CHE212 Innovation Project

Group 17

Krish Agarwal (230570)

Kshitij Srivastava (230584)

Khushi Khandelwal (230561)

Medha Agarwal (230645)

Aim

To calculate the effect of an air gap on thermal resistance across the ends of a metal rod by comparing heat conduction in a continuous metal rod and a segmented rod with small air gaps.

Theory

Heat transfer through a solid occurs primarily by conduction, governed by Fourier's Law:

$$q = -k \cdot A \cdot \frac{dT}{dx}$$

In an ideal continuous metal rod, thermal resistance is minimal due to good conductivity. However, introducing air gaps or interfaces between segments—especially with materials of much lower thermal conductivity—can increase thermal resistance.

The total thermal resistance of such a system can be calculated as:

$R=\Delta T/Q$

This experiment explores how segmenting a metal rod (even with negligible interfacial resistance material) affects heat flow.

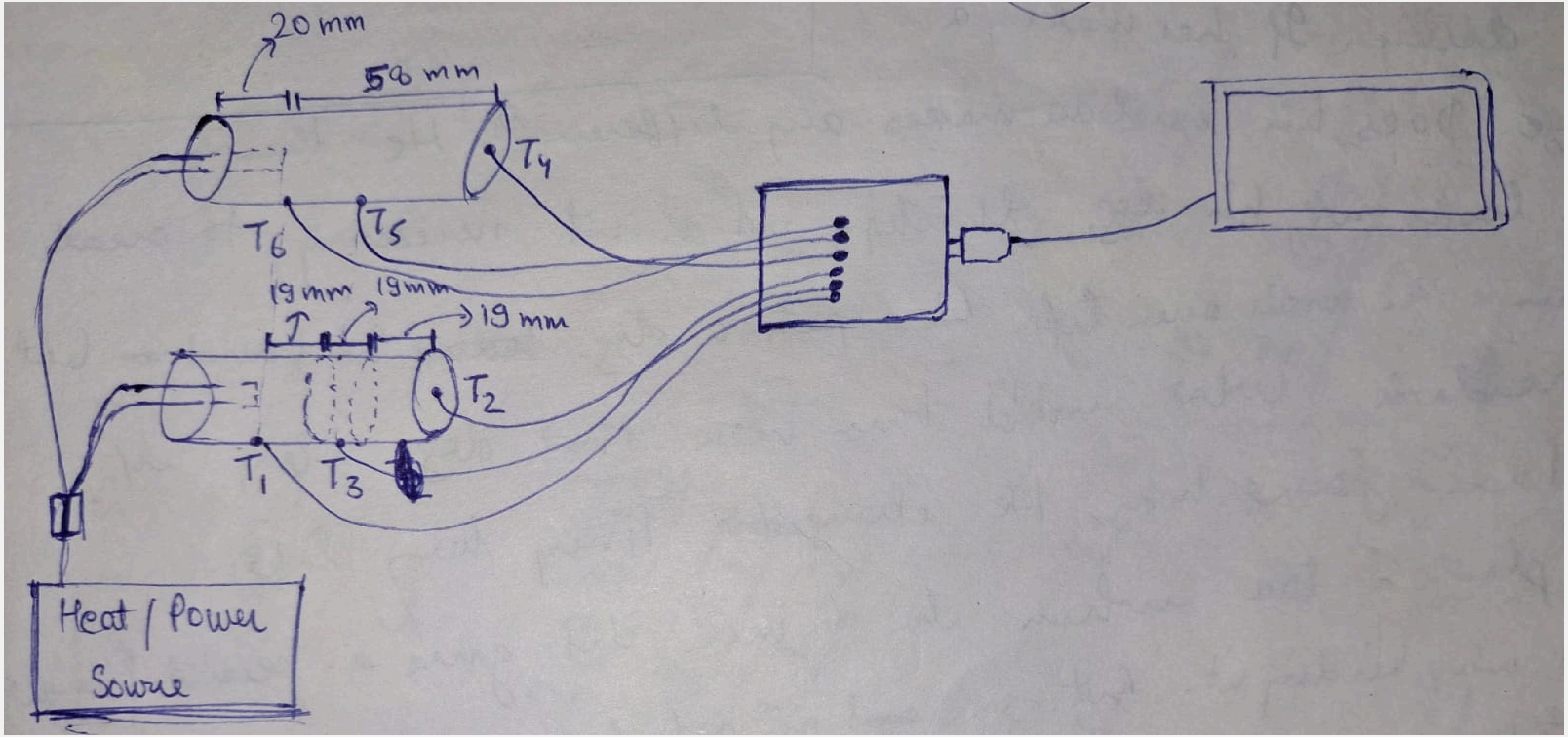
Innovation

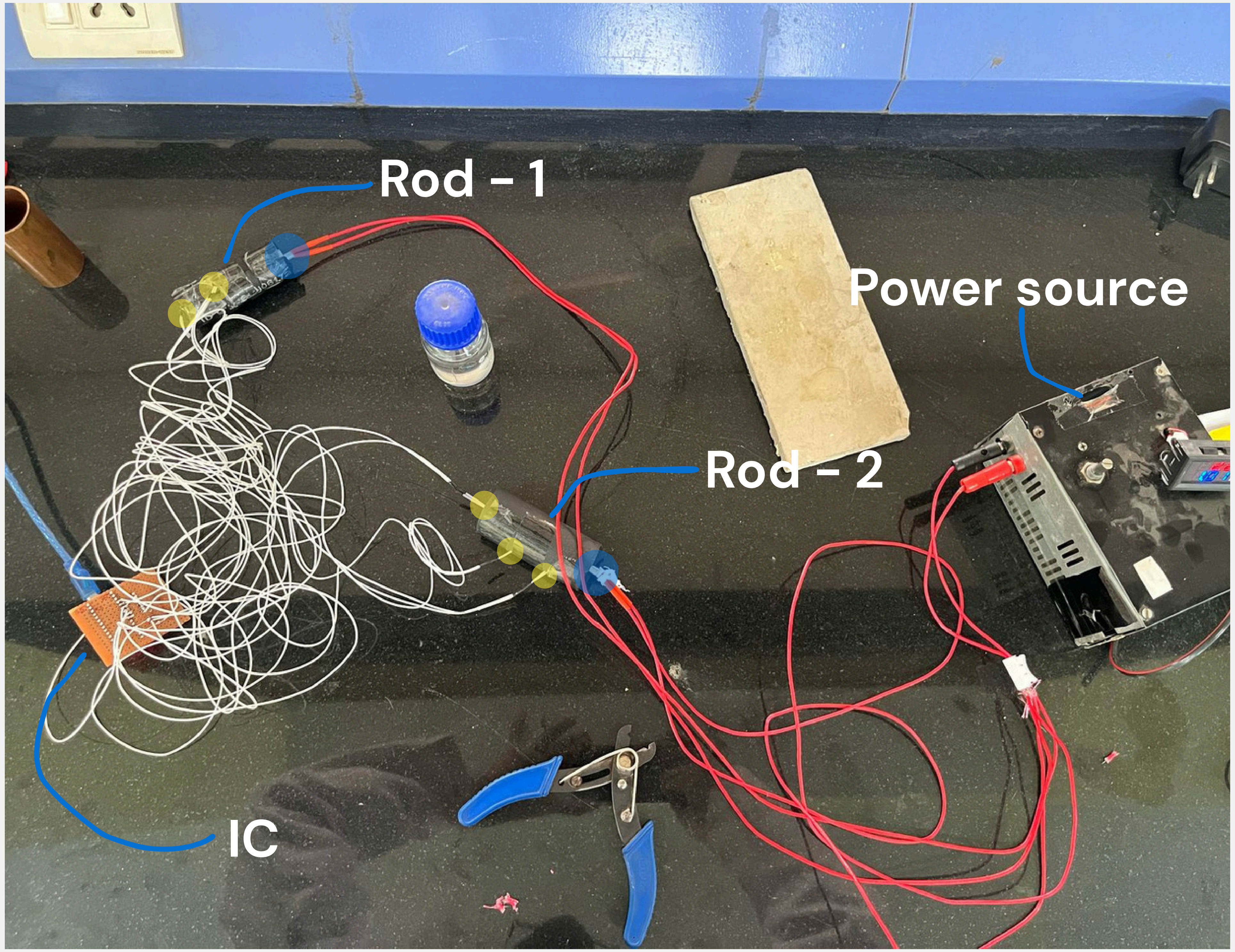
- **Direct Comparison:** The experiment compares thermal resistance in a fully continuous rod versus a segmented rod to highlight the air gap effect.
- **Realistic Simulation:** This setup mimics real-world scenarios where joints in metallic structures lead to heat transfer inefficiencies. So we find the resistance of that air gap.

Apparatus Required

- **Thermal Sensors:** Three sensors per setup (placed at both ends and in the middle).
- **Two Identical Metallic Rods:** One continuous rod and another divided into 3 equal segments.
- **Heat Source/ Heater:** To apply a controlled heat flux at one end of the rods.
- **Data Acquisition System :** For real-time temperature monitoring, we used CoolTerm software.

