4. Voltage, Current, and Power

MTVW 29-Jan-13

Objectives

1. To relate measurements of potential difference (or voltage) and current to: i) power supplied by a component and ii) power dissipated by a component.
2. To measure voltages and currents in series, parallel, and series-parallel circuits and relate the measurements to Kirchoff's voltage law and Kirchoff's current law.
3. To show that power delivered to an electric circuit is balanced by the power dissipated in the circuit.

Equipment

1. 12V and 5V DC power supplies (these are in the same case),
2. Five digital multimeters,
3. Two single pole single throw (SPST) switches,
4. Three 12V light bulbs and sockets.

Preparation and Background

Voltmeter Operation Review: When configured as a voltmeter, a multimeter displays the work done per Coulomb of charge in moving charge from the *black* or *com* terminal to the *other* or *red* terminal. Figure 1 shows a voltmeter connected across a resistor that is supplied power from a battery. Both the "real-world" setup and a schematic setup are shown. To measure the voltage difference, $V_{XY} = V_X - V_Y$, across the terminals X and Y of the resistor in Figure 1: connect the red lead of the voltmeter to X and the black lead to Y. The voltmeter reading indicates the voltage at the point connected to the red lead relative to that at the black lead; positive if the voltage is higher, negative if the voltage is lower.

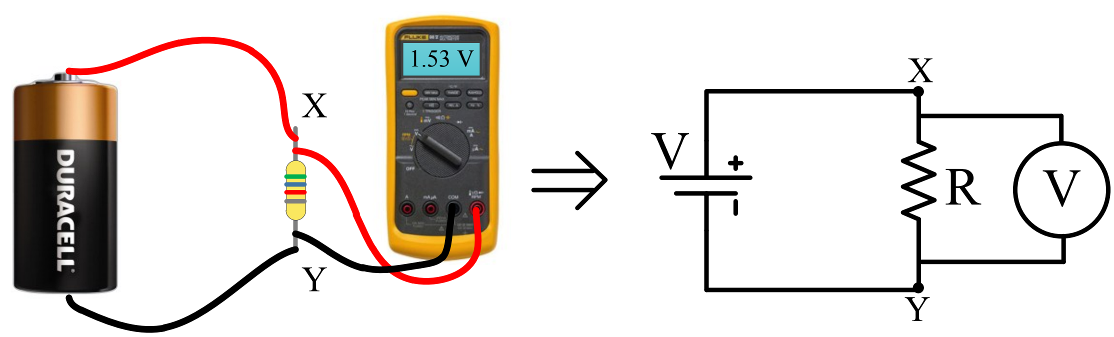


Figure 1: Practical Circuit Connections and their Schematic Representations (Voltage Measurements)

Ammeter Operation Review: A multimeter may be configured to measure DC current. Current is defined as the rate of change of charge with respect to time, usually the rate at which charge flows past a point or through a specified plane or surface. To measure the current flowing from X to Y in an electric circuit configure the multimeter as shown below, making sure to disconnect or break the circuit before switching to the ammeter function of the multimeter. Note, if you set the multimeter to read current and configure it like the voltmeter in Figure 1 you will blow the fuse in the multimeter.

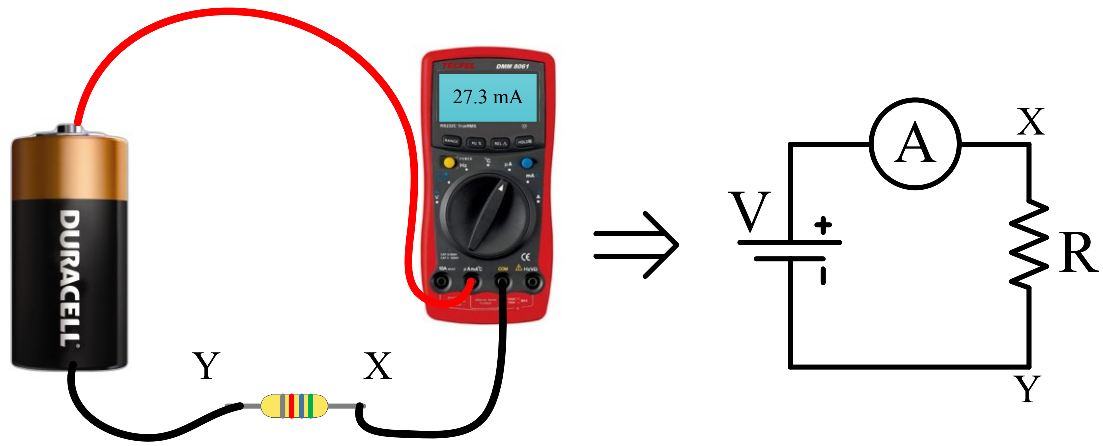


Figure 2: Practical Circuit Connections and their Schematic Representations (Current Measurements)

