* 1. If two resistors in series carry a current, which one generates more heat: the one with greater resistance or the one with the less? Explain your answer. (Use #8 on RS X.) Also explain whether your answer would be the same for a parallel connection. Don't contradict your opening statement.

2. Suppose a battery which has internal resistance "$R_i$" is connected to a load with resistance "$R_L$".
   a. Sketch a diagram showing the internal resistance as a separate resistor as you did on page 92.
   b. Show how the current can be calculated from the emf and the R values. (Use #2 on RS X.)
   c. Show how the terminal voltage can be calculated from the emf and the R values.
   d. Show how the load power can be calculated from the emf and R values. (Use # 15 on RS IX.)
   e. The load power is equivalent to the area of a certain region on the battery's voltage-vs-current graph. Describe that region with an illustration. (Use 2d.)
   f. Sketch graphs of power vs. load resistance and power vs load current. (See #9 on page 92.)
   g. According to 2e, we can maximize the load power by adjusting the load resistance until the load voltage is ___ of the emf. (fraction) When that adjustment is made, the ratio $R_L/R_i$ must be ___.
   h. This discovery has been saved in #__ on RS___. -Do 2f & 2g contradict 2d or 2e? ___

3. A **"Short Circuit"** is a good conductor connecting the terminals of a battery or power supply.
   a. In this case the load resistance is much _____ than the internal resistance, as in # __ on page 93.
   * b. Use 2b to show (with a formula) how the short-circuit current can be estimated. Define your symbols.
   c. The terminal voltage will be approximately ___ ___. -Does this agree with #7 on page 93? ___
   * d. The battery gives energy to the electrons as they pass through it. What happens to that energy in this particular circuit, and where does that conversion take place? (See page 88 and the top of page 87.)
   e. Does 3d agree with #1 and #2 on this page? ____ -Does 3d contradict 3c? ___
   f. Do you expect the energy transformation described in 3d to occur more slowly than it does in normal use of the battery?____ -Will it be more rapid? ___ *Please explain your answer.*
   * g. Although the resistance of an ordinary piece of wire is pretty small, there are *some* sources of electrical power with much less internal resistance. (An automobile storage battery is one example.) What will happen if a short piece of ordinary wire accidentally is connected between the terminals of such a battery or power supply? *Explain how you know. Don't let 3d or 3g contradict #1.*

* 4. There are two types of safety devices commonly used in automobiles and homes to prevent the type of catastrophes described in #3. Neither device wastes a significant amount of energy. Every home and automobile is equipped with several devices of one type or the other. Name those safety devices and explain how they work. (Copy from the bottom of page 86.)

* 5. Household wiring is almost always encased in grounded metal shielding which surrounds the insulated wires. What happens if you accidentally drive a nail through a wire inside a wall? (Copy from p. 86.)

6. A 1/4-ohm resistor and a 1/5-ohm resistor are connected in parallel to a 1.5-volt cell.
   a. Use the given data with the branch point law to predict the currents expected in each of the three components. Remember to say which current goes through which component.
   b. The terminal voltage turns out to be only 1.1 V. What are the actual current values in that case?
   c. Sketch this battery's voltage vs current graph. (See #3 on RS X.) -Is the battery an "ohmic" device?
   d. Use 6b to determine the battery's internal resistance. Please *show* how your answers in 6a-6d are obtained. *Start 6d with the definition of internal resistance. Also use #3 on RS X.*

7. A certain light bulb normally operates at 100 volts and 1.0 Amp.
   a. Determine the static resistance of the bulb under those conditions.
   b. That bulb is connected to a 100-volt power source with an internal resistance roughly equal to the one in 7a. Sketch the voltage vs current graphs for the battery and light bulb (superimposed) and *show* how they are used to estimate the bulb current and voltage. (Use 1 & 3 on RS X.)

* 8. A resistor and light bulb are connected in parallel. The currents through those two devices are found to be equal. Now the voltage is decreased, causing the bulb to shine less brightly. How do the two new currents compare? Please explain with graphs, as in #7. *Label the old and new voltage and current values on the axes of your graph.*

1. Given a six-volt battery with an internal resistance of 0.20 ohms:
   a. How much current can this battery deliver to a "short" circuit?
   b. How much current will result if two such batteries are connected in series and the combination is shorted?
   c. How much current will result if the same two batteries are shorted in parallel?

2. Suppose the emf's and internal resistances of several batteries are known. The questions below will be easy *IF* you understand what those words mean. (Use reasoning similar to #1.)
   a. How can the emf and internal resistance of a series combination of batteries be predicted?
   b. How can the emf and internal resistance of a parallel combination of several identical batteries be predicted?
   c. Suppose the batteries in the parallel combination have identical emf's but have different internal resistances. How can the combination's emf and Ri be predicted?
   d. What happens when batteries with unequal emf's are connected in parallel?
   e. Why might a person want to do that?

3. A storage battery has an emf of 12 volts. When it is powering the starter of an automobile, its terminal voltage drops to 9.0 volts.
   a. What does that drop in voltage tell us about the battery?
   b. Calculate the ratio $R_i/R_L$ for this situation.
   c. If two such batteries were connected in parallel and if the starter behaved like a simple resistor, what would the new terminal voltage be? (Review #2.)
   d. What will the terminal voltage be if the two batteries are connected in series to the same load? Hint: If you were able to do 3b, then apparently you know how the resistance ratio is related to the voltage ratio. Use the new resistance ratio to calculate the new voltage ratio.

4. Derive a formula for the voltage across the starter of an automobile in terms of the battery's emf, the ratio $R_i/R_L$, and constants.

