## C. Conductance, Sensitivity, and Terminal Voltage



1. **Conductance** is defined as the *reciprocal of resistance.* Conductance is measured in "mhos".
   a. One ohm = one ____ per ____, so one mho = one ____ per ____. ("Mho" is "ohm" spelled backward.)
   b. Define a symbol to represent conductance. Then use #9 on RS X to show how the conductance of a parallel combination can be determined from the conductances of its components.
   c. Show that the units balance in your formula. Then record it on RS X.

2. To make an ammeter less sensitive we can connect a bypass or "shunt" across it. The combination can then carry a greater current than the ammeter could alone, since the ammeter itself will then carry only a fraction of the combination current. (The shunt must be connected in _________ with the meter.)
   a. To make the ammeter *half* as sensitive (doubling its range) the shunt must carry a current equal to the ammeter current. The shunt conductance must then be _______ to the conductance of the ______.
   b. If the shunt conductance is *twice* the ammeter conductance then the shunt current will be ___ times as great as the ammeter current. The *combination* current will then be ___ times the ammeter current.
   c. The shunt in 2b reduces the ammeter sensitivity to ___ of its former value because the ammeter carries only ___ of the combination current. *Put fractions into the blanks.*
   d. If the shunt conductance is *N* times the ammeter conductance then the shunt current is __ times the ammeter current and the combination current is _____ times the ammeter current.
   e. The shunt in 2d reduces the ammeter sensitivity by a factor of ____ . -Do 2b & 2c agree with this? ___

3. Example: Suppose a 0.33-ohm ammeter has a 6.0-mho piece of wire connected across it.
   a. If the ammeter reading is 0.45 amps, the combination current must be _____ _____.
   b. This shunt makes the ammeter _____ as sensitive. (Insert a fraction. *Try not to contradict #2.)*

4. To make an ammeter *one fifth* as sensitive, (increasing its range by a factor of 5) we can use a shunt which always carries ____ times as much current as the ammeter. This shunt's conductance must be ____times the __________ of the ________. -Does this contradict 2d? ___ -in 2e? ___

5. Draw two resistors connected in series to a 1.5-volt battery. Draw a box surrounding the battery and *one* of the resistors. The places where wires penetrate the box are called "terminals". Label them "A" and "B". Label the resistor inside the box as "$R_i$", and label the external one "$R_e$". Let $R_i$ = 2.5 ohms.
   a. *Choose* a value for the external resistance and show how the resistance of the combination is found.
   b. Show how the given voltage and the resistance of the combination are used to calculate the current.
   c. The "**terminal voltage**" of the box is the potential difference between terminals A and B. How must the terminal voltage be related to the voltage across the external resistor? _______
   d. Show how the current in 5b and the external resistance are used to find the terminal voltage of the box.

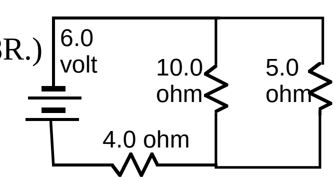
6. Increasing the resistance of $R_e$ will cause the current to ___crease and will cause the terminal voltage to ___crease. Decreasing the external resistance will cause the current to ___crease and the the terminal voltage to ___crease. Illustrate those changes by repeating #5 with very different external resistance values. Show your calculations clearly on the back of this paper. Then share your results.

7. Show (with an equation) how the terminal voltage can be calculated from the other two.

8. Use #5 & 6 to make a data table and a graph of terminal voltage vs current. Determine the slope of that graph (with units) and explain why it has that particular value. (How could we cause it to change?)

9. Use the shared data in #6 with #15 on RS IX to make a graph of the box's *output power vs current.*

10. In the circuit at the right find the wires that contain electrons at high pressure and color them red. Find the wires that contain electrons at lowest pressure and color them blue. Use another color for the wires with intermediate electron pressure. (See 78R.)




   a. Use #10 on RS X to calculate the conductance of the parallel combination.
   b. The 4.0-ohm resistor is in _________ with the first pair. (series, parallel)
   c. Use 9a on RS X to find the resistance of the three-part load.
   d. Use #2 on RS X to find the load current: **I** = ( ___ __ ) ÷ ( ___ __ ) = _______ _____
   e. The load current is the same as the battery current, which is the same as the current through the ___-ohm resistor. Calculate whatever you can from that known current and resistance: ___ = ____ ___
   f. Use #5 on RS IX to find the p.d. between the red wires and the ones with intermediate pressure.
   g. Use 10f to find the two remaining currents, and use the branch point law to check.

