3705 Lab 0 : Thermometry, specific heat and Newton's law of cooling

1) **Thermometry:** Do a calibration with ice water and with boiling water, and room temperature. How linear is the response of the thermocouple? Of the thermistor (temperature dependent resistor)? Fit these with a simple curve so that for a given value on either you can compute the temperature, T.

We will also be using thermistors throughout the various labs, and so it is important that you understand how to use them and convert the resistance to a temperature.

2) Now put the thermistor at a fourth temperature. How well does your formula for the fit do?

3) Use the digitizing meter to take a series of measurements with the thermistor, say every 10 seconds while something (like a block of copper) is cooling in air while touching both a thermometer and the thermistor.

4) Find an analytic form that fits the thermistor data well. You may find it useful to use your physics reasoning to come up with a simple functional form.

5) Repeat the step 3 & 4 with a thermocouple if available.

6) **Specific heats:** Heat (denoted Q, which is energy) is different than hot (which is the temperature T of a material). Heat measures a *quantity* of energy whereas temperature is a measure of how *concentrated* that energy is in a material...that is, roughly, the quantity of heat in a system divided by the number of subsystem's motions ("degrees of freedom") in which the energy is stored.

The specific heat is the **slope** of the heat versus the temperature of a substance...and so from the forgoing it has something to do with the number of degrees of freedom available to the substance. We measure it by dumping a known amount of heat into a substance and watching how much that causes the temperature to rise.

$$C_v = \frac{\delta Q}{M \delta T} \tag{1}$$

A calorie (Cal) is the amount of heat it takes to raise one gram of water one degree Celsius. A Joule is 0.24 Cal. There are thus 4.18 Joules in a Calorie. Sometimes you will see units of calories (cal) with a small 'c'. These are kilocalories (1cal = 1 KCal = 1000 Cal).

Measure the dimensions of the aluminum cube, Weigh it as well. Are your measurements consistent with the accepted density of aluminum? (density is mass per unit volume, that is, $\rho = M/V$).

7) Now devise an experiment to determine the ratio of the specific heat of aluminum to that of water. Do the experiment, record your data and report your specific heat ratio.

8) **Newton's Law of Cooling:** states that the rate of change of the temperature of a hot body in still air is proportional to the temperature difference between it and the air. In equations, this reads,

$$\frac{\mathrm{d}T}{\mathrm{d}t} = -C(T - T_{\mathrm{air}}) \tag{2}$$

where C is a contant (the "cooling rate") that depends only on the shape of the body, and perhaps on some material/surface characteristic. This C is not a specific heat !!!! It is a different constant. This "law" of cooling isn't a law in the sense of Newton's laws of motion, which are for more general and come from "first obsevations/assumptions". It is not too hard to derive a relation like Eq.(1) from convection currents that arise as a hot body cools in stagnant air. It is also straightforward to solve Eq.(2) for the temperature of body as a function of time.

$$T(t) = (T_h - T_0)e^{-Ct} + T_0 \tag{3}$$

In this part of the lab you will test Newton's law of cooling by measuring C for two pennies...one in its original condition and one that has been bent into a smaller hunk.

You will have to use the fit from your thermistor/thermocouple curve from parts 3 &4. Can you determine what the ratio ($C_{unfolded}/C_{folded}$ is between the cooling rate of the two pennies? Why the difference?

10) (Ice melt) With the thermistor installed in a cup full of snow, drop some salt into the snow. Does salt melt snow by heating it to melting? Record and remark on the thermistor traces with time.