Worksheet: Energy and Lighting

Name: _____ Group name: _____

Note: You are working with AC voltages of 120 V, which are dangerous. Be careful not to plug in anything that has exposed conductors. Be sure the bulbs are firmly screwed into sockets before plugging in, and unplug when changing bulbs.

Also Note: Since voltage and current are constantly changing in an AC circuit, one measures something called the "root mean squared" voltage V_{rms} and current I_{rms}. These are something like the effective DC equivalent of the AC circuit, such that the power from an AC circuit is $P = V_{\text{rms}} I_{\text{rms}}$.

1. Explain how an incandescent light bulb produces light. Why is it hot?

2. You will use a luxmeter to measure **illuminance** (brightness at a particular point), which is measured in the SI unit **lux.** Illuminance is luminuous power per area, and thus **1 lux = 1 lumen/m².** To convert to the luminuous power (lumens), hold the meter a fixed distance d from the source of light. Multiply lux by $4\pi d^2$ to get lumens ($2\pi d^2$ for the LED bulb). This is the area of a (half) sphere with radius d. Use 683 lumens = 1 Watt to convert to luminuous power.

   - Why is the lux meter measuring illuminance rather than luminous power?

   - Measure the average light output and the average electrical power for the three bulbs provided: incandescent, CFL and LED. To measure illuminance, switch on the luxmeter, take off the cap and press the "RANGE" key until you get a reading. To measure AC current, use the **clamp-on ammeter**. Wrap one wire of the cord around two fingers 10 times and thread the ammeter loop. Switch to the 200 ACA scale. I_{rms} is then 1/10 of the meter reading.

Type	illuminance	Distance d	Luminuous power P_L	V_{rms}	I_{rms}	electrical power P	Efficiency ϵ
Incand.							
CFL							
LED							

3. Research what DTE charges consumers for one kWh of electricity (rough figure is enough):

   - Cost: _____ $ / kWh

   - Think about the unit here: which physical quantity has as a unit **kWh**? What do you need to know from an electrical circuit to calculate it?

   - Calculate the total cost per year to **own** and **operate** each of the bulbs and enter into your table. Include the annualized purchase price (e.g. a $10 bulb that lasts 5 years will have an annualized cost of $2). Assume 3000 hours use per year (about 8 hours per day). The prelab provides some useful data.

Type	electrical power P (from 2)	average lifetime (h) (prelab)	Lifetime electricity costs	purchase price (prelab)	Average lifetime (yrs)	Annualized purchase price	**Total annual cost of operation**
Incand.							
CFL							
LED							

   - Calculate the total annual cost per luminuous power ($ per year and lumen). Which one is the **most efficient** light bulb to operate?

4. Carefully hook up the solar cell using the alligator clips to the $R = 780$ ohm resistor provided.

   - Use the lux meter to determine the distance from the halogen bulb needed to provide a **illuminance** of 700 lux (about 1 Watt/m^2).

     d = _____ ____

   - Hold the bulb directly above the solar cell at a distance of d. Use the **multimeter** in the DC setting and determine the voltage and current with a resistor load. Compute the electrical power.

     I = _____ _____, V = _____ ____

     P = _____ _____

   - Culate total **luminuous power** of the light hitting the solar cell. To do so, measure the area of the solar cell and use the fact that luminuous power is illuminance E_L times area A.

     A = _____ ____

     P_L = _____ ____

   - Find the **efficiency** of the solar cell:

     ϵ = _____ _____

   - Which of the following would be a practical use of the small solar cell (use 700 W/m^2)?

     a) Charge your phone (Takes about 5 watts for 30 minutes)

     b) Bring a quart of water to boil in 5 min (Takes about 400 kJ)

     c) Light your room with an LED lightbulb

   - Find another use: _____