1. Create an equation describing the curved graph that you made on page 90. (Use the method on page 16R.) Remember to make the units balance. Also remember to give evidence in showing that your equation is correct, as explained on pages 16R and 18.

2. According to RS II, if A is proportional to $B^C$ then a one-percent increase in the value of B will cause a ___-percent increase in the value of A. For example, to increase a light bulb current by one percent we must __crease the bulb's voltage ___%. (Use #1.)

3. We can use that trick to find the slope of a tangent line on the graph of such a relation. Let ($B_1$, $A_1$) be the coordinates of a point on the graph where we want to make a tangent line. If we can calculate the coordinates of another point on the graph which is very close to the first one then we can easily find the slope of a line connecting them. If the two points are close together then the curved segment between them will be almost linear and will have nearly the same slope as the tangent line:
   a. Let $B_2$ be just 1% greater than $B_1$, so that $B_2$ = ( ______ )$B_1$. (Insert a number.)
   b. If the exponent is "3", then $A_2$ must then be ____ percent greater than $A_1$, so that $A_2$ = ( ______ )$A_1$.
   c. In that example the slope of the tangent line must be ___ times A/B.

4. Suppose a certain voltage vs current graph is shaped like a square-root curve, so that V is proportional to I to the ___ power. When the voltage across the device is 6.0 V, the current through it is 0.065 A.
   a. Using the given data calculate the static resistance of that device.
   b. Using the trick in #3, show how the dynamic resistance of this device is calculated.
   c. If we cut the voltage in *half*, the new current will then be _____ times the original current, or ___ ____. The new static resistance will be _____ ___, and the new dynamic resistance will be ____ __. *Show how those numerical values are calculated, with units.*

5. In example 4b the dynamic resistance was equal to the static resistance multiplied by __. In 4c the *new* dynamic resistance is ___ times the *new* static resistance, because the exponent in the relation was __.

6. In #1 on this page we found that a light bulb's voltage is approximately proportional to the ___ power of its current. Therefore the dynamic resistance of a light bulb must be approximately ___ times its static resistance. Does this result agree with #8 on page 90? ___ Is the ratio of dynamic resistance to static resistance the same for all other points on the graph? ___

7. In Ch. IX we found that the rate at which a device consumes electrical energy is equal to the _______ of its voltage and its current. On page 90 you discovered that a resistor voltage is equal to the product of its ___________ and the ________ through it. Write those two equations. (Use "R" to represent the resistance, and "V" and "I" to represent voltage and current.)
   a. Use the second equation to eliminate the voltage from the first equation, showing how a resistor's heating power can be calculated from its current and resistance. *Check units.* **P =** ________
   b. Increasing the resistor current by X% must cause the resistor's heating rate to ___crease by ___%. (Use #2, above.)
   c. Show how a resistor's heating rate can be calculated from its *voltage* and resistance. *Begin with the same two equations, and remember to check units.*
   d. Increasing the resistor voltage by Y% causes its *heating rate* to ___crease by ___% Does #2 agree?
   e. The two new power formulas (7a and 7c) have been saved in #___ on RS X.

8. In #1 you found that a light bulb voltage is approximately equal to some constant times the ______ of its current. Write that equation, using "k" to represent the constant: $V_b$ = ______
   a. Use the light bulb equation to eliminate the "V" from the original power formula in #7, showing how the light bulb power can be calculated from "k" and "I": P = ________
   b. Increasing the current by 0.5% causes a bulb's energy consumption rate to __crease by ___%.

