Northcentral Technical College

Experiment 41

THERMAL ENERGY TRANSFER- CONDUCTIVITY

Read through Competencies, Apparatus, Introduction sections.

COMPETENCIES:

The student will be able to: measure temperature with a Celsius thermometer; measure temperature with a temperature transducer coupled with a computer; measure length with a metric steel rule; determine mass with a dial-o-gram balance; calculate head conductivity from mass, specific heat and temperature change; calculate heat conductivity from conductivity constant, thickness, cross-sectional area, time and temperature change; calculate percent variation; define conduction, convection, and radiation; analyze the factors affecting thermal conductivity.

APPARATUS:

Vernier LabPro Interface system with four temperature probes, rubber tubing, electronic balance, one large (1000 mL) plastic or Styrofoam beaker, heat conductivity apparatus, steel rule, steam generator, stopwatch, Bunsen burner, glass tubing.

INTRODUCTION:

Thermal energy may be transferred by radiation, convection and conduction.

Radiation is infrared radiation, a form of electromagnetic radiation. It travels through vacuums and can be readily stopped by a highly reflective surface. Things that absorb radiant heat will re-radiate it at a longer wavelength (lower frequency).

Convection is heat transfer by currents of unevenly heated molecules. In general, when a gas or liquid is heated it expands. This expansion causes the density of the material to decrease. The lower density material rises and cooler takes its place. It is most important in fluids (liquids and gases). A vacuum can best prevent it. The next best thing to a vacuum are small, restricted pockets of fluid.

Conduction, which this experiment deals with, is heat transfer from molecule to molecule. The high energy (hot) molecules transfer thermal energy to the low energy (cold) molecules. Conduction is the most important method of heat transfer in solids and affects a person's sense of temperature. A vacuum can best prevent it. The next best method is to use a porous material with a gas trapped in it.

The amount of heat transferred by conduction depends on the thickness of the material, the temperature difference, the cross-sectional area, the time during which the transfer occurs, and the thermal conductivity of the material (k).

The reciprocal of k is equal to thermal resistance (ρ). Thermal resistance is of special concern, because of energy conservation measures and fuel costs. The higher the value of ρ, the better material is as an insulator.

The factors affecting heat flow due to conduction may be expressed mathematically as follows:

$$Q = \frac{k\,A\,\Delta T\,t}{L} \quad \text{(Eq. 41.1)}$$

where
- Q = amount of heat, in calories
- t = time length, in seconds
- k = thermal conductivity, in cal/cm-s-ºC
- A = cross sectional area, in sq. cm.
- ΔT = temperature difference between hot and cold sides of the material, in ºC
- L = length or thickness of the material, in cm

One way of measuring the amount of heat flow is to use the heat that flows through an object to warm another material. The following formula is then used to calculate the amount of heat absorbed by the material.

$$Q = mc\Delta T \quad \text{(Eq. 41.2)}$$

where
- Q = heat, in calories
- m = mass, in grams
- ΔT = temperature change of the material water, in ºC
- c = specific heat in cal/g - ºC

The device used to measure temperature is an AD590JH temperature probe, which produces a current, which is proportional to its absolute temperature (about 1.0 microamperes per degree Kelvin). The AD590JH temperature probe is connected to the ULI current-to-temperature converter circuit.

The specifications on this system are as follows:
* Temperature Range: -50 ºC to 120 ºC
* Sensitivity: O.2 ºC

The AD590JH temperature probe is fairly durable, but not designed to be used with corrosive chemicals especially over long periods of time.

Stop Reading. Click Play in Panopto to view the Procedure.

PROCEDURE:
Connect the LabPro in the back of the computer and plug temperature probe A into channel 1, temperature probe B into channel 2, temperature probe C into channel 3 and temperature probe D into channel 4 of the ULI.

Turn on the computer and perform the following steps:
1. When the first Windows screen comes on, press **CTL**, **ALT**, and **Del** keys at the same time
2. When the second Windows screen comes on, the user name should be **Student ID Number**), the password box is **Your Password** (Student ID Number the First Time) and press **Enter**
3. Using the mouse, double click on the program group **Logger Pro 3.3**

4. Click on **FILE**
5. Click on **OPEN**

5. Double Click on the folder **Technical Physics**
6. From the list of experiments select **Experiment 41**

At this point in time, you are ready to start taking measurements.

Measure the diameter and thickness (from center of T_a hole to center of T_b hole) of the copper rod. See diagrams 40.1 and 40.2 for diagrams of lab setup and designation of specific points.

