1. Which requires less effort: (A) sipping soda through an ordinary soda straw, or (B) sipping soda at the same rate through a straw stuffed with cotton? ___

2. Which of the straws in #1 reqires *great effort* to use? __ Which one is *easy to use?* __ Which one *resists* the flow of fluid through it? ___ What interferes with that flow? ______

3. Suppose one person tries to blow into one end of a straw while someone else tries to blow into the other end with the same amount of effort. Will any air flow through the straw? ___

4. If the person at one end of the straw blows harder (with more pressure) than the other person, air flows through the straw from the end with the ______er pressure to the end with _______er pressure. It seems that air flow in a straw is caused by a ________ between the _______s at its ends.

5. A certain type of electrical meter is supposed to measure the *rate* at which electric charge flows through it *without interfering with that flow.*
   a. Should the resistance of this meter be great, or should it be small? ______
   b. What name have we already given to this kind of meter? ___________ (Copy from RS IX.)
   c. In what units is such a meter usually calibrated? ________ -*How* must it be connected? ________
   d. Name the quantity which it measures: ____________ (Copy from 78, 79, 80, 81, 82, or RS IX.)

6. *Another* type of electrical meter is supposed to measure *electron pressure difference* without altering that pressure difference significantly. Using RS IX, answer these questions about it:
   a. On page 83R we concluded that such a meter must have ______ resistance. (great, small)
   b. What name have we given to this kind of meter? _______
   c. In what units is this type of meter usually calibrated? ______
   d. What are two other names for "electron pressure difference"? _________ or _________ ________

Voltmeter Experiments For Beginners

FOR EACH QUESTION BELOW, YOU MUST COMPLETE FOUR STEPS:

First, you must draw circuit diagrams showing what you plan to do. (Use #6 on RS IX) -Second, you must show your plan to your teacher for approval. -Third, you must hook up the approved circuits and follow your plan. -Fourth, you must write a statement that answers the question clearly even when taken out of context, and *show it to your teacher immediately*. Each statement must have appropriate diagrams and data. Save copies for use on p. 85 & 86.

7. Measure the power supply voltage and estimate the uncertainty (SDC) of this measurement.

8. Measure the voltmeter's input and output currents in circuit #7. Remember to estimate their SDC's.
   * a. Compare the voltmeter current with the light bulb currents that you measured on page 82.
   * b. Using #12 on RS IX and #8 on page 83R, write a conclusion comparing the electrical resistance of a voltmeter to the resistance of a light bulb. *Be careful with prepositions.* (See 1b on p. 81.)

9. Draw a circuit with a resistor and light bulb connected in series to a power supply. Let "V_b" represent the battery voltage, let "V_r" represent the resistor voltage, and let "___" represent the bulb voltage.
   a. Write an equation relating the voltages across those three components. (It's easy if you understand the definition of "voltage". If you need help, use page 83R.) ___ = ___ + ___
   b. Draw three diagrams showing how to use *ONE* voltmeter to find out if your equation is correct. *Use the "voltmeter connection rule" in 6b on RS IX. Name each voltage that is being measured.*
   c. Get your plans approved. Then record the measurements (with SDCs) beside the diagrams.
   * d. If your results and your theory agree, then write a conclusion. (Describe the relationship clearly enough so that it is *always true*, even when taken out of context. Then copy it onto RS IX.)
   e. If the results do *not* agree with your theory, then find out why and explain. (First see if the voltmeter was zeroed in. Then see if a different voltmeter gives the same results.)

10. Now draw a resistor and light bulb connected in **PARALLEL** to a battery:
   * a. How must the voltages across the three devices be related? (Use the definition of "voltage" again.)
   * b. Measure the voltages across the 3 devices. *Get your plans approved first!* Record the voltages and use them to check 10a. Then *compare* the battery voltage in 10b with the one found in #7.
   c. Did you check to see if your answers to 9d and 10a are *always true*, even if taken out of context? __ If not, please clarify them so even a physics teacher will be unable to misinterpret them.

