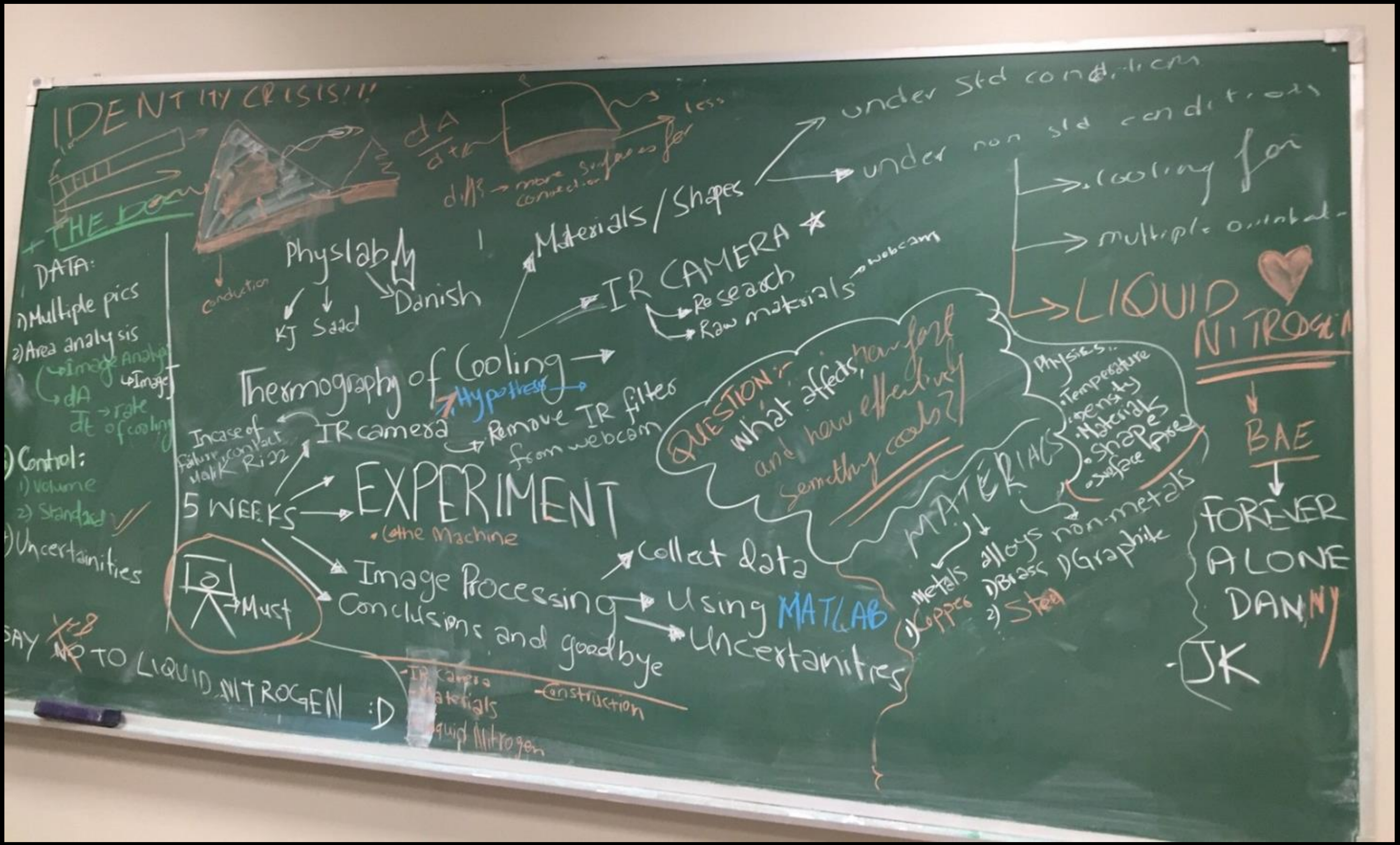
PHYSICS STUDIO 13

QUANTITATIVE EXPLORATIONS OF HEATING AND COOLING

CONTENTS

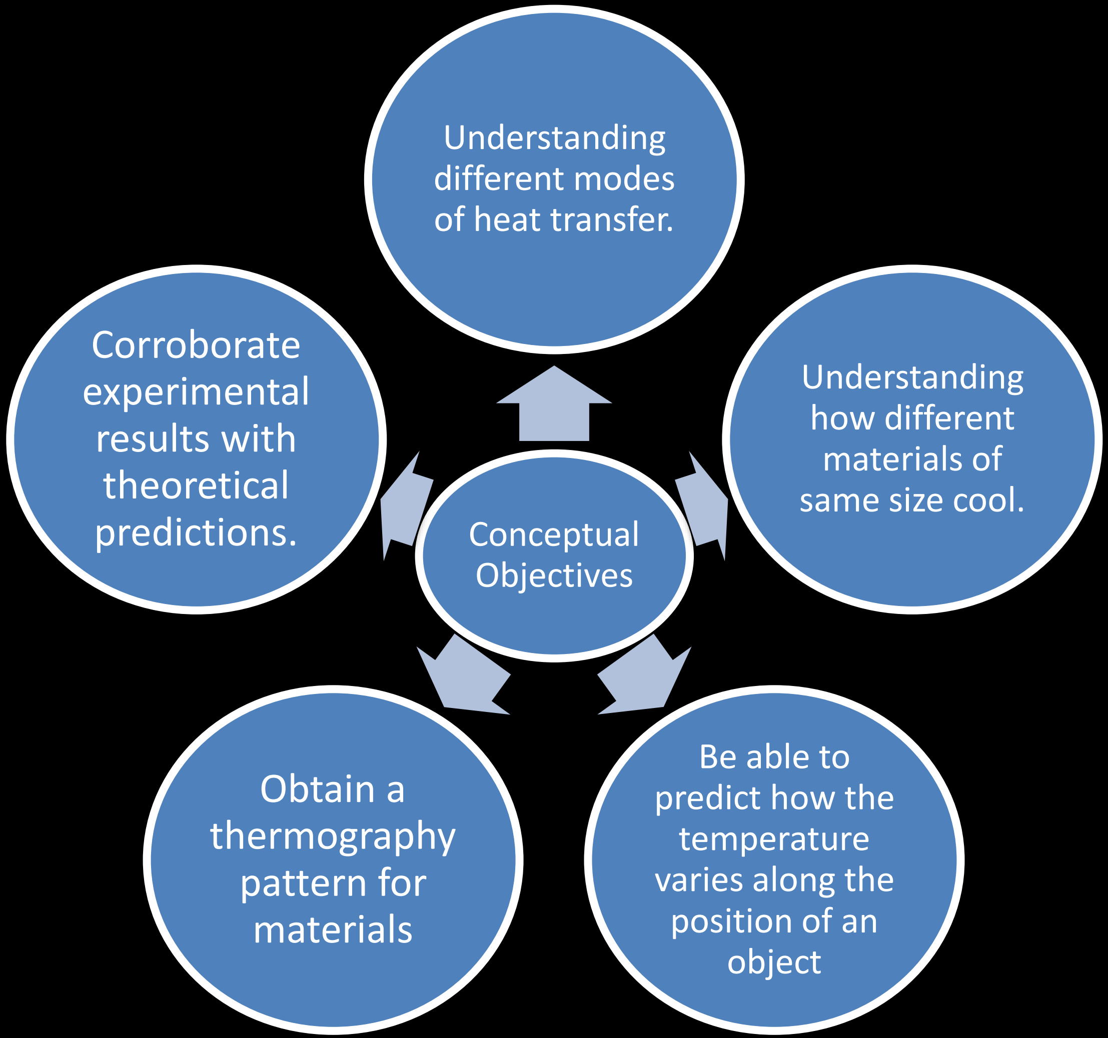
- Overview of Our Studio
- Objectives
- Theoretical Introduction
- Experimental procedure
- Data Analysis

