PHSX 101L **Experiment 9** **Name:**______________________

Title: Specific Heat

Object: To determine the specific heat of various substances.

Introduction: Specific heat is an indication of how much the temperature of an object will change when thermal energy is added or subtracted. Specific heat varies from substance to substance which means that two objects of the same mass but of different substances will change temperatures by different amounts when the same amount of energy is added or subtracted. For example, have you ever held a hot piece of pizza by its crust only to have the moister parts burn your mouth when you take a bite? The meats and cheeses have high specific heat, while the crust has a low specific heat capacity. The specific heat of a substance c would be the slope of a straight line of energy (E in general, or Q specifically for thermal energy) vs. the mass of the object times the change in temperature.

$$E = cm\Delta T \tag{1}$$

Therefore the specific heat of a substance can be calculated by measuring the change in temperature of an object when a known amount of energy is added (such as by doing mechanical work on the object).

Specific heats of different substances can be compared by measuring temperature changes as thermal energy flows from one object to another. For example, if a sample of hot metal is dropped into a quantity of cold water then they both arrive at a common temperature somewhere between the extremes. By using a good calorimeter to minimize losses or gains to or from the room we can assume that the thermal energy Q lost by the metal is gained by the water.

$$Q_{lost} = Q_{gained} \tag{2}$$

$$c_{\mathrm{m}} m_{\mathrm{m}} \Delta T_{\mathrm{m}} = c_{\mathrm{w}} m_{\mathrm{w}} \Delta T_{\mathrm{w}} \tag{3}$$

We'll first see the equivalence of mechanical work and thermal energy by doing work on some lead, assuming the work is transformed into thermal energy, and using that assumption to deduce the specific heat of lead. Then we'll use our new knowledge (and equation 3) to measure the specific heat of water; and then use the specific heat of water (and equation 3) to measure the specific heat of a different metal.

Apparatus: Draw the apparatus.

Procedure:

Using equation 1:

1. Put some lead shot in a plastic bottle and find the mass of the lead.
2. Measure the initial temperature (in °C) of the lead shot with a sensitive thermometer.
3. Drop the bottle n times (about 20 or 30) in quick succession from the lab bench to the floor.
4. Immediately measure the final temperature of your lead shot (the rise won't be much).
5. Calculate the mechanical work done (energy added) from $W = n\,Fd$ where F is the weight (in newtons) of the shot and d is the distance (in meters) from the floor to the lab bench. The result will be in units of Nm; and one Nm is equal to one joule. Now convert the energy from joules to calories.
6. Make a plot of energy (or work) (in calories) vs. mass times the change in temperature (in g °C). Your lead shot sample will provide one data point; also acquire the data from the other groups in the class on this procedure for other data points to plot. Use a ruler and eyeball a best-fit straight line through the origin.
7. The slope of your straight line is your experimental value for the specific heat of lead (in cal/g °C); compare it to the accepted value.

Using equation 3:

1. Measure the mass of a solid piece of lead or a quantity of lead shot.
2. Suspend the solid lead by a string or the shot in a cup in the steam generator to raise its temperature to the temperature of boiling water (not necessarily 100 °C at our altitude).
3. Put a quantity (about 1/2 the mass of your lead sample) of cold water in the calorimeter and measure its mass and initial temperature. Include 12.2 grams to account for the effect of the aluminum calorimeter cup.
4. Record the initial hot temperature of the lead.
5. Quickly dry the lead (if you used the solid) and put it in the cold water in the calorimeter.
6. As they equilibrate (gently use your stirring rod occasionally), record the highest water temperature as the final temperature for both the lead and the water.
7. Use these data along with the specific heat for lead (use the accepted value) to compute the specific heat for water from equation 3.

Now that you have found the specific heat for water, use the procedure above (for equation 3) to find the specific heat of a different solid metal sample, such as aluminum or steel or brass.

Results:

Using equation 1:

Mass of shot (first in g, then in kg): $m_{\mathrm{Pb}} =$ ______________ $m_{\mathrm{Pb}} =$ ______________

Weight of shot (in newtons): $(mg)_{\mathrm{Pb}} =$ ______________

Initial Temp.: $T_{\mathrm{Pb}_i} =$ __________ Final Temp.: $T_{\mathrm{Pb}_f} =$ __________ $\Delta T_{\mathrm{Pb}} =$ ______________

Energy added (first in J, then in cal): $E =$ ______________ $E =$ ______________

Experimental value for specific heat of lead (slope of line): $c_{\mathrm{Pb}} =$ ______________

Compare with accepted value: $c_{\mathrm{Pb}} =$ ______________ % error = ______________

Using equation 3:

Mass of lead (in grams): $m_{\mathrm{Pb}} =$ ______________

Initial Temp.: $T_{\mathrm{Pb}_i} =$ __________ Final Temp.: $T_{\mathrm{Pb}_f} =$ __________ $\Delta T_{\mathrm{Pb}} =$ ______________

Mass of water (add 12.2 g to account for the calorimeter cup): $m_{\mathrm{w}} =$ ______________

Initial Temp.: $T_{\mathrm{w}_i} =$ __________ Final Temp.: $T_{\mathrm{w}_f} =$ __________ $\Delta T_{\mathrm{w}} =$ ______________

Specific heat of water (solve equation 3 for c_{w}): $c_{\mathrm{w}} =$ ______________

Compare with accepted value: $c_{\mathrm{w}} =$ ______________ % error = ______________

Using equation 3 for a different metal (metal is ______________) :

Mass of water (add 12.2 g to account for the calorimeter cup): $m_{\mathrm{w}} =$ ______________

Initial Temp.: $T_{\mathrm{w}_i} =$ __________ Final Temp.: $T_{\mathrm{w}_f} =$ __________ $\Delta T_{\mathrm{w}} =$ ______________

Mass of metal (in grams): $m_{\mathrm{m}} =$ ______________

Initial Temp.: $T_{\mathrm{m}_i} =$ __________ Final Temp.: $T_{\mathrm{m}_f} =$ __________ $\Delta T_{\mathrm{m}} =$ ______________

Specific heat of metal (solve equation 3 for c_{m}): $c_{\mathrm{m}} =$ ______________

Compare with accepted value: $c_{\mathrm{m}} =$ ______________ % error = ______________

Discussion:

1. Why might the results in the first procedure not be very accurate?

2. How could one improve the results of this whole experiment?

3. Water is often used as a heat storage medium. Is there a physics reason for this, or is it just cheap and plentiful? What property of water determines the answer to this question? How unique is water with respect to this property?

Conclusions: