# Part of a Thermal Dynamics Unit[1]

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## Activity One: Understanding heat capacity.

**Obj** This activity will demonstrate to students the tremendous heat capacity of water. (Heat is the energy of moving molecules. Heat capacity is a measure of the ability of a material to absorb heat energy.)

**Materials**

- Glass Beaker with water
- Steel rod _ inch by 3 inch
- tongs
- Alcohol burner
- Thermometer

**Start Lesson** by beginning to heat the metal rod in burner and measuring temperature of water.

Inquire which is hotter?
Inquire which has more heat?
The standard answer would probably be the metal rod since by now it would be too hot to handle.

Allow rod to heat as much as safety allows.

**Predict** what will happen when rod is placed in water.
Standard answer: Water will heat up; rod will cool down.
By this point in unit my students would already have an understanding of heat flow. They would know that heat flows from the warmer object to the cooler until a state of equilibrium exists.

**Make sure the students** have some sort of quantitative understanding of the rod's temperature. (If it will sizzle when it hits the water, what is it's minimum temp? Ans: 100+ degrees. It is likely that through the discussion the metal rod will have reached 2-250 degree C.

Place metal rod into glass beaker. Measure temperature and with one finger feel the metal rod to discern that indeed it has reached equilibrium with the waters temp. (This will take only a few seconds).

**Implications:** The water temperature will likely only rise 5-10 C Degrees. It rose because the heat from the rod was transferred into the water. Graphing the temperature change of the rod and the water illustrates that the massive heat of the iron had a minimal effect on the temp of water. In fact, if we could extract that 10 degrees of heat from the water and put it back into the iron rod, the iron rod would once again be glowing hot.

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[1] Designed to build conceptual understanding of ALISON project measurements

**Water Holds A Lot of Heat**
Water displays the largest heat capacity of any common substance. Students in Seward are well aware of the implications of this phenomenon. Students who live by the ocean's edge have lots of ice…not so much snow. Students living 3, 6, or 12 miles out of town get increasingly more snow and less rain in the winter. This is all because of the ability of the water of hold, and thus release, great amounts of heat.

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## Activity Two: Exploring Temperature Gradient.

Students should already understand that heat moves from warmer to cooler. But can this rate be quantified?

**Materials:**

Plastic Liter Beaker
Glass 250 Ml Beaker
2 thermometers
Water sources: Must be able to have cool, warm, extremely cold (icy with NO ice particles), very hot (near boiling)

Define the term <u>temperature gradient</u> (the difference in temperature between a system where heat is flowing from a higher temp to lower.)

**Example**
If I had a beaker of 10C water in the glass beaker nested within the larger plastic beaker of water with 40C water, then the temperature gradient would be 30 degrees with the heat flowing from the larger to the smaller beaker.

**Activity One**
Smaller Glass Beaker: Fill with 200 ml of cold tap water.
Larger Plastic Beaker: Fill with 400 ml of hot tap water.

Measure initial temperatures.
Then nest the beakers together to allow the exchange of heat.
Measure temperature in 1 minute increments.
Stop when the liquids reach a fairly stable state (The rate of heat exchange when at 2 degrees difference will be small and take a long time to equalize to 0 degrees difference)

Graph Results

**Activity Two**
We will do the same activity, but this time we will spread out the temperature gradient using frigid water (no ice crystals however) and boiling (near boiling?) water. Predict the differences in regards to heat exchange and equilibrium.

Do the same activity only with the hotter/colder water.

Graph Results

If the activity has been performed consistently there will be two observations:

- The higher temperature gradient did take longer to reach equilibrium.
- The rate of heat flow was much greater in the larger temperature gradient.

This is called the Heat Flux. It is a crucial concept to understand the ALISON ice measurements. Three temperature readings are necessary to partially determine the heat flux: The bottom of the ice, top of the ice, the top of the snow. The ice bottom temperature is understood to be 0degrees. If it wasn't then heat flow would cause the disintegration and not the build-upof the ice layer. The ALISON scientists use temperature probes to determine top of ice temperature and top of snow temperature. This provides a crucial picture to how quick heat is flowing from the lake water into the colder atmosphere (or the other way around if the weather is above freezing).

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**Activity Three: Understanding Latent Heat.**

Now a paradox. So, students understand that the larger the temperature gradient, the higher the heat flux—the movement of heat from warmer to cooler. So, let's spread the temperature gradient out even further. It should give us data consistent with the last experiment….unless a state of matter is thrown in.

**Materials**

Same as the last experiment.

The one difference is the small glass beaker preparation.

> We will freeze water in the glass beaker but we need to be able to take the temperature from the core of the ice. Therefore, prior to the activity, tape a small test tube upright in the center of the beaker. This allows the water to freeze in the beaker yet gives us a portal in which to put the thermometer. Prior to the activity, put water into the test tube to allow it to get to the temperature of the ice without freezing. This will provide for more consistent measurements.

Have students predict what they think will happen when we stretch out the temperature gradient from 0 degrees to near boiling. Likely they would say that the curves would be steeper since the gradient is so large.

Perform the same procedure as before. Measure initial temperatures of beakers then after nesting the beakers together, measure in one minute increments.

The students will notice that the temperature gradient IS steep….but only for the hot water. The ice temperature will be unchanged. As the ice melts students can take a third reading of the water surrounding the ice. This also will be near or at 0 degrees. Ask students how they can account for the transfer of heat. Obviously the hot water is releasing its heat at high rate. Obviously this heat is flowing to the ice….yet there is no heat gain.

The reason is that a change of state of matter requires a huge amount of heat without the change of temperature. It requires on the order of 80 calories to change a ml of ice at 0 degrees to a ml of water at 0 degrees. This is the same going the other direction. Although it may be cold out, lake ice may be forming slowly as the water needs to lose incredibly large amounts of heat to change that frigid water into something a bit more solid.

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**Activity Four: Understanding Thermal Resistance.**

The final component to understand, at an elementary level, the ALISON project is the concept of Thermal Resistance…the ability for heat to travel through an object.

Here's a couple explores that seem to work.

**Mats**
Glass Beaker
Styrofoam cup
Water
Thermometers.

Put same amount of water in the beaker and Styrofoam cup. Measure initial temperature then put in snow/ ice water and observe the rate of heat loss. Students will likely talk about the insulating properties of the Styrofoam. Give them the concept of Thermal Resistance—the ability for heat to travel through an object.

Another way of demonstrating this is this activity,.

**Mats**
Aluminum rod _ inch by 1 _ foot
Steel rod _ inch by 1 _ foot

Alcohol burner
Birthday candles
Thumb Tacks
Patience.

- Mark rods in 2 cm increments
- Using lit birthday candles drip wax to stick thumb tacks on to rod (Practice this… it can be tricky. Suggestion: Clean rods and rough up slightly with steel wool)
- Students will put rods into alcohol lamp and measure the time that the first, second, third, etc thumb tacks fall off.

Students can graph results but it will be obvious that heat travels down the aluminum rod at twice the rate as the steel. This is the same principle as the former activity. Steel is a better insulator (has higher thermal resistance) than aluminum.

This becomes important to understand when lake ice forms then a layer of snow covers the surface. The density and depth of the snow affects the thermal conductivity of the lake. The less dense the snow, the higher the thermal resistance and the slower the heat is able to pass through this layer.