Line Diagram

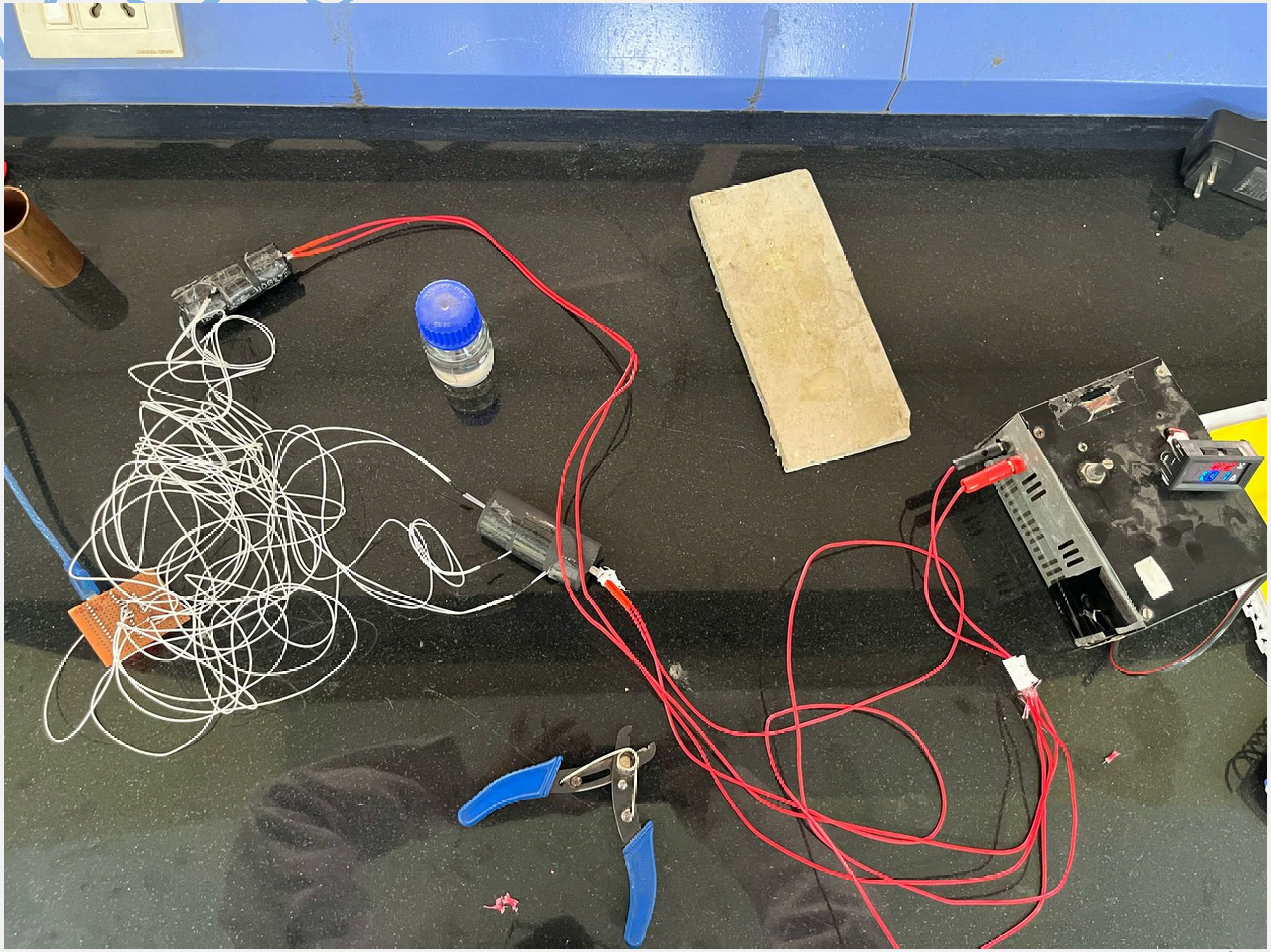




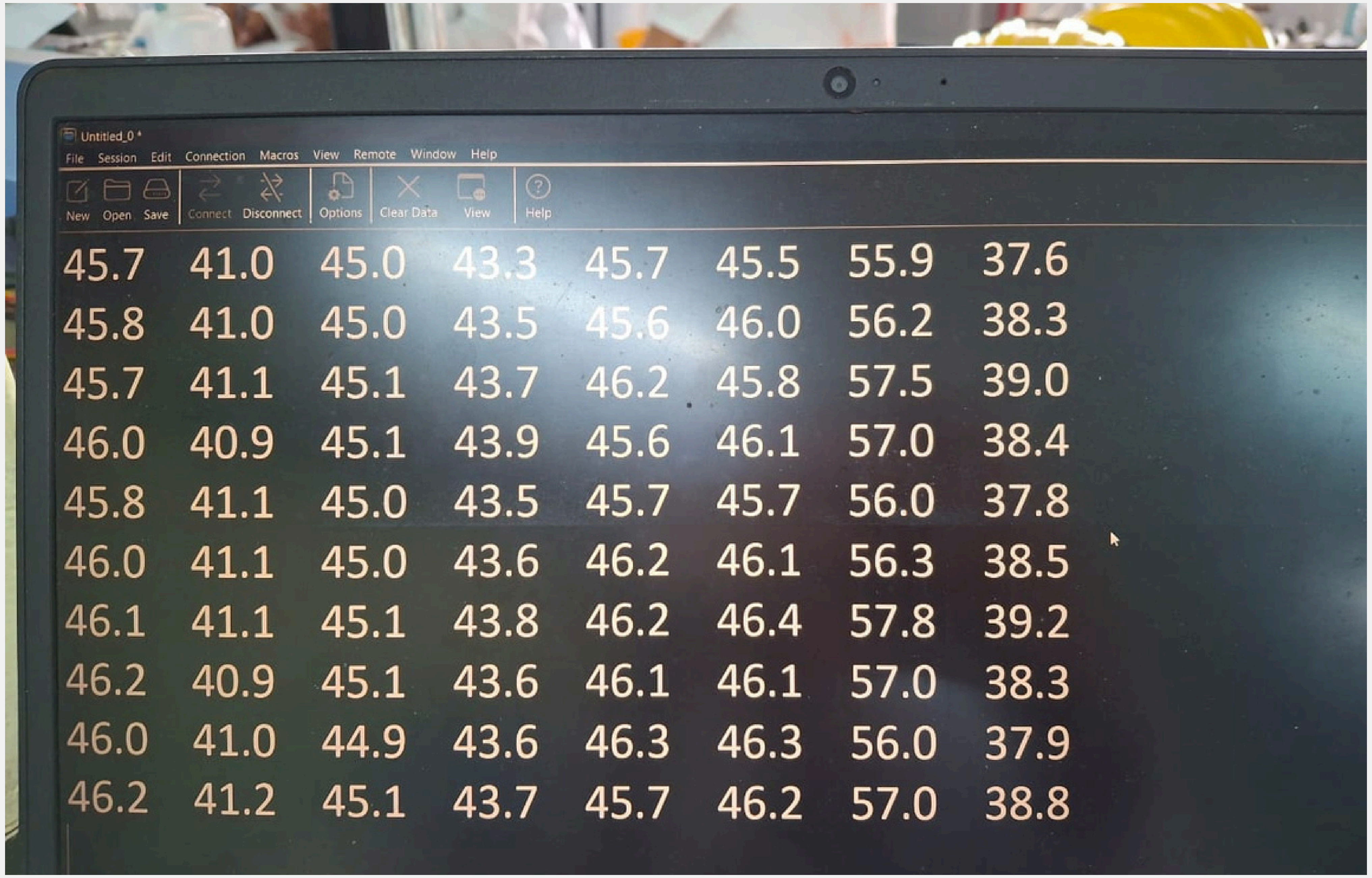
Two rods with three thermal sensors, two on the ends and one in the middle to measure temperature.