1. Draw a resistor and a light bulb connected in series to a battery. (Use the space to the right of 1b-e.) The battery current is *0.16 A*, the light bulb voltage is *3.0 V*, and the resistor voltage is *2.5 V*.
   a. Using #6 on RS IX, insert and label the three meters that could have made those measurements.
   b. Beside each meter write the appropriate reading with units. (They are *given* above.)
   c. Use #5 on RS IX to calculate this battery's voltage: **V_b =** ____ ___
   d. Use #3 on RS IX to determine the light bulb current: **I =** ____ ___
   e. Pushing electrons through this bulb requires ______ effort than pushing them through this resistor. (more, less) -That "effort" is measured with a _____meter.
   f. Which component in this circuit has the smaller resistance: the resistor, or the light bulb? __________ (See #12 on RS IX. If this is not obvious then you need page 83R.)
   g. If a modification of the bulb in this circuit caused its voltage to increase then we would have to conclude that the battery voltage ___creased OR that the resistor voltage ___creased. *Use #5 on RS IX.*

2. A different resistor and light bulb are connected in *parallel*. The current through this bulb is *0.4 A*, the resistor current is *0.25 A*, and the potential difference between the battery terminals is *6.0 V*.
   a. Diagram the circuit in the space at the right. Insert a meter for measuring the potential difference between the battery terminals and *one more meter* to measure the resistor current. *Use the connection rules.* Label the meters so we know which kind each one is.
   b. Record the given readings of the two meters beside them in the diagram, as in 1b.
   c. Use the "branch point law" (#3 on RS IX) to determine the battery current: ____ __
   d. In *this* circuit the potential difference between the light bulb terminals is ____ ____ the p.d. between the battery terminals. (less than, equal to, greater than)
   e. How much potential difference is there between the light bulb terminals? ___ ____
   f. *This* light bulb has ______er resistance than the resistor in this circuit. (greater, smaller)

3. If a great *effort* (pressure difference) produces only a small *flow* (current) through a device then we say that the device has _____ resistance. (great, small). -Does this contradict 2f, 1e or 1f above? ___ -Do all three of those answers agree with #2 on p. 84? ___ -with #8 on 83R?___ *Save #3 & 4 on RS I*X.

4. If a great current can be pushed through a device with very little effort then we say that the device has very ______ resistance. (See #8 on page 83R.) Does this contradict 1f, 2f, or #3? ___

5. What name did we give to the "effort" or "pressure difference" mentioned in 1e, 3 & 4? _________ Did we use that same name on page 83? ___ --#3 & 4 above have been recorded in #___ on RS IX.

6. Review the information about electrical meters in 5 & 6 on page 84, and in #4 above:
   a. We expect an ammeter's resistance to be _______ (great, small, unpredictable)
   b. The ammeter resistance is most easily detectable if the ammeter current is _______. (great, small)
   c. Which of the circuits on page 82 is best for detecting ammeter resistance? ______ (Use 6b, above.)
   d. According to #12 on RS IX, we should be able to detect ammeter resistance by measuring the _______ through the ________ and the ________ across the _________.
   e. Using 6c, draw a diagram or diagrams for making those measurements. Get your plan approved, and THEN make the measurements. Record the results beside your circuit diagrams, as in 1 & 2.
   * f. Near the diagram and data, write a clear and simple *conclusion*. (Using #3 or #4 with the data in 6e, write a statement comparing the ammeter's resistance with the resistances of other devices in the circuit.) If you *must* use the word "because", *try not to confuse cause with effect.*

7. When trying to measure current through a voltmeter on page 84, some students turned a knob to increase the ammeter's sensitivity. (The current was too small to measure on the 1A scale.)
   a. Please *underline* the phrase above which describes that alteration and use that clue in 7h.
   * b. Explain the meaning of "more sensitive" in this context.
   c. Draw a diagram of the circuit and ask your teacher to check it.
   d. When that alteration is made, the reading on the *voltmeter* ___creases from ____ to ____ ___.
   e. Is the power supply voltage affected by that change? ____
   * f. *SHOW* how a *second voltmeter* was used to obtain numerical evidence for 7e.
   g. Using #5 on RS IX along with the data in 7d and 7f, we must conclude that the potential difference between the *ammeter* terminals ___creased from ___ to ____ ___ when that adjustment was made.
   * h. This tells us that the ammeter's resistance depends upon some variable that you can adjust. What is the name of that variable and what have you discovered about that relation? (Use 7g & 7a.)
   i. Copy the evidence for 7h (diagrams and data) onto the back of page 86 and *also* onto RS IX.

