Lab 8
Series and Parallel DC Circuits

Learning Goals:

- to explore what happens to the voltage and the current in a simple circuit composed of batteries and light bulbs arranged in series and then arranged in parallel;
- to use a voltage sensor, a current sensor, and the *DataStudio* software to measure the voltage across parts of the series and parallel circuits and a current sensor to measure the current through the circuits;
- to use Ohm's Law to predict the current through, and voltage across, bulbs connected in series and parallel.

Apparatus:

Qty	Instrument	Instrumental Error	Instrumental Resolution
1	GLX		
1	Voltage Sensor (red +; black –)	± 0.020 volts	± 0.005 volts
1	Current Sensor (yellow +; green -)	± 0.002 amperes	± 0.0005 amperes
1	AC/DC Electronics Lab		
2	"D" cell 1.5 volt	See Voltage Sensor	
2	Small alligator connectors		

Theory:

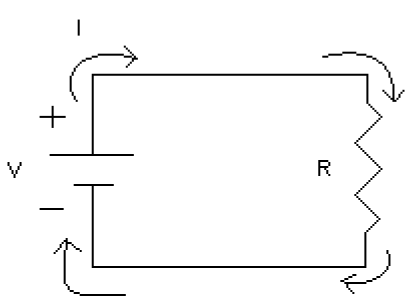
Basic Circuits

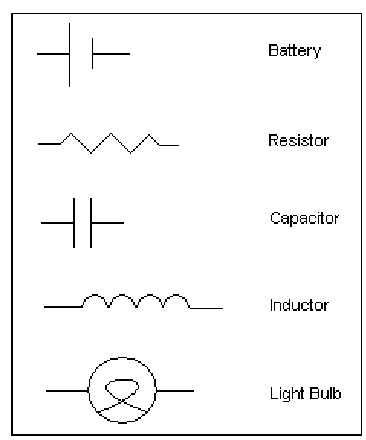
An electric circuit is closed loop of conductive material (metal wire) that connects several circuit elements together (batteries, resistors, capacitors, etc.) which produce, use, or store electrical energy. The energy flow within the circuit is represented by three main quantities. The first is *voltage*, with units of *volts* (V), which represents the difference in electric potential energy between two different points in the circuit. The second is *current*, with units of *amperes* (A), represents the movement of charge through the circuit over time. The last is *resistance*, with units of *ohms* (Ω), which is specific to resistors and represents the difficulty of charge flow through that element. These three quantities are related through *Ohm's Law*:

$$\textbf{(1)} \qquad \mathbf{V = IR}$$

where

V ≡ "voltage"
I ≡ "current"
R ≡ "resistance"





When a circuit has a constant, unchanging current, it is called a DC (Direct Current) circuit. Below is a diagram of a DC circuit with one battery and one resistor. Next to it is the key of symbols used for drawing circuits.

In this circuit, the battery on the left is called the *power source*, since it "adds" voltage, **V,** to the circuit. The resistor with resistance, **R,** is called the *load*, since it uses up all the voltage supplied by the battery. The current, **I,** flows in the direction of the arrows in the diagram, and can be found with Ohm's Law.

The resistor in the circuit above can represent anything attached to the circuit that uses up voltage, including light bulbs, toasters, televisions, or anything that requires electrical power to operate. *Electrical power*, **P,** is how much energy the resistor uses up over a finite amount time. This power will determine how bright the light bulbs burn in this lab.