Inception

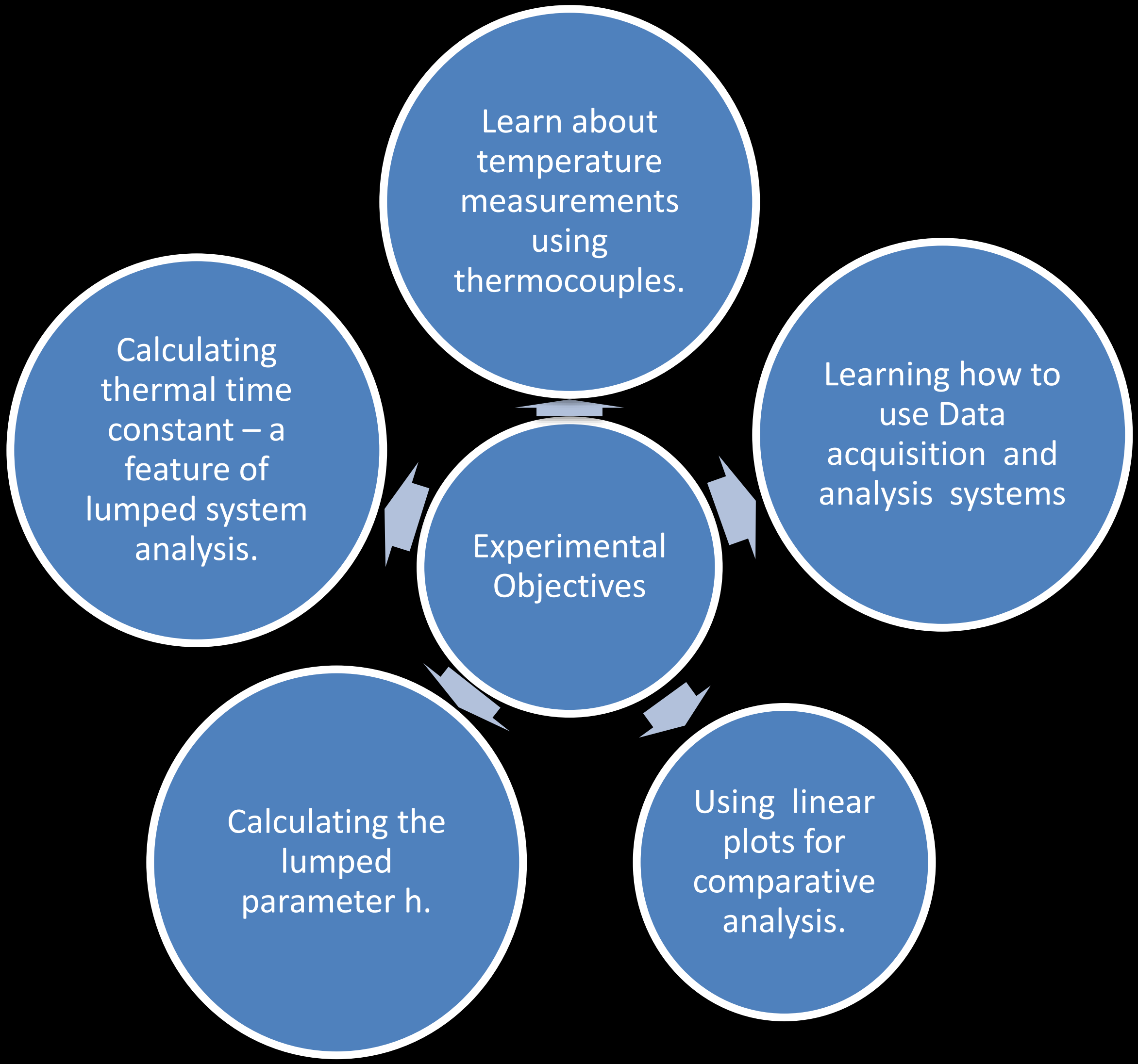


"Don't let three wanna-be scientists in a room together"

Theoretical Objectives



Experimental Objectives



THEORETICAL INTRODUCTION

WHAT IS HEAT AND HOW IS IT TRANSFERRED?

Heat is considered to be thermal energy in transit that flows between two objects which are kept at different temperature.

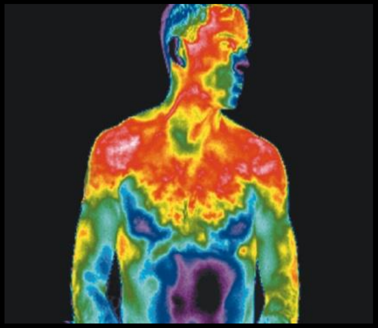
The transfer can be

1. By direct contact from source to destination body – Conduction combined with radiation.
2. Between two remote Objects through some material or space. - Radiation
3. By an intermediate fluid body. – Convection

WHY IS STUDYING HEAT TRANSFER IMPORTANT?

- Ventilation and Air conditioning systems.
- Power Generation
- Internal Combustion Engines in automobiles and Jet Aircraft
- Refrigeration systems
- Thermal management of electronics
- The human body
- Global Warming – A slow poison which will determine our future destinies




NEWTON'S LAW OF COOLING

"the rate of heat loss of a body is proportional to the difference in temperatures between the body and its surroundings while under the effects of a breeze."

It is equivalent to the statement is equivalent to that heat transfer coefficient is constant.

The condition is generally true for conduction and approximately true for convective heat transfer.

HEAT TRANSFER COEFFICIENT

It is the proportionality constant between heat flux and thermodynamic driving force

THERMAL TIME CONSTANT

A feature of lumped system analysis for thermal systems used when objects cool under the influence of convective cooling and warming.

Larger masses and larger heat capacities lead to slower change in temperature while larger surface areas A_s and better heat transfer h lead to faster temperature changes.

The body assumes the same temperature as the ambient at an exponentially slow rate determined by the time constant.

$$\Delta T(t) = \Delta T_0 e^{-t/\tau}$$

$$\tau = \frac{\rho c_p V}{h A_s}.$$

Temperature Progression Equation

Plotting a trend for temperature in a constant environment of cooling

$$T = T_0 e^{-h\left(\frac{A}{mC}\right)t}$$

$$T = T_0 e^{-h\left(\frac{A}{\rho\pi R^2 l C}\right)t}$$

Curved Surface Area$_{\text{cylinder}}$ $= 2\pi R l$

$$T = T_0 e^{-h\left(\frac{2\pi R l}{\rho \pi R^2 l C}\right)t}$$

$$T = T_0 e^{-\left(\frac{2h}{\rho R C}\right)t}$$

($\frac{h}{R}$ is the lumped parameter)

Big $\left(\frac{h}{R}\right)$ ⟶ faster cooling

Big radius objects cool slower and vice versa.

EXPERIMENTAL PROCEDURE

APPARATUS

- **Hot Plate**

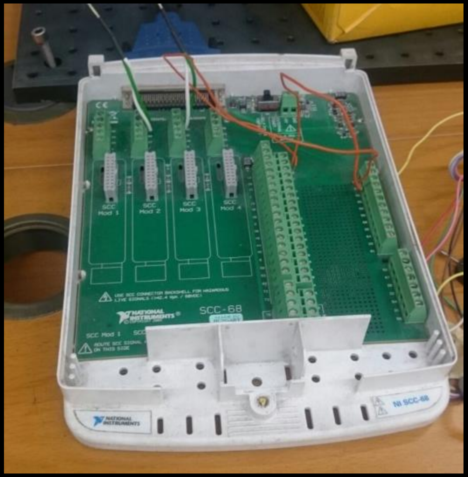
  Object placed insider bath of graphite powder on a hot plate. It reaches a maximum temperature of 300-400 degrees Celsius. The graphite powder was preheated before object added in.

- **Thermocouples**

  Thermocouples are attached to object using clamps or heat resistant tape.

- **Data Acquisition System**

  It acquires, digitizes and amplifies the thermocouple voltage signal. The signals are routed through the signal conditioning unit.

