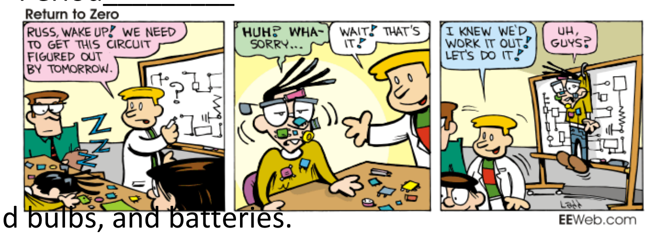
Name____________________________________
Period_________



<u>Lesson 11: Electric Circuits</u>

11.1 <u>Experiment: Conductors and Insulators</u>

For this experiment, you will need 4 wires, 2 round bulbs, and batteries.

(a) Connect the battery pack to a round bulb using a wire and connect another round bulb to the other end of the battery pack. PREDICT: What do you think will happen when the bulbs are connected by a wire?

Explain why you think this will happen.

(b) Now make the final connection. What happens? (Describe your observations)

(c) Draw a schematic diagram of your circuit.

(d) A circuit is an unbroken loop of conductors. Charge (q) can flow continuously in a circuit. If an insulator (like air) "connects" any parts of the circuit, charge will not flow easily. Design a circuit you could use to test whether objects are good conductors or good insulators. Draw your testing circuit here.

(e) Now use your circuit to test a variety of objects. Try paper, foil, the desk, your skin, *pencil lead*, a paper clip, and other items. What was a good conductor?

What was a good insulator?

11.2 Experiment: Charge Flow in Circuits

For this experiment, you will be using a compass along with your circuit from 10.1.

(a) What evidence have we seen that something (we'll call it "charge" [q]) flows through a circuit?

(b) PREDICT: Which way does the charge flow in each wire? Draw the circuit here and mark the directions with arrows on your circuit.

(c) To test this, move the circuit from the last section (10.1a) above a compass. Don't connect the compass into your circuit, just line a wire up with the needle above your compass. As you connect and disconnect the circuit, you should begin to notice something happening to the compass. What happens?

(d) Leaving everything exactly the same way on the table, reverse the battery pack and try again. What happens this time?

(e) Now move the entire circuit around, **leaving the compass in the same place**, and test each wire carefully. Write down whether the compass deflects clockwise (CW) or counterclockwise (CCW) in each case.

(f) What do your results say about the direction of flow in a circuit?

(g) Redraw the circuit and mark arrows beside each wire to show the direction of flow. Charge flows one way through a circuit. By convention, we take this direction to be out of the positive side of a battery and into the negative side.

11.3 Experiment: Charge Flow Strength & Resistors

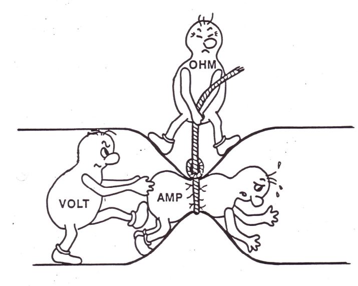
(a) Reconnect the circuit from the last experiment. Observe the bulb brightness. Now replace the round bulbs with long bulbs. How does the brightness change?

(b) How does the compass deflection change?

(c) Did charge flow at a greater rate through the round bulbs or through the long bulbs?

(d) Charge has more trouble flowing through some materials than others. This is called resistance. The more charge flow is difficult, the more the material resists it. As circuit components, these are called resistors and not all resistors are the same. Which is the stronger resistor: round bulbs or long bulbs?

How can you tell these are the stronger resistors?



11.4 Experiment: Resistors and Thickness

(a) Compare the thickness of connecting wires (W), supports inside the bulbs (S), the filament of the round bulbs (R), and the filament of the long bulbs (L). List them in order according to thickness:

CHARLIE CAMP
Automotive Technical Consultant
51 Dell Ave., Box 817
Mt. Baldy, CA 91759

THICKNESS: Thinnest _____ < _____ < _____ < _____ Thickest

(b) Now compare their ability to resist charge flow.

RESISTANCE: Lowest Resistance _____ < _____ < _____ < _____ Most Resistance

(c) Does charge flow more easily through thick or thin wires?

(d) Does charge flow more easily through long or short wires?

