

Calibrating a Thermocouple and Investigating Heat Transfer

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The experiment was conducted over a time period of two weeks including the time taken for learning new softwares like LabVIEW and Latex and using the software MATLAB.

1 Learning the Basics of LabVIEW:

LabVIEW is a programming software that is being used in almost all experiments currently being done in Physics Lab. I spent the first few days learning the basics of LabVIEW with the help of Sir Sohaib Shamim, online tutorials and the help manual of the software itself. Sir then gave me a few programs to generate to ensure that I was familiar with the software. These included:

- Building a VI in which the temperature varied sinusoidally from 20° C to 40° C and displaying the output on a graph. The LED lighted when the temperature exceeded 32° C.
- Building a VI which generated random numbers and sine waves simultaneously. The LED lighted when the random number was greater than 0.5 and sine wave negative. These numbers were then stored in a text file along with the time it occurred at.
- Accessing data using DAQ and producing various results through LabVIEW codes.

Coding for these programs was fun. However it took time and a lot of effort. These programmes allowed me familiarity with variety of tools of LabVIEW including boolean comparison tools, case structures and flat sequence structures, writing text files, add,shift registers etc.

1.1 Temperature variation

This VI was programmed to vary sinusoidally from 20° C to 40° C and display the output on a graph. An LED indicator was added which lighted when the temperature exceeded 32° C. A modification to this program was then added to show output on graph only when LED lights, ie when temperature exceeded 32° C.

1.2 Writing to Text Files

Writing a code for this program was particularly difficult as this included using tools such as case structures and flat sequence structures, add,shift registers etc and most importantly writing to text files. The program when correctly coded, generated random numbers and sine waves simultaneously. An LED indicator was present which lighted only when the random number was greater than 0.5 and sine wave negative. These values along with the time they occurred at were then recorded in a text file. However after a lot of effort and in the end, by a little help from Dr. Sohaib I was finally able to code it correctly.

1.3 Data Acquisition and Further Processing

Finally, I moved onto acquiring external signals into PC using DAQ. We are using the **SCC-68 module** in the physics lab. I learned how to generate a signal, vary it and access it on computer. The LabVIEW program allowed for it being displayed on a graph. I also learned, by studying an already created program ‘thermal’, how we can use and modify these signals.

I then proceeded with the experiment at hand.

2 Heat Transfer and Thermocouple Calibration

2.1 Objective of Experiment

There were two objectives of this experiment. First was the calibration of the thermocouple, to be used, so that the voltage signals can be converted to temperature. The second was to observe how a heated object cools down with time and the factors affecting the cooling rate. In one part of the experiment the object was cooled by forced air currents (predominant heat loss by convection) and in the other the system was made to act like a black-body cavity (predominant heat loss by radiation).

2.2 Thermocouple Calibration

2.2.1 Purpose

A thermocouple is made up of two wires (of different in composition). These wires are joined at one end to form a junction and the other end is attached to DAQ, connected to the PC. The junction is placed at the point of which the temperature needs to be measured. Due to difference in temperature, a temperature gradient is created between the two ends of the wire. This causes an EMF to be generated along the wire. To find the temperature reading therefore, we calibrated the thermocouple.

2.2.2 Procedure and Data Analysis

About 1400 ml of water was heated to about 80° C and then allowed to cool. A digital thermometer and the thermocouple, to be calibrated, were inserted. Care was taken that the thermometer probe and thermocouple probe were as close to each other and remained at same depth throughout the experiment. Results were recorded in a table and a graph plotted in MATLAB. A linear best-fit line was drawn and equation was found using MATLAB. This equation allowed conversion of EMF to temperature.

2.2.3 Results

The resulting graph is shown in Figure 1.

