* 1. Set up a long, straight bundle of vertical wires carrying a lot of current. Use iron filings to observe the shape of the wire's magnetic field lines. Sketch the pattern and write an *OPENING STATEMENT* describing those magnetic field lines in as much detail as possible. Read it aloud at home.

2. Use the sign rule on RS IX to determine the direction of electron flow in the vertical wires. Use a compass to determine the direction of the artificial magnetic field at several locations near the wires.
   a. Indicate those directions by drawing small arrows along the field lines in your sketch.
   * b. Write sentences beside the sketch describing the *direction* of electron flow in the wire and describing what *happens* to the wire's magnetic field if the direction of electron flow is reversed.

3. A "hand rule" can help you remember how the direction of a wire's *magnetic field* depends on the *electron flow* in the wire: Imagine grasping the wire with your thumb pointing in the direction of the electron flow. Your fingers then curl around the wire just as the field lines do. -Does 2b agree? ___
   a. Which hand must you use to make the fingers indicate the direction of the field? (Use 2b.) _______
   b. Which hand would you use if you thought (as Ben Franklin did) that electric current was a *positively* charged fluid flowing from the positive terminal of the battery to the negative terminal? ______ (At that time, there was no way to show Ben that he was mistaken. His concept of current is still in a lot of textbooks today, and is called "conventional" current.)
   * c. Copy the hand rule carefully, *using the phrases emphasized above.* (Saved in #__ on RS___.)

4. Imagine placing a straight wire on top of a magnetic compass with the wire parallel to the compass needle, as in 2c on p. 120: Then we start up a northward electron flow in that wire. *According to 3c,* we expect the wire's magnetic field to turn the compass needle ___________wise. *Check here when ___ you have tested that prediction. If #4 contradicts 3c you will get credit for neither answer.*

5. A wire's magnetic field is strongest at locations _________ the wire. (close to, far from) Illustrate by sketching a graph showing how the wire's field strength must depend upon distance from the wire.

6. The *total* magnetic field at a point near the straight, vertical wire in #1 is the vector sum of the wire's field, the earth's field, and any "stray" fields that may exist there. At some locations the wire's field is stronger than the earth's; at other locations it is weaker than the earth's field.
   a. Do you know the directions of the two main fields at almost every location?____
   b. Do you know which of those two is the stronger at almost every location? ____
   c. At almost every location in the neighborhood of the vertical wire can you do a rough vector addition to estimate the direction of the total magnetic field?___ -If so, please illustrate. If not, explain.

7. Suppose a compass is placed one meter north of a long vertical wire. The current in the wire is adjusted until the compass points 45 degrees east from north. Use #6 above *with page 34R* to predict which way the compass will point when placed at each of the following locations:
   a. One meter south of the wire: ______ b. North of the wire at a point where $B_W = B_E/2$: ____
   c. Two meters east of the wire: ______ d. Half a meter east of the wire: ____
   e. The total field is zero at a point ____ meters _____ from the _____.

8. Using #7, sketch a map of the total magnetic field near a vertical wire in the earth's magnetic field:
   a. At all locations *far* from the wire the total field's direction is ________ward.
   b. Put several arrows on your map to illustrate #7 and 8a.
   c. Using #1, draw some field lines close to the wire. Indicate their directions, as in #2.
   d. Describe the direction of the electron flow without contradicting 3c or 8c.
   e. Choose several points at an intermediate distance, where the wire's field has the same strength as the earth's. Draw a short arrow through each of those points to indicate the direction of the total field.
   f. Choose several locations along a north-south line passing through the wire.
      Use vector addition (as in #7) to indicate the direction of the total field at each of those points.
   g. Do the same for some other north-south lines and some east-west lines. Use symmetry to check.
   h. By now you should have small arrows distributed all over the paper. Using those arrows as guides, draw some smoothly curved field lines as you did on pages 117 & 118. Remember that field lines never intersect and never terminate in empty space. Don't leave large blank regions on your map.