$$\textbf{(2)} \qquad \mathbf{P = IV}$$

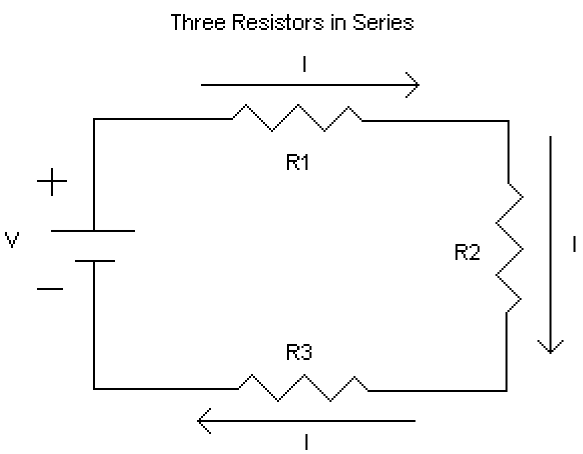
where

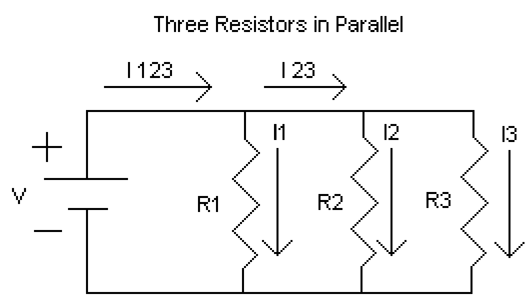
P = "power"
I = "current flowing through resistor"
V = "voltage lost across the resistor"

<u>Resistors in Series and Parallel</u>

In the above circuit, there is only one resistor. If there is more than one resistor in a circuit, how they are arranged makes a difference in how charge flows through that circuit. If several resistors are arranged in a straight line, without any splits in the wire between them, these resistors are said to be in series. If several resistors are connected to the circuit, but the wire splits into separate paths before reaching them, they are said to be in parallel. See the diagrams below that represent series and parallel circuits for three resistors.

When resistors are in <u>series</u>, <u>the current (I) flowing over each of them is the same</u>. However, the voltage





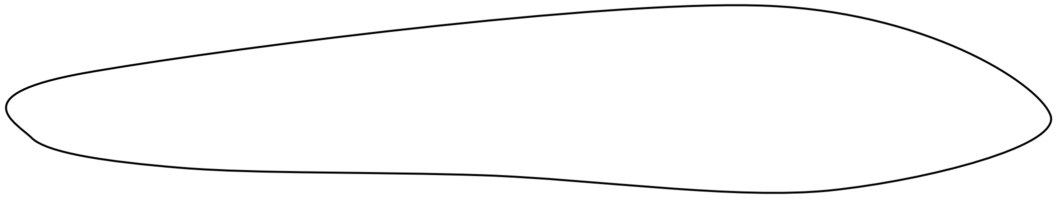
drop over each resistor may not be the same. This is because the charges have no choice but to flow through each of them in order to complete the loop back to the other end of the battery.

When the resistors are in <u>parallel</u>, however, <u>the current flowing over each resistor is different</u>. This is because the path splits before reaching the resistors, giving the charges a choice of direction to flow. If the resistances are different, so too will be the current. The voltage drop across each resistor in parallel; however, is the same.

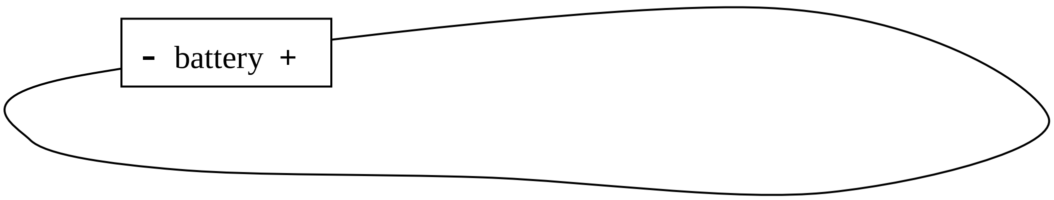
In this lab, you will be experimenting with different series and parallel configurations of light bulb resistors to determine how the current and voltage across the bulbs are affected. You can determine this by examining how bright, or dim, the bulbs become, and comparing that information with equation **(2)**.

Prelab:

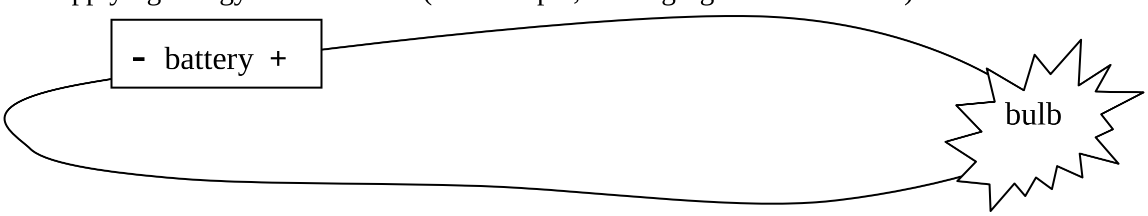
#1 Draw on the wire circuit below a set of little negatives and positives evenly distributed throughout the circuit.



