Team H

Experiment no. 2

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REPORT

Temperature Measurement, Heat Exchanger

For the course

MEC304 Integrated Mechanical Laboratory – I

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Written by	**Meet Vyas(AU2040084)**
Proofed by	**Jog Desai(AU2040089)**
Team members:	Spandan Mehta(AU2040073)
Team members:	Jay Vasani(AU2040184

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Executive summary

Abstract:

Temperature measurement is a critical aspect of various industries and applications. Accurate and reliable temperature measurement is essential in fields such as medical diagnosis, industrial process control, environmental monitoring, and material science research and development. The appropriate choice of temperature measurement device depends on factors such as the application requirements and temperature range.

Objectives:

The objective of this experiment was to explore different techniques used for temperature measurement and gain familiarity with national and international standards for temperature measurement. Other objectives included understanding the installation of temperature sensors such as thermowell, making a thermocouple junction, and using it, creating a reference temperature ice bath, using a resistance temperature detector (RTD), using a thermal imaging camera, and learning calibration of temperature sensors.

Methodology:

In this experiment, we utilized various temperature measuring devices, including a thermocouple, resistance temperature detector, thermistor, normal thermometer, infrared (non-contact) thermometer, and thermal imaging camera. We began by recording the ambient temperature and then made an ice bath using tap water as a reference. We then used a water heater to heat the water twice, recording the temperatures for all the available temperature-measuring devices.

Results:

Our findings suggest that different temperature measurement devices have varying degrees of accuracy. Therefore, the choice of temperature measuring device depends on the specific application for which it is required.

Conclusion:

In conclusion, temperature measurement is a crucial aspect of various industries and applications. Selecting the appropriate temperature-measuring device depends on factors such as application requirements, temperature range, and accuracy. The use of the different temperature measuring devices may be necessary for different applications. The techniques explored in this experiment can be applied in various industries to ensure accurate and reliable temperature measurements.

Keywords — Thermometer, Temperature Measurement, Thermocouple, Resistance Temperature Detector (RTD), Infrared(Non-Contact) Thermometer, Thermal Imaging Camera

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1. Introduction

- Introduction:

Measurement of temperature is crucial to many different sectors and applications. For diverse systems to operate correctly and be optimized, accurate and dependable temperature measurement is required. The failure of a system, decreased effectiveness, and even safety risks might result from inaccurate temperature measurement. The purpose of this experiment is to investigate various temperature measurement methods and highlight the significance of choosing the right thermometer for a given application.

- Motivation:

The goal of this experiment is to better understand temperature measurement methods and the significance of choosing the appropriate instrument for a given application. This information can be used in a variety of fields, including research and development in physics, chemistry, and material science, HVAC systems, industrial operations, and medicinal applications. The effectiveness and safety of various systems can be increased by comprehending temperature measurement methods and choosing the proper temperature measuring apparatus.

Applications:

Measurement of temperature is important in many different fields and applications. Accurate temperature measurement is essential in the HVAC sector for efficient system functioning. Temperature measurement is crucial for process improvement and quality assurance in industrial settings. Temperature measurement is essential for patient diagnosis and care in medical applications. Temperature measurement is essential for environmental monitoring in order to track and research the impacts of climate change. Temperature measurement is crucial in research and development for comprehending the physical characteristics of materials and chemical processes.

Engineering Challenges

The selection of the proper temperature measuring instrument is one of the main engineering problems associated with temperature measurement. Various temperature measurement instruments with varied degrees of precision and range are needed for various applications. The installation of temperature sensors, such as thermocouples and resistance temperature detectors, to provide precise temperature monitoring is another engineering challenge. To achieve reliable temperature measurement, temperature measuring equipment needs to be calibrated. Moreover, temperature measurement is crucial during the design and testing phases of developing new products to ensure the final product performs as planned. Temperature measurement is required for items that are in use to spot potential problems and enhance system performance.

2. Practical applications study

2.1 Solar PV Cells

In the solar thermal course, we worked with solar photovoltaic (PV) cells, which convert solar energy into electrical energy. The efficiency of solar PV cells depends on various factors, including temperature, shading, and spectral response. Proper temperature measurement is crucial for optimizing the efficiency of solar PV cells.

Field Experiment:

I conducted a field experiment to measure the temperature of the solar PV cell available at the University for our project of the course. I used it in the garden outside of the fabrication shop as it allowed me to directly understand the importance of the ambient temperature and correct temperature measurement to calculate the accuracy of the solar PV panel.

Methodology:

As my project is of top sprinkler cooling for the solar panel, I have attached two HW550 MAX6675 thermocouples to my setup. This thermocouple has the following specifications.

Size: 32*16*14mm
PCB Color: blue
Interface: SPI
Test Temperature Range: 0 ° ~ 1024 °, the converter temperature resolution is 0.25 °
Operating Voltage Range: 3.0 ~ 5.5V
Operating Current: 50mA
Operating Temperature Range: -20 ° ~ 85 °
Module Size: 15mm * 28mm, with a 3mm diameter screw holes
K type thermocouple junction location, use 301 ordinary terminals

These thermocouples were added to the setup in such a way that one was attached to the side of the solar panel to measure the temperature and the other one was attached to the source of the water supply for the water sprinkler to measure the change in efficiency by using the water cooling system and to measure temperature changes on the surface of the solar panel and in the ambient temperature.

Data Acquisition:

I collected data by recording the temperature measurements at different times throughout the day. I used an Arduino mega board connected to my laptop to measure the data. The data loggers were connected to the thermocouples, and the data was stored in my computer for later analysis.

Analysis:

I analyzed the collected temperature data to determine the effect of water cooling for Solar PV. I used the data to analyze efficiency at different times of the day and different temperatures of the water supply.

Desired Outcome:

Gaining a deeper knowledge of temperature measurement methods and how they are used in solar PV cells was the study's desired aim. We were able to spot possible problems and suggest fixes to increase the efficiency of solar PV cells by using several approaches to measure their temperature. This information can be used in a variety of contexts to optimize solar PV cell installation and raise energy efficiency.

2.2 Observations and findings

We observed that the temperature of the solar panel needs to be accurately measured with 2 significant digits to know the change in efficiency due to the top cooling with sprinkler system attached.

3. Theoretical and conceptual basics

3.1 Theoretical basis

a. Thermocouple

1. Seebeck effect (Thermoelectric effect)

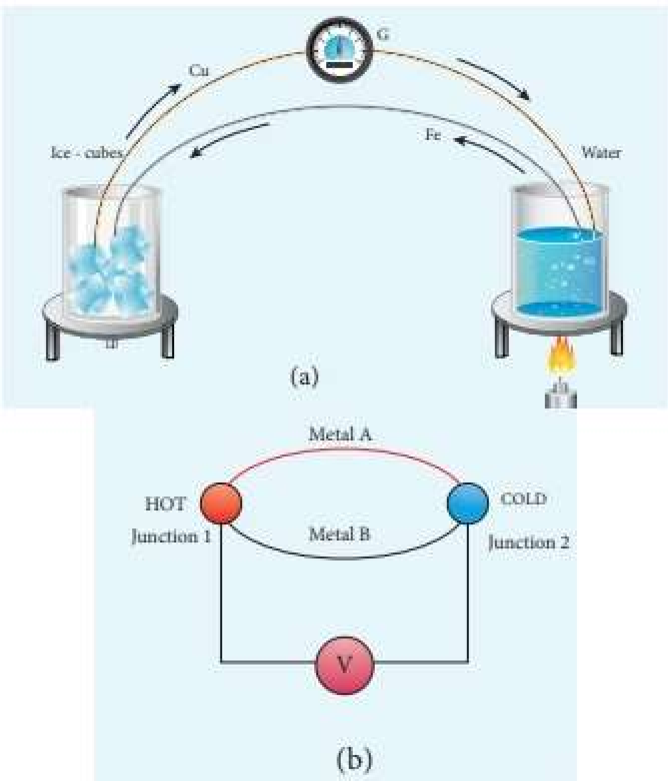


Figure 2.35 Seebeck effect (Thermocouple)

BrainKart. (n.d.). Seebeck Effect [Online image]. Retrieved from https://www.brainkart.com/article/Seebeck-effect_38434/.

- The seebeck effect also known as the thermoelectric effect, is the phenomenon where a temperature difference between two different types of conductive materials creates an electric voltage.

- The seebeck effect is based on the fact that when two different conductive materials are brought into contact a temperature difference between them can result in the migration of electrons from one material to the other. This electron migration create a difference in the electric potential between the two materials, and thus an electric current flows between them.
- The seebeck effect is used in thermocouples which are devices that use two different conductive materials to measure temperature. A thermocouple consists of two wires made of different metals, which are connected at two ends to form a closed circuit.

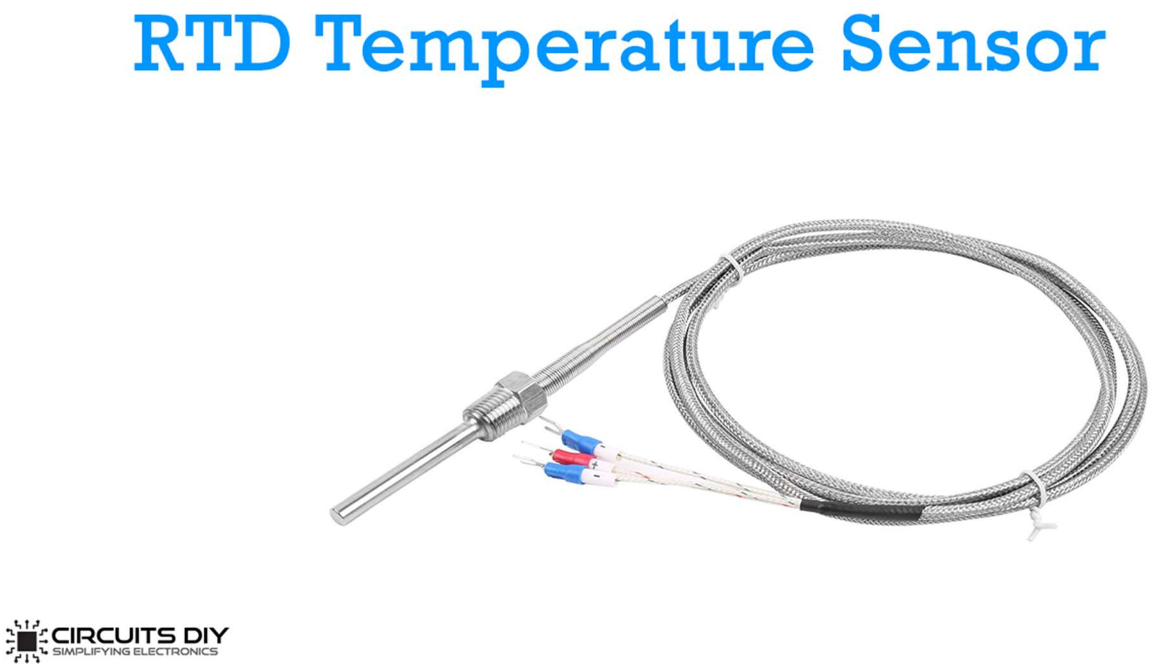
2. Seebeck Coefficient

- The seebeck coefficient also known as the thermoelectric power is a material dependent property that quantifies the magnitude of the voltage produced by the seebeck effect per unit temperature difference between two points in a conductive material.

3. Difference in bare bead and shielded thermocouple

- Bare-bead thermocouple consists of two exposed conductors whereas shielded thermocouples have a protective sheath surrounding the conductors. Shielded thermocouples provide better protection against environmental factors such as moisture, abrasion and corrosion, making them suitable for harsh environments. However, bare-bead thermocouples have a faster response time and can be more sensitive to small temperature changes due to exposed conductors.

b. Resistance Temperature Detector (RTD)



Circuits DIY. (2016). PT100 RTD Sensor Module [Online image]. Retrieved from https://www.circuits-diy.com/pt100-rtd-sensor-module/.

- RTD works on the principle of change in electrical resistance of a material with change in temperature.
- Platinum is the material used to make RTD elements the most frequently, however other materials like nickel, copper, and rhodium are also employed.
- With rising temperature, the RTD element's resistance rises linearly. The temperature is measured using this variation in resistance. RTDs are a popular option for precise temperature measurements because of their great accuracy, stability, and repeatability.

- Based on the design of the sensing element, RTDs can be divided into two types: wire-wound and thin-film RTDs. Whereas thin-film RTDs employ a thin coating of platinum coated on a substrate, wire-wound RTDs use a thin platinum wire wrapped around a ceramic or glass core. Compared to wire-wound RTDs, thin-film RTDs are often thinner and respond more quickly.

c. Thermistor

- A thermistor is a temperature sensor that works on the principle of a change in electrical resistance with temperature. It is made of semiconductor material, such as metal oxides, with a negative temperature coefficient, meaning that its resistance decreases as the temperature increases. The change in resistance is highly sensitive to temperature and can be used to measure temperature with high accuracy and resolution.

d. Non-contact Thermometer

- Non-contact thermometers use infrared technology to measure the temperature of a person without the need for physical contact. The device detects the infrared radiation emitted by the person's body and converts it into a temperature reading. This allows for quick and hygienic temperature measurements, making it ideal for use in public places during a pandemic.

e. Thermal Imaging Cameras

- Thermal Imaging Cameras operate on the principle of detecting infrared radiation emitted by objects or people. They use a special lens to focus the infrared radiation on to a detector, which converts it into an image. The resulting image displays different colors or shades of gray to represent variations in temperature, allowing for non-contact temperature measurements and detection of temperature anomalies.

3.2 Abbreviations and Acronyms (Times New Roman, Font size 10, Italic)

HVAC – Heating Ventilation and Air Conditioning

RTD: Resistance Temperature Detector

TCR: Temperature Coefficient of Resistance

3.3 Equations (Times New Roman, Font size 12, Italic)

The rate of heat transfer is proportional to the temperature difference between the objects and the thermal conductivity of the material. This concept is described by the Fourier's law of heat conduction:

$$q = -kA(dT/dx) \tag{1}$$

where q is the heat transfer rate, k is the thermal conductivity, A is the surface area, and (dT/dx) is the temperature gradient across the surface.

The seebeck coefficient, denoted as S, defined as the ratio of the electric field to the temperature gradient in a given material

$$S = -\Delta V/\Delta T \tag{2}$$

Here ΔV is the voltage difference produced between the two points in the material due to a temperature difference ΔT between them. The negative sign in the equation represents the fact that the direction of the voltage is opposite to the voltage of the gradient.

3.4 Validation with theory

NA

4. Pre-experiment planning

Prior to starting the experiment, several activities were performed to ensure the safety of the team and the success of the experiment.

4.1 Safety

The apparatus used for the temperature measurement experiment was first tested along with grounding and testing each of the electrical equipment for pretesting. We also made our own thermocouple using a bare bead solder by separating the two different metal wires from the wire which was allotted to us. This was later used as a temperature measuring device. The heater used in the water heating process was also tested before using for the experiment to not cause any fires. Every member of the group was wearing full clothing along with shoes to maximise the protection from any hazardous event occurring. We cleaned the water beaker and cleaned it off the beaker before using it as a test apparatus. We did the experiment in a secluded environment and there was no possibility of anything interfering with the experiment.

