University of Michigan
Physics 106 **Fall 2014**
Lab 9: Solar Heating and Solar Energy

Name: ______________________________ **Partners:**______________________________

A. Solar Heating

We all know a car parked under sunlight can get hot quickly. According to the National Highway Traffic Safety Administration about 25 children per year die from severe hyperthermia in parked cars. To demonstrate the severity of solar heating of a car we will monitor the temperature rise in a jar that is placed near an incandescent light bulb.

1. In this experiment you will be using a 45 Watt indoor floodlight to represent the sun. We will use a simple jar to represent the car. Place the jar about 6 inches from the lamp. Make sure the thermocouple is placed inside the jar and the multimeter gives a correct temperature reading. Start monitoring the temperature after you turn on the light bulb. Try to make a temperature reading every 30 seconds and plot the measured temperature as function of time. It is interesting to note that you can put transparent plastic wrap in between the lamp and the jar and the temperature increase would not be any different. Discuss your findings.

2. Let the jar and thermocouple cool off and then repeat the same experiment adding the black foil to the jar. This models a black car interior. Does this make a difference? Why?

3. Let the jar and thermocouple cool off and then repeat the same experiment using the LED lamp. Does this make a difference? Why?

B. Solar Heating of Water

In many countries, solar energy is used to heat water. To demonstrate such passive use of solar energy, we will try to heat water placed in a test tube painted in black.

1. You will again be using a 45 Watt indoor floodlight which will represent the sun. Fill the black test tube fully with water (about 10 mL) and place it 6 inches from the lamp. Make sure the thermocouple is placed inside the water and the multimeter gives a correct temperature reading. Monitor the temperature after you turn on the light bulb on for 10 minutes. Try to make a temperature reading every minute and plot the measured temperature as function of time. Based on the temperature reading calculate how much energy in calories is transferred from the lamp to the water in 10 minutes. Remember 1 calorie is the energy required to raise the temperature of 1 gram of water by 1 degree.

2. Measure the light output from the 45 Watt indoor floodlight by placing the light meter 6 inches from the light bulb. Assuming a painted area of 10 cm^2 (10^{-3} m^2) calculate how much energy in calories is transferred from the lamp to the water in 10 minutes. Remember **1 lux=1 lumen/m^2; 1 lumen = 1.46×10^{-3} W; and 1 calorie/second = 4 W.**

3. Is the energy delivered from the light bulb greater or less than the energy absorbed by the water?

4. When we do the same experiment with a LED lamp with similar luminosity, we were not able to heat the water. Why do you think this is? (Hint: There are forms of light which are not visible to the human eye or the light meter.)

C. Solar Cells

Solar energy can also be captured by solar cells that convert solar energy into electrical energy. You will measure the efficiency of a real solar cell.

1. First, you need to establish a fixed light input. Use the light meter to determine the distance from the LED bulb needed to provide 700 lux (about 1 watt/m^2). If you hold the bulb at this distance from the solar cell, what will be the luminous power falling on the cell? (You will need to measure the area of the solar cell.) Call this P_{lum}. Show your work.

P_{lum} = ___________W

2. Now you can measure the electrical power. Connect the solar cell to a ~800Ohm resistor. Hold the LED light at the established distance. Use the multimeter to measure the voltage across the resistor. Find the power. Recall for a resistor $P=IV=V^2/R$. Show your work.

P_{ele} = ___________ W

3. **Efficiency of the solar cell:** The ratio of electrical and light power is the efficiency $\epsilon = \frac{P_{ele}}{P_{lum}}$. What do you get for the efficiency of the solar cell?

Question: If solar energy were not free, and if we asked Bill Gates to pay for the energy that earth gets from the sun, how long would it take for Bill Gates to spend all of his money? Motivated by this question, we introduce a funny unit of energy (Gates).

A fun new unit of energy: Let us introduce a unit of energy called Gates, named after Bill Gates. We define 1 Gates as the amount of energy you can buy using $100 Billion at a price of 10 cents per kWh.

$$1 \text{ Gates} = 10^{12} \text{ kWh}$$

The amount of solar electromagnetic radiation incident on earth is known as the solar constant and has a value of 1.361 kW/m^2. The radius of earth is 6.37×10^6 m.

Group Discussion: This is a humbling calculation for understanding the magnitude of solar energy. We learn that even Bill Gates's fortune would be depleted very quickly, if the sun were not free. It also illustrates the potential for solar energy.