Electrical Measurements

Purpose

1. To become familiar with the basic elements of an electrical circuit.

2. To measure max voltage , max current and power for an individual lamp connected to an AC voltage source.

3. To measure max voltage , max current and power for 2 lamps connected in parallel and then in series to an AC voltage source.

Theory

To begin, let us define the basic quantities used in describing an electrical circuit. An ELECTRIC CURRENT, *I*, is a flow of electrons, or more generally, a flow of electric charge. The fundamental unit of electric charge is called the COULOMB (abbreviated C); one coulomb is the equivalent of the total charge carried by 6.2×10^{18} electrons. The charge of one electron is: -1.6×10^{-19} C. The unit of electric current, called the AMPERE (or AMP for short, abbreviated A) is defined as a rate of flow of one coulomb of charge per second. An AMMETER is a device used to measure current.

In order to maintain an electric current, two factors must be present. One is a CLOSED CIRCUIT - an unbroken loop of electrically conducting materials to provide a path for the current. The second is a source of energy. Energy must be transmitted to the electrons to keep them in continuous motion through the closed circuit. The source of energy may be a battery or an electric generator. In our homes, we obtain electrical energy by plugging into any wall outlet. Each outlet represents one terminus of a complex network of wiring that ultimately connects to a large electrical generating plant.

The VOLTAGE (more properly known as the POTENTIAL DIFFERENCE), *V*, is a measure of the amount of energy that can be supplied to each unit of electric charge by the energy source. The standard unit of energy is called a JOULE (abbreviated J), and the unit of potential difference is called a VOLT (abbreviated V). One volt is equal to one joule per coulomb - that is, one joule of energy supplied to each unit of charge. Thus a wall outlet, which is a 120-volt source, can supply more energy to a given quantity of charge than the typical battery, which supplies only 1.5 volts.

It should be noted that it is possible to have a voltage without a current: voltage represents energy made available to electrons, but there is no current unless the circuit is closed. This is an important safety consideration when wiring an electrical circuit, for one must be careful not to “short out” an open circuit with a conductor of electricity such as a piece of metal *or one's fingers*!

The terminals of a VOLTMETER can be connected to any two points in an electrical circuit. The voltmeter then gives a reading of the potential difference between the points - that is, it indicates the energy available to every unit of charge that flows from one point to the other.

Electric POWER, *P,* is the *rate* at which energy is being supplied or used in an electrical circuit. The unit of power is the WATT (1 watt = 1 joule/sec), abbreviated W. Thus, for example, a “60-watt bulb” consumes energy at the rate of 60 joules per second. It can be readily demonstrated that the *power, **P***, in watts, supplied or consumed is equal to the product of the *voltage, **V*** (energy/charge, measured in volts), times the *current, **I*** (charge/sec, measured in amps):

$$P = VI \qquad (1)$$

The energy obtained from the source by the moving charge is in turn delivered to the various devices that may be found in circuits - light bulbs, toasters, stereo receivers, etc. Such devices are designed to convert electric energy into other desirable forms of energy such as light, heat, or sound. These devices are usually rated in watts - that is, in terms of the rate at which they consume energy. This rating depends in turn on a property of the device known as its RESISTANCE.

The *resistance, **R***, of any electrical device or circuit element is equal to the *voltage, **V*** (the potential difference across its terminals), divided by the *current, **I***. That is,

$$R = V/I \qquad (2)$$

The standard unit of resistance is called the OHM (1 ohm = 1 volt/ampere), abbreviated Ω; the above equation is known as OHM’S LAW. It is often written equivalently as $V = IR$.

The simplest type of electric circuit has a single device (e.g., a light bulb) connected by low-resistance conducting wires to a voltage source. When *two* devices are included in a circuit, they are connected either in SERIES or in PARALLEL. We say that two devices are *in series* when they are connected one after the other, end to end, and thus have only one terminal in common, as shown in Figure 6 below. The same amount of current flows through each device. There is no other place for the current to go. However, the voltage across each device is different, depending on their respective resistances, and is given by Ohm's law.

We say that two devices are *in parallel* when they are connected across the same potential difference, and thus have both sets of terminals connected together, as shown in Figure 5 below. In this case, the two devices have the same voltage, but each has a different current flowing through it. The current in a circuit divides when it reaches any branch point or junction; of course, the total current entering the junction must equal the sum of the currents in the branches.