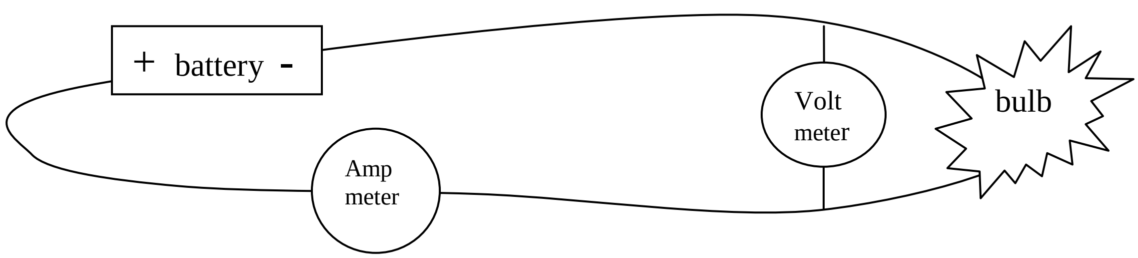
#2 Draw on the wire circuit below a set of little negatives moving through the circuit under the influence of a source of energy (for example, a battery to provide an electromotive force)



#3 Draw on the wire circuit below a set of little negatives moving through the circuit under the influence of a source of energy (for example, a battery to provide an electromotive force) and passing through a resistor (for example, a light bulb) and supplying energy to the resistor (for example, making light from the bulb)

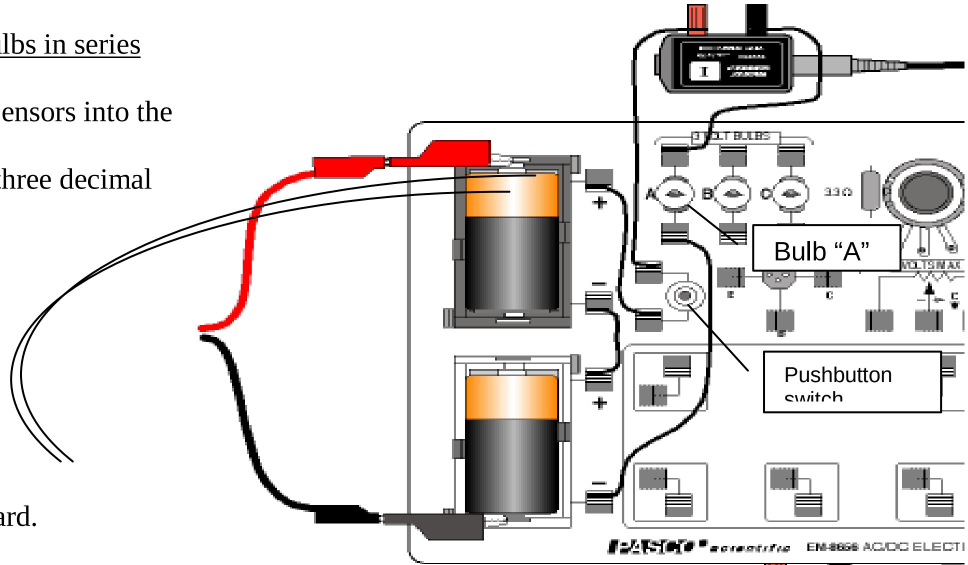


#4 Draw on the wire circuit below a set of little negatives moving through the circuit under the influence of a source of energy (for example, a battery to provide an electromotive force) and dividing so that some pass through a resistor (for example, a light bulb) and supplying energy to the resistor (for example, making light from the bulb) and some pass through a voltmeter that measures the energy supplied by each little negative. These negatives recombine and then pass through an ammeter that counts the number of little negatives that pass through it per second.