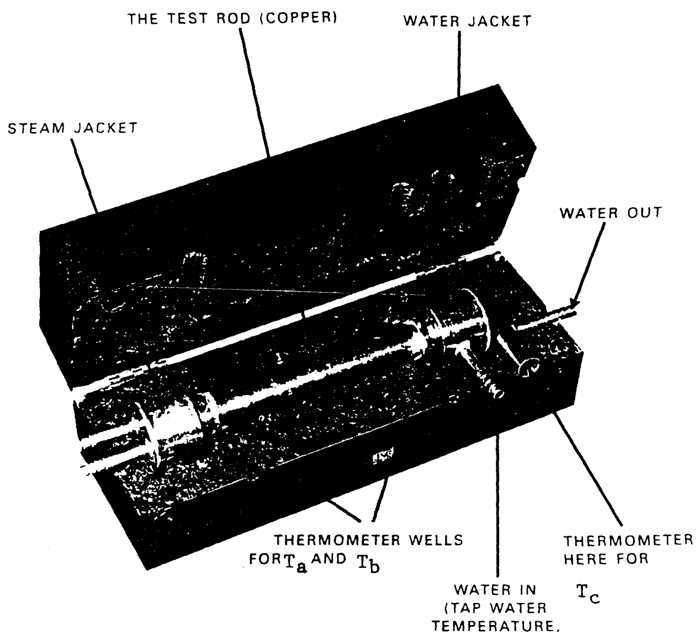

Fig 40-1: Thermal Conductivity Apparatus
(Central Scientific Company)

Turn the cold-water faucet on and let it run while you are setting up the rest of the experiment. This will allow the cold water to read a constant minimum temperature. Set up the thermal conductivity apparatus shown in Fig. 40.2.

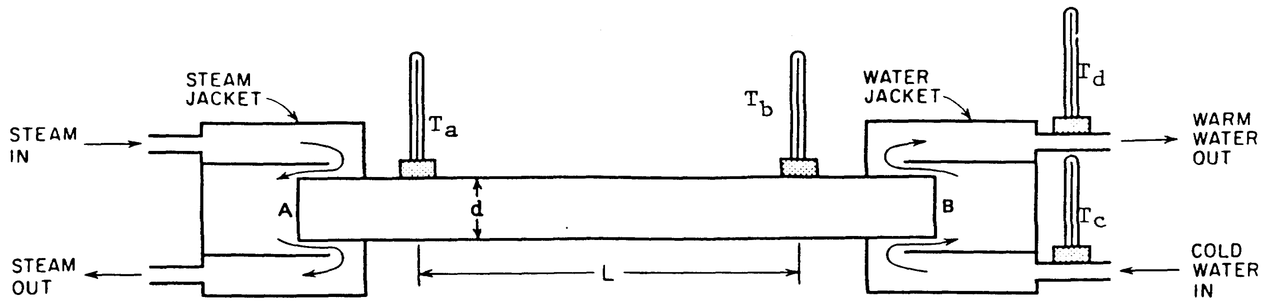

Fig. 40.2 Simplified Diagram of Thermal Conductivity Apparatus

Place the "A" temperature probe in the "T_a" well, and the "B" temperature probe in the "T_b" well. Insert the "C" temperature probe with the small stopper in the (T_c) pipe. BE CAREFUL OF THESE PROBES - THEY ARE EXPENSIVE! Note the thick cork insulation in the apparatus that will minimize heat losses to the room. Close the box. Fill the steam generator with hot water to within 1/4 in. of the top of the glass gage. Heat the water with a Bunsen burner. You may have to elevate the burner to shorten the heating time. KEEP THE FLAME AWAY FROM THE TUBING! Hang the steam delivery hose over a ring on a ring stand to keep the hose from melting. This will also eliminate low spots, which would collect condensate.

Take the plastic 1000 ml or Styrofoam beaker and determine its mass with the triple beam balance. Use this for all mass of water determinations.

When steam is present, pull the burner out from under the generator. Connect the steam delivery hose to the upper tube on the end of the apparatus with the two horizontal tubes. Make sure there are no low spots in this hose. Connect a drain hose to the lower horizontal tube and run it into the sink. Connect a hose from the horizontal tube on the other end of the apparatus to the cold-water tap. Connect another hose with a glass tube in the end of it to the vertical tube. This is the water collection hose.

Now, put the burner back under the generator, and turn on the cold water so that you have the slowest possible steady water flow that will fill the beaker in 3.0 minutes. You are now ready to use the computer to monitor temperatures.

Now wait until the temperature (T_c) no longer is changing. **THIS IS THE MOST IMPORTANT STEP IN THE EXPERIMENT!** When this temperature is stable, simultaneously start the watch and start collecting water in the beaker for three minutes. Read T_a, T_b, T_c and record on data sheet. As soon as there is enough water in the collection beaker, use temperature probe "D" to take its temperature (T_d) and record on data sheet. At the end of the three-minute trial, read T_a, T_b, T_c and record on data sheet.