The *equivalent resistor*, *R*eq, is the *single* resistor that has the same effect as *all* the resistors of the original circuit *acting together*. One can readily show that if you have two resistors, *R*1 and *R*2, in *series*, the *equivalent* single resistance, *R*eq, is given by

$$R\text{eq} = R1 + R2 \qquad (3)$$

One can also show that if you have two resistors, *R*1 and *R*2, in *parallel*, the *equivalent* single resistance, *R*eq, is given by

$$1/R\text{eq} = 1/R1 + 1/R2 \qquad (4)$$

Running the experiment (the data sheet is on page 5)

1) Open www.falstad.com/circuit

2) Click Run/ stop to stop the default simulation.

3) Click Circuits in the top menu and select Blank Circuit (the last item). Now you are ready to build your circuit.

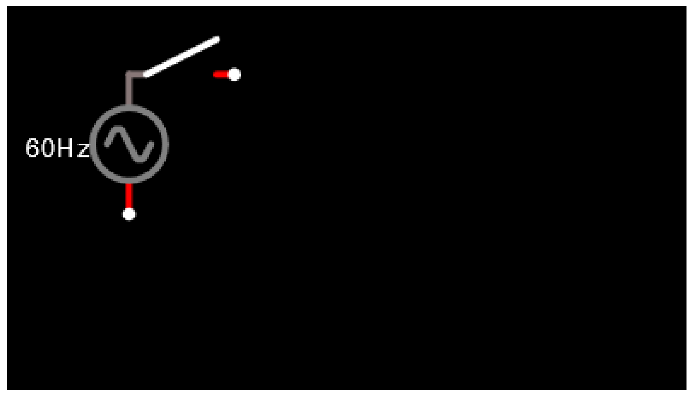

Figure 1: First steps for constructing a circuit

Part 1: Individual lamp

4) Click Draw in the top menu. Click Inputs and sources, and select Add A/C Voltage source (2 terminals). Place it by clicking then dragging the mouse. Move the mouse on it till its color becomes light blue, then right click and edit it. Adjust the Max Voltage to 156 (it already knows the unit is volts, so do not write the unit). Adjust the frequency to 60. Click Apply and then OK.

5) Click Draw and click passive components, and select Add Switch. Now place it in the position as shown in fig.

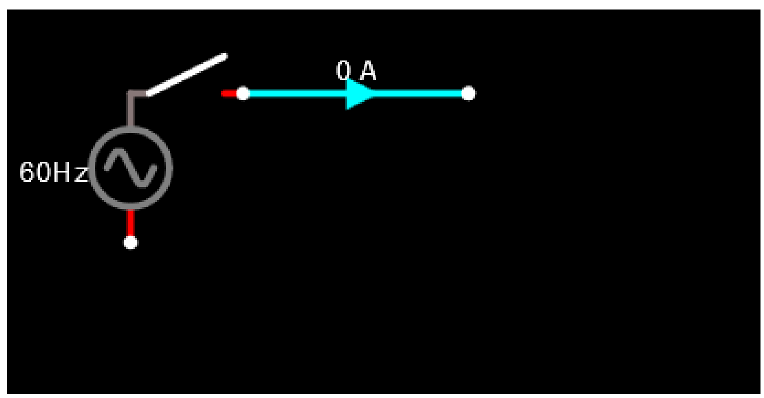

Figure 2: next steps

1, by dragging the mouse.

6) Click draw and Click Outputs and labels and select Add Ammeter. Insert it after the switch as shown in fig. 2. Bring the mouse over it and right click it and **select view in scope**.

7) Click Draw and click Outputs and labels, and select Add Lamp. Drag the mouse to insert the lamp after the Ammeter as shown in fig. 3.

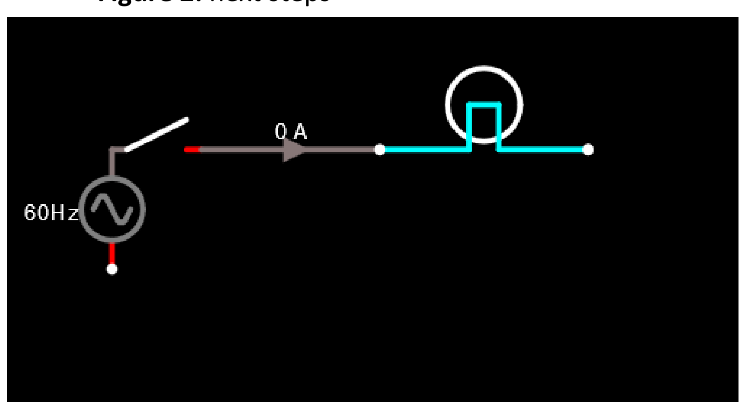

Figure 3: following step adding a light bulb.

8) Right click the lamp and edit its power to 40 (it already knows that the unit is W: Watts).