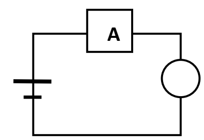
(e) If R = Resistance, ρ = resistivity (having to do with the material), A = cross-sectional area (the “thicknes”), and L = length of a resistor, complete the following equation using all 4 variables:

$$R = \rho * \frac{(\_\_\_\_\_)}{(\_\_\_\_\_)}$$

11.5 Exercise: Resistors in Series and in Parallel

(a) Connect a single round bulb in series with the battery pack (like before, but with only one bulb). Observe the brightness and describe it.

(b) Now connect an ammeter in series with the battery pack by breaking open the circuit at the battery and inserting the ammeter in between the battery and the wire. This will measure the charge flow rate (the **current**) in units of Coulombs per second, or Amperes (Amps [A] for short). How many Amps of current flow through the wire in this case?

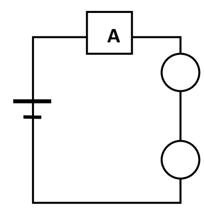


__________ A

* Note that the flow rate of charge (the current) is the ratio of how much charge flows per unit time:

$$I = q/t$$

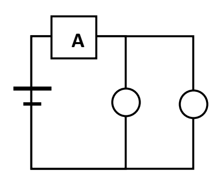
(c) Now add another bulb in series (one line) by breaking open the circuit by disconnecting a wire beside the bulb and inserting another identical bulb in there. What happened to the brightness?



What was the new flow rate in Amps?

__________ A

(d) Remove the second bulb and re-make the circuit from part (a) – the one with only one bulb in it. This time, connect the second, identical bulb in parallel with the first bulb (branching off to another path) by simply connecting both wires of the second bulb across the ends of the first bulb.
What happened to the brightness of the first bulb?



What was the new flow rate in Amps?

__________ A

(e) When adding a resistor in series, as in part (c), does the flow rate through the battery increase or decrease?

What does this say about the overall resistance when you add a resistor in *series*?

To calculate the total (equivalent) resistance of a group of resistors **in series**:

$$R_{total} = R_1 + R_2 + R_3 + ...$$

(f) When adding a resistor in parallel, as in part (d), does the flow rate through the battery increase or decrease?

What does this say about the overall resistance when you add a resistor in *parallel*?

(g) Explain how you can add a resistor to a circuit so that it decreases the overall resistance. Is this possible? [Refer to your answer to part (f)]

To calculate the total (equivalent) resistance of a group of resistors **in parallel**:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$

11.6 Series and Parallel Advantages

(a) Set up a circuit with 2 round bulbs in series. Partially unscrew one bulb and describe the results.

(b) Set up a circuit with 2 round bulbs in parallel. Partially unscrew one bulb and describe the results.

(c) Would you wire your house in series or parallel?

Why?

(d) How does this relate to Christmas lights?

11.7 Exercise: Straws and Resistors

For this exercise, we will explore resistances in series and parallel by blowing through straws and stirrers in different combinations.

(a) Blow through a straw then blow through a coffee stirrer. Which one lets more air through per second?

Which one is easier to blow through?

Which one has the smallest resistance?

Is this more like a round bulb or a long bulb?

(b) Now securely attach a straw around the back of a stirrer so that it is airtight.
PREDICT: do you think this will be easier to blow through the combination or through the straw by itself?

(c) Blow through the straw-end of the combination straw/stirrer.
Was this more like blowing through the straw by itself or the stirrer by itself?

Blow through the stirrer-end this time. Compare this to blowing through the straw-end.
Was it easier or harder this way?

(d) Compare the resistance of the combination with the resistance of a single straw. Which is greater?

(e) Compare the resistance of the combination with the resistance of a single stirrer. Which is greater?

(f) This time, place two straws side by side and blow through them that way.
Was this easier or harder to blow through than one straw by itself?

Which one lets more air through per second, the single straw or the double straw?

Which one has the smallest resistance, one straw or 2 straws side by side?

By adding the straw to the side, was it easier or harder to blow through?

Explain why adding a straw in this way makes the air flow change the way it does.

(g) Now cut a small section from the end of one straw and blow through that.
Was this easier or harder to blow through than a full-length straw?

Which one lets more air through per second, the shortened straw or the full-length straw?

Which one has the smallest resistance?

