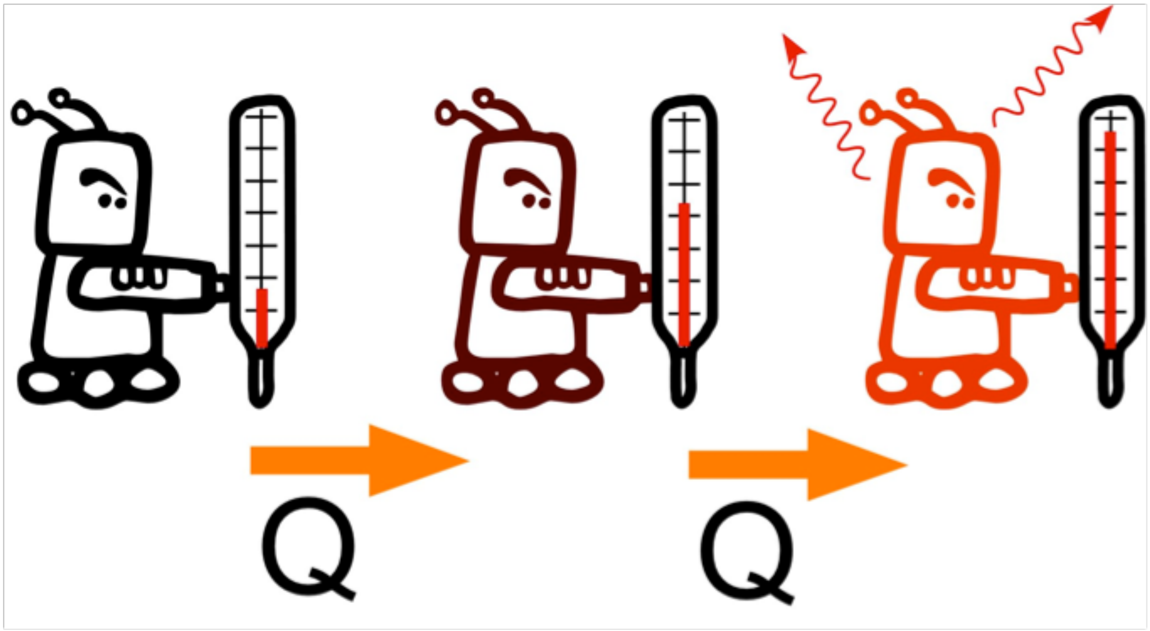

Unit 7.
Thermal Energy

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A TIME for PHYSICS FIRST

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Exploring Heating Lab

Purpose:

Explore heating, temperature and thermal energy

Pre-lab discussion:

1. Is temperature the same as thermal energy? How do you know?

2. What is the difference between cold objects and hot objects?

3. Give an example where
   a) a temperature of 80°F would be considered hot.
   b) a temperature of 80°F would be considered cold.
   c) Why are your answers different for parts (a) and (b) ?

4. Does energy get transferred from cold to hot or from hot to cold? Explain.

5. What do you call the energy transfer between hot and cold?

Materials:

- Paper towels to clean up spills

Station 1: Steel Spheres

- Colliding steel spheres
- A sheet of paper

Station 2: Three cups

- A cup of hot water (but not so hot that your hand burns)
- A cup of cold water
- A cup of water at room temperature

Station 3: Warm water and ice

- A couple of ice cubes
- A cup or beaker with very warm water

Station 4: Cold and Warm water

- A cup with cold water
- A cup with very warm water

Station 5: Cup and Spoon

- Cup of hot water
- Metal spoon

Station 5: Ice melting blocks

- Two black blocks (ice-melting blocks set)
- O-rings
- Two ice cubes

Station 7:

- Thermoelectric converter

Directions:

Work with the materials at each of the stations and answer the following questions. Some stations involve predictions before you try the activity.

6. Station 1: Steel Spheres

   a) Have one person hold up a sheet of paper, and another hold the two spheres on either side of the paper. Bring the spheres together so they collide (with the paper in between). What do you observe?

   b) What kind of transformation of energy takes place?

   c) What effect does the energy transformation have?

   d) Did the temperature of any of the objects change? Which one(s)? How do you know?

7. Station 2: Three beakers

   a) Predict: What would happen if you put one hand in warm water, the other in cold water, left them there for 3 or 4 minutes, and then put both hands in room-temperature water?

   b) Try it, and explain your observations.

   c) Do the words "hot", "cold" and "warm" mean the same thing in all situations? How are they related to previous experience?

8. Station 3: Warm water and ice

a) Predict: What do you think would happen if you put ice cubes in the warm water?

b) Try it. Describe what happens.

c) Which of the two, ice cubes or water, has more thermal energy?

d) Is there any energy transfer at this station?

e) Does the energy transfer occur from water to the ice, ice to water, both ways, or neither?

