Student's Name: Date:

Introduction to Circuit Analysis Laboratory

Lab Experiment 3

Resistivity Circuit: Resistance and Voltage Measurement

Electrical components/elements can be connected to form a network or circuit. Depending on the elements interconnection we can determine the equivalent resistance and voltage distribution among the elements and determine whether they are series, parallel, or series-parallel circuit.

3.1. Resistance and Voltage Measurements

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

3.1.1. Voltage Measurement Using a Digital MultiMeter, DMM

Before placing the testing probes in the circuit to measure voltage, we have to set our DMM to measure voltage. To set up the DMM, 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 we are measuring no more than 9 V, you can set the measure dial to 20 V dc volts. But if we want to measure 9 V and we set the measure dial to 2 V, the DMM will show an Over Load message, why? Because the voltage range in the DMM 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 DMM 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 DMM leads across the component whose voltage we 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 DMM has to be in ***parallel*** to the measure component.

3.1.2. Resistance Measurement

To measure resistance, firstly we have to set the DMM to measure resistance. To set up the DMM, make sure that the red probe is connected to the **VΩmA** socket and the black probe to the **COM** socket. After it, if we don't know the resistance value, we set the measure dial to the highest resistance, and once the DMM is connected to circuit to measure resistance, we lower the measure dial until we get a reading from the DMM.

Once the DMM is set up to measure resistance, the next step is to place the DMM's probes across the component whose resistance we want to measure. We basically place the DMM's probes in ***parallel*** to the measure component.

Lab Experiment Procedure

Part 1 – Resistivity Circuit

Exercise 3.1 - Building a Resistivity Circuit from a Circuit Schematic

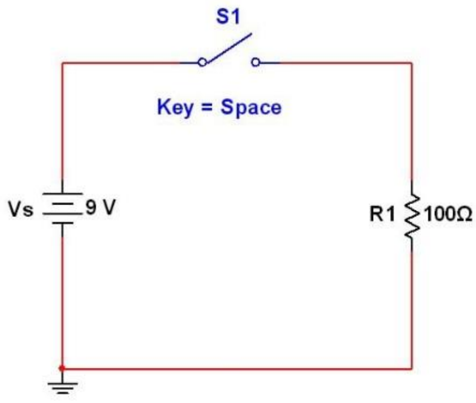
- Obtain the resistors needed to build the circuits according to Table 3.1.
- Before building the following circuits, measure the resistance of each resistors using a DMM and record the measurements in Table 3.1.

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.

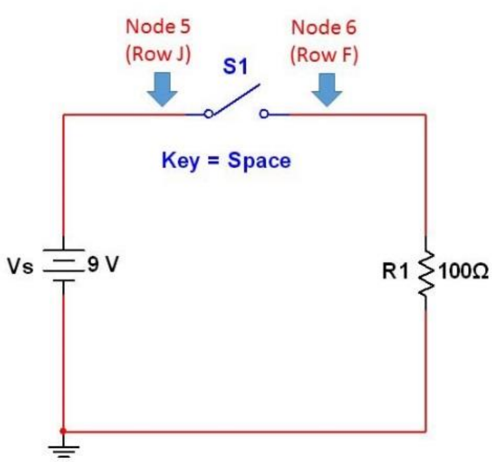
a) Building a resistivity circuit with one resistor

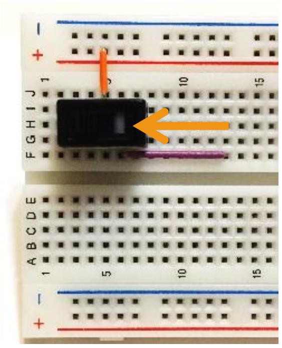
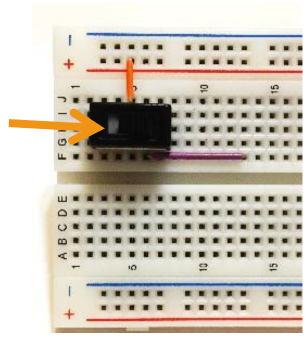