Determine the mass of the water collected and record on data sheet. **DO NOT CHANGE THE COLD WATER FLOW UNTIL THE ALL LAB GROUPS ARE FINISHED!!!!!!!!!**

Repeat the above procedures two more times.

When all the measurements have been taken, do the following;

1. Single click on **Stop**

2. Single click on **File**

3. Single click on **Exit**

4. When asked if you want to save the experiment, single click on **No** (do not save your data)

To use the spreadsheet program do the following

1. Using the mouse, double click on the program **Excel**
2. Click on **FILE**
3. Click on **OPEN,**
4. Click on the **G** Drive
5. Click on the **Physics Folder**
6. Double Click on the subfolder **Technical Physics Excel Files**
7. From the list of experiments select **TPExp41.xls**

Fill in the appropriate cells in the spreadsheet. When you are finished, print out a copy of the spreadsheet for each person in the group by doing the following

8. Click on **FILE**, click on **Print**, and click on **OK**

When finished with this, get out of the program by doing the following

9. Click on **FILE.**
10. Click on **Close.**
11. When asked if you want to save your data, click on **NO.**
12. Get out of Windows and turn off the computer.

SAMPLE CALCULATIONS

For the first trial

1. Calculate the amount of heat absorbed by the flowing water using equation 41.2. (Use ΔT as $T_d - T_c$)

2. Calculate the amount of heat that was conducted by the copper by using equation 41.1. (Use ΔT as $T_a - T_b$)

3. Calculate the percent variation between the heat that was absorbed by the water and the heat that was conducted by the copper.

$$\text{Percent Variation} = \frac{|Q_1 - Q_2|}{\frac{(Q_1 + Q_2)}{2}} \times 100\%$$

where Q_1 = amount of heat conducted by the copper (Eq. 41.1)

Q_2 = amount of heat absorbed by the water (Eq. 41.2)

DATA SHEET:

Thermal Conductivity of Copper, in cal/cm-s-	
Diameter of the copper Rod, in cm =	
Area of the Coppoer Rod, in cm^2 =	0
Length Between Ta and Tb, in cm =	
Time for all trials, in sec =	
Specific heat of Water, in cal/g-C =	

	Trial 1	Trial 2	Trial 3
Starting Temperature of Ta, in C			
Ending Temperature of Ta , in C			
Average Temperature of Ta, in C	0	#DIV/0!	#DIV/0!
Starting Temperature of Tb, in C			
Ending Temperature of Tb , in C			
Average Temperature of Tb, in C	0	#DIV/0!	#DIV/0!
Starting Temperature of Tc, in C			
Ending Temperature of Tc , in C			
Average Temperature of Tc, in C	0	#DIV/0!	#DIV/0!
Average Temperature of Td, in C			
Mass of Water Collected, in g			
Heat Transferred by the Copper Rod, in cal	#DIV/0!	#DIV/0!	#DIV/0!
Heat Absorbed by the Water, in cal	0	#DIV/0!	#DIV/0!
Percent Variation	#DIV/0!	#DIV/0!	#DIV/0!

Name: ___________________________

Date: ____________________________

SAMPLE CALCULATIONS:

1. Heat conducted by the copper for trial 1.

2. Heat absorbed by the water in trial 1.

3. Percent variation for trial 1

ANALYSIS:

1. List two reasons for the error (difference between the heat that was conducted by the copper and absorbed by the water) in this experiment?

2. Which of the following is a better material for an efficient automobile radiator or air exchanger core and why? (Aluminum, Brass, Copper, Iron, or Steel)

3. Argon gas is used between the layers in a thermo pane window to reduce the heat loss of the window. Explain why using some or all of the factors listed in the table below?

Quantity	Air	Argon
Specific Heat	0.17	0.1253
Conductivity	0.00055	0.0000409
Density	1.2929 g/L	1.7837 g/L

4. Explain why, on a cold day, a piece of steel feels colder to the touch than apiece of wood.

5. A glass window is 2m x 1.5m and is 0.75 cm thick. The inside temperature is 20 ºC and the outside temperature is -29 ºC. How many calories of heat are lost through this window in one day?

6. Extra Credit

An ice chest is 22 inches long, 14 inches wide and 16 inches high. The foam plastic walls of the ice chest are 1.25 inches thick. A 10.0 lb of ice at 32 ºF is placed in the ice chest on an 80 ºF day in summer. How long will it take the ice to melt? Assume that the ice chest loses heat equally from all sides and the cover of the ice chest remains closed.