Lab Experiment 3

Voltage and Current Measurement

Part 1 – Voltage and Current

A basic electric circuit is built of a source, such as a battery, a switch, interconnection wires, and a load, such as a lamp. When the electric circuit is built and the switch is closed, flow of charges will travel in a closed path causing the light of the lamp to come on. These flow of electrons are known as electric currents. Electric currents has **magnitude** and **direction**. The magnitude and direction of each current is a measurable fact using an ammeter. Even ammeters are available as individual instruments, they are combined instruments called Multimeter or Volt-Ohm-Milliammeter, VOM. Figure 3.1 shows both digital and analog multimeters. Digital multimeter uses a numerical readout, while analog multimeter uses a needle pointer to indicate the measure values.

Figure 3.1 – Digital and Analog multimeter

How to set the multimeter to measure voltage and current

How to measure voltage?

Before placing the testing probes in the circuit to measure voltage, you have to set your multimeter to measure voltage. To set up the multimeter, make sure that the red probe is connected to the **VΩmA** socket and the black probe to the **COM** socket.

To measure a dc quantity, set the measure dial to the desired dc voltage range V⎓. For example, if you are measuring no more than 9 V, you can set the measure dial to 20 V dc volts. But if you want to measure 9 V and you set the measure dial to 2 V, the multimeter will show an Over Load message, why? Because the voltage range in the multimeter presents the highest measurable voltage. That is why, if the measure dial is selected to 2 dc V, then the highest voltage that you can measure is 2 dc V.

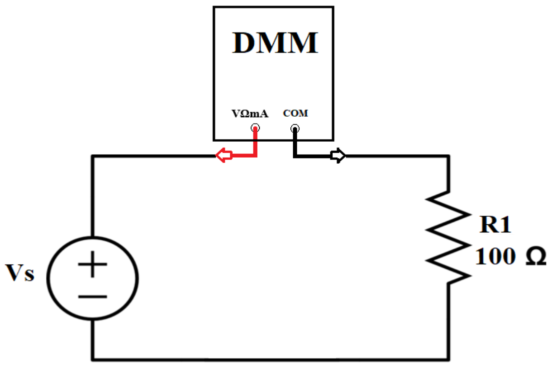
Once the multimeter is set up to measure voltage, the next step is to measure the voltage across a component in the circuit. Once the circuit is power, you can place the multimeter leads across the component whose voltage you want to measure.

This technique is applied because voltage is the potential difference between two points. It is also good to remember that to measure the voltage across a component, the multimeter has to be in ***parallel*** to the measure component.

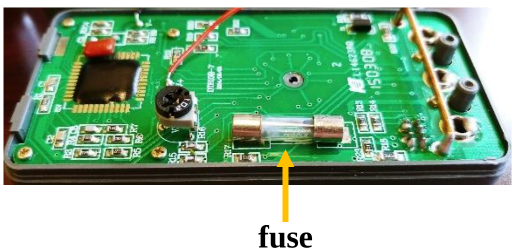
How to measure current?

Measuring current is more complicated than measuring resistance or voltage. There are two main reasons for this:

1. *The connection of the multimeter with the measure component. In* order for the multimeter to measure the current through a component, the multimeter has to be connected with the measure component in a way that the current can go through the multimeter and the component. This means that the multimeter must be made part of the current path of the circuit. In order to make the multimeter part of the current path of the circuit, the original circuit must be "broken" and the meter connected across the two points of the open break. When the multimeter is part of the open break, the multimeter is connected in ***series*** with the measure component.



2. The fuse of the multimeter. One of the most common mistakes with the use of the multimeter to measure current is to connect the probes in parallel with the measure component. This will immediately short power to ground through the multimeter causing the power supply current going through the multimeter. As the current rushes through the multimeter, the internal fuse will heat up and then burn out as 200 mA flows through it.[1]
Remember that a fuse is a safety device consisting of a strip of wire that melts and breaks if the current exceeds a safe level. A fuse that is burned becomes an open circuit in an electric circuit.



