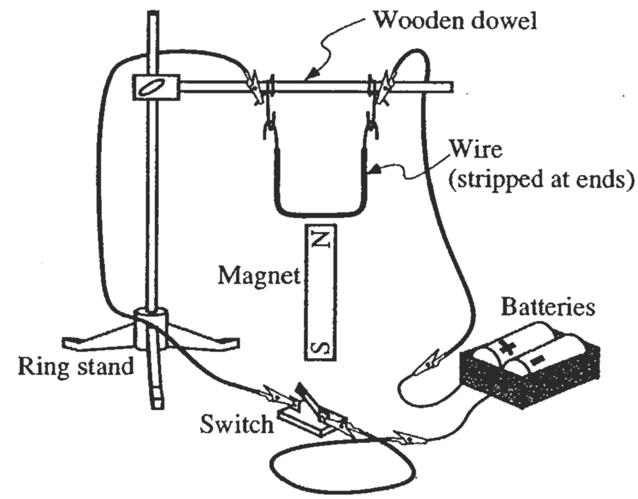
MAGNETIC INTERACTIONS

I. The magnetic force on a current-carrying wire in a magnetic field

Obtain the following equipment:

- magnet
- wooden dowel
- ring stand and clamp
- battery and battery holder
- switch
- two paper clips
- three alligator-clip leads
- 30 cm piece of connecting wire
- magnetic compass
- enlargement showing magnet and wire

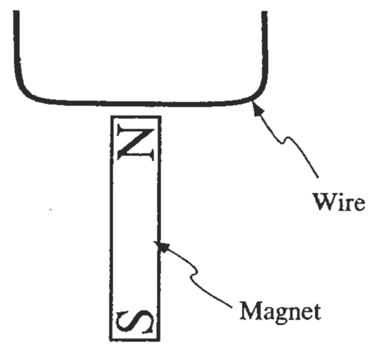


Hang the connecting wire from the paper clips as shown so that it swings freely. Do not close the switch until told to do so.

A. On an enlargement of the figure below, sketch field lines representing the magnetic field of the bar magnet. Show the field both inside and outside the magnet.

On the diagram, indicate the direction of the current through the wire when the switch is closed.

Predict the direction of the force exerted on the wire by the magnet when the switch is closed. Explain.



Check your prediction. (Do not leave the switch closed for more than a few seconds. The battery and wires will become hot if the circuit is connected for too long.)

B. Make predictions for the following five situations based on what you observed in part A. Check your answers only after you have made all five predictions.

1. The magnet is turned so that the south pole is near the wire while the switch is closed.

   Prediction:

   Observation:

2. The leads to the battery are reversed (consider both orientations of the magnet).

   Prediction:

   Observation:

3. The north pole of the magnet is held near the wire but the switch remains open.

   Prediction:

   Observation:

4. The north pole of the magnet is held: (a) closer to the wire and (b) farther from the wire.

   Prediction:

   Observation:

5. The magnet is turned so that it is parallel to the wire while the switch is closed.

   Prediction:

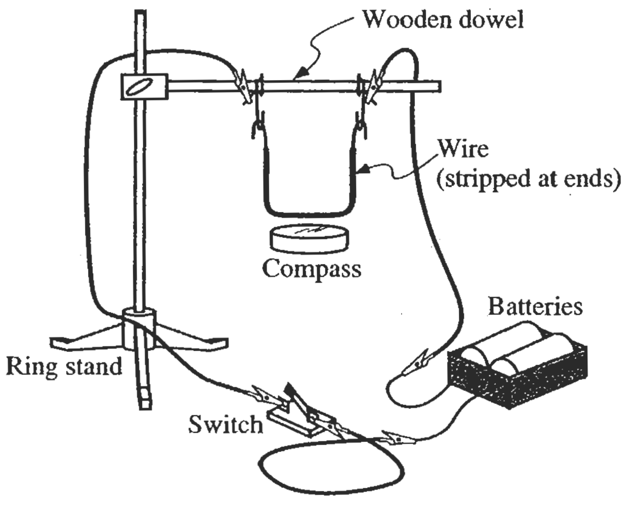
   Observation:

Resolve any discrepancies between your predictions and your observations. (*Hint:* Consider the *vector* equation for the magnetic force on a current carrying wire in a magnetic field: $\vec{F} = i\vec{L} \times \vec{B}$.)

