1. An "active" device propels electrons through a circuit. A "passive" device does *not* actively propel electrons through a circuit. For example, a _________ is a passive device. (See #6 on page 87.) The rate at which charge flows through a passive device depends on the effort with which it is pushed. *The purpose of this experiment is to explore that relationship.*
   a. The "effort" with which charge is pushed is called "___________" and can be measured with a "______meter" connected in _________with the component. (See #5 on page 85.)
   b. The "rate at which charge flows" through a device is called "electric _________".
   Such a rate can be measured with a "______meter" connected in __________ with the device.
   c. The SI unit of current is the _________, which is defined on RS IX as one _________ per sec.
   d. If the voltage across a passive component is zero then the ________ through it must be ___.
   e. Therefore a passive component's voltage vs current graph must start at the ________.
   f. "Active" is the opposite of _____ive. A _________ is an example of an "active" component.

2. Connect a light bulb and a resistor in series to an adjustable power supply. Get your plans approved, collect data and make voltage-vs-current graphs for the resistor *and* for the light bulb.

3. For obscure historical reasons, electric currents are usually represented by the letter "**I**".
   The slope of a voltage vs current graph is called "*resistance*" and is represented by the letter "**R**".
   a. ***IF*** the graph is linear then its equation is called "**Ohm's equation**": V = _____
   b. Define the symbols in your equation clearly. (Don't be vague.) *Save* 3a & 3b on RS X.
   c. The graph of _________ ________ vs ________ in #2 is described by Ohm's equation.
   d. The standard unit of resistance is the "**Ohm". *One Ohm must be one _____ per _____.***
   * e. Does Ohm's equation describe *all* circuit components correctly?_ *If not, what are its limitations?*
   f. The resistance of a perfect insulator (non-conductor) must be ______. (zero, infinite)
   g. The resistance of a perfect conductor must be ______. Does 3a contradict 3f or 3g? ___

4. Use #12 on RS IX to decide which of the following has the greatest resistance, and which has the least: (A) Two identical resistors in series (See #8 on p. 79) (B) One of those resistors used alone (C) The same two connected in parallel (like breathing through two nostrils instead of one)

5. A device in which voltage is proportional to current is called an ***ohmic device.***
   a. Which of the devices tested in #2 is ohmic? ___________ -Does 3c agree? ___
   * b. *Show* how the resistance of that device is determined in *RANGE* form. from the two straight lines on your graph, as in Ch. I and Ch. II *Use 1d, and use the Olympic Rule.*

* 6. On pages 85 and 86 you measured the current through a voltmeter. Show how one of those data sets (in SI units) is used to determine the resistance of a voltmeter with a range of 0-5 V. (See 1e on page 86.) *If necessary, repeat the measurements.* Mention which brand of voltmeter you are describing, and give the range settings on *both* meters. Remember to round off properly and to give units. Show how the percent uncertainty of the resistance is calculated. -Where will you find a copy of that resistance when you need it on page 99? ___

7. A device in which voltage is *not* proportional to current is said to be ***"non-ohmic"***.
   The *quotient* of **voltage ÷ current** in such a device is called **"STATIC RESISTANCE"**.
   The *slope of a tangent line* on a voltage vs. current graph is called **"DYNAMIC RESISTANCE"**.
   a. For which type of device (ohmic or non-ohmic) is it necessary to use those two adjectives? _____
   b. Name a familiar non-ohmic device. _________ -Copies of those definitions are on RS ___.