[1] *How to Use a Multimeter*, https://learn.sparkfun.com/tutorials/how-to-use-a-multimeter/fuse, retrieve on 8/16/18

Lab Experiment Procedure

Part 1 – Resistivity Circuit

Exercise 3.1 - Building a Resistivity Circuit from a Circuit Schematic

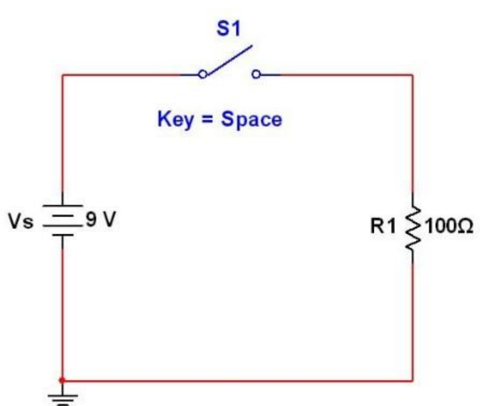
- Obtain the resistors needed to build the circuits according to Table 3.1.
- Before building the following circuits, measure the resistance of each resistors using a DMM and record the measurements in Table 3.1.

Elements	Actual Value (include unit)	Measured Resistance (include unit)
R_1	100 Ω (brown, black, brown, gold)	
R_2	330 Ω (Orange, orange, brown, gold)	
R_3	47 Ω (yellow, violet, black, gold)	
R_4	470 Ω (yellow, violet, brown, gold)	
R_5	220 Ω (red, red, brown, gold)	

Table 3.1 – Components measurements

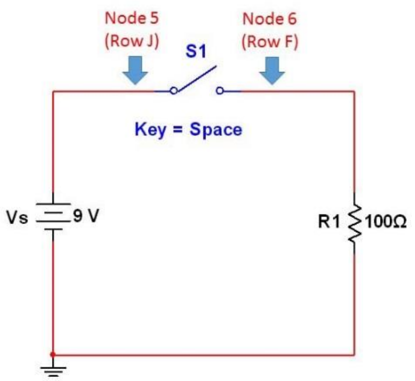
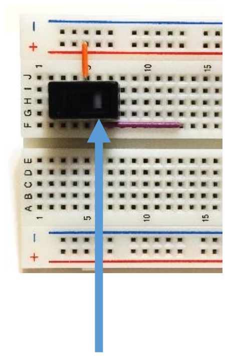
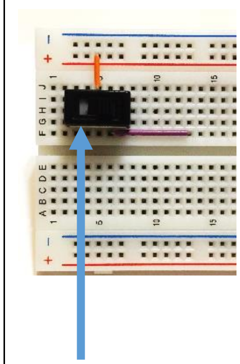
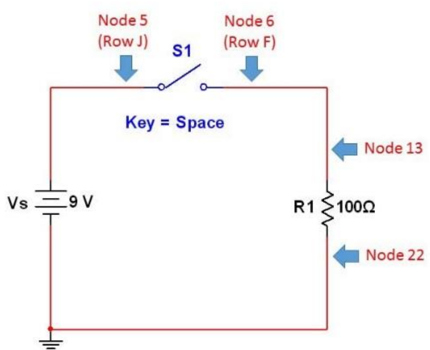
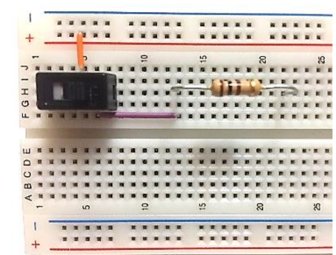
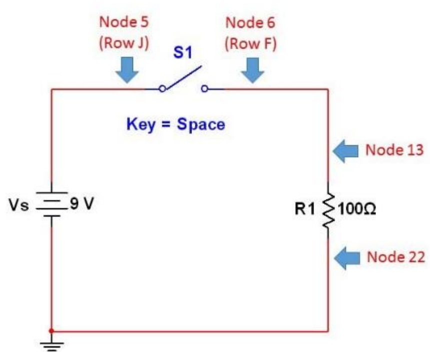
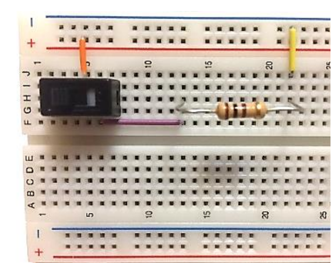
- Having the components, we can start making the connection of each resistor according to circuits.

