Circle your lab day and time.

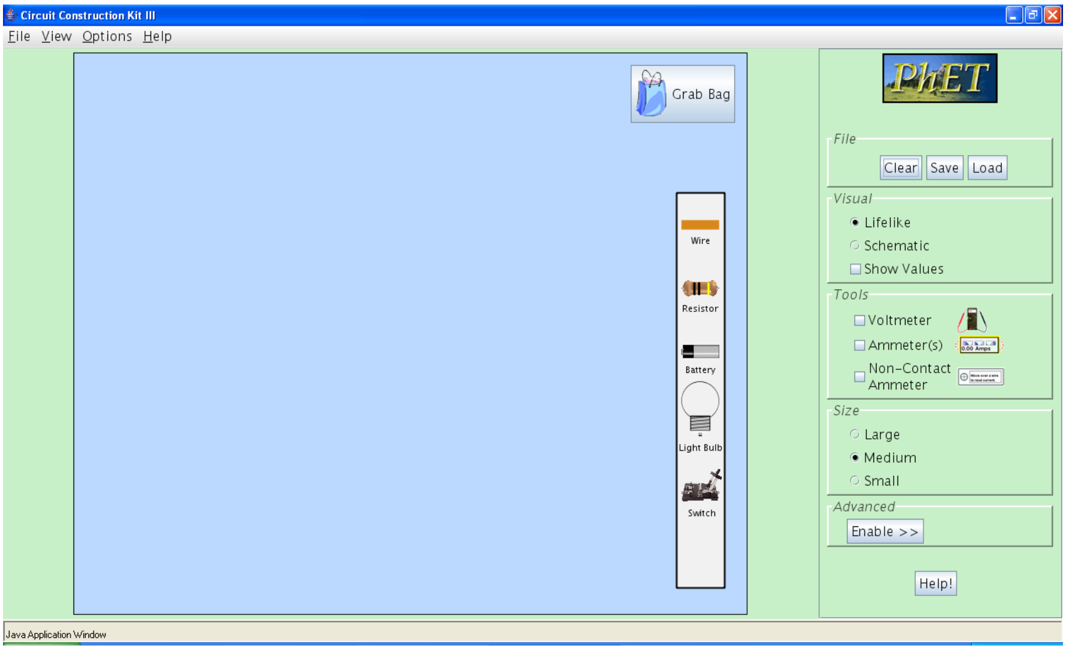
Your name: ______________________

TA name: ______________________

Mon	Tue	Wed	Thu	Fri
8-10	10-12	12-2	2-4	4-6

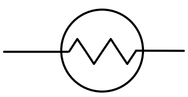
Lab 4: Current, Voltage, and the Circuit Construction Kit

The Circuit Construction Kit (CCK) is a computer simulation that allows you to build electrical circuits that behave like real circuits. We'll be using this simulation to learn more about circuits and the concepts of voltage and current. The simulation is available on the web at http://phet.colorado.edu if you'd like to try it out. Note that it can be used to solve CAPA and other physics problems.



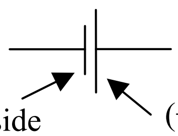
The above screenshot shows the CCK workspace. In the white box towards the right, you can find wires, resistors, batteries, light bulbs, and switches. Drag them out onto the workspace and connect them as needed. You can change the length or the orientation of a wire by dragging at its ends. The dots in the wire represent charges, and they will move to show current flow. On the far right you can find options panels and measurement tools. We'll be using the voltmeter and the ammeter in this lab. **We will *not* be using the non-contact ammeter**.

In some cases, the lab will ask you to draw a **schematic** of your circuit. By "schematic" we mean that you should use symbols to represent resistors, light bulbs, and batteries rather than literal pictures. We will be using the following symbols:


light bulb

R

resistor

battery

(–) side (+) side

PART I: Light Bulbs

1. Suppose you are given a battery, a light bulb, and a few pieces of wire. *Without* using CCK, how would you connect the light bulb to the battery to make it light up? Draw a picture showing your solution. Check your answer with your TA.