Circuit 3.1 – Resistivity circuit with 1 resistor

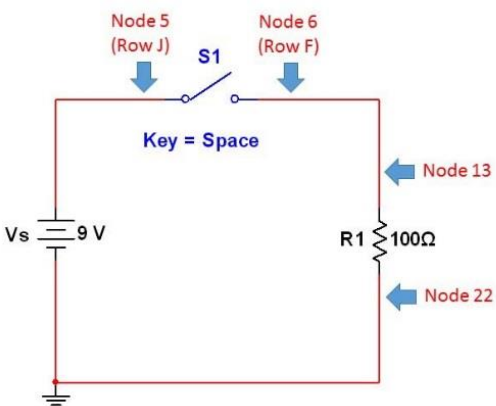
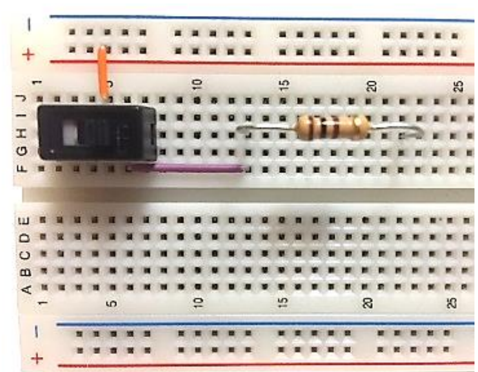
There are different ways to build and make connections among the elements within the circuit. One way to do so is by the order of the elements:

Step 1a)

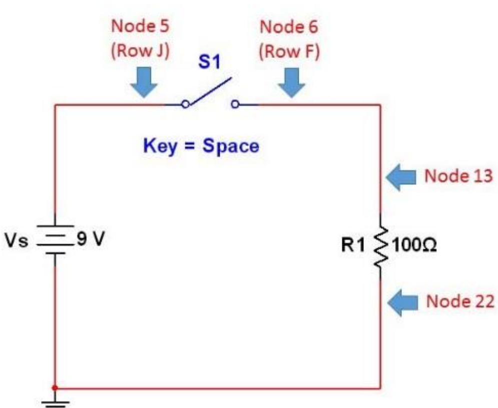
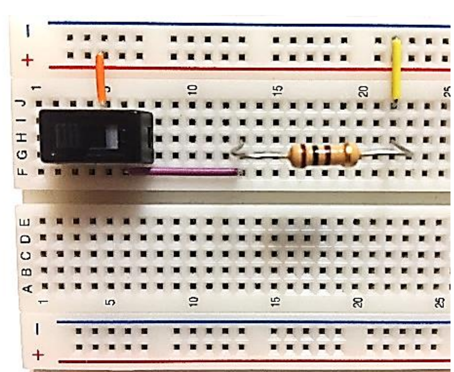
Circuit Schematic	Description
	To build the circuit, we need to place the switch first. Put the middle leg of the switch in a node 5 and Row H, which needs to be connected to "+".The right leg of the switch needs to be connected to one side of R1. So put a jumper wire in a hole of "+" and in a node 5 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.

Protoboard Connection	
Switch: OFF 	Switch: ON 

Step 2a)

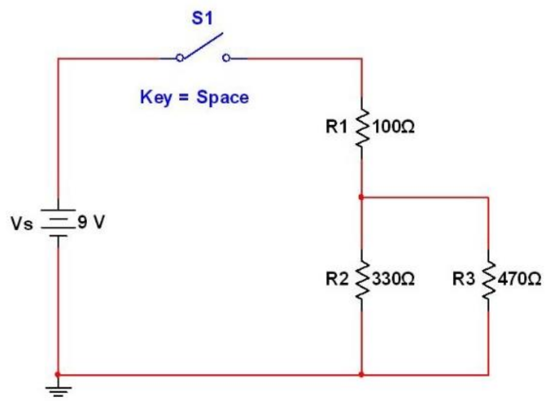
Circuit Schematic	Description	Protoboard Connection
	Place R1 between nodes 13 and 22 of Row H.	