This is the **power supply** we used for generating the heat

Thus we used Voltage of **2.2 V** and current of **1.07 A** Therfore the Q supplied was **2.354 Watts**



This is the **setup** we connected the power supply to the heater which heated one of the the end of the rod



This is the software we used which was **CoolTerm**. The readings of the temperature sensors was captured by this.

Procedure

01

Two identical metallic rods of the same material and dimensions were chosen. One rod was left intact, while the second rod was divided into three equal segments and rejoined using a material with negligible thermal resistance, ensuring proper alignment and minimal heat loss at the joints.

02

For each setup, three thermal sensors were carefully mounted—one at each end and one in the middle of the rod.

03

Both rods were properly insulated along their lengths to minimize heat losses due to convection and radiation, ensuring that conduction was the dominant mode of heat transfer.

04

One end of each rod was connected to a constant heat source.

Procedure

05

All 6 sensors readings were continuously being recorded until steady state was achieved(when readings stopped changing with time)

06

The temperature differences between the two ends were calculated from the sensor data for both the single rod and the segmented rod.

07

Using the temperature gradient and the amount of heat provided, the thermal resistance across each rod was computed.

08

The thermal resistances of the single rod and the segmented rod were compared to analyze the effect of air gaps.

Observation Table

Time (min)	T1 (*C)	T2 (*C)	T3 (*C)	T4 (*C)	T5 (*C)	T6 (*C)
0	29.8	29.9	30	29.3	30.0	29.4
1	30.6	30.1	30.4	30.1	30.4	30.4
2	31.8	30.2	31.2	30.4	31.2	30.9
3	32.9	31	32.1	31.8	32.1	32
5	34.7	32.2	34	33.3	34.0	33.4
10	38.4	35.1	37.2	36.3	37.2	37.9
15	40.5	37	39.7	39	39.7	39.6
20	42.3	38.4	41.5	40.4	41.5	41.8
25	43.4	39.3	42.7	41.5	42.7	43.3
30	44.4	40	43.7	42.2	43.7	44.3
35	45.2	40.8	44.3	43	44.3	45.2
40	43.4	39.3	42.7	41.5	42.7	43.3
45	46.3	41.7	45.2	44.4	45.2	46.4
50	46.6	41.8	45.5	44.9	45.5	46.9
52	46.7	41.5	45.7	44.4	45.7	47.3

Calculations

$$\dot{Q} = \frac{VI}{2} = \frac{2.2 \times 1.07}{2} = 1.177\ W$$

Continuous Rod

$$\text{Resistance} = \frac{\Delta T}{\dot{Q}} = \frac{47.38 - 44.59}{1.177} = 2.370\ °C/W$$

$$R_c = 2.370\ °C/W$$

Segmented Rod

$$\text{Resistance} = \frac{\Delta T}{\dot{Q}} = \frac{46.68 - 41.47}{1.177} = 4.426\ °C/W$$

$$R_s = 4.426\ °C/W$$

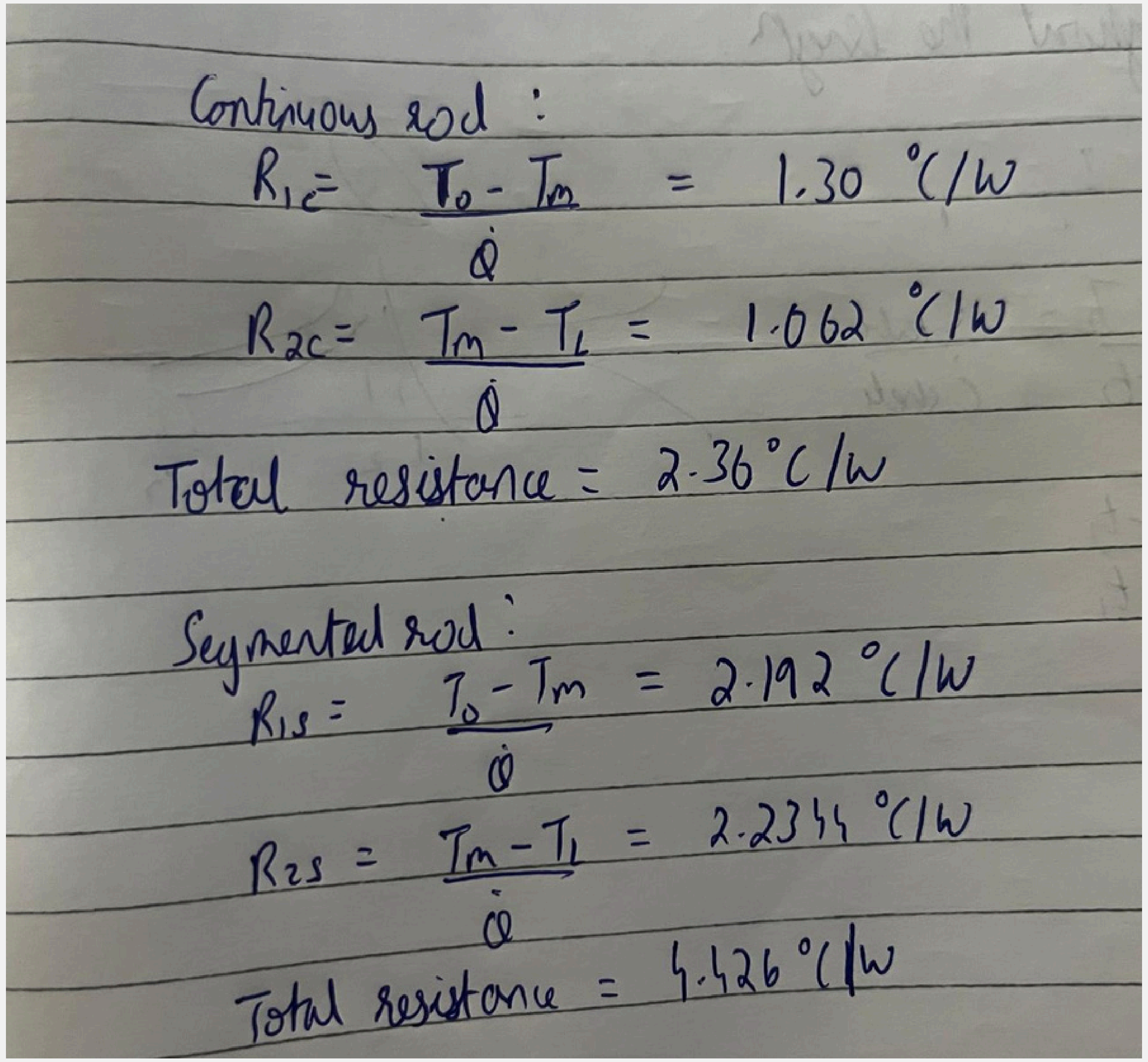
Thermal contact resistance $= R_s - R_c = 2.056\ °C/W$

