T1: Termal Conductivity
&
T3: Termal Expansion

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10:00 A.M - 1:00 P.M

1 Introduction:

In this experiment we will attempt to discover two physics concepts related to temperature. The first experiment T1 will be to investigate the thermal conductivity of two metal bars, a copper bar and an aluminium bar. The second experiment T3 involves discovering the coefficient of thermal expansion for three metal bar's copper, steel and aluminium.

T1:

We know from coming into contact with different materials that they each behave differently to heat, some materials such as metals are extremely good at conducting heat and shouldn't be touched with your bare hands, while other materials such as wood are poor conductors of head and despite one end being on fire the other end could be perfectly fine to touch.

The equation we will be using for this experiment is:

$$H_{out} = kA\frac{T_H - T_C}{L} \tag{1}$$

where k is the coefficient of thermal conductivity, A is the cross sectional area of the rod, T_H is the temperature at the hot end, T_C is the temperature at the cold end and L is the length of the rod.

As we can see there are a lot of variables within this equation that affects the heat given off, such as the heat flow being proportional to the cross-sectional are and the difference in temperature between the two ends of the rod, and inversely proportional to the length. The purpose of this experiment is to account for all of these variables so that we can simply isolate the variable k and discover the coefficient of thermal conductivity for the two metals tested.

T3:

Another fact about metals and heat is that as a metal is heated its length expands. This relationship, often referred to as thermal expansion is described by the equation:

$$\Delta L = \alpha L_0 \Delta T \tag{2}$$

where ΔL is how much the length has changed by, α is the coefficient of thermal expansion, L_0 is the initial length of the rod and ΔT is the change in temperature.

The variable α in this equation is dependent on the type of metal used, by recording data for each other variable in this equation we will hopefully be able to isolate the coefficient of thermal expansion for the three metals tested to a high degree of accuracy.

2 Method Experimental Set-up:

T1:

We started out by setting up the apparatus as shown in fig. 2.1, before getting a lab technician to verify that the equipment was set up properly. We made sure to fill the calorimeter with cold water and placed the cooling slats into the water. We connected the power supply set at 12 V up to a heater for the metal bar, and set up the lab quest to record the three temperatures over a period of 3600 s or 1 hour. Once the time was complete we saved the values obtained, measured the mass of the water inside the calorimeter and repeated the experiment for the aluminium bar.

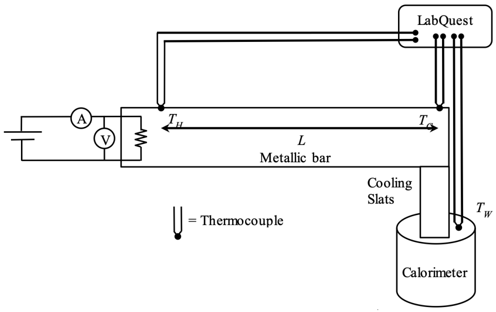

Figure 2.1: Diagram of T1 Setup

T3:

The first step of this experiment is to measure the length of each metal rod, all of which were found to have a length of 69.5 cm. The first metal tube was placed in the base shown in fig 2.2, and was locked into place using a stainless steel pin and a spring arm on the dial gauge. The thermistor lug was then attached to the middle of the metallic tube they were aligned so that maximum contact was being made between the lug and the tube, and a foam insulator was placed over top. A multimeter was plugged into the base of the mount and set to measure the resistance given off.

While the metal bar was at room temperature the resistance given off was measured as R_{rms}. When our water heater had generated enough steam the tube was placed to the end of the copper tube, the side that the tube was placed was raised up so that the steam could condense and the water would travel down the tube. We calibrated our dial gauge to zero and recorded the expansion based on the pressure indicated by the dial. Recording the new resistance on the multimeter and expansion on the dial gauge for two other temperatures. We repeated all these steps for two other metal tube's. A graph was made of ΔL vs $L\Delta T$.

