Name:

Physics 589 – Electricity – Sonnenfeld

1 Power dissipated by a resistor and Microcalorimeter:

1.1 Theory

You will show that the electrical power into a resistor is correctly given by the formula

$$P = IV \tag{1}$$

Or the alternate formula:

$$P = V^2/R \tag{2}$$

.

You will do this by using a resistor to heat water and converting the resistor power into electrical energy using the formula

$$U_{elec} = P\Delta t \tag{3}$$

Once you know the electrical energy U_{elec} added to the resistor you will to see if the thermal energy needed to heat the water matches the predicted electrical energy.

The thermal energy is

$$U_{thermal} = mC_p\Delta T \tag{4}$$

Here m is the mass of the water in grams, C_p is the specific heat of water ($C_p = 4.19J/g \cdot C$) and ΔT is the temperature rise of the water (in degrees C).

Setting $U_{thermal} = U_{elec}$ allows to solve for ΔT.

$$\Delta T = \frac{U_{elec}}{4.19m} \tag{5}$$

1.2 Setup

Get a 2" thick styrofoam sheet. Use a 3/4" drill to drill a (roughly) three 3/4" deep holes (taking care not to puncture all the way through the sheet). These are your microcalorimeters. Get an 18 Ohm, and a 33 Ohm resistor and a 6 V lantern battery. Get a temperature sensor (ideally the thermocouple that comes with the Klein Tools multimeter). (Assumes a 3 ml syringe or a plastic pipette is provided and that a stopwatch or other timing device is available).

1.3 Measure Initial Values

Bring water to room temperature Pour a glass of water a couple hours before you begin to allow it to come to room temperature.

Measure and record V_B V_B is your battery voltage. Use your voltmeter. A 6 V battery is not really 6.0 Volts.

Measure and record R_{18} and R_{33} Check your resistors. If they are more than two Ohms different from the specification contact your instructor (there was probably a mistake).

Meter out 2 ml of water Use a pipette or the provided 3 ml syringe to meter out a known amount of water (2 ml is a good target) into each of the three microcalorimeters. Record this value.

Measure T_0 T_0 is the initial temperature of your water. Insert your temperature probe and leave it in one of the calorimeters. Be sure to specify whether in Fahrenheit of Celsius.

1.4 Take Data

Your heater will be one of the resistors provided. (You will do the experiment twice, first with R_{18} and then with R_{33}.) You will use a separate calorimeter for each run. The third calorimeter allows you to repeat one run if you make a mistake.

Safety Note. Note that you should not connect your resistor until it is already in the water. You will be putting a large amount of heat into your resistor and if you do it out of the water it may begin to smoke and will certainly be dangerously hot. Once the resistor is in the water you may touch it. It will be hot, but will not burn you immediately.

The data you need to take is to record the time since you began and the temperature in the cell. Record your data in a chart like that below. Note you will need two charts (one for R_{18} and one for R_{33}). The other columns of the chart will be filled out in the Data Analysis section.

1.5 Data Analysis

For this part it is certainly appropriate to use a computer spreadsheet if you know how. You will analyze the data as follows:

Calculate U_{elec}: Fill in the 2nd column of the table using equation 3 and calculating the power using either equation 1 or 2. Δt is the time from the beginning of the experiment. Thus the first row is for your initial values. For the second row, ΔT is 20 seconds, 40 seconds for the third row, etc. Note that U_{elect} will be different for the two different resistors. This is actually the point of the lab.

Calculate ΔT: ΔT is the temperature difference from row one.

Time Δt (s)	Electrical Energy U_{elec} Joule	Temperature in F T deg. F	Temperature Change in F ΔT deg. C	Temperature Change in C ΔT_{act} deg. C	Theoretical Temp Chnge. ΔT_{th} deg. C
0					
20					
40					
60					
100					
120					
140					
160					
180					

Calculate ΔT_{act} in C: Assuming your thermometer measures in degrees F, convert to degrees C. If your thermometer is already in C, then you can skip this step.

Calculate ΔT_{th} in C: Use equation 5 to calculate the theoretical value of ΔT using the value of U_{elec} from the 2nd column.

Having completed the table, plot the results both actual and theoretical. The theoretical values are likely to all be 20% or more larger than the experimental values. Also, you may find that the slope of the experimental line decreases with time. Can you imagine why this might be? It does not have to do with electricity, it is more about what happens as you heat the water. Try to explain what is going on here.

Note, if your experiment and theory are more than a factor of two different, you almost certainly made an error in your measurements or analysis. Contact your instructor with your raw data and a sample calculation of U and ΔT theory.