Step 3a)

Circuit Schematic	Description	Protoboard Connection
	Connect the other side of R1 to the Ground.	

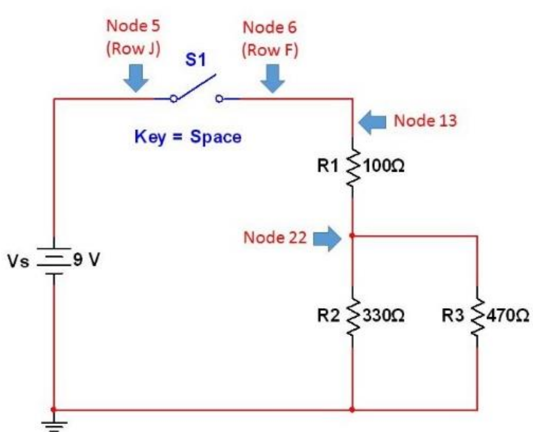
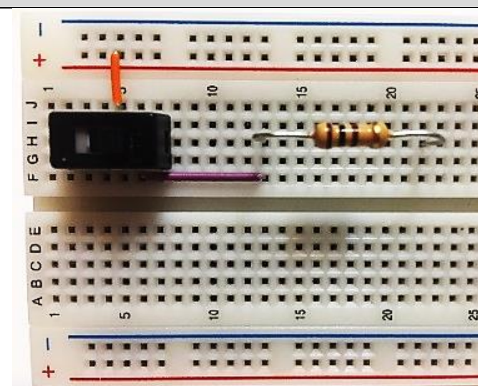
Once the circuit is built, turn the switch to a close or ON position and measure the total resistance, by placing the multimeter testing probes in between the + and – node of the breadboard. Record the measure resistance in Table 3.2.

b) Building a resistivity circuit with 3 resistors

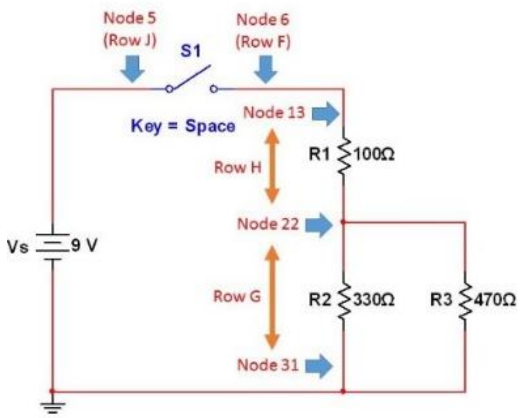
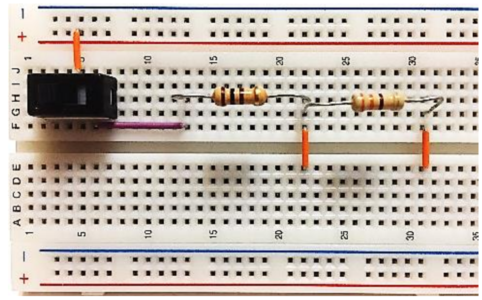