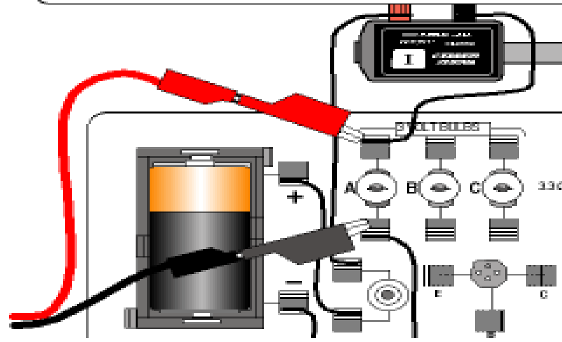
#5 True or False: The voltmeter is connected in series with the bulb and the ammeter is connected in parallel with the battery. _______.

Procedure Voltage and current for bulbs in series

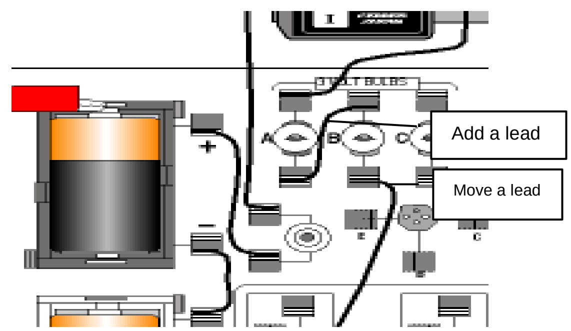


1. Connect the Voltage and Current Sensors into the GLX.
2. Set The GLX for digits display of three decimal places of both voltage and current
3. The voltage Digits display will show the voltage *across* whatever part of the circuit you select. The current Digits display will show the current *through* the circuit.

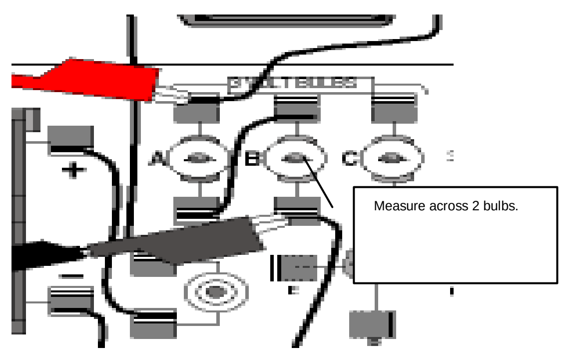
4. Insert one ‘D’ cell battery into the AC/DC Electronics Laboratory board.
5. Use wire leads to build up a circuit with the D cell, the pushbutton switch, the Current Sensor, and bulb “A” as shown.
6. Clip the leads of the Voltage Sensor to the positive and negative terminals of the battery holders as shown. *Note: The diagram is not to scale and doesn’t show the connections to the GLX.*



7. Measure the **no load voltage V’**$_S$ of the dry cell and record it in the Data Table
   Note: Data recording is easier if one person records data, a second person presses the push- button switch, and a third person handles the Voltage Sensor leads.
8. To measure current and voltage for one bulb, press and hold the pushbutton switch.
   Observe bulb “A” and the Digits displays of Voltage and Current.

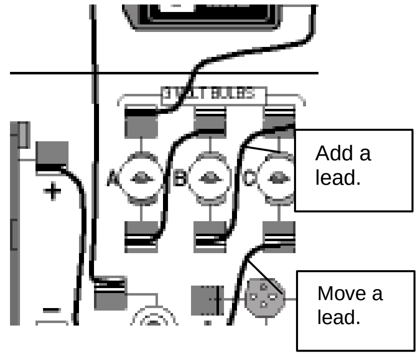


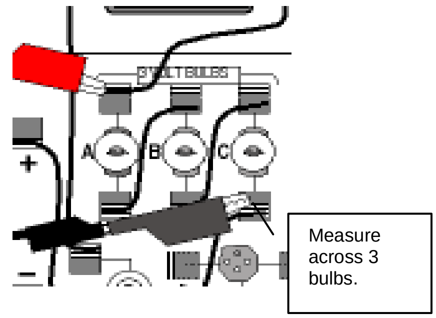
9. Record the values of voltage *across* the voltage source (D cells) and current *through* the circuit in the Data section.
10. Move the Voltage Sensor leads to the spring clips on either side of bulb “A” and record the voltage *across* the light bulb in the Data Table.
11. Release the pushbutton switch.
12. Repeat procedures 8-11 for bulb B
13. Repeat procedures 8-11 for bulb C
14. Study Two Bulbs in Series. Change the circuit to add bulb “B” in series. Move the wire lead from the negative terminal of the battery holder to the spring clip below bulb “B”. Add a wire lead from the spring clip below bulb “A” to the spring clip above bulb “B” as shown.