9. Suppose I want to use one of the new power formulas to calculate a light bulb's power: Should I use its static resistance, or its dynamic resistance? *Explain your answer.*

1. Almost any two different conducting materials placed in an electrolyte form a "cell". Chemical reactions tend to remove electrons from one material and force them into the other until a certain potential difference is reached. The reaction cannot continue until the potential difference is reduced. The part of a circuit that is outside of the cell is called the "load". You can change the current in a cell by switching to a load with different __________. (measurable *property* that most loads have.)

2. In the experiments on page 84 (reviewed and checked in #3 on page 86) and again in #8 on page 88 we found that that ___creasing the load resistance *greatly* causes the power supply current to ___crease, and the power supply voltage to ___crease slightly. * *Give voltages, currents, and load resistances from one of those experiments as evidence. Show how the resistances are calculated.*

3. Use a voltmeter, an ammeter, and a big adjustable resistor to make a *voltage vs. current* data table and graph describing the lab power supply. Remember to get your plans approved before you begin, and to make your graph *while* the experiment is in progress. Also remember to cover a *wide* range of currents. A large team works best. Take turns making measurements. *Do not contradict #2.* __

4. A battery's "terminal voltage" is the potential difference *between its terminals.* A battery is "ideal" if its terminal voltage does *not* depend noticeably on current. *Both* definitions are on RS ___.
   a. Sketch a voltage vs. current graph describing the behavior of an *ideal* battery.
   b. How does it differ from the graph you made in #3? *-It has a different* __________.
   c. Where have we previously seen a voltage vs current graph similar to the one you made in #3? ___
   d. Does the power supply behave like an ideal battery? ____
   e. Does it behave like an ideal battery with some other familiar device connected internally? ___

5. Guess what is meant by the "internal resistance" of a cell or battery. (Clue: Its numerical value is *positive*.) If you care to, you can find out from a book if your guess was correct.

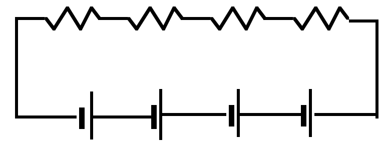
* 6. Explain how a battery's internal resistance can be determined from a graph of terminal voltage vs. current. (This "operational" definition of internal resistance is being saved on RS __.) Illustrate your explanation by using the *graph* from #3 (*NOT* the data table) to determine the internal resistance of the lab power supply in *range* form. Show clearly how the SLV & GLV are calculated in SI units.

* 7. Construct an equation to describe that same graph, using letters, not numbers. Then give the values of the constants in range form. Then use your equation to estimate (as a range) the maximum current that can be obtained from our lab power supply. *Round off properly.* In explaining your estimate, be sure to mention what load resistance would be required to obtain this current. Also mention the special name given to that kind of load. (Copy it from RS X.) *Try not to contradict your graph.*

8. In 4e we saw that a real battery behaves like an ideal battery with an internal _______ connected in _______. The voltage of the ideal part is called the cell's "electromotive force", or "emf".
   * a. How can the emf of a cell be determined from its voltage vs. current graph? *Please illustrate.*
   b. That procedure is an "operational definition" of emf. A copy has been saved on RS ___.

9. How must the terminal voltage of a cell or battery be related to its load voltage? _______ (If this is not obvious then you need to review the definition of "voltage" on page 83R.)
   * a. Sketch a graph of terminal voltage vs load resistance. (Use 6-8 on p. 92.) Show how you use such a graph to estimate a cell's emf. Then explain why emf is sometimes called "open-circuit voltage".
   b. Does a cell's emf depend on its load, as terminal voltage does? ___ -Is it a "property" of the cell? __

10. Four one-ohm resistors are connected in series with four "ideal" one-volt cells:
    a. Predict the current. (Use page 83R) **I =** ______ __
    b. What is the greatest voltage in this circuit,? _____ __
    c. Between which two points is it found? (Label them "A" and "B".)



11. Now the circuit is rearranged as in the second diagram:
    a. Is the current affected by this alteration? ____
    b. What is the greatest voltage in the circuit now? ____
    c. Between what two points is it found? _________
    d. Suppose there is a switch in the circuit: How much voltage is there between its terminals when the switch is open? _____