Circuit 3.2 – Resistivity circuit with 3 resistors

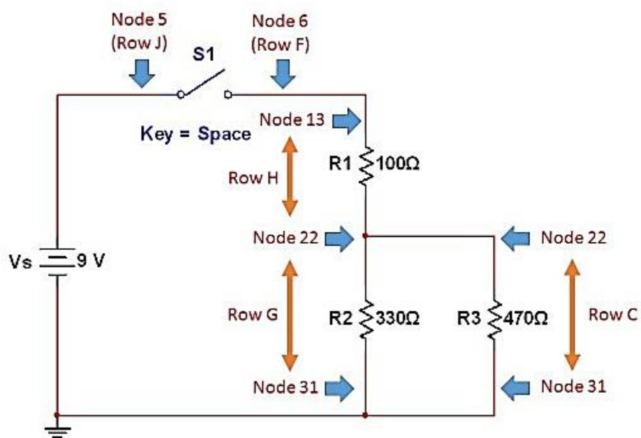
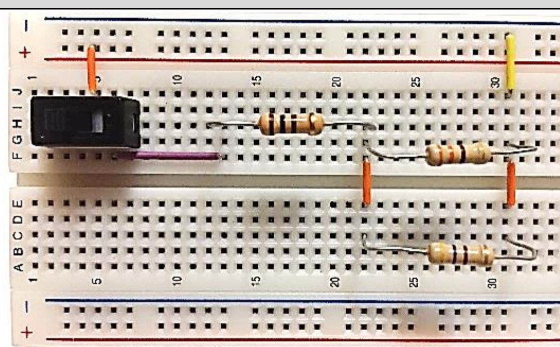
Step 1b)

Circuit Schematic	Description	Protoboard Connection
	From the Circuit from step 3a, remove the jumper wire to the Ground.	

Step 2b)

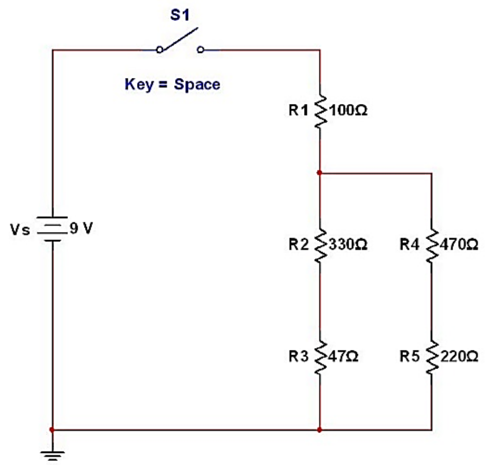
Circuit Schematic	Description	Protoboard Connection
	Place R2 between nodes 22 and 31 of Row G and put jumper wires between Row F and E of nodes 22 and 31.	

Step 3b)

Circuit Schematic	Description
	Place R3 between nodes 22 and 31 of Row C and connect the other sides of R2 and R3 to the Ground.
Protoboard Connection	
	

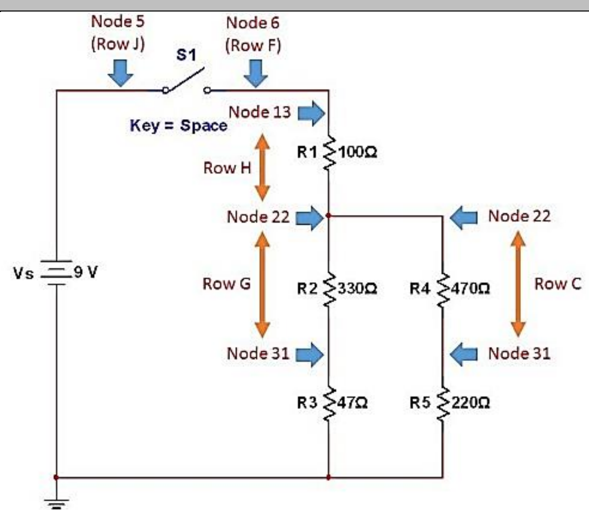
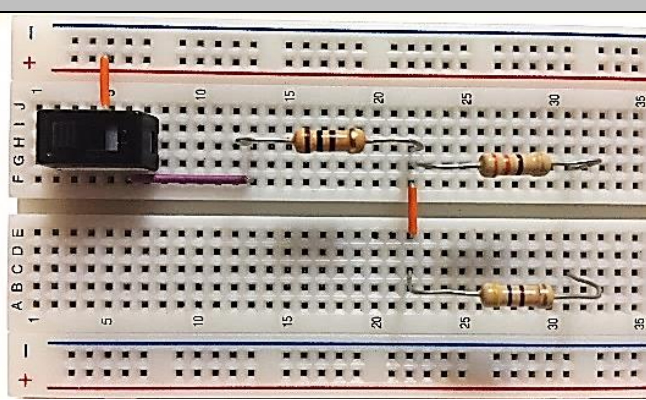
Once the circuit is built, turn the switch to OPEN or OFF position and measure the total resistance and record the measure resistance in Table 3.2.

