Experiment 1: The Electrical Equivalent of Heat

① Measure and record the room temperature (T_r).

② Weigh the EEH Jar (with the lid on), and record its mass (M_j).

③ Remove the lid of the EEH Jar and fill the jar to the indicated water line with cold water. **DO NOT OVERFILL.** The water should be approxmately 10°C below room temperature, but the exact temperature is not critical.

④ Add about 10 drops of India ink to the water; enough so the lamp filament is just barely visible when the lamp is illuminated.

⑤ Using leads with banana plug connectors, attach your power supply to the terminals of the EEH Jar. Connect a voltmeter and ammeter as shown in Figure 1.1 so you can measure both the current (I) and voltage (V) going into the lamp. **NOTE:** For best results, connect the voltmeter leads directly to the binding posts of the jar.

⑥ Turn on the power supply and quickly adjust the power supply voltage to about 11.5 volts, then shut the power off. **DO NOT LET THE VOLTAGE EXCEED 13 VOLTS.**

⑦ Insert the EEH Jar into one of the styrofoam Calorimeters.

⑧ Insert your thermometer or thermistor probe through the hole in the top of the EEH Jar. Stir the water gently with the thermometer or probe while observing the temperature. When the temperature warms to about 6 or 8 degrees below room temperature, turn the power supply on.

➤ **NOTE:** You may want to turn the lamp on to help the cold water reach this starting temperature. If you do, be sure that you turn the lamp off for several minutes before you begin your measurements, so you are sure the water temperature is even throughout the jar. Record the starting time (t_i) and the temperature (T_i).

⑨ Record the current, I, and voltage, V. Keep an eye on the ammeter and voltmeter throughout the experiment to be sure these values do not shift significantly. If they do shift, use an average value for V and I in your calculations.

⑩ When the temperature is as far above room temperature as it was below room temperature (T_r - T_i = Temperature - T_r), shut off the power and record the time (t_f). Continue stirring the water gently. Watch the thermometer or probe until the temperature peaks and starts to drop. Record this peak temperature (T_f).

⑪ Weigh the EEH Jar with the water, and record the value (M_{jw}).

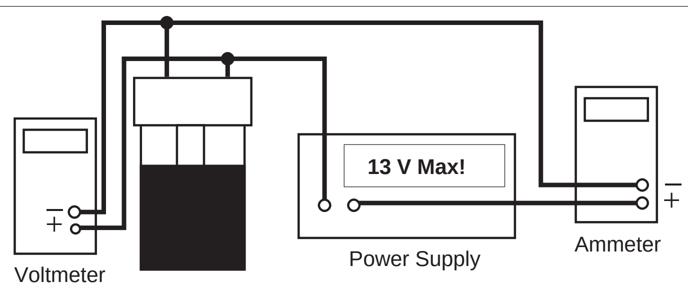

Figure 1.1 Electrical Connections

Data

T_r = ______________________________

M_j = ______________________________

M_{jw} = ______________________________

V = ______________________________

I = ______________________________

t_i = ______________________________

t_f = ______________________________

T_i = ______________________________

T_f = ______________________________

Calculations

In order to determine the electrical equivalent of heat (J_e), it is necessary to determine both the total electrical energy that flowed into the lamp (E) and the total heat absorbed by the water (H).

E, the electrical energy delivered to the lamp:

E = Electrical Energy into the Lamp = $V \cdot I \cdot t$ = ______________________

$t = t_f - t_i$ = the time during which power was applied to the lamp = ________

H, the heat transferred to the water (and the EEH Jar):

$H = (M_w + M_e)(1 \text{ cal/gm C})(T_f - T_i)$ = ______________________

$M_w = M_{jw} - M_j$ = Mass of water heated = ______________________

M_e = 23 grams. Some of the heat produced by the lamp is absorbed by the EEH Jar. For accurate results, therefore, the heat capacity of the jar must be taken into acount (The heat capacity of the EEH Jar is equivalent to that of approximately 23 grams of water.)

J_e, the Electrical Equivalent of Heat:

$J_e = E/H$ = ______________________________________

Questions

① What effect are the following factors likely to have on the accuracy of your determination of J_e, the Electrical Equivalent of Heat? Can you estimate the magnitude of the effects?

a. The inked water is not completely opaque to visible light.

b. There is some transfer of thermal energy between the EEH Jar and the room atmosphere. (What is the advantage of beginning the experiment below room temperature and ending it an equal amount above room temperature?)

② How does J_e compare with J, the mechanical equivalent of heat. Why?

Experiment 2: Efficiency of an Incandescent Lamp

Repeat Experiment 1, except do not use the India ink (step 4) or the styrofoam Calorimeter (step 7). Record the same data as in Experiment 1, and use the same calculations to determine E and H. (Convert H to Joules by multiplying by J_e from the first lab.)

In performing the experiment with clear water and no Calorimeter, energy in the form of visible light is allowed to escape the system. However, water is a good absorber of infrared radiation, so most of the energy that is not emitted as visible light will contribute to H, the thermal energy absorbed by the water.

The efficiency of the lamp is defined as the energy converted to visible light divided by the total electrical energy that goes into the lamp. By making the assumption that all the energy that doesn't contribute to H is released as visible light, the equation for the efficiency of the lamp becomes:

$$\textbf{Efficiency} = (E - H_j)/E.$$

Data

T_r = ______________________________

M_j = ______________________________

M_{jw} = ______________________________

V = ______________________________

I = ______________________________

t_i = ______________________________

t_f = ______________________________

T_i = ______________________________

T_f = ______________________________

Calculations

In order to determine the efficiency of the lamp, it is necessary to determine both the total electrical energy that flowed into the lamp (E) and the total heat absorbed by the water (H).

E, the electrical energy delivered to the lamp:

E = Electrical Energy into the Lamp = $V \cdot I \cdot t$ = ___________________________

$t = t_f - t_i$ = the time during which power was applied to the lamp = ________

H, the heat transferred to the water (and calorimeter):

$H = (M_w + M_e)(1\ \mathrm{cal/gm\ C})(T_f - T_i)$ = ____________________________________

$M_w = M_{jw} - M_j$ = Mass of water heated = _______________________________

$H_j = H\ J_e$ = ____

M_e = 23 grams. Some of the heat produced by the lamp is absorbed by the EEH Jar. For accurate results, therefore, the heat capacity of the jar must be taken into acount (The heat capacity of the EEH Jar is equivalent to that of approximately 23 grams of water.)

Efficiency:

$$\frac{E - H_j}{E} = \underline{\hspace{10cm}}$$

Questions

① What effect are the following factors likely to have on the accuracy of your determination of the efficiency of the lamp? Can you estimate the magnitude of the effects?

a. Water is not completely transparent to visible light.

b. Not all the infrared radiation is absorbed by the water.

c. The styrofoam Calorimeter was not used, so there is some transfer of thermal energy between the EEH Jar and the room atmosphere.

② Is an incandescent lamp more efficient as a light bulb or as a heater?