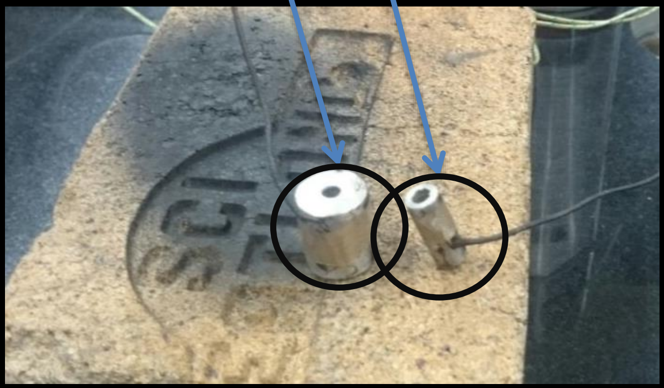


EXPERIMENTAL RESULTS

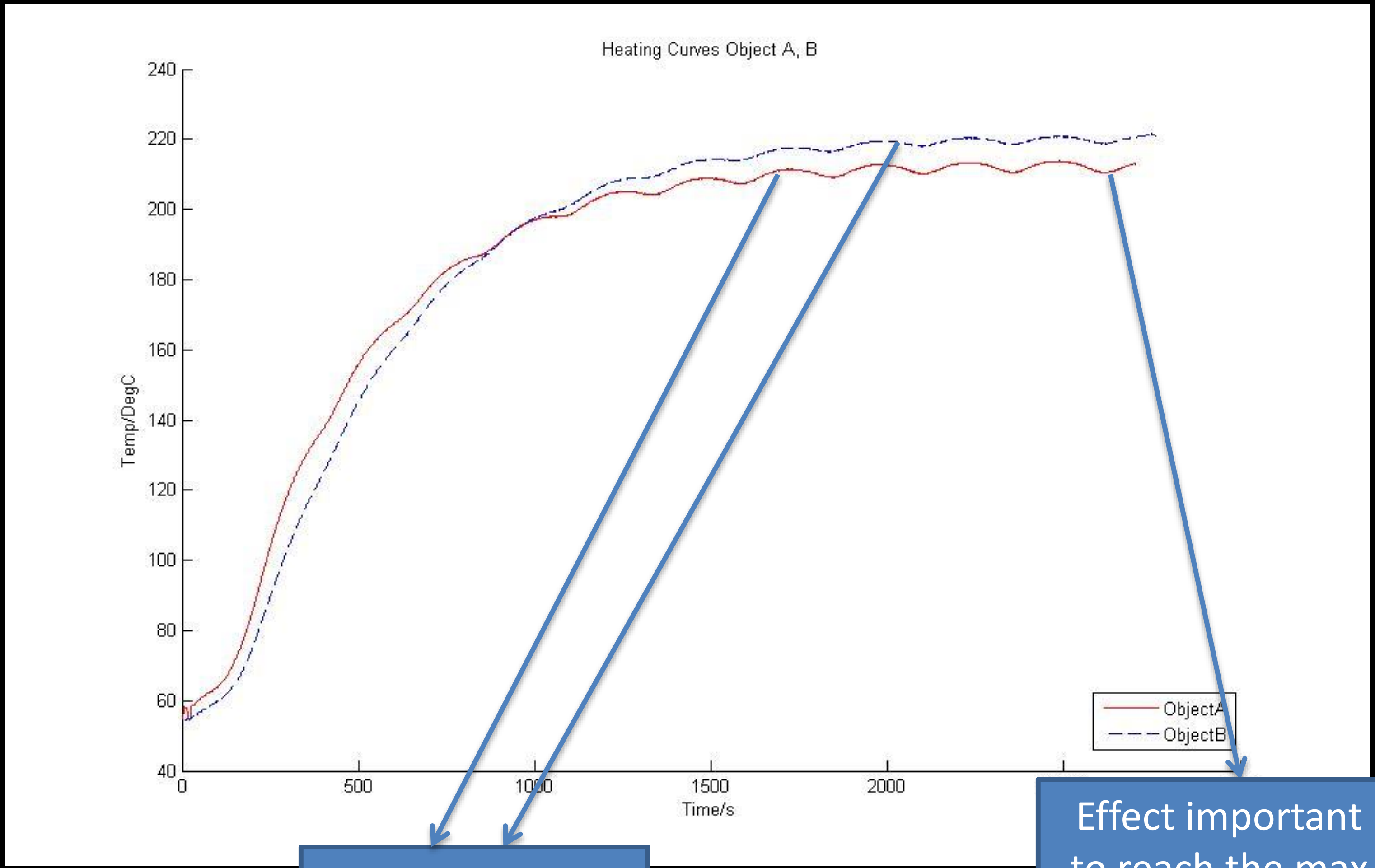
Effect of (dimensions) thickness on cooling

- Two objects used for samples
- Height Kept the same
- Internal Radius kept the Same
- Same material for both, and hence constant heat coefficient
- The only variable in this case, was the **radius**

- Material: Aluminum
- Heat Co-eff: 205(W/mk)
- Dimensions:
  - Small: Rad = (1.97)mm
  - Large : Rad = (3.97)mm



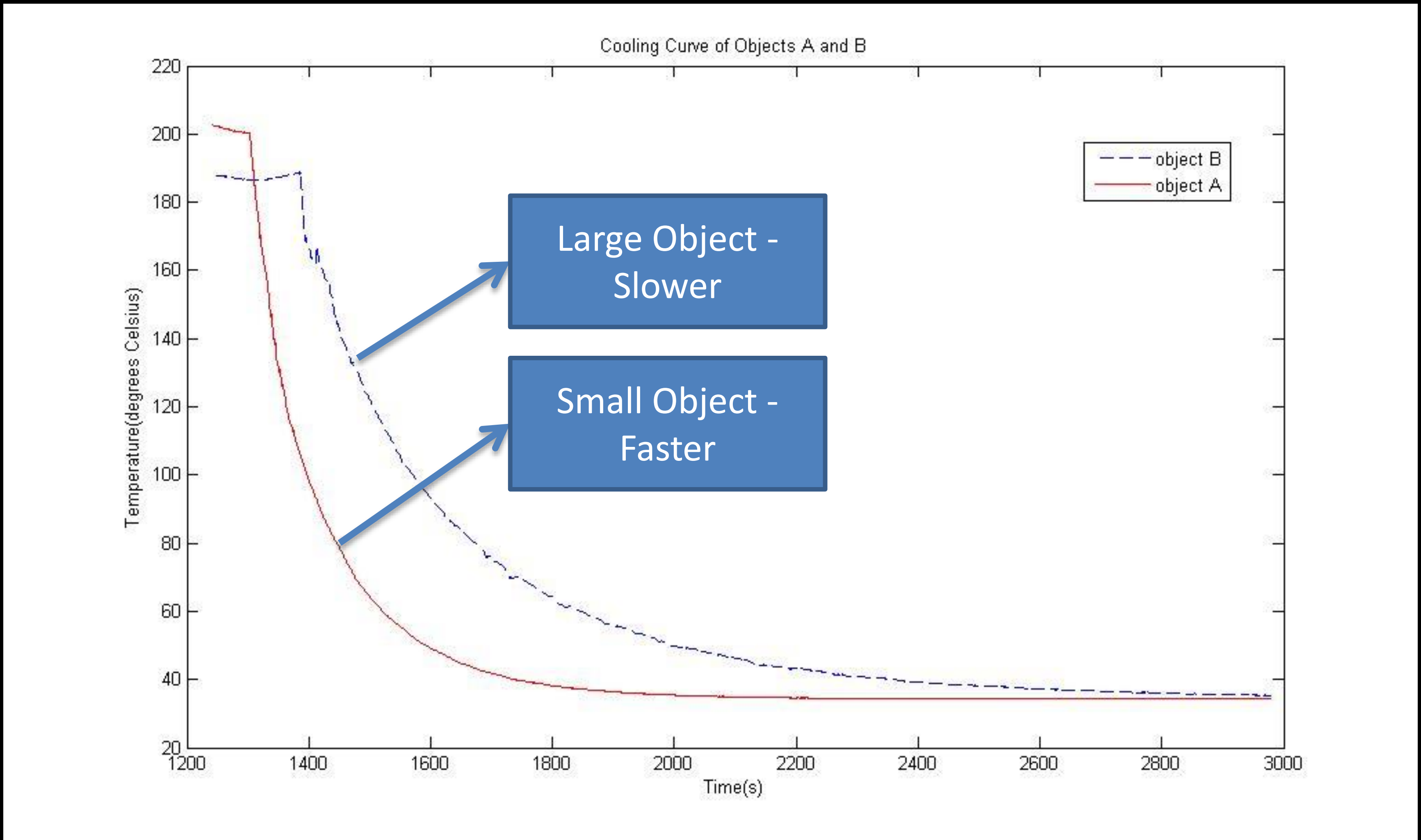
Heating Phase



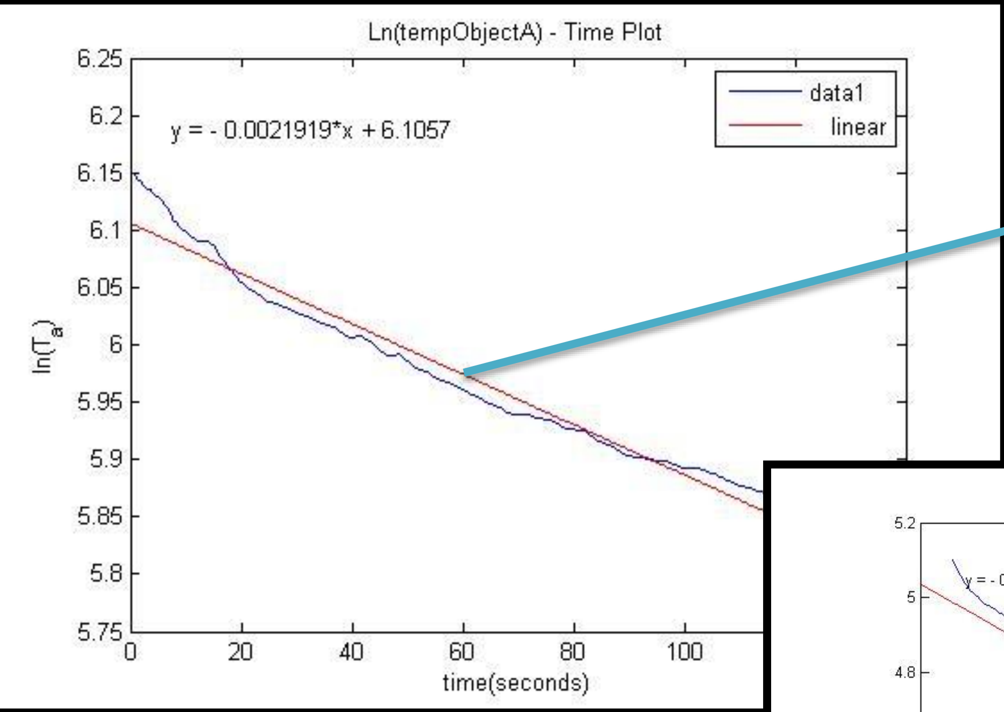
Thermostat Effect!

Effect important to reach the max temperature

Cooling Phase

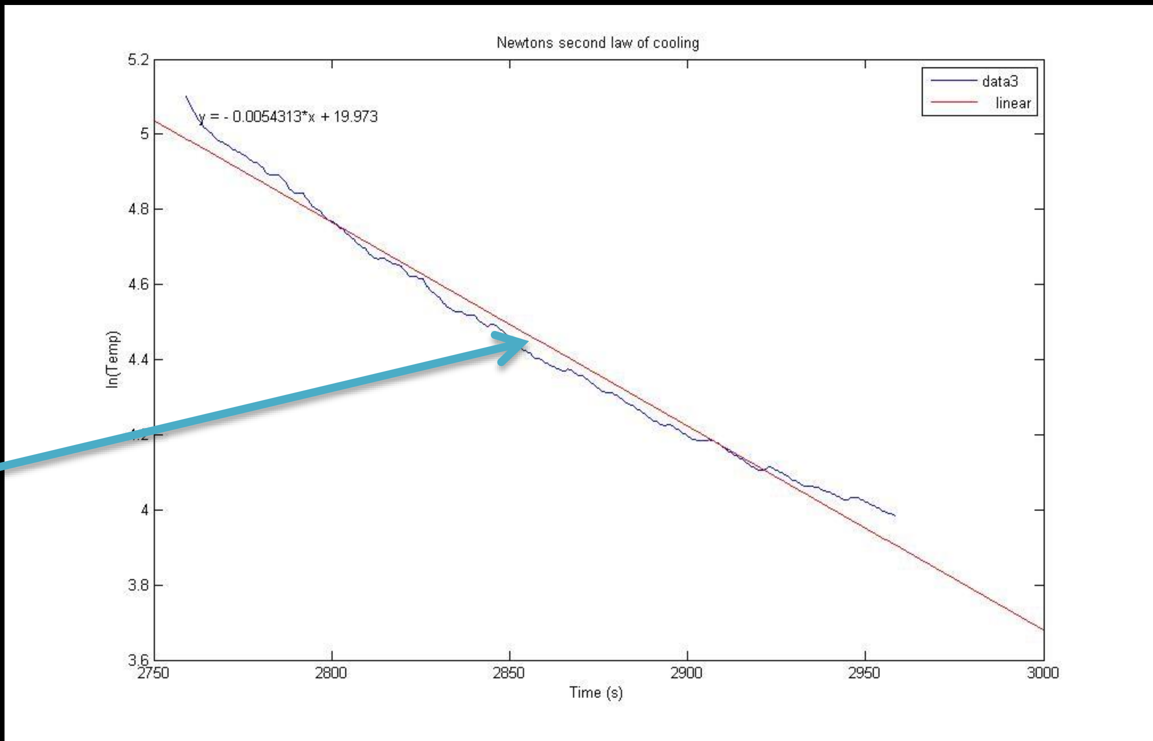


Linearized Plots



Large Object:

Linear Gradient Obtained:
-0.0021919



Small Object:

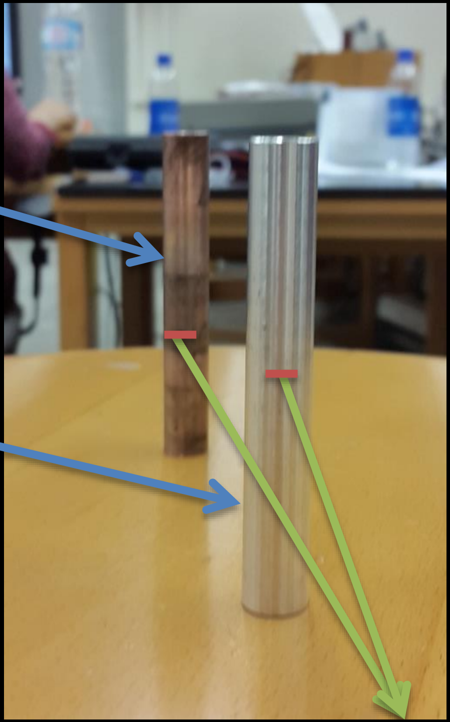
Linear Gradient Obtained:
-0.0054313

Effect of Material on cooling

Pure **Aluminum** and freshly faced **Copper** used as sample objects with the exact same dimensions

