

## Circuit Construction Kit (CCK) Lesson Plans

A series of three labs, several days of class

**Learning Goals:** Students will be able to

- Discuss basic electricity relationships: simple, series and parallel, and more complex
- Analyze the differences between real circuits and the simulated ones
- Build circuits from schematic drawings
- Use a multi-meter to take readings in circuits
- Provide reasoning to explain the measurements and relationships in circuits

**Background:** We will have studied static electricity and talked about a general model of current. We talk about using a common model where the movement of large groups of electrons is from high PE to lower PE like water falling off a cliff. We discuss that this is just a simple model to help us make sense of the relationships. I often use the analogy of students running a cross-country race with using all the energy of one energy bar. Hill height, body mass, and speed are some things that they will see effect the outcome. The three labs are guided inquiry-based to prepare the students for the text readings and subsequent word problems.

### ***Circuit Construction Kit Introduction:***

I demonstrate how to use a real multi-meter. I show a battery being measured and hold up a real resistor. For the simulation, I only demonstrate that a real wire is not linear like ones in the simulation. I have tried using all the versions of CCK and prefer the DC only version.

**For the Teacher:** Some basic skills for using CCK you might want to try these things yourself so you can help students with their difficulties:

1. Adding parts
2. Connecting parts with wires
3. Deleting wires or parts to add parts. You can't just add after the circuit is built.
4. Using the voltmeter and ammeter. The non-contact ammeter is especially handy, but the other one is realistic.
5. The difference between schematic and lifelike views. In all my student directions, I plan to use schematics.
6. Clearing the image to start something else.
7. Using high voltage on may cause the system to freeze.

**Lesson:** I have written a series of three labs for circuits. During the labs, students use both real equipment and the simulation. Sometimes, the simulation is used first to allow students to build their own ideas. Then, there are parts where they use real equipment and verify their answers with the simulation. Before the second lab, we will have a class discussion about resistance using the illustrations on our text and analogies. One analogy that I use: the students pretend they are trying to get to the office from a classroom. We talk about how hall size, distance to the office, congestion, size of students in the hall and whether or not they are moving effects the time and energy it takes to get there. (There are also versions of each activity that require only CCK)

**Post Lessons:** I use concept questions that I have written aligned with each activity. I use personal response systems throughout the unit to check for skills and use the results to identify who needs some more help.

## Some Properties of Electric Circuits (Uses CCK only )

Learning Goals: Students will be able to

- Discuss basic electricity relationships
- Build circuits from schematic drawings
- Use an ammeter and voltmeter to take readings in circuits.
- Provide reasoning to explain the measurements and relationships in circuits.

### I. Observing voltage relationships

Go to the PHeT web site and use the Circuit Construction Kit simulation (CCK). Drag out three batteries. Measure the voltage of each using the voltmeter and record the voltage in a table like the one shown. Then move the batteries end to end as below to measure combined voltage.

Battery	Voltage (V)
1	
2	
3	
1+2	
1+2+3	



$1+2$

$1+2+3$

- a. Describe the relationship between the number of batteries and the voltage and explain what you think might be happening.
- b. What could you vary to test your description about the relationship? (Right click on the batteries to change characteristics ) Run several tests recording your data in an organized table.
- c. Talk to another group about their description, tests and results. Rewrite your description to include the more broad tests.

### II. Using voltage

Use the Circuit Construction Kit simulation to build a circuit with a battery and a light bulb in the *Lifelike* visual mode.

- a. Draw what your circuit looks like.
- b. How does the voltage of the battery compare to the light bulb voltage? Explain what you think is happening.
- c. Vary the voltage of the battery and write observations about how the brightness is affected by voltage.
- d. Think about a real light bulb and battery; explain what you think is happening that causes the changes in brightness.

