

# Electrical Equivalent of Heat

**Purpose:** To determine the equivalence between heat energy in calories and electrical energy in joules

**Equipment:** Calorimeter, EEH jar, India ink, thermometer, power supply, voltmeter, ammeter, connecting wires.

## Introduction:

The electrical energy,  $\Delta E$ , delivered to a light bulb can be calculated from

$$1) \quad \Delta E = I V \Delta t$$

where  $I$  is the current in amps,  $V$  is the voltage in volts, and  $\Delta t$  is the time that the current flowed.

The heat,  $\Delta Q$ , transferred to a container (the EEH jar in this experiment) filled with water can be calculated by

$$2) \quad \Delta Q = (M_w + M_e)(1\text{cal/g}^{\circ}\text{C}) \Delta T$$

where  $M_w$  is the mass of the water,  $M_e$  is the mass of water that has a heat capacity equivalent to the jar. For the EEH jar in your experiment today use  $M_e = 23$  g.

If we assume that all of the electrical energy given to the light bulb goes into heating the water and the jar then the electrical equivalent of heat  $J_e$  (in joules/cal) can be calculated by

$$3) \quad J_e = \Delta E / \Delta Q$$

## Procedure:

### Part I The Electrical Equivalent of Heat

1. Measure and record the room temperature ( $T_{\text{rm}}$ ).
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 approximately  $10^{\circ}\text{C}$  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 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.

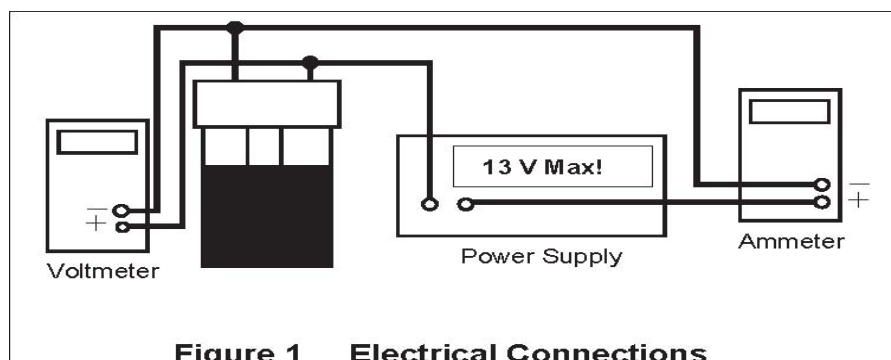


Figure 1 Electrical Connections

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 through the hole in the top of the EEH Jar. Stir the water gently with the thermometer 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 ( $T_{rm} - T_i = T - T_{rm}$ ), shut off the power and record the time  $\Delta t$ . Continue stirring the water gently. Watch the thermometer 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 ( $M_{jw}$ ).
12. Using equations 1,2 and 3 determine the electrical equivalent of heat,  $J_e$ .
13. Discuss sources of error in your experiment.

## **Part II 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  $\Delta E$  and  $\Delta Q$ .

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  $\Delta Q$  is released as visible light, the equation for the efficiency of the lamp becomes:

$$\text{Efficiency} = (\Delta E - \Delta Q) / \Delta E.$$