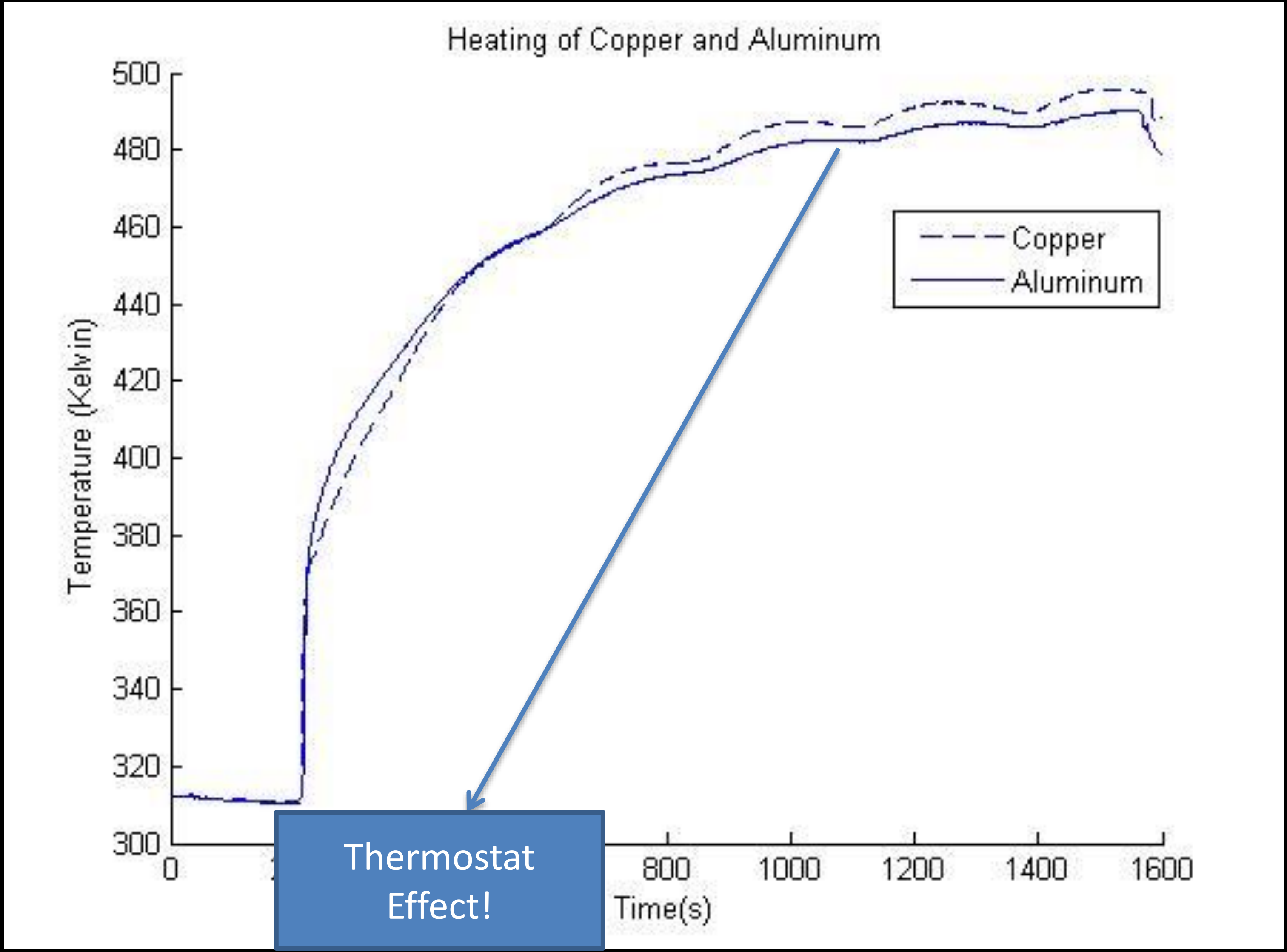
Copper

Aluminum

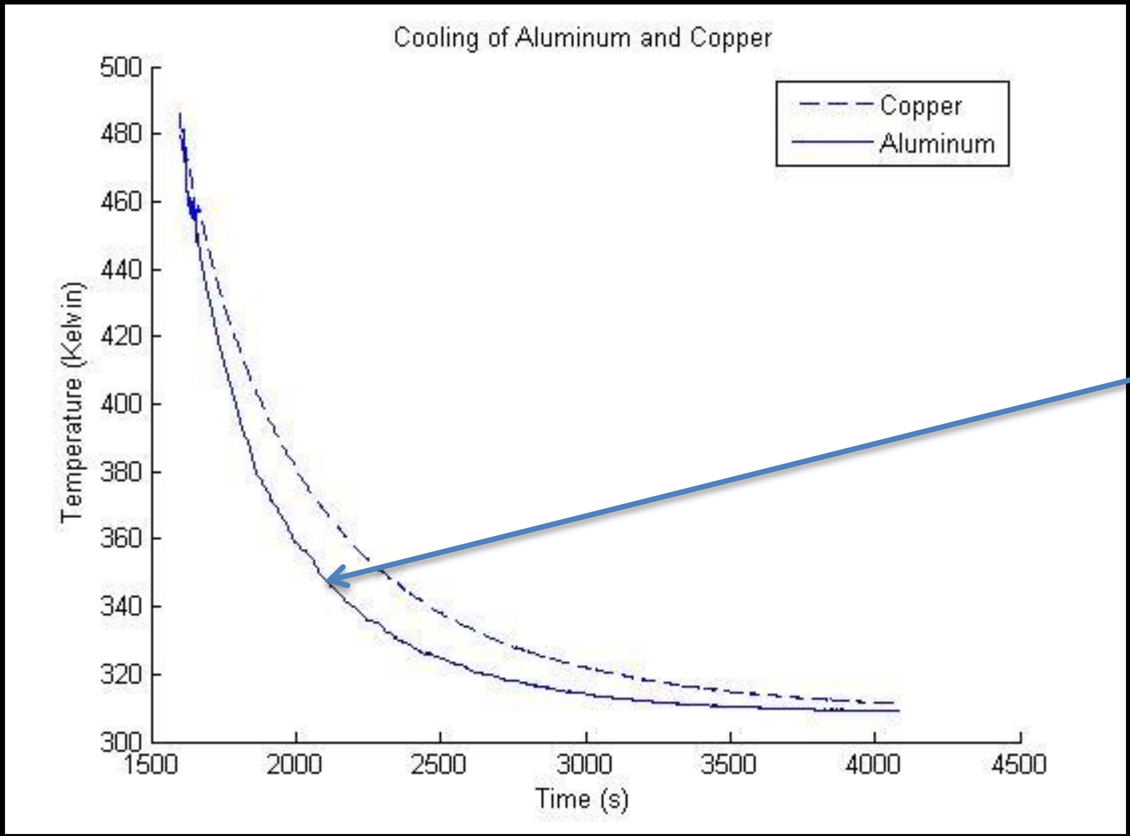


Thermocouple attachment point

Heating Phase



Cooling Phase



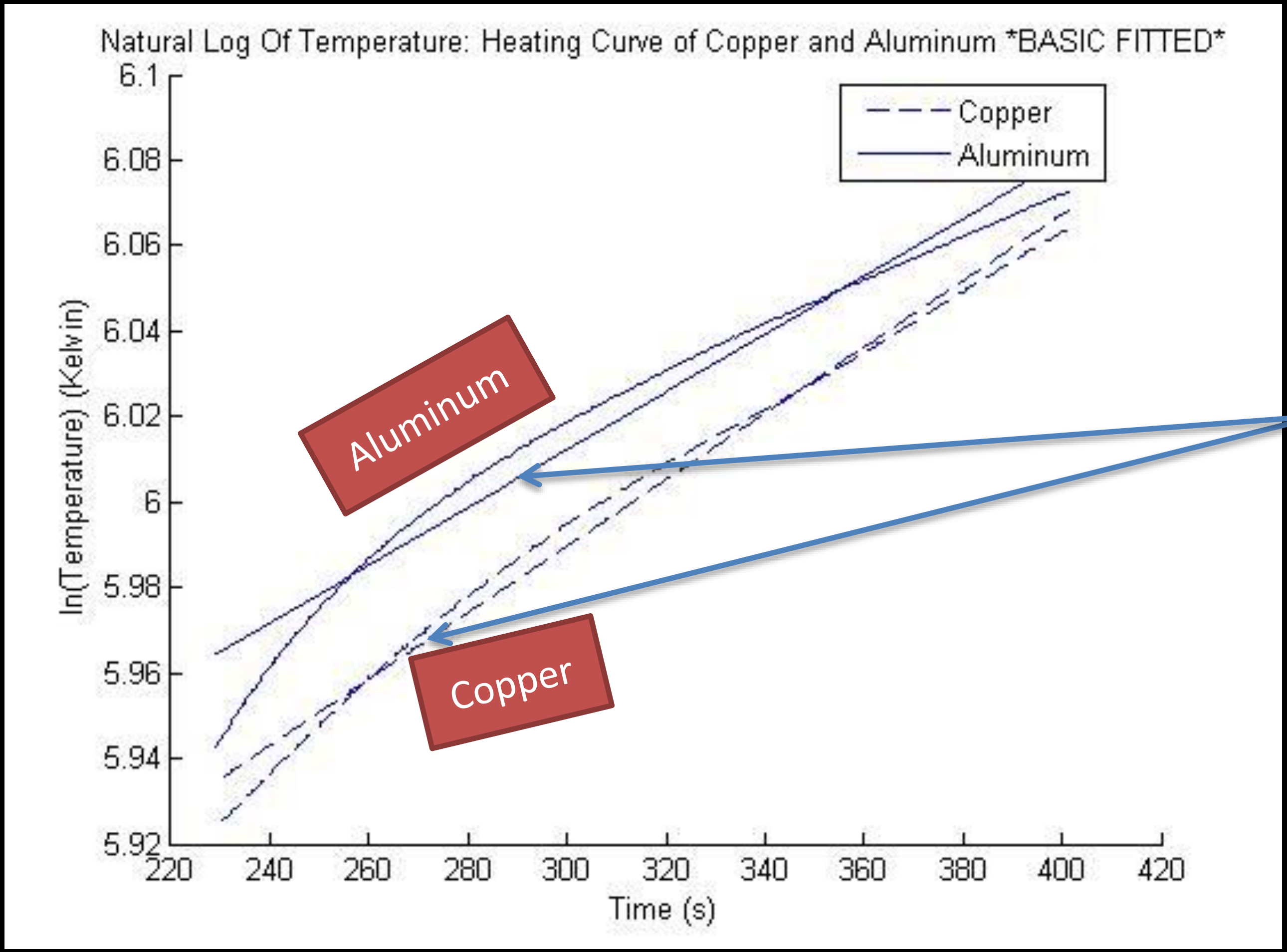
Aluminum cools faster, why?