a) Building a resistivity circuit with one resistor



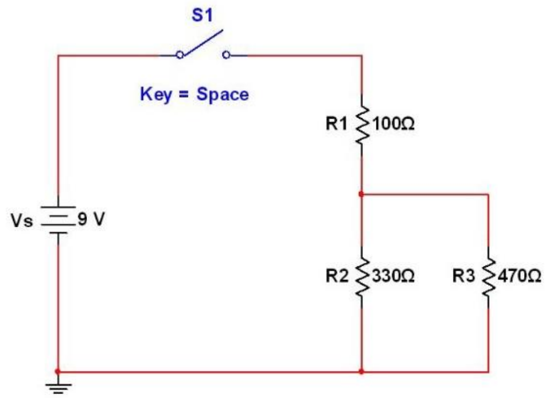
Circuit 3.1 – Resistivity circuit with 1 resistor

There are different ways to build and make connections among the elements within the circuit. One way to do so is by the order of the elements:

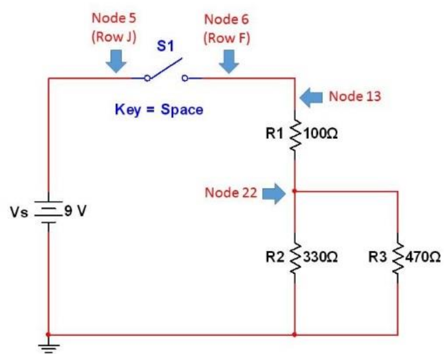
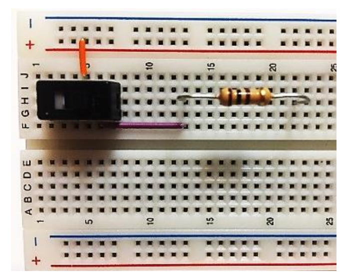
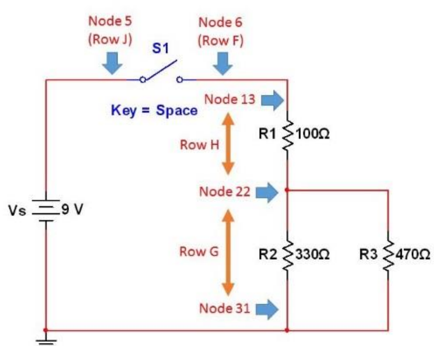
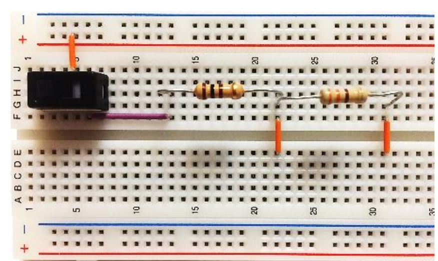
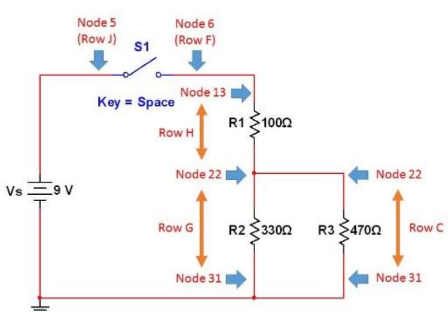
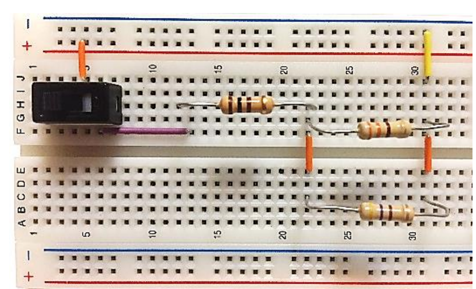
Circuit Schematic	Description	Protoboard Connection
	To build the circuit, we need to place the switch first. Put the middle leg of the switch in a node 5 and Row H, which needs to be connected to "+".The right leg of the switch needs to be connected to one side of R1. So put a jumper wire in a hole of "+" and in a node 5 and Row J. And put another wire between nodes 6 and 13 of Row F. It should be OFF when you slide the button to the left and ON when the button to the right.	Switch: OFF  Switch: ON 
	Place R1 between nodes 13 and 22 of Row H.	
	Connect the other side of R1 to the Ground.	

