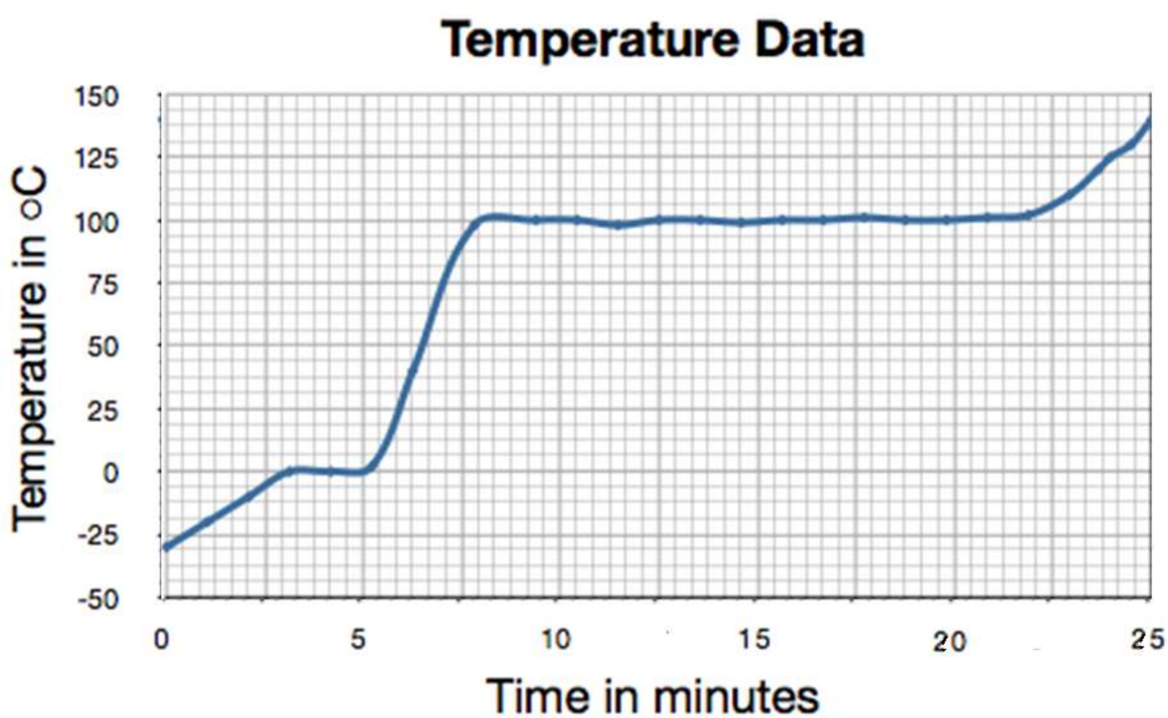
Name: Group member names:
Student number:

Physics 157 Tutorial – week of September 24th

In this tutorial, you will get some practice with problems involving heat transfer and how this leads to temperature changes and phase changes. **Work in groups of three or four, but hand in your own worksheet (at the end of the tutorial session),** to be graded for participation credit. You are not required to finish everything on the worksheet. Show your work. Hints and useful formulae are at the back.

Question 1: Exhausted after a challenging week of classes, you decide to relax by heading out to a restaurant with your friends. Soon after ordering, a server comes by and places a glass filled with a mysterious transparent liquid in front of you on the table. "What's going on?" you think to yourself. "I didn't order that. Are they going to charge me for that? Is someone trying to poison me?" You don't want to cause a major scene, so you decide to remain quiet about this very disturbing development. However, when nobody is looking, you furtively transfer the liquid to a thermos for later analysis. You place it in the freezer when you get home to preserve the sample. Later, you measure the mass of the sample to be 200g, and with the material in a sealed container, you add heat at a constant rate of 500W (1W = 1 J/s), measuring the temperature as a function of time. Your data is below:



a) Label each part of the graph above, indicating the phase of the material and whether a phase change is occurring. What are the melting and boiling points?

b) How much heat flows into the material between 10 and 14 minutes?

See the hint on the last page if you are stuck.

c) Approximately what is the specific heat in the liquid phase, in J/(kg K)?

d) Compared to this, is the specific heat for the solid phase smaller or larger?

e) What is the latent heat of vaporization for this material?

f) Compared to this, is the latent heat of fusion smaller or larger?

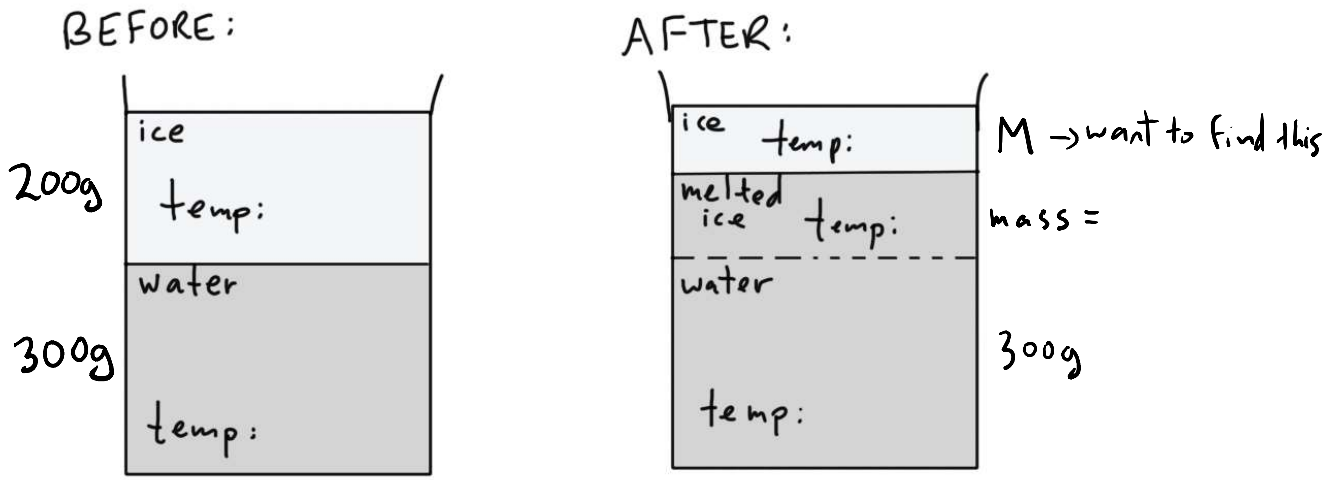
g) You begin to suspect the mysterious liquid may be water. Are the values you calculated consistent with this?