9. Station 4: Cold and Warm water

a) Predict: What do you think would happen if you put 1/2 cup of warm water into 1/2 cup of cold water?

b) Try it. Describe what happens.

c) Does cold water or warm water have more energy?

d) Is there any energy transfer?

e) Does the energy transfer occur from warm to cold, cold to warm, both ways, or neither?

f) Predict: What do you think would happen if you put 1/2 cup of cold water into 1/2 cup of warm water?

g) Try it. Describe what happens.

h) Is there any energy transfer?

i) Does the energy transfer occur from warm to cold, cold to warm, both ways, or neither?

10. Station 5. Cup and Spoon

a) Place a spoon inside a cup of hot water. Touch the spoon immediately after you put it in the liquid, and twice more one minute and two minutes later. Write your observations:

b) Which way do you think the energy transfer occurs - from the cooler spoon to the warmer liquid, or from the warmer liquid to the cooler spoon?

11. Station 6: Ice melting blocks

a) First touch the two black blocks (A and B). Write down what you observe for each of the two blocks.

b) Predict: What do you think will happen if you put an ice cube on each of the blocks? Explain your reasoning.

c) Try it. (Place the rubber o-ring on the block so melting water does not spill everywhere)

d) Record your observations and explain them.

12. Station 7: Thermoelectric convertor

a) Add cold water to one cup and hot to the other. What happens? Describe your observations, and research the internet to find out why this device works as it does.

Temperature and Thermal Energy Lab

Materials:

Part 1:

- Five 1.5” long bolts and 5 nuts that fit the bolts
- Two twist ties
- Two 6”x6” squares of mesh fabric. Place the 5 nuts in one mesh square, gather up the edges and tie with a twist tie. Do the same for the 5 bolts.
- Two Styrofoam cups
- A hot pot to boil water
- Tongs
- Celsius thermometer

Part 2:

- Water at room temperature
- Two thermometers, one in C the other in F.
- A cup of very warm water
- Ice cubes

Purpose:

What is the difference between temperature and thermal energy? In what units is temperature measured?

Pre-lab discussion:

1. Predict: when you say something is hot or cold, what do you mean?

2. What do you think temperature means?

3. What temperatures would you call “hot” and “cold?”

4. Does thermal energy get transferred from cold to hot or hot to cold? Explain.

Part 1: Temperature and Thermal Energy

Directions:

5. Examine the bags with the nuts and the bolts. Place both bags in a hot pot. Cover the bags with water and turn on the hot pot. Let the water reach the boiling point and continue to boil the nuts and bolts for 5 minutes.

6. Predict, discuss, and prepare the next step while the water boils:

   a) Place water at room temperature in two Styrofoam cups (~1/2 cup in each cup). Mark them Cup #1 and Cup #2.

   b) Measure the temperature (using a Celsius thermometer) of the water in each Styrofoam cup:
   Cup #1: Cup #2

   c) When the nuts and bolts are in the boiling water, how do the temperatures of the nuts and the bolts compare to that of the boiling water?

   d) Measure these temperatures using the thermometer:
   Temperature of nuts: Temperature of bolts:

e) Predict: If you drop the 5 nuts into Cup # 1, and the 5 bolts into Cup # 2, what do you think will happen? Will there be any difference between the two cups? Explain.

7. Using tongs, transfer the nuts to Cup # 1 and the bolts to Cup #2, and measure the temperature.

a) What is the temperature of the nuts and the bolts just before they have been transferred to the cups?

b) How are the nuts and bolts different?

c) After you transferred the nuts and bolts into the cups, what caused the temperature to change in each cup?

d) Is the temperature change the same or different in the two cups? If different, which cup showed a greater rise in temperature?

e) If the bolts and nuts are at the same temperature when in the boiling water, why are there differences in temperature in the two cups?

8. Write a sentence that describes the difference between temperature and thermal energy.

9. Revisit your earlier statements in the pre-lab discussion and discuss how you must modify them, if necessary, to reflect what you have learned in this activity.

Post-lab discussion:

10. Discuss the following questions within your lab groups:

a) When something is hot, does it have ”more hot,” “more thermal energy” or “more temperature” (all, some or none)? Explain.

b) When something is cold, does it have “more cold,” “less thermal energy” or “less temperature” (all, some or none)? Explain.

c) When you put something hot into a cup of something cold, what is the process that occurs? In which direction does the energy transfer occur? Explain.

d) Can energy be transferred from a hot object to a cold object? Explain.

e) Can energy be transferred from a cold object to a hot object? Explain.

f) Looking at the statements above, what factors determine how much energy a substance will transfer?

Part 2: Temperature scales:

Pre-lab discussion:

11. Examine the two thermometers. One is calibrated in degrees F the other in degrees C. Read the thermometer, and write down your ideas about why the two thermometers read different values, even though both are measuring the temperature of the same room.