9) Click Draw and Add wire (you do not need to click Draw again it will keep giving you wires, until you choose another component from the Draw). Add a small horizontal piece of wire after the lamp, then release the mouse, then at its terminal drag another vertical piece of wire downwards and so on as shown in fig. 4 to complete the circuit.

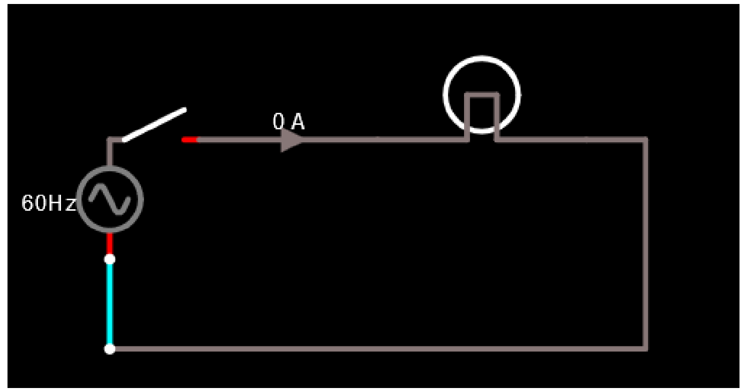

Figure 4: Completing the circuit.

10) An Oscilloscope (scope for short) is a device that displays the voltage. Move the mouse over the lamp until its color becomes light blue, and right click and select add scope. This will add a scope at the bottom of the simulator that will display the voltage across, v and the current, I through the lamp when you run the simulator.

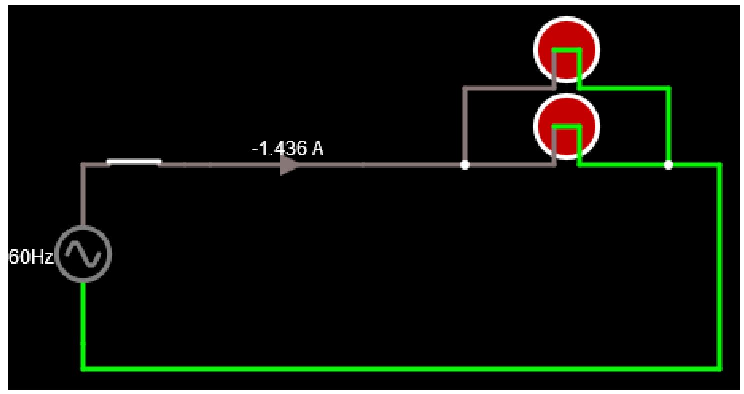

Figure 5: Adding a light bulb in parallel

11) Close the switch and run the simulator by clicking the Run/stop at the top right of the simulator. Stop after about 4 cycles are displayed**. If you place the mouse on at a point of the graph**, (we need the peak (maximum) points) it displays the corresponding voltage, or current, for that point on top of the graph and the lamp in the circuit for which these values are displayed will have light blue color. Record these values.

12) Now we want to use a lamp of power = 60 watts. To do that, bring the mouse over the lamp that is already in your circuit till its color becomes light blue, then right click it and edit and enter 60 in power.

13) Right click the graph and select Reset. Then with the switch closed, click Run/Stop to run the simulator. Record v max and I max and power as you did in step 11.

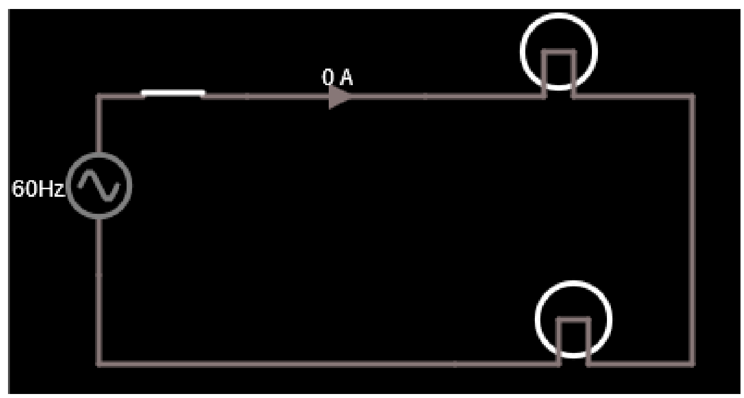

Figure 6: connecting 2 light bulbs in series

Part 2: Two lamps in parallel

We will connect two lamps in parallel and find the voltage across them and the current and power in each.

