IOT ENABLED THERMAL LUNCH-BOX

A Project report submitted in partial fulfilment of the requirements for the award of the degree of

Bachelor of Technology
in
Mechanical Engineering

Submitted by

B. VAMSI KRISHNA	**319126520069**
P. MANOHAR SAI	**319126520100**
S. YADIDIAH SUNDAR	**319126520110**
P. ANAND RAJ	**319126520064**
K. UDAY KUMAR	**319126520086**

Under the Esteemed Guidance of

J.V. BHANU TEJ **M. Tech., (Ph.D).**

Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES (A)

(Permanently Affiliated to Andhra University, Approved by AICTE, Accredited by NBA Tier-I, NAAC)

Sangivalasa, Visakhapatnam (District) Andhra Pradesh -India– 531162.

APRIL 2023

DEPARTMENT OF MECHANICAL ENGINEERING
ANIL NEERUKONDA INSTITUTE OF TECHNOGY & SCIENCES
(UGC Autonomous & Permanently Affiliated to Andhra University)

CERTIFICATE

This is to certify that the Project Report entitled "**IOT ENABLED THERMAL LUNCH-BOX**" being submitted by **B. Vamsi Krishna (319126520069), P. Manohar Sai (319126520100), S. Yadidiah Sundar (3191265201100), P. Anand Raj (319126520064), K. Uday Kumar (319126520086)** to the Department of Mechanical Engineering, ANITS is a record of the bonafide work carried out by them under the esteemed guidance of **Mr. J.V. Bhanu Tej**. The results embodied in the report have not been submitted to any other University or Institute for the award of any degree or diploma.

PROFESSOR & HEAD
Department of Mechanical Engineering
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCE
Sangivalasa-531 162 VISAKHAPATNAM Dist. A.P.

Project Guide	**Head of the Department**
Mr. J. V BHANU TEJ	**Dr. B. NAGA RAJU**
Assistant Professor	Professor
Dept. of Mechanical Engineering,	Dept. of Mechanical Engineering
ANITS	ANITS

THIS PROJECT IS APPROVED BY THE BOARD OF EXAMINERS

INTERNAL EXAMINER ____________ 18.4.23

EXTERNAL EXAMINER 18/4/23

ACKNOWLEDGEMENTS

We express immensely our deep sense of gratitude to **MR J.V. BHANU TEJ** Assistant Professor, Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences, Sangivalasa, Bheemunipatnam Mandal, Visakhapatnam District for his valuable guidance and encouragement at every stage of the work made it a successful fulfilment.

We are very thankful to Prof. **K. SRI RAMA KRISHNA**, Principal. Prof. **B. Naga Raju**, Head of the Department, Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences for their valuable suggestions.

We express our sincere thanks to the members of non-teaching staff of Mechanical Engineering For their Kind co-operation and support to carry on work**.**

Last but not the least, we like to convey our thanks to all who have contributed either directly or indirectly for the completion of our work**.**

B. VAMSI KRISHNA	(319126520069)
P. MANOHAR SAI	(319126520100)
S. SUNDAR	(319126520110)
P. ANAND RAJ	(319126520064)
K. UDAY KUMAR	(319126520086)

ABSTRACT

Our project aimed to address the problems with existing thermal lunch boxes, such as moisture build-up and bulkiness, as well as the limitations of traditional heating boxes that require AC power and take more time to heat. To achieve this, we designed an IoT-enabled thermal lunch box that allows for a controlled heating cycle prior to lunchtime through a mobile app and Wi-Fi.

We used Peltier models to achieve the heating function, with timing and IoT operation achieved through node MCU and relays. Solar panels were used to charge batteries for this operation. To optimize the design, we conducted transient analysis using Ansys software on different shapes and materials of the box.

We fabricated and tested the designed model and compared the results with the Ansys simulation. We also tested different shapes of the box under similar boundary conditions in Ansys and found that a round box was the most efficient for thermal distribution to food.

Keywords: *ANSYS, IOT (internet of things) , Peltier Module, NODE MCU*

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF GRAPHS

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Overview of Thermal Lunch Box

A thermal lunch box, sometimes referred to as a thermal food container, is a particular kind of lunch box made to keep food warm or cold for a long time. These lunch boxes are often constructed from insulated materials that can hold heat or cold, such as foam, plastic, or metal. When going to work, school, or on a picnic, persons who want to bring hot or cold food with them are best served by thermal lunchboxes. From little containers that hold a single serving to huge boxes that may store a whole dinner for several people, they are available in a range of forms and sizes.

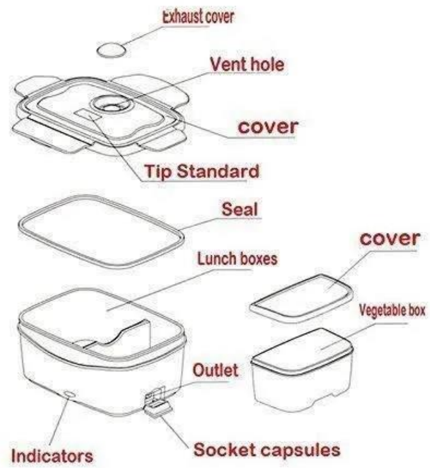


Fig 1.1 **Thermal Lunch Box**

A tight-fitting lid is a common feature of thermal lunch boxes that helps keep heat or cold inside. Some also have built-in cutlery, including forks and spoons. They are more environmentally friendly than disposable containers because they are frequently simple to clean and durable.

In general, thermal lunch boxes are an easy and useful way to take food and maintain the proper temperature while also minimizing waste and saving money on eating out for lunch.

1.2 **Types of Lunch Boxes**

There are numerous varieties of lunch boxes on the market, each with special characteristics and aesthetics. Here are a few of the most well-liked lunchbox designs:

- **Insulated lunchboxes**: These are lunchboxes that maintain the proper temperature for the food inside. Typically, they are constructed from insulating materials like foam, plastic, or metal.

Fig 1.2 **Insulated lunchbox**

- **Bento Boxes**: Bento boxes are a common style of lunchbox that originated in Japan and are now well-known all over the world. They make it simple to pack a well-balanced supper because they are made to keep various types of food in distinct compartments.

Fig 1.3 **Bento Lunch Box**

- **Lunchboxes Made with Sustainable Materials**: These lunchboxes are built from environmentally friendly materials like glass, stainless steel, or bamboo. They are an environmentally beneficial choice because they are recyclable and cut down on waste.

Fig 1.4 **Eco-Friendly Lunch Boxes**

- **Disposable Lunch boxes:** Paper or plastic lunch trays meant for single use are considered disposable. They are useful at outdoor gatherings, picnics, and times without access to restrooms.

Fig 1.5 **Disposable Lunch boxes**

❖ **Electric lunchboxes**: To warm the food inside, these lunchboxes plug into an electrical outlet and have an integrated heating system. These are perfect for those without access to a microwave who nevertheless want a warm lunch.

Fig 1.6 **Electric lunchbox**

1.3 HEAT TRANSFER

Whether you want to keep your food warm or cold for a long time, understanding heat transmission in thermal lunch boxes is crucial. There are three basic methods that heat is transferred: conduction, convection, and radiation.

Heat is transferred through a substance or between materials in contact when **Conduction** occurs. With a thermal lunch box, the walls and lid are often made of insulating materials that reduce the rate of heat transfer by conduction, like plastic or foam. This aids in maintaining a steady temperature inside the container.

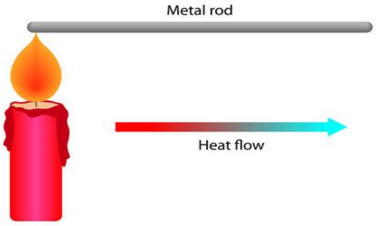


Fig 1.7 **Conduction**

Heat is transferred via a moving fluid, such as air or water, by **Convection**. With a thermal lunch box, the air inside the container can function as a fluid, and the air's movement can aid in uniformly dispersing heat inside the box. To reduce convection and boost insulation, certain thermal lunchboxes are built with features like air vents or airtight sealing.

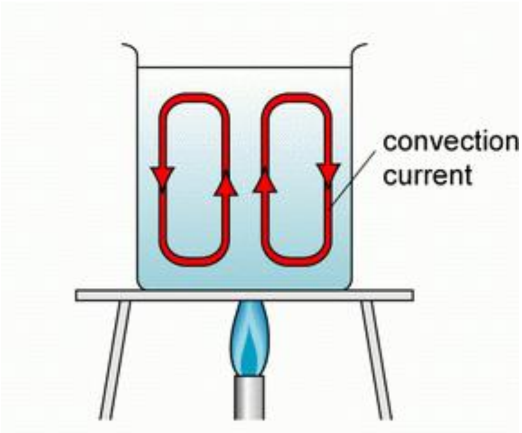


Fig 1.8 **Convection**

Heat is transferred via electromagnetic waves, or **Radiation**. Food can still be kept warm or cold via radiation, even though it normally contributes less to heat transfer in thermal lunch boxes than conduction and convection. For instance, if the thermal lunch box is placed in direct sunshine, solar radiation may heat it up and raise the temperature within.

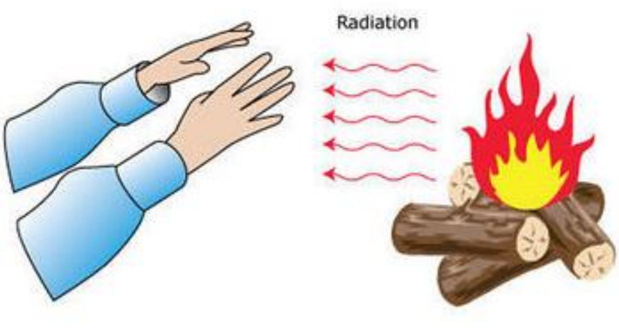


Fig 1.9 **Radiation**

1.4 SOLAR ENERGY

The energy produced by the sun's rays is referred to as **Solar energy**. It is a plentiful and renewable form of energy that is gaining popularity to produce electricity. Solar PV systems use photovoltaic cells in solar panels, which turn sunlight into direct current (DC) electricity. An inverter is then used to transform this electricity into alternating current (AC) electricity, which can be utilized to power residences, companies, and even entire cities.

All things considered, solar energy is a promising renewable energy source that has the potential to be essential in our move away from fossil fuels and towards a more sustainable energy future.

Fig 1.10 **SOLAR ENERGY**

1.5 NODE MCU

Using the Lua scripting language, developers can create IoT (Internet of Things) applications with the help of Node MCU, an open-source firmware and development kit. Its foundation is the ESP8266 microcontroller, which has built-in Wi-Fi connectivity and supports a variety of input/output possibilities.

For developers to quickly prototype and create IoT applications, Node MCU offers a straightforward and user-friendly platform. Wi-Fi connectivity, TCP/IP networking, and a variety of input/output choices, such as digital and analogue inputs and outputs, PWM (pulse width modulation) outputs, are all supported natively by this device.

The Lua scripting language, which is a compact, simple-to-learn programming language that works well for IoT applications, can be used to programme the Node MCU firmware. Moreover, Node MCU comes with several libraries and APIs that make it easier for developers to create and deploy IoT applications.

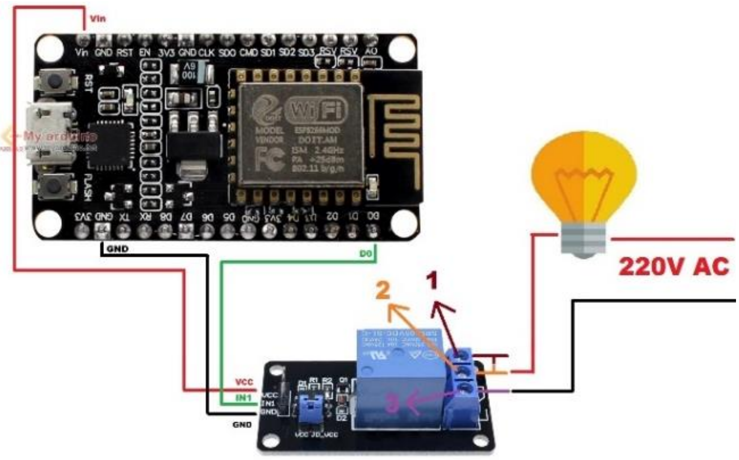


Fig 1.11 **NODE MCU with RELAY**

1.6 IOT (Internet of Things)

IoT stands for "Internet of Things" and refers to the interconnected network of physical devices, vehicles, appliances, and other items that are embedded with sensors, software, and network connectivity. These devices can collect and exchange data through the internet, enabling them to communicate with each other and with humans in real-time.

The IoT has many applications in various industries, such as healthcare, transportation, manufacturing, and agriculture. For example, in healthcare, IoT devices can be used to monitor patients' vital signs and send alerts to healthcare providers in case of emergencies. In transportation, IoT sensors can be used to optimize traffic flow and reduce congestion. A lunchbox that has IoT (Internet of Things) technology installed allows it to connect to the internet and communicate with other systems or devices by exchanging data. With the help of this technology, a variety of features and services can be offered, including tracking the location and temperature of the lunchbox, keeping an eye on the food's contents and expiration dates etc.

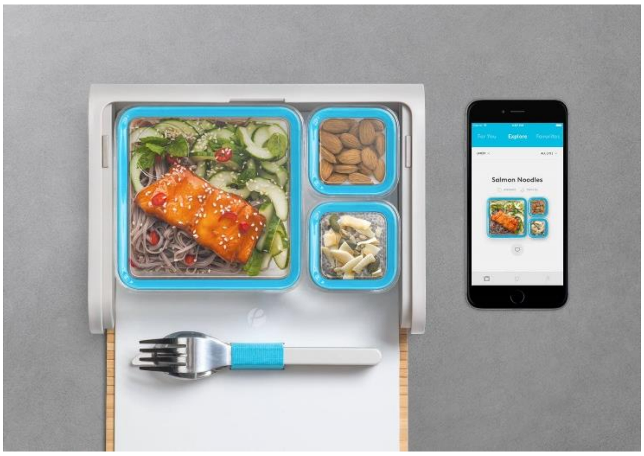


Fig 1.12 **IOT APPLICATIONS**

1.7 PELTIER EFFECT

The Peltier effect is a phenomenon in which a temperature differential results from an electrical current passing across a junction of two distinct conducting materials. While the other side of the connection becomes heated, one side becomes cool. Thermoelectric generators can also be created using Peltier coolers. When the device is used as a cooler, a voltage is delivered across it, causing a temperature difference to develop between the two sides. When used as a generator, the device heats up on one side more than the other, which causes a differential in voltage to develop between the two sides (the Seebeck effect). Yet, due to various design and packaging considerations, a well-designed Peltier cooler will be a mediocre thermoelectric generator and vice versa.

Compared to vapor-compression refrigeration, this technology is used for refrigeration far less frequently. Comparing a Peltier cooler to a vapor-compression refrigerator, its main benefits include the absence of moving parts and flowing liquid, extremely long lifespan, imperviousness to leaks, compact size, and adaptable design. Poor power efficiency and high cost for a given cooling capacity are its key drawbacks (a low coefficient of performance or COP). Several businesses and researchers are working to create affordable, effective Peltier coolers. (See materials that conduct heat.)

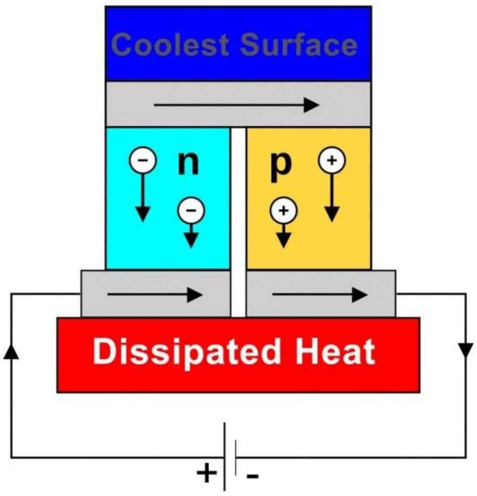


Fig 1.13 **PELTIER EFFECT**

1.8 PROBLEM DEFINITION

Traditional thermal lunch boxes have problems like moisture build-up and bulkiness, while heating boxes require AC power and take more time to heat. To overcome these problems, we need an innovative solution that provides efficient heating and temperature control without any moisture build-up or bulkiness.

1.9 OBJECTIVE

The objective of this project is to design an IoT-enabled thermal lunch box that can address the problems of traditional lunch boxes and provide convenient heating options. We aim to achieve this by using Peltier models to achieve heating function and timing, with IoT operation through node MCU and relays. We also aim to use Ansys software to optimize the shape and material of the box for efficient thermal distribution.

Our key objective is to provide an efficient, convenient, and cost-effective solution for heating food that is easy to use and does not require AC power. By achieving this objective, we hope to provide a practical solution for people who are looking for a reliable and easy-to-use thermal lunch box.

CHAPTER 2

LITERATURE SURVEY

The literature survey on IOT-enabled thermal lunch boxes is essential to understand the existing technologies, materials used in food contact surfaces, energy storage technologies, and thermoelectric cooling cells. It helps to identify the gaps and challenges, leading to the development of an innovative and sustainable thermal lunch box. The following journal articles were referred to find the gaps and challenges for our problem.

2.1 LITERATURE REVIEW

Ronald H. Schmidt et al. [1]: Food contact surfaces should be smooth, impervious, free of cracks and crevices, non-porous, non-absorbent, non-contaminating, non-reactive, corrosion resistant, durable, and cleanable. Materials used in food contact surfaces must be non-toxic, and materials containing heavy metals (e.g., lead, cadmium, hexavalent chromium or mercury) or other toxic materials must be avoided. Moreover, the material must possess good heat conducting capacity.

Rakibul Hossain et al. [2]: Cost-effective, eco-friendly, and oil and grease-resistant food serving containers should be fabricated. By this implementation we can reduce the plastic pollution in the serving of food, and we can avoid food poisoning. With help of various eco-friendly materials, we can achieve this issue to overcome the food spoiling issue.

Ahmed Elsayed et al. [3]: The development of energy storage technologies is very important to convert the available energy and improve its utilisation, since many energy sources are not available at any time in nature and some energy sources are reducing. Thermal energy storage is used in these technologies. In our Project we’ve to retain/maintain the available heat for longer hours without any external source of energy provided to heat the food content within the box itself.

P. Kolber et al. [4]: The Peltier circuit, the basic element of the cooling thermoelectric cell, consists of semiconductors p-type and n-type connected in series with copper plates. The copper plates, on both sides, are thermally bonded to each other through ceramic plates, but are electrically insulated. In this module there are two types of junctions i.e., hot junction and cold junction in which how much heat is generated at one side, that much cooling effect is generated on the cooler junction side. With the help of this module, we can heat food and cool liquids simultaneously with D.C power supply

YU. G. GUREVICH, et al. [5]: In recent years, devices based on the Peltier effect, which is the basis for solid-state thermoelectric cooling, have evolved rapidly to meet the fast-growing electronic industry. The Peltier effect corresponds to the heat extraction or absorption occurring at the contact between two different conducting media when a direct current (DC) electric current flows through this contact. The thermoelectric cooling in n-n, p-p, and p-n junction contacts, as well as inhomogeneous bulk semiconductors, are analysed. Both degenerate and nondegenerate electron and hole gases are considered. The role of recombination and nonequilibrium charge carriers in the contact cooling (heating) effect is discussed.

Nakul Mahalle et al. [6]: The current work is emphasized to design and analysed Heating & Cooling system which can be utilized as a non-conventional energy source. In this proposed work a portable system has been developed on the principle of „Thermoelectric Module‟. The module is implemented for hot side and cold side, The cold side of the thermoelectric module was utilized for cooling purposes whereas the rejected heat from the hot side of the module was eliminated using heat sinks and fans.

K. M. Kretzschmar et al. [7]: A method is described whereby absolute values for the Seebeck coefficient, the thermal conductance and the thermal capacity of thermoelectric devices may be obtained without the need to measure temperature differences or heat flows. The only requirement in addition to the device to be calibrated and its usual recording apparatus is a source of d. c. current and some metal blocks of known thermal capacity. A mathematical theory of the method is presented and tested experimentally. The method has been used to calibrate semiconductor thermoelements and muscle thermopiles and it is applicable in principle to many other devices such as calorimeters.

D.M. Rowe et al. [8]: Thermoelectric materials, which can generate electricity from waste heat or be used as solid-state Peltier coolers, could play an important role in a global sustainable energy solution. Such a development is contingent on identifying materials with higher thermoelectric efficiency than available at present, which is a challenge owing to the conflicting combination of material traits that are required. Nevertheless, because of modern synthesis and characterization techniques, particularly for nanoscale materials, a new era of complex thermoelectric materials is approaching.

Chao Wang, et al. [9]: A new thermoelectric hybrid battery system has been proposed to utilize the battery waste heat. For example: FeS2 TEHB is used to reproduce electricity and decrease temperatures has the battery is discharging and charging. In annealing process, when Fe7S8 nanocrystals are introduced, there will be a decrease in lattice thermal conductivity and an increase in Seebeck coefficient. This results in improving the battery efficiency by converting the unavoidable heat that was generated by battery into electricity.

2.2 SUMMARY:

The literature reviewed in this context covers a range of topics, including the characteristics of food contact surfaces, oil-resistant food serving containers, thermal energy storage using latent heat storage materials, efficiency testing of thermoelectric cooling cells, the Peltier effect in semiconductors, solar-based heating and cooling systems using thermo-electric modules, the use of the Peltier effect for calibration of thermoelectric devices, recent developments in thermoelectric materials, and hybrid thermoelectric battery electrodes. These studies suggest that a well-designed IoT-enabled thermal lunch box should have a smooth, impervious, and non-contaminating food contact surface, be made of eco-friendly materials, store thermal energy for longer periods, be powered by a Peltier module, and utilize solar-based heating and cooling systems.

CHAPTER 3

DESIGN & MATHEMATICAL CALCULATIONS

3.1 Peltier Module:

The performance of a Peltier module is affected by various factors, such as the size of the module, the number of thermocouples, the materials used, the current and voltage applied, and the temperature difference across the module. Generally, larger Peltier modules can handle more current and produce a greater temperature difference, but they may also require more power and have a higher cost.

Peltier module: **TEC1-012704**

Size of the Peltier **40mm x 40mm x 3.6mm**.

Operating Voltage is **12V**.

Maximum Current- Imax (A) is **4A**.

If 11V lipo battery is used to power the Peltier,

Power input P =V*I = 11*4 = 44 W

Assuming a 50 °C temperature difference and an electrical power input of 44 W,

the heat flux for a Peltier device with a 16 cm^2 side surface area as follows:

Heat flux = Power input / Side surface area / Temperature difference

Heat flux = 44 W / 16 cm^2 / 50 °C = 0.055 W/cm^2

3.2 Conductivity of Box Material:

Food grade steel, also known as stainless steel, has good thermal conductivity. The thermal conductivity of stainless steel can vary depending on the specific grade of steel and its composition, but, it has a thermal conductivity ranging from about **12 W/mK** to **20 W/mK**.

Stainless steel is a popular material for food processing and storage equipment due to its **high resistance to corrosion**, **ease of cleaning**, and **durability**. The thermal conductivity of stainless steel is an important factor in the design and performance of food processing and storage equipment, as it affects how quickly and evenly heat is transferred through the material. However, stainless steel is often preferred in food processing and storage applications due to its superior resistance to corrosion and its ability to maintain its structural integrity in high-temperature environments.

S.No	Material	Density Kg/m3	Thermal conductivity W/mC	Specific Heat J/kgC
1	304 Stainless Steel	8000	16.2	500
2	Aluminum 1100-O	2710	222	904

3.3 Specific Heat Required to Reheat Rice Contents:

The specific heat required to heat cooked rice depends on the mass of the rice, the initial temperature of the rice, the desired final temperature, and the specific heat capacity of the rice.

The specific heat capacity of cooked rice can vary depending on factors such as the variety of rice, the method of cooking, and the water content of the rice. In general, the specific heat capacity of cooked rice ranges from about **1.3 to 2.2 J/g°C.**

To calculate the specific heat required to heat cooked rice, you can use the following formula:

$$Q = m * c * \Delta T$$

Where:

Q = the heat required to raise the temperature of the rice (in joules, J)

m = the mass of the rice (in grams, g)

c = the specific heat capacity of the rice (in joules per gram per degree Celsius, J/g°C)

ΔT = the change in temperature (in degrees Celsius, °C)

Calculation:

For example, if you have 100 grams of cooked rice at an initial temperature of 20°C and you want to heat it to a final temperature of 60°C, using a specific heat capacity of 1.5 J/g°C for cooked rice, you can calculate the specific heat required as follows:

Q = 100 g * 1.5 J/g°C * (60°C - 20°C) Q = 6000 J

Therefore, you would need to supply **6,000 joules** of heat to raise the temperature of **100 grams** of cooked rice from **20°C to 60°C**, assuming a specific heat capacity of **1.5 J/g°C** for the rice.

3.4 BATTERY CAPABILITIES:

The *11.1V - 2200mAH - (Lithium Polymer) Lipo Rechargeable Battery - 30C* is a type of high-performance battery commonly used in remote control vehicles, drones, and other electronic devices that require a lightweight, high-energy-density power source. Here is what each of the specifications means:

11.1V: This is the nominal voltage of the battery, which means that it is designed to deliver an average voltage of 11.1 volts when it is fully charged.

2200mAh: This is the capacity of the battery, measured in mill ampere-hours (mAh), which represents the amount of charge that the battery can store. A 2200mAh battery can supply a current of 2200 milliamps for one hour, or 1100 milliamps for two hours, and so on.

Lithium Polymer (LiPo): This refers to the chemistry of the battery, which uses a polymer electrolyte instead of a liquid electrolyte, making it more flexible, lightweight, and efficient than other types of batteries.

30C: This is the discharge rate of the battery, which indicates the maximum current that can be drawn from the battery without damaging it. A 30C battery can discharge at a rate of 30 times its capacity, or **66 amps** in this case (**2200mAh x 30C = 66A)**.

3.5 SOLAR PANEL CAPABILITIES:

The time required to charge a 11.1V 2200mAh LiPo battery via 12V solar panels depends on several factors, such as the size and efficiency of the solar panels, the amount of sunlight available, the charging current, and the state of charge of the battery. Assuming you have a 12V solar panel with a power output of 50W and an efficiency of 20%, and you are using a charger with a charging current of 1A, the charging time for the 11.1V 2200mAh LiPo battery can be estimated using the following formula:

Charging time = (Battery capacity / Charging current) x Charging efficiency

Using the above formula, the estimated charging time for the 11.1V 2200mAh LiPo battery would be:

Charging time = (2200mAh / 1000mA) x 0.75 (assuming a charging efficiency of 75%)

Charging time = **1.65 hours** or approximately **100 minutes**

CHAPTER 4

TRANSIENT THERMAL ANALYSIS USING ANSYS

4.1 Introduction

Ansys offers a standardised platform for product development, from design concept to testing and validation at the very end. Offerings from the company's simulation platform division are employed in a variety of multi-physics disciplines, including heat transfer, fluid mechanics, statics, solid mechanics, etc. But Ansys is best known for its finite element analysis (FEA) software, which has been increasingly popular as a modelling and simulation tool over time (and particularly since the development of powerful computers) for use in addressing a variety of challenging engineering issues.

4.2 ANSYS Software

- Handling of engineering problems essentially consists of three steps: model creation, problem solving, and outcome analysis. The three primary components of Ansys, like many other FEA systems, are the processors, also known as pre-processor, solution processor, and post-processor

- Users can create geometry, define materials, and create element mesh using the Ansys pre-processor. Users of the Ansys processor can apply loads on problems to find solutions. The Ansys post-processor enables tabular results listing and visualisation, as well as printouts of the data

- Ansys provides a whole software package that covers the entire physics spectrum, giving users access to almost every area of engineering simulation that a design process demands. Ansys is trusted by businesses worldwide to provide the best return on their investments in engineering simulation software.

4.3 Finite Element Analysis

Since it helps to avoid the need for time-consuming trials to optimise process parameters such sheet metal thickness, the material of the sheet, punch fillet, and percentage clearance, the finite-element method (FEM) is a useful option for the analysis of sheet metal processes. FEM simulations are being utilised more frequently to analyse and improve the punching process. Computer simulations can produce reliable results while minimising the amount of experiments. The outcomes vary depending on the element type and analysis mesh type

4.4 Procedure in ANSYS

Step 1: Start an ANSYS Workbench Project

Step 2: Create a Transient Thermal Analysis System

Step 3: Add a New Material

Step 4: Create Geometry

Step 5: Create a Profile Sketch To customize units.

Step 6: Create an Extruded Body

Step 7: Launch the Transient Thermal module

Step 8: Generate Mesh

Step 9: Apply Boundary Conditions

Step 10: Solve and Retrieve Results

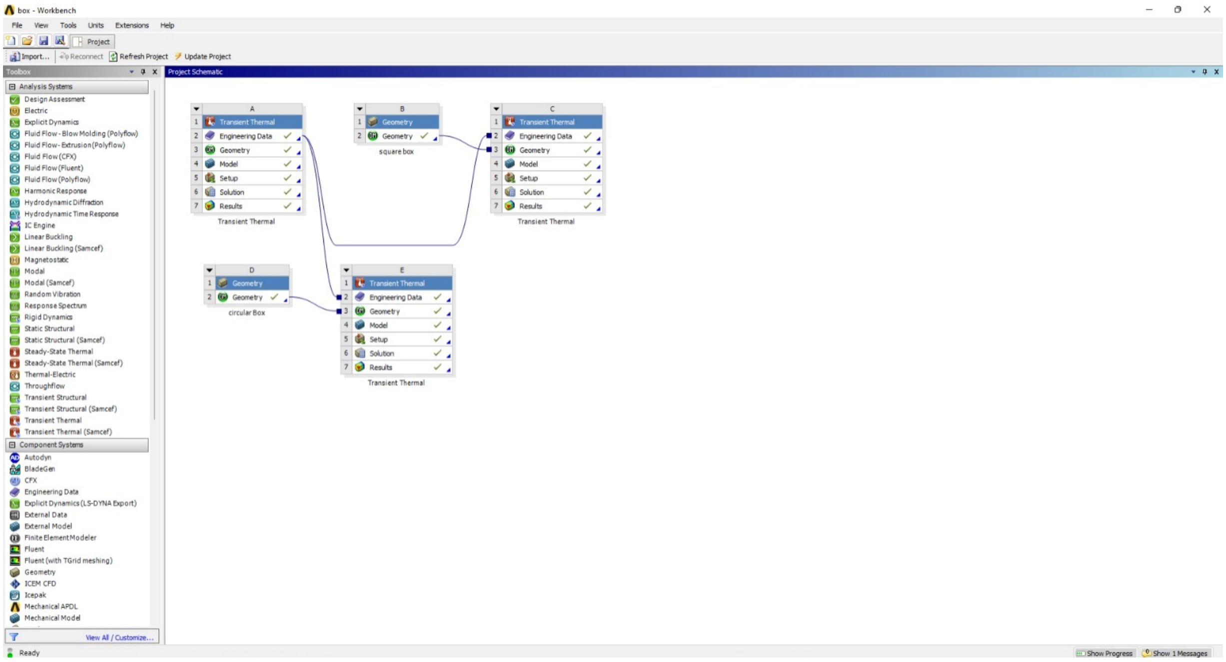


Fig 4.1 **ANSYS Workbench**

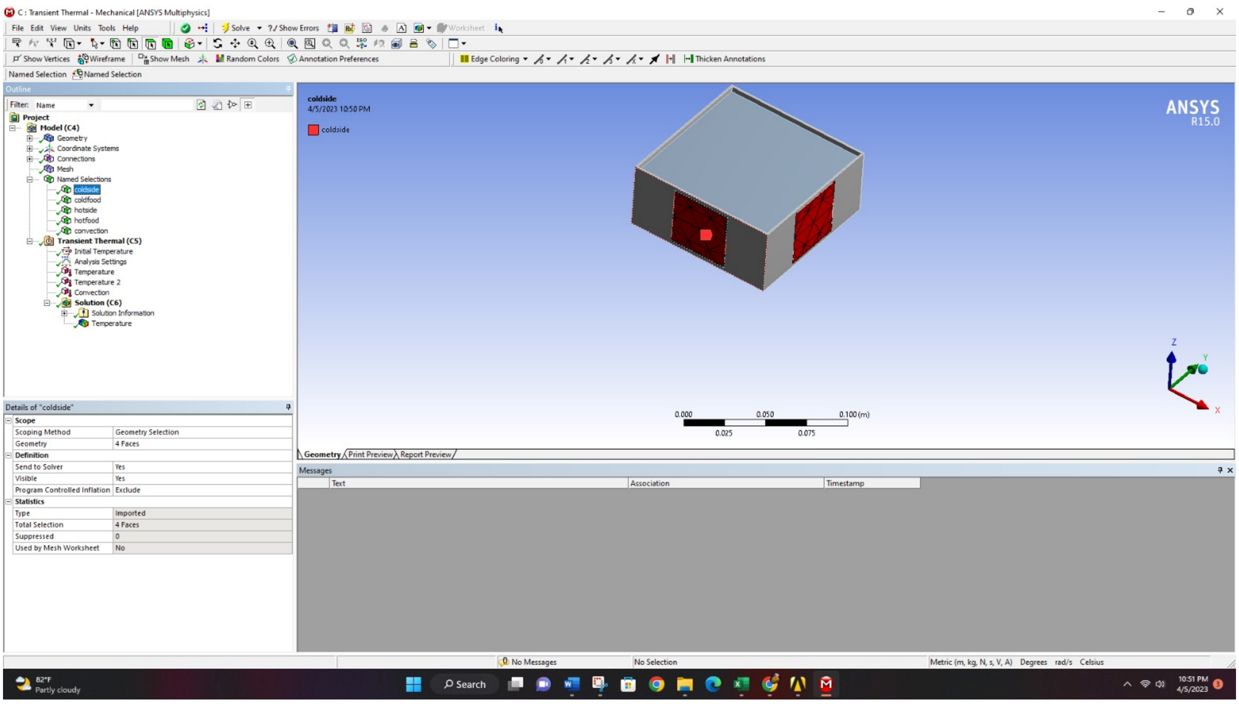


Fig 4.2 **Square Box with Peltier**

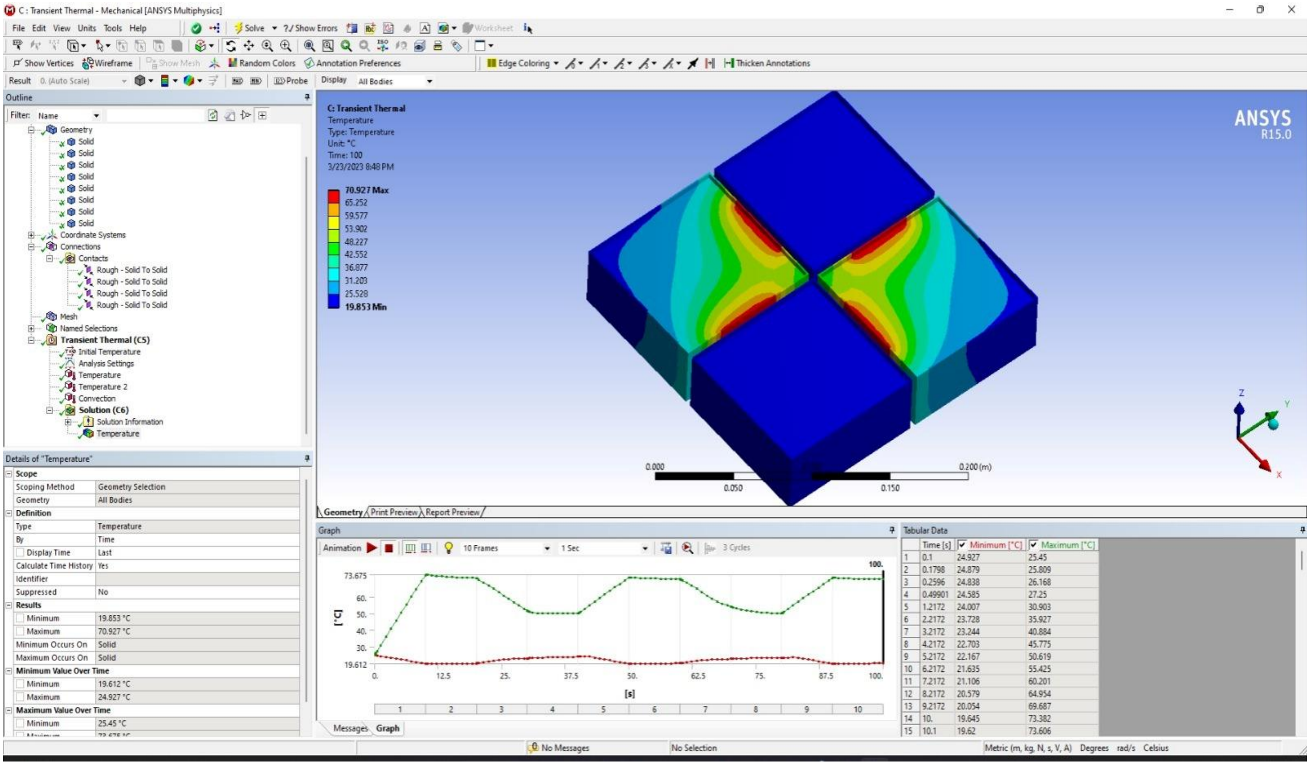


Fig 4.3 **Transient Thermal Analysis of Steel Square Box**

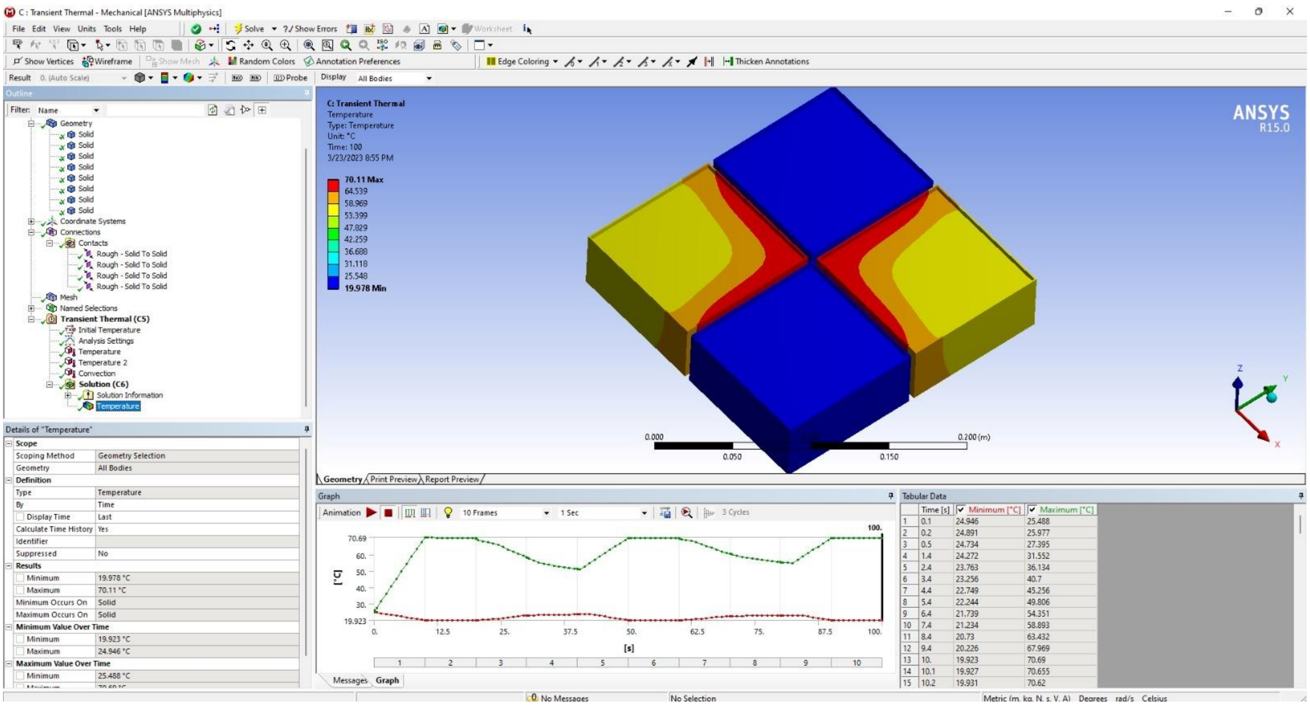


Fig 4.4 **Transient Thermal Analysis of Aluminium Square Box**

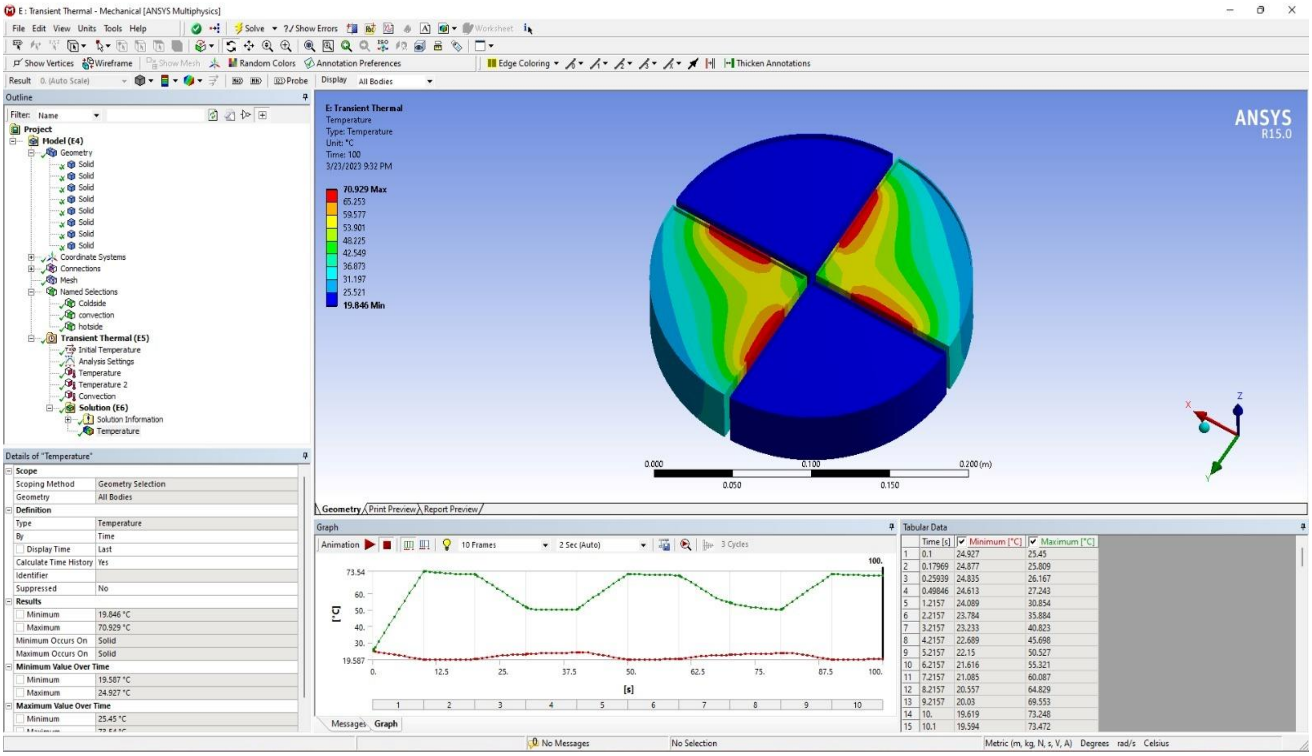


Fig 4.5 **Transient Thermal Analysis of Steel Round Box**

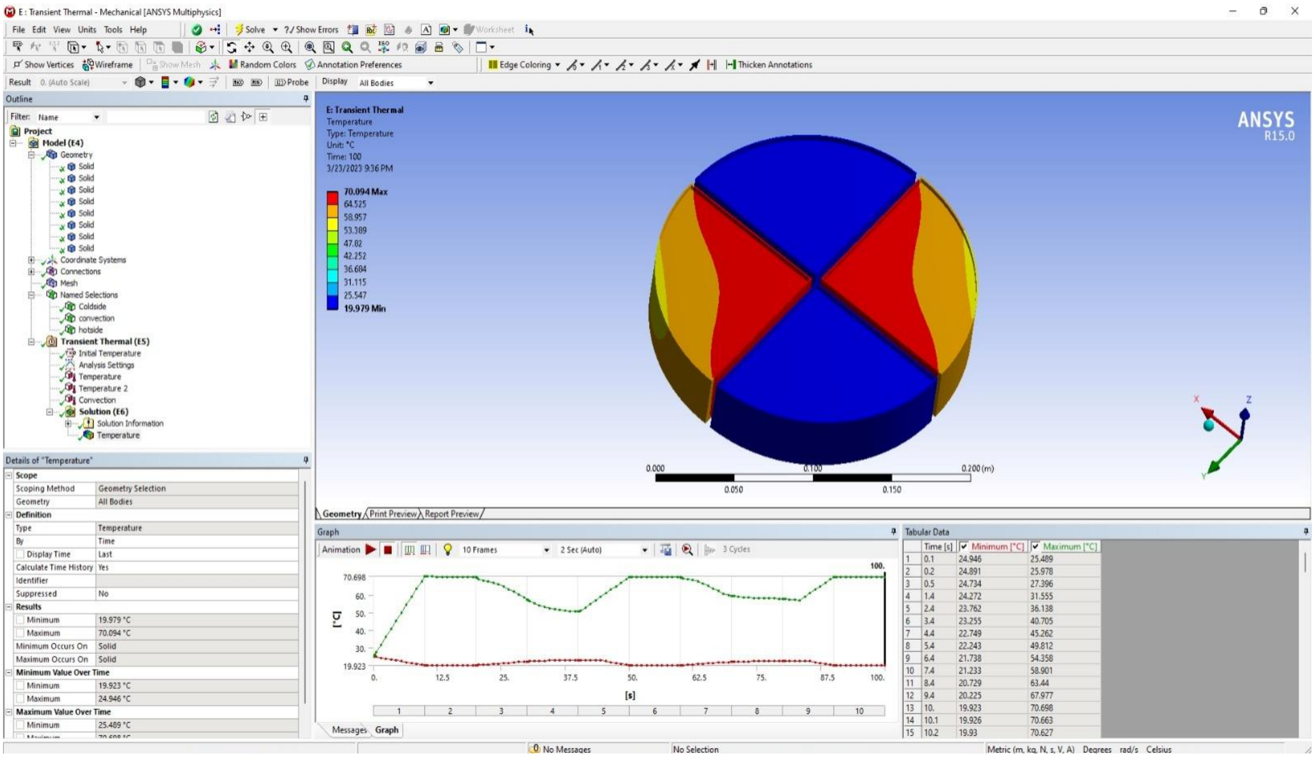


Fig 4.6 **Transient Thermal Analysis of Aluminium Round Box**

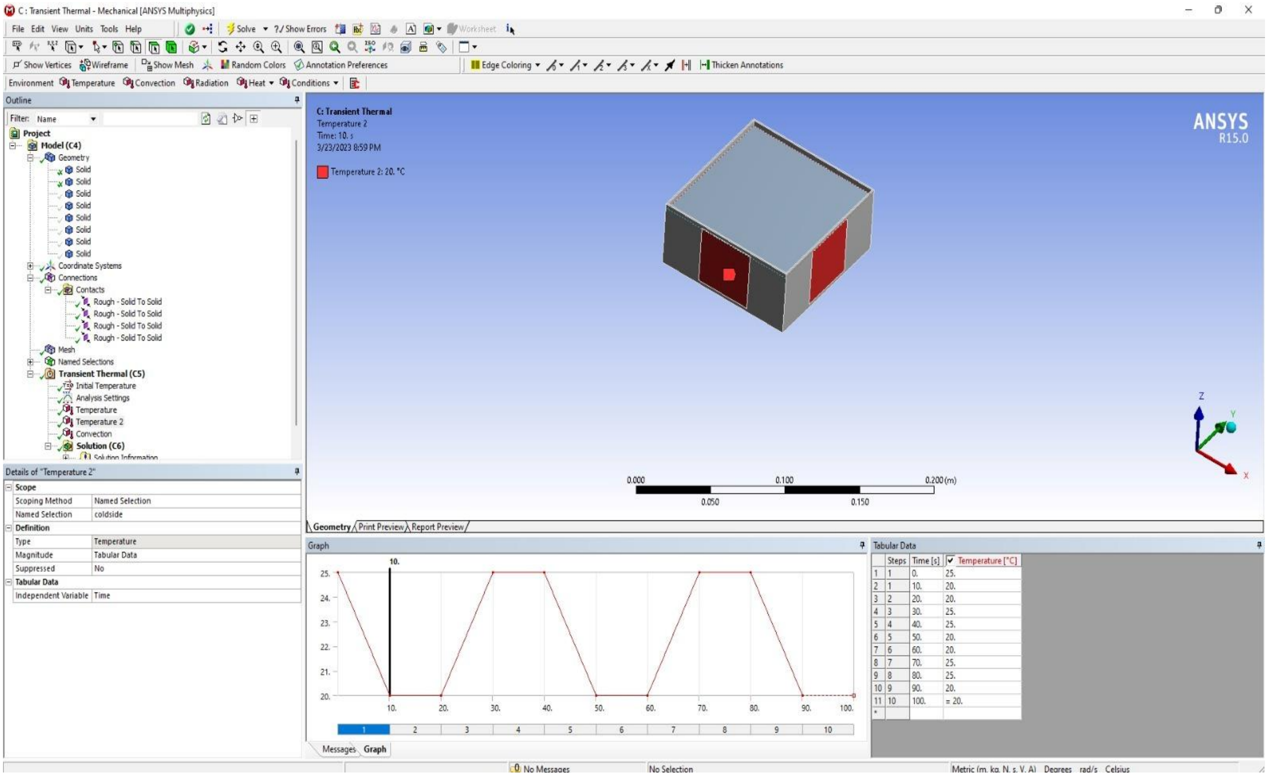


Fig 4.7 **Transient Thermal Analysis of Peltier Module**

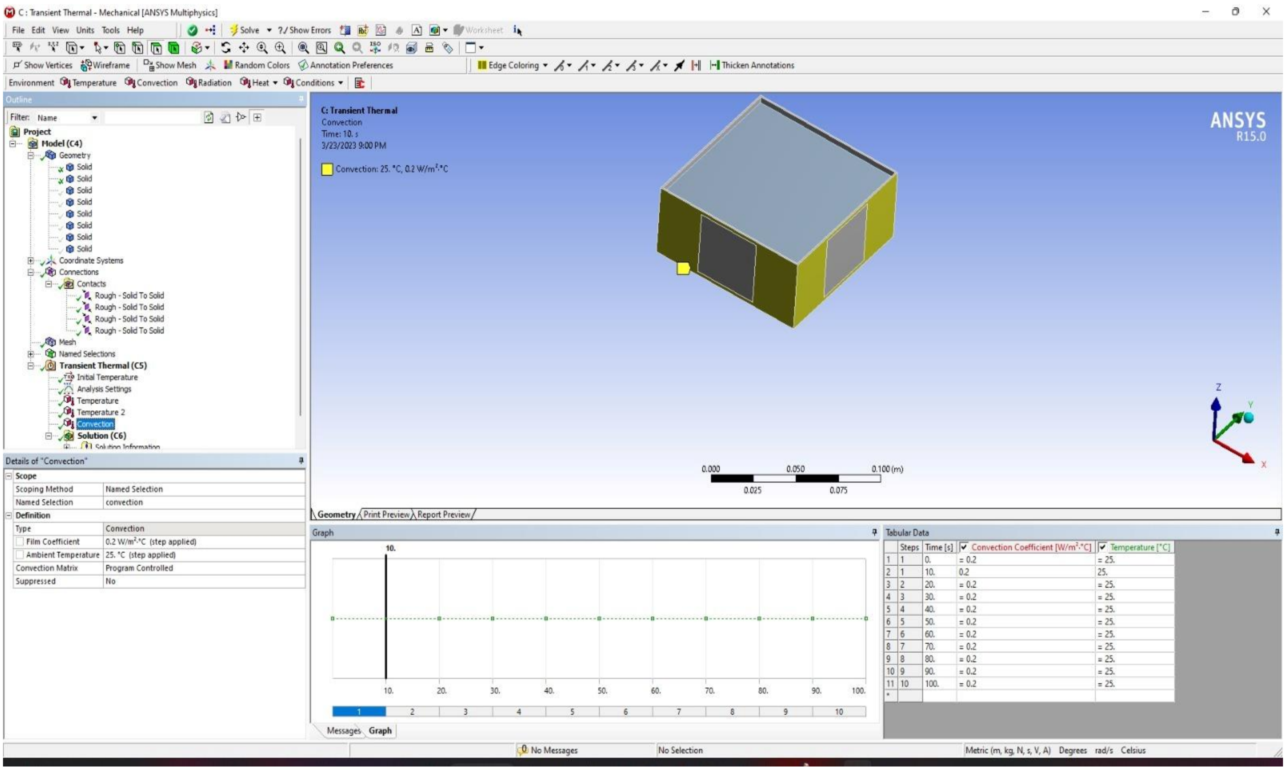
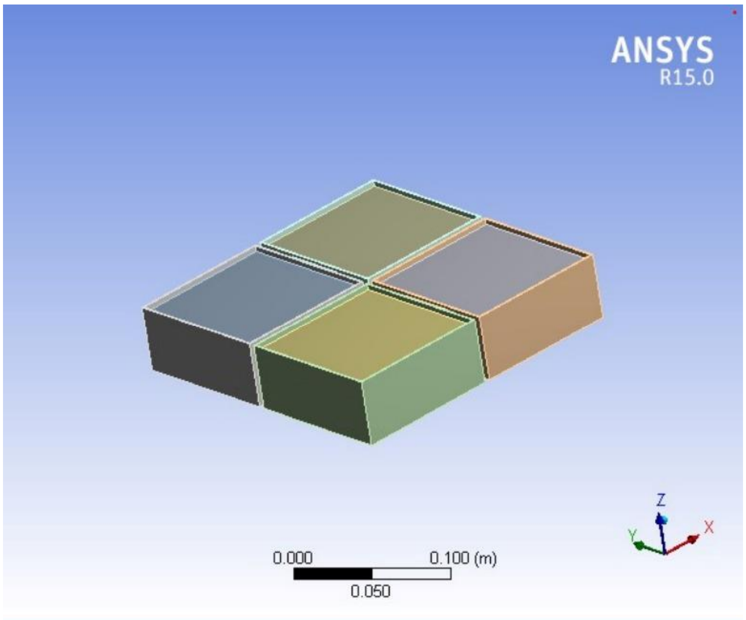
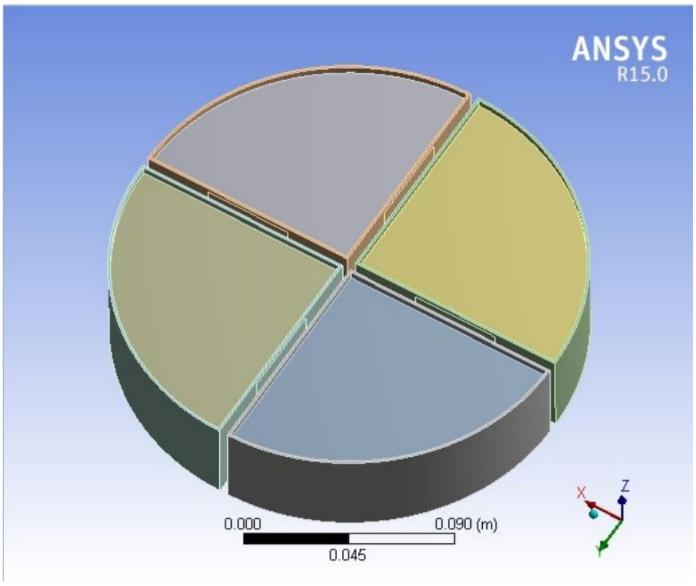


Fig 4.8 **Transient Thermal Analysis of Box Walls**

4.5 Modelled in Design Modular of Ansys Workbench



4.9 **Square Box Model**



4.10 **Circular Box Model**

4.6 Material Data

Table 4.1 **Material Data of Stainless Steel**

Material Properties				
S.No	**Material**	**Density Kg/m3**	**Thermal conductivity W/mC**	**Specific Heat J/kgC**
1	Rice 70% Moisture	720	0.295	2930
2	304 Stainless Steel	8000	16.2	500
3	Aluminum 1100-O	2710	222	904
4	Air	1.2	0.026	1005

CHAPTER 5

EXPERIMENTATION ON PROTOTYPE

5.1 Working Components

The Peltier module is a thermoelectric device that can be used to heat or cool an object depending on the direction of current flow through it. It typically consists of two plates made of different materials, with a layer of thermoelectric material in between. When current flows through the module, one plate becomes hot and the other plate becomes cold.

To power the Peltier module, it needs to be connected to a DC power source such as a lipo battery. The positive (+) terminal of the Peltier module should be connected to the positive (+) terminal of the lipo battery, and the negative (-) terminal of the Peltier module should be connected to the negative (-) terminal of the lipo battery.and current that is applied. For the module to work at its best, these elements must be carefully considered.

Fig 5.1 **Thermoelectric Peltier Module**

Fig 5.2 **LiPo Rechargeable Battery** (11.1V - 2200mAH**)**

The *11.1V - 2200mAh - (Lithium Polymer) LiPo Rechargeable Battery - 30C* is a type of battery commonly used in remote-controlled vehicles, drones, and other electronics that require a high-power density and long runtime. The **11.1V** refers to the voltage of the battery, which is a measure of the electrical potential difference between the positive and negative terminals. In this case, the battery has a nominal voltage of 11.1 volts, which is the average voltage over the battery's discharge cycle.

The battery's capacity, or how much electrical charge it can hold, is indicated by the 2200mAh. The battery can run for a longer period before needing to be recharged the larger its capacity. The battery in this instance has a capacity of **2200 milliampere-hours**, which implies it can provide 2200 milliamperes of current for an hour. Because of its low weight and great energy density. The battery's discharge rate, or 30C rating, is a measurement of how quickly it can release energy. In this instance, the battery can produce a current of up to **66 amps (30 x 2200mAh)** without suffering harm because its discharge rate is **30 times** its capacity (measured in amps).

One advantage of LiPo batteries is that they have a long cycle life, making them a more economical and environmentally responsible option than disposable batteries. They do, however, need handling and care because, if not handled correctly, they can quickly be destroyed or become unstable.

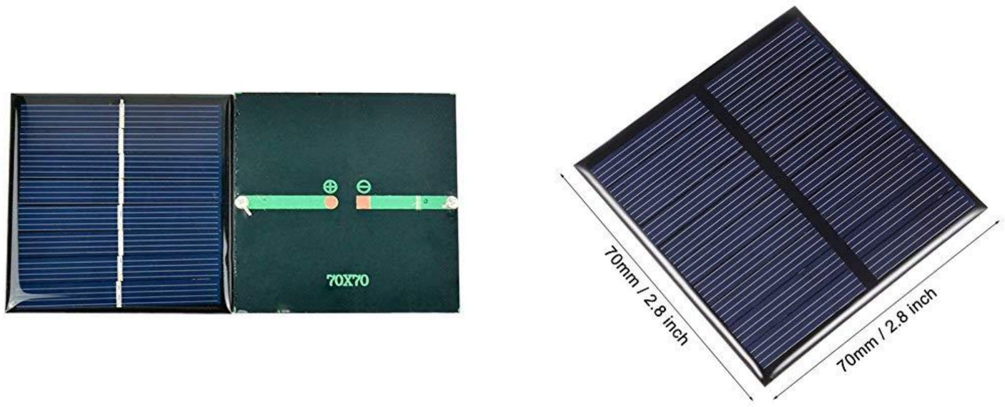


Fig 5.3 **Square Shape Mini Solar Panel (6V-100 mAh)**

A micro solar panel, sometimes referred to as a little or compact solar panel, is a gadget that transforms solar energy into electrical energy. Smaller in size and wattage than normal solar panels, mini solar panels are frequently used in portable solar applications like camping, outdoor lighting, and small electronic gadgets.

A small solar panel that uses the sun's energy to produce electricity has a square shape and a **6V-100mAh capacity**. It is a portable and lightweight device that can be used for a variety of tasks, including powering small motors or Lights, small remote-controlled devices.

This small solar panel has a **6V-100mAh** capacity, which means that it can produce up to 100 milliampere-hours of electricity for every hour it is exposed to sunshine. Although its capacity might not be adequate for high-power applications, it is acceptable for low-power gadgets that only need a little energy.

In conclusion, a square-shaped micro solar panel with a 6V-100mAh capacity is a practical tool for harnessing solar energy to produce small amounts of electrical energy. It is a practical addition to any outdoor enthusiast's arsenal because to its portability, light weight, and ability to be used for numerous low-power tasks.

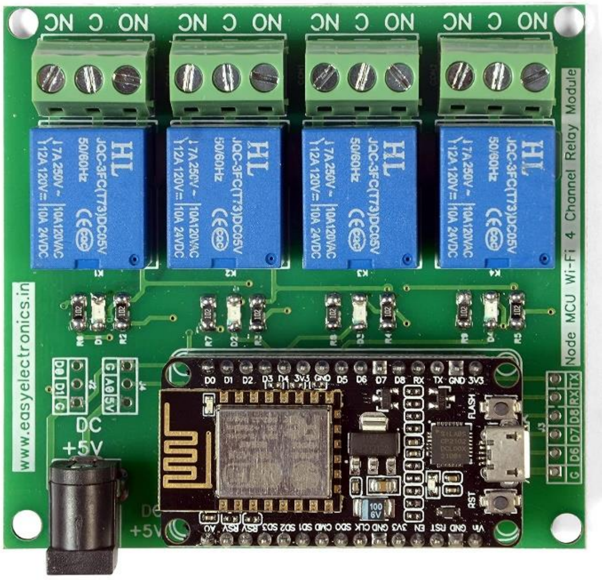


Fig 5.4 **NodeMCU Based 4-Channel Relay Board**

A relay is an electrically operated switch that can be used to control the flow of current to a device. It consists of an electromagnet and a set of switch contacts. When current flows through the electromagnet, it creates a magnetic field that pulls the switch contacts together, allowing current to flow through them.

To control the power supply to the Peltier module, a relay can be used. The relay needs to be connected to the lipo battery in the same way as the Peltier module, with the positive (+) terminal of the relay connected to the positive (+) terminal of the lipo battery and the negative (-) terminal of the relay connected to the negative (-) terminal of the lipo battery.

To connect the Peltier module to the relay, one wire from the Peltier module should be connected to the normally closed (NC) terminal of the relay, and the other wire from the Peltier module should be connected to the common (COM) terminal of the relay. This configuration will allow the Peltier module to be powered when the relay is not energized.

A Nod MCU is a small, low-cost microcontroller board that can be used to control electronic devices. It is based on the ESP8266 WiFi module, and can be programmed using the Arduino IDE. To control the state of the relay, the Nod MCU can be connected to one of the digital output pins of the board, with one wire connected to the output pin and the other wire connected to the ground (GND) pin of the Nod MCU. This will allow the Nod MCU to control the state of the relay by setting the output pin to either high (5V) or low (0V) depending on the desired state.It's important to ensure that the power supply to the Nod MCU and the power supply to the Peltier module are separate and not connected to each other. This will prevent any potential damage to the Nod MCU due to high currents drawn by the Peltier module.

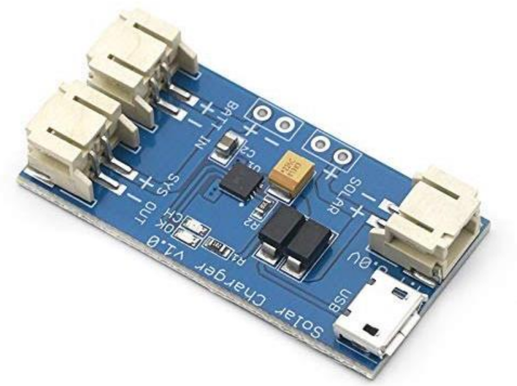


Fig 5.5 **Mini Solar LiPo Charger Board 500Ma**

A little circuit board called a ***500mA Small Solar Lipo Charger Board*** is made to charge lithium polymer (LiPo) batteries with solar energy. Little portable gadgets like hobby drones, remote-control automobiles, and miniature robots frequently use it. The board has a micro-USB connector for charging the battery as well as a solar panel input.

Additionally, it contains a built-in charging and protection circuit that makes sure the battery is charged effectively and safely. Small batteries can be charged rather quickly thanks to the 500mA charging capacity. A single-cell LiPo battery with a nominal voltage of **3.7 volts** can be charged using the board.

The 500mA Small Solar Lipo Charger Board is a helpful part for compact, portable applications that need a dependable and effective charging solution overall. It is a well-liked option among DIY enthusiasts and hobbyists since it offers a convenient and small solution to harvest solar power for LiPo battery charging.

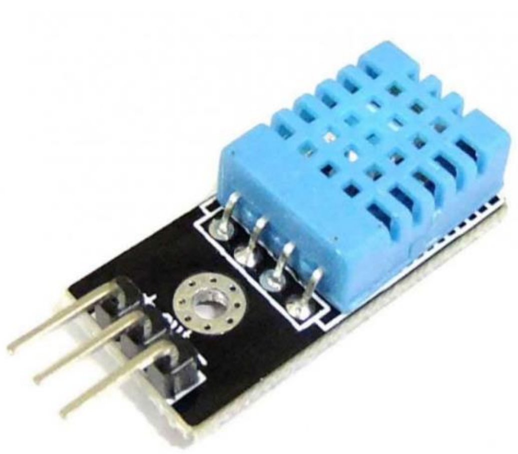


Fig 5.6 **DHT11 Temperature and Humidity Sensor Module**

The DHT11 is a widely used, low-cost temperature and humidity sensor module that is used in a variety of settings including weather stations, HVAC systems, and environmental monitoring. This sensor module can measure relative humidity between **20%** and **90%** with an accuracy of **5%** and temperatures between 0°C and 50°C with an accuracy of 2°C.

A capacitive humidity sensor and a thermistor that measures *temperature* make up the DHT11 sensor module. Moreover, it features an integrated signal processing circuit that offers a digital output through a single wire interface. The output signal is a 40-bit digital signal that includes information on both humidity and temperature.

The DHT11 sensor module's low price is one of its main benefits, which makes it the best option for situations where cost is a key consideration. It also offers an easy-to-use interface and only needs a single digital pin to connect to a microcontroller or other devices. The DHT11 sensor module does have certain restrictions, though. It can take up to 2 seconds to give a reading due to its somewhat poor response time. In comparison to other high-end sensors on the market, it also has less accuracy. DHT11 temperature and humidity sensor module is a cost-effective and easy-to-use sensor for *measuring* ***temperature*** *and* ***humidity*** in various applications.

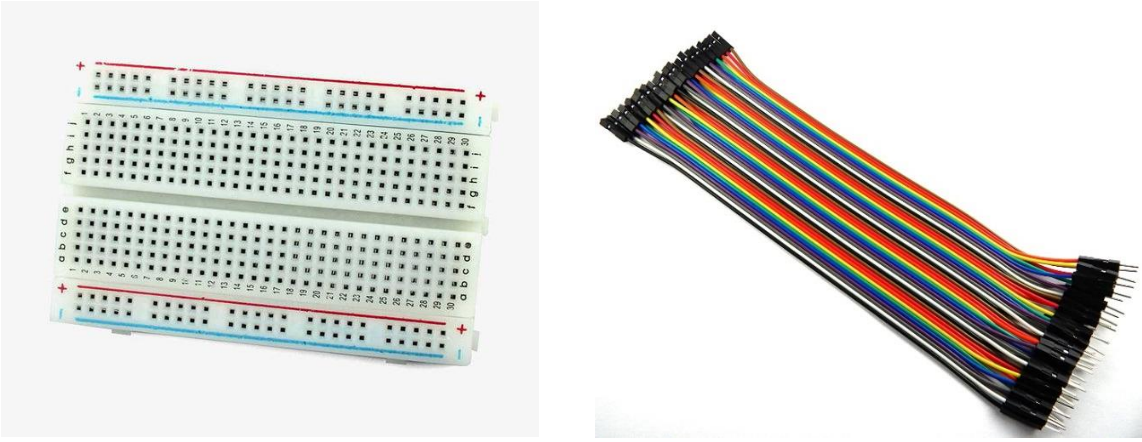


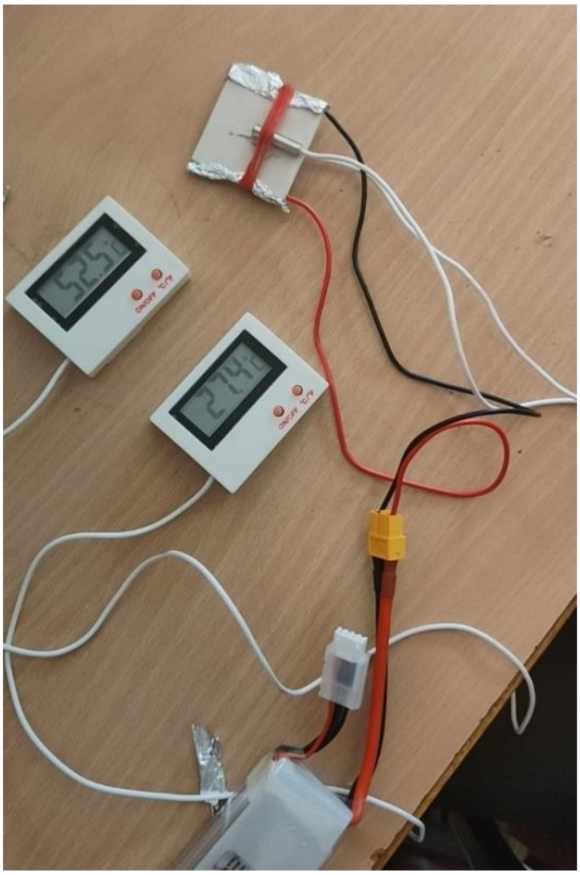
Fig 5.7 **Breadboard with Jumper Wires**

An electronic circuit can be built using a **breadboard**, sometimes referred to as a prototype board, without the need of solder. It is frequently used by engineers, students, and electronics enthusiasts to test out circuit designs and prototypes. Often composed of plastic, breadboards have a grid of holes drilled into the surface. Each row and column of holes has an electrical connection to the one before it. This eliminates the necessity for soldering and enables the connection of electronic components by simply inserting them into the holes.

Electrical cables known as ***Jumper wires*** are employed to temporarily link various places on a printed circuit board (PCB), breadboard, or other electronic circuit. They frequently serve as a quick and adaptable means of connecting components in electronics prototyping, testing, and development.

Jumper wires can be *male-to-male*, *male-to-female*, or *female-to-female* and come in a variety of lengths and colours. Male-to-male jumper wires are used to connect parts with male headers or pins, such as Arduino boards, sensors, and displays, and have pins on both ends. Male-to-female jumper wires, which link components with female headers or pins, such as breadboards and PCBs, have a pin on one end and a socket on the other. Female-to-female jumper wires are used to connect two components having female headers or pins. They have sockets on both ends.

5.2 PELTIER TEMPERATURE ANALYSIS



5.8 **COOL** side is **27.4 °C** after **38 Sec**

Table 5.1 Experimental values for Transient analysis

Time in Sec	Hot side in Deg C	Cold side in Deg C
0	33.8	34.7
10	38.2	32.3
20	50.7	30.6
30	62.3	28.4
40	73.3	26.4
50	93.1	24.3
60	101.6	22.3
70	109.3	20.2
80	110.5	18.2

5.3 CIRCUIT ASSEMBLY STEPS:

1. Connect the positive (+) terminal of the Peltier module to the normally open (NO) terminal of the relay.

2. Connect the common (COM) terminal of the relay to the positive (+) terminal of the lipo battery.

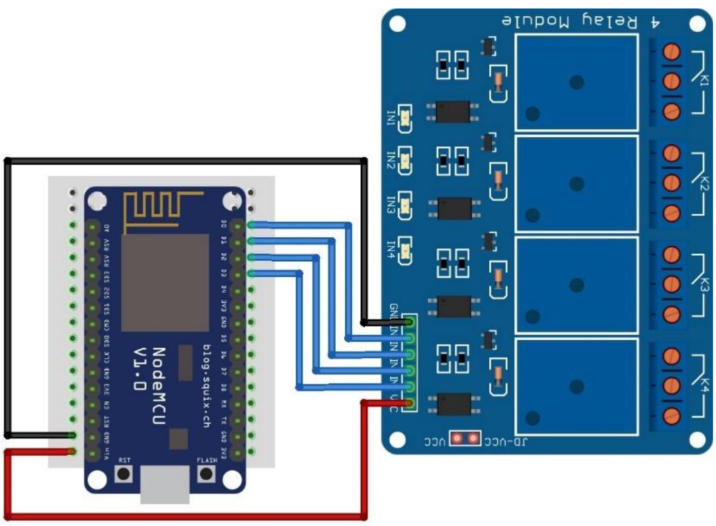
3. Connect the negative (-) terminal of the Peltier module to the negative (-) terminal of the lipo battery.

4. Connect one wire from the output pin of the Nod MCU to the input pin of the relay.

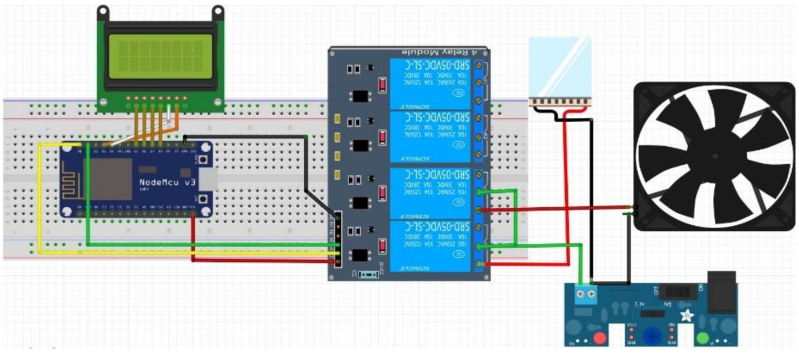
5. Connect the other wire from the input pin of the relay to the ground (GND) pin of the Nod MCU.

6. Power the Nod MCU with a separate power source such as a USB cable or a separate battery.

7. Program the Nod MCU to control the state of the relay by setting the output pin to either high (5V) or low (0V) depending on the desired state.



5.9 **Circuit Assembly**



5.10 **Circuit with Fan & LCD Display**

Blynk can be used to control a NodeMCU board over Wi-Fi, and in your specific case, it can be used to control the relay that is connected to the NodeMCU. Blynk is a popular Internet of Things (IoT) app that allows users to easily build and control smart devices with their smartphones.

Steps to Control Relay through Blynk app over the internet:

1. Set up a Blynk account and create a new project.

2. In the Blynk app, add a button widget to your project.

3. In the NodeMCU code, configure the Wi-Fi settings to connect to your local Wi-Fi network and establish a connection to the Blynk server.

4. Configure the NodeMCU code to read the state of the button widget in the Blynk app and send a signal to the relay accordingly.

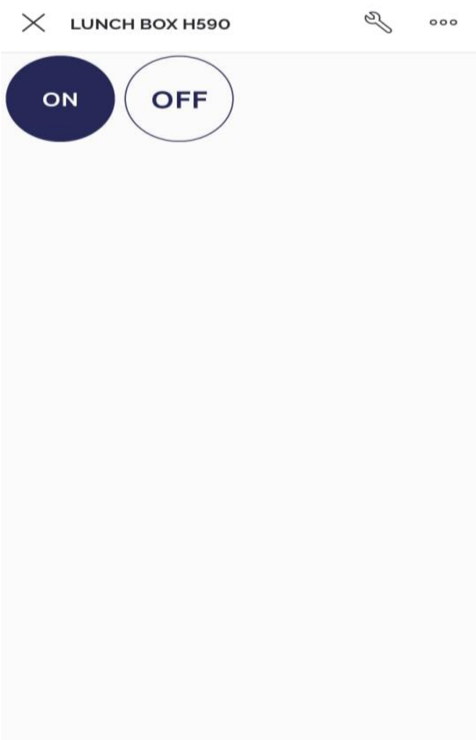
5. When the button widget in the Blynk app is pressed, the signal will be sent to the NodeMCU, which will in turn activate or deactivate the relay.

5.11 **Blynk APP Connectivity**

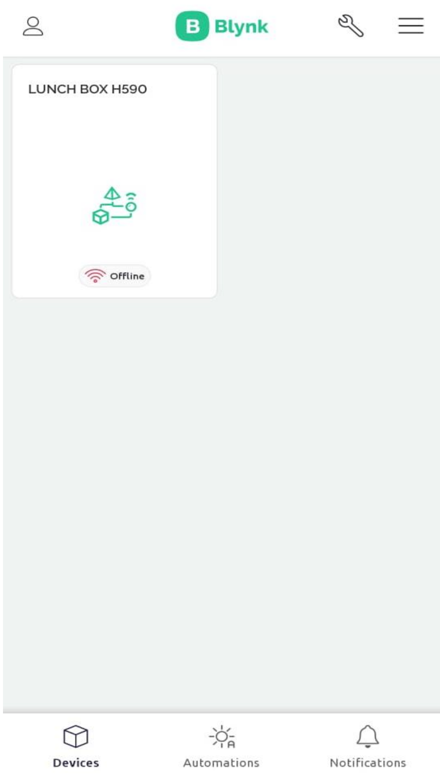
5.4 NODE MCU CODE:

```
#define BLYNK_TEMPLATE_ID "*****************"

#define BLYNK_TEMPLATE_NAME "LUNCH BOX"

#define BLYNK_AUTH_TOKEN "*******************************"

char auth[] = BLYNK_AUTH_TOKEN;

char ssid[] = "*************";//Enter your WIFI name

char pass[] = "*************";//Enter your WIFI password

BLYNK_WRITE(V0) {

  digitalWrite(D4, param.asInt());

}

BLYNK_WRITE(V1) {

  digitalWrite(D5, param.asInt());

}

BLYNK_WRITE(V2) {

  digitalWrite(D3, param.asInt());

}

BLYNK_WRITE(V3) {

  digitalWrite(D1, param.asInt());

}

void setup() {

   pinMode(D1, OUTPUT);

   pinMode(D3, OUTPUT);

   pinMode(D4, OUTPUT);

   pinMode(D5, OUTPUT);

  Blynk.begin(auth, ssid, pass, "blynk.cloud", 80); }
```

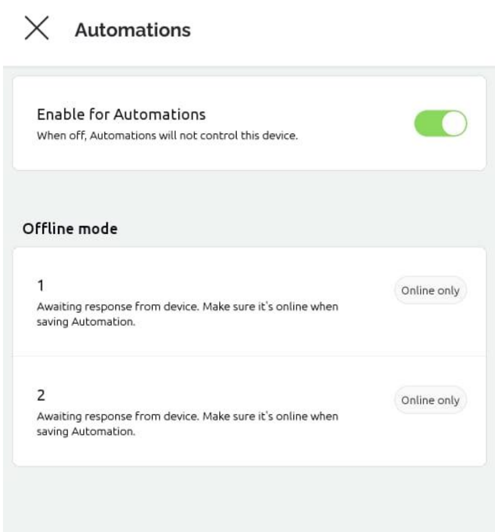
5.5 APP INTERFACE



5.12 **ON & OFF Interface**



5.13 **Devices Interface**



5.14 **Automations Interface**

CHAPTER-6

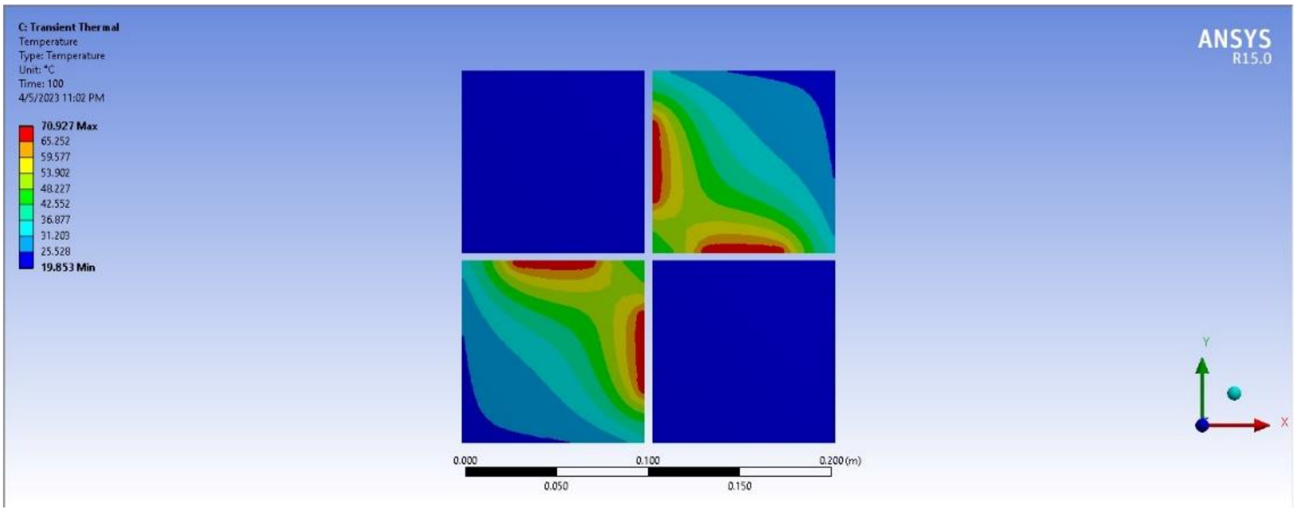
RESULTS & DISCUSSIONS

6.1 Results and Discussions

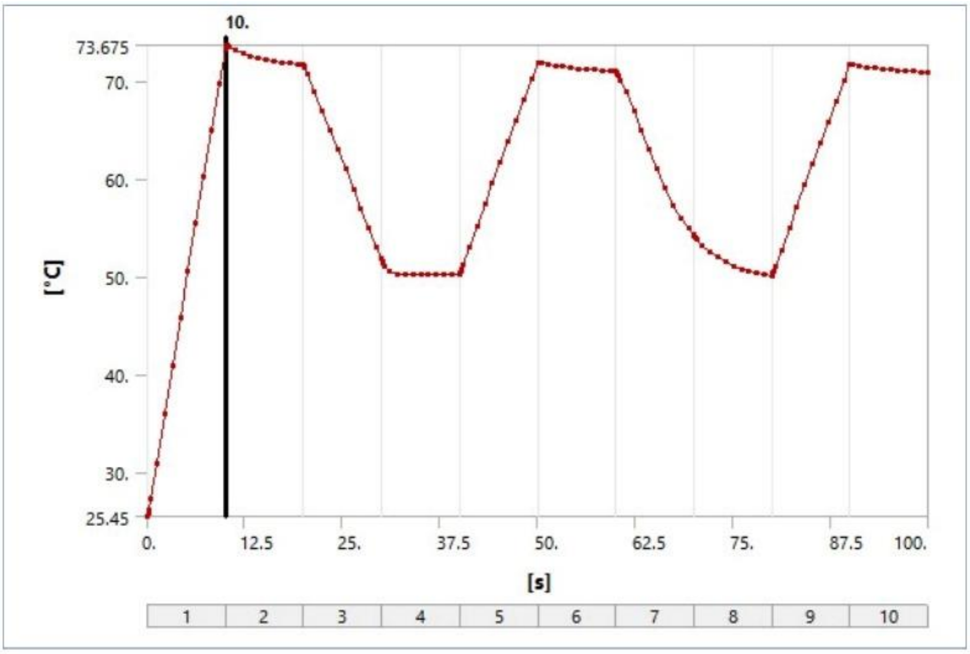
The present work has dealt with the study of heat transfer from box Materials by analytically using software. In comparison between square box and circular box was also accomplished to obtain an idea on the effectiveness of box design.

Analysis is performed on two geometrical models 4 cups square and 4 cups circle and the follow in results are obtained.

6.2 Square Stainless Steel Box Design

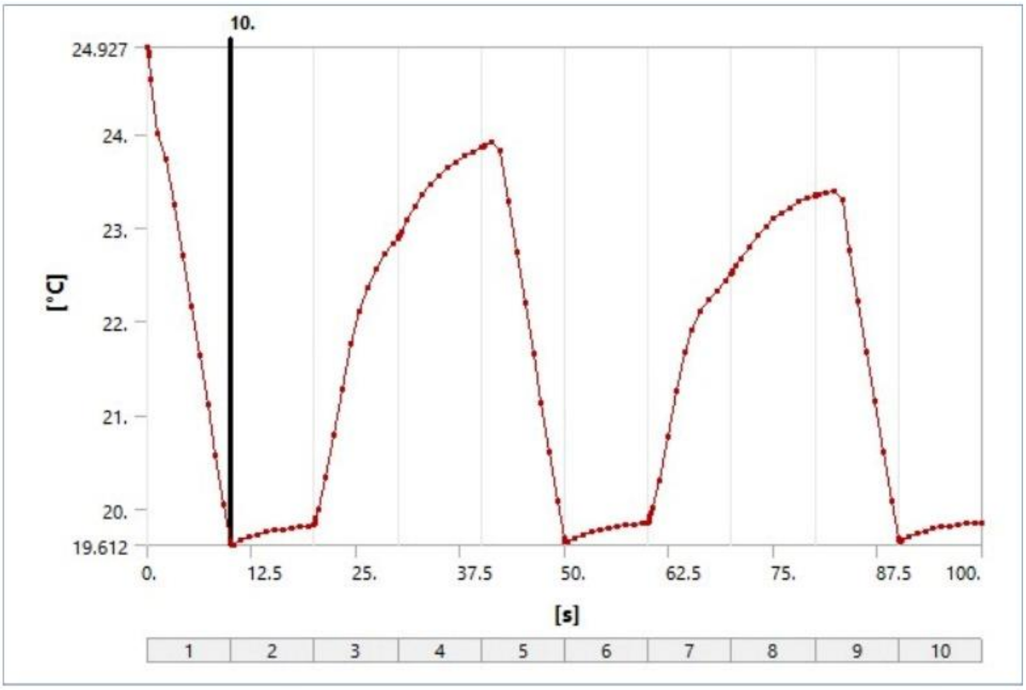


6.1 **Stainless Steel Square Box Temperature Distribution**



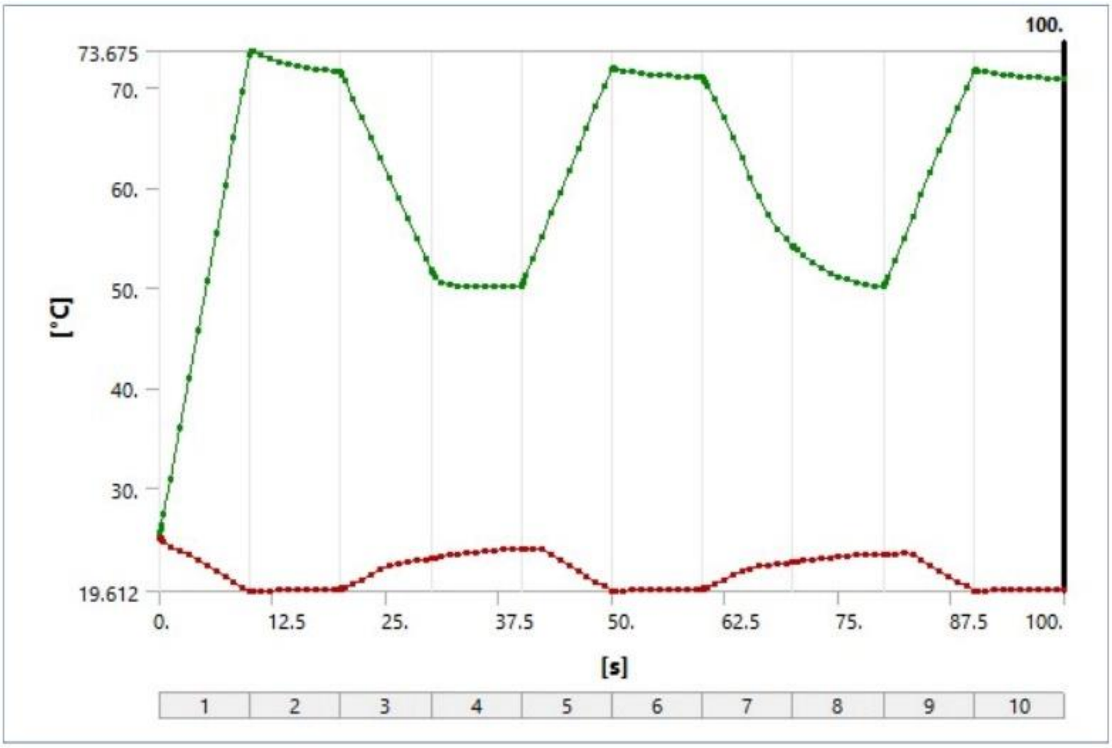
Graph 6.1 **Stainless steel square box temperature distribution in rice chamber**

Stainless steel square Lunch box temperature distribution in rice chamber is as show in figure 6.1, the temperature of the rice at dwell is 52deg C.



Graph 6.2 **Stainless steel square box temperature distribution in air chamber**

Stainless steel square Lunch box temperature distribution in air chamber is as show in figure 6.2, the temperature of the air.



Graph 6.3 **Max vs Min temperatures in the stainless-steel lunch box**

Stainless steel square Lunch box temperature distribution Max vs Min is as show in figure 6.3

6.3 Square Aluminium Box Design

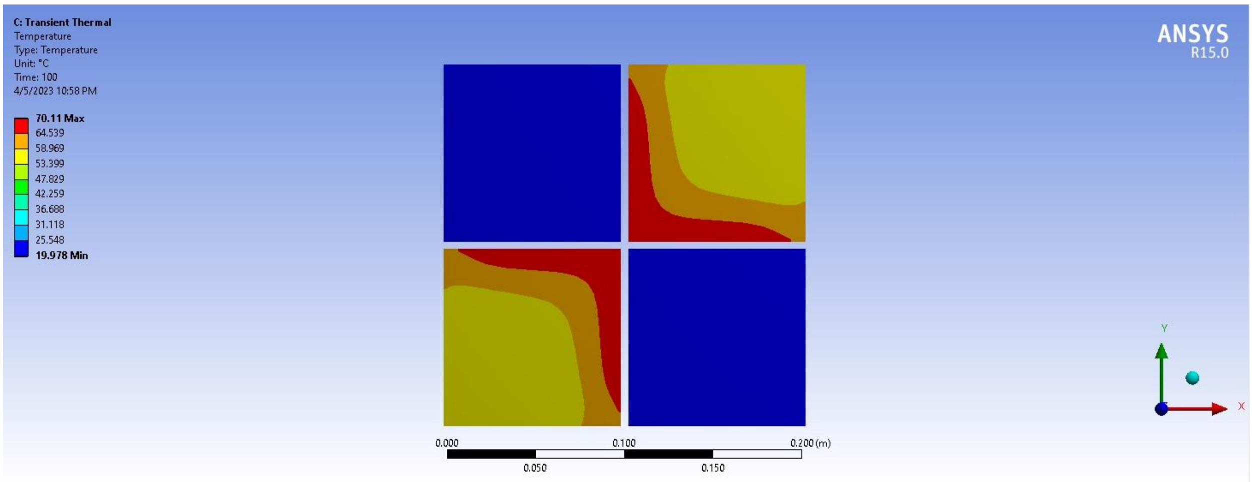
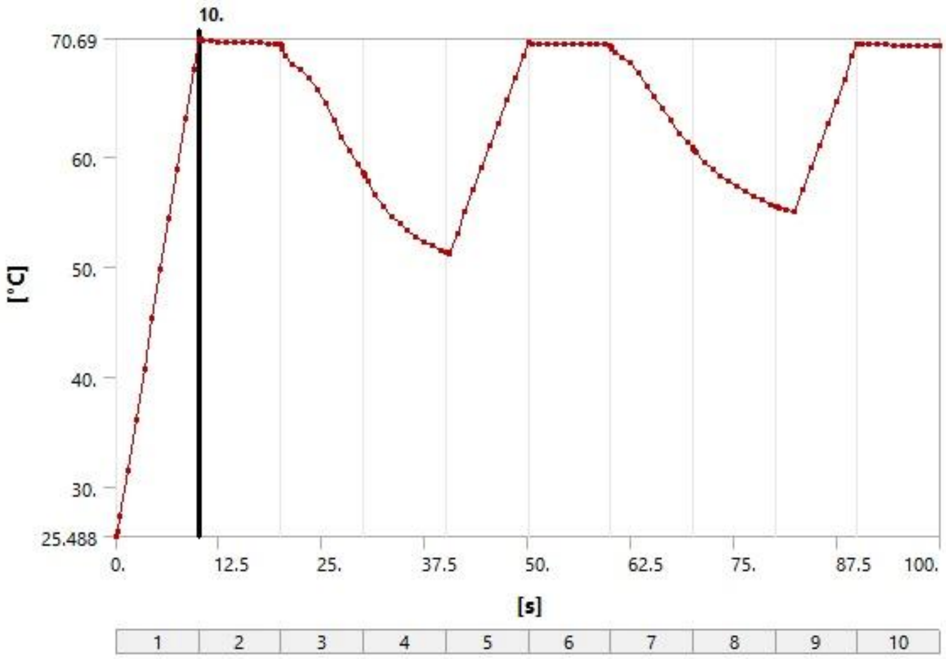
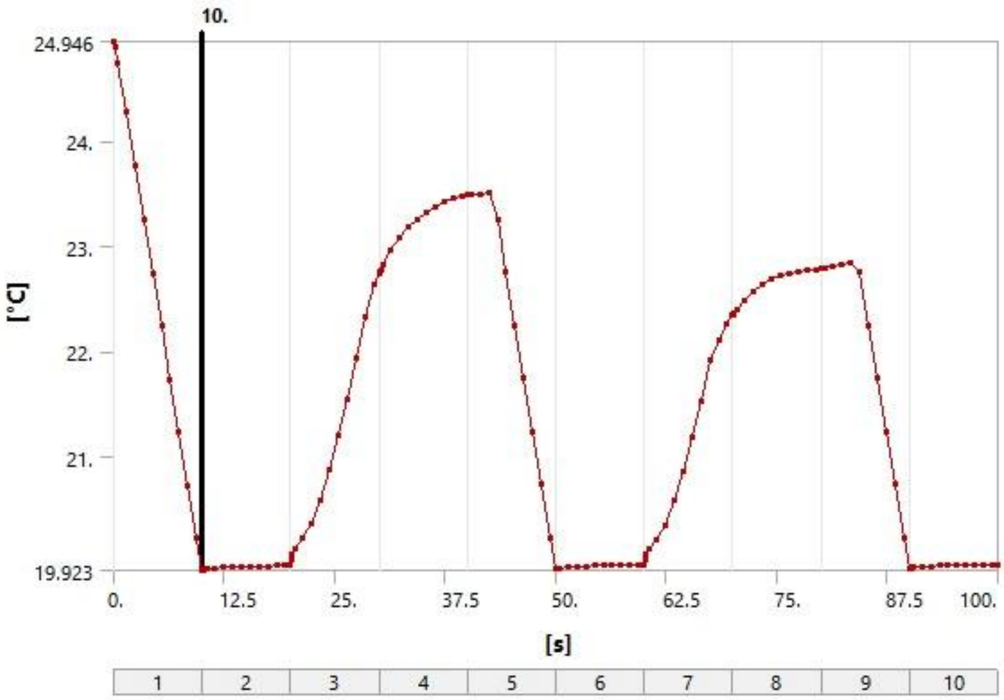


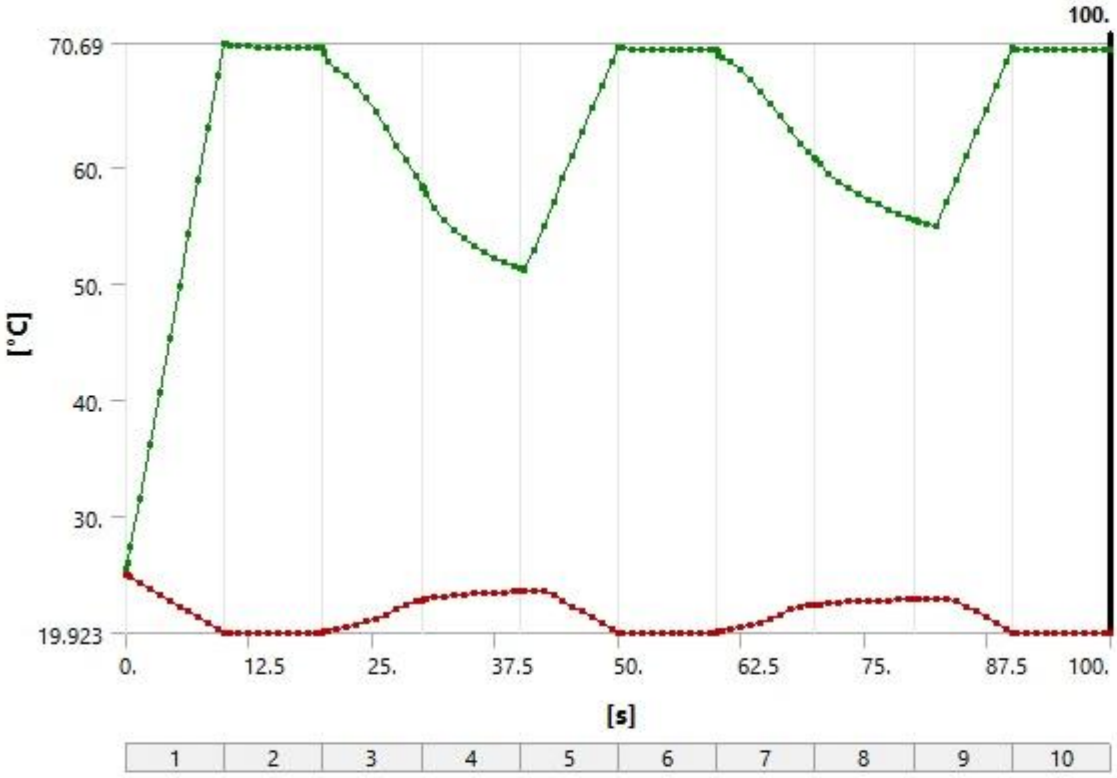
Fig 6.2 **Aluminium Square Box Temperature Distribution**



Graph 6.4 **Aluminium square box temperature distribution in rice chamber**



Graph 6.5 **Aluminium square box temperature distribution in air chamber**



Graph 6.6 **Max vs Min temperatures in the Aluminium lunch box**

6.4 Round Stainless-Steel Box Design

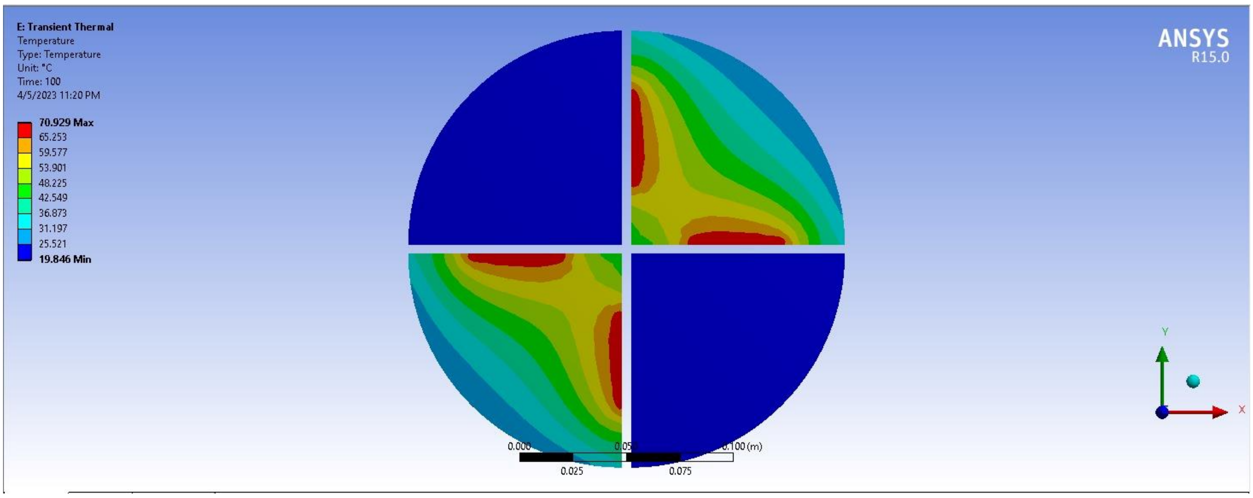
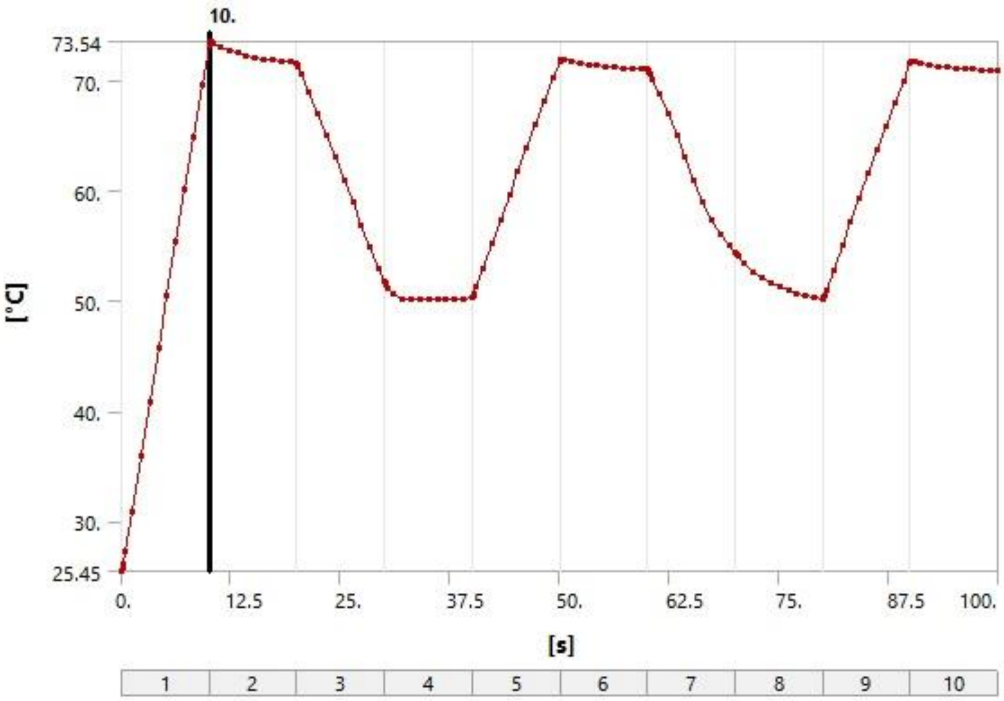
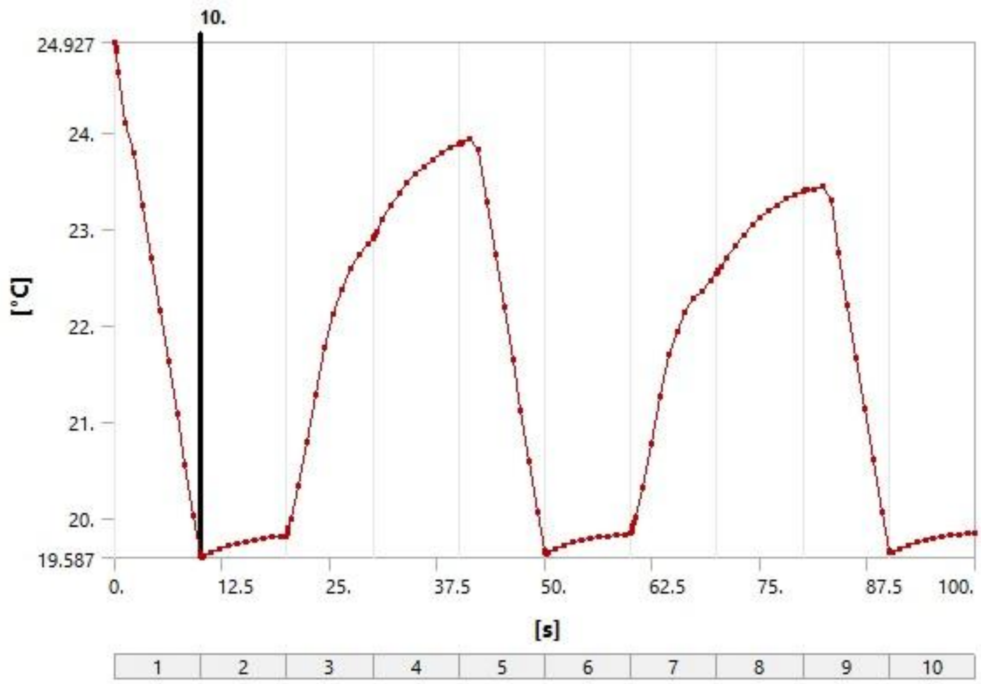


