



**Koya university**  
**Faculty of Engineering**  
**Chemical Engineering Department**

**Heat Transfer Laboratory**

**Exp N. 5**

**Group D**

**Linear Heat Transfer**

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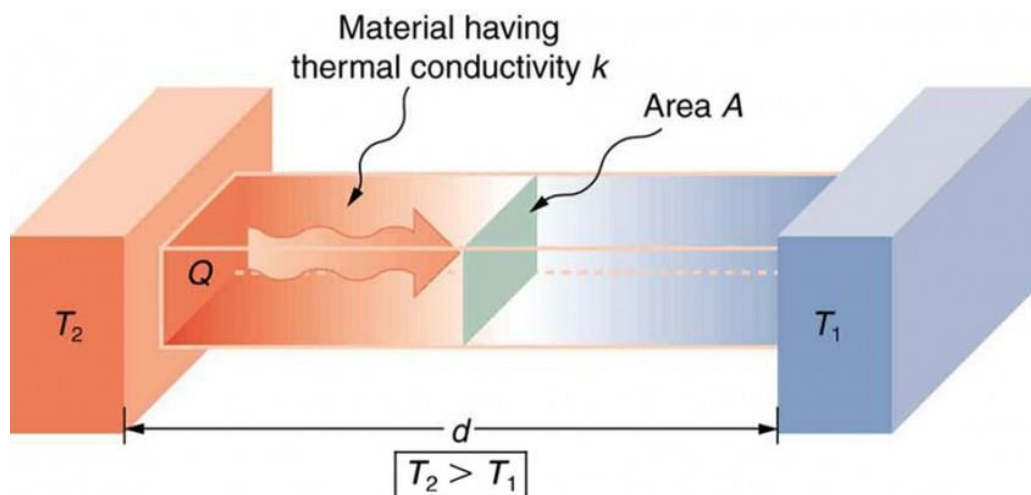
**Aim:**

To calculate thermal conductivity (K) and determine the effect of distance (X) on Temperature (T).

## Introduction:

Heat transfer is a fundamental concept in chemical engineering, governing energy exchange in various industrial processes. Linear heat transfer specifically refers to heat flow through a medium in one dimension, driven by a temperature gradient. This phenomenon follows Fourier's Law, which states that heat flux is proportional to the temperature gradient and the thermal conductivity of the material. Understanding linear heat transfer is essential for designing heat exchangers, insulation systems, and other thermal management applications.

In this experiment, we investigate the principles of linear heat transfer by analyzing heat conduction through different materials. By measuring temperature variations along a solid medium, we can determine the thermal conductivity and evaluate factors affecting heat transfer efficiency. This study provides insights into real-world engineering applications, where controlling heat flow is crucial for optimizing energy efficiency and process safety.



## History:

The study of heat transfer has evolved over centuries, with key contributions shaping our modern understanding of linear heat conduction. The foundation of heat transfer theory dates back to ancient civilizations, where early scientists and engineers explored thermal phenomena in metallurgy, construction, and daily life.

One of the most significant milestones in the history of linear heat transfer came in the early 19th century with Joseph Fourier (1768–1830). Fourier formulated the Fourier's Law of Heat Conduction, which mathematically describes how heat flows through a solid material due to a temperature gradient. His work, published in *The Analytical Theory of Heat* (1822), laid the groundwork for modern heat transfer analysis.

Throughout the 19th and 20th centuries, further advancements were made in thermal conductivity studies, material science, and engineering applications. Scientists such as Jean-Baptiste Biot, James Clerk Maxwell, and Ludwig Boltzmann contributed to the theoretical and experimental understanding of heat conduction, radiation, and thermodynamics. The development of empirical methods and experimental techniques allowed engineers to apply heat transfer principles in industrial processes, including chemical processing, power generation, and manufacturing.

In modern engineering, linear heat transfer plays a critical role in designing heat exchangers, insulation systems, and electronic cooling solutions. Advances in computational modeling and materials science continue to enhance our ability to control and optimize heat flow in various applications.

## Equipment:

- 1- Measuring point : switching between temperature sensors of points.
- 2- Temperature display
- 3- Power : give amount of Power (Watt) as we need.
- 4- Power display: Displays the Power in watt
- 5- Switches between manual or pc (software), in this exp we use manual.
- 6- Heater switch
- 7- The Heating spot
- 8- Temperature sensors
- 9- The metal sample
- 10- water flow: to prevent from equaling heat condition.



## **Procedure:**

1-we setup the sample first

2-we start the heater and regulate the power.

3-the heat start transferring from the first spot to the following spots.

4-we link the end of the metal to the steady water flow to avoid equal Temperature in both sides.

5-we wait for about 45m in order for the heat to transfer .

6 – then we read the Temperature in each point and bring it to calculation .

7- we can change the sample to get better understanding of thermal conductivity as property of materials .

