INTRODUCTION: This material corresponds with Hecht 2nd Ed. Chapter 13. Although it may sound silly, watching a cup of hot water cool is really quite interesting. Trust me! We will find out where the heat goes as the water cools, and we will try out different kinds of cups, covered and uncovered to explore conduction, convection, and radiation. It is a good idea to read all the steps in each part before you start. Note there is only one set-up of EXPERIMENT D. Your group will need to cycle through that station at some point during the lab.

Material in this lab has been adapted from Sokoloff RealTime Physics.

Pre-Lab Homework

Directions: These pre-lab homework problems are to be done before you get to lab. They are predictions, your hypothesis of what you think might happen. You will actually perform each of the experiments and discover if your predictions were on the mark or not. Write down what you honestly think will happen, so that at the end of the experiment you can compare your ideas with what you saw. Your TA will be able to better help you in lab if they can see from your pre-lab what ideas you have about what is going on. You will not be graded down for wrong predictions, but you will lose points for no predictions.

1. *Suppose you have a cup of hot coffee (or tea, or chocolate, or water). You place this cup on a table and let it sit for a very long time.*
   A. *How cool does the coffee get?*
   B. *Where does the heat go?*
   C. *Does the **rate** at which the water cools stay constant or change as it cools?*
   D. *Make a graph of your prediction, what you think will happen to the temperature of the coffee over time. (Hint: time on the X-axis, temperature on the Y-axis.) Be sure to clearly indicate initial temperature and room temperature on your graph. How is the answer to part C shown on your graph?*

2. *Suppose you have two Styrofoam coffee cups, one with a lid and the other without a lid. Your two coffee cups are filled with coffee, and you put the lid on one cup. You set these two cups on a table.*
   A. *Which cup of coffee do you think will cool faster, the cup covered with its lid, or the cup without a lid?*
   B. *Why do you think the cup you picked will cool faster? (Try to explain using conduction, convection, or radiation, if you can).*

3. *Suppose you have two coffee cups, one cup is Styrofoam with a lid and the other is a metal cup with a lid. Your two coffee cups are filled with coffee, and you put the lids on both cups. You set these two cups on a table.*
   A. *Which cup of coffee do you think will cool faster, the covered Styrofoam cup covered with its lid, or the metal cup with its lid?*
   B. *Why do you think the cup you picked will cool faster? (Try to explain using conduction, convection, or radiation, if you can).*

EXPERIMENT A: Two Styrofoam Cups and One Lid

Materials:

- Hot water
- Two Styrofoam cups
- One metal cup
- Covers or lids for all the cups
- Graduated cylinders
- One thermometer with two thermocouples
- Watch, clock, or timer

1. Measure 75ml of tap water in your graduated cylinder and pour it into one of the Styrofoam cups. Mark the water level on the cup with a pen. Do the same to the other Styrofoam cup.
2. Take one lid and one thermocouple and push the thermocouple through the small hole in the lid.
3. Quickly fill the cups to the fill line with hot water. Put the lid on one cup and the other thermocouple in the uncovered cup.
4. Record the initial temperature of the water in both cups and take readings every 30 seconds for 5 minutes. You should have a total of 11 readings for each cup.

Questions for Experiment A:

A.1 Graph the data you acquired on one graph. Make sure to label the axes and use either different colored ink or symbols to distinguish the covered and uncovered cups.

A.2 By looking at your graph, which cup has a slower rate of cooling? How do you know—what property of the graph tells you this?

A.3 Which mode of heat energy transfer (conduction, convection, or radiation) is most affected by covering the cup? How do you know—what are you using to make your decision?

A.4 How do these results compare with your predictions in pre-lab Homework #1 and #2?

EXPERIMENT B: One Metal Cup, One Styrofoam Cup, Two Lids

1. You will do the same experiment as in Part 2, only this time you will use one metal cup and one Styrofoam cup. You will need to cover both cups, so make sure you have your lids prepared.
2. During this procedure, touch the sides of the cups with your finger and write down which cup ***feels*** hotter to the touch.

Questions for Experiment B:

B.1 Graph the data you acquired on a new piece of graph paper. Make sure to label the axes and use either different colored ink or different symbols to distinguish the metal and Styrofoam cups.

B.2 By looking at your graph, which cup has a slower rate of cooling? How do you know—what part of the graph tells you this?

B.3 Which mode of heat energy transfer (conduction, convection, or radiation) is most affected by substituting one metal cup? How do you know—what are you using to make your decision? How does this relate to your observations when you felt the two cups?

B.4 How do these results compare with your predictions in pre-lab Homework #3?

EXPERIMENT C: Calculating Heat and Energy

1. You will use your data from parts 2-4 to calculate the amount of heat transferred out of each cup and the rate of power lost.

Questions for Experiment C:

C.1 Make a summary data table that includes for each cup the mass of water used and change in temperature. You should also include other relevant information.

C.2 What equation would you use to calculate the amount of heat transferred out of each cup? Check with your TA, then do these calculations.

C.3 What equation would you use to calculate the amount of power transferred out of each cup? (Hint: Think about what power is). Do these calculations.

C.4 Which cup has the greatest power loss? Which cup has the least?

C.5 Can you think of any examples where this type of information could be useful in everyday life?

EXPERIMENT D: Conduction through Various Metal Bars

1. This equipment at this set-up contains four metal bars, brass, iron, copper, and aluminum. The four bars all are bent so that they all meet at a central core. This central core is placed in a glass dish.
2. Look carefully at the ends of the metal bars. You should see a small groove at the end of each bar. You will need to take the wax that is available at the station and cut a piece to fit inside the groove at the end of each bar. Make sure you cut the wax so that it is long enough to hang out beyond the groove in the metal bar by a few millimeters.
3. You should touch each of the metal bars and note if there is any initial temperature difference. Once you have all the wax in place, pour hot water into the glass dish and record your observations in your lab book.

Questions for Experiment D:

D.1 After the water has been poured, can you feel any temperature difference between the metal bars?

D.2 Without looking at a table, which metal of the four do you think has the highest thermal conductivity? Explain your reasoning. Which do you think has the lowest? Again, explain your reasoning. Check with your TA to verify your reasoning.