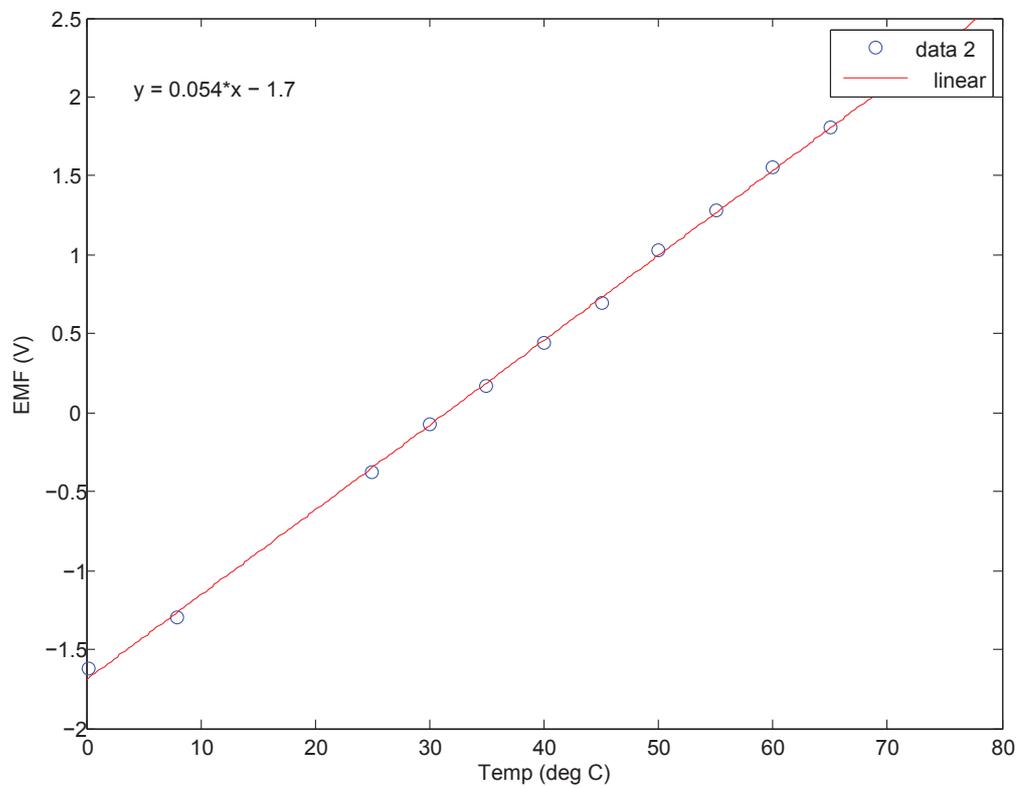


Figure 1: Thermocouple Calibration

The Equation obtained was:

$$T = 19\varepsilon + 31, \quad (1)$$

where T is the temperature in degrees Centigrade and ε is the EMF.

2.3 Cooling By Forced Air Currents

This was to find how forced convection changes value of h . We used a black-coated, roughened, mild steel cylinder for the complete experiment.

2.3.1 Setup and Procedure

We had to find mass and surface area of the cylinder. An electronic mass balance was used to find mass of the cylinder and a vernier calliper was used to find the diameter of the cylinder. Readings at random points were taken and averaged to reduce error.

$$\text{mass} = 0.472 \text{ g}. \quad (2)$$

$$\text{Area} = 2\pi r^2 + \pi r h = 0.0104 \text{ m}^2. \quad (3)$$

After taking measurements, the cylinder was kept in a graphite bath and heated to about 200°C . The heating took approximately 2 hours. Meanwhile two thermocouples were connected to **SCC-68 module**. The junction of one was attached to the cavity in such a way so that it measures the temperature of cavity air. The other was attached to a clamp. The cylinder after heating was placed immediately in the cavity, and the clamp attached to it. The transfer was done using tongs and thermal gloves and done as quickly as possible to allow for minimum heat loss. The fan was switched on and labVIEW program run. A perforated lid was placed on top of the cavity to close it off.

2.3.2 Data Acquisition and Data Analysis Program

I modified the previously created program 'thermal' to adapt it to our current objectives. The program now gave us the values of EMF generated by each thermocouples instead of converting it to temperature. The files therefore gave us EMF along with time. These values were stored in a file which was

stored in the user defined position(*the user has to first give file pathways for the program to run*). I then coded a new MATLAB file, “thermal2”, which allows for the loading of this data into MATLAB and processes it to convert EMF into temperature. To do this, the user has to input gradient and y-intercept of the equation found for thermocouple calibration. I kept in mind the fact that our incoming batch will be using the MATLAB for the first time and therefore simplified the procedure for them. After running the MATLAB code, the user has to use the obtained vectors to plot graphs and use the values to find h , by inserting the required equation.

2.3.3 Results

The cooling down took approximately $1\frac{1}{2}$ hours. The graphs obtained are shown in Figure 2.

