Thermal Properties

This is the outline of exercises that we want you to do in lab. This is a complement to the material in the lab manual. Please read the manual to learn about the tools and techniques; use this document to guide your experiments and calculations in the lab.

You should complete the first three problems below in any order, and then continue on to the remaining activities in any order you wish. **You must complete the last activity in the last five minutes of lab.**

There will be hot water in lab, **be very careful** around it! Make sure you do not put anything in the microwave except for the water in the provided container.

Problem #1: Radiative Cooling

The question you are to answer: Which will cool off more quickly - a cylinder painted black, one painted white, or a bare metal cylinder?

First, let's talk something out - in your lab report, answer the question:

- What is *emissivity*?
  - What kind of objects do you have around your house which have a high emissivity? A low one? How can you tell? Discuss this in some detail in your report.

Next, you'll do some measurements! First though, make sure to set your LabQuest to record for five minutes (though more is a bit better). Now:

- Bring 1ish liter of water to a boil in the hotpot at your pod.
- Gently submerge all three aluminum cylinders in the water heater for 30 seconds - don't drop them in, even on the metal mesh it can break the glass. Start your thermometer readings, remove the cylinders, quickly dry them, and immediately mount them on the thermometers at your station. Note which line on the graph corresponds to which thermometer. Collect temperature data for the three cylinders as they cool over several minutes.
- While you are taking data, close your eyes and have a labmate place the back of your hand near each of the cylinders, **but don't touch them** (they're pretty toasty, and we don't care about *conduction* after all!). Which one(s) seems to emit the most thermal radiation?
- Once the cylinders have cooled by at least 30°C, note the relative rate of cooling of the cylinders - at the same temperature. Perhaps as each cools through 70°C. What conclusions can you draw?

Now, do some explanation:

- How can you explain the different rates of cooling of the cylinders? Explain this in terms of concepts you have learned in this course.
- Oftentimes, when folks bake a large potato in their oven (or loaf of bread, when grilling veggies, etc...) they wrap it in shiny aluminum foil. This serves two purposes: to trap in some moisture, and something a bit more physics-ey to make the potato cook "better". Not faster, but better. Explain how this foil coating affects the cooking process, and why folks might do this.

Towel off the cylinders and set them in the yellow bin, then hang the towel on the stand to dry when you are done with this station.

Problem #2: Measuring Efficiency of a Microwave Oven

The question you are to answer: What is the efficiency of a microwave oven?

We define efficiency by the ratio of "what you get" divided by "what you pay". In a microwave oven, and "what you get" is energy transferred to food. First steps:

- Check the label on the back of the microwave oven. What is the noted power? This is the input power used by the microwave - "what you had to pay."

To answer the big question, you'll be warming water - the frequency of the microwaves is set to somewhat efficiently transfer energy to water. You've got a thermometer (which should stay out of the microwave at all times) and a microwavable cup which should serve you well. When you put the lid on, keep the steam vent open!

- Design an experiment to measure the energy absorbed by a container of water. What will you measure? What factors do you need to take into account? What calculations will you need to do? Explain this all in your group's report.

Next, take some measurements, following your plan. Finally, complete your calculation:

- What is the efficiency of the microwave oven? Discuss this result - does it seem reasonable?
- What factors might you expect to affect the oven's efficiency? Discuss how you (or the manufacturer) might deal with those issues.

Empty out your cup, and towel it and the lid off before putting them back in your red bin. Spread the towel across the bin to dry, and make sure the thermometer is off.

Problem #3: The Heat Pump

The question: How do you represent this process with an Energy flow diagram?

You have a Peltier device mounted between aluminum fins. It can be connected (by the attached plugs) to a hand-crank generator, which will supply electrical power. The current can be reversed by reversing the direction you spin the crank, or switching the wires. You should feel the temperature of the two sides of the peltier device with your finger - the temperatures we should be operating this device at should be fairly comfortable to the touch. One thing to note: Be gentle with the generators, you are strong enough to strip the plastic gears, but kind enough to avoid doing so. Turn the handle at a rate of 2-3 times per second (but again, please stay gentle!).

- Run the current through the peltier device for a while in one direction. What do you notice happening to the temperature of the)

You should be able to verify that the peltier device is in fact working as a heat pump, and not just a heater (what's the difference?). Now answer a few questions:

- When one side of the peltier device warms, where does the thermal energy come from? There are two sources - identify both.
- When the left side warms, a certain amount of thermal energy is being "pumped into" your finger. Is this more than, or less than, the thermal energy extracted from your finger on the right side as it cools? They are certainly not equal, explain why!
  - Sketch out an energy-flow diagram like those in found in your textbook to illustrate your point.
- If you have an air conditioner, a fridge, or a freezer at home, it operates in a similar manner. Would it be useful in the summer to set up the unit in the middle of your room and leave the door open? Explain your reasoning.

Problem #4: Determining an Unknown Metal

The action plan: By measuring the specific heat of metal pellets, determine the metal they are made of.

First, some prep work: The metal pellets will be drying and warming in an oven. You must make sure that the pile of pellets you use are completely dry when you use them. It should take about 15 minutes to thoroughly warm and dry from room temperature to the temperature of the oven, which you can take as the initial temperature of the pellets.