8-at the end switch of the heater and drain the water flown to the floor of the lab

## Calculation:

### Calculate thermal conductivity (K) for stainless steel

$$Q=32\text{watt } D=25\text{mm}=0.025\text{m } \Delta X=60-20=40\text{mm}=0.04\text{m}$$

$$\Delta T=T_3-T_7$$

$$\Delta T=103-28=75\text{K}$$

$$A=\pi 0.025^2/4=0.0004906\text{m}^2$$

$$K=\frac{32*0.04}{0.0004906*75}=34.787 \text{ W/m.K}$$

### Calculate thermal conductivity (K) for Brass

$$Q=32\text{watt } D=25\text{mm}=0.025\text{m } \Delta X=60-20=40\text{mm}=0.04\text{m}$$

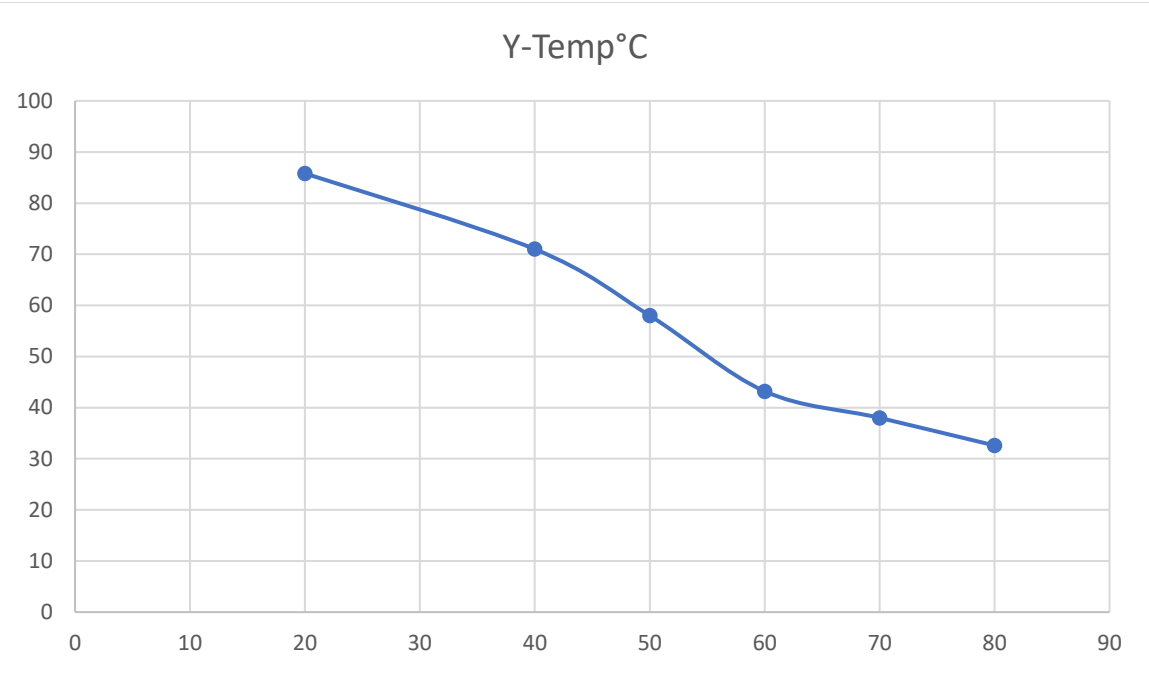
$$\Delta T=T_3-T_7$$

$$\Delta T=85.8-43.2=42.6\text{K}$$

$$A=\pi 0.025^2/4=0.0004906\text{m}^2$$

$$K=\frac{32*0.04}{0.0004906*42.6}=61.245 \text{ W/m.K}$$





X-Thickness (mm)

## **Conclusion:**

The study of linear heat transfer is fundamental in chemical engineering, as it provides essential insights into how heat moves through materials under a temperature gradient. By applying Fourier's Law, engineers can analyze and predict heat conduction behavior, which is crucial for designing efficient thermal systems such as heat exchangers, insulation, and industrial reactors.

This experiment highlights the importance of material properties, temperature differences, and conduction mechanisms in controlling heat transfer. Understanding these principles allows engineers to optimize energy efficiency, enhance process safety, and develop advanced materials for thermal management. As technology progresses, further research in heat transfer continues to drive innovations in energy conservation and industrial applications.

## Discussion:

### Twana Dler

1- How does the temperature gradient influence the rate of heat transfer in a solid material?

- According to Fourier's Law, the rate of heat transfer is directly proportional to the temperature gradient. A steeper temperature gradient (higher temperature difference over a given distance) results in a higher heat flux, meaning heat transfers more rapidly through the material.

2- How does the thermal conductivity of a material affect the heat transfer rate, and how can it be experimentally determined?

- Thermal conductivity ( $k$ ) determines how efficiently a material conducts heat. Materials with high thermal conductivity (e.g., metals like copper and aluminum) transfer heat faster than those with low thermal conductivity (e.g., wood, plastic, or insulation materials).
- It can be experimentally determined by measuring the steady-state heat flow through a material while recording temperature differences and dimensions, then applying Fourier's Law:  
 $q = -kA \frac{dT}{dx}$  where  $q$  is heat flux,  $dT/dx$  is the temperature gradient, and  $k$  is the thermal conductivity.