15. Press and hold the pushbutton switch.
16. Record in the data section the values of voltage *across* the voltage source (D cells) and current *through* the circuit with two bulbs in series.
17. Move the Voltage Sensor leads to the spring clips on either side of bulb “A” and record the

voltage *across* bulb “A” as before.
18. Move the Voltage Sensor leads to the spring clips on either side of bulb “B” and record the voltage *across* bulb B.
19. Move the sensor leads so one is on the clip above bulb “A” and the other is on the clip below bulb “B” and record the voltage *across both bulbs.*
20. Release the pushbutton switch.
21. Study three Bulbs in Series. Change the circuit to add bulb “C” in series. Move the wire lead from the negative terminal of the battery holder to the spring clip below bulb “C”.
22. Add a wire lead from the spring clip below bulb “B” to the spring clip above bulb “C” as shown.
23. Press and hold the pushbutton switch.
24. Record in the Data section the values of voltage *across* the voltage source (D cells) and current *through* the circuit with three bulbs in series.
25. Move the Voltage Sensor leads to the spring clips on either side of bulb “A” and record the voltage *across* bulb “A” as before. Move the leads and measure the voltage across bulb “B”. Move the leads and measure the voltage across bulb “C”.
26. Next, move the sensor leads so one is on the spring clip above bulb “A” and the other is on the spring clip below bulb “C” and record the voltage *across three bulbs.*
27. Unscrew any one of the three bulbs and record what happens to the other two bulbs and record the observation in the Data section.
28. Screw the bulb back into its socket.
29. Release the pushbutton switch.





Data Voltage and current for bulbs in series . (record in notebook)

Answers to two predictions: use complete sentences ________________________________.

Voltage and Current for Single Bulbs	Leave blank	**Voltage and Current for Bulbs in Series**	Leave Blank
One Bulb	Leave blank	**Two Bulbs in Series**	Leave blank
Voltage **V'_S** across voltage source with no load	volts	Voltage **V'_S** across voltage source with no load	volts
Voltage **V_S** across voltage source connected to bulb A	volts	Voltage **V_S** across voltage source connected to bulbs A and B	volts
Current through circuit: **I**	amps	Current through circuit: **I**	amps
Voltage across bulb “A” **V_A**	volts	Voltage across bulb “A” **V_A**	volts
One Bulb	Leave blank	Voltage across bulb “B” **V_B**	volts
Voltage **V'_S** across voltage source with no load	volts	Voltage across A and B **V_{AB}**	volts
Voltage **V_S** across voltage source connected to bulb B	volts	Leave blank	Leave blank
Current through circuit: **I**	amps	**Three Bulbs in Series**	Leave blank
Voltage across bulb “B” **V_B**	volts	Voltage **V_S** across voltage source	volts
One Bulb	Leave blank	Current through circuit: **I**	amps
Voltage **V'_S** across voltage source with no load	volts	Leave blank	Leave blank
Voltage **V_S** across voltage source connected to bulb C	volts	Voltage across bulb “A” **V_A**	volts
Current through circuit: **I**	amps	Voltage across bulb “B” **V_B**	volts
Voltage across bulb “C” **V_C**	volts	Voltage across bulb “C” **V_C**	volts
Leave blank	Leave blank	Voltage across bulbs A to C **V_{ABC}**	volts

Calculations Voltage and current for bulbs in series .

1. Calculate the resistance of bulb A using $R_A = V_A/I$, of bulb B using $R_B = V_B/I$, of bulb C using $R_C = V_C/I$
2. Calculate the total resistance of three bulbs in series using $R_t = R_A + R_B + R_C$.
3. Calculate the theoretical value of the current through each bulb with the bulb and source connected using $I = V_S/R_*$
4. Calculate the theoretical value of the circuit current with the bulbs and source connected using $I = V_S/R_t$

Calculation Results Voltage and current for bulbs in series (record in notebook)