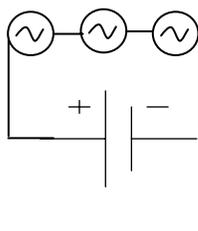
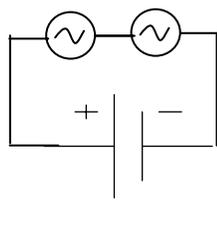
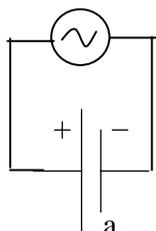
### III. Using voltage in series circuits

Use CCK to build the circuits below with a battery at about 12 volts and light bulbs. Turn on the voltmeter and ammeter to measure voltage of the battery and current into it. Record bulb brightness with descriptive language.

Figure 1

Figure 2

Figure 3



# of bulbs	Battery voltage (v)	Current into battery(A)	Brightness of bulbs
1			
2			
3			

- a. Summarize the relationships you observed and explain what you think is happening.
- b. Test to see if changing the battery voltage causes you to modify any of your conclusions. Explain what you measured and any conclusions you draw from your tests.
- c. What happens when you take a wire out of a circuit? Explain what you think is happening
- d. Test using the voltmeter or ammeter in different ways. For example: Does it matter if you take the reading on the left or right of the battery? Switch the meter ends? Describe your tests and results.

## Some Properties of Electric Circuits (Uses CCK only)

### IV. Using voltage in parallel circuits

Redo Part III but use figures 4-6 for the circuits. Make a new table and answer the questions.

Figure 4

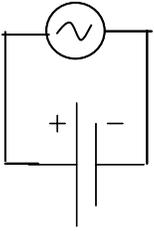


Figure 5

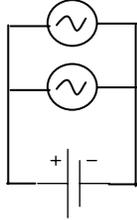
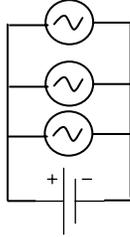
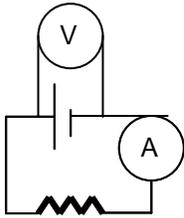


Figure 6



### V. Observing voltage and current relationships with resistors

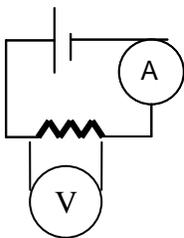
Use CCK to build the circuit below. Vary the voltage of the battery. Record the battery voltage and the current in the circuit in a table.



- Explain what might be happening to cause the change in current.
- How are current and battery voltage related? What is the shape of the graph?
- Describe how you could use the simulation to verify the relationship. Test your ideas and make modifications to your original answers if necessary. Be sure to explain your reasoning.

### VI. Observing voltage and current relationships for variable resistors.

Build the circuit below. Vary the value of resistor at least ten times. Record in a data table: resistance, current and voltage for each trial.



- Chart and determine the algebraic relationship for resistance and current.
- Chart and determine the algebraic relationship for resistance and voltage.
- Explain the relationships in terms what you think is happening in the circuit. Include how this experiment is like the one where you added light bulbs.

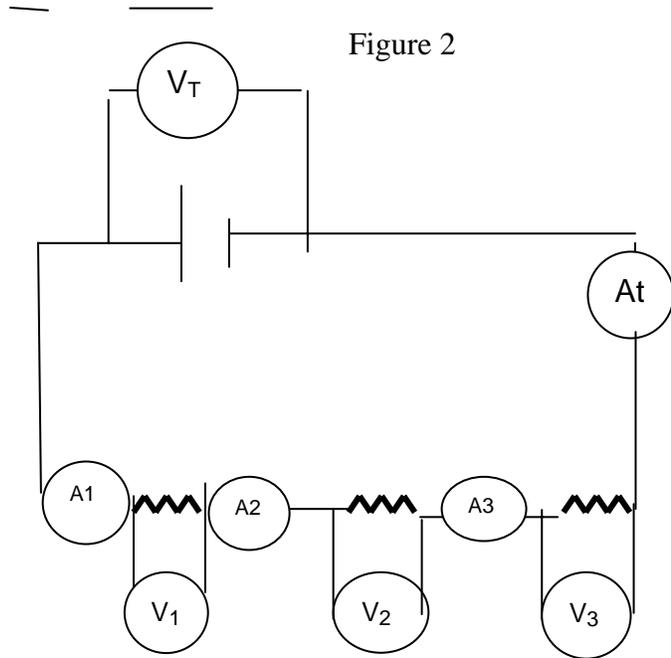
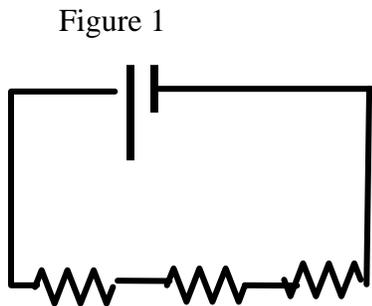
## Resistors in Series and Parallel Circuits (Using CCK simulation)

