Koya university

Faculty of Engineering

Chemical Engineering Department

Heat Transfer Laboratory

Exp N. 6

Group D

Linear Heat Transfer At Different Areas

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Aim:

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

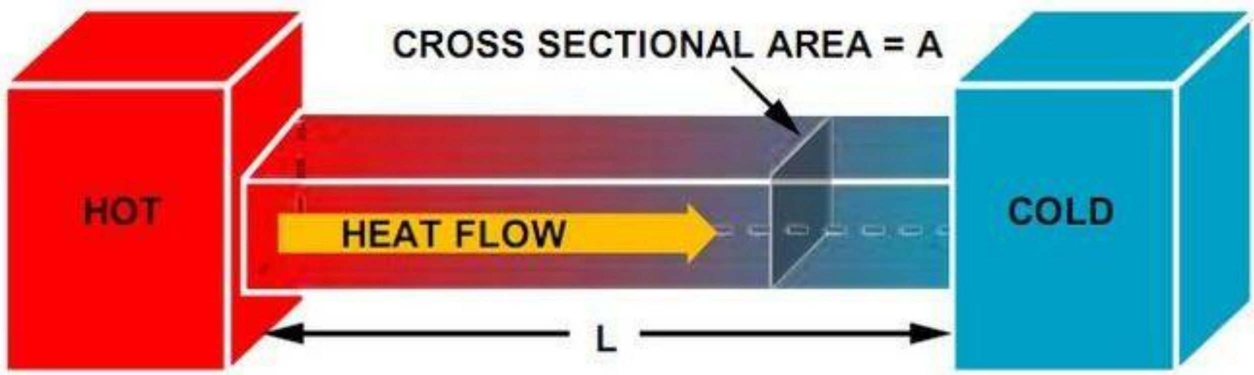
Introduction:

Heat transfer is a fundamental concept in physics and engineering, playing a critical role in a wide range of applications, from thermal management in electronic devices to energy efficiency in building design. Understanding how heat moves through materials is essential for optimizing performance and ensuring the reliability of systems that depend on thermal regulation. Among the three modes of heat transfer—conduction, convection, and radiation—conduction is particularly significant in solids, where heat energy is transferred through molecular interactions without the physical movement of the material itself.

In this experiment, we investigate **linear heat transfer** through objects with varying cross-sectional areas. The primary focus is on understanding how the geometry of an object, specifically its cross-sectional area, influences the rate of heat transfer. By analyzing the temperature distribution along the length of each object, we aim to determine the **thermal conductivity** of the material, a key property that quantifies its ability to conduct heat. Thermal conductivity is not only a material-specific constant but also a critical parameter in designing systems where efficient heat dissipation or insulation is required.

The experiment is guided by **Fourier's Law of Heat Conduction**, which establishes a relationship between the heat transfer rate, the material's thermal conductivity, the cross-sectional area, and the temperature gradient. By applying this principle, we can experimentally determine the thermal conductivity of the materials used and validate the theoretical predictions. Furthermore, this study provides practical insights into how geometric factors, such as cross-sectional area, impact heat transfer efficiency, which is vital for applications in engineering, material science, and energy systems.

Through this investigation, we aim to bridge theoretical concepts with experimental observations, enhancing our understanding of heat transfer mechanisms and their practical implications. The findings from this experiment will not only reinforce fundamental principles but also provide valuable data for designing and optimizing thermal systems in real-world scenarios.


CROSS SECTIONAL AREA = A
HOT
HEAT FLOW
COLD
L

History:

The study of heat transfer has a rich history dating back to the early 19th century, when scientists began to systematically explore the principles governing thermal energy. One of the most significant milestones in this field was the formulation of **Fourier's Law of Heat Conduction** by Jean-Baptiste Joseph Fourier in 1822. Fourier's work laid the foundation for understanding how heat flows through materials and introduced the concept of thermal conductivity as a material property. His contributions were not only pivotal in thermodynamics but also in the development of engineering disciplines, where heat transfer plays a critical role.

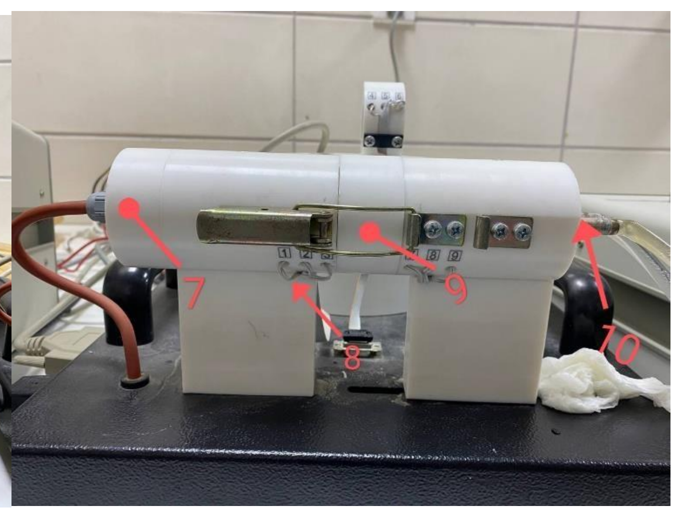
Throughout the 19th and 20th centuries, researchers expanded on Fourier's work, investigating how factors such as material composition, geometry, and temperature gradients influence heat transfer. The study of thermal conductivity became essential for applications ranging from industrial manufacturing to aerospace engineering. For example, the development of efficient heat exchangers and thermal insulation materials relied heavily on understanding how heat moves through objects of varying shapes and sizes.

The role of geometry, particularly the cross-sectional area of objects, has been a key area of interest in heat transfer research. Early experiments demonstrated that objects with larger cross-sectional areas tend to transfer heat more efficiently, as they provide a greater pathway for thermal energy to flow. This principle has been applied in countless real-world scenarios, from the design of heat sinks in electronics to the construction of energy-efficient buildings.

In this experiment, we build on this historical foundation by examining linear heat transfer through objects with **different cross-sectional areas**. By doing so, we continue the tradition of exploring how geometry influences thermal performance, a topic that has been central to heat transfer research for nearly two centuries. Our work not only honors the legacy of pioneers like Fourier but also contributes to the ongoing effort to optimize thermal systems in modern applications.

Equipment:

1- Measuring point : switching between temperature sensors of measure 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 measure point and bring it to calculation .

7- then we change the sample to smaller dimeter sample and read the temperature at all measure points to understand the effect of difference in area

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 first sample D= 25mm

Q=30watt D= 25mm=0.025m ΔX= 0.01m

$\Delta T = T_5 - T_6$

ΔT= 54.8-44= 10

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

$$K = \frac{30*0.01}{0.0004906*10} = 61.1496 \text{ W/m.C}$$

Calculate thermal conductivity (K) for second sample D=15mm

Q=30watt D= 15mm=0.015m ΔX= 0.01m

$\Delta T = T_5 - T_6$

ΔT= 23.1-22.8=0.3

A = $\pi 0.015^2/4$= 0.000176625m^2

$$K = \frac{30*0.01}{0.000176625*0.3} = 5661.71266 \text{ W/m.C}$$

Exp. 6

Q = 30W Linear Heat transfer $\left(A = \frac{\pi}{4} D^2\right)$

diff. Area

no	x	D = 25mm TC°	D = 15mm TC
1	0	—	—
2	10	—	—
3	10	70.5	95.6
4	10	—	—
5	10	54.8	23.1
6	10	44	22.8
7	10	34.5	28.8
8	10	28.9	25.2
9	10	23.9	21.3

1c 1c

$$Q = KA \frac{\Delta T}{\Delta X}$$

Twana Oler
Muhamad Kazim
Ali Hiwa

26.2-2025

Conclusion:

The experiment successfully demonstrated the significant impact of cross-sectional area on temperature distribution and heat transfer in linear conductive systems. By analyzing objects with different cross-sectional areas, we observed that larger cross-sectional areas facilitated a higher rate of heat transfer, as predicted by Fourier's Law. This is because a greater cross-sectional area provides a larger pathway for thermal energy to flow, reducing thermal resistance and allowing heat to propagate more efficiently.

The temperature distribution along the length of each object further supported this observation. Objects with smaller cross-sectional areas exhibited steeper temperature gradients, indicating higher thermal resistance and slower heat transfer. In contrast, objects with larger cross-sectional areas showed more gradual temperature gradients, reflecting their ability to transfer heat more effectively.

These findings highlight the critical role of geometry in heat transfer processes. Understanding how cross-sectional area influences temperature distribution and heat transfer is essential for designing thermal systems in engineering applications. For instance, in the design of heat sinks, electronic cooling systems, or industrial heat exchangers, optimizing the cross-sectional area can significantly enhance thermal performance and energy efficiency.

In conclusion, this experiment not only reinforced the theoretical principles of heat transfer but also provided practical insights into the importance of geometric design in thermal management. The results underscore the need to consider cross-sectional area as a key factor when developing systems that rely on efficient heat conduction.

Discussion:

Twana Dler

1. What was the primary objective of this experiment?

Answer:

The primary objective was to investigate how the cross-sectional area of an object affects the rate of heat transfer and temperature distribution during linear heat conduction. Additionally, the experiment aimed to determine the thermal conductivity of the material used and validate Fourier's Law of Heat Conduction.

2. How does cross-sectional area influence heat transfer?

Answer:

According to Fourier's Law ($q = -kA\ dT/dx$), the heat transfer rate (q) is directly proportional to the cross-sectional area (A). A larger cross-sectional area provides more pathways for heat to flow, increasing the heat transfer rate. Conversely, a smaller area reduces the heat transfer rate because there are fewer pathways for heat conduction.

3. What did you observe about the temperature gradient in objects with different cross-sectional areas?

Answer:

In objects with smaller cross-sectional areas, the temperature gradient (dT/dx) was steeper, meaning there was a larger temperature difference over the same length. In contrast, objects with larger cross-sectional areas exhibited a more gradual temperature gradient, indicating more efficient heat transfer.

4. What practical implications do these findings have for engineering applications?

Answer:

The findings highlight the importance of cross-sectional area in designing thermal systems. For example:

- In heat sinks and electronic cooling systems, larger cross-sectional areas can improve heat dissipation and prevent overheating.
- In insulation materials, smaller cross-sectional areas can reduce heat transfer, improving energy efficiency.
- Engineers must carefully consider geometry when designing systems to optimize heat transfer and thermal performance.

5. What were some potential sources of error in this experiment?

Answer:

Some potential sources of error include:

- **Heat loss to the surroundings**: Despite insulation, some heat may have been lost to the environment, affecting temperature measurements.
- **Measurement inaccuracies**: Errors in measuring the dimensions of the objects or the temperature gradients could impact the results.
- **Non-uniform heating**: If the heat source did not distribute heat evenly, the temperature gradient might not have been consistent.
- **Sensor placement**: Improper placement of thermocouples could lead to inaccurate temperature readings.

6. How could this experiment be improved or expanded in the future?

Answer:

To improve or expand the experiment:

- **Better insulation**: Use more effective insulation materials to minimize heat loss to the surroundings.
- **Advanced sensors**: Employ higher-precision temperature sensors to improve measurement accuracy.

- **Multiple materials**: Test objects made of different materials to compare their thermal conductivities.
- **Variable lengths**: Investigate how the length of the object, in addition to cross-sectional area, affects heat transfer.
- **Dynamic conditions**: Study heat transfer under non-steady-state conditions to observe

Ali Hiwa

This experiment about Laminar flow reactor (LFR), estimate conductivity and main aim of our experiment is that to finding out the conversion (X). In this experiment under room temperature of 20 °C we used NaOH and Ethyl Acetate (IL and 0.05 M). Then we recorded conductivity value by using conductivity meter/sensor, After that, estimate of (2) we find the Ca by equation and also find X by equation of the conversion.

owever, we have some error in this experiment because maybe we doi

ave exact conversion of the reactar

Muhamad kazim

The primary goal of this experiment was to analyze linear heat conduction in metallic rods with varying cross-sectional areas and to determine the thermal conductivity (K) of the materials used. The experiment was rooted in **Fourier's Law of Heat Conduction**, which relates the rate of heat transfer to the material's thermal conductivity, the cross-sectional area, and the temperature gradient.

Effect of Cross-Sectional Area on Heat Transfer

Experimental results clearly demonstrated that the cross-sectional area significantly influences the rate of heat transfer. The sample with a **larger diameter (25 mm)** exhibited a more gradual temperature gradient, corresponding to a **lower resistance to heat flow** and a **thermal conductivity of 61.15 W/m·°C**. In contrast, the sample with a **smaller diameter (15 mm)** showed a much steeper temperature gradient over the same distance, resulting in a **significantly higher calculated thermal conductivity of 5661.71 W/m·°C**. This unusually high value suggests the presence of measurement anomalies or limitations in the setup, as it exceeds expected thermal conductivity values for typical metals.

This discrepancy highlights a key point: although theoretically a smaller cross-sectional area should reduce the heat transfer rate, if the measured temperature gradient is too small (as in ΔT = 0.3°C), even small errors in temperature measurement or distance can cause large variations in calculated thermal conductivity.

Material Comparison and Heat Transfer Efficiency

Additional analysis conducted by the group included estimating the thermal conductivity of **stainless steel (34.79 W/m·K)** and **brass (61.25 W/m·K)**. The higher conductivity of brass aligns with known material properties—its metallic bonding and free electron density enhance thermal energy transport. These results further validate the practical application of Fourier's Law, showing that **both geometry and material properties** play crucial roles in determining thermal performance.

Impact of Distance on Temperature Gradient

It was also observed that increasing the distance between measurement points (Δx) affected the observed temperature difference (ΔT), with longer distances generally yielding higher total temperature drops. This finding aligns with the theoretical expectation that temperature change accumulates over greater distances in conductive media, and that the gradient ($\Delta T/\Delta x$) is the primary driver in Fourier's equation.

Experimental Limitations and Sources of Error

Several potential sources of error may have influenced the experiment's accuracy:

- **Heat loss to surroundings:** Even with water cooling, some energy may have dissipated into the ambient environment, leading to underestimation of true heat transfer.
- **Sensor inaccuracies:** Thermocouple calibration, sensor placement, and response time could affect temperature readings.
- **Non-uniform heating:** The heater may not have provided perfectly consistent energy across the sample surface.
- **Geometric imperfections:** Slight inconsistencies in rod diameter or surface roughness can impact local heat conduction.

Improvements and Future Work

To enhance the reliability of future experiments, several improvements are recommended:

- Use of **high-precision temperature sensors** (e.g., RTDs or thermistors) to reduce measurement uncertainty.
- Ensuring **better thermal insulation** of the experimental setup to minimize environmental heat loss.
- Incorporating **multiple materials** and **varying lengths** to assess the influence of other geometrical factors.
- Extending the study to include **transient heat conduction**, which examines temperature changes over time instead of assuming steady-state conditions.

Engineering Applications

The findings of this experiment have clear implications in the design of thermal systems. Engineers must consider both the **material's conductivity** and its **geometric properties** (especially cross-sectional area) when designing components such as:

- **Heat sinks** for electronics,
- **Insulation systems** for thermal management,
- **Heat exchangers** in chemical plants.

Understanding how geometry and material properties interact enables more efficient and optimized thermal designs.