Resistance of Continuous Rod = 2.370 *C/W

Resistance of Segmented Rod = 4.426 *C/W

Thermal Contact Resistance = 2.056 *C/W

Calculations



Continuous rod :

$$R_{1c} = \frac{T_o - T_m}{\dot{Q}} = 1.30\ °C/W$$

$$R_{2c} = \frac{T_m - T_L}{\dot{Q}} = 1.062\ °C/W$$

Total resistance = 2.36 °C/W

Segmented rod :

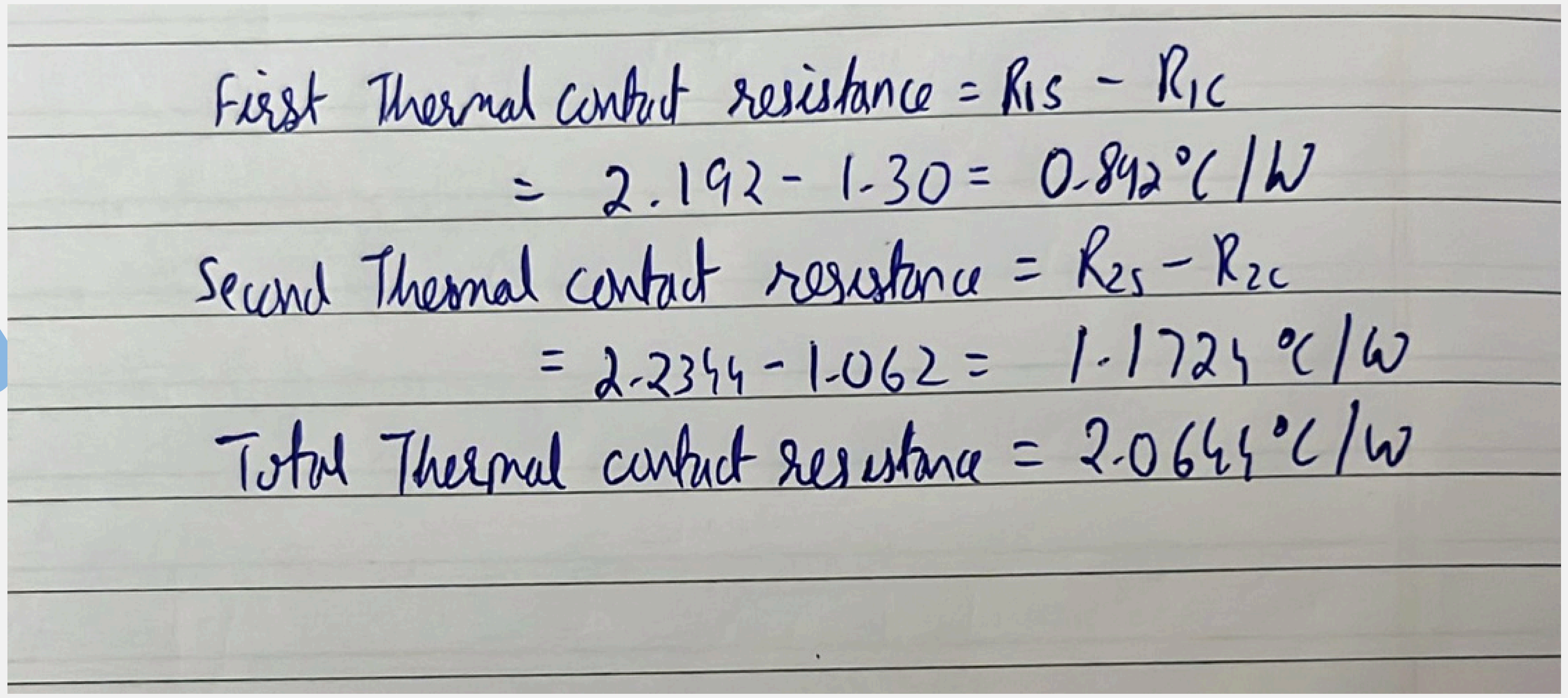
$$R_{1s} = \frac{T_o - T_m}{\dot{Q}} = 2.192\ °C/W$$

