* 1. On page 123 you discovered how the magnetic force *on a segment of wire* depends upon the field strength, electric *current* in the wire, length of the segment, and the angle between the segment and the field. Combine those relations into a single equation. Carefully define each symbol in that equation, *including* the one representing the proportionality constant.

2. Must the value of the proportionality constant depend on the units that you choose for the variables in this new formula? ___ What SI unit do we have already for force? _________ -for current? ________ -for length? _______ Do we already have a standard unit for magnetic field strength? ____ *If so, please name it and give the page number on which it first appeared.*

3. Recall the "F = ma" experiment on pages 47-50. After discovering that "F" is proportional to "ma", we invented a standard force unit. We chose the size of this unit to make Newton's proportionality constant exactly one, so that this important law would be simple and easy to remember:
   a. One "newton" was defined as "the amount of force needed to accelerate one ________ of matter at the rate of one ______ per _____". We recorded that "long" definition on RS___. Is it still there? __
   b. By inserting those numbers into Newton's second law we obtained a "short" version of the definition: "One newton is equal to one _________ multiplied by one ______ per ______." Is that still on RS V?

4. Now you can use similar reasoning to simplify equation 1 by inventing a much-needed SI unit for __________ ________ _________. This SI unit is named after Nicolai Tesla, who invented the modern AC electric motor and other wonders too numerous to mention. You should read his biography some day, *but you should learn to spell his name now.*
   a. One "**Tesla**" must be the amount of __________ic field required to exert a force of one ________ on one meter of wire carrying a current of one ______ in a direction _________________ to the field. *After filling in the blanks please copy this "long" definition onto RS XIV for future reference.*
   b. On page 123 you discovered a new magnetic force law. (You summarized it in #1 on this page and then simplified it by choosing units cleverly.) Now solve it for "B": **B =** _____
   c. Take the numerical values with SI units given in 4a and plug them into equation 4b to get a "short" version of the definition: **"One _________ = one _________ per _____________."**
   d. When reduced to *fundamental* units this becomes **T =** ______________. (Recorded on RS ___)

5. **Summary:** Whenever a segment of current-carrying wire is placed in a _________ic field so that it is *not* ____________ to the field, a magnetic force is exerted on the ______ by the ________ _______.
   a. The direction of that force can be predicted with a ______-hand rule in which the fingers are straight, indicating the direction of the _________ _______. The thumb indicates the direction of the _______ flow, and the _______ indicates the direction of the _________ exerted on the ______ by the ______.
   b. A copy of that hand rule has been recorded in #__ on RS ___.
   c. The strength of that force is predicted in SI units by the equation **F =** _______.
   d. In that equation the letter "B" represents__________ _______ ________, "__" represents the _________ic current in the _________, the letter "__" represents the segment's ____________, and "__" represents the angle between the _______ and the ________.
   e. Did you say which hand to use in 5a? __ In 5c did you use the improvement that we made in #4? ____
   f. A copy of 5c & 5d can be found in #___ on RS __.

* 6. Describe our simple method for measuring the strength of any magnetic field in SI units. (See 4b.) Include an *opening statement* and a step-by-step *procedure*. Don't forget the first and last steps! That procedure is an "operational definition" for magnetic field strength. Keep a copy. *Illustrate* your description by using experimental data on page 123 to calculate the strength of the field inside your coil. Also say how much *coil current* was used to generate that field. Explain your uncertainty estimate and identify the major source of uncertainty in that result.

7. A "solenoid" is a cylindrical coil of wire. In the tangent galvanometer experiment we found that the magnetic field generated by a coil is proportional to the _____ _____. (See #7 on RS XIV.)
   a. Please write that relation as an equation: **B =** _____
   b. Define the symbols in your equation, including the one representing the proportionality constant. (We call it a "coil constant" because it is likely to be different for each type of coil.)
   * c. Calculate the coil constant for your solenoid in *range* form, with SI units in simplest form. (Use #6 & 7a.) This result has been saved in # ___ on RS ___. *Did you round off properly?* ____

* 1. Draw a rectangular loop of current-carrying wire. Let "W" represent its width, and let "L" represent its length, measured vertically. Imagine electrons flowing clockwise in that loop.
  a. Suppose the loop is in a uniform magnetic field directed to your right. How can the magnetic forces acting on each side of the loop be calculated from B, I, W, and L?
  b. Describe the directions of those forces. (Note: a force with zero strength has no direction.)
  c. Find out what "torque" is. (Try using a book.) --Is there any torque exerted on the loop? ___

2. Suppose a circular loop of current-carrying wire is oriented randomly in a uniform magnetic field. The field will always try to make the loop rotate *unless* the axis of the loop is: (Choose the best)
   A. parallel to the field. B. not parallel to the field.
   C. perpendicular to the field. D. not perpendicular to the field.

3. Suppose the magnetic torque in #1 causes the loop to rotate, and that nothing impedes that motion.
  a. Which of the choices given in #2 best describes the *rotation* axis? ____
  b. The magnetic torque will cause the loop to rotate with increasing speed until the axis *of the loop* is: ____ (Choose a letter from #2.) *The axis of the loop is NOT the same as the rotation axis.*

4. What will happen after the loop reaches that orientation mentioned in 3b? *If you claim that the rotation suddenly or gradually stops, then you must explain what impacts or forces cause it to do so.*

* 5. Find out how galvanometers and electric motors work. (Use your textbook and #3 on page 126.) Explain briefly on the back of this paper.

6. We know that electric currents produce magnetic fields. We also know that a magnetic field can exert a force on a current-carrying wire. If two such wires are parallel then the field produced by one wire must exert a force on the other.
  a. Describe the direction of the magnetic force on each wire if the currents have the same direction. (Use a hand rule.)
  b. Do the same for currents in opposite (antiparallel) directions.
  c. Sketch magnetic field maps for both parallel and antiparallel currents, showing the combined magnetic fields produced by the two currents ONLY. *Use vector addition.* Remember that field lines do not intersect and do not have ends. Leave no large empty regions in your map.

7. (optional) Imagine a wooden block with two holes drilled into its top. The two holes are filled with mercury and are connected by a "U"-shaped piece of wire with its two ends dunked in the two holes. The block is placed in a strong, horizontal magnetic field. If the wire is not parallel to the field and carries an electric current there will be a magnetic force on the wire. If the force is strong enough and is directed upward, the wire will jump up out of the mercury.
  a. What information would you need in order to predict the strength of the upward force on the wire?
  b. How would you arrange the wire and the field to maximize the force?
  c. How would you make sure that the force would be upward and not downward?
  d. How would you use the information mentioned above to predict the force? (Write a formula.) _____
  e. Does the horizontal magnetic field exert forces on the vertical segments of current-carrying wire?___ If so, describe their directions and explain what effect (if any) they will have on the motion. If not, explain why not. (Use the hand rule.)
  f. What additional information would you probably need to measure in advance in order to predict how high the wire can jump? *Please define symbols to represent each of these quantities.*
  g. What well-known laws or basic principles might help you in making that prediction? ________
  h. Show how such a prediction could be made. Reduce your method to a single formula involving the letters mentioned in 7a and 7f. ___________ Do the units check? ___
  i. The jumping height is easy to measure, but the magnetic field strength is not. Show how equation 7h can be used to calculate the magnetic field strength from the jumping height and other easily measured quantities.