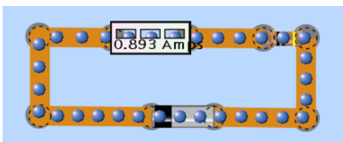
2. Now use CCK to light up one light bulb with one battery. Draw a picture of your solution.

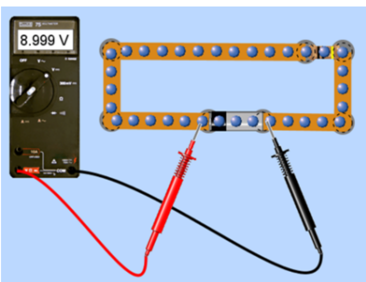
Once you've gotten it to work, compare it to your picture. Are they the same? If not, how are they different and why?

3. Next, use CCK to light up two bulbs at the same time using one battery. Try to find at least *two different* ways to make it work. Do the bulbs have the same brightness in either case? Make a schematic (symbols and whatnot) of each of your solutions.

PART II: Measuring Current and Voltage

We can measure current with a device called an **ammeter** (as shown on the right). The ammeter has to be part of the circuit for this to work; we need to hook it up so that current can come in one end and go out the other end.





We can measure voltage differences with a **voltmeter** (as shown on the left**)**. The voltmeter has a black and a red lead. To find out the voltage difference between two points on a circuit, put one lead on one point and the other lead on the other point. The voltmeter cannot be part of the circuit for it to work.

4. In CCK, set up a circuit that has one light bulb and one battery. Measure and record the current going into the light bulb and the current coming out of the light bulb.

Current going in:	Current going out:
How do these two numbers compare? Does that make sense? Why or why not?	

5. Next, measure and record the voltage difference across the light bulb. After you measure the voltage difference, swap the red and black leads (put the black lead on the point on the circuit where the red one was, and vice versa) and record the new reading.

Voltage difference:	Voltage difference (swapped):
What happened to your measurement? Why?	

6. Now measure the voltage difference across the battery. It should be slightly different from the voltage difference across the bulb.

Voltage difference:
Why is this? (This isn't necessarily something you've been taught; take your best shot.)

7. See if you can find the 'missing' voltage using your voltmeter. If you find it, say where.

PART III: Ohm's Law

Ohm's Law tells us that in most circuits, voltage, current, and resistance are related through a simple formula: $\Delta V = IR$. Let's check to make sure our simulation follows this rule. Build a circuit with one *resistor* and *one battery*. You get to choose the resistance of the resistor and the voltage of the battery. If your circuit catches fire, turn down the battery voltage until it stops burning.

8. Write down the resistance of the resistor, and then measure and record the voltage difference across the resistor and the current through the resistor.

Resistance:	Voltage difference:	Current:
Is Ohm's Law satisfied? Show your reasoning.		

9. Use Ohm's Law to figure out the default resistance of one of the CCK light bulbs. Build whatever circuit is necessary to do so. Include a schematic of your circuit with your answer.

Circuit:	Light bulb resistance:

PART IV: The Series Circuit

We've mostly been working with the simplest possible circuit so far: one with a single battery and a single light bulb or resistor. A more complicated circuit is the series circuit, which has two or more resistors in a row. If we have a few resistors in series with resistances R_1, R_2, etc, we can treat them as being equivalent to one resistor with resistance R_{eff}. Your next task is to determine the rule for how resistors in series combine. For example, if you have two resistors in series with resistances R_1 and R_2, what is R_{eff}? What if you have three resistors (R_1, R_2, R_3) in a row?

10. Build some series circuits and make whatever measurements you need to determine the rule for combining resistors in series. Draw pictures of two circuits that you used to determine the rule and then write the rule for combining resistors in series. Also write down some relevant measurements that you made and show that they obey Ohm's Law.