5. Suppose I have a car that is hard to start. Will it be more effective to connect an extra battery in series with the original one, or in parallel? Use #4 to show that there are *two different answers* to that question. One type of combination is best if the ratio is very small, and the other is best if the ratio is large. Also figure out what ratio is the boundary between these two cases.

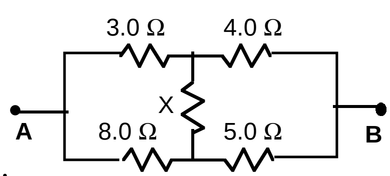
6. At 110 volts, a certain light bulb carries a current of 1.00 A. Under these conditions the dynamic resistance of the bulb is approximately twice its static resistance, as on page 90. Predict its static resistance, its dynamic resistance, and its power. *Show* how each of those quantities is calculated.

7. Suppose the voltage in #6 is raised to 117 V. Use the information given above to estimate the change in current. (It may be helpful to sketch a graph, and to review page 92b.)

8. Calculate the new current, new power, and the new static resistance in #7. Try for ±1% precision.

9. "Impedance" is sort of like resistance. The term is often used in descriptions of microphones, amplifiers, tape recorders, and loudspeakers. When two such components are to be connected, why is it important to "match" their impedances? (See 12c on RS X.) What sort of problems may be created by serious mis-matches?

* 10. Determine the resistance between terminals A and B of this combination. Do it once with x = 0 and again with x = infinity. *Show how.*
For any other x value the resistance must be between ____ and ____ __.



1. A "galvanometer" is a very sensitive ammeter. Galvanometers are named after *Luigi Galvani* (1737-1798) who is also remembered for the galvanizing process and the galvanic effect. What variable must a galvanometer's needle deflection depend on? ______

* 2. Imagine that you have found two galvanometers with no numbers on their faces. Without damaging them, how can you use batteries, wire, and resistors to determine which is more sensitive?

3. "FSD" means "full-scale deflection" or "100% deflection". If the needle on a galvanometer or any other meter moves halfway across the dial, its amount of deflection is said to be "one half of full-scale deflection", or "50% of FSD".
   * a. In descriptions of galvanometers, what is meant by ***"FSD current"*** and ***"FSD voltage"***?
   b. What do you expect a graph of galvanometer needle deflection vs current to look like?

* 4. Using 3b, write an *improved* operational definition for galvanometer sensitivity. In other words, describe a simple procedure for *measuring* the sensitivity of a galvanometer. Also give an SI unit appropriate for galvanometer sensitivity. Check your spelling and save this information on RS X.

* 5. A galvanometer or ammeter connected directly between the terminals of a battery was called a **"No-No"** or **"BOZO"** circuit on page 81. Why is it important to avoid such connections?

6. In #2 on RS IX we wrote that a voltmeter must have two properties: *Copy this onto RS X.*
   a. You decided on pages 84 & 83R that it must have a _____ resistance. (great, small)
   b. It must give readings proportional to the __________ __________ between its _________s.

7. How can we modify a galvanometer to *give* it those properties?
   We can connect a ____________ in __________ with it. (That's how voltmeters are made.)

8. On page 92 we discovered that a galvanometer can be made *less* sensitive by connecting a "shunt" in _________ with it. (That's how galvanometers are converted into ____meters.)
   a. The voltage across the shunt will then be _______ to the voltage across the __________.
   b. The ammeter current can be calculated by _____ing the galvanometer current and the _____ _____.

9. A certain ammeter has a 2.0-ohm shunt for its 0.1-amp range and a 20-ohm shunt for its 0.01-amp range. It also has scales for 10 amp, 1 amp, 10 milliamps, 1 ma, and 0.1 ma. Please show how that information is used to determine each of the following:
   a. When set on its most sensitive range, all shunts are disconnected. The FSD current is then ___ __.
   b. What percentage of the ammeter current goes through the galvanometer in that case? _____
   c. When it is set on a less-sensitive range most of the ammeter current goes through the _______. Only a tiny fraction of that ammeter current goes through the ____________ in this case.
   d. To calculate this meter's FSD voltage we must _________ that shunt current by the _________ of the shunt. Do it here. Remember to round off properly. ( _____ ___ )( _____ ___ ) = ____ volt.
   e. Using 9a, the resistance of this galvanometer must be: ( ____ ___ ) ÷ ( ____ ___ ) = _____ ohms.

10. Suppose you are given the ***conductance*** of a galvanometer and the conductance of its shunt: How did you use such information on page 92 to predict the conductance of the combination? _____ *Please answer with one verb.* This trick is recorded in #10 on the chapter___ review sheet.

11. A certain voltmeter has 5, 25, 50, 250, and 500-volt ranges. When it is set on the 5-volt range, the resistance of this voltmeter is 5000 ohms. Use scientific notation and round off properly:
    a. Calculate this meter's FSD current. ____ ____
    b. Calculate the resistance that it must have when set on its 500-volt scale. ____ ___
    c. Describe the graph of voltmeter resistance vs. range. ________ _____ _______ ____ ________
    d. Determine the slope of that graph. ( ____ ____ ) ÷ ( _____ _____ ) = ________ _______
    e. Determine the sensitivity of the galvanometer part of this voltmeter. (Use #4.) ___ ____
    f. Explain how your answers to parts "a", "d", and "e" are related.

* 12. Three measurable properties of galvanometers are mentioned above in ***boldface italics***. Describe the graph of *conductance vs. range* for the ammeter in #9 and explain *which* measurable property of the galvanometer determines the slope of that graph. Also explain how the slope is related to that property. Check units and save a copy. Use the data in #9 to illustrate and verify your answer.