Measuring Power: The electrical power supplied by an electrical component with terminals X and Y is equal to the current flowing into X (and out of Y) multiplied by the voltage across the terminals, $V_{YX} = V_Y - V_X$.

$$P = VI$$

If the power is negative then the component dissipates or stores power. *I.e.* power supplies provide power and have a positive power, but resistors dissipate power and thus have a negative power. However, we normally do not talk in terms of positive or negative power. We would usually say either power supplied or power dissipated/stored.

Ohm's Law: The current through a resistive element is equal to the voltage drop across the element divided by its resistance.

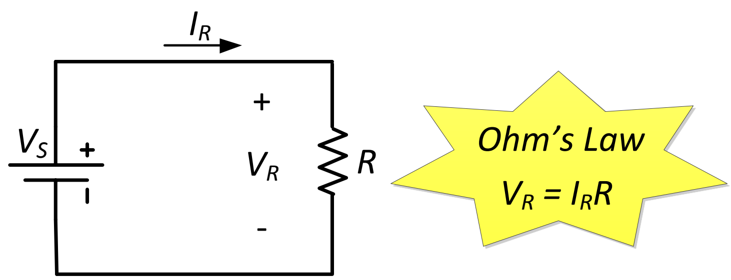


Figure 3: Demonstration of Ohm's Law

Kirchoff's Voltage Law (KVL): The sum of potential differences around a closed loop is zero. Alternatively, the sum of the voltage supplies in a closed loop must equal the sum of the voltage drops.

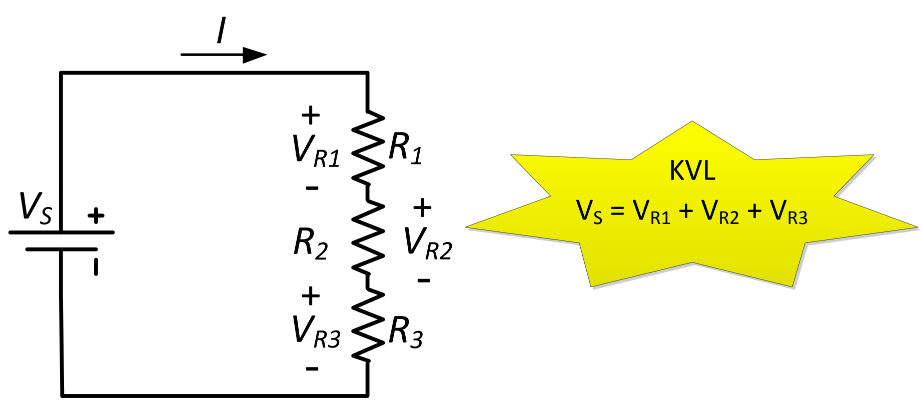


Figure 4: Demonstration of Kirchoff's Voltage Law

Kirchoff's Current Law (KCL): The sum of currents entering a node must be equal to the sum of the currents leaving.

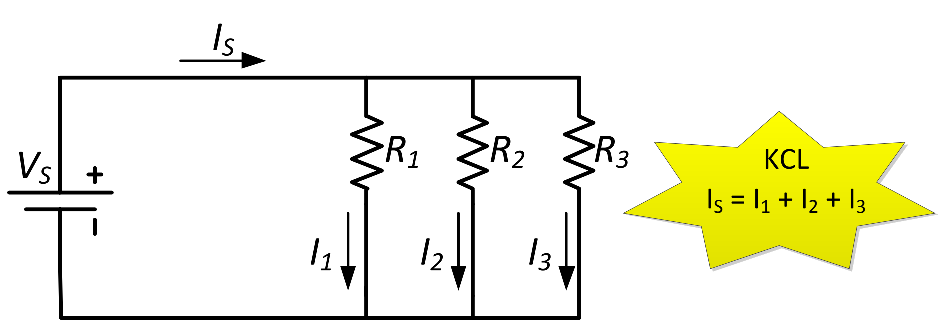


Figure 5: Demonstration of Kirchoff's Current Law

Experiment

Provide answers to questions and observations in the Worksheets section.