Once the circuit is built, turn the switch to a close or ON position and measure the total resistance, by placing the multimeter testing probes in between the + and – node of the breadboard. Record the measure resistance in Table 3.2.

b) Building a resistivity circuit with 3 resistors

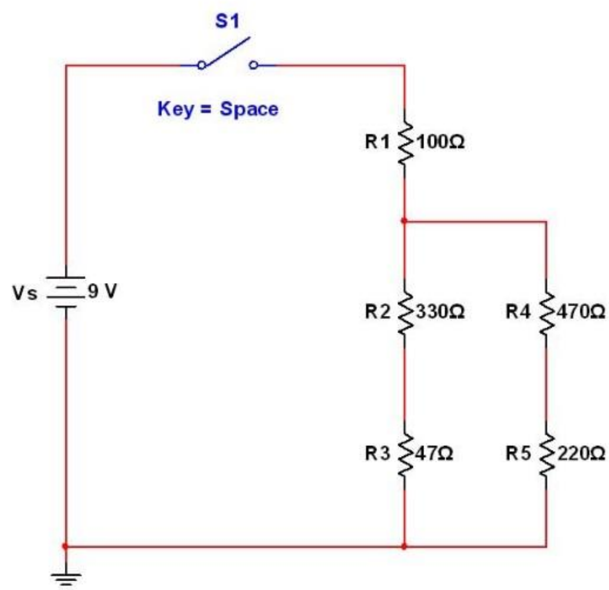


Circuit 3.2 – Resistivity circuit with 3 resistors

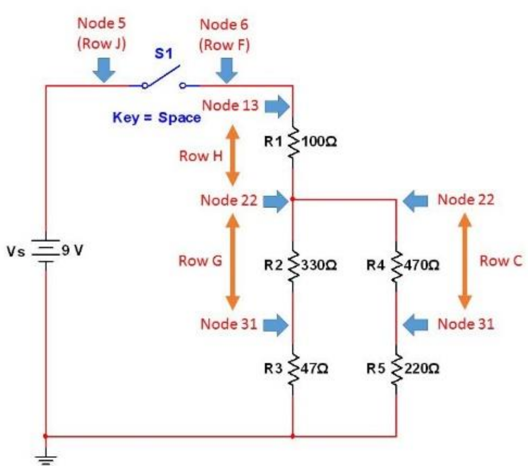
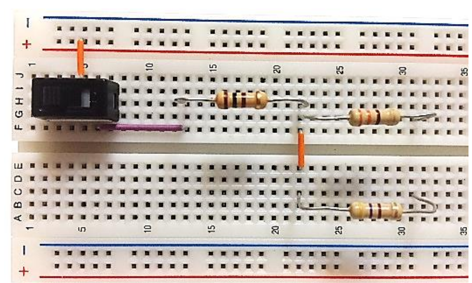
Circuit Schematic	Description	Protoboard Connection
	From the Circuit 3-1, remove the jumper wire to the Ground.	
	Place R2 between nodes 22 and 31 of Row G and put jumper wires between Row F and E of nodes 22 and 31.	
	Place R3 between nodes 22 and 31 of Row C and connect the other sides of R2 and R3 to the Ground.	

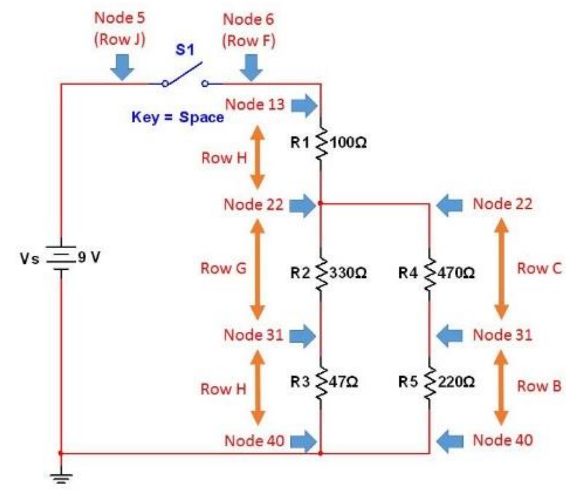
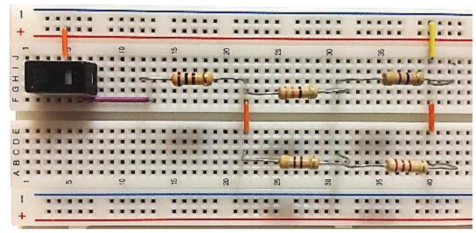
Once the circuit is built, turn the switch to OPEN or OFF position and measure the total resistance and record the measure resistance in Table 3.2

