Heat Transfer and Flow

OBJECTIVES

The objectives of this experiment are to help students understand heat transfer, heat transfer during phase change, and simple fluid flow governed by Bernoulli's equation. The experiment emphasizes working in groups, combining results, and data analysis. The experiment has five parts:

<u>Cooling Water in Metal Containers</u>
In the first part, students will use multiple thermocouples to measure temperatures as metal containers of water cool in an ice and water mixture. Using temperature and weight changes of the ice, the water, and temperature changes of the water in the containers, students will be able to draw conclusions concerning latent heat, sensible heat, and heat transfer. The initial temperature of the water in the metal containers will be different for each group.

<u>Melting the Ice Block</u>
In the second part, students will investigate the melting of a block of ice (with embedded thermocouples) in a water bath also containing a thermocouple. Again the students will be able to use weight and temperature changes to draw conclusions about latent heat, sensible heat, and the effect of area on heat transfer. The size of the ice blocks will vary for each group.

<u>Cooling a Flowing Liquid</u>
In the third part, the students will investigate the cooling of a fluid flowing through the ice water bath. Three containers will be used; the water will flow by gravity from a warm container, through an ice bath, and into a final container. The flow rate for the water will vary for each group. Using the temperature changes across the ice water bath and the weight change in the final container, the students will be able to measure the amount of heat transfer between the ice water bath and the flowing water. Using data from different groups, the students will be able to make conclusions about the effect of the flow rate on heat transfer.

<u>Measuring Flow and Head</u>
In the fourth part, the students will investigate the effects of liquid head on the flow out of a reservoir. Liquid head is a name for the height difference between the fluid level in the reservoir and the end of the tube where the water flows out. Using several measurements made by each group the students will be able to see how the flow changes with liquid head and by comparison between theoretical and actual results, make conclusions about the losses in the tubing.

<u>Boiling Liquid</u>

In this experiment, an open container of water will be heated to boiling. Temperatures will be recorded at regular intervals before and after boiling begins. Heating will be ended before all of the liquid has boiled away.

MATERIALS FOR EACH GROUP

Several thermocouples, three insulated containers, a block of ice with two thermocouple leads frozen inside the block, a supply of ice, warm water, metal containers which can be filled with water, a reservoir with an outlet near the bottom, a measuring device, a scale, a coil of tubing, flexible tubing, and a timing device.

EXPERMENTAL PROCEEDURES

Groups**:** The class should be divided into groups containing four or five students. Each group should perform these experiments and then combine data for analysis and conclusions.

Cooling Water in the Metal Containers

This experiment starts with several metal containers each with a known amount of water at a known temperature, a supply of crushed ice, some water, and an insulated container.

(1) Weigh the crushed ice and use several thermocouples to measure its temperature.
(2) Weigh the water and measure its temperature.
(3) Put the water into the insulated container.
(4) Open one metal container of water and measure its temperature (also weigh the amounts of water in each container).
(4) Place a thermocouple in the water to monitor the temperature of the water.
(5) Put the remaining containers into the insulated container with the water and ice.
(6) Put a thermocouple into the ice water mixture and close the lid.
(7) At the end of the allotted time, remove the lid of the insulated container**.**
(8) Measure the temperature of the ice and water mixture.
(9) Weigh the ice.
(10) Weigh the water.
(11) Measure the temperature of the water in the metal containers.

Melting the Ice Block

This experiment starts with a cylinder of ice in which two thermocouples have been frozen one at the center and one halfway to the outside wall, an insulated container, and some warm water. The temperature of the warm water and the temperature of the ice block should be the same for all groups. The cylinders of ice should have the same height but different radiuses.

(1) The ice block should be weighed, and its surface area measured.
(2) The insulated container should be filled with the warm water. There should be enough water so that when the block of ice is added it will basically fill, but not run

over the container. The weight and the temperature of the water should be measured.

(3) Add the ice block to the water.
(4) Place a thermocouple in the water to monitor the temperature of the water.
(5) Record the temperature of the water and the ice at regular time intervals.
(6) At the end of the allotted time, remove the ice from the water, weigh the ice, measure the area of the ice, and record the temperatures.
(7) Weigh the water.

Cooling Liquid

This experiment starts with a reservoir of warm water, 100° plus, connected by tubing to a copper coil submerged in a second reservoir filled with an ice bath, and exiting to a third reservoir. Thermocouples should be arranged to record the temperature of the water in the warm reservoir, the ice water bath and the entrance and exit of the coils. Each group should use similar warm water reservoirs and similar ice bath conditions.