PT = MC(delta)T

Aluminum C = 900Jkg(-1)K(-1)
Copper C = 385Jkg(-1)K(-1)

Power (directly proportional) = C

Linearization of heating Plot



Linear Gradients:

Aluminum:
0.00067579 (slower)

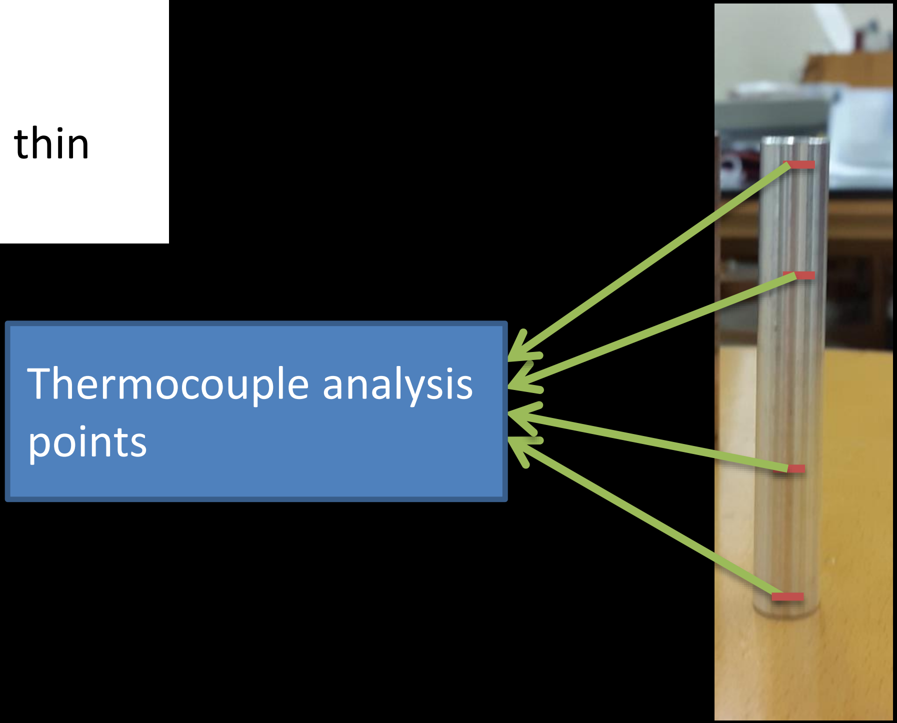
Copper:
0.0007765 (higher)

Varying Position on multiple Objects

Two different experiments conducted to cover this aspect:

1. Top and Bottom of a Small (larger width Aluminum rod)

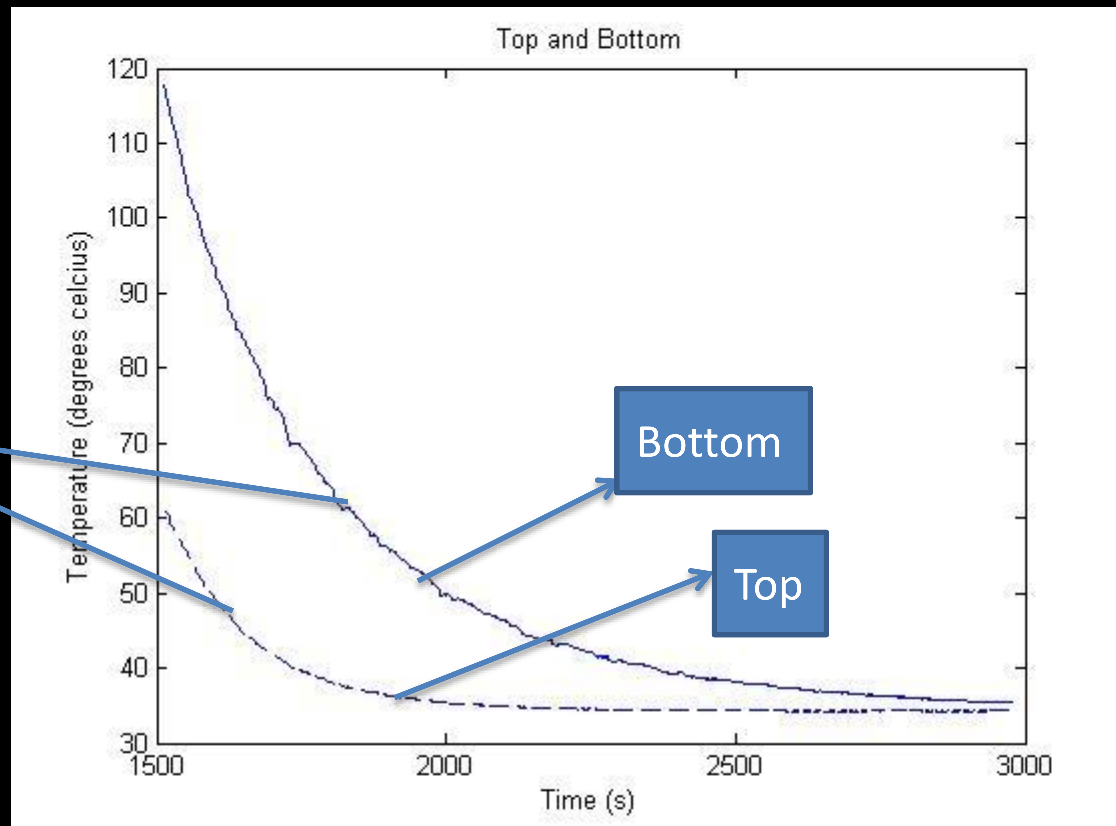
2. Four points analyzed off of a long and thin aluminum rod