8. Draw a straight line on your curved graph from the origin to a distant point on the curve.
   a. The slope of that line is the "________ic resistance" of the device when it operates at that point.
   * b. Show how the *other* kind of resistance is calculated for the same point on the same graph.
   * c. Which kind of resistance is the greater for this type of component?
   d. To increase the resistor current by 1% you must __crease its voltage by __%. (See 17f on RS II.)
   e. To increase the bulb current by 1% you must __crease its voltage by roughly __%. *Use 8c!*

1. How long does it take for a 100-watt light bulb to use a penny's worth of electrical energy?

2. How high must you climb to do one kW-hr of work? -Would you climb that high for a dime?

3. Review the definition of "specific heat". Look up the specific heats and densities of aluminum, iron, and some material that is similar to common rock. For each of the following samples, figure out how much heat would be released when its temperature falls one centigrade degree.
   a. One kilogram of water
   b. One cubic centimeter of water
   c. One kilogram of iron
   d. One cubic centimeter of iron
   e. One cubic centimeter of lead
   f. One cubic centimeter of aluminum
   g. One cubic centimeter of rock

4. In a solar heating system, water is heated by sunlight. It then goes to a hot storage tank. When heat is needed, the hot water is pumped from the tank through the radiators in the house. To be effective, the tank needs to have a large "heat storage capacity", so that you can transfer a lot of heat from the tank to the house without lowering the tank's temperature very much.
   * Could we improve the tank's heat storage capacity by throwing in some chunks of rock or any other common and inexpensive solid? Explain your reasoning. *Notice that if the solid is more dense than water, you will be putting in more matter than you remove.*

5. Suppose we force electrons to move back and forth through a resistor so that the voltage vs. time graph and the current vs. time graph are both sinusoidal. (That's called "alternating current".)
   a. Figure out what the instantaneous power vs. time graph will look like.
   (You may wish to review some trigonometric identities.)
   b. Show how the average power can be calculated from the current and voltage amplitudes.

6. Suppose we want to manufacture AC voltmeters and ammeters. We want them to give readings that are proportional to voltage amplitude and to current amplitude, respectively. We also want the two proportionality constants to be equal. We don't want that constant to be equal to 1, however, because some dull-witted people may try to calculate electrical power by multiplying AC voltmeter readings by AC ammeter readings.
   a. How wrong would such a DWP be if the proportionality constants were each 1.00?
   The calculated power would be ____ times the true average power. (Explain.)
   b What proportionality constant will enable the DWP to get the correct result?
   -Each meter reading must be ____ times the amplitude.
   c. Now suppose the same DWP uses the improved meters described in 6b to measure the power delivered by a square-wave AC generator: Will the result be correct? (Explain)

7. Suppose a light bulb's voltage vs time graph is sinusoidal. Since light bulb current is NOT proportional to voltage, we know that the current vs time graph will *not* be sinusoidal.
   a. Make sketches showing approximately how the shape of the current vs time graph will differ from the shape of the V-t graph. (Use the known shape of the V-I graph as a clue.)
   b. How will the graph of instantaneous power vs time differ from the one described in 5a?
   c. Will the power formula (5b) be valid in this example? ___
   If not, will it predict a power that is too large, or too small? (Explain)

8. Actually, it takes time for a light bulb filament to heat up or to cool down. This means that at the peak of the voltage vs current graph the filament temperature is ______, (rising, falling) --so the resistance is _____ing, so the current must be _____ing. What can you conclude about the shapes of the various graphs and about the average power? *Illustrate with sketches.*

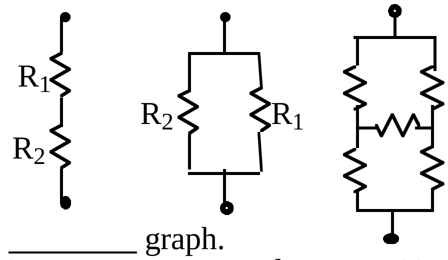
9. What is meant by "RMS voltage" and "RMS current"? What is the *product* of an RMS voltage and an RMS current? Is that true for square-wave AC as well as for sinusoidal AC?

* 10. Improving the precision of one part of an experiment usually means sacrificing the precision of some other part. With that fact in mind, explain why further improvements in the heating experiment on page 88 are not practical with existing equipment.