Learning Goals: Students will be able to

- Discuss basic electricity relationships in series and parallel circuits
- Build circuits from schematic drawings
- Use voltmeters and ammeters to take readings in circuits.
- Provide reasoning to explain the measurements in circuits.

### I. Series Circuit

Construct the circuit figure 1 using The Circuit Construction Kit (CCK) simulation at the PHeT site. Make the resistors have different value and record the value of each resistor. Use the ammeter moving it to take readings in the different places seen in figure 2. Then use the voltmeter to take voltage readings. Calculate R using Ohm's Law ( $V=IR$ ) for the total resistance in last column.



Resistor	Voltage(V)	Current (A)	Resistance ( $\Omega$ )
1			
2			
3			
Total	$V_T$ reading	$A_T$ reading	$R_T = V_T / I_T$

- a. How is the total resistance related to the individual resistances? Total current to the individual currents? Total voltage to the individual voltages?
- b. Write a paragraph explaining what you think is happening in series circuits to cause the above relationships to occur. (You made a similar circuit with light bulbs using CCK. You may want to experiment with the sim again, keeping in mind that light bulbs are just resistors that glow.)

## Resistors in Series and Parallel Circuits

(Using CCK simulation)

### II. Parallel Circuits

Wire the circuit in figure 1 with the same value resistors that you used in Part 1. Take readings in different places shown in figure 2 by moving the meters. Make a table like the one below, calculating total resistance using Ohm's Law ( $V=IR$ ) for the last column.

Resistor	Voltage (V)	Current(A)	Resistance( $\Omega$ )
1			
2			
3			
Total	$V_T$ reading	$A_T$ reading	$R_T=V_T/I_T$

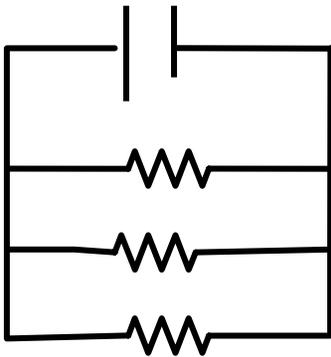


Figure 1

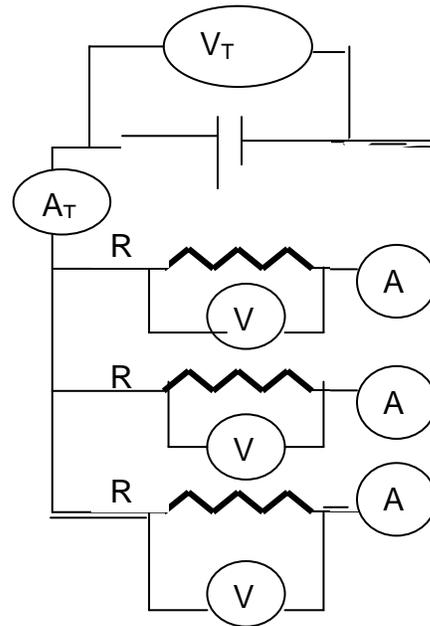


Figure 2

- How is the total resistance related to the individual resistances? Explain what you think is happening.
- Look up the mathematical relationship for finding total resistance in a parallel circuit. Show that your data fits the equation.
- Imagine you and your friends are running in the neighborhood like electrons flowing through a circuit. Make up stories that would serve as analogies for a parallel versus series circuits. Share your stories with another group and see if they make sense.
- Summarize the similarities and differences between the series and parallel circuits. Include your reasoning about what you think is happening.

## Combo Circuit Lab

(uses only CCK )

Learning Goals: Students will be able to:

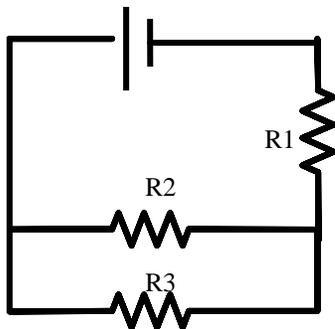
- Build combination circuits from schematic drawings,
- Provide reasoning to explain the measurements in circuits.

Procedure: Open *Circuit Construction Kit* from the PHeT web site.

1. Put three resistors on the work area. Right click on each to make the resistances different from one another. Make a data table like the one given and record the individual resistances.

2. Build the circuit given in Figure A. Make a table like the one below and complete it by measuring the voltage across each resistor and the power supply and measuring the current through each resistor and the total current coming out the power supply.

Figure A

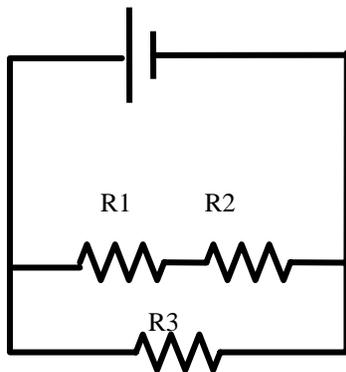


Resistor	Individual resistance (ohms)	Current (amps)	Voltage (Volts)	Resistance in the circuit (ohms) $R=V/I$
1				
2				
3				
total	(Theoretical)			

3. Provide evidence that your table information is reasonable. Write down your reasoning and show your calculations. Before you take apart your experiment, show your results to your instructor to see if they are acceptable. Credit is given only if the results are correct and your reasoning is sound.

4. Repeat the procedure with the circuit in Figure B.

Figure B



# Introduction to Properties of Electric Circuits

*This version uses some lab equipment and CCK*

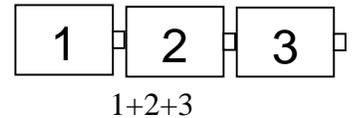
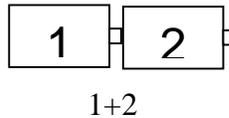
Learning Goals: Students will be able to

- Discuss basic electricity relationships
- Analyze the differences between real circuits and the simulated ones
- Build circuits from schematic drawings
- Use a multimeter to take readings in circuits.
- Provide reasoning to explain the measurements and relationships in circuits.

## I. Observing voltage relationships

Label three batteries 1, 2 and 3 with masking tape. Measure the voltage of each separately and record the real voltage in a table like the one shown. Then hold the batteries end to end as below to measure voltage for combinations.

Battery	Voltage (V) Real	Voltage (V) Simulation
1		
2		
3		
1+2		
1+2+3		



- Describe the relationship between the number of batteries and the voltage and explain what you think might be happening.
- Go to the PHeT web site and use the **Virtual lab Version** of *Circuit Construction Kit simulation (CCK)* to do the same procedure. How does the real world data differ from the simulation? Explain what might cause the differences.
- Using CCK, what could you vary to test your description about the relationship between the number of batteries and the voltage? (Right click on the batteries to change characteristics ) Run several tests, recording your data in an organized table.
- Talk to another group about their description, tests and results. Rewrite your description to include the more broad tests.
- What do you see as the benefits of using the simulation?

## II. Using voltage

Use the Circuit Construction Kit simulation to build a circuit with a battery and a light bulb in the *Lifelike* visual mode

- Draw what your circuit looks like.
- How does the voltage of the battery compare to the light bulb voltage? Explain what you think is happening.
- Vary the voltage of the battery and write observations about how the brightness is affected by voltage.
- Think about a real light bulb and battery; explain what you think is happening that causes the changes in brightness.