c) Building a resistivity circuit with 5 resistors



Circuit 3.3 – Resistivity circuit with 5 resistors

Circuit Schematic	Description	Protoboard Connection
	From the Circuit 3-2, remove the jumper wire to the Ground.	

	Place R3 and R5 between nodes 31 and 40 of Row H and Row B, respectively. And put a jumper wire between Row F and E of a node 40 and connect the other sides of R3 and R5 to the Ground.	

Once the circuit is built, turn the switch to OPEN or OFF position and measure the total resistance and record the measure resistance in Table 3.2

Element	Actual Value (include unit)	Measured Resistance (include unit)
Total Resistance (Circuit 3.1)	100 Ω	
Total Resistance (Circuit 3.2)	293.875 Ω	
Total Resistance (Circuit 3.3)	343.796 Ω	

Table 3.2 – Total resistance measurement

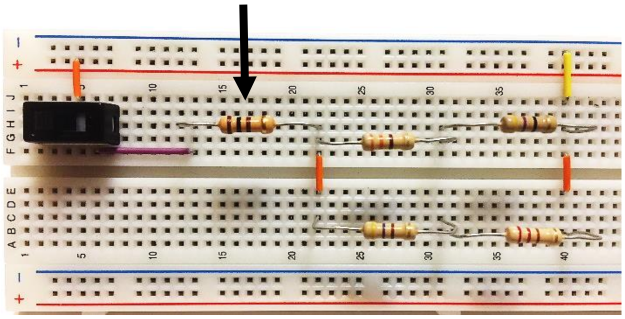
Part 2 - Measuring the current in a resistivity circuit

Exercise 3.2 – Measuring the current through each resistor in Circuit 3.3

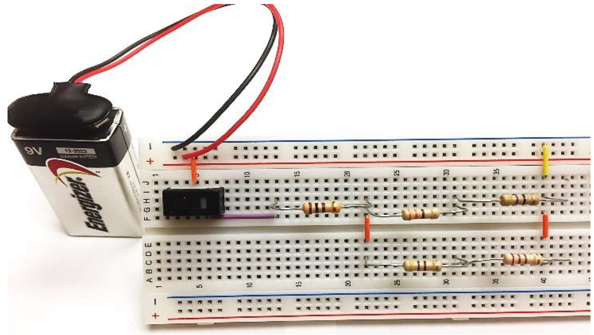
To measure current, we need to provide power to the circuit:

- Set the power supply to 9 V or use a 9 V battery.
- Connect the red lead of the power supply to the “+” node of the protoboard.
- Connect the black lead of the power supply to the “-” node of the protoboard.
- Double check the circuit connection with the lab instructor.
- Set the DMM to measure current: set it to read the highest current first.
- **Always remember:** to measure current of an element, one terminal of the element must be “**broken**” and the DMM must be placed in between the ‘break’. In order words, the DMM is used as a bridge between the measured element and the other element on the circuit. Check Figure 3.2.

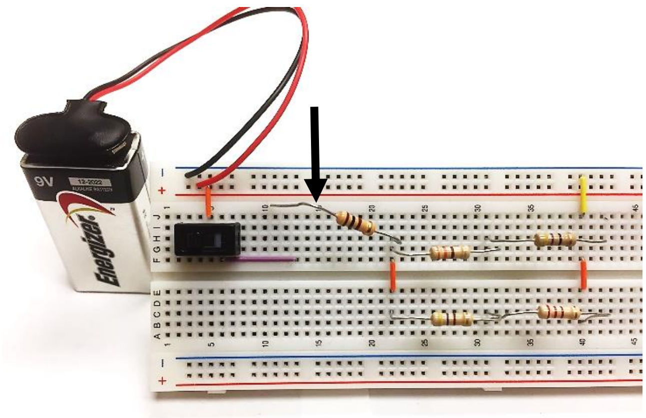
1. To measure the current through 100 Ω.