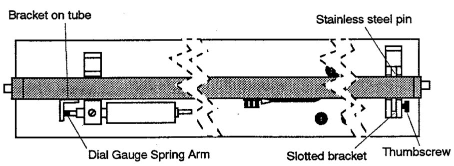

Figure 2.2: Diagram of T3 Setup

3 Results:

T1:

Answer the following questions:

1. Keeping all other parameters constant, state the effect on the heat flow of:

(i) Increasing the heat input — Increases the heat flow

(ii) Increasing the diameter of the rod — Increases the heat flow

(iii) Increasing the length of the rod — Decreases the heat flow

(iv) Increasing the temperature difference between the ends — Increases the heat flow

2. State the reason why one end of the bar is placed in thermal contact with the cooling slats that are submerged in a water bath.

In order for the experiment to work successfully one end of the tube needs to be hot and one end needs to be cool, the cooling slats submerged in cold water ensures that the cold end of the tube remains at that temperature and doesn't reach thermal equilibrium with the temperature at the other end of the tube, thus making the experiment null.

3) Results and Analyses

Aluminium tube

Voltage of Power Supply	12 V	12 V
Current out of the power supply	2.77A	2.77 A
Diameter of the aluminium rod, d	25 mm	0.025 M
Distance between points of temperature measurement on rod, L	48 cm	0.48 M
Temperature at the hotter end of the rod, TH	92.4°C	365.55 K
Temperature at the colder end of the rod, TC	42.1°C	315.25 K
Initial temperature of the Water, Twi	19.1°C	292.25 K
Final temperature of the Water, Twf	32.1 °C	305.25 K
Mass of water, mw	830.5 g	0.8305 Kg
Duration of experiment,	3600 s	1 Hour

Copper tube

Voltage of Power Supply	12 V	12 V
Current out of the power supply	3.178A	3.178A
Diameter of the copper rod, d	24.45mm	0.02445 M
Distance between points of temperature measurement on rod, L	48 cm	0.48 M
Temperature at the hotter end of the rod, TH	87.9°C	361.05 K
Temperature at the colder end of the rod, TC	50.8 °C	323.95 K
Initial temperature of the Water, Twi	25.4 °C	298.55 K
Final temperature of the Water, Twf	41°C	314.15 K
Mass of water, mw	750.6 g	0.7506 Kg
Duration of experiment,	3315 s	55.25 Minutes / 0.92 Hour

Source of Uncertainty	Estimated value/percent
Cross-sectional area of rod	$\pm 3.14 \times 10^{-3}$ m
Temperature measurements	$\pm$ 0.005°C
Length of the tube	$\pm$ 0.005 m

State, with reasoning, if you think the conductive bar method would work well for a material with poor thermal conductivity.

Due to how the tube needs to be cooled on one end and heated on the other in order for the condensation to occur and for this experiment to be a success, it would be extremely difficult to replicate these effects in an experiment involving materials that are poor thermal conductors, as such it would probably be best to use another method that doesn't involve thermal conductivity to occur to measure the coefficient.

Finding the thermal coefficient using Method 1

$$k = \frac{(V)(I)(L)}{A(T_H - T_C)}$$

Thermal Conductivity Coefficient of Aluminum:

$$k = \frac{(12V)(2.77A)(0.48m)}{(4.91\times10^{-4}m^2)(365.55K-315.25K)} = 646.03W \cdot m^{-1} \cdot K^{-1}$$

Thermal Conductivity Coefficient of Copper:

$$k = \frac{(12V)(3.178A)(0.48m)}{(4.7\times10^{-4}m^2)(361.05K-323.95K)} = 1049.8W \cdot m^{-1} \cdot K^{-1}$$