(h) When you add a straw end-to-end, the straw is effectively lengthened.
What does this do to the resistance?

What does this do to the air flow?

(i) When you add a straw side-by-side, the straw is effectively widened.
What does this do to the resistance?

What does this do to the air flow?

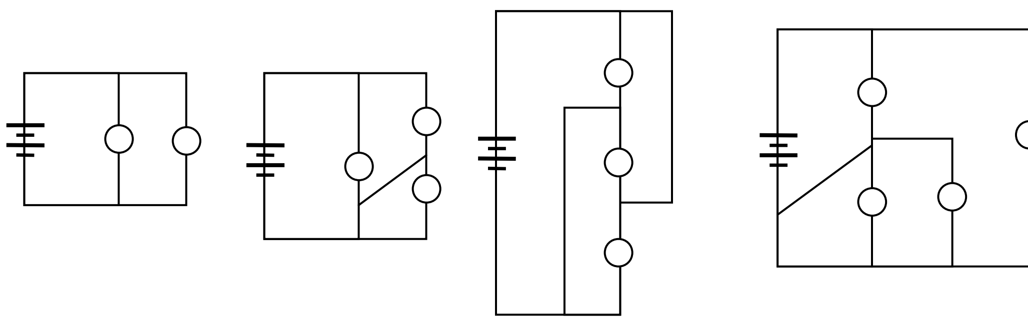
11.8 Voltage = Electric "Pressure" = Colors in a Diagram

Charge forced out the "+" side of a battery is compressed as it tries to force its way through a resistor. Once the charge gets through, the "–" side "vacuums it up", reducing the "pressure" there. This "electric pressure" concept is called Electric Potential = Voltage (measured in units of Volts [V]).

We can use colors to represent these "pressures", where red is the highest pressure in thecircuit, orange is high, yellow Is "normal", green is low, and blue is the lowest "pressure" .

The + side of the battery and the wire connected to it are always red.
The – side and its wire are always blue.
Any wire gets the same pressure (and color) as what it's connected to.
Resistors can't be colored, since they'd be "rainbowing" their way gradually from one color to the next.

(a) Using these rules, color code each circuit pictured below.

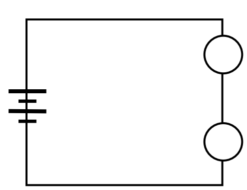


(b) Like air, charge flows from high pressure to low pressure.
Indicate with an arrow the direction charge flows through each bulb in your diagrams.

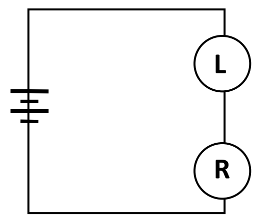
(c) You may have noticed that some bulbs in your diagram couldn't have a flow direction. That's because charge won't flow through them. They will be unlit and have zero Amps of current through them.
Why is there no flow in these cases?

11.9 Series Voltage Division

(a) As with air, the bigger the difference in pressures, the more the flow. If there are 2 equal bulbs in series, each one is half as bright as just one bulb. Therefore, it's half the difference in pressure (color) across each bulb.
Draw and color code a circuit with 2 round bulbs in series. What color should the middle wire be?



(b) Because it's just as far from red (the + side wire) to yellow as it is from blue (the – side wire) to yellow, the only way to have the same difference across each bulb is to make the middle wire yellow. Now remove one of the round bulbs and replace it with a long bulb.
Draw and color code the circuit.



(c) Which bulb was brighter?

(d) Which bulb had the biggest voltage difference (color difference) across it?

(e) Circle the correct word in the statement below:

In series, the resistor with the **greatest / least** resistance has the greatest voltage difference across it.

This is true in general for resistance values in series.

11.10 Experiment: Measuring Voltage and Current

(a) Make a circuit with one round bulb and one long bulb in series with a battery pack containing **only two batteries**.
Draw and color code this circuit.

(b) Now add a voltmeter V in series with the long bulbs. What happens to the bulbs?

(c) Draw and color code the new circuit you just made.

(d) Next, replace the voltmeter [V] with an ammeter [A]. <u>What happens to the bulbs now</u>? Compare this brightness to the brightness without the ammeter from part (a).

(e) Draw and color code this circuit.

(f) When placed in series, which had the largest voltage difference across it, the voltmeter [V] or the ammeter [A]?