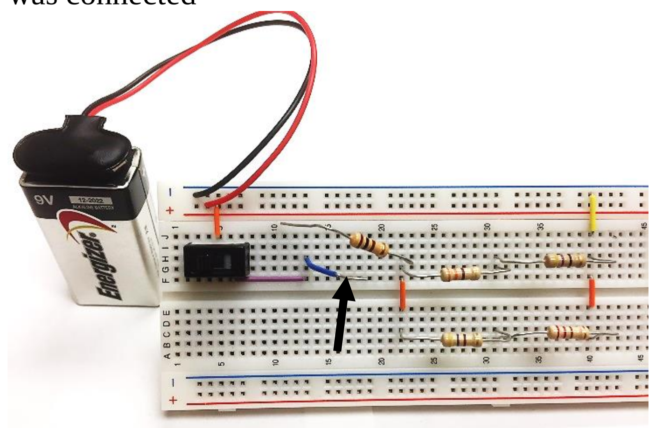
2. Connect the 9 V battery to the circuit. Make sure that the switch should be OFF.



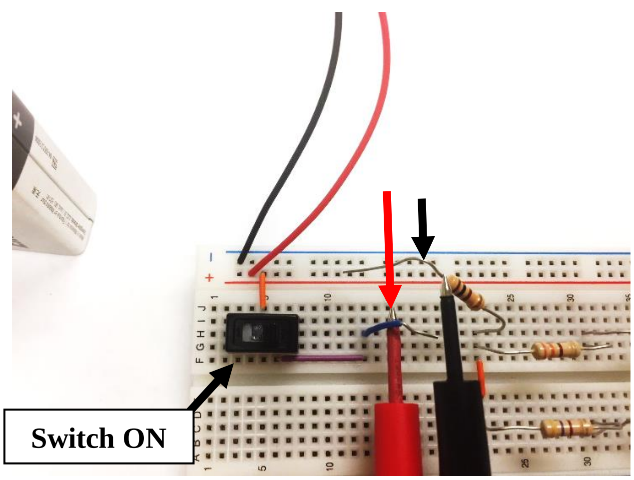
3. Break one of terminal of 100 Ω resistor



4. Optional: place a jumper wire where the terminal was connected



5. Switch ON the circuit and place the DMM probes in between the break to measure current through 100 Ω resistor.



Circuit diagram of step 5: measuring current through R1.

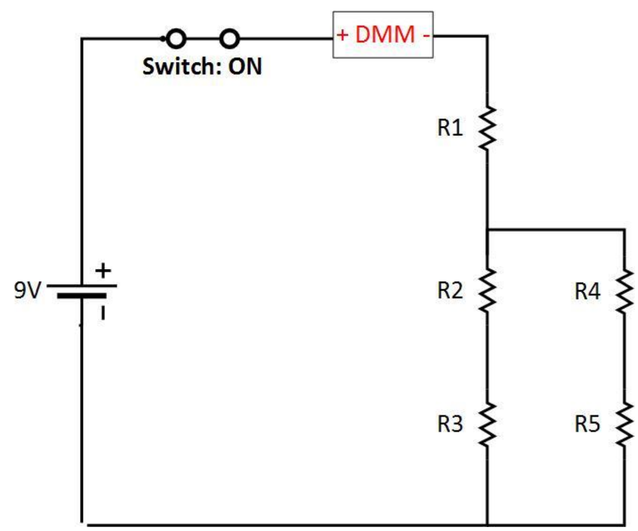


Figure 3.2 – Steps to measure current through a resistor

- Repeat the previous step and measure the current through each resistor. Record the measurements in Table 3.3

Elements	Measured Value (include unit)
I_{R1}	
I_{R2}	
I_{R3}	
I_{R4}	
I_{R5}	
I_S = Current through the battery	

Table 3.3 – Current measurements from Circuit 3.3

Note: The current distribution and flow for Circuit 3.1 is showed in below, Figure 3.2. You can use the measured current value in Table 3.2 and compare them with Figure 3.1

