Name: ______________________________________ Date: ____________

Using a Multimeter to Analyze a Circuit: Measuring Current and Voltage— Calculating Power and Resistance

Background Information and Pre-Lab Activity

Materials:

- One solar module
- One small DC motor with fan attachment

An electric circuit is an interconnection of electrical elements. Connecting two electrical elements together—such as a solar module and a small motor—will create a very simple circuit. Before beginning the lab experiment with connecting the solar module to the motor. Notice what happens if you connect only one side of the solar module with the motor and leave the other clip unattached. Try connecting both of the wires from the solar module to the motor in both possible configurations by switching which tab you connect the red and black wires to. What do you observe?

Electricity is caused by the flow of charge. In reality, this is the motion of negatively charged particles (called electrons) through a wire. If the circuit isn't a complete circle—such as when you connected only one of the wires from the solar module to the motor—we call this an open circuit, and it stops the electrons from being able to flow.

There are a few important ways that we talk about electricity in order to understand how much we have and what we can do with it. The amount of current in a circuit tells us how fast charge is flowing through the wire. Voltage is the force pushing the current through the wire, and it tells us the difference in the amount of electric potential energy per unit of charge between two places in the circuit. Voltage is caused by the separation of oppositely charged particles that are attracted to one another. Pulling a negatively charged particle away from a positively charged one requires energy and the amount of energy required can be described by the voltage between those two particles. Then, if you allow it to, that negatively charged particle will recombine with the positively charged one, creating electricity.

You can think of voltage like the force of gravity—if you let a ball drop from a high place, it will fall. The higher the ball, the more energy it has—and the more energy that will be transformed into motion once you let it go. At the point where the current is being "pushed" out of the solar module, you will have a lot of voltage, much like the ball when it's held up in the air. As the current flows through the circuit and causes the motor to operate, the voltage will decrease—like your ball as it falls toward the ground. By the time the current reaches the other side of the solar module, the voltage is back to zero. Therefore, measuring the voltage across the two terminals of the solar module (the voltage between the red and black wires) will tell you the difference in electrical potential energy per unit of charge between those two points.

Power is the product of voltage and current (power = voltage x current) and tells us the rate at which a device will generate or dissipate electrical energy. Often the devices that we use every day are rated in terms of their power requirement—like a 100-Watt light bulb. Resistance is the opposition to electrical current, and the more resistance that a circuit has, the more voltage is required to push the same amount of current through the circuit. In this lab we will use resistors to supply known resistances to our circuits.

Introduction:

A digital multimeter is a tool that can give you important numerical data about an electric circuit. We will use a multimeter to measure the voltage (in volts "V") across a resistor and the current (in amps "A") through the circuit. To do this, we will start by setting up a simple series circuit using a solar module and a resistor. We will then take the appropriate readings using the multimeter and use these measured values to calculate the power dissipated by the resistor. We will also investigate the relationship between voltage, current, power and resistance.

Materials:

- One solar module
- One Vernier Resistor Board
- One black alligator test lead
- One multimeter

The Vernier Resistor Board has seven resistors built into it. By clipping leads into the two holes on either side of one of the resistors, it is possible to include the resistor – and therefore a known resistance—in your circuit. The following resistances are available:

- R1: 10 Ω
- R2: 15 Ω
- R3: 20 Ω
- R4: 20 Ω
- R5: 39 Ω
- R6: 51 Ω
- R7: 100 Ω

The multimeter has four different operating modes and each mode allows you to measure a different thing.

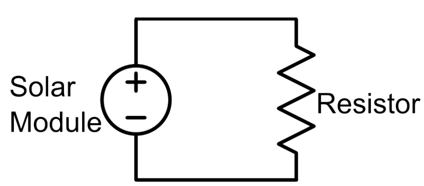
- Direct current (DC) voltage: V⎓
- Alternating current (AC) voltage: V∿
- DC Current: A⎓
- Resistance: (Ω)

In this lab we will be using the multimeter to measure DC voltage and DC current. Before taking any measurements, it's important to make sure you have the multimeter set to the correct measurement mode.