3. If we heat up a material, will the thermal conductivity change, and how?

- Yes, thermal conductivity can change with temperature, but the effect depends on the material type:
  - ❖ Metals: As temperature increases, thermal conductivity decreases because atomic vibrations increase, causing more scattering of free electrons, which reduces heat transfer efficiency.

- ❖ Non-metals (insulators like ceramics and polymers): Thermal conductivity generally increases with temperature because heat transfer relies on phonon movement, which becomes more efficient at higher temperatures.
- ❖ Gases: Thermal conductivity increases with temperature because higher molecular kinetic energy enhances heat transfer through collisions.

4- How does the steady-state temperature distribution along a solid conductor support Fourier's Law of Heat Conduction?

- In a steady-state system, temperature remains constant at each point over time, forming a linear temperature gradient in a uniform material. This aligns with Fourier's Law, where the heat transfer rate is constant and proportional to the temperature gradient. A linear temperature profile confirms that no heat is being accumulated or lost in the system.

5- Why do different materials exhibit varying temperature profiles for the same heat input, and how is this related to their thermal conductivity?

- Materials with higher thermal conductivity distribute heat more evenly, leading to a shallower temperature gradient. In contrast, materials with lower thermal conductivity resist heat flow, causing a steeper temperature gradient. This explains why metals heat up quickly and maintain nearly uniform temperatures, while insulators have significant temperature drops along their length.

6- In practical applications, how can engineers use knowledge of heat transfer, thermal conductivity, and distance to improve energy efficiency in industrial processes?

- Engineers apply these principles to design efficient insulation, optimize heat exchanger performance, and minimize energy losses in industrial systems. For example:
  - Using materials with high thermal conductivity for heat exchangers ensures efficient energy transfer.
  - Using insulating materials with low thermal conductivity in pipelines and reactors reduces heat loss.

- Adjusting the thickness of materials optimizes heat flow based on process needs (e.g., thinner materials for rapid heating, thicker ones for insulation).

**( muhamed kadhim )**

In this experiment, we focused on determining the thermal conductivity (K) of two materials: stainless steel and brass, while also investigating the relationship between distance (X) and temperature (T) during linear heat transfer. The experiment involved measuring temperature differences at various points along a metal sample, allowing us to apply Fourier's Law of heat conduction to calculate the thermal conductivity of each material.

### **\*\*Thermal Conductivity Results:\*\***

The values obtained for thermal conductivity were as follows:

- Stainless Steel: 34.787 W/m·K
- Brass: 61.245 W/m·K

These values are in line with the general knowledge of the thermal conductivity of these materials. Brass, with its higher thermal conductivity, allows heat to transfer more efficiently compared to stainless steel, which has a relatively lower conductivity. This difference can be attributed to the distinct atomic structures and bonding forces present in each material, with brass having more mobile electrons that facilitate better heat transfer.

### **\*\*Effect of Distance on Temperature:\*\***

During the experiment, we observed the temperature variation across the metal sample as heat was transferred from the heating spot to the cooler areas. As expected, the temperature difference between two points (T) was directly influenced by the distance (X). A larger distance between the two points resulted in a larger temperature gradient, supporting the prediction that the heat transfer rate is inversely proportional to the material's thickness and the distance over which the heat is transferred.

Moreover, the experimental setup involved a steady water flow at the ends of the metal to prevent heat equalization, a necessary step to maintain a consistent temperature gradient along the material. This ensured that the heat transfer could be analyzed without the influence of temperature equalization at the boundaries, which could otherwise skew the results.

### **\*\*Experimental Challenges and Considerations:\*\***

Several factors could have affected the accuracy of the measurements. For instance, the precision of the temperature sensors and the resolution of the power settings could introduce slight errors in the readings. Additionally, ensuring the uniformity of the power supplied to the heater and maintaining a steady water flow to avoid heat equalization were critical, but could have been challenging due to external influences such as slight fluctuations in room temperature or variations in the water flow.

### **\*\*Conclusion and Implications:\*\***

Overall, the results from this experiment highlight the importance of material properties in heat transfer and demonstrate how distance and temperature differences contribute to the rate of thermal conductivity. By understanding these principles, engineers can design better thermal management systems, such as heat exchangers and insulation, and optimize energy efficiency in industrial processes. The comparison between stainless steel and brass also underlines how the choice of material affects heat conduction and, consequently, the performance of thermal systems. This knowledge is particularly useful in fields such as chemical engineering, materials science, and energy conservation.

Future studies could expand on this experiment by exploring additional materials, varying the applied power, or introducing more advanced temperature sensors for higher precision in measurements. Further research on the effects of temperature and material properties on heat

transfer could also provide a more comprehensive understanding of the factors that influence thermal conductivity in real-world applications.