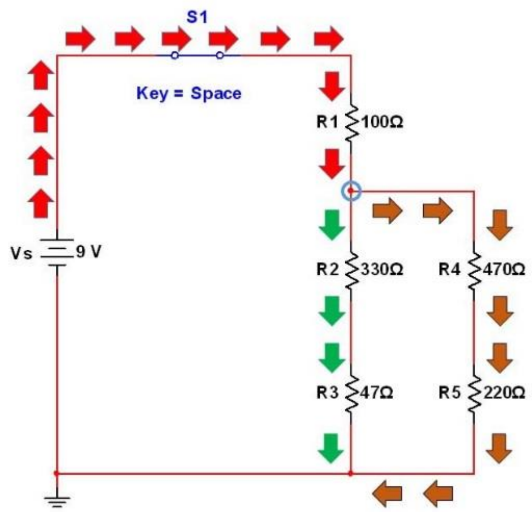


Figure 3.2 – Current flow within a resistivity circuit

Part 3 - Measuring the voltage in a resistivity circuit

Exercise 3.3 – Voltage measurement across a resistor

- Before measuring the voltage, check the circuit connections with the lab's instructor.
- Prepare the DMM to measure voltage.
- To measure the voltage drops at a resistor, simply place the DMM measurement's leads "across" the resistor as shown in Figure 3.3.

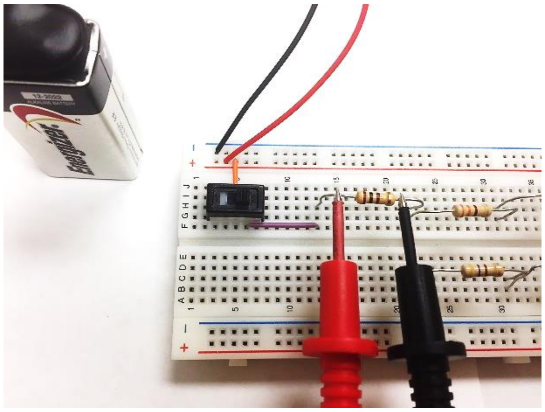


Figure 3.3 – Measuring voltage across a resistor

- Following the previous step, measure the voltage across each resistor and record the measurements in Table 3.4.

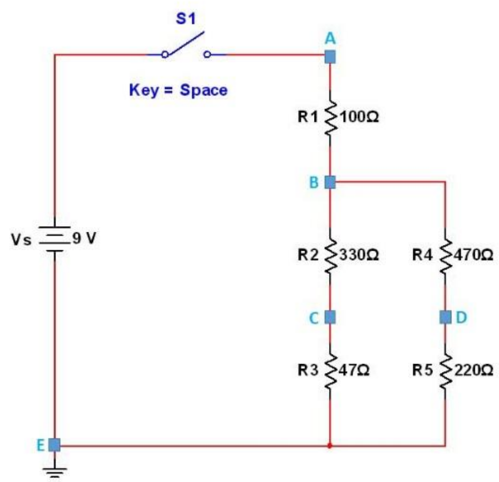
Voltage Label	Voltage Magnitude
Vs	
V_{R1}	
V_{R2}	
V_{R3}	
V_{R4}	
V_{R5}	

Table 3.4 Voltage Measurement from Circuit 3.3

Exercise 3.4 - To measure the voltage at a node with respect to ground

Be aware that in the field of electronics the word **ground** is often used to indicate the **reference point** rather than physical ground. In this case, the reference point is the negative node of the protoboard.

- Clip one negative lead of the DMM to the circuit ground (point E) or reference point (the negative – node)
- To measure the voltage at each node of Circuit 3.1, clip the other meter lead, (the one connected to the meter jack labeled with a plus sign, usually the red lead) to each node in succession (namely point A, B, C and D) as shown in Circuit 3.2.



Circuit 3.4 – Resistive circuit, Circuit 3.3, with label in each node

- Record the each measured voltage in Table 3.5.
- Include the polarity of the voltage with respect to ground in Table 3.4. Positive voltages are displayed with no sign by the DMM, while negative voltages are shown with a minus sign. For Circuit 3.1, all the nodes are positive with respect to ground because the battery's negative terminal is taken to be reference (ground).

NOTE: If an analog meter were used, a negative voltage would cause a meter deflection off the left side of the scale possibly causing meter damage. An analog meter can only measure positive voltages. To fix this error, swap the DMM's leads position, measure the voltage again, and mark the reading as a negative value.

