University of Michigan
Physics 106 **Fall 2014**
Lab 7: Energy, Heat, Temperature, Calories

Name: ______________________________ **Partners:**______________________________

Heat and temperature are frequently confused. Heat is energy. Temperature is measure of the average energy of the molecules or atoms in a substance. Heat flows from high to low temperature. Adding or subtracting heat will change the temperature of an object.

Today you will assemble simple *calorimeters* and measure the energy deposited in a known amount of water (100 ml=100 gm) from different energy sources. The calorimeter consists of the water in a Styrofoam cup and a digital thermometer. As you will see, the energy transferred to the water is proportional to the temperature rise of the water, and this can be used to measure energy.

Section 1: Electrical Power and Water Calorimetry

1. In our light-bulb circuits, electrical energy from the battery is transformed into heat and light in the light-bulb. When we consider the more general case of a resistor, we say that when current flows through a resistor, it gets hot. Describe what happens microscopically in the resistor so that the flow of current creates heat:

2. Heat is energy in motion. Heat flowing out of the resistor is transmitting a certain amount of energy each second. The energy per second is called **Power** and is measured in **Watts (W).**

It turns out that the power dissipated in a resistor is simply given by the product of the current and the voltage:

$$\mathbf{P = IV}$$

Using Ohms Law, I = V/R, we can re-express this as:

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

Calculate the power dissipated by a 30Ω resistor when it is connected across 15V. Express your answer in Watts.

3. Energy is measured in **calories (cal)**. So the power, energy per second, is calories per second.

1 watt = ¼ calories per second
1 calorie/second = 4 W

Calculate the calories per second delivered by the resistor circuit in Part 2.

4. How many calories does the resistor deliver in 5 min? (Show your work)

5. Now we are going to use temperature to measure energy. You will measure the temperature with a *thermocouple:* a junction of two dissimilar metals (like a battery) that generates a small voltage that is temperature dependent. The multimeter measures this voltage and uses the thermocouple *calibration* to convert to temperature.

Pour 100 ml (= 100g!) of water into the Styrofoam cup. Measure the initial temperature of the water and write it down. Leave the thermocouple in the water.

Initial water temperature___________________________

6. **Read these instructions fully before doing anything:** You have a 30Ω resistor and a power supply that you can set to 15V, reproducing the situation in your calculations on page 1. You are going to power it up, feel it with your fingers to verify it is getting hot, dunk it in the water, put the lid on, and measure the temperature after it has been in the water for 5 min. While you are waiting, proceed with the steps below. Note: if you leave the resistor out of water for too long, it will get too hot and explode. It needs to be in the cool water before it gets too hot. Verify that it is warming up, then put in the water, and put the lid on.

Ready? Do it.

7. When a substance is heated, it turns out that the change in temperature is proportional to the change in heat energy. *The temperature is a measure of the amount of energy that has been internalized into the motions of the atoms in the material.*

In fact, the **calorie** is defined in this way:

1 calorie is the energy required to raise the temperature of 1 gram of water by 1 degree.

Based on your numbers for Sec. 1.4 and Sec. 1.5, and your knowledge of the mass of water in the cup, predict what your thermometer should read at the end of the 5 min period.

8. After 5 min, what is the temperature of the water? How does it compare to your prediction above? Comment generally on your understanding of what has happened, starting from the voltage on the resistor.

Section 2: Food Energy

Now we will reverse the technique, and use the temperature rise in water to measure energy. The energy of interest now is food energy, and the method you will use here is a simplified version of the real technique used to measure the caloric content of food.

1. Put 100 ml of water in the soda can. Put the screen on top of the stove, and put the soda can on top of that. Put the thermocouple in the water, measure the temperature and write it down.

2. Put a single large piece of popcorn in the stove, set it on fire, and watch the water temperature. When the popcorn is completely burned, record the final water temperature.

3. Based on the definition of the calorie in Section 1.7, calculate the heat transferred to the water, in calories.

4. The heat in Sec 2.3 is some fraction of the total energy released in oxidation of the popcorn. Suggest an estimate of this fraction, based on your setup. Using your estimated fraction, what is the total energy released in the oxidation of the popcorn?

5. Our bodies metabolize the energy from food by the same process of oxidation as above. It is performed more slowly, molecule by molecule, but the energy release is the same. The unit of this energy is the Food Calorie (Cal). 1 Food Calorie = 1000 calories. Based on your number in Sec 2.4, how many Calories does your body get out of 1 piece of popcorn?