Directions:

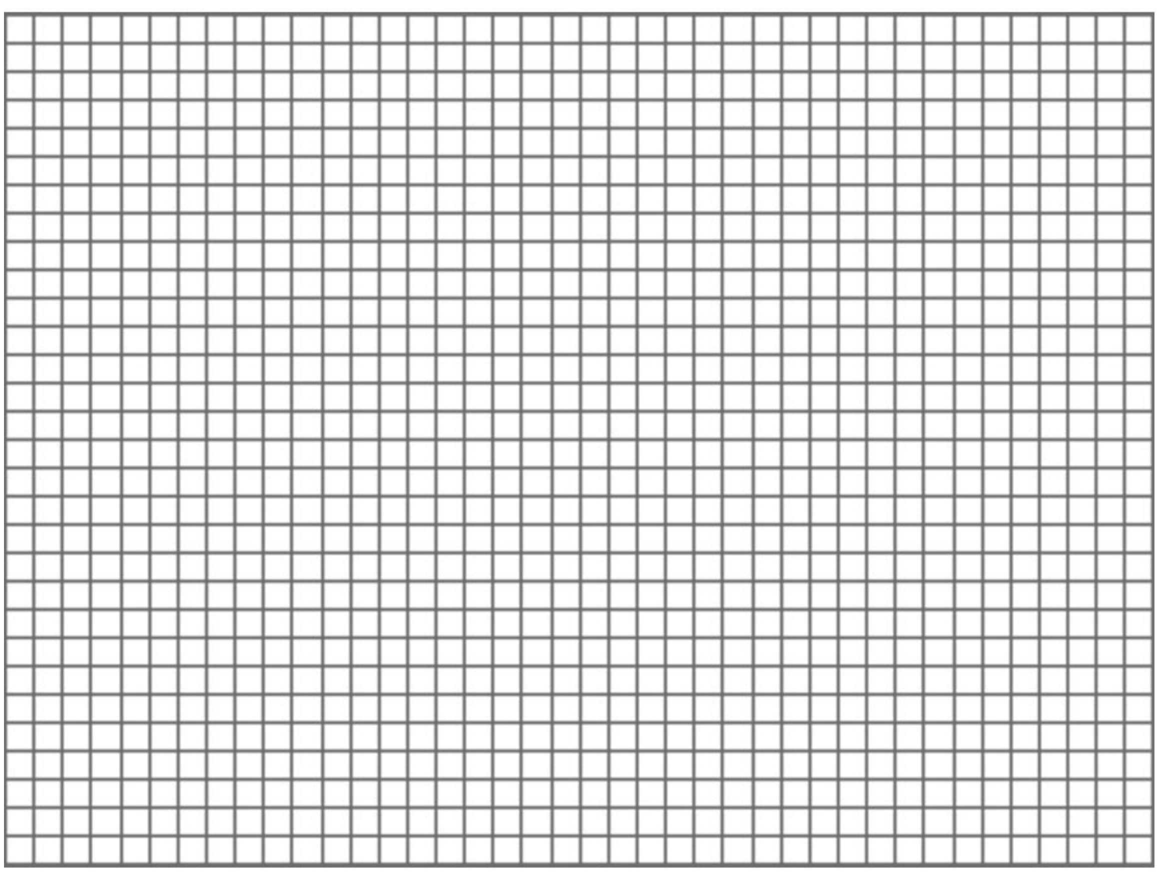
12. Design an method by which you can figure out the relationship between the two scales graphically. Brainstorm ideas within your groups, and whiteboard them.

a) Procedure:

b) Data Table:

c) Graph: Plot ˚C on the horizontal axis and ˚F on the vertical axis

Title of graph:



13. Draw a best fit line to the data. Calculate the slope, and obtain a conversion formula between degrees C and F from the slope.

Part 3: Researching temperature:

Directions:

1. Use the library or the internet to figure out the following temperatures:

   - Liquid helium
   - Iron melting
   - Surface of Sun
   - Surface of Moon
   - Surface of Jupiter
   - Center of Earth
   - CO2 solidifying
   - Ice
   - Boiling water
   - Liquid nitrogen
   - The temperature of three other things of interest to you

2. Convert all temperatures to the same scale!! Are C and F the only temperature scales? After the class has decided on the scale they will use, draw a graph and mark the temperatures on it.

3. Mark the temperatures at which you would feel "freezing cold" and "sweaty hot". How does this range compare to the range of temperatures in the universe?

Heating through Conduction Lab

Materials:

- Two insulated cups with lids
- Bent metal rod (with flat segment insulated)
- Hot pot to boil water
- Cold water
- Two thermometers, stopwatch and graph paper; or two temperature probes connected to a computer or data gathering device

