HEAT TRANSFER

INNOVATION PROJECT

Title:-Heat Transfer in a Spoon

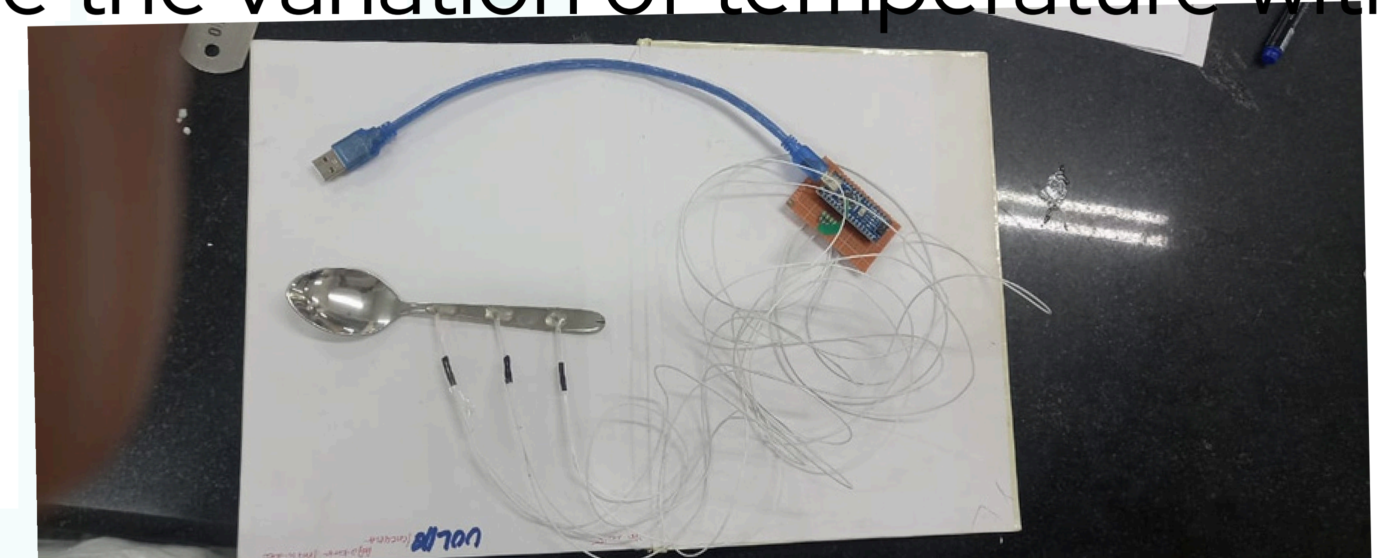
Introduction to the problem

OBJECTIVE:- Study of heat transfer through a spoon.

- To study the heat transfer behavior of a metal spoon when partially immersed in hot water.
- To observe the variation of temperature at different positions with respect to time.