To find h the following equation was inserted in MATLAB:

$$h = \frac{\frac{(-mc)}{(A)} \frac{dT_2}{dt} - \epsilon\sigma(T_2^4 - T_1^4)}{T_2 - T_1} \quad (4)$$

2.4 Black Body Cavity

This part of experiment dealt with heat loss due to radiation.

2.4.1 Setup and Procedure

The cylinder was again heated to about 200° C, in a graphite bath. The interior of the cavity was painted black to allow for absorption of radiation from heated cylinder. In addition the fan was covered with another lid with its interior painted black. The cylinder was placed in the cavity using tongs and thermal gloves immediately and thermocouple clamped to it. This time the cavity was closed using a non-perforated lid. LabVIEW program was then run.

2.4.2 Data Acquisition and Data Analysis

Again LabVIEW was used to obtain the EMF signals and store them in a file along with a time stamp. The MATLAB code ‘thermal2.m’ was run to convert to process the data as before. The process of cooling down took approximately 3 hours.

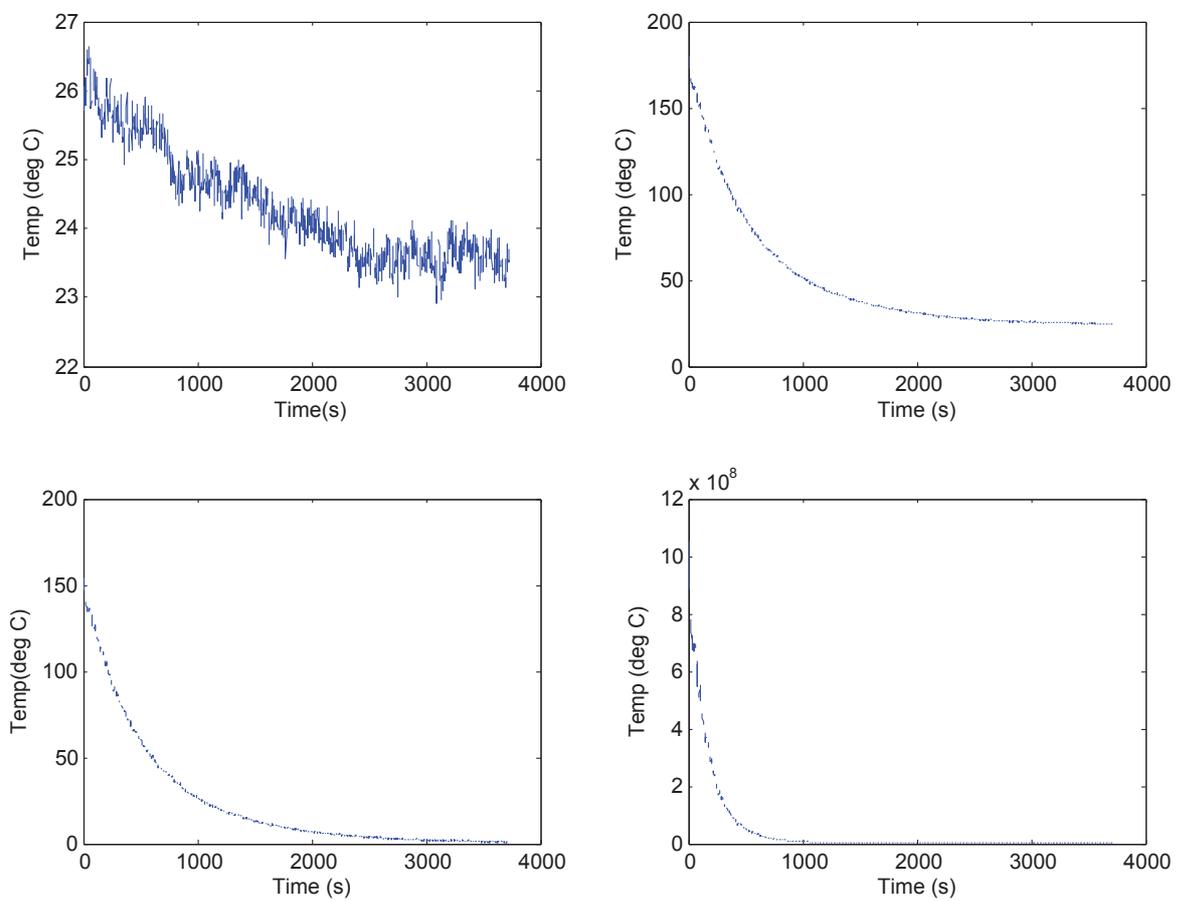


Figure 2: (a) Cooling Curve of Cavity,(b) Cooling curve of Cylinder, (c) $T_2 - T_1$, (d) $T_2^4 - T_1^4$.