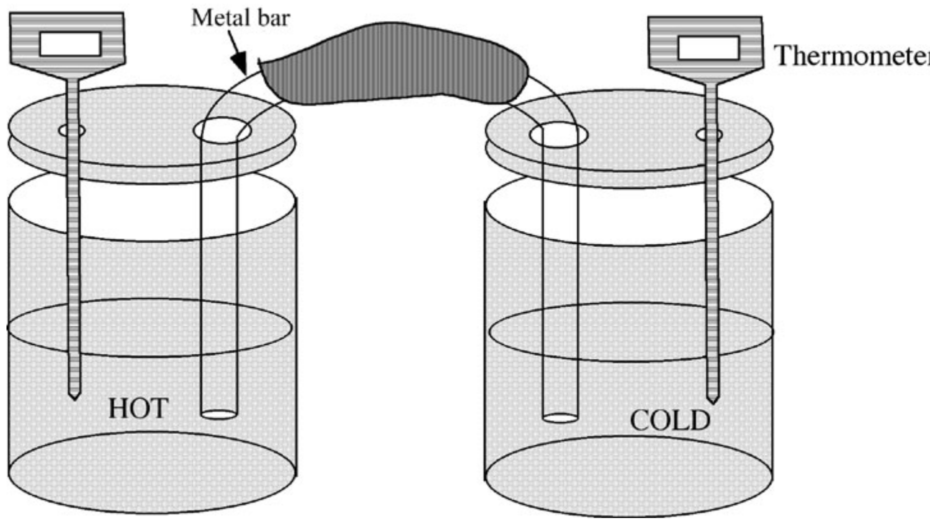
Purpose:

What factors determine the transfer of energy through a solid object?

Pre-lab discussion:

1. Discuss the following scenario: two insulated cups are placed side by side on a table. Each is filled about half-full: one with hot water, the second with cold water. Discuss ways in which energy can be transferred from one cup to the other *without* pouring water from one cup to another.

2. Predict: A bent bar is inserted so one end of the rod is in the hot-water cup, the other in the cold-water cup. What do you think might happen? Explain your reasoning.



3. Discuss the factors that might affect the change in temperature of the water in the cups (the cups are insulated from the room, so they do not gain or lose energy to the environment).

Directions:

4. Have students design and conduct their experiment. If you are using temperature probes, discuss with your teacher how they work.

   a) The Experimental Question:

   b) IV:

   c) DV:

   d) Constants:

   e) Hypothesis:

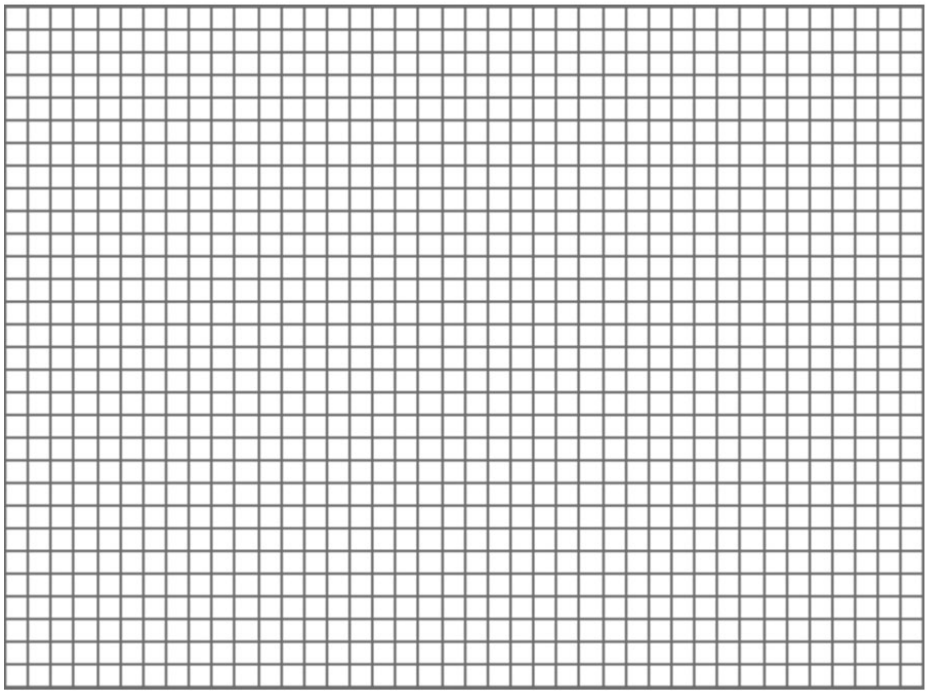
   f) Materials List:

   g) Procedure:

   h) Data Table:

i) Graph: (temperature on the vertical axis, time on the horizontal)

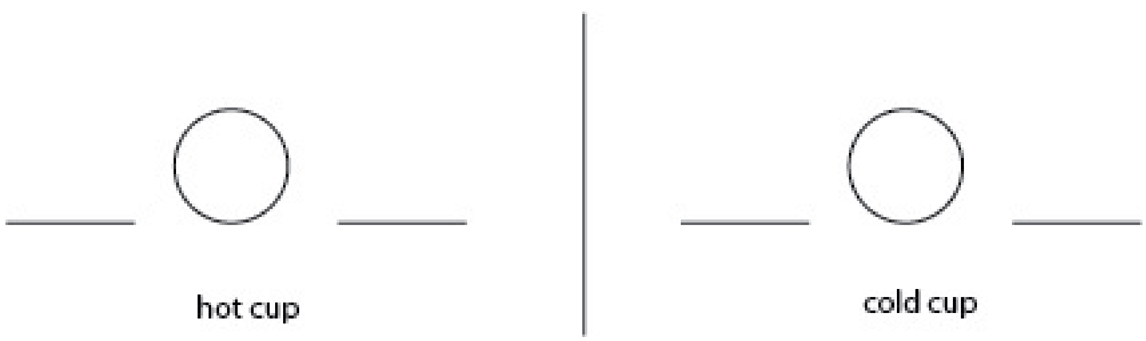
Title of graph:



Post-lab discussion:

If possible, plot the data on the board or a common spreadsheet so that data from all groups in the class is presented on the same graph.

