Week 4 Challenge Homework

Laws of Thermodynamics, Calorimetry, and Heat Transfer

Submission Details | Submit a digital copy (PDF, jpg, etc.) to Canvas. Include solutions to the metacognitive exercise and each question. Please use the interface to associate each page of your submission with the assignment. It makes grading much easier. Please clearly indicate which question is being solved. If data is needed to complete a problem, be sure to cite the source you've acquired your data from. Typed work will not receive credit. See the course website for further details.

Group Submissions | You may submit a group collaboration to Canvas. Add each group member to the submission. Each group member should contribute to the work. Clearly indicate which part of the submission is written by each member (color or labels are preferable).

Sensemaking | You will be asked to apply sensemaking in some problems. More information about sense-making can be found on the BoxSand Sensemaking page, which is linked on the Canvas homepage.

Metacognitive Exercise

Each week will feature a metacognitive exercise, followed by one or two challenge problems to solve. The metacognitive exercise will usually ask you to reflect on your solution to the previous week's challenge problems.

Review your solution to the Week 3 Challenge Homework. If you do not have a copy of it anymore, you can find it on Canvas or Gradescope, under the Week 3 Challenge Homework assignment. Also, review the solution which has been posted to the BoxSand solutions archive (click here for a link). Solutions are posted a few days after the assignment is due.

(a) In 3 – 5 sentences, compare your solution with the provided solution to Question 2 from the week 3 challenge homework. What did you do differently than the provided solution? Are there aspects of your solution that you liked better? Are there aspects of the provided solution that you liked better? (hint: there is a significant aspect of the provided solution that your instructors don't like!)

(b) What types of representations can you identify in your solution to question 1? (some physics representations include diagrams, symbols, numbers, words, graphs, sounds, etc.) What types of representations can you identify in the provided solution to question 1? How do each of these representations contribute to the problem solution?

Question 1:

Beer brewing begins with steeping grains in hot water, releasing the sugars inside. The sugar water is then heated to a boil and hops are added. The hot temperature of the boil extracts oils from the hops and provides sanitation from unwanted bacteria. The whole mess is cooled down and once it is safe enough for yeast to survive, they are added. The yeast converts the sugars to alcohol, and the oils from the hops provide many things including flavor and antibacterial benefits.

(a) If 16.5 lbs of grain at 67 ºF are added to 5 gal of hot water and the equilibrium temperature of the mixture is to be 154 ºF, what must the initial temperature (strike temp) of the hot water be? The specific heat of malt grains is about 0.44 times that of water. Also assume no energy is lost during the time the system comes to equilibrium.

(b) How much did it cost to heat the 5 gals of tap water from 110 ºF up to the strike temp? Assume the heating takes 47 minutes, electricity costs 15 ¢ per kilowatt-hour, and only 10% energy is lost during heating.

(c) During the one-hour steeping stage, where the water and grain mixture started at 154 ºF, the mixture only lost 2 ºF. What was the average energy per time lost by the mixture.

(d) The steeping was done in a cylindrical vessel (cooler) with outside dimensions 20 inches tall and 15 inches in diameter. The thickness of the walls is 1 inch. Estimate the thermal conductivity of the steeping vessel assuming a room temperature of 67 ºF.

Question 2:

At the Earth's distance from the Sun, the intensity (intensity is power / area) of solar radiation is 1370 W/m^2. The temperature of the Earth is affected by the *greenhouse effect* of the atmosphere. This phenomenon is caused by our atmosphere's absorption of infrared light emitted by the surface, which makes the surface temperature of the Earth higher than if it were airless. For comparison, consider a spherical object of radius r with no atmosphere at the same distance from the Sun as the Earth. Assume its emissivity is the same for all kinds of electromagnetic radiation and its temperature is uniform over its surface. Assume the temperature of space just outside the Earth's atmosphere is 4 Kelvin.

(a) Explain why the projected area over which this spherical object absorbs sunlight is πr^2 and the surface area over which it radiates is $4\pi r^2$.

(b) Compute its steady-state temperature.

(c) Use *Known Values* sense-making to determine if this is a reasonable value by answering the following prompts.

- Find and cite a source for the average steady state temperature of the Earth. This is your known value (often, known values are predictions of a reasonable value for your a found answer).
- Compare your answer from part (c) with this known value.
- In light of this comparison, explain why your answer to part (c) is reasonable (or not!).

(d) Why would an increase in greenhouse gases such as water vapor, carbon dioxide, and methane be cause for alarm?