Finding the thermal coefficient using Method 2

$$k = m_w c_w \frac{(T_{wf} - T_{wi})}{T_H - T_C} \frac{L}{A\Delta t}$$

Thermal Conductivity Coefficient of Aluminum:

$$k = (0.8305kg)(4190JK^{-1}kg^{-1}) \frac{(305.25K-292.25K)}{365.55K-315.25K} \frac{0.48M}{(4.91\times10^{-4}m^2)(3600s)} = 244.22$$

Thermal Conductivity Coefficient of Copper:

$$k = (0.7506kg)(4190JK^{-1}kg^{-1}) \frac{(314.15K-298.55K)}{361.05K-323.95K} \frac{0.48M}{(4.7\times10^{-4}m^2)(3315s)} = 408.72$$

T3:

Length L_0 copper tube	R_{rm}	$R_T max$	Expansion of tube length (ΔL)	T
69.5 cm	13kΩ	1.33k Ω	6.8×10^{-4} m	80.5°C
69.5 cm	13kΩ	2k Ω	5.5×10^{-4} m	69°C
69.5 cm	13kΩ	3k Ω	4.3×10^{-4} m	58°C
69.5 cm	13kΩ	4k Ω	3.9×10^{-4} m	50°C

18 ° C Room temp

Using Eq. 2:

$$\alpha = \frac{\Delta L}{L_0 \Delta T}$$

$$\alpha = \frac{6.8\times10^{-4}m}{(0.695m)(80.5-18)} = 15.7 \times 10^{-6}$$

$$\alpha = \frac{5.5\times10^{-4}m}{(0.695m)(69-18)} = 15.5 \times 10^{-6}$$

$$\alpha = \frac{4.3\times10^{-4}m}{(0.695m)(58-18)} = 15.5 \times 10^{-6}$$

$$\alpha = \frac{3.9\times10^{-4}m}{(0.695m)(50-18)} = 17.5 \times 10^{-6}$$

Length L_0 steel	R_{rm}	$R_T max$	Expansion of tube length (ΔL)	T	α
69.5 cm	11.7kΩ	1.156k Ω	5×10^{-4} m	84°C	14×10^{-6}
69.5 cm	11.7kΩ	2k Ω	4.2×10^{-4} m	69°C	12×10^{-6}
69.5 cm	11.7kΩ	3k Ω	3×10^{-4} m	58°C	11×10^{-6}
69.5 cm	11.7kΩ	4k Ω	2.5×10^{-4} m	50°C	11.24×10^{-6}

Length L_0 aluminium tube	R_{rm}	$R_T max$	Expansion of tube length (ΔL)	T	α
69.5 cm	12.2kΩ	1.33k Ω	8.6×10^{-4} m	73°C	22×10^{-6}
69.5 cm	12.2kΩ	2k Ω	8.2×10^{-4} m	69°C	23×10^{-6}
69.5 cm	12.2kΩ	3k Ω	6×10^{-4} m	58°C	22×10^{-6}
69.5 cm	12.2kΩ	4k Ω	5.2×10^{-4} m	50°C	23×10^{-6}