Question 2: In this question, we'll work through a problem that's very similar to a number of past midterm and exam questions:

Suppose you start with 200g of ice at temperature -25 degrees Celcius, and place this into 300g of tap water, initially at 20 degrees Celcius. Eventually the drink reaches equilibrium. What mass (if any) of ice is left?

(Neglect the heat capacity of the cup and heat exchange with the environment.)
Useful Constants: $c_{\text{ice}} = 2100\text{J/kg K}$, $c_{\text{water}} = 4190\text{J/kg K}$, $L_{\text{fusion water}} = 334,000\text{J/kg}$.

A good first step is to draw before and after pictures to help you visualize the situation, and label them with known and unknown quantities. For now, we will assume that there is ice left at the end:



a) Assuming that some ice is left at the end, fill in the temperatures on the diagram and the mass of the ice that has melted. (*hint at the back)*

To analyze this, a good start is to treat each part separately and understand the net heat added to each part during the process. Q will be negative for parts that cool. (*hint at the back)*

b) For the water initially present, what is Q for the process (answer in Joules):

$Q_{\text{water}} =$

How much heat is added to the ice up to the time it starts melting?

$Q_{\text{ice, warming}} =$

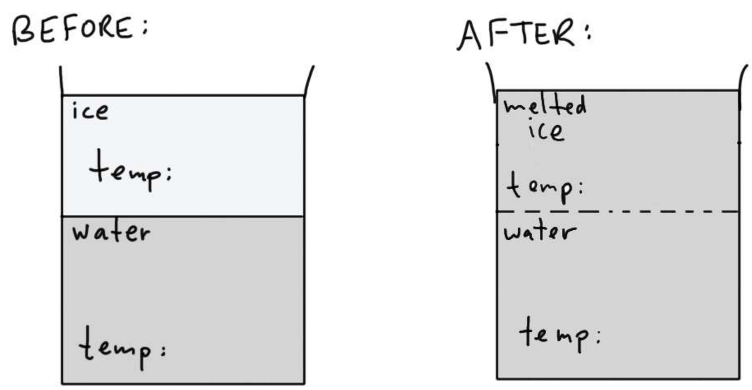
How much heat is added to the ice that melts? *Hint: what is the appropriate mass to use here?*

$Q_{ice,melting}$ =

c) What must be the sum of the quantities in part b? Why?

d) Using the idea from c, and your results from b, write down an equation and solve it for the mass M (*check your result with the possible answers on the last page*)

If it happened that our result was negative, that would tell us that there is actually no ice left over, and the final temperature will be greater than zero. In this case, the problem is actually simpler, since we can start with the following picture:



e) As an example of this (if you have time), work out the final temperature of water if we start with 50g of ice at -25°C and 450g of water at 20 °C. Use similar steps to what you did above, and show your work on the next page.

Hints: In this case, you have an unknown variable T (the final temperature) and you should have three contributions to the heat for the melted ice component. You can check your result against the possible answers on the last page.

If you still have time, try this question from a previous midterm. It's a little more complicated since the initial amount of ice is an unknown.

3. A Starbucks chemical engineer wants to design the perfect iced coffee drink. This drink is to be served at temperature of 0°C and contain 25% crushed ice by mass. Initially the engineer starts with 200 grams of coffee at 80°C and mixes in crushed ice at temperature of −10°C. Find the initial amount of crushed ice to add in order to obtain the desired drink.

(Neglect the heat capacity of the cup and heat exchange with the environment.)
Useful Constants: $c_{\text{ice}} = 2100\text{J}/\text{kg}\,\text{K}$, $c_{\text{water}} = 4190\text{J}/\text{kg}\,\text{K}$, $L_{\text{fusion water}} = 334,000\text{J}/\text{kg}$.

Useful formulae:

Relation between heat Q flowing in to a material and temperature change (c = specific heat):

$$Q = m\, c\, \Delta T$$

Relation between heat flowing in to a material and amount of mass changing phase (L = latent heat for that phase change):

$$Q = m\, L$$

Hints: wait until you are stuck before using the hints, then try them one at a time.

For each hint, write the missing letters in the blank spaces, in order. For example: putting p,y,c,t,r,l in __h__si__s __uto__ia__ in gives "physics tutorial"

Hint for question 1b): missing letters: z, o, n, l, k, g, h, f, g, o

Hint: It is not __er__, and you do __ot need to __oo__ at the __rap__ to __i__ure it __ut.

Hint for question 2a): missing letters: v, y, h, g, e, l, b, m

Hint: E__er__t__in__ is in __qui__i__riu__ in the final picture.

Hint for question 2b): missing letters: u, w, q, t, n, p, g

Hint: In each part, __se one of the t__o e__ua__io__s at the to__ of this pa__e.

Possible answers: 140000, 4100, 88, 64, 43, 30, 23, 8.8, 0.156, 0.042, 0.0064, 0.000032, 0.00001001