II. The magnetic field of a current-carrying wire

A. Suppose you place a small magnet in a magnetic field and allow it to rotate freely. How will the magnet orient relative to the external magnetic field lines? Illustrate your answer below.

B. Suppose you hold a magnetic compass near a current-carrying wire as shown. (A *magnetic compass* is a magnet that can rotate freely.) The face of the compass is parallel to the tabletop.



1. *Predict* the orientation of the compass needle when the switch is closed. Sketch a diagram that shows the wire, the direction of the current through it, the direction of the magnetic field directly below the wire, and the predicted orientation of the compass needle.

2. Check your answer. If the deflection of the needle is not what you predicted, resolve the discrepancy. (*Hint*: Is there more than one magnetic field affecting the compass?)

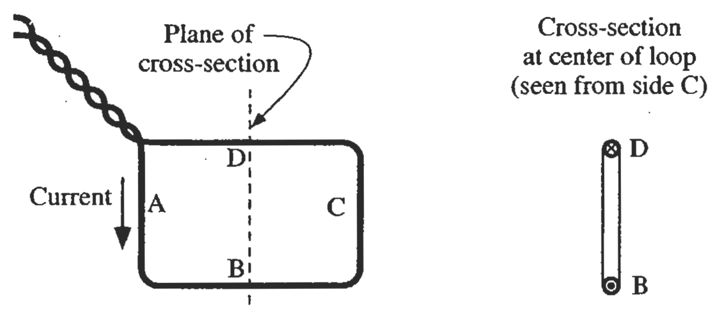
C. Now suppose that you hold the compass at some other locations near the wire (*e.g.*, directly above the wire or to one side of a vertical wire). For each location, *predict* the orientation of the compass needle when the switch is closed. Make sketches to illustrate your predictions.

Check your answers. If the orientation of the compass needle is not what you predicted, resolve the discrepancy.

D. Sketch the magnetic field lines of a current-carrying wire. Include the direction of the current in the wire in your sketch.

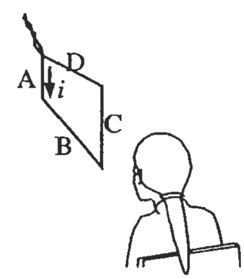
III. Current loops and solenoids

A. A wire is formed into a loop and the leads are twisted together. The sides of the loop are labeled A–D. The direction of the current is shown. (The diagram uses the convention that ⊙ indicates current out of the page and ⊗ indicates current into the page.)



1. On the top two diagrams at right, sketch magnetic field lines for the loop. Base your answer on your knowledge of the magnetic field of a current-carrying wire.

   Explain why it is reasonable to ignore the effect of the magnetic field from the wire leads.



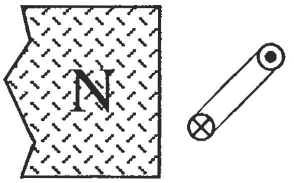
2. Consider the magnetic field of a bar magnet.

   How are the magnetic field lines for the current loop similar to those for a short bar magnet?

   Can you identify a "north" and a "south" pole for a current loop?

   Devise a rule by which you can use your right hand to identify the magnetic poles of the loop from your knowledge of the direction of the current.

B. A small current loop is placed near the end of a large magnet as shown.

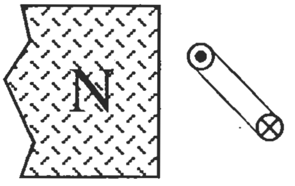


1. Draw vectors to show the magnetic force on each side of the loop.

   What is the net effect of the magnetic forces exerted on the loop?