5. Draw energy bar graphs for the hot cup at the beginning and end of an experiment; and for the cold-water cup at the beginning and end of the experiment:



6. Is there any energy transfer that occurs in this experiment? Explain.

7. Is energy conserved in this experiment? Explain.

8. Is it possible to take all the thermal energy in the hot cup and transfer it to the cold cup, so the hot-water cup now becomes cold, and the cold-water cup becomes hot? Explain.

9. If the bent bar had a longer length between the cups, what do you think would be different in this experiment? What if the bar was thicker? Explain.

10. Student group A starts with a *half-cup* of hot water and a half-cup of cold water. Student group B starts with a *full cup* of hot water and a half-cup of cold water. What would be different about in their experimental results?

11. Student group A starts with a half-cup of *hot* water and a half-cup of cold water. Student group B starts with a half-cup of *warm* water and a half-cup of cold water. What would be different about in their experimental results?

Heating through Convection Lab

Materials:

- Three beakers or flasks (preferably 500 mL glass)
- Water
- A source of heat, such as a hot plate or sterno burner
- A few drops of food coloring or coarse grained pepper

Purpose:

What is convection, and how is it different from conduction?

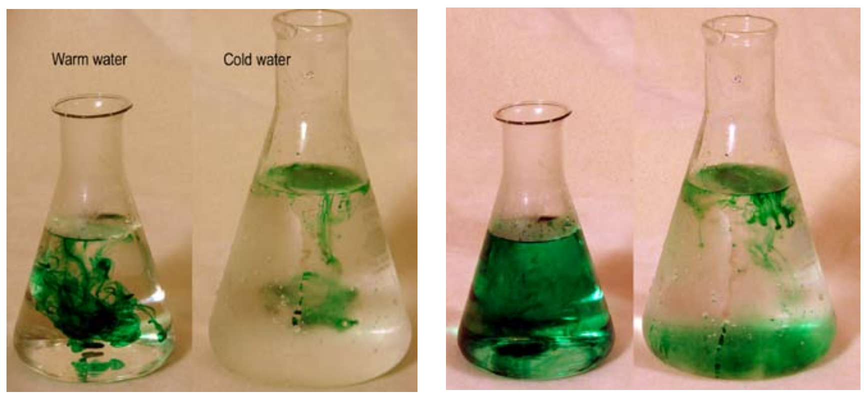
Pre-lab discussion:

1. Think about how a pot of water heats up when we set it on a stovetop. Where is the source of thermal energy? How does the thermal energy reach the water on the top of the pot?

2. Let's suppose that we gently add a few drops of food coloring into the beaker (no stirring). Predict: what do you think you will see a minute later if:

   a) The water is warm?

   b) The water is cold?



Beakers of warm and cold water. Left: soon after adding food coloring. Right: five minutes later.

   c) The beaker of cold water (with drops of food coloring) is heated.

Directions:

3. This experiment will be conducted as a demonstration. Here's what will be done in the demonstration:

First, in a beaker of cold water, and 3-4 drops of food coloring will be added gently.
Second, in a beaker of warm water, 3-4 drops of food coloring will be added gently.
After a minute or two, make observations.
Third, take a beaker of cold water, place a thermometer in the beaker, and gently add three or four drops of food coloring. Place it on a hot plate or other source, and warm the beaker.

a) What happens to the food coloring in the heated beaker?

b) At the same time, what happens to the temperature of the water in the beaker?

c) What does this experiment demonstrate about how water heats up in this situation?

d) What happens to the water as it heats up if no food coloring were added?

e) By what mechanism does the water warm up? Conduction? Something else?

f) If it is a different mechanism, how is it different from conduction?

g) What do you think will happen to a birthday candle lit on the space shuttle?

Heating through Radiation Lab

Materials:

- Three metal cans with lids - one painted black, one white and one silver
- Three temperature probes
- An infrared or incandescent lamp
- Graduated cylinder

Purpose:

Can heating occur without contact with the hot object?

Pre-lab discussion:

1. How do you think energy from the sun reaches the earth? Is it conduction? Or convection? Why or why not?

2. Why is it that a dark T-shirt feels hotter in the summer than a white one? What if you could wear a shiny silver-colored T-shirt?

3. Look at the three cans. Which one do you think would get hotter if we placed the three under an infrared or other hot lamp? (Or, for that matter, outside in the sun on a hot day). Explain your reasoning.

Part 1: Which one gets hotter?
Directions:

4. Design an experiment where you measure which of the three cans gets hotter when placed under a hot lamp, and obtain a curve for the rate of heating. Brainstorm ideas, and then whiteboard your ideas in groups.