Circuit 1:	Circuit 2:
Rule for combining resistors in series:	

PART V: The Parallel Circuit

A circuit that has two resistors parallel (with the right and left ends connected together) is called a parallel circuit because the current can flow in two parallel paths around the circuit. If we have a few resistors in parallel with resistances R_1, R_2, etc, we can also treat them as being equivalent to one resistor with resistance R_{eff}. Your next task is to determine the rule for how resistors in parallel combine. For example, if you have two resistors in parallel with resistances R_1 and R_2, what is R_{eff}? What if you have three resistors (R_1, R_2, R_3) in parallel?

11. Build some parallel circuits and make whatever measurements you need to determine the rule for combining resistors in parallel. If you do not find the rule, discuss it with your TA. Write down the rule, and draw pictures of two circuits that you used to determine it. Also write down some relevant measurements that you made, and show that they obey Ohm's Law.

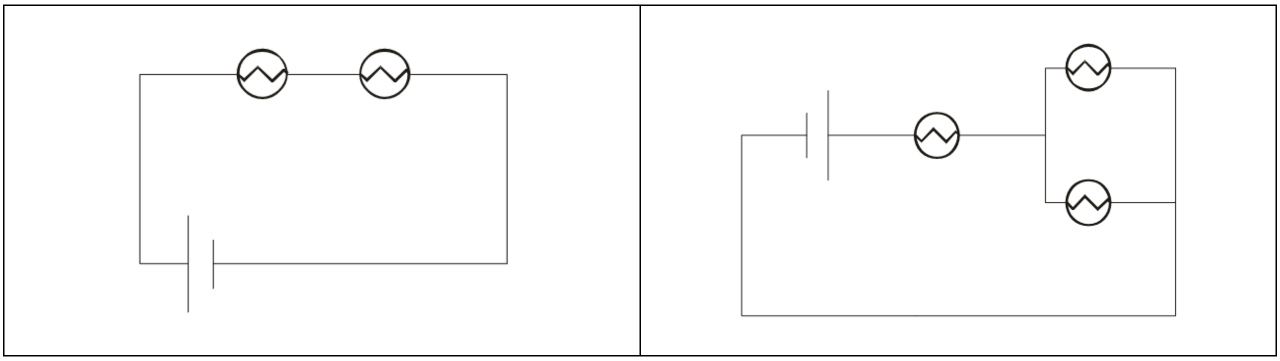
Circuit 1:	Circuit 2:
Rule for combining resistors in parallel:	

PART VI: Conservation of charge

You know already that certain quantities, like momentum and energy, are conserved. These things cannot be created from nothing or destroyed. We have also stated that charge is conserved, meaning the *net* charge (magnitude of positive charge minus magnitude of negative charge) can never be created or destroyed. Current, meanwhile, is the flow of charge through a circuit. In this section, we will examine the consequences of conservation of charge on the flow of current.

12. Suppose you have a circuit in front of you, with the opportunity to take some measurements. If charge cannot be created or destroyed, what do you think this tells us about what the current does at a junction in the circuit?

13. Build the following circuits and measure the currents through all the light bulbs and the battery. Write down on the pictures of the circuits the measurements you take. What do you notice?
(Note: Quantities like light bulb resistance and battery voltage can be adjusted in CCK. For these circuits, just use the default values.)



14. What does the conservation of charge tell us about how current behaves at a junction in a circuit?

PART VII: Changing the Voltage

15. Using one of the circuits you constructed above, add a second battery at some point in the circuit. Measure the voltage and the current in this circuit and compare your answers with the values you recorded for the original configuration. Explain the differences that you find. Experiment by inserting the battery at another point in the circuit or in the opposite direction and record what you find. (It is possible to add a battery to any branch of a series or parallel circuit, but applying Ohm's law to a parallel circuit can get complicated.)