.

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

Right to left.

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.

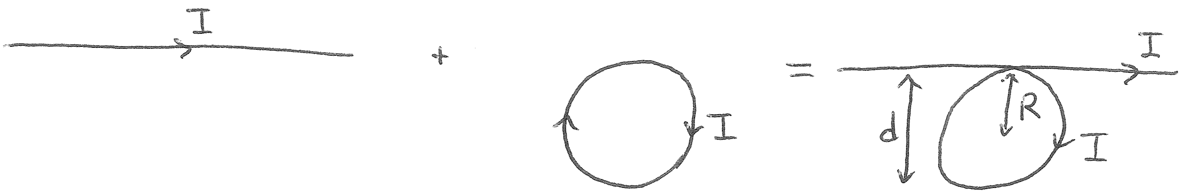
The attractive force between the opposite poles pulls the iron to the left.

Knight, 2nd edition

Chapter 33 Exercises and Problems

#48

This can be thought of as a superposition of a line of current moving in a straight line and a loop of current:



$$B_{wire} = \frac{\mu_0 I}{2\pi r} = \frac{\mu_0 I}{2\pi(\frac{1}{2}d)} = \frac{\mu_0 I}{\pi d}.$$

$$B_{loop} = \frac{\mu_0 I R^2}{2[(z^2+R^2)^{3/2}]} = \frac{\mu_0 I (\frac{1}{2}d)^2}{2(0+[\frac{1}{2}d]^2)^{3/2}} = \frac{\mu_0 I}{d}.$$

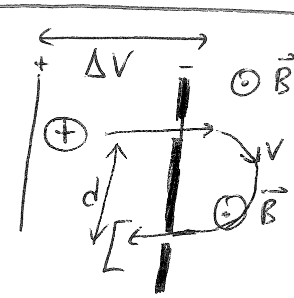
The right hand rule for finding $\vec{B}$ due to a current tells you that both the wire and the loop produce fields pointing into the page at the centre of the ring, so

$$\vec{B} = \vec{B}_{wire} + \vec{B}_{loop} = \left(\frac{\mu_0 I}{\pi d} + \frac{\mu_0 I}{d}\right) \text{(into the page)}$$

$$= \frac{(4\pi \times 10^{-7}\ T\cdot m/A)(5.0\ A)}{0.020\ m}\left(\frac{1}{\pi} + 1\right) \text{(into the page)}$$

$$= 4.14 \times 10^{-4}\ T \text{ (into the page).}$$

#64



Use energy conservation to figure out how ΔV affects the speed of an ion.

$$(E_k)_i + U_i = (E_k)_f + U_f$$

$$0 + q\Delta V = \frac{1}{2}mv^2 + 0 \Rightarrow \Delta V = \frac{mv^2}{2q}.$$

If the ion is undergoing circular motion due only to the magnetic force,

$$F = qvB = \frac{mv^2}{r} \Rightarrow v = \frac{qBr}{m}.$$

$$\Delta V = \frac{m}{2q}\left(\frac{qBr}{m}\right)^2 = \frac{qB^2r^2}{2m} = \frac{qB^2(d/2)^2}{2m} = \frac{qB^2d^2}{8m}.$$

After this, it becomes a messy calculator problem without much physics involved. If you really want to see the answers, here they are:

$$m_{N_2^+} = 2 \times 14.0031 \frac{g}{mol} \times \frac{mol \times 10^{-3}\,kg/g}{6.022\times10^{23}\ \text{ions}} - 9.11\times10^{-31}\,kg = 4.650556\ldots\times10^{-24}\,kg$$

$m_{O_2^+} = 5.312064\ldots\times10^{-24}\,kg$; $m_{CO^+} = 4.648680\ldots\times10^{-24}\,kg$.

$$\Delta V_{N_2^+} = \frac{(1.60\times10^{-19}C)(0.200T)^2(0.080m)^2}{8(4.650556\ldots\times10^{-24}kg)} = 110.094\,V.$$

$\Delta V_{O_2^+} = 96.3848\,V$; $\Delta V_{CO^+} = 110.139\,V$.

#68. RAILGUN!!!

a) Using the right hand rule for forces on charges moving through a magnetic field, the current must go into the page.

b) The force on the bar is $F = I\ell B$. The amount of work done on the bar is

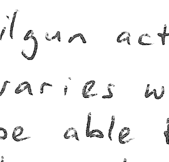
$$W = \vec{F}\cdot\Delta\vec{x} = (I\ell B)(d)\cos 0° = I\ell Bd$$
$$= \Delta E_k + \Delta U = \Delta E_k + 0 = \tfrac{1}{2}mv_f^2$$
$$\Rightarrow v_f = \sqrt{\frac{2I\ell Bd}{m}}.$$

Note that this is a simplified version of how a railgun actually works. Actual railguns will have a magnetic field that varies with the distance away from the conducting rails. You should be able to produce a more accurate model with some effort. We have also glossed over the effect of motional EMF from Chapter 34, which may affect the current if the power supply for the railgun can't compensate.

#73

An electron of charge q does one circle around the atom in

$$\Delta t = \frac{\Delta d}{v} \Rightarrow I \approx \frac{\Delta q}{\Delta t} = \frac{q}{\Delta d/v} = \frac{qv}{2\pi r}.$$



The magnetic field of a current loop is

$$B = \frac{\mu_0 I r^2}{2(z^2+r^2)^{3/2}} = \frac{\mu_0(qv/2\pi r)r^2}{2(0^2+r^2)^{3/2}} = \frac{\mu_0 qv}{4\pi r^2}$$
$$= \frac{(4\pi\times10^{-7}\,T\cdot m/A)(1.60\times10^{-19}\,C)(2.2\times10^6\,m/s)}{4\pi(5.3\times10^{-11}m)^2} = 12.53\ldots T \approx 13\,T.$$