5. Conduct the experiment:
   a) The Experimental Question:

   b) IV:

   c) DV:

   d) Constants:

   e) Hypothesis:

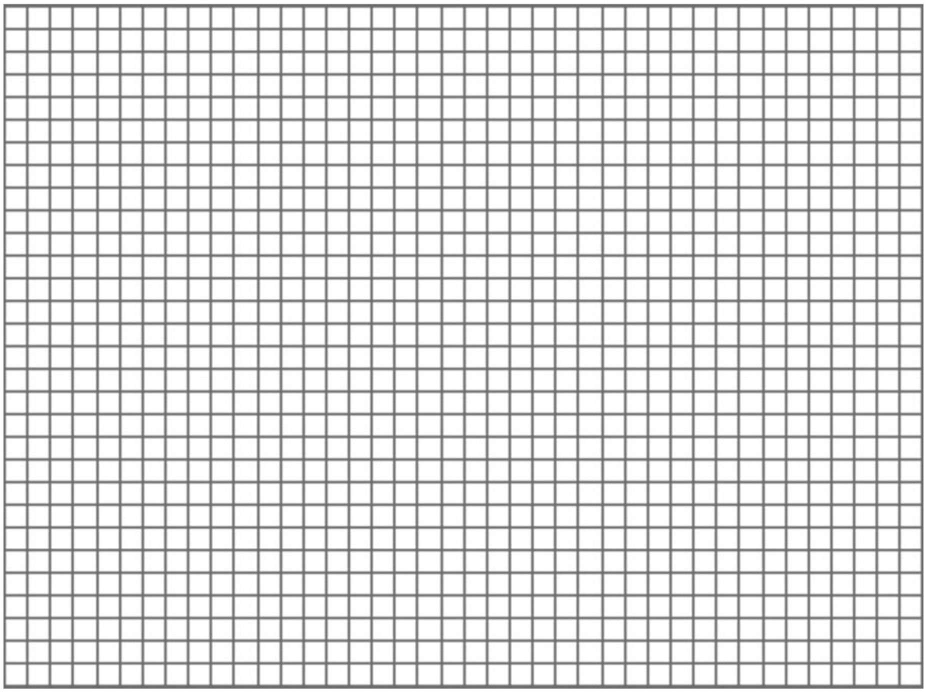
   f) Materials List:

   g) Procedure:

   h) Data Table:

i) Graph:

Title of graph:



Part 2: Which one cools faster?

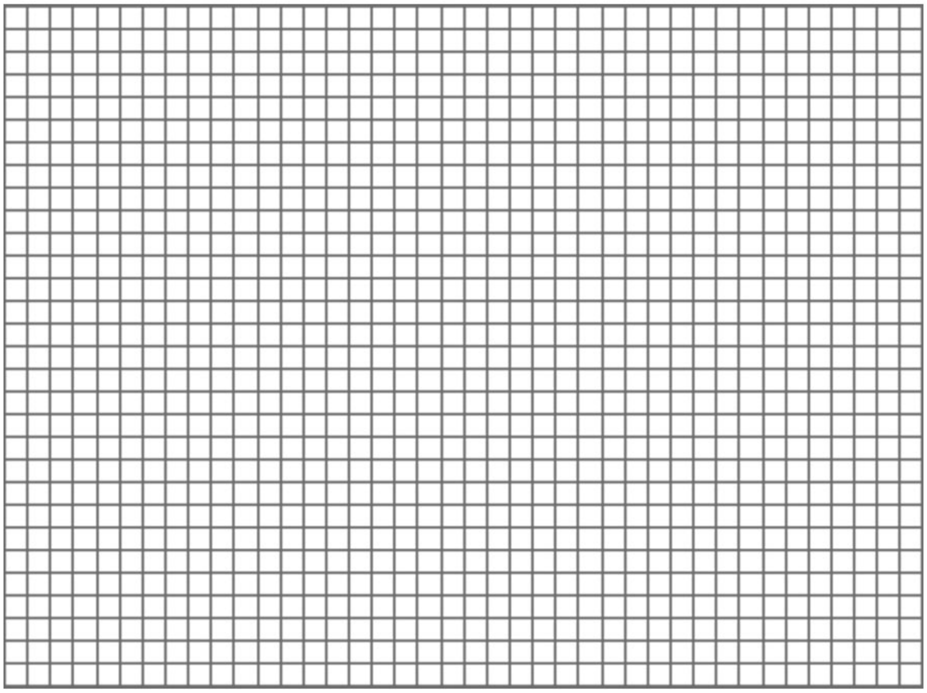
6. Predict what you think will happen if you reverse the situation: what if we placed hot water in the three cans. Which one would cool the fastest, and which one the slowest? Or would all cool at the same rate?

