1. When electric charge flows through a wire in a magnetic field, is the magnetic force exerted on the wire itself, or is it exerted on the moving electrons *in* the wire? Let's do an experiment to find out:

* a. Describe a procedure for injecting electrons into a vacuum. (See #1 on RS XII.)

* b. Describe how the point where the electrons hit a surface can be made visible. (See #4 on p. 104.)

* c. Use those tricks to find out if magnetic deflection of moving electrons is really possible. If it is, find out if the hand rule correctly predicts the *direction* of the force. Describe and illustrate your predictions, your experiment, and your observations. Remember to sketch the field lines in your illustration, and *explain how you determined the direction of the field.*

* d. State your conclusion clearly on a separate sheet of paper so you can submit it for credit again with page 127. *Please try not to confuse "force" with "field".*

2. If a magnetic force can act on a moving charged particle in a vacuum, it should be possible to figure out the *strength* of such a force. In your opinion, what information will be needed in order to make that prediction? Think of at least two variables which this force must depend upon. Then use dimensional analysis to figure out what you can about the new force formula.

3. Let "N" represent the number of mobile electrons *in each meter of wire*.
Let "S" represent electron speed in the wire, and let "Q" represent the charge of an electron.
   a. How can you use N and S to calculate the current in the wire, in electrons per sec? _____
   b. How can that current be converted to coulombs per second? Please answer with an equation using only the symbols defined above: (See RS IX.) **I =** _____

4. If a wire with length "L" is in a magnetic field with strength "B", then the magnetic force exerted on that wire is given by equation #14 on RS XIV, which says: **F =** _____

5. Use equation 3b to eliminate the current from equation 4 to obtain a formula for the magnetic force on a moving *group* of electrons in the wire. **Force on group =** _____
-Have you defined each of your symbols clearly? ____

6. How is the number of electrons in that group related to the length of the wire? _____
-Which symbol defined above represents the proportionality constant in that relation? _____
(The units will tell you.) Conclusion: **The number of electrons in the group =** _____

7. If you know the total force on the *group* of particles (from #5), and you know *how many* particles are in the group (from # __), then it's easy to create a general formula for the force exerted on each particle in the group: **Magnetic Force On One Particle =** _____ Do the units balance in this equation? ___ -Does it contradict 2 & 3? ___ This discovery is being saved in #__ on RS ___.
The symbols in this new equation are clearly defined in #___ above and also on RS ___.

* 8. In 1c you tested a "hand rule" for predicting the direction of the *magnetic force on a particle* when you are given the directions of its *velocity* and the *magnetic field*. That rule is recorded in #__ on RS__. That rule can be modified to make it work for a ***positively*** charged particle. Using those *italicized* words, state the new rule clearly enough so that it can stand alone. *Keep a copy.*

9. Imagine a charged particle coasting through a magnetic field in a vacuum, with the particle's velocity perpendicular to the field:
   a. Does the magnetic force do any work on the particle? ____ (See page 58 or #2 & #8 on RS VI.)
   b. Does the kinetic energy change? ____ -Does 9b contradict 9a? ____
   c. What kind of curve must the path of the particle be? _____ (See pages 72-73 or #6 on RS VII.)
   d. Is the word "radius" useful in describing that kind of curve? ___
   e. What information would a physicist need in order to predict the radius of the path taken by a charged particle moving through a magnetic field? (After reviewing #7, list the independent variables which the path radius must depend on.)
   f. Is it possible to create a path radius formula using only those variables and dimensional analysis? *If so, show how.* If not, then what units must the missing quantity have?

1. In terms of mass, speed, and path radius, how much centripetal force is required to keep a particle on a circular path? (See #5 on RS VII.) **F = _____, where "__" represents the particle's speed.**

2. What exerts the centripetal force on the particle in the examples on page 125? _____ _____

3. Suppose you know the charge ("__") and velocity ("__") of the particle and the strength and direction of the magnetic field ("__"). You can use that information (in SI units) to predict the direction and strength of the force mentioned in 1 & 2:
   a. On page 125 you showed that the magnetic force on a moving particle is predicted by the equation F = _____, where "__" represents the angle between __ and __. (See #17 on RS XIV.)
   b. ***If*** the magnetic field is uniform and ***if*** the particle's velocity is perpendicular to the field ***then*** the path of the particle will be a _____.
   c. If the path is circular (as in #1) then the angle mentioned in equation 3a must be ___degrees.
   d. In that special case equation 3a reduces to **F = _____.**

* 4. Use the equations above to create a "path radius formula" for predicting the path radius when you are given the charge, mass, speed, and magnetic field strength. Simplify that formula if you can and then show that the units check. Using what you learned in #3, explain what the formula means and explain its limitations. *This discovery has been recorded in #__ on RS__.*

5. Here are some clues to help you discover a formula predicting the speed of the electron as it emerges from an electron gun: (Also see page 119 or RS XIV.)
   a. We can control that speed by adjusting the _____ between the gun's _____ and its _____.
   b. As usual, that adjustable quantity will be represented by the letter "__".
   c. When a particle is moved from point A to point B, the quotient of the work done on the particle divided by the charge of the particle is the "_____ _____ between A and B", *by definition.*
   d. Is that definition still recorded on RS IX?___ -What page did it come from? ____
   e. The SI units for that quotient must be _____s per _____, also known as "_____s".
   f. The roles of "A" and "B" will be played by the gun's _____ & _____. -Does 5a agree?
   g. According to the definition reviewed in 5c, the kinetic energy of an *electron* arriving at the plate of a vacuum tube can be calculated by multiplying the _____ of the _____ (in _____.) by the _____ _____ between the _____ and the _____ (in _____s). -Does 5a agree? __
   * h. Write your answer to 5g with symbols instead of words. (Write it as an equation involving the electron's mass, speed, charge, and other easily measurable quantities.) Define your symbols. *To avoid confusing "velocity" with "voltage", do NOT use the letter V to represent "speed".*
   i. Solve equation 5h algebraically for the unknown speed. Remember to check units. **S = _____**

* 6. Use 5i to eliminate the "speed" from the path radius equation which you developed in #4. Simplify the resulting equation until no symbol appears in it more than once. Then solve the resulting equation for the mass of the particle, and show that the units balance. On page 127 you will use this formula to measure the mass of an electron, so you must *define* all the symbols and *keep a copy.*

7. Example: Suppose we accelerate some charged particles with a 2.0-kilovolt particle beam gun and send them through a 2.5-Tesla magnetic field. We find that they follow a curved path with a radius of 4.85 centimeters. Each particle has a charge equivalent to three protons. What mass must each particle have? *Show how you use the given data with #6 to obtain your answer in SI units.*

8. In the Tangent Galvanometer experiment on pages 120 & 121 you discovered how a solenoid's magnetic field depends on its current. A description of that relation is in #__ on on RS XIV:
   B = _____, where "__" represents the coil's _____.

9. The slope of a coil's B vs I graph is called a "coil constant", as in 7c on page 125 and on RS XIV. According to page 123, that slope _____ __ the same for different types of coil. (must be, can't be)
   a. On p. 124 we used the _____ _____ _____ and _____ to calculate a coil constant.
   b. In what *simple* SI units must that constant be expressed? _____ per _____
   c. We found that the numerical value of that constant was "between _____ and _____ _____."
   d. That result is still recorded in # ___ on RS __. *You'll need it for the electron mass experiment!*