NAME ______________________ LAB PARTNERS ______________________

Instructor ______________________ ______________________

Thermal Conductivity

Experiment **11**

INTRODUCTION

When you heat a pot of water on a hot stove, thermal energy quickly flows into the water raising its temperature until it boils. Thermal energy or heat is transferred through the pot, which is made of a relatively good conducting material. Wood, on the other hand, is a poor conductor of heat. You can hold one end of a lighted match without getting burned. In this experiment, we will study the heat conducting properties of several materials.

THEORY

Consider a conductive bar initially at room temperature. If one end of the bar is placed on a heat source, the temperature at that end will begin to rise making the molecules vibrate with larger amplitude. These molecules will cause their neighbors to vibrate with larger amplitude as well and so on until this effect is propagated along the entire bar.

The amount of heat transferred through the bar per unit of time is given by

$$\frac{\Delta Q}{\Delta t} = kA\frac{\Delta T}{L}. \qquad (1)$$

Here ΔT is the temperature difference between the ends of the bar, A is its cross-sectional area, and L is its length. See Figure 11.1. The constant k is known as the thermal conductivity of the material. Good conductors such as silver or copper have high thermal conductivity constants.

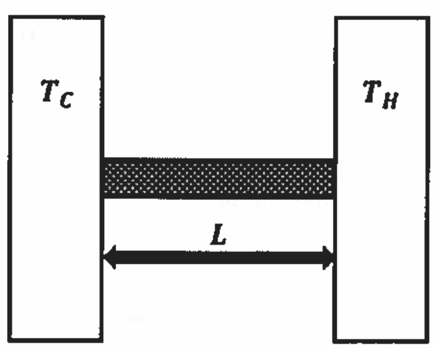

Figure 11.1: The amount of heat transferred through the bar is proportional to its cross sectional area, the temperature difference between its ends, and inversely proportional to the length of the bar

In this experiment, we will calculate the rate of heat flow for different conducting materials. We will also study how the cross-sectional area affects heat conduction. The heat conduction apparatus used in the experiment has 4 metal bars, as shown in Figure 11.2. One end of each bar is heated using a Peltier device. Temperature is monitored using sensors (thermistors) placed at two locations in each bar. Temperature readings are taking with thermistors at locations T1 through T8.

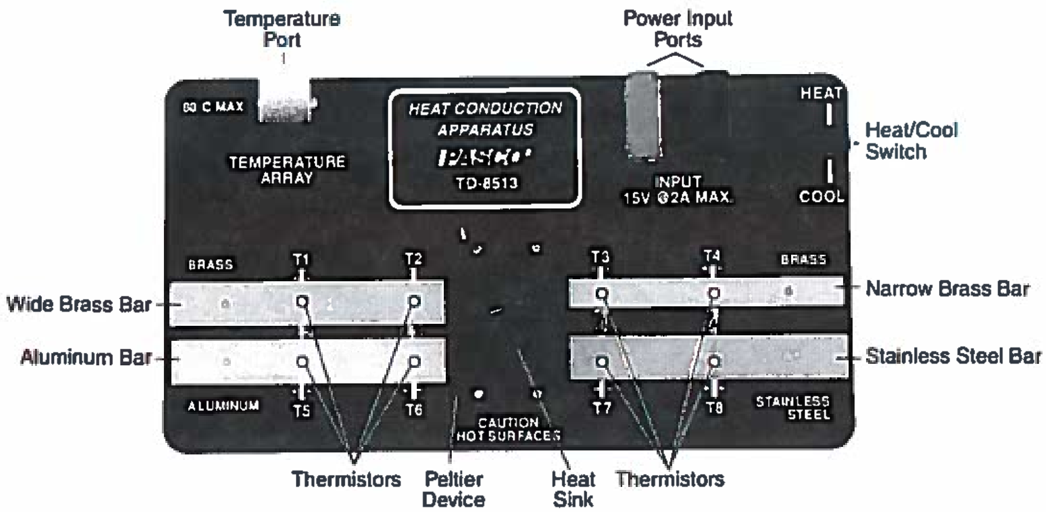

Figure 11.2: The heat conduction apparatus

EXPERIMENT NO. 11

1. The Heat Conduction Apparatus (HCA) is already connected to a power supply and you are ready to take measurements.

Leave the power supply **OFF** for now. Place the insulating covers on the bars.

2. Log in to the **Student** account. From the **Start** menu, open the **1122** folder and the **Exp11-Thermal Conductivity** file.

3. In this part of the experiment, you want to determine which material (between brass, aluminum, and stainless steel) is the better heat conductor. We will compare temperature readings T1, T5 and T8, see Figure 11.2.

All three temperature readings are taken at an equal distance from the heat source (Peltier Device). By comparing how the temperature changes with time at that distance from the heat source, you should be able to determine which material is the best conductor.

Drag T1 from the data panel and drop it on the **Graph** icon on the display panel. Then add T5 and T8 in the same way. This will create a single graph showing the three temperature readings as a function of time. Maximize the graph window.

4. With power supply still, **OFF**, collect a test run, check that all bars are at room temperature (around 20.0°C).

There might be slight differences in temperature readings between sensors because they have not been calibrated. This difference will not affect your results.