7. Design an experiment where you measure the rate at which the three cans cool.

8. Conduct the experiment:
   a) The Experimental Question:
   b) IV:
   c) DV:
   d) Constants:
   e) Hypothesis:
   f) Materials List:
   g) Procedure:
   h) Data Table:

i) Graph:

Title of graph:



Post-lab discussion:

9. From the first graph, rank the order in which the three cans heated up (from fastest to slowest).

10. From the second graph, rank the order in which the three cans cooled down (from fastest to slowest).

11. Analyze your data:

   a) What relationship do you see between which ones heated the fastest and cooled the fastest?

   b) If you wanted a cup of coffee to stay hot for a long time, what color should the cup be? Explain.

c) If you wanted a glass of ice water to stay cold for the longest time, what color should it be? Explain.

d) How do you think an insulated flask is constructed, and what is it that allows it to keep hot liquids hot for a long time? Which heating mechanism(s) is it based on?

e) How about the plastic insulated mugs – which heating mechanism is it based on? Does it work equally well with the lid on and the lid off? Why or why not?

Energy Required to Change the Temperature of an Object Lab

Purpose:
Do all metals need the same amount of energy to change their temperature the same amount?

Pre-lab discussion:

1. We've all touched something hot and gotten our fingers singed. We might even have seen a hot poker plunged into water and seen the water boil away. But are all hot materials equally likely to boil water if they are plunged into cold water?

   a) Discuss what factors might affect what will happen if a hot metal object is transferred to cold water. If you wish, you could make comparisons of two situations, such as, "if I take a light hot metal object and put it in a vessel with one cup of cold water vs. a heavy metal object in a one cup of cold water then…."

   b) What do you think will happen if a hot object is plunged into cold water?

   c) Will the effect you predict be the same for all hot objects? Explain.

Materials:
- An electric pot to warm water
- 25 and 100 ml measuring cylinders
- A Celsius thermometer or temperature probe
- Rods of five metals, all with the same mass
- Two or three other materials of similar mass (e.g., small pebbles, marbles, a block of wood, etc)
- Gram balance (digital or analog)
- A pair of tongs with insulated handles
- A pair of oven mitts or gloves
- 5 graduated cylinders wide enough to hold the rods
- Cold water

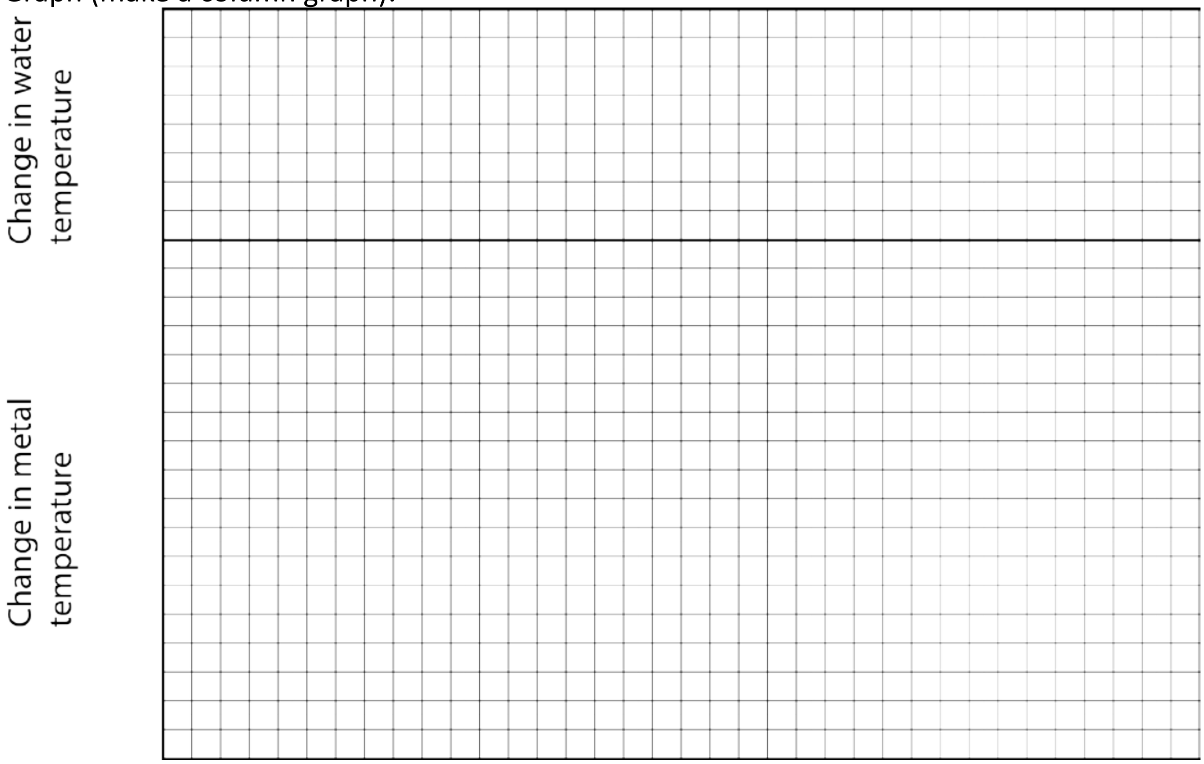
Directions:

2. Examine the materials you are given. Then design an experiment to answer the question "if we heat different metals to the same temperature, are there differences in the amount of energy the metals lose as they cool down?"