2. Suppose that the loop were to rotate until oriented as shown.

   Now, what is the net effect of the magnetic forces exerted on the loop?



   Is there an orientation for which there is no net torque on the loop? Draw a diagram to illustrate your answer.

3. Are your results above consistent with regarding the current loop as a small magnet? Label the poles of the current loop in the diagrams above and check your answer.

C. A solenoid is an arrangement of many current loops placed together as shown below. The current through each loop is the same and is in the direction shown.

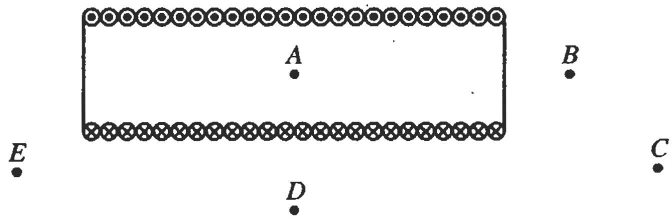
Obtain or draw an enlargement of the figure.

1. At each of the labeled points, draw a vector to indicate the direction and magnitude of the magnetic field. Use the principle of superposition to determine your answer.

2. Sketch magnetic field lines on the enlargement.

   Describe the magnetic field near the center of the solenoid.

Cross-sectional side view



3. How does the field of the solenoid at points *A–E* compare with that of a bar magnet (both inside and outside)?

   Which end of the solenoid corresponds to a north pole? Which end corresponds to a south pole?

4. How would the magnetic field at any point within the solenoid be affected by the following changes? Explain your reasoning in each case.

   - The current through each coil of the solenoid is increased by a factor of two.

   - The number of coils in each unit length of the solenoid is increased by a factor of two, with the current through each coil remaining the same.

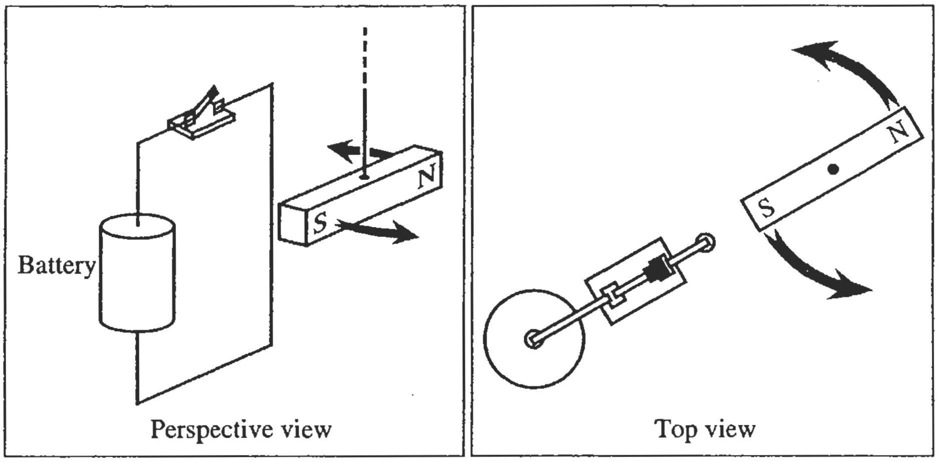
MAGNETIC INTERACTIONS

Name ________________

1. A magnet is hung by a string and then placed near a wire as shown. When the switch is closed, the magnet rotates such that the ends of the magnet move as indicated by the arrows.

   At the instant the switch is closed determine:

   - the direction of the current through the wire segment nearest the magnet. Explain.



   - the direction of the net force exerted by the magnet on the wire segment (assume the magnet is in the position shown). Explain.

2. Shown at right is a cross-sectional view of two long straight wires that are parallel to one another. One wire carries a current i_o out of the page, the other carries an equal current i_o into the page.

   a. Draw a vector on the diagram to show the direction of the magnetic field, if any, at point P. Explain your reasoning.