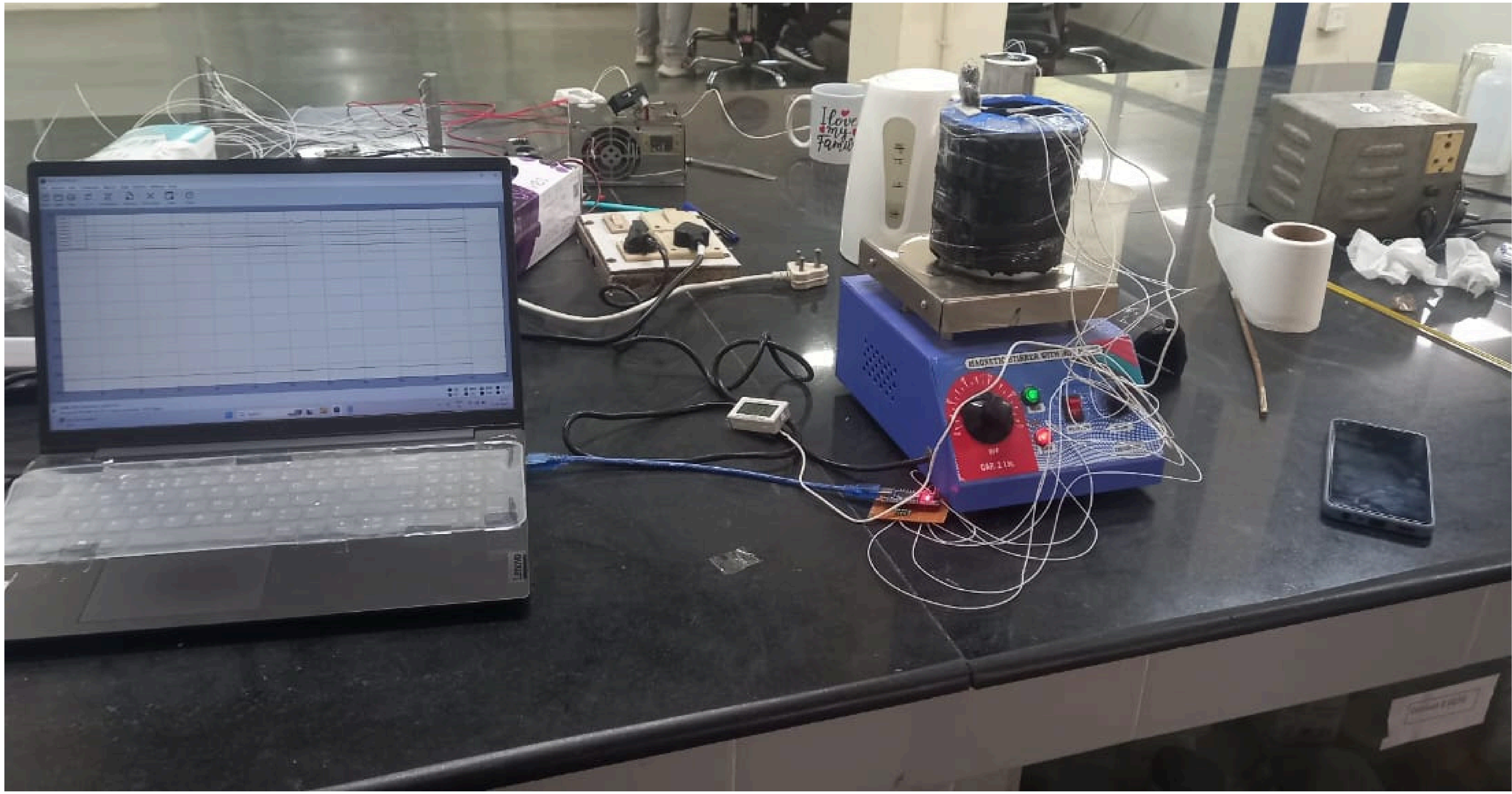
- To observe the variation of temperature with respect to position at transient time.

- To observe the variation of temperature with respect to position at steady state.



Experimental setup

MATERIALS REQUIRED:- A Spoon, Temperature sensors, Beaker, Hot water, etc.



Innovative Aspects

- **Everyday Object, Scientific Insight:-** A simple metal spoon turned into a model to study conduction and thermal behavior in solids
- **Multi-Point Temperature Mapping:-** Three thermal sensors placed at uniform intervals allow real-time analysis of heat conduction along the spoon.
- **Real-Time Transient to Steady-State Analysis:-** Observed how temperature evolved over time and along the length of the spoon. capturing both transient and steady-state phases.
- **Visual & Intuitive Demonstration of Fourier's Law:-** Enabled clear understanding of heat conduction principles through direct observation and data plotting.
- **Low-Cost, Scalable, and Educational:-** Ideal for STEM education, offering hands-on learning with minimal resources.
- **Potential for Further Exploration:-** Can be extended to study effects of different materials, orientations, or environmental conditions.

Methodology

- **Apparatus Used:**

Metal spoon (as the conducting object) at ambient temperature.

Beaker filled with hot water(at 85 C)

Three thermal sensors (e.g., thermocouples or digital temperature probes)

Stopwatch or timer for recording time

Data logger

- **Sensor Placement:**

Thermal sensors were attached to the spoon at three uniformly spaced positions along its length.

- **Initial Condition:**

Spoon at room temperature before immersion.

- **Procedure Start:**

Spoon was partially immersed in hot water while sensors started recording temperature at regular time intervals.

- **Temperature vs. Time Recording:**

Temperatures at all three points were recorded simultaneously over time until the system reached steady state.

- **Transient Phase Analysis:**

Data plotted to analyze how each point on the spoon heats up over time.

- **Steady-State Profile:**

Final temperature distribution across the spoon analyzed once all sensor readings stabilized indicating that the system has reached a steady-state condition.

- **Data Processing:**

Plots of:

Temperature vs. Time at each sensor (transient behavior)

Temperature vs. Position at steady state

- Observed and analyzed the transition from transient heating to steady-state conduction in a real object.

Theory

Heat Conduction in Solids:-

- Heat conduction is the transfer of thermal energy through a material due to a temperature gradient.
- Governed by **Fourier's Law**:

$$Q=-k\,A\,dT/dx$$

; Where:

Q= heat transferred

k= thermal conductivity of material used

dT/dx = Temperature gradient

A= area of cross section

- In the experiment, heat flows from hot water into the metal spoon, and then along the spoon via conduction.
- The temperature at each point on the spoon changes with time, which introduces transient heat transfer behavior.

Transient & Steady-State Heat Transfer:-

- **Transient Heat Transfer:** Occurs when temperature at a point changes with time.
  Governed by the heat diffusion equation:

$$\frac{d^2T}{dx^2} = \frac{hP}{kA_c}\left(T - T_\infty\right).$$

- **Steady-State Heat Transfer:**

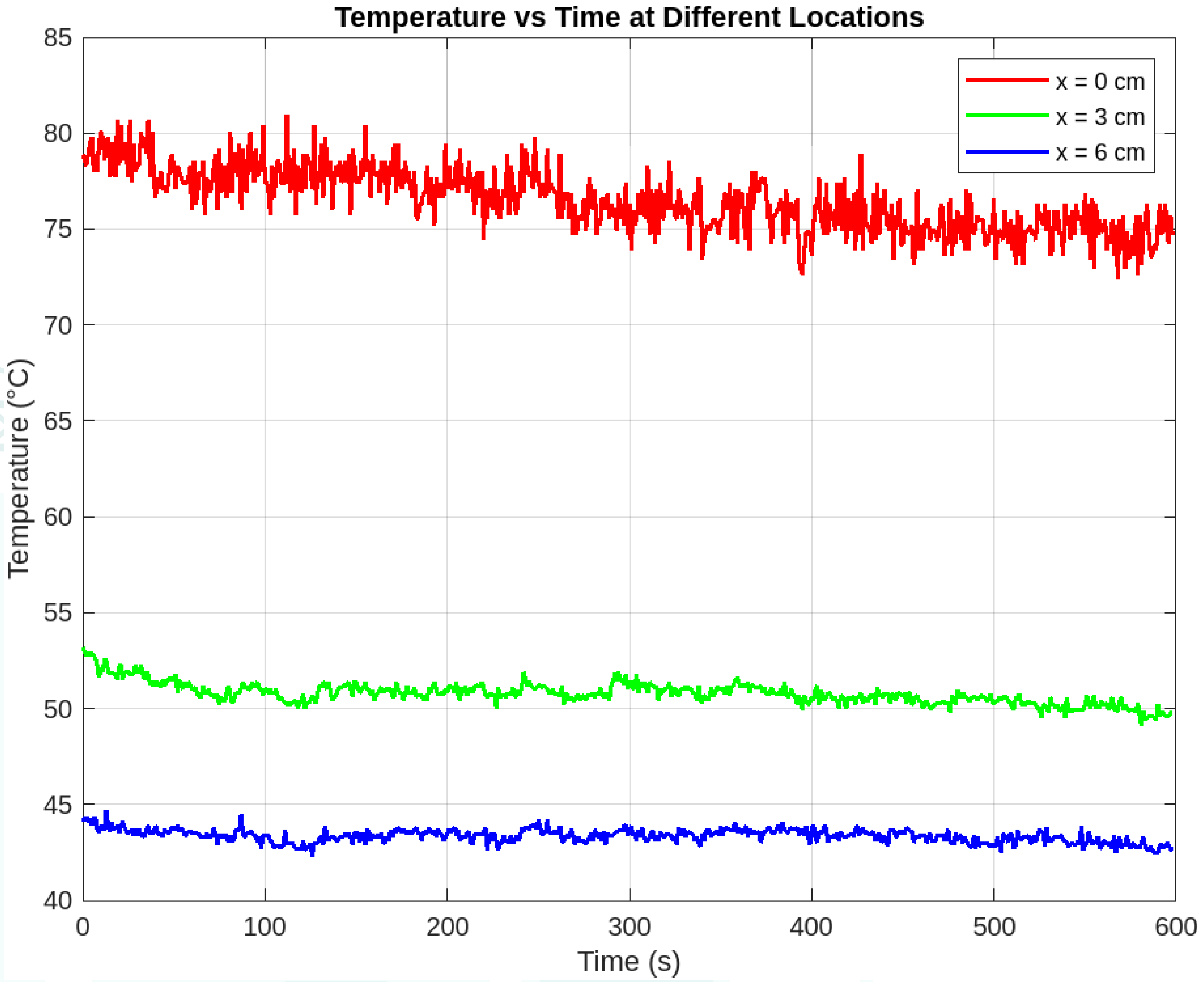
Reached when temperature at each point becomes constant with time.
Heat flux remains constant along the spoon.

- In the experiment:

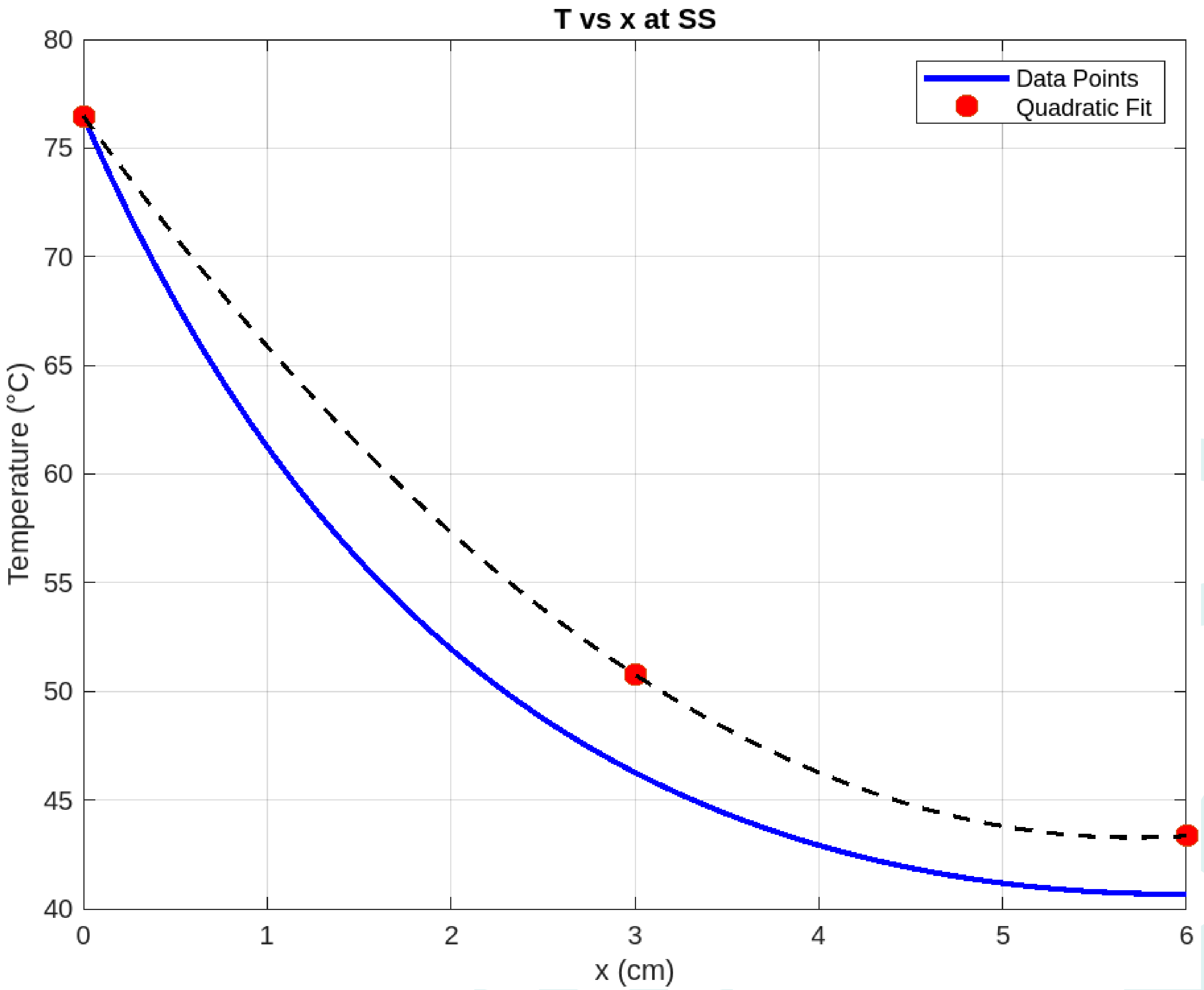
Initially, the spoon undergoes transient heating.
Over time, it reaches a steady-state temperature profile where no further change occurs
>>>h = 8.8 W/m^2K

Results and Analysis

- We analyzed the recorded temperature data, and get following plots.