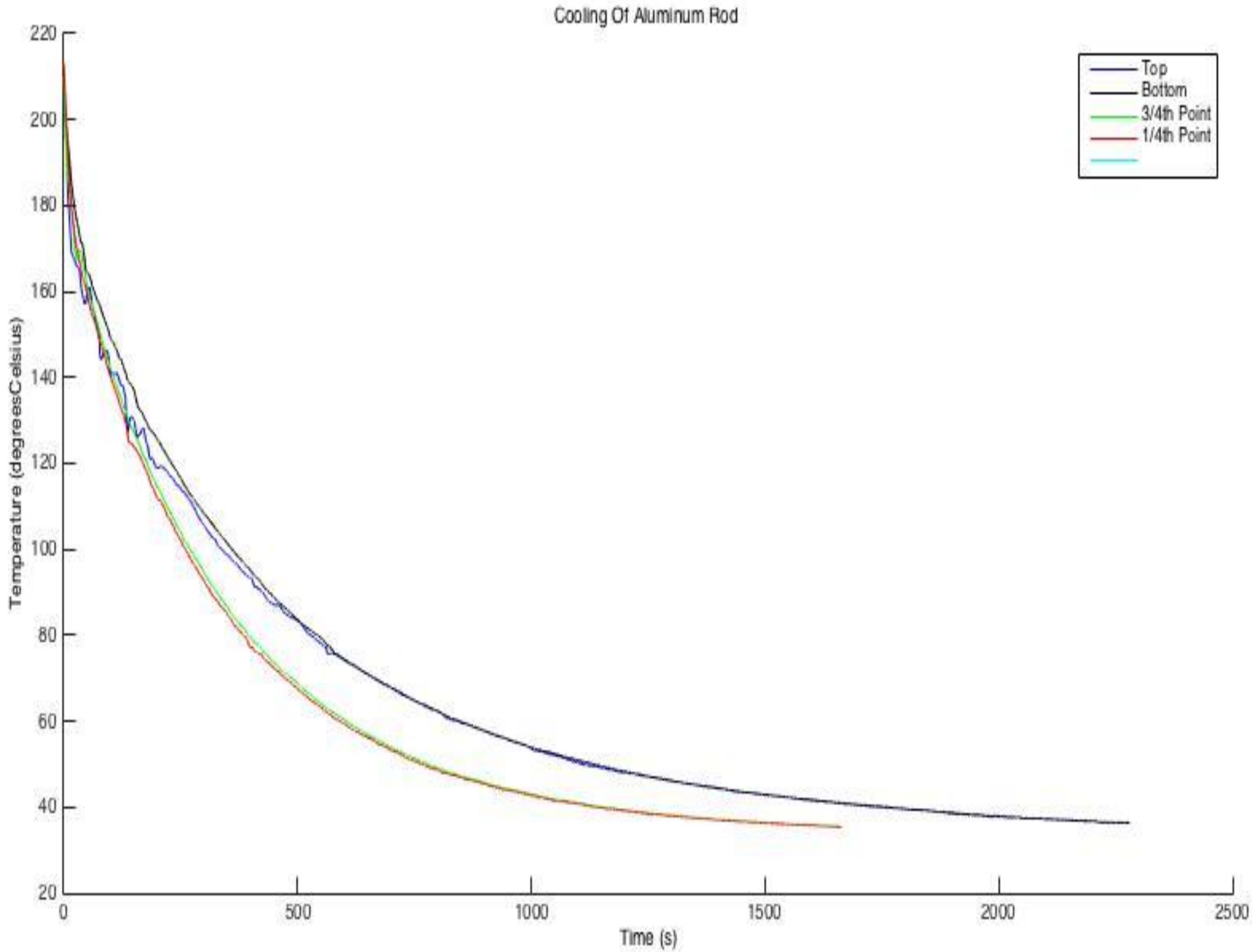
Small Object multipoint analysis

Top of object = Cools Faster

Makes intuitive sense. The bottom is in contact with an insulator

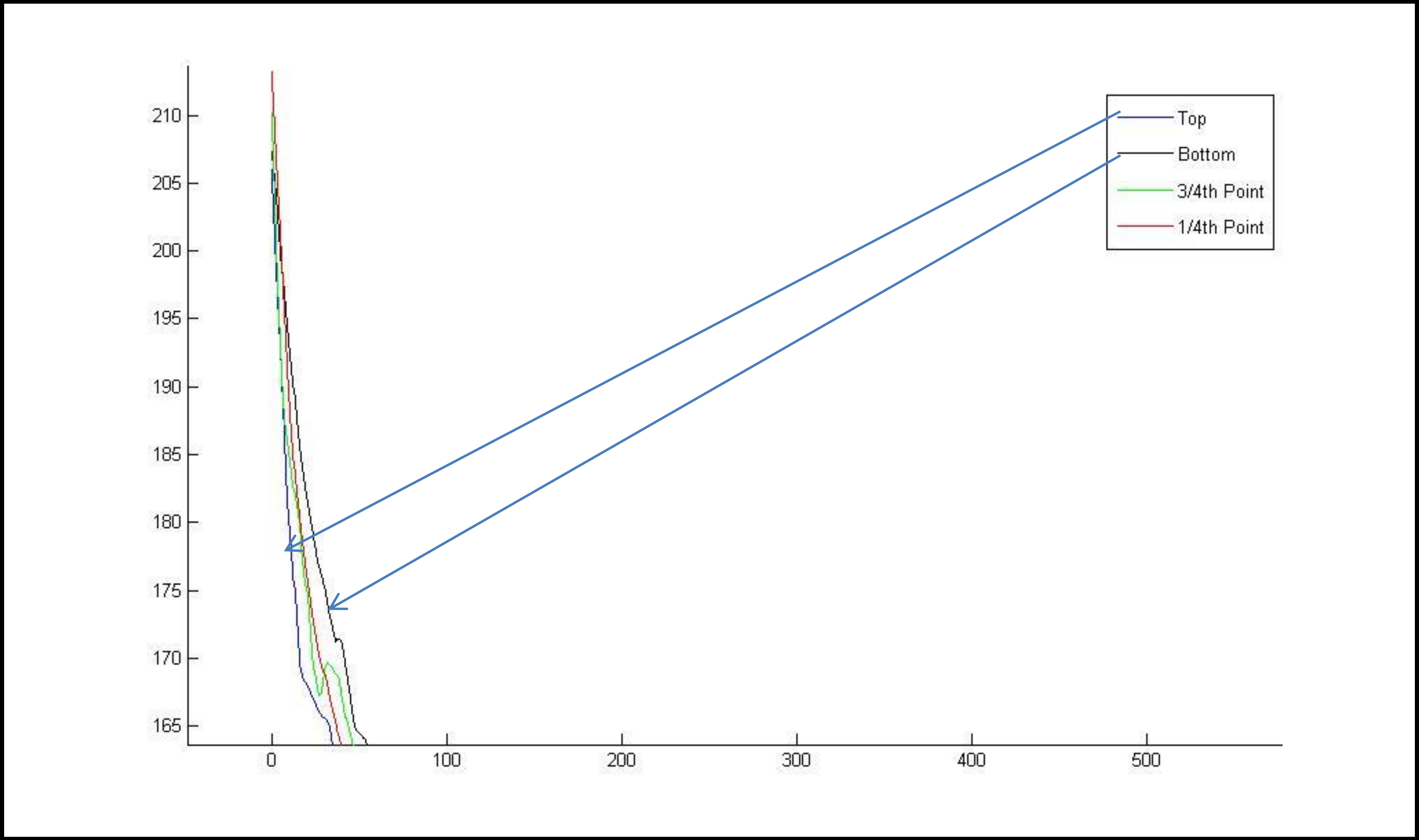


Pièce De Résistance



Cooling Of Aluminum Rod
Top
Bottom
3/4th Point
1/4th Point
Temperature (degreesCelsius)
220
200
180
160
140
120
100
80
60
40
20
0
500
1000
1500
2000
2500
Time (s)

Initial Phase

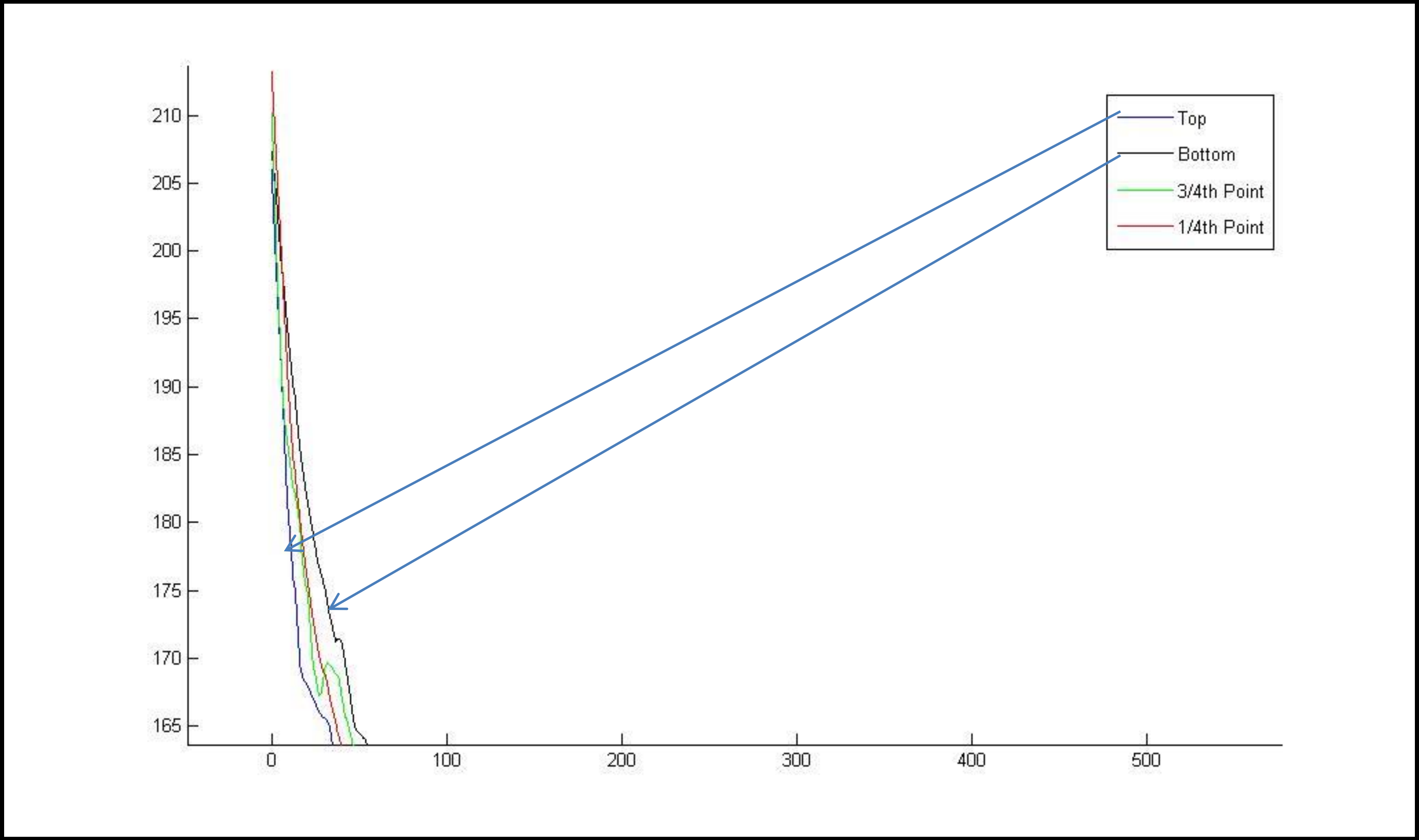


What to Bear in Mind?