1. What did the graph of resistor voltage vs. current look like in the previous experiment? ___________ What name did we give to the *equation* which describes that graph? ___________ What name did we give to its *slope*? (See RS X.) _______ Did that slope change when we increased the current? _____

2. We also made a graph of light bulb voltage vs. current. Are both graphs sketched on this paper and also on your chapter review sheet? ___ Which device has a resistance that depends on current? ____

3. The diagrams at the right show three "resistor combinations". The dots at the top and bottom represent their terminals.
   a. What do you expect the voltage vs. current graph to look like for any such combination? ____________
   b. Does Ohm's equation correctly describe the behavior of a resistor combination? ____



4. The "resistance" of such a combination is the slope of its voltage vs ________ graph.
   a. Does the slope of such a graph depend on current? __ -on voltage? __ Does 4a contradict #1 or 2? ___
   b. Does the slope depend on the resistances of the resistors in the combination? _____
   c. What symbols do you expect to see in a formula for predicting the resistance of such a combination? _________ Does 4c agree with 3a? __ -with 4a? _____ -with 4b?____

5. Sketch two resistors connected in series to a battery. Label them R_1 and R_2, as in #3. Let "I_1" represent the current through R_1, let "I_2" represent the current through R_2. Let "V_1" represent the voltage across R_1, and let "V_2" represent the voltage across R_2.
   a. Modify or redraw your diagram to show the instruments necessary for measuring the voltages and currents named above. How many ammeters are really needed?____
   b. Use #5 on RS IX to show how the voltage across this series combination of resistors can be calculated from the other two voltages: $\mathbf{V_c}$ = _________.
   c. Show how the current through the combination is related to I_1 and I_2: $\mathbf{I_c}$ = _____ (Use #3 on RS IX)
   d. *Whenever* you use Ohm's equation the three subscripts must be ________. (alike, different) In *this* example Ohm's equation says: $\mathbf{V_1}$ = ______ , $\mathbf{V_2}$ = ______ , and $\mathbf{V_c}$ = _________
   e. Use 5d to eliminate the voltages from equation 5b. Then use 5c to simplify the result. You will then have a formula for the equivalent resistance of a __________ combination of two resistors in terms of the symbols mentioned in 4c. (Write an adjective into the blank.) *Saved in #___ on RS ___*

   * f. State the new formula *(NOT the old definition)* in symbols *and* in words on the back of this paper.
   g. Does 5f contradict #4c? ___ Is 5f clear and always true? ____ (If not, please rewrite it, using 5e.)

6. The resistance of a *parallel* combination is obviously ___________ than the resistance of either of its components. (See #6 on RS X.) Let's use logic similar to #5 to create a new formula for that resistance:
   a. Sketch a diagram showing R_1 and R_2 connected in parallel to a battery.
   b. How must the three currents be related in this case? $\mathbf{I_c}$ = ______, as in #3 on RS IX.
   c. How must the three voltages be related? (Use RS IX again.) $\mathbf{V_c}$ = _______
   d. What does Mr. Ohm say about the three currents? $\mathbf{I_1}$ = _____, $\mathbf{I_2}$ = _____, $\mathbf{I_c}$ = ______
   e. Use 6d to eliminate the currents from 6b.
   f. Use 6c to simplify the result. (Each symbol should appear in the equation only once.) ___ = ______
   g. Does this new formula agree with #4 on this page? ____ --with #6 on RS X? ______

   * h. Write the new formula in symbols and in words. Show that the units balance. *Saved in #___ on RS __*
   i. Does 5f contradict 6h?___ *If so, write a short essay explaining why that doesn't bother you.*

7. Summary: Only two kinds of device are correctly described by Ohm's equation: The first is __________s, as in #1. The other is __________ _____________s, as mentioned in #3.

8. One person concluded from #2 that the resistance of tungsten depends on current, and the resistance of certain other materials does not. Another person noticed that the tungsten filament in the light bulb became very hot when the current was turned on, and that its temperature changes a lot whenever the current is changed. This person concluded that the resistance of a material depends on its temperature.
   a. Could one of them be correct? ___ -Could both be correct? ___ -Could both be wrong? ___

   * b. Describe a simple experiment that shows which conclusion is correct. Give results.
   c. Is a diode an ohmic device? _____ Explain your answer by sketching a diode's voltage-current graph.