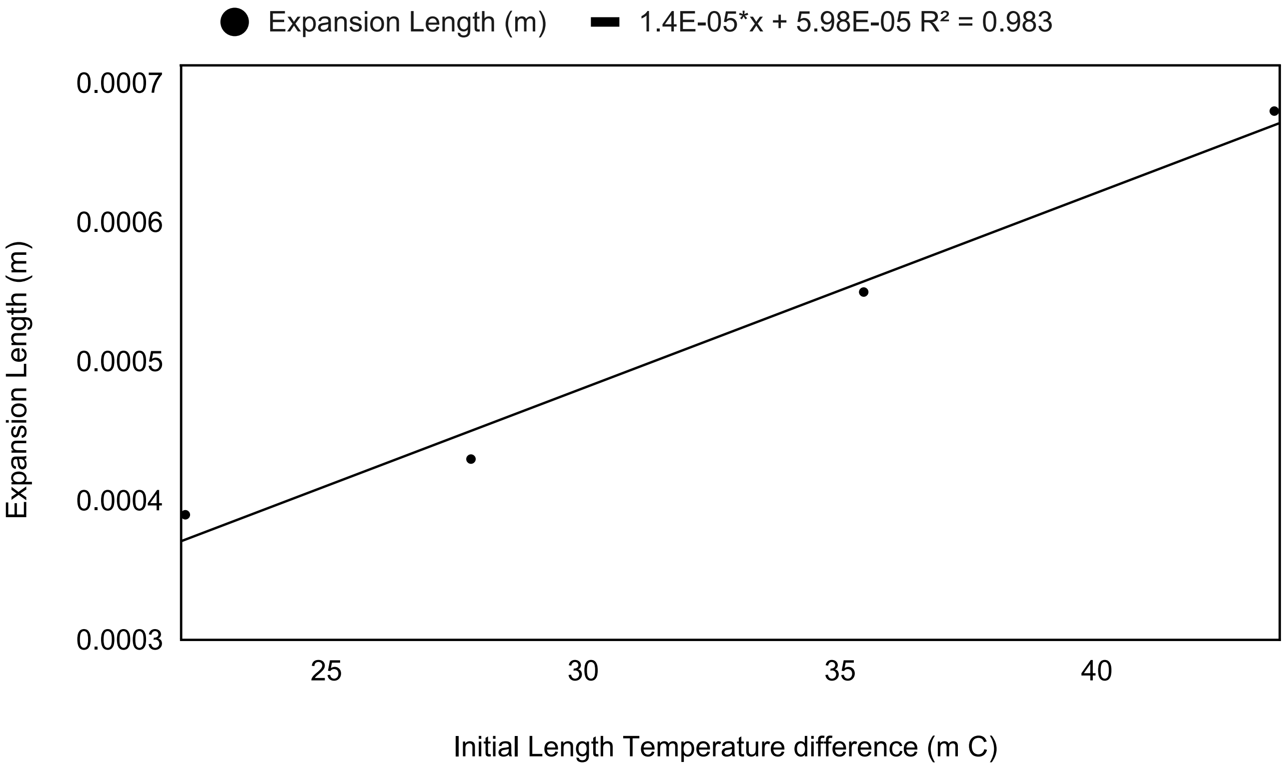

Figure 3.1: Copper tube Graph

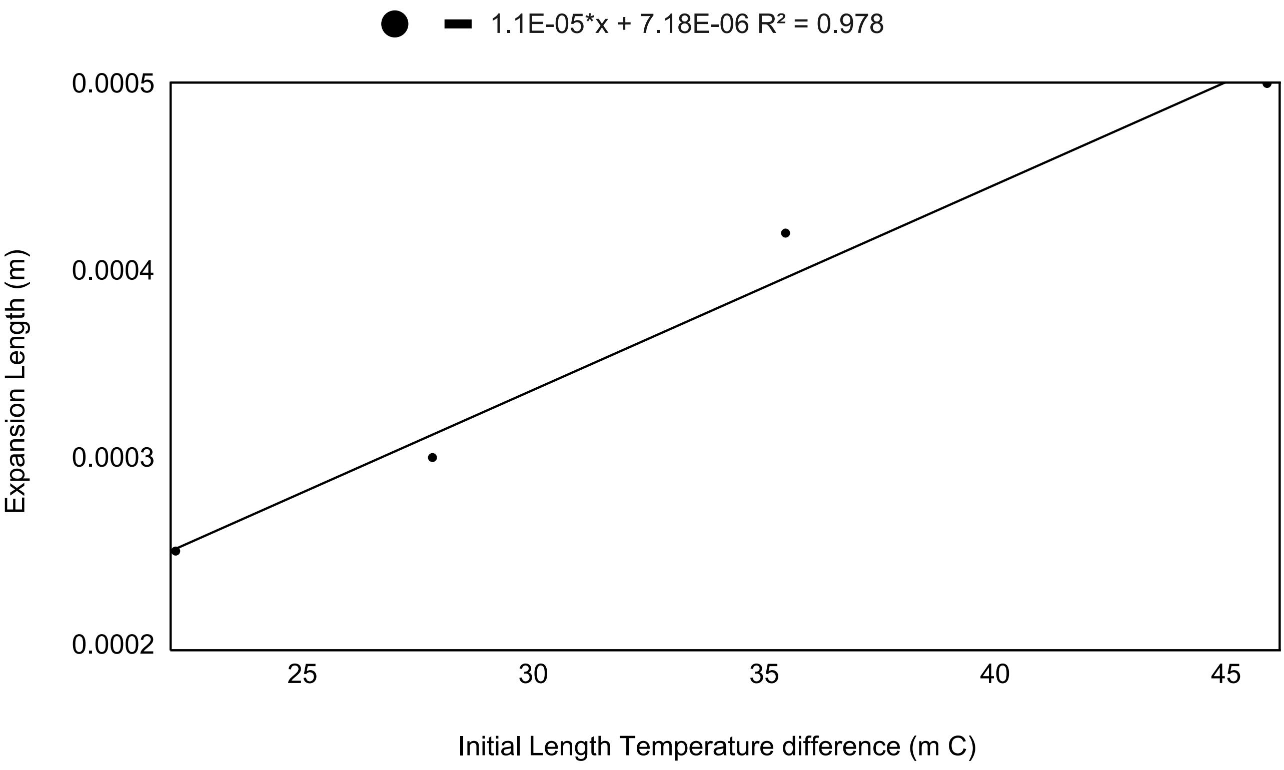

Figure 3.2: Steel tube Graph

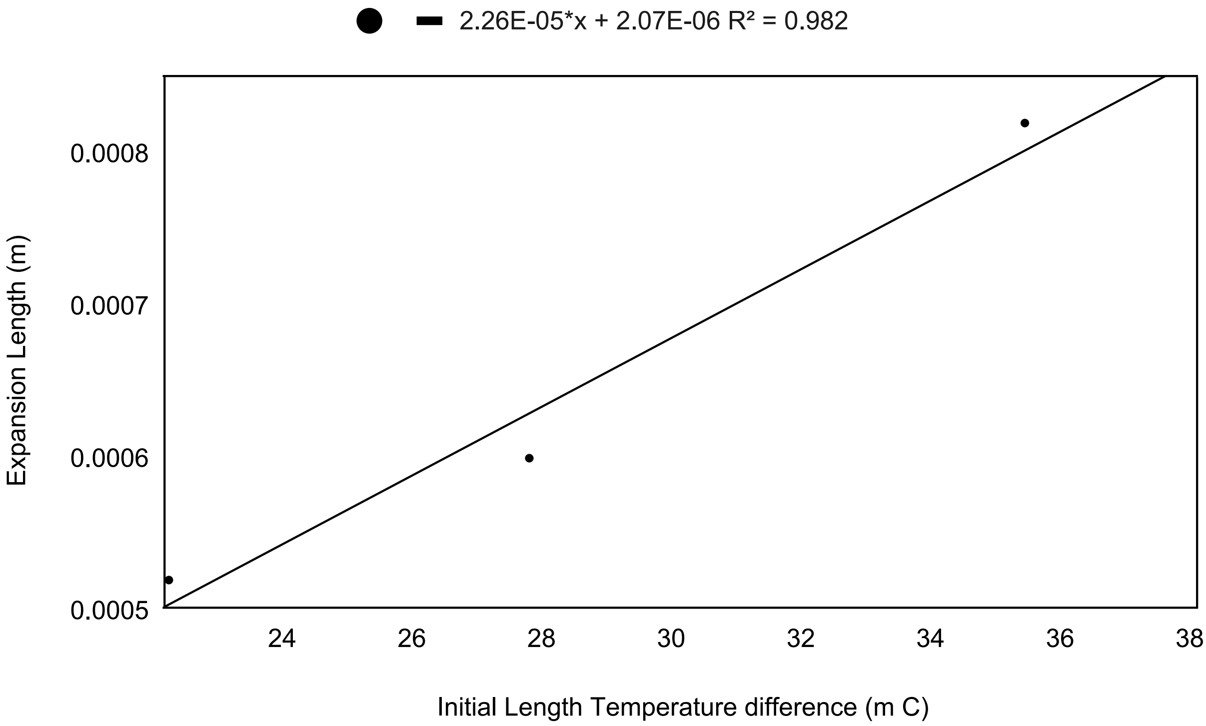

Figure 3.3: Aluminum tube Graph

Q1. Explain in your own words a microscopic model for the thermal expansion of a solid.

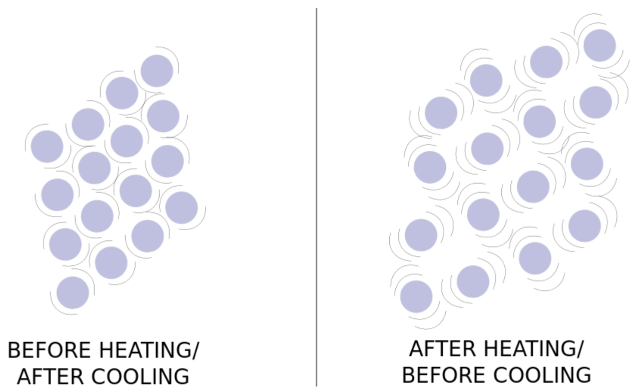

Figure 3.4: Molecules before and after being heated

When molecules are heated they are given a form of energy which they use by vibrating, this vibration causes the molecules to move further away from each other, on a microscopic level this movement is extremely small and the space between the molecules is only a tiny amount, however as an entire metal tube is heated and all of the molecules gain this energy we get a very noticeable expansion of the solid as it accounts for all this movement between the molecules.

4 Discussion:

In this experiment we used two methods to find the values for both the coefficient of thermal conductivity and the coefficient of thermal expansion, in both cases the second method always gave more accurate readings. This is most likely due to the second method involving more values and averages to base our answer on, for this reason it would be beneficial to carry out this experiment using the second methods if attempting to reproduce the results.

Since both of these experiments rely on heat as a main factor in their succession, if we wanted to increase the accuracy of our results it would be helpful to carry out the main components of the experiment in a controlled environment where the equipment could not be impacted by external sources such as the air and movement of other people in the lab, it would always be helpful to constantly measure the temperature in the room as some of the experiments rely on a change in temperature as a variable, and the temperature of the lab was not always constant

5 Conclusion

T1:

Our value for k_{copper} using method 1 was $1049.8 Wm^{-1}K^{-1}$ which is 161.8% off the textbook answer. Our value for k_{copper} using method 2 was $408.72 Wm^{-1}K^{-1}$ which is 1.93% off the textbook answer

Our value for $k_{aluminum}$ using method 1 was $646.03 Wm^{-1}K^{-1}$ which is 173.74% off the textbook answer Our value for $k_{aluminum}$ using method 2 was $244.22 Wm^{-1}K^{-1}$ which is 3.48% off the textbook answer

T3:

Our average value for α_{copper} using method 1 is 16.05×10^{-6} which is 2.72% off the textbook answer The slope of our graph α_{copper} method 2 is 14×10^{-6} which is 15.15% off the textbook answer

Our average value for α_{steel} using method 1 is 12.06×10^{-6} which is 3.08% off the textbook answer The slope of our graph α_{steel} method 2 is 11×10^{-6} which is 5.98% off the textbook answer

Our average value for $\alpha_{aluminium}$ using method 1 is 22.5×10^{-6} which is 2.17% off the textbook answer The slope of our graph $\alpha_{aluminium}$ method 2 is 23×10^{-6} which is 0% off the textbook answer