Unit 16 *Homework Problems*

Learning Goals:

F.16 Qualitatively or quantitatively describe how mixtures of substances will achieve thermal equilibrium (with no phase changes).

16-1) Suppose you are on a trip to Bremen, Germany, enjoying many of those famous Bremer Lebkuchens with your traveling companion, when he suddenly becomes quite sick. You quickly decide to purchase a thermometer at the market square Apotheke so you can take his temperature. If it is above normal you should consult a local Ärztin. Although there are no units listed on the thermometer it reads 37.0 when you take the temperature of your sick friend.

(a) What units is the thermometer probably calibrated to record?

(b) Would you try to locate an Ärztin for him? Explain.

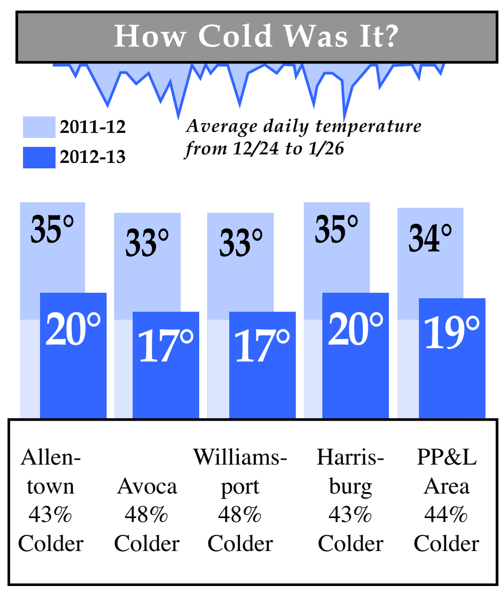
(c) What is your friend's temperature in the Kelvin scale?

Hint: Normal body temperature varies from person to person and with the time of day, but it is typically 98.6 °F.

16-2) The March 2013 edition of PP&L Connect contained a bar graph of average temperatures in PA towns for Dec and Jan during the winters of 11-12 and 12-13.

(a) You are given the "% changes" in the Fahrenheit scale. What are the "% changes" between the two winters using the Celsius scale?

(b) Given what you know about temperature scales, discuss whether the report of how much colder each town was in "% change" is meaningful. Would it make more sense to base the calculations on the Celsius scale instead? Why or why not?



16-3) Why must a thermometer be calibrated? You have a glass bulb thermometer with no markings on it and a second thermometer that is a different physical size that is marked in degrees C. Explain how you would calibrate the unmarked thermometer.

16-4) Which is better at transferring thermal energy, water or air? How does this fact explain the length of time it takes an electronic temperature sensor to reach thermal equilibrium in air compared to the time it takes in water?

16-5) Suppose a plastic pipe and a metal pipe have been sitting next to each other for a long time in a chilly room.

(a) Will one of the objects feel colder than the other? If so, which one?

(b) If you measure the temperature of each object will one of them be at a lower temperature than the other? What is the evidence to support your answer?

(c) Explain why you think one object will, or will not, feel colder than the other (*i.e.*, what do you think is going on at the macro (not micro) scale based on your observations in class).

16-6) (a) If you put a glass of cold juice at 10°C on a table outside on a hot summer day when the temperature is 40°C, how "hot" will the juice get?

(b) Using the Excel spreadsheet included with this assignment, create an accurate plot of the juice's temperature in Celsius as a function of time in minutes if it takes the juice 10 minutes to warm up to 25°C. (Careful, 25°C is not the final temperature of the juice.) Include a printout of the graph and your final value for α. What units does α have? (*Note: the spreadsheet models the equation at the end of Activity* 16.7.2, *page* 450 *of Module* 3.)

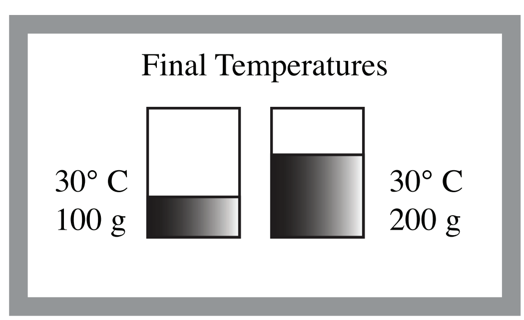
(c) Explain the shape of the graph, especially changes in the rate of warming as the cold juice warms up, in terms of your observations in the lab.

(d) If you put a juice at 10°C in a refrigerator where the temperature is 5°C, how "cool" will it get?

(e) Compare the *initial* rates of warming in situation (a) and cooling in situation (d). Are they the same or is one larger? Explain!

16-7) Suppose you have 300g of boiling water and 300g of icy water (with no ice left in it). If the water from the two containers is mixed together, what will the final temperature of the water be? Explain.

16-8) (a) The two containers of water shown in the diagram on the right are completely insulated so no energy can be transferred into the system or out of the system from the environment. The water in both containers started at 20 °C, and thermal energy was transferred to the water in each container using heating coils until the final temperatures indicated in the diagram are reached. Which container had the most energy transferred to it?