c) Building a resistivity circuit with 5 resistors

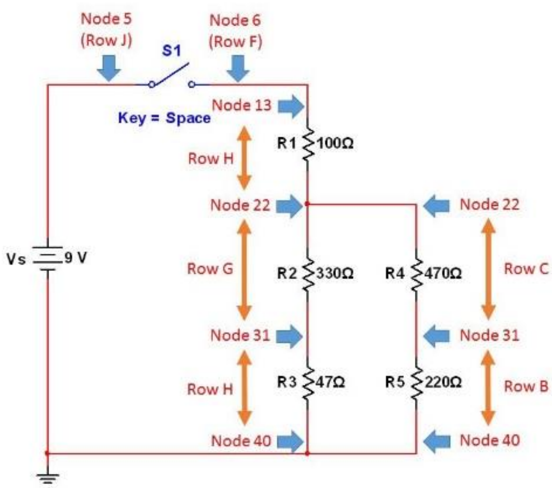
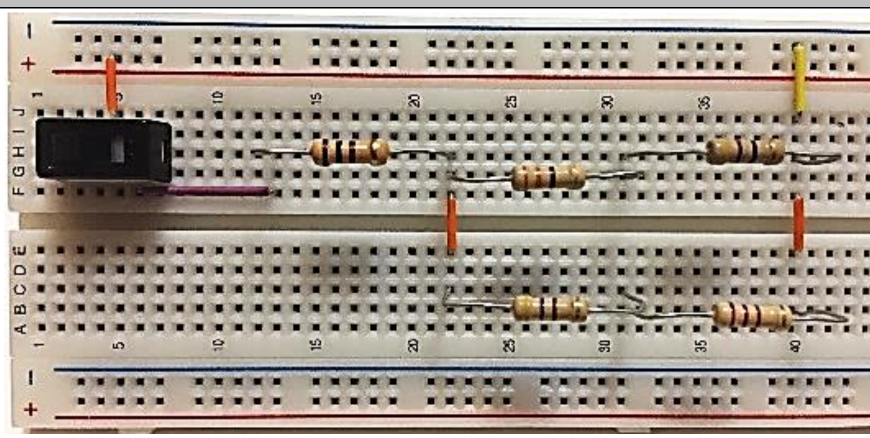


Circuit 3.3 – Resistivity circuit with 5 resistors

Step 1c)

<table>
<tr><th>Circuit Schematic</th><th>Description</th></tr>
<tr><td>
</td><td>From the Circuit 3-2, remove the jumper wire to the Ground.</td></tr>
<tr><th colspan="2">Protoboard Connection</th></tr>
<tr><td colspan="2"></td></tr>
</table>

Step 2c)

<table>
<tr><th>Circuit Schematic</th><th>Description</th></tr>
<tr><td>
</td><td>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.</td></tr>
<tr><th colspan="2">Protoboard Connection</th></tr>
<tr><td colspan="2"></td></tr>
</table>

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	Measured Resistance (include unit)
Total Resistance (Circuit 3.1)	
Total Resistance (Circuit 3.2)	
Total Resistance (Circuit 3.3)	

Table 3.2 – Total resistance measurement

Part 2 - Measuring the voltage in a resistivity circuit

- Before measuring the voltage, check double check Circuit 3.3's 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 probes "across" the resistor as shown in Figure 3.2.