## Introduction to Properties of Electric Circuits

*This version uses some lab equipment and CCK*

### III. Using voltage in series circuits

Use CCK to build the circuits below with a battery at about 12 volts and light bulbs. Turn on the voltmeter and ammeter to measure voltage of the battery and current into it. Record bulb brightness with descriptive language.

Figure 1

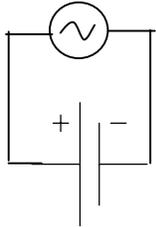


Figure 2

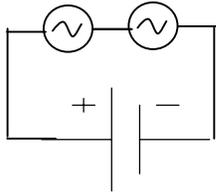
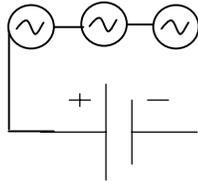


Figure 3



# of bulbs	Battery voltage (v)	Current into battery (A)	Brightness of bulbs
1			
2			
3			

- Summarize the relationships you observed and explain what you think is happening.
- Test to see if changing the battery voltage causes you to modify any of your conclusions. Explain what you measured and any conclusions you draw from your tests.
- What happens when you take a wire out of a circuit? Explain what you think is happening
- Practice using the voltmeter and ammeter in several circuits. Describe how using a voltmeter is different from using an ammeter.

### IV. Using voltage in parallel circuits

Redo Part III but use figures 4-6 for the circuits. Make a new table and answer the questions.

Figure 4

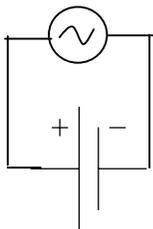


Figure 5

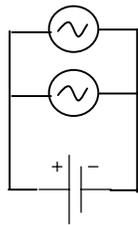
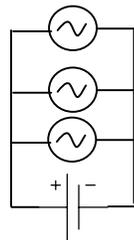


Figure 6

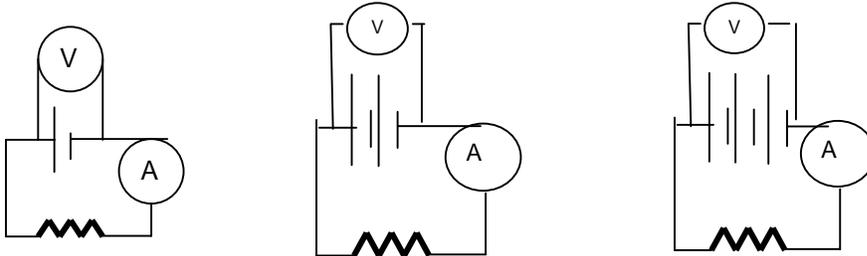


## Introduction to Properties of Electric Circuits

*This version uses some lab equipment and CCK*

### V. Observing voltage and current relationships with resistors

Get a real resistor that is less than  $100\Omega$ . Connect the following circuits without the meters. Then use one multimeter to get your readings by changing the mode and moving it. Record your data in a table like the one below.

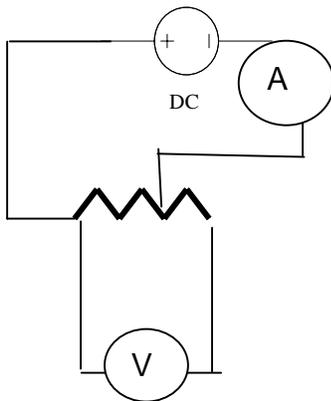


Number of batteries	Voltage (V)	Current (A)
1		
2		
3		

- Explain what might be happening to cause the change in current.
- How are current and battery voltage related? What would be the shape of the graph?
- Describe how you could use the simulation to verify the relationship. Test your ideas and make modifications to your original answers if necessary. Be sure to explain your reasoning.