Procedure:

Step One: Set up your circuit

- Connect the leads of the solar module across the R1 (10 ohm) resistor
- This creates a **series** circuit configuration, which means that all of the electrical elements are in a single loop
- In a series wiring connection the current (or flow of electrical charges) has only one path through which it can flow
- Your circuit will be structured like this:

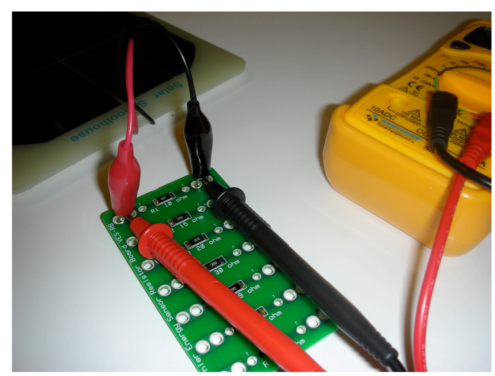


Step Two: Set up the multimeter to measure DC voltage

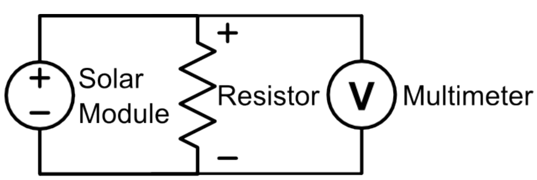
- Insert the black plug (“lead”) into the COM (common) socket in the middle
- No matter what you are measuring (or what “mode” you want to be in) the black lead should always be in the center
- Insert the red lead into the hole labeled with a “V” for voltage

Step Three: Connect the multimeter to your circuit to measure the voltage across the resistor

- Remember that voltage is the “electrical potential difference” between two points in your circuit, and we want to measure how much the voltage changes across the resistor. Given this, consider how you think the multimeter should be connected in the circuit.
- Draw what you think your circuit should look like (with the multimeter) in the space below. Explain your thinking. Use the symbols given to represent each of the circuit elements and draw lines between them to represent the wires. You can either use red and black colored pencils to represent the different wires or you can use a “+” to indicate the red wire and a “–” to represent the black wire.



The correct circuit should be set up like this:



- In order to set this up, connect the red lead of the multimeter to the red lead of the solar module where it connects to the resistor
- Now connect the black lead of the multimeter to the black lead of the solar module where it connects to the resistor

Step Four: Take your voltage measurement

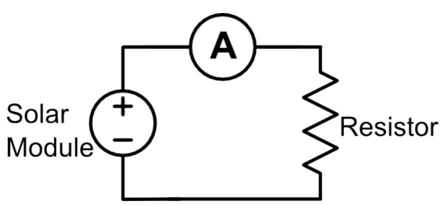
- Turn the knob so that it points to the appropriate number in the direct current (“DC”) voltage range
- The DC voltage range is indicated by this symbol:
- You should select the number (200m, 2, 20, etc.) that is close to, but greater than your expected voltage.

- Check to see what rated voltage your solar module is. This information is usually on the back. The voltage will be given as a number with volts (V) as the unit. Select the voltage setting that is closest to the stated voltage without being lower. *(For example, for a 2V module you would use a 2 volt setting, but for a 2.5 V module, you would use the 20-volt setting.)*
- *TIP:* If you're not sure what number to pick, it's always better to start larger and then adjust downward.
- Put the solar module into your light source and read the voltage.
- Remember to adjust the knob if you aren't getting a reading or the value you're getting is very small.
- Record the voltage reading in Table 1. Remember to include units.

Step Five: Connect the multimeter to your circuit to measure the current through the resistor

- Remember that current is the flow of electricity through the circuit and that – if there is only one loop – there is only one path through which current can flow, and the current flow everywhere in the circuit will be the same. We want to measure the current through the resistor. Given this, consider how you think the multimeter should be connected in the circuit.
- Draw what you think your circuit should look like (with the multimeter) in the space below. Explain your thinking. Use the symbols given to represent each of the circuit elements and draw lines between them to represent the wires. You can either use red and black colored pencils to represent the different wires or you can use a "+" to indicate the red wire and a "–" to represent the black wire.