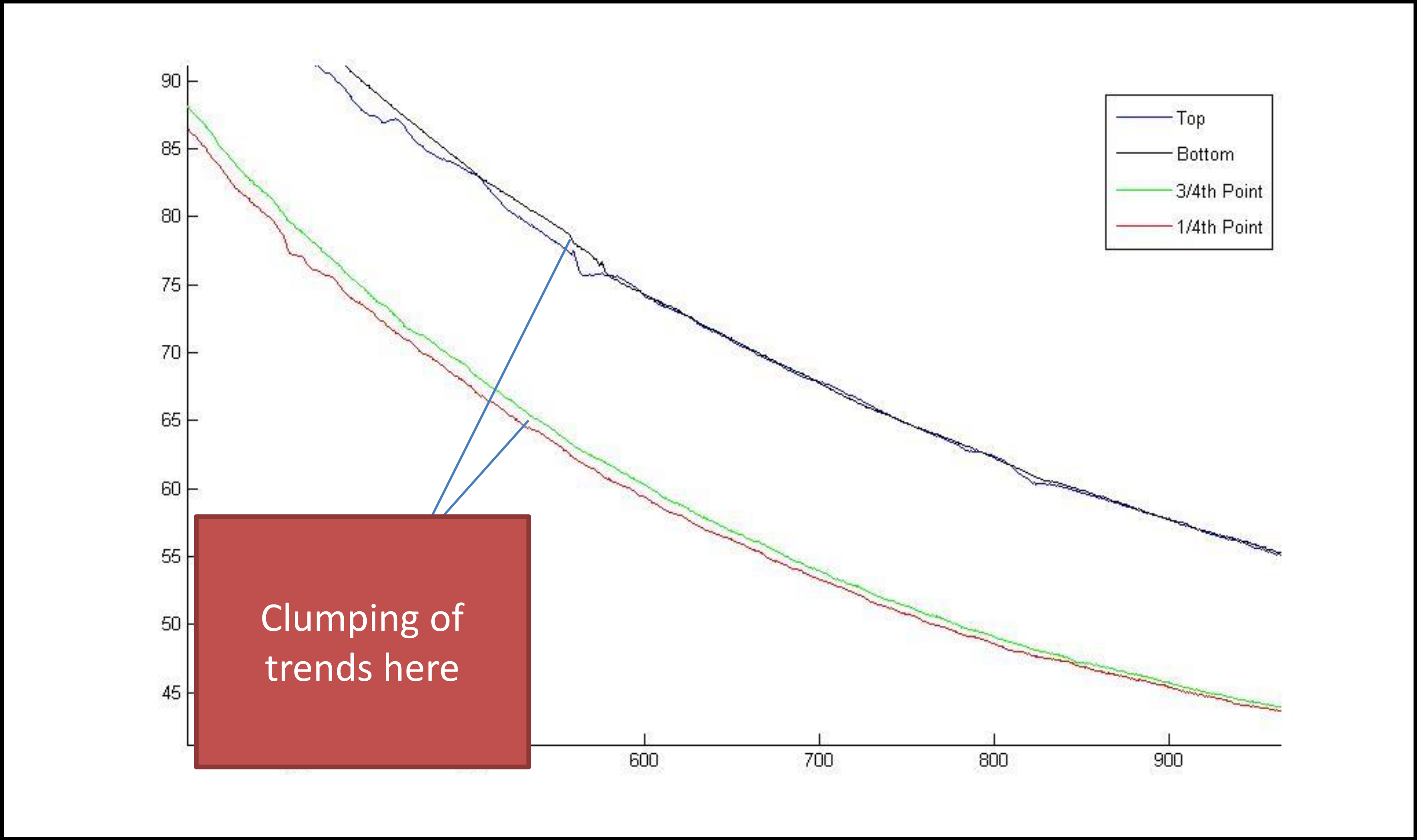
- Internal Heat Transfer
- Possibility of Draught
- Variable Temperature along the length of the rod
- Increased exposure to air at the top
- Flat on an insulator at the bottom

Now, lets take another look.

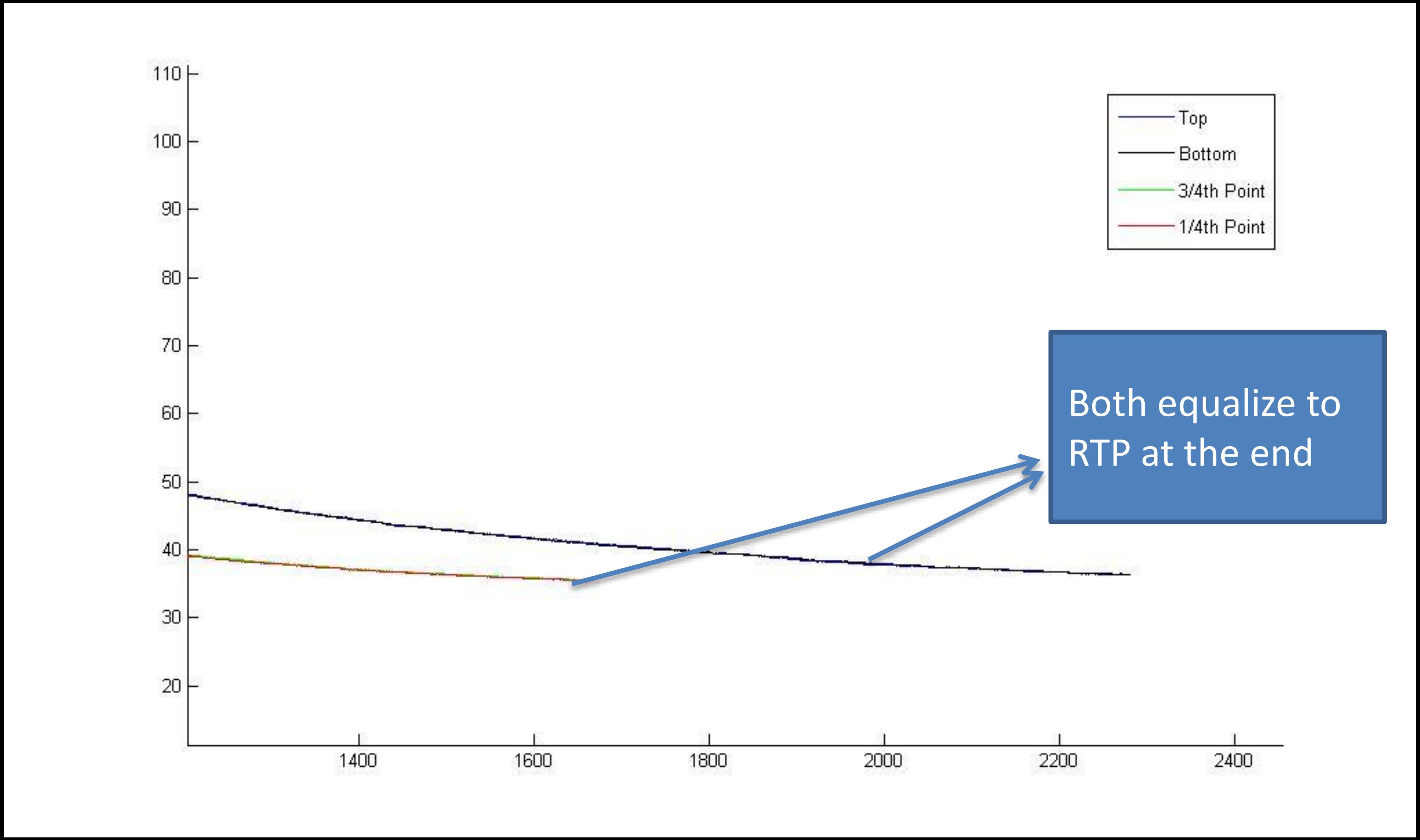
Initial Phase



Mid Cooling Phase



End of Cooling Phase



What have we learnt?

SCIENCE WORKS!

Who we are?

Batch of 2019 (SSE)

Danish Farid

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THANK YOU LUMS!