Node	Display number in DMM	Voltage written as
A *(sample)*	9	V_A= + 9V
B		
C		
D		

Table 3.5 Voltages from different node to ground

Measuring the voltage between two nodes (Double subscript notation)

In the electronics field, it is common to represent the voltage between two points in the circuit using a double subscript. V_{AB} indicates the voltage at point A with respect to point B. If one were to measure this voltage with a DMM, one would put the black meter lead at the point indicated by the second (reference) subscript and the red meter lead at the point indicated by the first subscript. Therefore, to measure V_{AB}, the black meter lead is connected at node B and the red meter lead at node A. This is exactly the same as measuring the voltage across the resistor R1.

For example, to measure V_{BA}, one would put the **red meter probe** at node **B,** and the **black meter probe** at node **A**. This would obviously result in the same voltage but the meter would indicate a negative sign because the voltage in node B is lower than the voltage in node A. This shows that $\mathbf{V_{BA} = V_B – V_A}$

Exercise 3.5 Measuring and calculating voltage between nodes

- From Circuit 3.3, measure the voltages indicated in Table 3.6
- It is also important to notice that $V_{AB} = V_A - V_B$, where the voltage of V_A and V_B is obtain from Table 3.5. Using those information, calculate each node voltage as indicated in Table 3.6.
- Complete Table 3.6.

Voltage to be measured	Measured Voltage	Written as	Calculation using Table 3.5 Voltage at first node minus voltage at second node	Comment
V_{AB}				
V_{BA} *(Sample)*	-2.6 V	V_{BA} = -2.6V	$V_{BA} = V_B – V_A$ V_{BA} = 6.4V – 9V= - 2.6V	- sign indicates B is lower in voltage than A
V_{BC} *(Sample)*	+5.6 V	V_{BC} = +5.6V	$V_{BC} = V_B – V_C$ V_{BC} = 6.4V – 0.8V = + 2.6V	+ sign indicates B is higher in voltage than C
V_{CB}				
V_{DB}				
V_{CA}				
V_{AC}				

Table 3.6 – Measuring and calculating voltage between nodes

Measuring the voltage rises and the voltage drops

When moving around a circuit in a particular direction, if one goes across a circuit element and encounters a voltage polarity from – to + then the voltage is considered a voltage rise and is usually assigned a + sign. For example, going from B (black probe) to A (red probe) goes from – to + therefore it is considered a voltage rise of 2.6V (or V_{AB} = +2.6V). Alternately, if one encounters a voltage polarity from + to – then the voltage is considered a voltage drop and is usually assigned a – sign. Here for example, going from A (black probe) to B (red probe) goes from + to – therefore it is considered a voltage drop of 2.6V (or V_{BA} = –2.6V). Note that a voltage is either a rise or a drop depending on the direction taken, which is usually use the test probe as reference.

Exercise 3.6 Measuring the voltage rises and voltage drops

Don't forget that all voltage measurements were done **across** elements or **from one terminal to another**.

- Using the information from Table 3.5 complete Table 3.7

To point	From point	Calculation using Table 3.5	Rise or drop?	Write + for rise Write - for drop
A	C			
D	A			
Ground (E)	C			
D	Ground (E)			
B	D			

Table 3.7 Voltage rises and voltage drops

Turn off all lab and testing equipment, dissemble the circuit, and place all components back in the lab kit. Answer the following lab questions.

Questions

1. According to this experiment, which is/are the most difficult step/s to measure the current through a resistor? Explain your answer.

2. You are trying to measure the current through a resistor, you power the circuit, set the multimeter to measure the current, and connect the multimeter in series with the circuit. The multimeter shows 'OL'. How would you troubleshoot this error? Mention three alternatives to troubleshoot this error and explain.

3. According to this experiment, which is/are the most difficult step/s to measure the voltage across a resistor? Explain your answer.

4. For a given circuit, when you measure a voltage from node C to node A, the multimeter displays **-3.5V**. What does the negative sign mean? Which node has the lower voltage? Explain your answer

Student's Name: ______________________________ Lab instructor's signature ____________________________

-- LAB EXPERIMENTS ENDS HERE --