4.2 Independent and dependent variables

The fixed parameters in the experiment were the temperature measuring devices used and the heating capacity of the water heater. Both of these can be known by reading the specifications of these devices. The ambient temperature and the tap water temperature were the independent parameters.

The dependent variable was the temperature of the hot water after it was heated with the water heater, as measured by the thermometer depending on the water heating capacity of the heater.

4.3 Result formulae/relations

There were no such result relations for this experiment.

4.4 Pre-test uncertainty analysis

To determine the systematic standard uncertainty in each measurement, the uncertainty associated with each of the fixed and independent variables was calculated. The uncertainty in the thermometer was determined to be ±0.5°C. The uncertainty associated with the volume of water used and the initial temperature of the water were both negligible.

The random standard uncertainty for each measurement was calculated based on the data collected during the experiment. The standard deviation of the readings was used to calculate the random uncertainty in the measurements.

Overall, the uncertainty values were determined to be adequate to successfully arrive at conclusions on the questions posed in the objectives.

4.5 Test matrix

Serial Number	System	Thermometer (℃)	IR Thermometer (℃)	Thermal Imaging (℃)	Thermistor (℃)	Thermocouple (℃)
1	Ambient					
2	Tap Water					
3	Heated Water-1					
4	Heated Water-2					

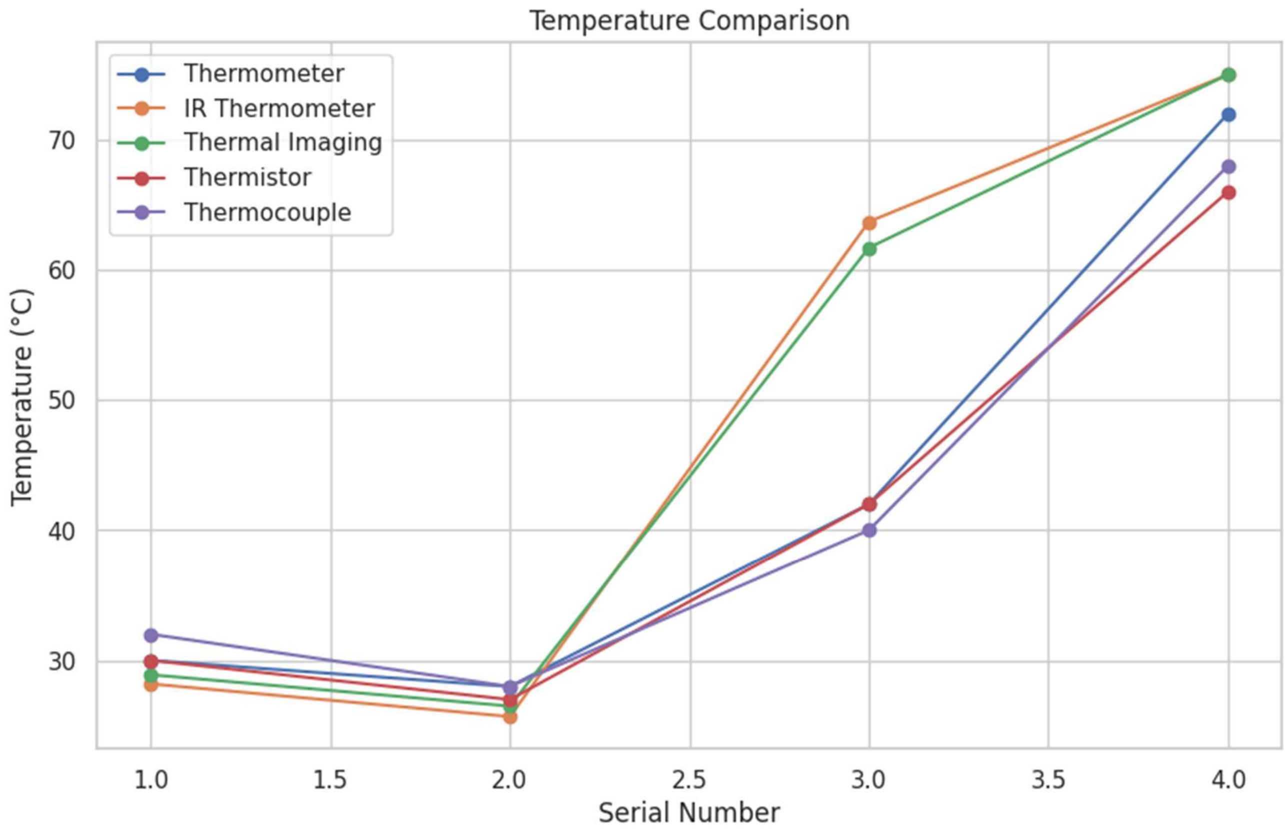
5. Experiment execution

We first calibrated all the temperature sensing devices and checked all other factors for errors and uncertainties. We then checked the ambient for temperature measurement. After that, we created a test apparatus using a beaker by cleaning it and then checking the tap water temperature. After that, we heated the water in two turns using a water heater and then noted down the temperature using each temperature sensing device which led to the end of the experiment.

6. Data analysis and discussion

Serial Number	System	Thermometer (℃)	IR Thermometer (℃)	Thermal Imaging (℃)	Thermistor (℃)	Thermocouple (℃)
1	Ambient	30	28.2	28.9	30	32
2	Tap Water	28	25.7	26.5	27	28
3	Heated Water-1	42	63.7	61.7	42	40
4	Heated Water-2	72	75	75	66	68

- Uncertainty -