- You will determine the specific heat of metal pellets by measuring the temperature change of water in a styrofoam cup when a scoop or two of hot pellets are added. You can ignore any heating of the cup, if you are careful. Discuss why the styrofoam cup is pretty ignorable in this situation.
- How will you calculate the energy gained by the water? How will you calculate the energy lost by the pellets?

Now, run an experiment:

- To determine the specific heat of the pellets, what data will you need? How will you collect this data?

Next, take some measurements, following your plan.

Finally, complete your calculation:

- What is the specific heat of the pellets? How does this compare to that of water?
  - Why might you have expected that, given your temperature changes?
  - Why, then, is it important that the pellets be completely dry?
- Compare your result with the a table of specific heats of common materials in the text (or online) to determine the metal.
  - Discuss your results. Did you determine the pellets were a reasonable metal?
    - If not, is your number likely too high? Too low? Discuss why your data might have become skewed in this fashion.

Use one of the strainers in lab to pour out the water, separating out the pellets. Return the pellets to the oven, spreading them out to facilitate drying. Spread the towel across the yellow bin to dry, and make sure the thermometer is off. Be sure to dump out your water at the end of lab.

Problem #5: (Don't) Drop it Like it's Hot

The question you are to answer: What is the physics behind Reusable Hand Warmers?

Each group will be allotted one reusable heat pack to use during the lab - make sure to bring it back to your station before "triggering" it. When you do so (in just a minute, don't do anything yet!), you will gently flex the metal disk inside so that it "pops" - **do NOT fold the metal disk**! If you've used a tape measure before, you know what that pop is like, and why you should never fold it! **Before you do anything**, answer a few questions:

- Sketch out a normal phase change diagram - a graph of temperature as a function of energy - for a material going from the solid phase to liquid to gas.
- What temperature is the packet initially? Use the IR thermometer, not the metal thermometer, to do so.
- What phase is the material in the packet in, initially?

Now, gently trigger the reusable heat pack, and record your observations:

- Describe what happens to the packet in the first few seconds.
- Describe what happens to the packet over the next several minutes. Note: You can knead it gently while it works.
- Note the temperature from the start, and over the course of several minutes.

Return the heat pack to your TA, so that they can put the pack in boiling water for several minutes to "recharge" it for the next lab's use. Now, explain:

  - The pack started out as a liquid. Where does the energy warming your hands "come from"? Be fairly thorough in your explanation. You should redraw and update your earlier phase change diagram to assist with your explanation.
  - How does putting the heat pack in boiling water "recharge" it? Discuss this in terms of energy and phases.

There are ways of doing this at home, particularly in the winter - ask your TA for more information!

Problem #6: Bent out of Shape

The question you are to answer: When do phase changes occur?

The wire you will use should be in a plastic bag in a bin at the front - make sure it returns to the bag! The wire tends to blend into the carpet rather well, and we'd rather not lose it. Make some observations:

- Take a piece of the shape-memory wire and gently flex it, then straighten it out. Note how "stiff" it feels.
- Now place it in the toasty 70°C (ish) water, then do the same while the wire is warm. What happens?
  - Wait for the wire to cool a bit and then try bending it again. What do you notice? Describe the differences.
- As you saw, when the wire undergoes a phase change it changes shape. What temperature bath is required to make the memory wire readily undergo this phase transition?
  - If the water is slightly cooler, will the phase change still occur, albeit at a slower rate?
  - Discuss why this makes sense in terms of phase changes.

Final Activity: Clean Up

There's likely a bit of mess around your station, so let's tidy up:

  - Make sure you empty all containers of water, and dry them out with your station's towel. Set them on their sides to dry out. Check <u>every</u> container!
  - Return the styrofoam cup and one thermometer to the yellow bin, the microwavable cup and it's thermometer to the red.
  - Put the three (dry) aluminum cylinders on their mounted thermometers.
  - Hang your towels over the bins and stand to dry.
  - Plug in the labquest.
  - Return any other materials to their places at the front stations.
  - Return the Thermal Camera (set to greyscale, °C, and an emissivity of 0.95) to your TA. Do NOT plug it in to charge.

Report

You'll be recording your work on the whiteboard tables as you go, and so be clear when summing up your process and your conclusions. Keep your discussions short, sweet, and to the point, please. Be sure to indicate what work you did on the report (as opposed to what your lab partners did).

Remember: The point of the report is to show your TA how well each of you understand the material, how well you designed and performed experiments, how well you can discuss your results, and how much of a scientist you were - not to show them you can parrot the textbook, always get the "right" answer, or do everything. The process, your reasoning, and your improvement are the key to earning full credit.

Be sure that each of your group members submit this assignment as soon as possible (ideally at the end o your lab), and take some time to consider how lab went for you and your peers, and how you can improve the experience next week.

Looking Ahead: Cooking up the Science!

This isn't something to calculate today, but something to think about: Cooking is, essentially, the art or science of transferring the right amount of energy to the right materials. Why would it make sense that some food items need to cook for long periods of time, while others do so quickly? What is it about their composition, shape, etc... that determine this?