$$R_{2s} = \frac{T_m - T_L}{\dot{Q}} = 2.2344\ °C/W$$

Total resistance = 4.426 °C/W

Sum of Resistance of both segments are approximately equal to the full rod

Calculations


First Thermal contact resistance = $R_{1S} - R_{1C}$

$= 2.192 - 1.30 = 0.892\ °C/W$

Second Thermal contact resistance = $R_{2S} - R_{2C}$

$= 2.2344 - 1.062 = 1.1724\ °C/W$

Total Thermal contact resistance = $2.0644\ °C/W$

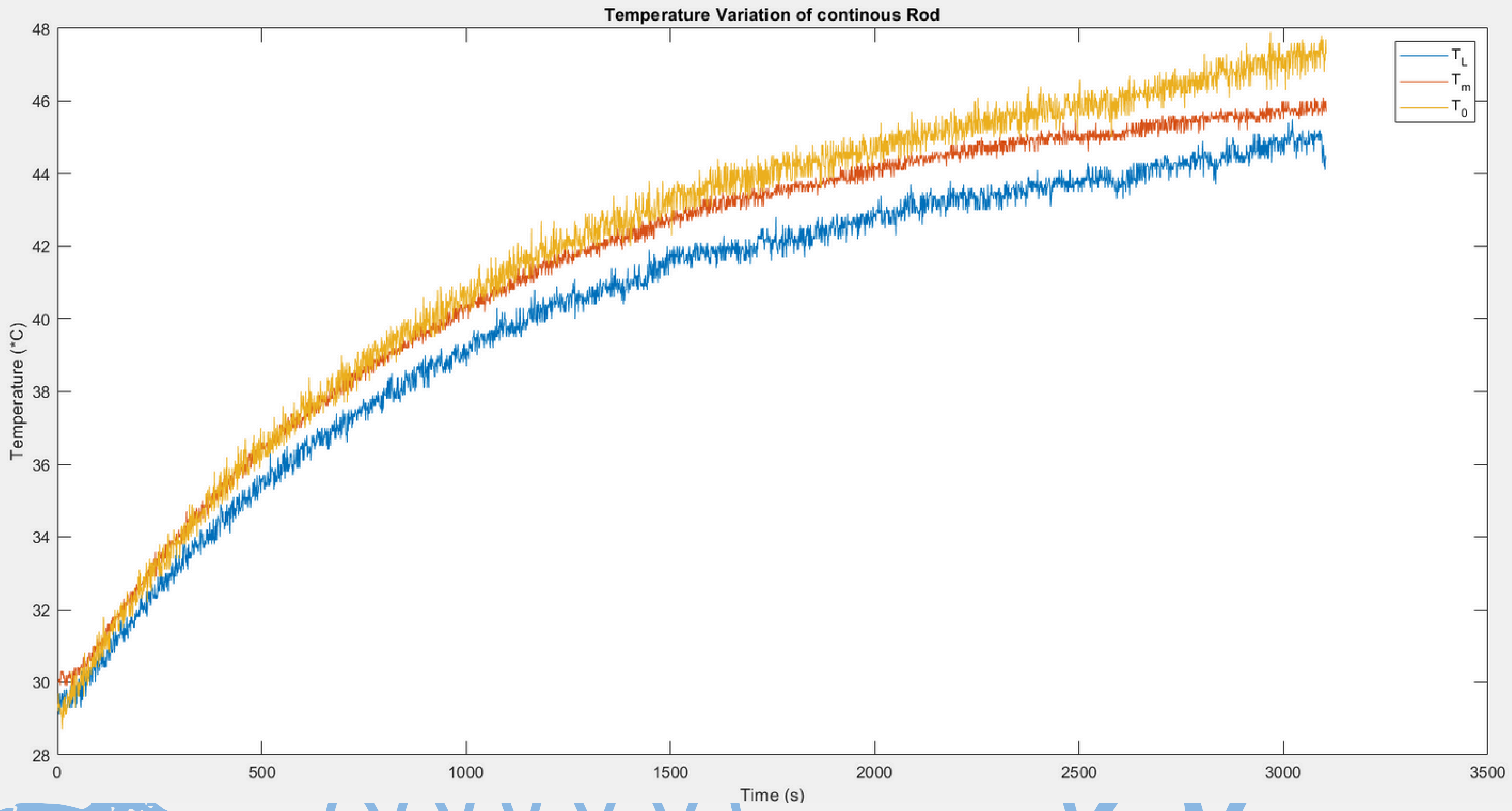
First Thermal Contact Resistance = 0.892 *C/W