I. Resistance In Voltmeters and Power Supplies

1. In the space at the right, draw a diagram of the circuit used on pages 84 & 85 to measure the current through a voltmeter. Write the meter readings beside the diagram, with units and SDC's. If you forgot to save the data from that experiment then get your plan checked again and repeat the measurements *now*.
   a. The ammeter was set on its 0-to- ____ ____ range. (It had to be very _______tive, as in #7 on p. 85, because the voltmeter current was very _______.)
   b. The current through the voltmeter was found to be ____ ± ____ _____.
   c. The voltmeter was set on its 0-to- ____ _____ range.
   d. The potential difference between the voltmeter terminals was ____ ± ____ ___.
   e. When these results are needed on p. 90 & 99 they will be found recorded on the _______ of RS ____.

2. If you use a reasonably sensitive ammeter to measure the voltmeter current you will notice that switching the *VOLTMETER* to a different range causes the *AMMETER* reading to change:
   a. __creasing the voltmeter sensitivity (by switching it from the ____ ___ range to the ____ ____ range) causes the ammeter reading to __crease from ___ ___ to ___ ___. *Please don't contradict 1b or 1*c.
   b. What can we conclude about voltmeter *resistance* and voltmeter *sensitivity?* (Use #12 on RS IX.)
   "____creasing the ___________ of a voltmeter causes its ___________ to ___crease."

3. When we measured the current through a voltmeter (as we did in #1a above) we found that the power supply current was very _______. (great, small) When we ___creased the power supply *current* to roughly _____ A (by connecting a resistor and light bulb in parallel, as on page 82 and in 10b on page 84) the power supply *voltage* ___creased from ____volts to _____ volts.
   a. Have you verified those measurements with your teacher present? _____
   b. If the power supply voltage changed, then it must have changed because some other measurable quantity was adjusted. We must conclude that **the *power supply voltage* depends on the *power supply* ___________, which was measured with a ____meter.**
   * c. Using 2b as a model, write a conclusion about the relationship between the two variables mentioned in 3b. Remember to use the word "causes" as we did in 2b. Try not to contradict your own data, and try not to confuse cause with effect. *Be careful with prepositions.*

4. About electrical safety and shocks:
   a. Human bodies are moderate conductors of electricity. By making my own body part of an electric circuit (using my hands as terminals) I have found that no electrical effects could be felt even at 40 volts DC, which is the highest DC voltage that our power supply can provide. I *would* feel the current if the voltage were much higher or if I used more sensitive parts of my body, such as my tongue.

   b. Using AC (current alternating at 60 cycles per second), I begin to feel a tingling sensation when the voltage is raised to about 20 volts. It becomes increasingly unpleasant as the voltage is increased and can be very dangerous at 110 volts, which is the level used in most home wiring.

   c. You get a shock only if there is an electric current through your ____. (home, wire, body) Touching only one part of a circuit is safe even at thousands of volts. Birds perched on power lines verify that fact every day. But it is unwise to rely upon that fact because you may unconsciously touch another part of the circuit, completing a path for electrons through your ____. For example if you climb the metal tower that supports the power line and try to grab one of those birds you are fried by the flow of electrons through your _____ from the wire into the grounded _________. Radiator pipes and bathtubs often function in similar fashion, because home appliances are connected to those pipes.

   d. Modern electrical appliances with moving parts have three-prong plugs. The third prong connects the metal framework of the appliance to the ground by way of the metal shielding on your home wiring. That makes it impossible for any voltage to exist between the outside of the appliance and anything else you are likely to touch. If something wears out or breaks inside, causing a "live" wire to touch the framework of the appliance, the low-resistance path to ground provided by that third prong allows a _____ (great, small) flow of electrons, blowing a ***fuse*** or causing a ***circuit breaker*** to switch off the power. That low-resistance path is called a "short circuit". The two safety devices which can shut off the power automatically when there is a short circuit are called _____s and ________ ________s.