(1) Fill the first reservoir with warm (100° plus) water.
(2) Fill the second reservoir with an ice water bath. Measure the quantity of ice, the quantity, of water and the temperature.
(3) Connect the tubing and elevate the reservoirs so that the water will flow from the warm water reservoir through the coils in the ice water reservoir, and then into the final reservoir.
(4) Measure the temperature in each reservoir and at the inlet and outlet of the copper coil.
(5) Measure the flow rate of the water into the final reservoir.

Measuring the Flow and the Head

This experiment starts with a single reservoir of water at room temperature and a tube which allows the water to flow into an exit container which can be located at several different levels below the liquid level in the reservoir.

(1) Fill the first reservoir with water.
(2) Place the exit container at the first designated level below the reservoir.
(3) Measure the amount of water that flows into the exit container in a given time.
(4) Repeat steps two and three for several given locations.

Boiling Liquid

This experiment starts with an open container of room temperature water that will be heated until the water has been boiling for some time, with some liquid still present in the container.

(1) Weigh the water.
(2) Measure the temperature of the water at regular intervals until the hearing is stopped.
(3) Weigh the water.

RESULTS AND CALCULATIONS

In this part of the experiment the student will tabulate the results of the experiments and make calculations.

Cooling Water in the Metal Containers

Ice in the Ice Water Bath

(1) What was the temperature change for the ice?
(2) How much heat transfer was required for this temperature change?
(3) What was the weight change for the ice?
(4) How much heat was required to melt the ice?

Water in the Ice Water Bath

(1) What was the temperature change for the water?
(2) How much heat transfer was required for this temperature change?

Water in Containers

(1) What was the temperature change for the water?
(2) How much heat transfer was required for this temperature change?

Graphic Results

(1) Collect the data from all of the groups make a graph showing amount of heat transfer from the water in the containers vs. amount ice melted.

Melting the Ice Block

Ice Block

(1) The ice block should be weighed, its surface area measured, and its average temperature estimated.
(2) How much heat transfer was required for this temperature change?
(3) How much ice had melted?
(4) How much heat transfer was required?
(5) What was the temperature change for the water?
(6) How much heat transfer was required?

Graphic Results

(1) The groups should combine data and plot a graph of temperature change vs. surface area of the ice blocks, for the given time period.

Cooling Liquid

Ice in the Ice Water Bath

(1) What was the temperature change for the ice?
(2) How much heat transfer was required for this temperature change?
(3) What was the weight change for the ice?
(4) How much heat was required to melt the ice?

Water in the Ice Water Bath

(1) What was the temperature change for the water?
(2) How much heat transfer was required for this temperature change?

Water Flowing Through the Coils

(1) What was the flow per unit time through the coils?
(2) What was the temperature change across the coils?
(3) How much heat transfer was required to cause this change?
(4) What was the required heat transfer rate per unit time?

Graphic Results

(1) Collect the data from all of the groups make a graph showing amount of heat transfer from the water vs. water flow rate and a graph showing temperature change vs. water flow rate.

Measuring the Flow and the Head

Flow From the Container

(1) Calculate the theoretical flow rate.
(2) Compare this flow with the measured flow rate.

Graphic Results

(1) Collect the data from all of the groups and make a graph showing amount of head vs. amount of flow. Make one graph from the theoretical results and one from the measured results.

Boiling Water

Water in the Container

(1) Make a temperature vs. time chart for the boiling water.
(2) How much heat transfer was required to bring the water to boiling temperature?
(3) How much heat transfer was required to change the water from liquid to steam?

Graphic Results

(1) Collect the data from all of the groups and compare results.

CONCLUSIONS

Cooling Water in the Metal Containers

(1) Did the ice and water reach a constant temperature?
(2) Did heat transfer continue after this occurred?
(3) Was the ice bath itself cooled or heated?
(4) Why would the temperature of the ice bath stop changing?
(5) What conditions are required for the ice bath to change temperature?
(6) Trace the heat flow in this problem?
(7) What conclusion can be drawn from the graphic results?

Melting the Ice Block

(1) How much ice was melted?
(3) How much heat transfer was required to cool the ice to this temperature?

(4) How much heat transfer was required to change the ice into water?
(5) Trace the heat flow in this problem?
(6) What conclusion can be drawn from the graphic results?

Cooling Liquid
(1) What was the total heat transfer from the flowing water?
(2) What was the total heat transfer into the ice water bath?
(3) Trace the heat flow in this problem?
(4) What conclusion can be drawn from the graphic results?

Flow From the Container
(1) Compare the difference between the expected flow rate and the measured flow rate. What were the causes of the difference?

Boiling Water
(1) When and why did the temperature of water stop changing?
(2) How does this relate to the constant temperature in the ice bath?