The correct circuit should be set up like this:



- In order to do this, disconnect the black solar module lead from the R1 resistor and connect it to the black lead from the multimeter.

- Now connect the black alligator lead to the other side of the resistor. The other end of this black alligator lead then needs to be connected to the red lead from the multimeter.
- To make sure you have the circuit set up correctly, trace the circuit loop with your finger, making sure that the current will start at one of the solar modules leads, go through the multimeter and the resistor and then return to the other solar module lead.

Step Six: Take your current measurement

- Once again, you should select the number (20m, 200m, 10, etc.) that is close to, but greater than your expected current.

- Check to see what the rated current of your solar module is. The current will be given as a number with amps (A) as the unit. Select the current setting that is closest to the stated voltage without being lower.
  (For example, for a 100mA solar module use the 200m-amp setting, but for a 1A solar module, use the 10A setting.)
- If you use the 10A current setting you will need to move the red lead from the right plug to the left plug on the multimeter as shown on the right. Otherwise (for current readings below 200mA), leave the red lead in the left plug.
- Put the solar module into your light source and read the current.
- If you aren't getting a good reading, adjust the knob and remember to move the lead when necessary.
- Record the current reading in Table 1. Remember to include units.

Step Seven: Repeat steps 1-6 for three other resistors on the board of your choice.

Results and Analysis:

Table 1

Resistor	Resistance (R)	Voltage (V)	Current (I)	Power (P)
R1	10 Ω			

Calculate the power dissipated in each resistor. Recall that power is the product of voltage and current (Power = Current x Voltage).

Example – If you measured 2.05 V of voltage and 0.220 A of current, the power dissipated in the resistor would be:

$$P = I \times V = 2.05\,V \times 0.220\,A = 0.451\,W$$

Fill in the last column of Table 1. Remember to include units.

Calculate the resistance in the circuit using **Ohm's Law**. Ohm's law says that voltage is equal to the product of current and resistance (Voltage = Current x Resistance). Using your measured voltage and current, calculate the resistance in your circuit.

Example – If you measured 2.05 V of voltage and 0.220 A of current the expected value of the resistor would be:

$$V = I \times R$$
$$R = \frac{V}{I} = \frac{2.05\,V}{0.220\,A} = 9.32\,\Omega$$

Now find the percent difference between the resistance you calculated above and the resistance given on the label of the Vernier Resistor Board. The formula to find the percent difference is given below.

$$Percent\ Difference = \frac{Calculated\ Resistance - Label\ Resistance}{Label\ Resistance} \times 100\%$$

Assuming that the above example calculations were done using the 10 Ω resistor, the percent difference would be:

$$Percent\ Difference = \frac{9.32\ \Omega - 10\ \Omega}{10\ \Omega} \times 100\% = -6.8\%$$

Fill in Table 2 with the resistances calculated from your measurements and the corresponding percent differences. Remember to include units.

Table 2

Resistor	**Label Resistance**	**Calculated Resistance**	**Percent Difference**
R1	10 Ω		

Conclusion Questions:

Were your calculated values for the resistance exactly equal to the resistances given on the resistor board?

Most resistors have a "manufacturing tolerance" that indicates how much the actual resistance of the device can vary from the label resistance. If we assume that the manufacturing tolerance for the resistors on the resistor board is ±5%, would the resistance values you calculated meet that specification?

What observations did you make about the effect that resistance has on the voltage, current and power in a circuit?

Challenge Questions:

Determine the equation you would use to find the power dissipated in the resistor using voltage and resistance.

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What is the resistance of a refrigerator light bulb that dissipates 25 Watts of power while operating at 120 Volts?

Why do you think that having "manufacturer tolerances" for resistors is important?

What do you think would have happened if you had made a mistake and put your multimeter in series with the resistor while trying to measure voltage? In other words, if you tried to measure voltage using the circuit set up below, what value would you get? Why do you think this is?