3. Be sure to wear gloves and use the tongs to pick up the hot pieces of metal.
    a) The Experimental Question:
    b) IV:
    c) DV:
    d) Constants:
    e) Hypothesis:
    f) Materials List:
    g) Procedure:
    h) Data Table:
    Since it is important to track several pieces of information, here is a sample table. Make your own table or add rows as needed. Remember that temperature change is T_f-T_i, which can be positive or negative!:

Metal	Initial temp	Final temp	Temp Change (include sign)		Water	Initial temp	Final temp	Temp Change (include sign)

i) Graph (make a column graph):

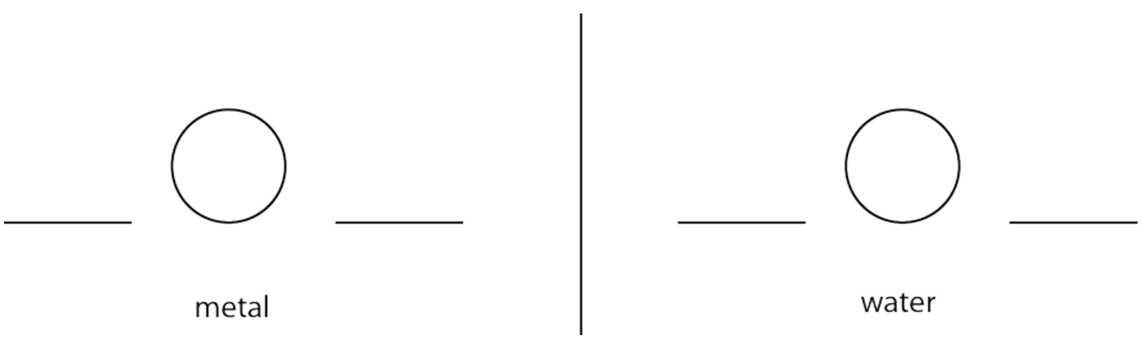


Post-lab discussion:

4. Compare your results for aluminum first:

a) What do you think is the connection between the heat released by the metal and the heat absorbed by the water?

b) Draw an energy bar graph for the metal and for the water.



c) If you compare the metal to the water, which one of them had a larger change in temperature? What might be the reason for these differences?

5. Compare different metals:

   a) Are your observations similar for the other metals ? Explain.

   b) Compare the changes in temperature for the other metals. What might be a possible reason for the differences among the metals?

6. Now that you have tried the metals, try some other substances.

   a) For example, we know that hot water stores thermal energy. What do you think would happen if you used hot water of the same mass as one of the rods and mixed it into the cold water? Predict and then try it out. Does water need more or less energy than the metals to change its temperature?

   b) Try materials easily available in the room (which you can boil to 100°C.)

   c) What does this experiment tell you about how much energy materials need to change their temperature?

   d) Typical of a day in the Midwestern United States, the temperature suddenly drops from 35°C to 15°C. What would the water in an outdoor unheated (20-foot diameter) swimming pool feel like an hour or two after it suddenly turned cold?

e) What does this experiment tell you about why cities near the sea have climate that is not too hot and not too cold?

f) What could you guess about the rates at which land and sea warm up?

g) On a very hot day, why is it that people have trouble walking barefoot in the sand, but they can swim barefoot in the sea?

h) What does this experiment tell you about the ice-melting blocks station in the Exploring Thermal energy lab?

Heating Objects: Thermal Expansion Lab

Materials:

- Ball and ring
- Bimetallic strip
- Sterno heater or microburner
- Ice water

Purpose:

What happens to the size of objects of different substances during heating?

Pre-lab discussion

1. Predict: if you take a metal rod and heat it up, what do you think will happen to its size?

Directions:

2. Examine the two demonstration items (see pictures). What do you think will might happen if you heated them up?

3. Observe the demonstrations
   a) Push the ball through the ring. Remove it from the ring, then warm it and see if the ball can pass through the ring. Explain what you see, in detail:

   b) Next, heat the ball and the ring, and see if the ball passes through the ring. Describe what you see, and explain your observations.

   c) Next, cool the ball and the ring by placing them in cold tap water. Does the ball pass through the ring? Describe what you see, and explain your observations.

d) Warm the bimetallic strip and watch what it does. Explain what you see, in detail.

4. Predict: what do you think might happen to the above demonstrations if start with all the objects at room temperature, and we cooled the following objects by plunging them in ice water. Explain your prediction.

a) Cool the ball but not the ring

b) Cool the ring but not the ball

c) Cool both the ball and the ring

d) Cool the bimetallic strip

Post-lab research and discussion:

5. Research the effects of the expansion of materials when heated. Choose topics of interest to you. Sample topics might be

- How do thermostats work?
- Why do roads develop cracks after the winter?
- Why are concrete roads not poured in continuous panels, but poured in large panels with gaps between them?
- If you fill a water bottle to the top (with no head room) and freeze it, the bottle will crack. Why does that happen?
- Why do overhead electrical wires that look taut in the winter sag in the summer?

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