### VI. Observing voltage and current relationships for variable resistors.

Use a real variable resistor connected to a power supply set on about 3 volts to make a circuit. Then use a multimeter to read the current and voltage where indicated. Vary the length of the resistor by moving the slider. Make a data table using with at least 10 lengths.



- Chart and determine the algebraic relationship with  $r^2$  for length and current.
- Describe what you think is happening within the circuit to make sense of the relationships. This experiment is similar to the one where you used CCK and varied the number of light bulbs. (*Remember light bulbs are just glowing resistors*).
- Write an error analysis in terms of precision and explain what you think could cause the variations.

## Resistors in Series and Parallel Circuits

(Using CCK and equipment)

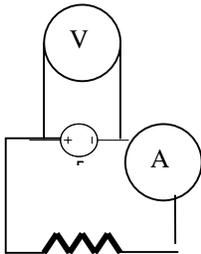
Learning Goals: Students will be able to

- Discuss basic electricity relationships in series and parallel circuits
- Analyze the differences between real circuits and the simulated ones
- Build circuits from schematic drawings
- Use a multimeter to take readings in circuits.
- Provide reasoning to explain the measurements in circuits.

I. Get three real resistors with different color codes. Label them 1,2 and 3 with masking tape.

a. Measure their resistances' with the multimeter set to ohms. Make sure there is **no** power or you will blow the meter fuse. Record the measured resistances in a table like the one below.

b. Then wire one resistor to a power supply set on about 3 volts as shown below. Measure and record the current and voltage. Calculate the resistance using  $V=IR$ . Record this in the "powered" column. Repeat with each of the other two resistors.



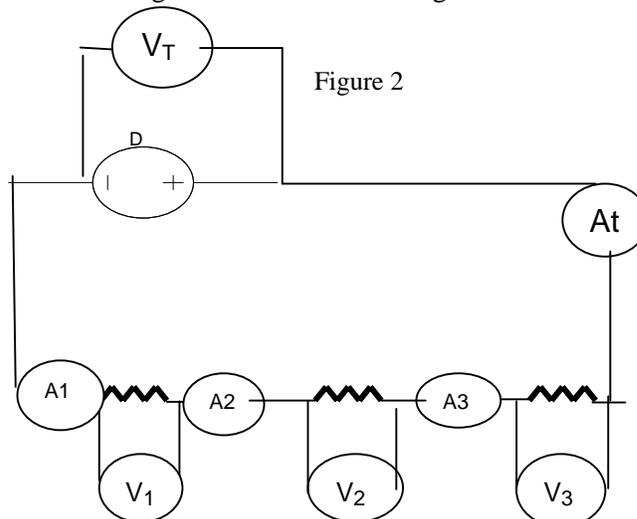
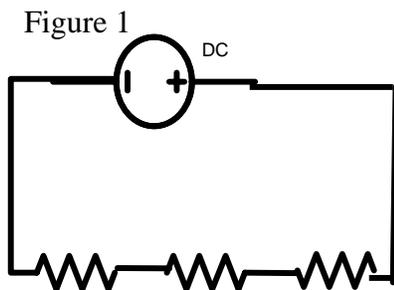
#	measured R ( $\Omega$ ) (no power)	voltage(V)	current (A)	Calculated R( $\Omega$ ) (powered)
1				
2				
3				

c. What is the relationship between the resistance without power and with? What do you think might be causing the changes in resistance?

d. Check to see how the simulation compares to reality in terms of resistance and describe your findings.

### II. Series Circuit

Wire the circuit figure 1 using the same resistors you used in part II. Use just one multimeter again, moving it to take readings in the different places seen in figure 2. Calculate R using Ohm's Law for the last column.