(g) Which had the greatest resistance? (Hint: remember your rule for series voltage division)

(h) Which measuring device didn't change the circuit when added in series?

(i) Remake the original circuit from part (a). This time add the voltmeter [V] in parallel across the long bulb. What happens to the bulbs?

(j) Draw and color code this circuit.

(k) Now, making sure there are **<u>only two batteries</u>** in the circuit, replace the voltmeter [V] with an ammeter [A]. <u>What happens to the bulbs</u>?

(l) Draw and color code this circuit.

(m) When placed in parallel, which had the same voltage difference across it as the long bulb?

(n) Which measuring device didn't change the circuit when added in parallel?

(o) Should a measuring device change what it's measuring?

Explain.

Circle the correct words in the following statements in the next two steps:

(p)

Ammeters must be placed in **series / parallel** in order to "catch all the flow" therefore they are designed with very **high / low** resistance.

(q) Voltmeters must be placed in **series / parallel** in order to get the difference between the voltages before and after the bulb, therefore they are designed with a very **high / low** resistance.

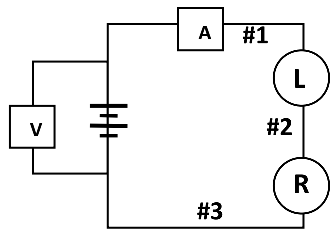
11.11 Current and Voltage in Series

For this experiment, make a circuit containing one round bulb and one long bulb in series. We will be measuring how current and voltage split up in a series circuit.

(a) PREDICT: Will there be the most charge flow (current) through the round bulb, the long bulb, or the battery?

(b) PREDICT: Will there be more voltage difference across the round bulb or the long bulb?

(c) Make the appropriate measurements to fill in the table. *Remember that the ammeter* A ***must*** *be connected in series by breaking open the circuit and inserting it between the 2 parts*.



	I (A)	ΔV (V)	I*ΔV (W)
#1 Entering L			
#2 Entering R			
#3 Through Battery			

(d) Which bulb had more current flow through it?

(e) Which bulb had more voltage across it?

Circle the correct words in the following statements in the next two steps:

(f) The **current / voltage** is always the same in all parts of a series circuit.

(g) In series, the **current / voltage** adds up to the total across the battery (the "emf" or ε).

(h) If you multiply current and voltage, you calculate the power output of the resistor in units of Joules per second or Watts [W]. This is the rate at which the energy from the battery is used. For light bulbs, energy leaves the circuit as heat and light, so it is related to bulb brightness. More power output (more Watts) means more brightness.

PREDICT: If you add up all the outputs, should they equal more or less than the input from the battery?

Why?

OHM NEVER FORGOT HIS DYING UNCLE'S ADVICE.

(i) Now try it. Add up all the outputs you measured and compare the total to the battery's output.

P_{Round} + P_{Long} = (______W) + (______W) = _________ W

$P_{battery}$ = ________W

(j) Is there a significant difference?

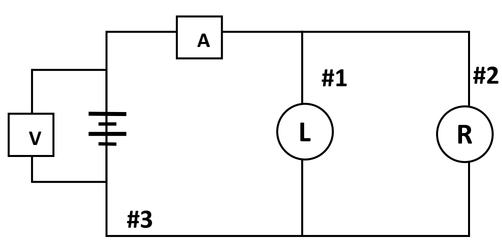
11.12 <u>Current and Voltage in Parallel</u>

This time, put the round bulb and long bulb in parallel with each other and connect the battery.

(a) PREDICT: Will there be more charge flow (current) through the round bulb, the long bulb, or the battery?

(b) PREDICT: Will there be more voltage difference across the round bulb or the long bulb?

(c) Make the appropriate measurements to fill in the table.



	I (A)	ΔV (V)	I*ΔV (W)
#1 Entering L			
#2 Entering R			
#3 Through Battery			

(d) Which bulb had more current flow through it?

(e) Which bulb had more voltage across it?

Circle the correct words in the following statements in the next two steps:

(f) The **current / voltage** is always the same across each resistor in parallel.

(g) In parallel, the **current / voltage** splits so that it adds up to the total in the branch before and after the paths split.

(h) Examine the power outputs and input column. Add up all the outputs and compare it to the input from the battery. Is there a significant difference?

(i) What physical conservation law would be violated if the outputs were different than the input?