2.4.3 Results

The graphs obtained are shown in Figure 4.

3 Report Writing

The last part of this experiment was to write a report. This was to be done using \LaTeX . I downloaded and installed the required softwares for this. Then I spent approximately 1 and a half day trying to learn how to use this software, which uses WinEdt as interface. I think I am still not very clear about how to use \LaTeX , however I was able to generate this report, which was a difficult process for me.

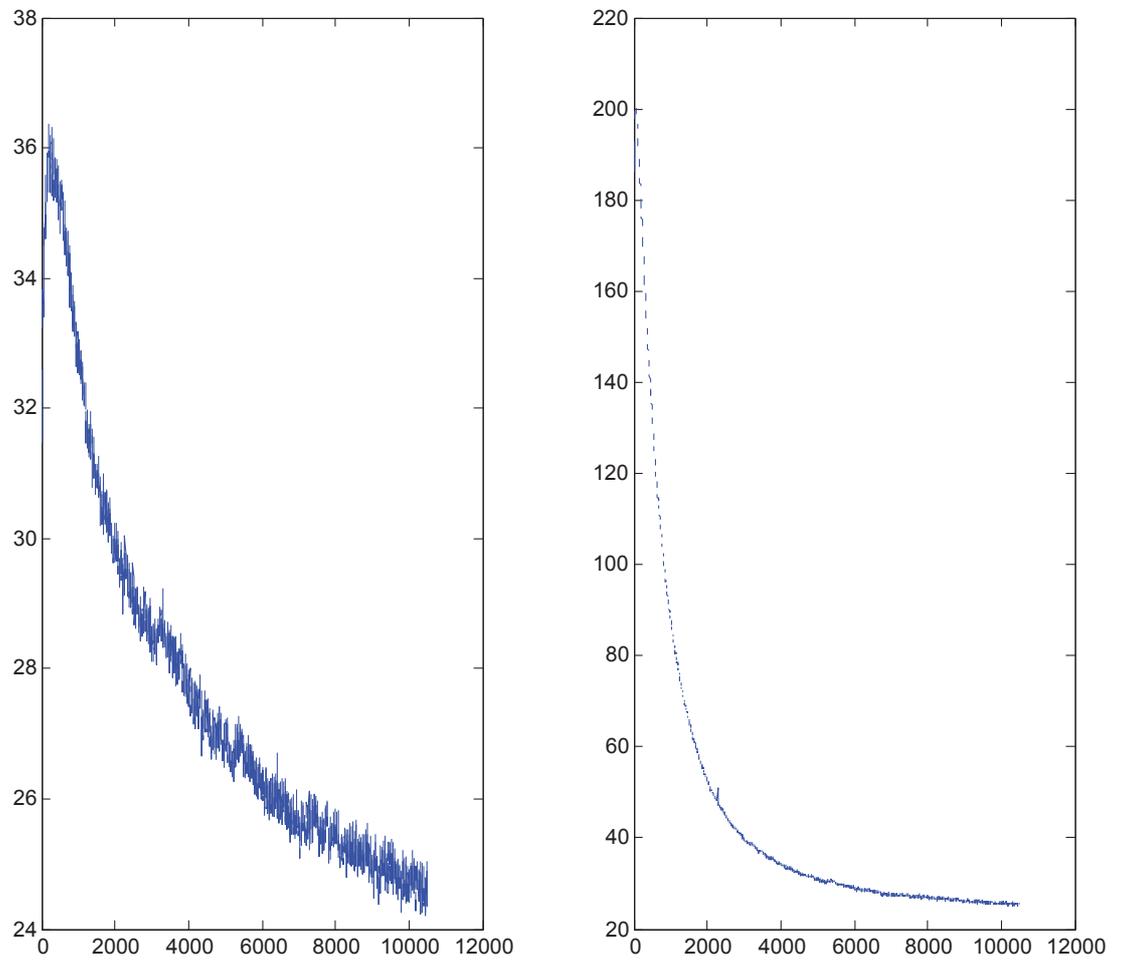


Figure 3: (a) Cooling Curve of Cavity,(b)Cooling curve of Cylinder.