#	measured R ( $\Omega$ )	voltage(V)	current (A)	Calculated R( $\Omega$ ) (powered)
1				
2				
3				
Total	Not measurable	$V_T$ reading	$A_T$ reading	$R_T = V_T / I_T$

## Resistors in Series and Parallel Circuits

(Using CCK and equipment)

- a. Compare the measured resistance and resistance under power to the results from part I. Describe any differences or similarities in the relationship and explain what you think is happening.
- b. What is the relationship between the total resistance and the individual resistances? Total current and the individual currents? Total voltage and the individual voltages?
- c. Write a paragraph explaining what you think is happening in series circuits to cause the above relationships to occur. (You made a similar circuit with light bulbs using CCK. You may want to experiment with the sim again, keeping in mind that light bulbs are just resistors that glow.)

### IV. Parallel Circuits

Wire the circuit in figure 1 with the same resistors. Take readings in different places shown in figure 2 by moving the multimeter. Make a table like the one below, calculating R using Ohm's Law for the last column.

Resistor number	measured R( $\Omega$ )	Voltage (V)	Current(A)	Calculated R( $\Omega$ ) (powered)
1				
2				
3				
Total	Not measurable	$V_T$ reading	$A_T$ reading	$R_T = V_T / I_T$

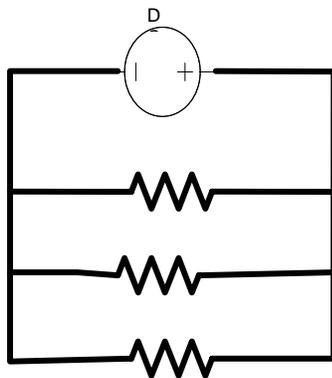


Figure 1

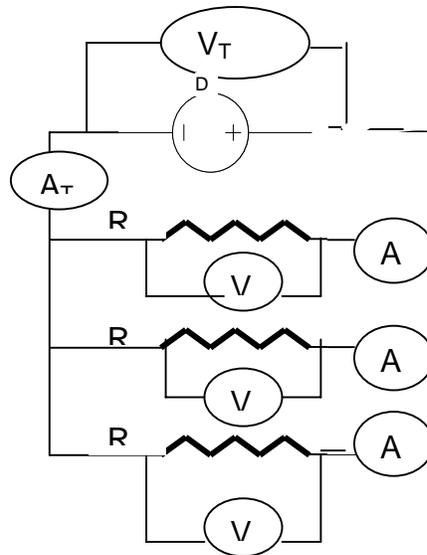


Figure 2

- a. Check your ideas about measured versus powered resistance. Explain, using the data, how your ideas are supported or need to be modified.
- b. How is the total resistance related to the individual resistances? Explain what you think is happening.
- c. Look up the mathematical relationship for finding total resistance in a parallel circuit. Show that your data fits the equation.
- d. Imagine you and your friends are running in the neighborhood like electrons flowing through a circuit. Make up stories that would serve as analogies for a parallel versus series circuits. Share your stories with another group and see if they make sense.
- e. Summarize the similarities and differences between the series and parallel circuits. Include your reasoning about what you think is happening.

## Combo Circuit Lab

(uses lab equipment and CCK)

Learning Goals: Students will be able to:

- Analyze the differences between real circuits and the ideal ones,
- Build circuits from schematic drawings,
- Use a multimeter to take readings in circuits.
- Provide reasoning to explain the measurements in circuits.

Procedure:

1. Get three different resistors under  $100\Omega$ . Make a data table like the one given.
2. Measure the dead resistances with an ohmmeter and record.
3. Build the circuit given in Figure A. Set the DC power supply on about 3.0 V. Measure the voltage across each resistor and the power supply. Also measure the current through each resistor and the total current coming out the power supply.
4. Provide evidence that your table information is reasonable. Write down your reasoning and show your calculations.
5. Use *Circuit Construction Kit* by PhET to check your values and reasoning.
6. Before you take apart your experiment, show your results to your instructor to see if they are acceptable. Credit is given only if the results have limited error and your reasoning is sound.
7. Repeat the procedure with the circuit in Figure B.

Resistor	Measured resistance (ohms)	Current (amps)	Voltage (Volts)	Resistance in the circuit (ohms) $R=V/I$
1				
2				
3				
total	(Theoretical)			