Instrument	Mean (°C)	Standard Deviation (°C)	Least Count (°C)	Error (%)
Thermometer	43	17.578	1	40.88
IR Thermometer	48.15	21.591	0.1	44.84
Thermal Imaging	48.025	20.879	0.1	43.48
Thermistor	41.25	15.352	1	37.22
Thermocouple	42	15.62	1	37.19

- Inference

1. Thermometer: The thermometer shows a relatively moderate error of 40.88%, indicating that it may have some degree of accuracy in temperature measurement. However, the wide standard deviation of 17.578°C suggests a significant variation in its readings, impacting its precision.
2. IR Thermometer: The IR thermometer exhibits a higher error of 44.84%, indicating a larger deviation from the true value. The relatively large standard deviation of 21.591°C further suggests a significant variation in its measurements, reducing its precision compared to other instruments.
3. Thermal Imaging: The thermal imaging device shows a similar error of 43.48% as the IR thermometer, suggesting a comparable level of deviation from the actual temperature. The standard deviation of 20.879°C indicates moderate variation in measurements, affecting its precision.
4. Thermistor: The thermistor demonstrates a lower error of 37.22%, implying a relatively smaller deviation from the true temperature. The standard deviation of 15.352°C suggests a moderate variation in its readings, indicating a reasonable level of precision.
5. Thermocouple: The thermocouple exhibits a similar error of 37.19% as the thermistor, indicating a comparable level of deviation from the actual temperature. The standard deviation

of 15.620°C suggests a moderate variation in measurements, implying a reasonable level of precision.

7. Conclusions

Temperature Measurement is an important aspect of many industries and applications, from medical diagnosis to industrial process control. Various types of thermometers, including non-contact thermometers and thermocouples, are used to accurately and reliably measure temperature. Choosing the appropriate type of thermometer depends on the application, requirements, temperature range and other factors relating to the equipment. The thermistor and thermocouple appear to provide relatively more accurate and precise temperature measurements compared to the thermometer, IR thermometer, and thermal imaging device.

8. References

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9. Material to be uploaded

Specification Sheets