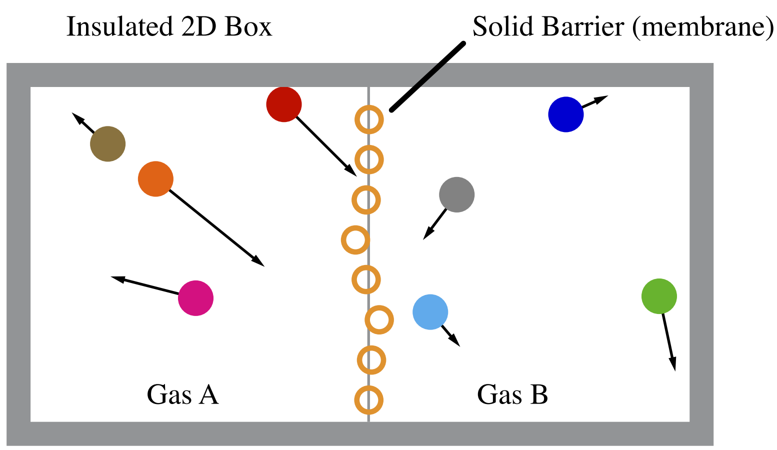


(b) Explain how it is possible to transfer different amounts of thermal energy to these containers and get the same temperature change.

16-9) Explain on the basis of your observations in the laboratory how you know that heat is the process of transferring thermal energy and not a substance that flows from a hotter body to a colder one. Refer to specific activities.

16-10) Using An Idealized Atomic Model Of Two Substances To Explain Thermal Energy Transfer: Some people are puzzled by the fact that two substances at different temperatures that are in contact but do not mix with each other can change temperature until they reach the same temperature (known officially as "thermal equilibrium"). Long before the idea of matter being made of atoms was widely accepted, scientists tried to explain phenomena such as temperature changes by asking questions like: "Suppose two separate substances are made of atoms, and so is the barrier between them." How might they exchange thermal energy? And, how might the thermal energy carried by the atoms be related to temperature?

Physicists often create simplified models of reality as a way of trying to understand basic phenomena that can serve to explain the behavior of real systems. One such model is of some atoms that are in a gaseous state pinging around on one side of a two-dimensional box. These atoms are separated from another set of gas atoms by a membrane consisting of a layer of atoms attached to each other by fairly tight chemical bonds. However, when a gas atom collides with a bound atom, then the bond is stretched like a spring, so the solid atoms can oscillate like an object on springs. This is shown in the diagram below.



Idealized Model of Atoms in Two
Gases Separated by a Solid Membrane

An animated QuickTime movie of this model, called "Thermal Energy Transfer", has been made. You should look at this animation using either the Logger Pro or Movie Player software. Figure out how the animated model can be used as a construct to explain thermal energy transfer. Although you may want to use some of the analysis features of Logger Pro to help you along, you don't really have to do any graphs or calculations to answer the questions that follow.

(a) Do the gas atoms seem to lose kinetic energy when they collide with the walls of the container? What evidence from the movie are you using to draw this conclusion?

(b) Do the gas atoms seem to lose energy when they collide with each other? What evidence from the movie are you using to draw this conclusion?

(c) What is happening at the beginning of the movie? Does the total kinetic energy of Gas A seem to be the same or significantly different than that of Gas B? What evidence from the movie are you using to draw this conclusion?

(d) What is happening at the end of the movie? Does the total kinetic energy of Gas A seem to be the same or significantly different than that of Gas B? What evidence from the movie are you using to draw this conclusion?

(e) Does the total energy of the system (consisting of Gas A, Gas B, and the solid membrane) seem to change as a result of all the collisions?

(f) How can you use the observations you just made to explain the thermal energy transfer process? **HINTS:** What is the role of the membrane? Could you associate temperature with kinetic energy of the atoms in the gases or in the membrane? If one of the gases starts at a lower energy than the other would it tend to lose or gain energy as a result of the collision processes?

16-11) Suppose you transfer thermal energy to a perfectly insulated cup of liquid and observe how much the temperature changes. Then, you decide to repeat the same experiment several times making changes. For each of the following changes indicate whether the change in temperature will be larger, smaller or the same as that measured before the alteration:

(a) transfer the same amount of thermal energy as before but at a faster rate;

(b) transfer more thermal energy to the cup;

(c) start with a warmer liquid;

(d) put less of the liquid in the cup;

(e) increase the temperature outside the cup;

(f) change to an equal mass of liquid with a larger specific heat; and

(g) use the same volume of a more dense liquid with the same specific heat.

16-12) A Physics 212 student, for her semester project, wants to find the specific heat of a new metal alloy created by the company she is interning with. She warms a 150. g sample of the alloy to 540.°C, and then quickly puts it in 400. g of water at 10.0°C, which is contained in a perfectly insulated 200. g aluminum cup (also at 10.0°C). The final temperature of the system (metal alloy, water, and aluminum cup) is 30.5°C. What is the specific heat of the metal alloy?