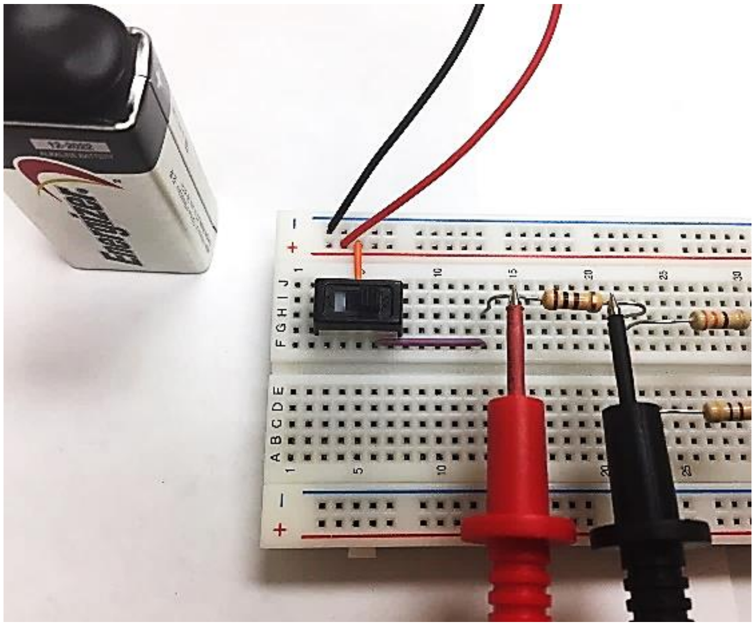


Figure 3.2 – Measuring voltage across a resistor

- Turn the switch ON of Circuit 3.3
- Measure the voltage across each resistor in Circuit 3.3 and record the measurements in Table 3.3.

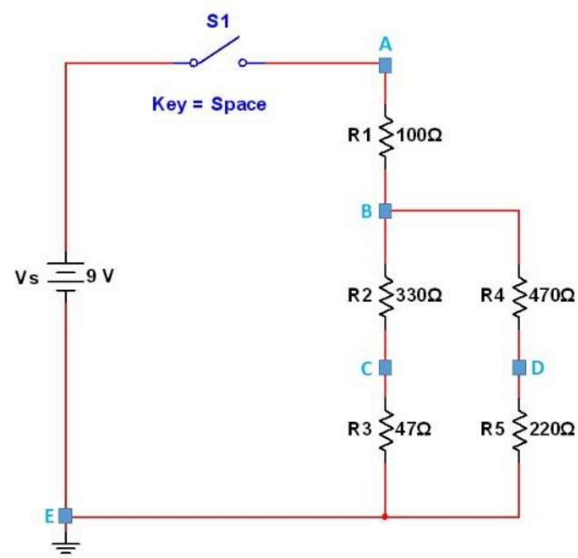
Voltage Label	Voltage Magnitude
Vs	
V_{R1}	
V_{R2}	
V_{R3}	
V_{R4}	
V_{R5}	

Table 3.3 Voltage Measurement from Circuit 3.3

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 3.3, 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 3.4.



Circuit 3.4 – Resistive circuit, Circuit 3.3, with label A, B, C, E, and E in each node

- Record the each measured voltage in Table 3.4.
- 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 3.3, 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 3.4 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 $\mathbf{V_{BA} = V_B – V_A}$

- From Circuit 3.4, measure the voltages indicated in Table 3.5.
- 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 3.4. Using those information, calculate each node voltage as indicated in Table 3.5.
- Complete Table 3.5.

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 3.5 – 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.

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

- Using the information from Table 3.4 complete Table 3.6

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 3.6 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 Signature: ______________Lab instructor's signature ________________Date: ______________

-- LAB EXPERIMENTS ENDS HERE--