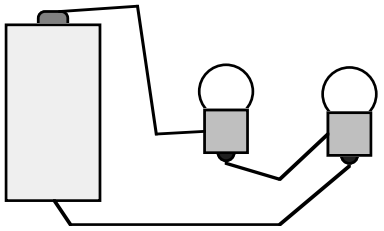
Homework III

Session III.1

1. The light bulb is a poor carrier of electricity; as such it is similar to the fluid flow restriction, like our glass capillaries.

a. Draw a fluid analogy to the following electrical circuit:



b. Given what you know about the effect of a fluid flow constriction, do you expect more or less electricity to flow than if there was a single bulb in the circuit? Consider both the case in which the pump in your fluid circuit supplies a constant pressure and the case in which it supplies a constant flow. Which way seems the best analogy for the battery? Explain your reasoning.

2. Strings of Christmas lights come in two varieties: the kind in which the whole string goes out if a single bulb fails, and the kind in which each bulb burns independently of all the others.

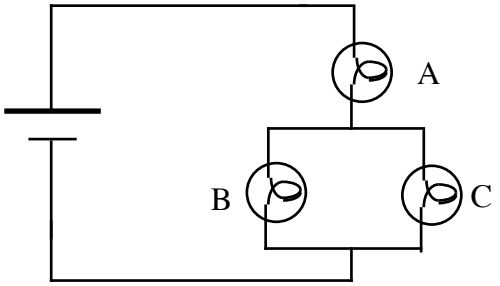
a. Design a circuit with a single battery and three bulbs in which all bulbs go out if one fails (or equivalently, is removed from its socket). You may test this in the lab if you wish.

b. Design a circuit with a single battery and three bulbs in which the two remaining bulbs stay lighted if one fails (or equivalently, is removed from its socket). You may test this in the lab if you wish.

c. Which design do you think would be cheaper to manufacture?

Session III.2

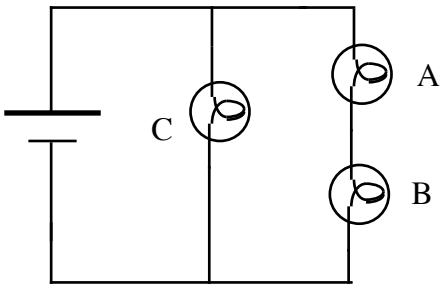
1. Consider the circuit below that you saw at the end of the last activity guide.



Assume that all the bulbs are identical. If the battery supplies a total current of 5 Amperes (the unit of electrical current), then how much current flows through each of the bulbs, A, B, and C?

2. When you use the battery on your car to start it, the battery acts in this case much like our water gun pumps--it pumps out a constant current (as much as it can) and the starter uses as much as it can get. With this in mind, if your battery is weak and you want to "jump start" your car with a second battery in addition to your original battery, which is the better way to wire that second battery relative to the original battery, series or parallel? Explain.

3. Consider the circuit below which contains three identical bulbs.



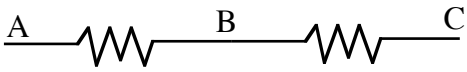
a. Rank the bulbs in order of brightness. Explain.

b. How do each of the bulb brightnesses compare to that of a single bulb run by a single battery?

Session III.3

1. A resistor with a resistance of 200 Ω has 50 mA (there are 1000 mA in an Ampere) flowing through it. What is the voltage across it?

2. Consider the resistor in problem 1. A second, identical resistor is added in series with it, and the voltage increased so as to maintain the current at 50 mA.

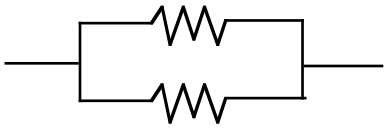


a. What is the voltage across the first resistor (i.e. voltage difference between point A and point B)?

b. What is the voltage across both resistors together (i.e. voltage difference between point A and point C)?

c. The effective resistance of a combination of resistors is the total voltage divided by the total current (Ohm's Law). What is the effective resistance of the combination of the two resistors in series?

3. a) Think about the resistor in problem 1 yet again. If we add a second resistor in parallel, each resistor has the same voltage across it as the original resistor. What is the current flowing through the second resistor? What is the total current flowing out of the battery (e. g. coming in from the far left)?



b) What is the effective resistance, as defined in probem 2c, of this combination? How would you generalize the effective resistance of any two idential resistors of resistance R in parallel with one another?

c) You saw that resistance of a Nichrome wire was proportional to its length. How do you expect the resistance to change if you double the wire's cross-sectional area? (Hint: you may consider this to be equivalent to two identical resistances in parallel.)

d) The relationships between wire dimensions and resistances alluded to in b) can be expressed mathematically as

$$R = \frac{\rho \ell}{A}.$$

where *r* is a constant for a given material known as the resistivity. The resistivity of copper is about 1.7 x 10^{-8} W m. What is the resistance of a copper wire 1 mm in diameter and 30 m in length (typical of household wiring)?