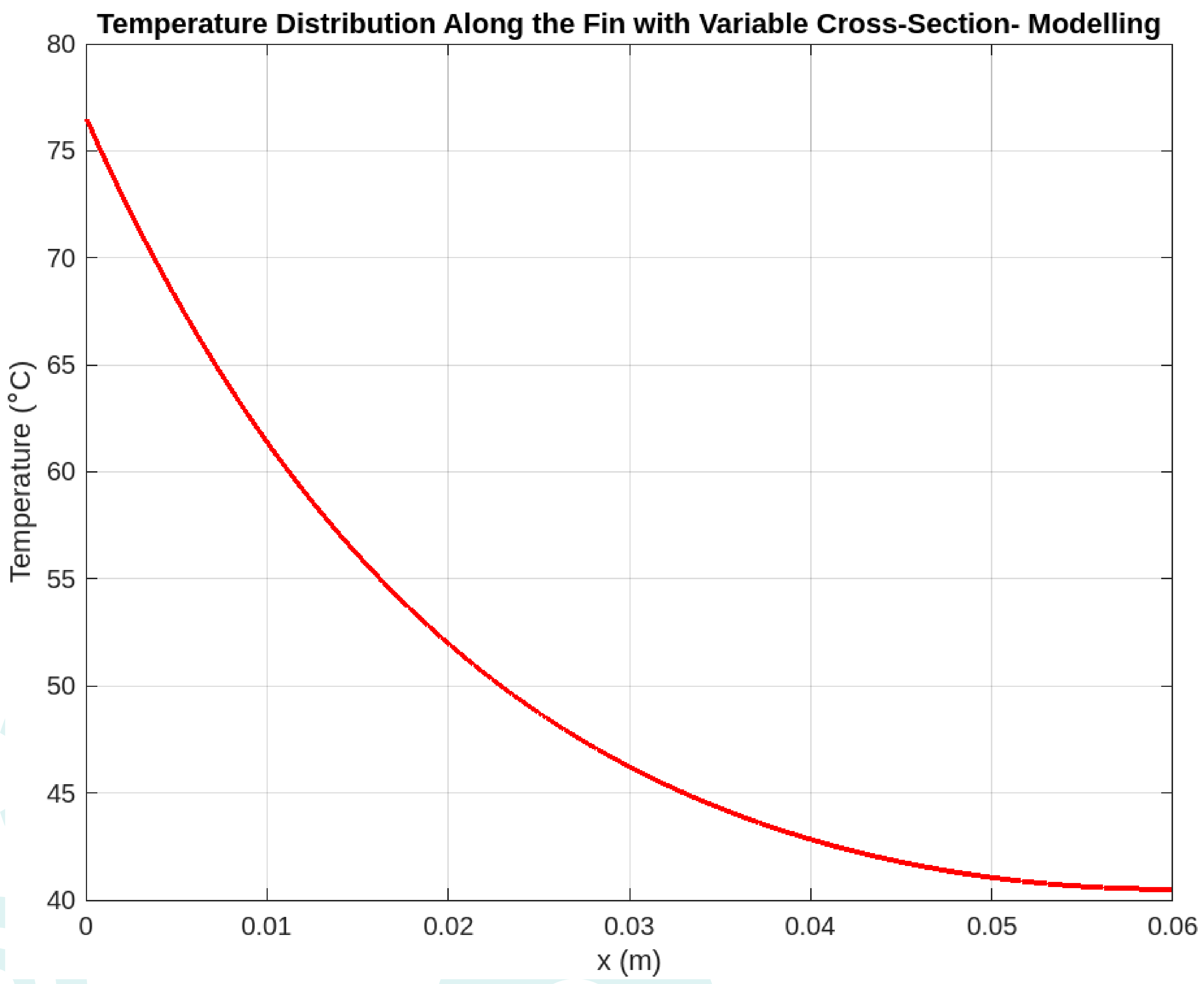
Temperature Vs Time plot



Temperature profile at steady state

T(x) = 1.0153x^2 + -11.6120x + 76.4781

We plot the modelled plot



Modelled temperature profile at steady state

Avg Temp :T1=76.478, T2=50.78, T3= 43.358

https://drive.google.com/drive/folders/1LWvH6mAS
E8uT3LVbj4DQkr0S2wLL2HEv?usp=sharing

- Heat input during the experiment:- 7.5*10^(-7) (W)

Key Observations:

- Transient to Steady-State Behavior clearly visualized.
- Sensor data effectively captured the spatial and temporal evolution of temperature.
- Heat flow direction and temperature gradient consistent with Fourier's law of conduction.

Conclusion and Future work

- **Conclusion:-**

1. Successfully studied heat conduction in a metal spoon using a simple and accessible setup.
2. Observed clear temperature variation along the spoon with time, transitioning from transient to steady-state heat transfer.
3. The experiment demonstrated the principles of Fourier's Law and the role of thermal diffusivity in real materials.
4. Multi-sensor data collection enabled a detailed understanding of the spatial and temporal temperature profile.

- **Future Work:-**

1. Extend the experiment to compare different materials (e.g., copper, plastic) to observe conductivity differences.
2. Introduce heat loss to the environment into the model for more realistic simulations.
3. Use infrared thermal imaging for more detailed surface temperature mapping.
4. Incorporate numerical modeling to predict and validate experimental results.

Thank You

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