If everything is in order, delete the test data, click on **Experiment**, and select **Delete ALL Data Runs**.

5. Press **Start** to begin collecting data, wait for about 5.00 seconds, and then turn the power supply **ON**. Your graph will show in real time how the temperature increases in each material. Watch the temperature graph and allow it to increase for 10.0 minutes. After 10.0 minutes, the program will automatically stop recording data.

Click on the icon **A** and then somewhere on the graph to label the graph with your names. Print a copy of the graph of temperature (T1, T5, and T8) as a function of time for each group member.

6. Which material do you think is the best conductor? Which is the worst? Explain how you reached your conclusions.

7. The three temperature readings used in the previous step were taken by thermistors on the "far" end of each metal bar, see Figure 11.2. Notice that each bar has a thermistor placed "close" to the heat source as well, for example, T1 is the "far" reading of the wide brass plate and T2 its "close" one.

Create a *T versus t* graph for each material. Each graph must include the "close" and "far" temperature readings of the material. Label and print the *T versus t* graph for each group member.

In Table 11.1, record the moment at which each temperature ("far" and "close") started to increase.

Calculate the speed of the heat pulse down each bar. The separation between "far" and "close" thermistors is 3.00 cm in each case. Show your calculations.

Table 11.1: Thermal Conductivity – the Heat Pulse Calculations

Material	t_{close}	t_{far}	Δt	v_{pulse}
Brass				
Aluminum				
Stainless Steel				

Is there a correlation between which material was the better heat conductor and which on has a faster velocity?

8. We now need to create a calculation for the temperature difference (ΔT) between the close and far thermistors for all three bars studied above.

Click on the **Calculate** button and then type "$DT_{brass} = T2 - T1$" under **Definition** and click **Accept**. When you are asked to define variables T1 and T2, simply drag them from the Data Panel and drop them where it says **Please define variable "T1"** (and T2, respectively) in the **Calculator Window.**

Now click on **Properties** and type "DT" on **Variable Name** and then "C" under **Units**. Click **OK**. The last two steps simply define the name and unit of the new variable you created.

Follow this procedure to define ΔT for the other two bars. Be sure to subtract the "far" temperature from the "close" temperature. Display all three calculations in a ΔT *versus* t graph. Label and print the ΔT *versus* t graph for each group member.

Notice that ΔT reaches a steady state after a few minutes. Which bar has the largest ΔT? Which bar has the smallest ΔT?

What is the correlation between ΔT and how good a conductor each material is?

9. Why does the ΔT peak increase and then decrease? Why does this peak occur at different times for different bars?

Locate the peaks and write in Table 11.2 the time at which each peak occurred.

Notice that ΔT in each bar approaches a final equilibrium value. Estimate this final value for each bar and record it in the table.

Table 11.2: Thermal Conductivity – Temperature Difference

Material	Time of ΔT peak	ΔT
Brass		
Aluminum		
Stainless Steel		

10. The rate of heat flow $\Delta Q/\Delta t$, (in joules per second) is given by

$$\frac{\Delta Q}{\Delta t} = kA\frac{\Delta T}{L},$$

where k is the thermal conductivity of the material, A is the cross-sectional area of the bar, and x is the distance between the thermistors. See the information sheet provided on your station for the conductivities of brass, aluminum, stainless steel, and the dimensions of the bars. Calculate the final heat flow rate in each bar and record them in the Table 11.3. Show your calculations in a space next to the table.

Table 11.3: Thermal Conductivity - Rate of Heat Flow Calculations

Material	$\Delta Q/\Delta t$
Brass	
Aluminum	
Stainless Steel	

11. Which bar has the highest heat flow rate?

Is there a correlation between ΔT and the heat flow rate?

12. You now want to compare the heat conducting properties of the two brass bars. Notice that their widths are different. Which brass bar do you think will be the better heat conductor? Explain your answer.

13. Create a graph of ΔT *versus* t for the narrow brass bar, include the wide bar in the same plot. Label and print the graph for each group member.

14. Complete the Table 11.4. Please show detailed calculations in a space bellow the table.

Table 11.4: Thermal Conductivity - Rate of Heat Flow Calculations for Brass Bars

Material	Area	Time of ΔT peak	ΔT	$\Delta Q/\Delta t$
Brass (wide)				
Brass (narrow)				

Why is ΔT lower in the wide brass bar than in the narrow one?

Why is the heat flow lower in the narrow brass bar than in the wide one?

Before you leave, log out of the computer without saving data

QUESTIONS

1. A rectangular house window ($h = 1.50\text{ m} \times w = 0.650\text{ m}$) is made of a 1.25 cm thick glass ($k = 0.840\text{ W/m}\cdot\text{K}$). How much heat is lost during a period of 12.0 hours if the inside and outside temperatures are 25.0°C and 10.0°C respectively?

2. Two rods, with thermal conductivities k_1 and k_2, are used to transfer heat between two regions with temperatures T_H and T_C ($T_H > T_C$) as shown. Each rod has length L and cross sectional area A. The rods are first configured in parallel (left) and then in series (right). Which configuration has the largest heat flow rate? Write an expression for the heat flow of each configuration.