1. Simple Electric Circuits

a) Connect the 12V DC supply in series with a Single Pole Single Throw (SPST) switch and light bulb as shown in Figure 6 below. Points along the schematic are labeled so you can relate the schematic to the actual components. For example the power supply terminals are A and F. The terminals of a SPST switch are denoted B and C and the terminals of the light bulb, D and E. A single wire or lead connects each of A to B, C to D, and E to F. Use a voltmeter to measure and record the quantities in Table 1. The double subscript notation makes it easy to identify the path or loop over which voltages are accumulated. For example, the first column of Table 1 identifies the voltages associated with traversing a closed path or loop from F-A-B-C-D-E-F. The second column identifies the voltages associated with traversing a closed path or loop F-E-D-C-B-A-F. How is V_{DE} related to V_{ED}?

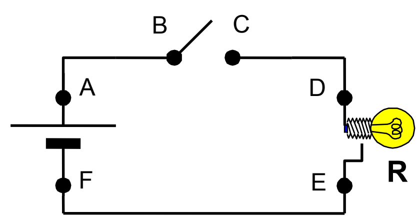


Figure 6: Resistive circuit with a light bulb as the resistive element

b) Now connect the 12V DC supply in series with a SPST switch, two light bulbs and two ammeters as shown in Figure 7 below. Measure and record the voltages and currents listed in the Table 2. How are I_1 and I_2 related? How does the brightness of the bulbs in Figure 7 compare with each other and the brightness of the bulb, **R**, in Figure 6? Complete Table 2 by computing the power for each component in the circuit as described in the Preparation and Background.

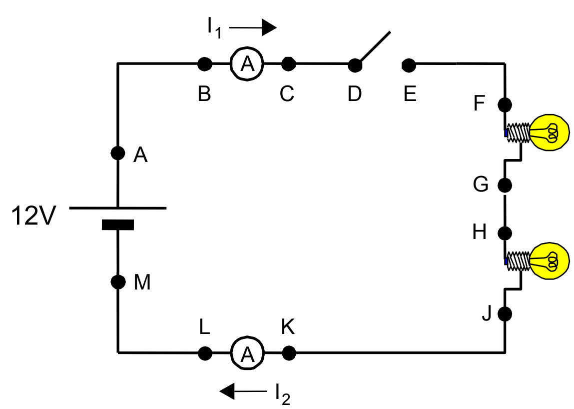


Figure 7: Resistive circuit with two series connected light bulbs.

2. Series and Parallel Circuits

a) For each of the circuits in Figure 8 predict the brightness of each bulb (when the switch is closed) as it compares to the brightness of other bulbs in the same circuit and also compare to the brightness of the reference bulb **R** in Figure 8 (i), i.e., brighter, same, less bright, significantly less bright. Record your predictions on the worksheet.

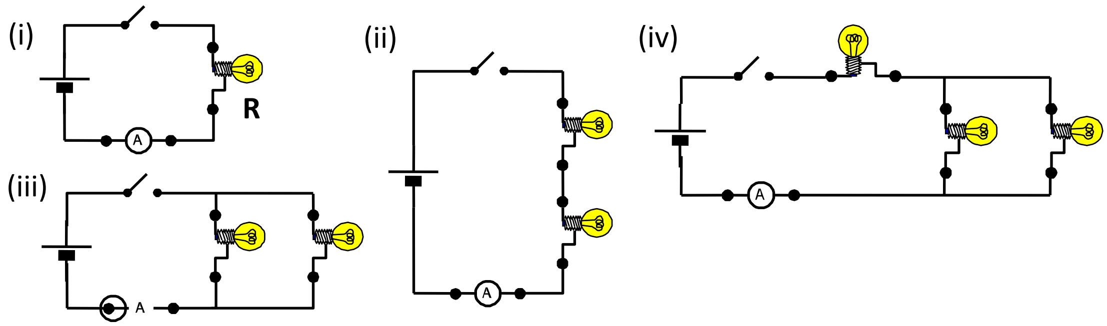


Figure 8: Other Series and Parallel Topologies.

b) Now wire up the circuit in Figure 9. There is a certain combination of switch positions, {S1, S2} that results in an electrical equivalent to one of the circuits in Figure 8. Experiment with various switch positions and complete Table 3 to verify your predictions. Use measurements of voltage across each bulb and current through each bulb to compute the dissipated powers, P_A, P_B and P_C and also enter these into Table 3.