1) Click Draw, and select outputs and labels and click add Lamp. Now insert it in parallel with the one already in the circuit as shown in fig. 5, and then click Draw, and select add wire and add a wire as shown in fig. 5 so that the 2 lamps are in parallel. Now move the mouse over this 2nd lamp until its color becomes light blue and right click and edit. Enter 40 in the power (it already knows the unit is w: watts). Also, right click this lamp and select add scope (so that the graph displays its voltage and current).

2) With the switch closed, run the simulator for about 4 cycles of the voltage and current to appear, then stop the simulation. Record the max voltage, max current and the power for each lamp.

Part 3: Two lamps in series

1) Repeat part 2 with the same 2 lamps but now connected in series. To do that delete the bottom wire, click Draw and select Select/Drag Sel. Drag Lamp 2 in place of that wire, and connect the gap with a wire as shown in fig. 6.

You do not need to add the scopes again, they are already at the bottom of the simulator. Run the simulator and repeat the steps in part 2 (i.e. measure max v and max current and power for each lamp, and record your values). Stop the simulator. The result should look like fig. 7.

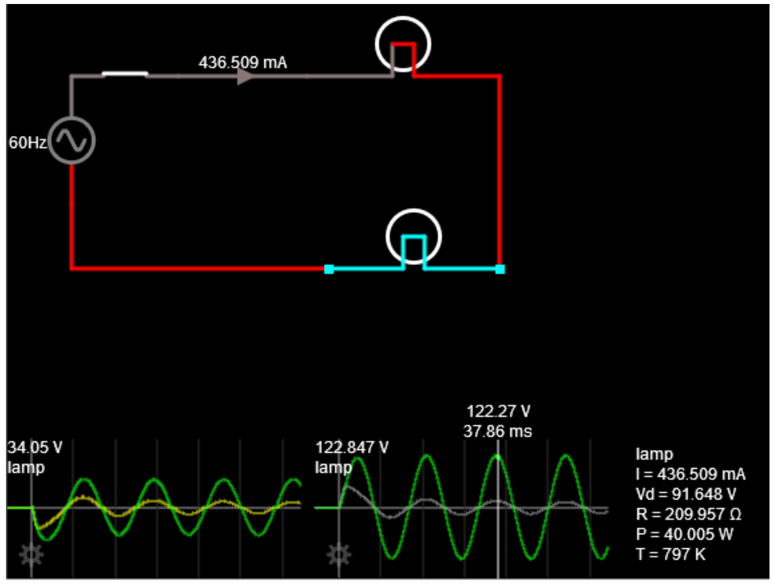

Figure 7: An example for simulation for 2 bulbs in series

Questions

1. Which has a greater resistance, a 60-watt bulb or a 40-watt bulb?

2. How does the calculated power compare with the rated power of each bulb in parts (1) and (2)?

3. How does the effective (combined) resistance of the two bulbs in parallel compare with their individual resistances?

4. How does the combined power output of the two bulbs in parallel compare with their combined rated power?

5. When the two bulbs are connected in series, does each lamp draw full power? Can you explain why?

6. When two bulbs are connected in parallel and one of the bulbs is disconnected, what happens to the power output of the other bulb?

7. When two bulbs are connected in series and one of the bulbs is disconnected, what happens to the power output of the other bulb?

8. Which type of connection - series or parallel - is more suitable for use in wiring the outlets in a home? Explain your answer.

9. When a fuse or circuit breaker "blows", all of the lights go out. Is the fuse connected in series or in parallel with the lights?

The data sheet is on the next page

Data Sheet

Name: **Group:**

Date experiment performed:

Table 1: Individual Light Bulbs

	Current, I, (A)	Voltage, V (V)	Resistance, R (Ω)	Power, P(W)
60- Watt Bulb				
40- Watt Bulb				

Table 2: Two Light Bulbs in Parallel

Total Current, I_{total} (A) as max I displayed by scope of ammeter	Current, I, (A)	Voltage, V (V)	Resistance, R (Ω)	Power, P(W)
	I_{40} =	V_{40} =		
	I_{60} =	V_{60} =		
	$I_{40} + I_{60}$ =	Average =	Avg V/ I_{total} =	Avg V X I_{total} =

R_{eq} (Theory) = ………………….Ω Avg V/ I_{total}= …………………. Ω %difference= …………………….%

Table 3: Two Light Bulbs in Series

	Current, I (A)	Voltage, V (V)	Resistance, R (Ω)	Power, P (W)
60W Bulb		V_{60} =		
40 W Bulb		V_{40} =		

R_{eq} (Theory) = ……………….Ω (V_{60} + V_{40})/ I = ……………..Ω % difference= …………………..%

Answers to questions:

1.

2.

3.

4.

5.

6.

7.

8.

9.