Second Thermal Contact Resistance = 1.1724 *C/W

Total Thermal Contact Resistance = 2.0644 *C/W

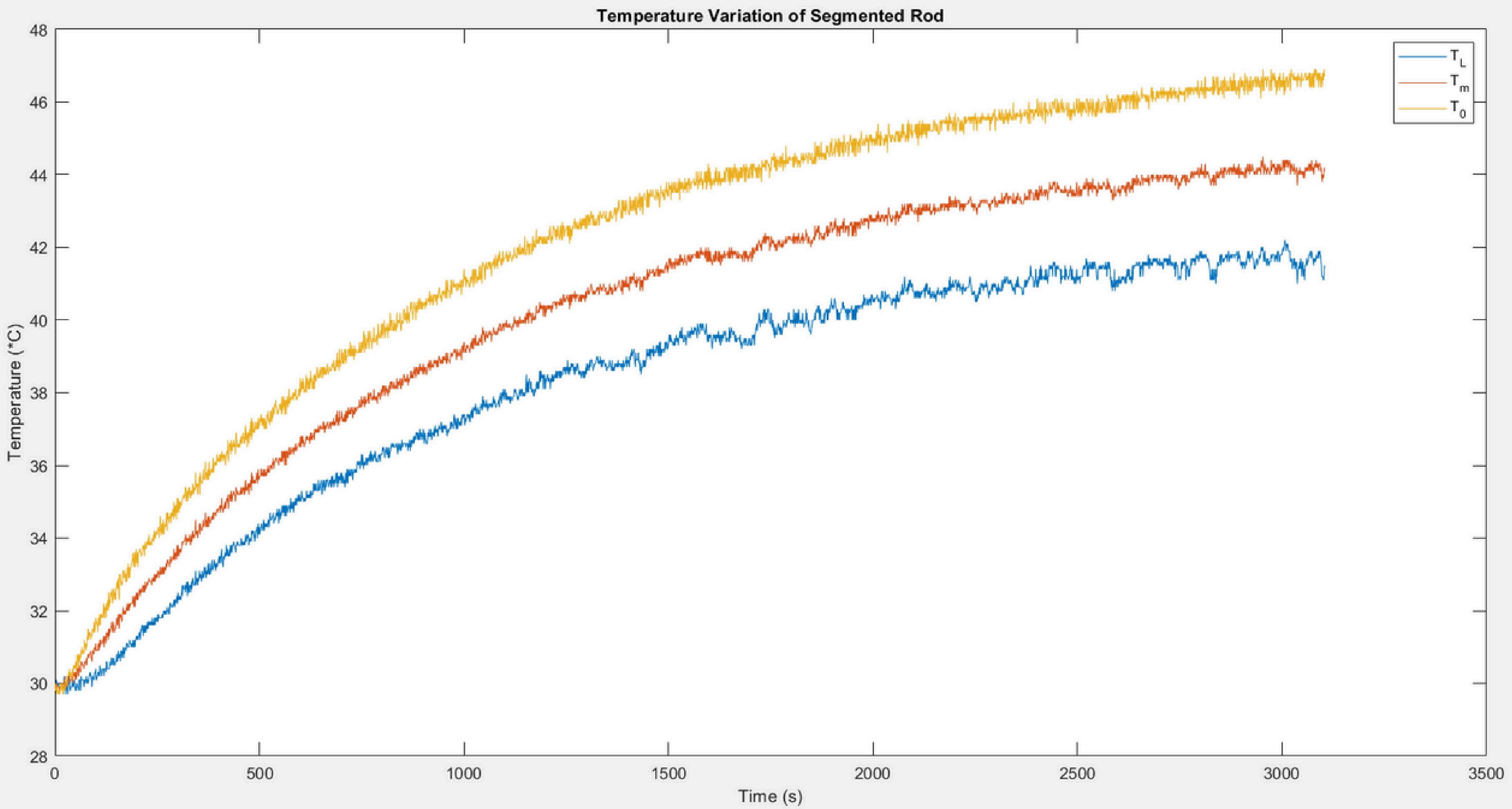
Observations

- Temperature Variation of Continuous Rod



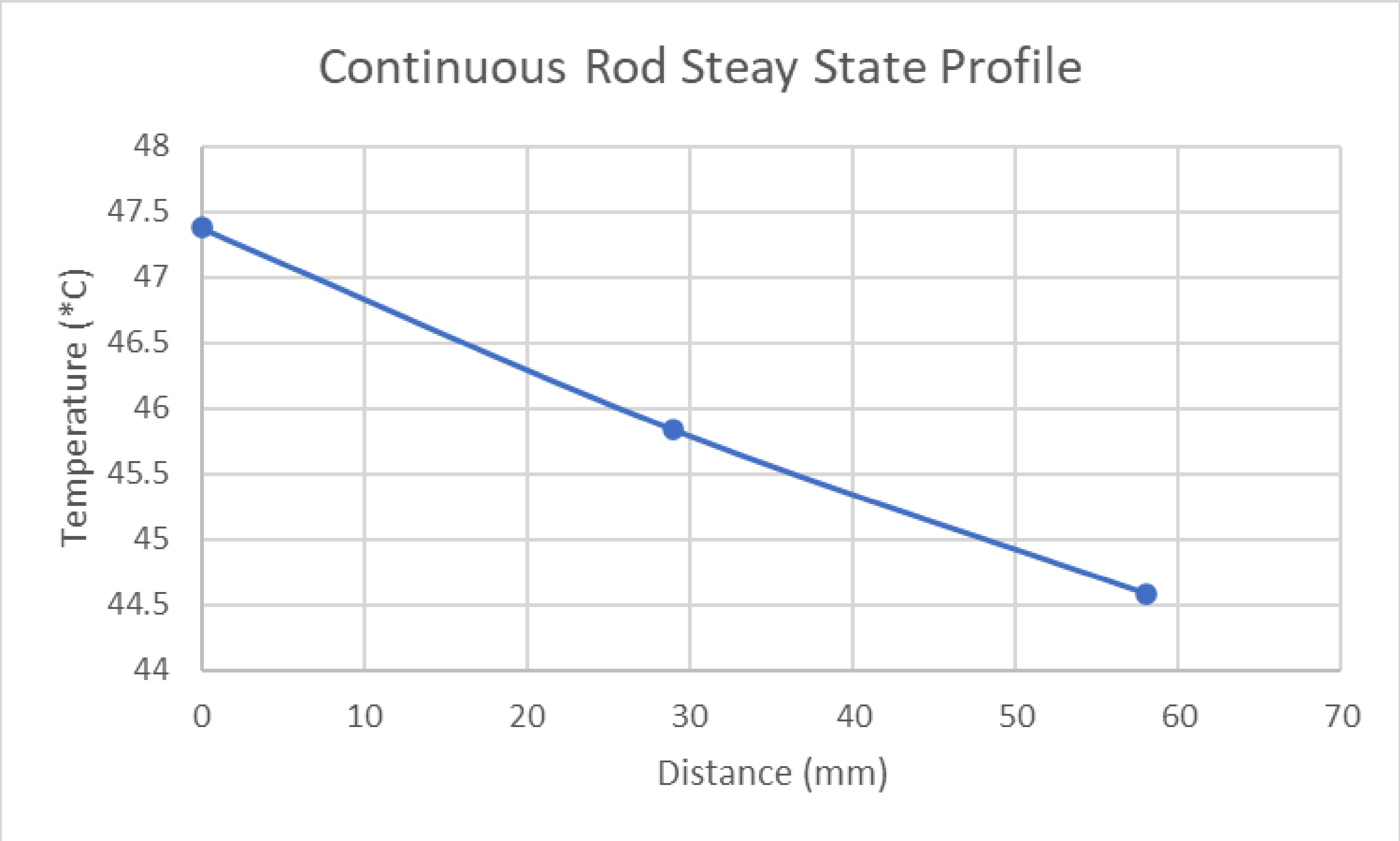
Observations

- **Temperature Variation of Segmented Rod**



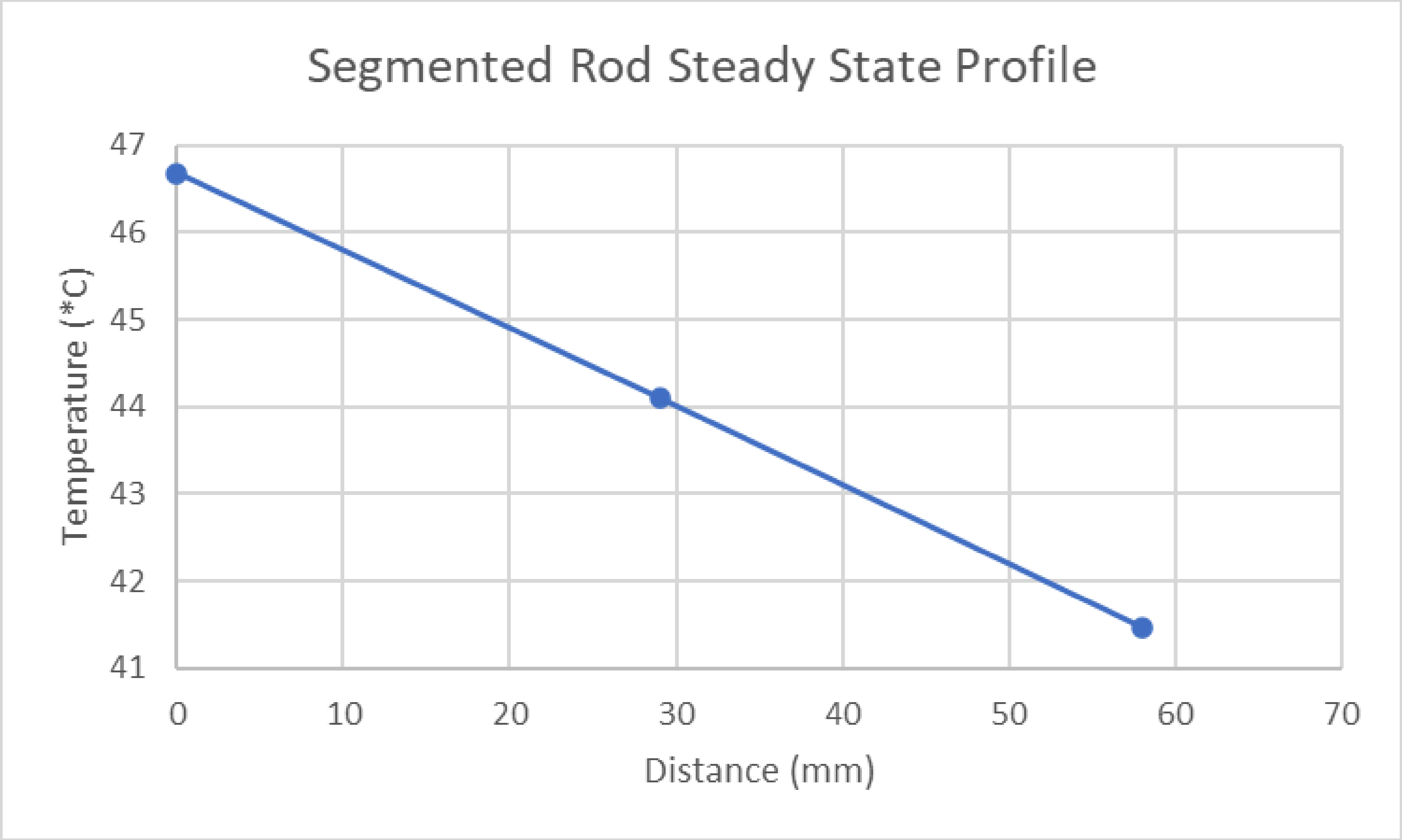
Observations

- **Steady State Profile of Continuous Rod**



Observations

- **Steady State Profile of Segmented Rod**



Observations

- **Resistance of Segmented Rod is more than that of Continuous Rod**

Due to additional contact resistances at the interfaces.
These joints introduce air gaps and surface imperfections that hinder heat flow.

- **Resistance due to small air gap is comparable that due to rod**

Even though the air gap is much smaller in length, its very low thermal conductivity means:

$$Rair=Lair/(Kair*A)$$

can be comparable to or larger than the resistance of a much longer solid rod:

$$Rrod=Lrod/(Krod*A)$$

Conclusion

- Resistance of segmented rod is much more than that of continuous rod

  The segmented rod shows higher resistance due to the following reasons:

  - Imperfect Segment Cuts:

  The cuts between segments may not be perfectly flat or smooth, resulting in poor physical contact and increased resistance at the joints.

  - Presence of Air Gaps:

  Small air gaps between the segments may act as insulating barriers, obstructing the flow of current and increasing the overall resistance.

Thank you!

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