9. Another wire carries current through a magnetic field in a direction parallel to the field. Using vector addition again, describe one total field line near the wire. Compare its shape to something familiar.

* 1. Make a sketch showing how a uniform magnetic field is distorted by a current-carrying wire placed in the field and perpendicular to that field. (Copy it from page 122.)

a. It seems that the wire pushes the field lines to one side. Is it reasonable to expect the field to push back on the wire? Answer with an opening statement written beside the sketch. *Try not to mystify the reader. If necessary, ask someone to explain the "opening statement" concept to you.*

b. State a *NEW hand rule* for predicting the direction of that hypothetical push on the wire, given the directions of the field and the flow. (Ask for help if you need it.) Save a copy for future reference.

c. Do you expect any magnetic force to act on a wire which is *parallel* to the field? If not, explain. If so, explain how to predict its direction. *Start with a field map, as in #9 on page 122.*

* 2. Place a wire in a strong magnetic field. Arrange it so that any magnetic force exerted on the wire in the manner predicted above will be easy to detect. Find out if the force exists and if its direction agrees with the prediction made with the hand rule in 1b. Then describe what you *did*, what you *saw*, and what you *conclude* from that observation. Again, please try not to mystify the reader.

* 3. Describe some uses for this new kind of magnetic force. (Use your textbook.)

4. Imagine two identical segments of current-carrying wire in a uniform magnetic field, oriented perpendicular to the field. Let "F" represent the magnetic force exerted on *one* of them by the field.

a. In terms of F, how much force must act on the pair of them? ___

b. If the two are in series, we conclude that doubling the length of a current segment causes the magnetic force on it to be ______ed. In other words, **F is proportional to the _______** of the _____.

c. If the two are in parallel, then the pair is equivalent to a single segment with double current. This shows that doubling the current in a wire must cause the magnetic force on it to be ________ed. In other words, **F must be proportional to the _________ in the _______**.

5. Suppose the magnetic field is generated by electric current in a coil of wire:

a. We can double the field strength by ________ing the number of turns in the coil, because the field produced by a pair of coils is the ________ sum of the fields produced by the individual coils.

b. The force exerted on the wire by the double coil's field must be ___ times stronger than the force exerted on the wire by the original coil, because the new field is ___ times stronger than the original.

c. In #6 on page 120, magnetic field strength is represented by the letter "__". Using that symbol, write a conclusion like 4b and 4c describing how the force in 5b must depend on field strength.

6. Develop a way to measure the magnetic force on a segment of current-carrying wire. You may use any convenient force units in the experiment, but it will be necessary to convert to standard units later. Remember to obtain the necessary information about the string and current balances BEFORE leaving the lab. Do not allow the balance current to exceed 5 A. Do not allow the coil current to exceed 4 A.

* 7. Describe and illustrate your apparatus and measuring technique clearly.

* 8. Measure the coil current, the balance current, and the length of the wire segment. Record those results (with plausible uncertainty estimates) on the back of this paper. Then explain *clearly* how the magnetic force on the segment is measured and converted to SI units, and how the SDC of that force is measured. *Keep a copy of your data for use on page 124.*

9. It is difficult to adjust the angle between the magnetic field and the wire, but you can easily reverse the direction of the current. In effect that changes the angle by ____ degrees.

a. What happens to the sign (or direction) of the force whenever you make that change? ____

b. Put some dots on a sketched graph to illustrate what 9a tells us about the graph of force vs angle.

c. Do you expect that graph to be smooth and continuous? ____ (Please illustrate.)

d. What familiar function does your sketch resemble? ____

e. What does 9d predict about the force on a wire that is parallel the field? ____ -Does 1c agree? __

* f. Make a *guess* about how the force may depend on the angle. *Don't write it as a fact.* Then describe *how* that guess might be tested. (Explain what must be measured and what must be done.)