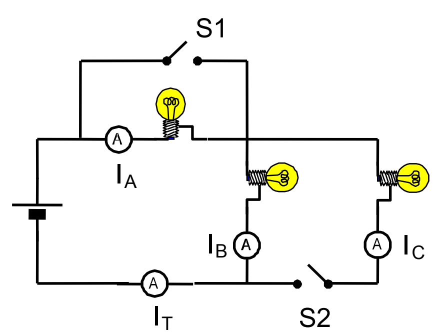


Figure 9: Changing circuit topology with open and short circuits.

3. WORKSHEET :

Table 1: Circuit Measurements for the Circuit of Figure 6.

Switch Closed		**Switch Open**	
V_{AF} =	V_{FA} =	V_{AF} =	V_{FA} =
V_{BA} =	V_{AB} =	V_{BA} =	V_{AB} =
V_{CB} =	V_{BC} =	V_{CB} =	V_{BC} =
V_{DC} =	V_{CD} =	V_{DC} =	V_{CD} =
V_{ED} =	V_{DE} =	V_{ED} =	V_{DE} =
V_{FE} =	V_{EF} =	V_{FE} =	V_{EF} =
Sum =	**Sum =**	**Sum =**	**Sum =**
How is V_{ED} related to V_{DE}?			
Your observations of the sum of the voltages going around the loop F-A-B-C-D-E-F:			
Your observations of the sum of the voltage rises around the loop F-E-D-C-B-A-F:			

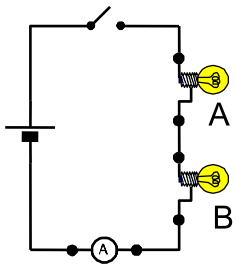
Table 2: Voltage differences and power for all segments of the circuit of Figure 7.

Switch Closed		**Switch Open**	
I_1 = I_2 =		I_1 = I_2 =	
Measurements	**Computed Power (IV)**	**Measurements**	**Computed Power (IV)**
V_{AM} =	**Source AL =**	V_{AM} =	**Source AL =**
V_{BA} =	**Wire BA =**	V_{BA} =	**Wire BA =**
V_{CB} =	**Meter CB =**	V_{CB} =	**Meter CB =**
V_{DC} =	**Wire DC =**	V_{DC} =	**Wire DC =**
V_{ED} =	**Switch ED =**	V_{ED} =	**Switch ED =**
V_{FE} =	**Wire FE =**	V_{FE} =	**Wire FE =**
V_{GF} =	**Lamp GF =**	V_{GF} =	**Lamp GF =**
V_{HG} =	**Wire HG =**	V_{HG} =	**Wire HG =**
V_{JH} =	**Lamp JH =**	V_{JH} =	**Lamp JH =**
V_{KJ} =	**Wire KJ =**	V_{KJ} =	**Wire KJ =**
V_{LK} =	**Meter LK =**	V_{LK} =	**Meter LK =**
V_{ML} =	**Wire ML =**	V_{ML} =	**Wire ML =**
Sum =	**Sum =**	**Sum =**	**Sum =**

2. a)

Predict the brightness of the bulbs. Use > = or < to denote the relationship. For example if the brightness of X and Y and R are the same and brighter than Z denote this: (X = Y = **R**) > Z.

(ii)



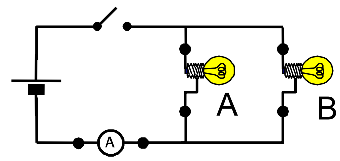
Prediction:

Observation:

Measured Power for A:

Measured Power for B:

(iii)



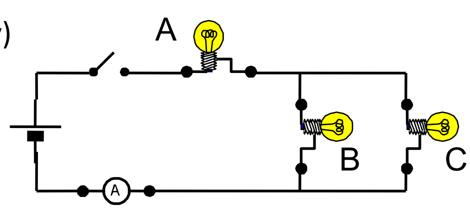
Prediction:

Observation:

Measured Power for A:

Measured Power for B:

(iv)



Prediction:

Observation:

Measured Power for A:

Measured Power for B:

Measured Power for C:

2 b) **Table 3: Variations in circuit topology.**

Equivalent	S1	S2	P_A	P_B	P_C
Figure 8 (i)					
Figure 8 (ii)					
Figure 8 (iii)					
Figure 8 (iv)					