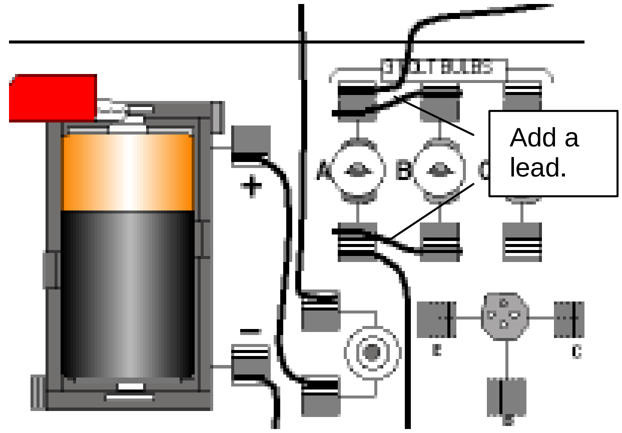
Calculated Resistance	Leave blank	**Calculated Series Resistance**	Leave Blank
One Bulb	Leave blank	**Two Bulbs in Series**	Leave blank
R_A	ohms	$R_t = R_A + R_B$	ohms
R_B	ohms	**Calculated Current** $I = V_S/R_t$	amps
R_C	ohms	**Three Bulbs in Series**	Leave blank
Leave blank	Leave blank	$R_t = R_A + R_B + R_C$	ohms
Calculated Current	Leave blank	**Calculated Current** $I = V_S/R_t$	amps
$I_A = V_S/R_A$	amps	$I = V_S/R_t$	amps
$I_B = V_S/R_B$	amps	Leave blank	Leave blank
$I_C = V_S/R_A$	amps	Leave blank	Leave blank

Analysis Voltage and current for bulbs in series . (use complete sentences) (record in notebook)

1. What happens to the rest of the bulbs in the *series* circuit of three bulbs if one bulb is removed? ____.
2. What happens to the voltage across the voltage source as more bulbs are added in a series circuit? .
3. How did your calculated (theoretical) value for current through the bulbs in series compare to the actual (measured) value for current? ______________________________.
4. Calculated resistance of bulb A ______ohms, of bulb B ____ohms , of bulb C ____ohms
5. Calculated total resistance of three bulbs in series using $R_t = R_A + R_B + R_C$. Ans.: ___________ohms
6. Calculated theoretical value of the circuit current using $I = V_S/R_t$ Ans.: _____amps

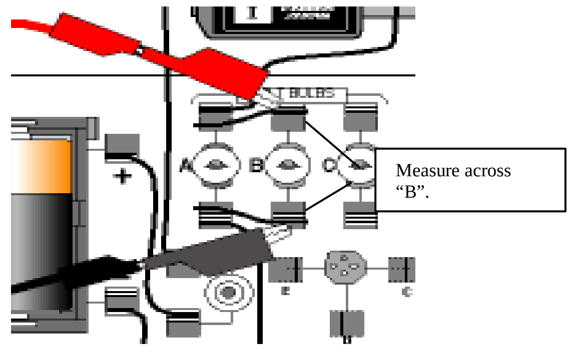
Procedure Part II Measure voltage and current for bulbs in parallel.

33. To study two bulbs in parallel, return the AC/DC laboratory board to the way it was at the beginning of Procedure 4 except that two dry cells are to be connected to each other in series. Measure the no load voltage of the two cells and record it in the Data Table.

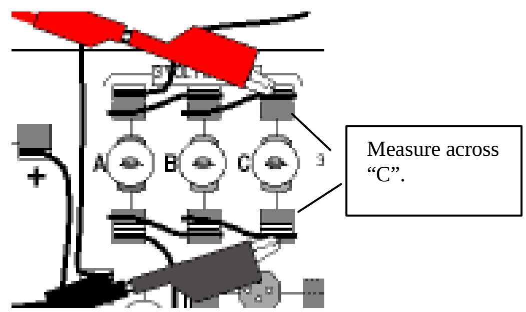


Note: The measurements of voltage and current for one bulb in parallel are the same as the measurements for one bulb in series. Use the values calculated in Data Table Part I B for R_A and R_B and R_C and record them in Data Table N below.

34. Change the circuit to add bulb “B” in parallel to bulb “A”. Add a wire lead from the spring clip above bulb “A” to the spring clip above bulb “B” as shown.
35. Add a second wire lead from the spring clip below bulb “A” to the spring clip below bulb “B”.



36. Press and hold the pushbutton switch.
37. Record the values of voltage *across* the voltage source (V_S) and current *through* the circuit (I) with two bulbs in parallel in the Data Section..
38. Move the Voltage Sensor leads to the spring clips on either side of bulb “B” and record the voltage *across* bulb “B” as before.
39. Release the pushbutton switch.
40. To study three Bulbs in parallel, change the circuit to add bulb “C” in parallel to the other bulbs. Add a wire lead from the spring clip above bulb “B” to the spring clip above bulb “C”. Add a second wire lead from the spring clip below bulb “B” to the spring clip below bulb “C”.



41. Press and hold the pushbutton switch.
42. Record the values of voltage *across* the voltage source (D cells) and current *through* the circuit with three bulbs in parallel.
43. Move the Voltage Sensor leads to the spring clips on either side of bulb “B” and record the voltage *across* bulb “B” as before. Move the leads to the spring clips on either side of bulb “C” and record the voltage *across* bulb“C”.
44. Unscrew any one of the three bulbs and record what happens to the other two bulbs. Screw the bulb back into its socket. Release the pushbutton switch. Click ‘Stop’ in *DataStudio*.
45. Recall the resistances of bulbs A, B, and C from Data E and record them in the table N below.
46. Calculate the total resistance of three bulbs in parallel using $1/R_t = 1/R_A + 1/R_B + 1/R_C$. Assume each bulb has the same resistance.
47. Calculate the total current through the circuit usintg $I = V_s/R_t$

Data Measure voltage and current for bulbs in parallel. (use complete sentences) (record in notebook)

1. If one bulb in a parallel circuit of many bulbs is removed, what happens to the rest of the bulbs?____.
2. What happens to the *voltage* across the voltage source change as more light bulbs are added in a parallel circuit? ____.
3. What happens to the *voltages* across the light bulbs in a parallel circuit change as more light bulbs are added to the circuit? ____.
4. What happens to the *current* through a parallel circuit change as more light bulbs are

added in parallel? ____.

5. What happens to the *brightness* of each bulb in a parallel circuit as more bulbs are added?
____.

6. What happens in the parallel circuit of three bulbs if one bulb is removed? _________.
7. What happens to the *current* through a series circuit change as more light bulbs are added in series? ____.
8. How did your calculated (theoretical) value for current through the resistors compare to the actual (measured) value for current?_______________________________________.

9**.** Table (record in notebook)

Voltage and Current for Bulbs in Parallel	
Resistance of Single bulbs	
R_A = ohms, R_B = ohms, R_C = ohms	
Two Bulbs in Parallel	
Item	**Value**
Voltage across voltage source with no load: **V'_S**	Volts
Voltage across voltage source connected to bulbs A and B: **V_S**	Volts
Current through circuit: **I_S**	Amps
Voltage across bulb "A" **V_A**	Volts
Voltage across bulb "B" **V_B**	Volts
Voltage across A and B **V_{AB}**	Volts
Total resistance of two bulbs in parallel **R_t**	Ohms
Theoretical value of current in circuit **$I = V_S / R_t$**	Amps
Three Bulbs in Parallel	
Item	**Value**
Voltage across voltage source with no load: **V'_S**	Volts
Voltage across voltage source connected to bulbs A, B and C: **V_S**	Volts
Current through circuit: **I_S**	Amps
Voltage across bulb "A" **V_A**	Volts
Voltage across bulb "B" **V_B**	Volts
Voltage across bulb "C" **V_C**	Volts
Voltage across A to C **V_{ABC}**	Volts
Total resistance of three bulbs in parallel **R_t**	Ohms
Theoretical value of current in circuit **$I = V_S / R_t$**	Amps

Part III Using the oscilloscope (demonstration)
Procedure

48. Use the voltage sensor to measure the voltage across the battery with no bulbs attached to it. Use the oscilloscope instead of the GLX voltage sensor to measure the voltage across the battery with no bulbs attached to it.
49. Compare the voltage value measured by the GLX with the voltage measured by the oscilloscope in procedure 7 and comment on the findings in the data table below.

Part III
Data (record in notebook) Findings: ____.