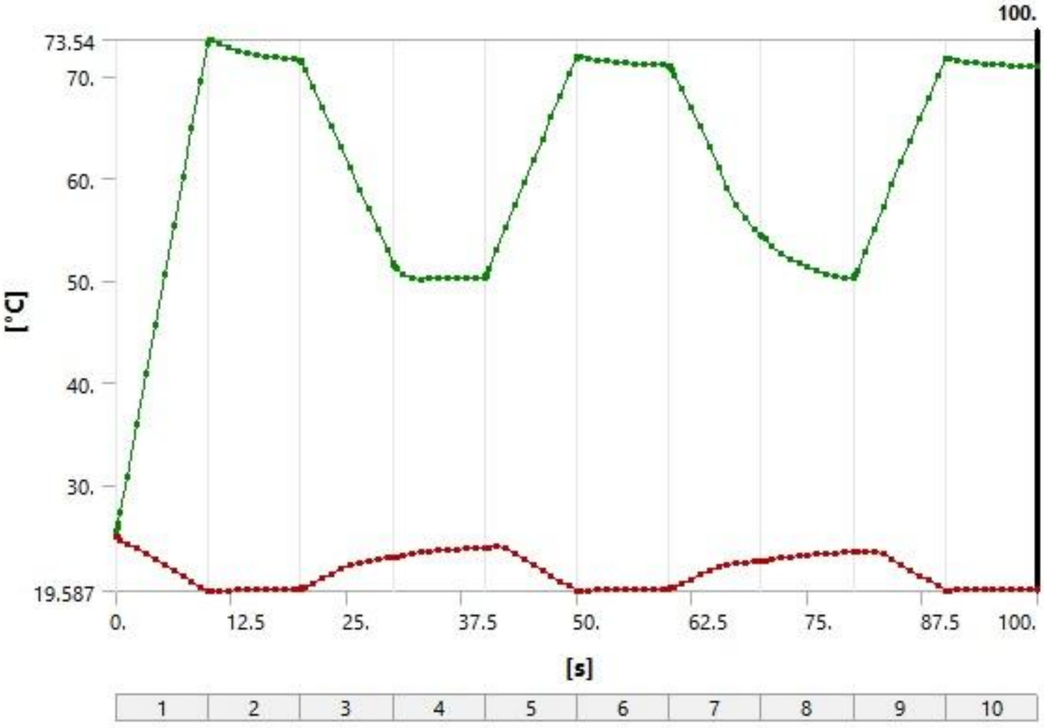
Fig 6.3 **Stainless Steel round Box Temperature Distribution**



Graph 6.7 **Stainless steel round box temperature distribution in rice chamber**



Graph 6.8 **Stainless steel round box temperature distribution in air chamber**



Graph 6.9 **Max vs Min temperatures in the stainless-steel round lunch box**

6.5 Round Aluminium Box Design

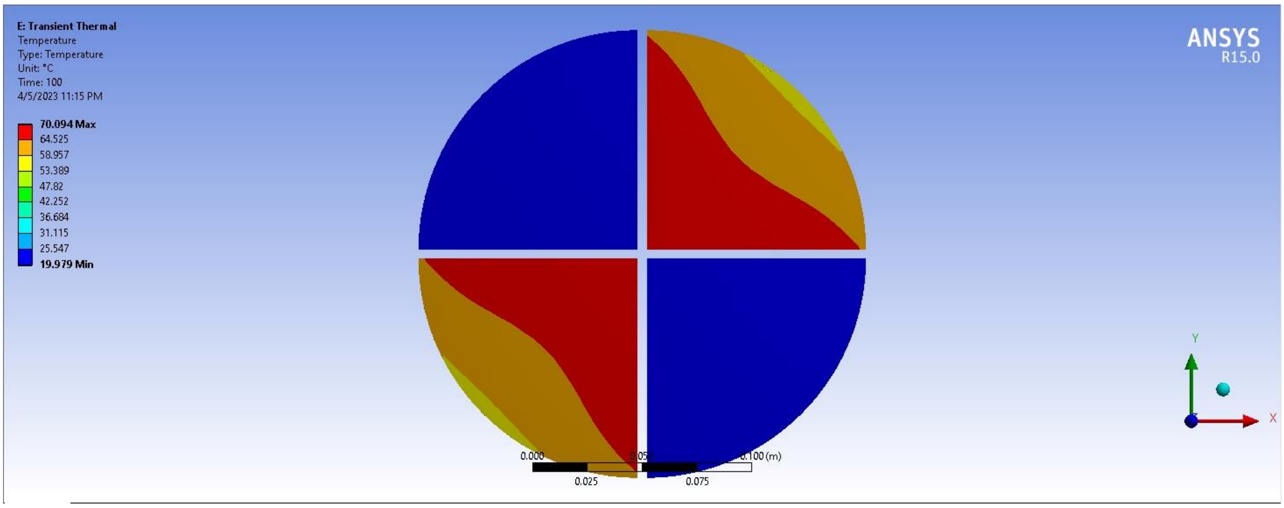
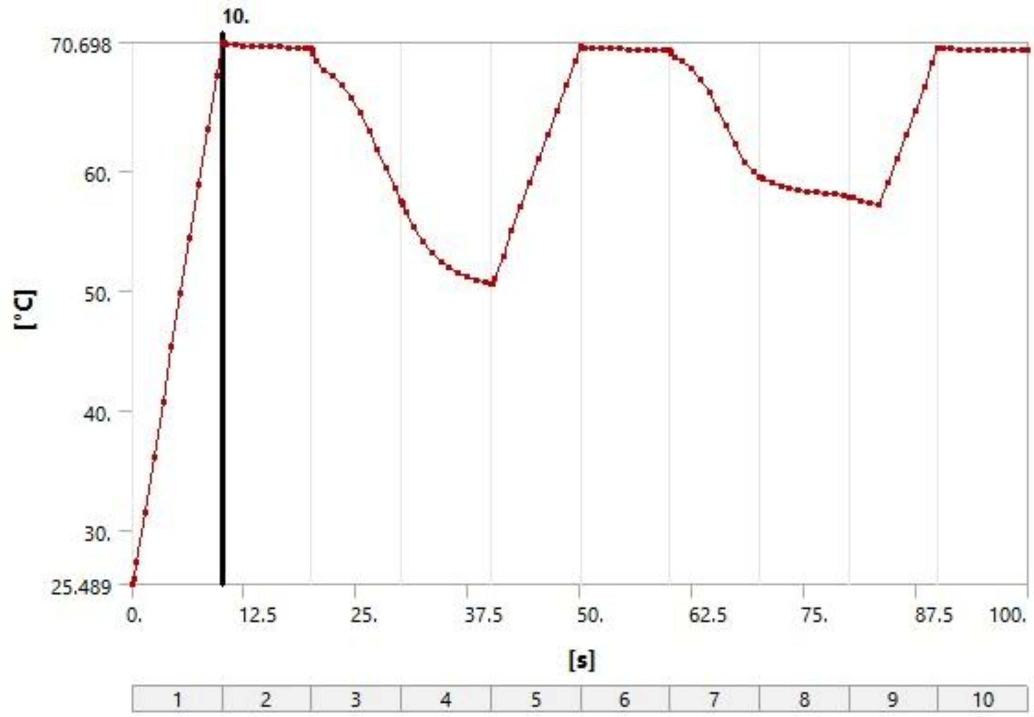
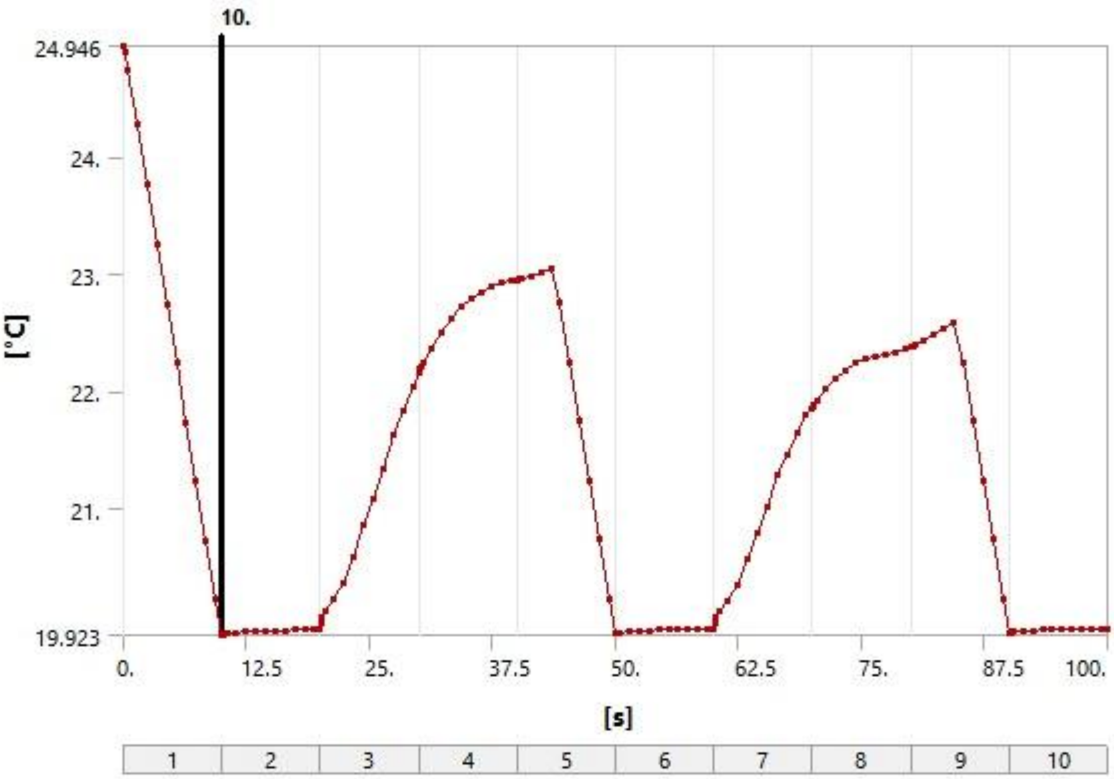


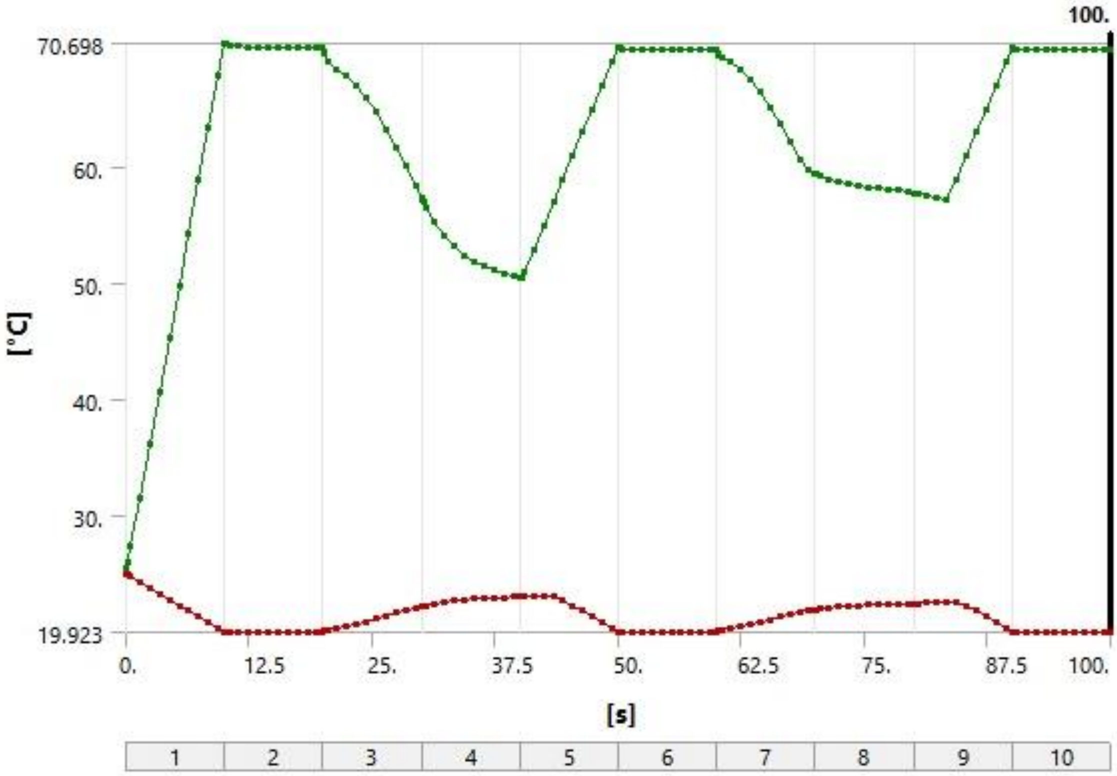
Fig 6.4 **Aluminium round Box Temperature Distribution**



Graph 6.10 **Aluminium round box temperature distribution in rice chamber**



Graph 6.11 **Aluminium round box temperature distribution in air chamber**



Graph 6.12 **Max vs Min temperatures in the Aluminium round lunch box**

Aluminium round Lunch box temperature distribution Max vs Min is as show in figure 6.12.

The analysis results shows that the maximum and minimum temperatures of the both square and circular boxes similar. The simulation results shows the temperature distribution is even in circular box than square. The food portion in the corner is not heating at all in the square boxes for the designed configuration. As the thermal conductivity of aluminium 1100-O is more, the food acquiring required temperature quickly than the 304-stainless steel. Aluminium material can react with some kinds of food, hence as per the application the desired material can be choosen.

CHAPTER-7

CONCLUSIONS & FUTURE SCOPE

In conclusion, we have successfully designed an IoT-enabled thermal lunch box that addresses the problems of traditional lunch boxes and provides convenient heating options. By using Peltier models, we have achieved an efficient heating function with accurate timing, and through the use of node MCU and relays, we have enabled IoT operation for easy temperature control through a mobile app and Wi-Fi. Furthermore, the use of Ansys software has allowed us to optimize the shape and material of the box for efficient thermal distribution, resulting in a more compact and lightweight design.

Overall, the designed thermal lunch box provides a practical and cost-effective solution for people who need to carry and heat their food conveniently. With the increasing trend towards smart homes and smart devices, we believe that IoT-enabled lunch boxes have great potential to become a part of everyday life for many people.

7.1 Conclusions:

1. The simulation results suggest that aluminium is more efficient than stainless steel for a thermal lunch box, due to its better temperature distribution.

2. The geometry of the lunch box also plays a role in temperature distribution, with a round lunch box having a more even temperature distribution compared to a square lunch box.

3. These findings can help in the design and selection of materials for thermal lunch boxes.

4. The use of IoT technology in the lunch box, such as preheating remotely, can enhance the user experience and convenience.

5. Further research could explore the use of other materials and geometries for thermal lunch boxes, as well as additional IoT features to improve functionality.

7.2 Future Scope:

Some potential future research and development areas for an IoT-enabled thermal lunch box could include:

1.Optimization of the Peltier module and power supply to improve the efficiency and heating/cooling performance of the lunch box.

2. Integration of sensors to monitor food safety and quality, such as temperature and humidity sensors, and even food weight sensors to track consumption.

3. Development of smart control algorithms that can learn user preferences and automatically adjust temperature and heating times accordingly.

4. Exploration of alternative materials and designs to further improve heat retention and temperature distribution, such as ceramic or composite materials.

5. Investigation of new features, such as voice control, mobile app integration, or even incorporating biodegradable materials for a more sustainable lunch box.

REFERENCES

1. Ronald H. Schmidt, Daniel J. Erickson, Steven Sims and Philip Wolff, Characteristics of food contact surface materials: stainless steel 2012 Vol.32 No.10 pp.574-584 ref.30
2. Rakibul Hossain, Mehdi Tajvidi, Douglas Bousfield, Douglas J. Gardner, Multi-layer oil-resistant food serving containers made using cellulose nanofiber coated wood flour composites Volume 267, 1 September 2021, 118221
3. Ahmed Elsayed Abdelkafy Amer, Vladimir Lebedev , Thermal Energy Storage by Using Latent Heat Storage Materials, International Journal of Scientific & Engineering Research Volume 9, Issue 5, May-2018, SSN 2229-5518, IJSER © 2018
4. P. Kolber , D. Perczyński , K. Peszyński , B. Landowski , EFFICIENCY TESTING OF THERMOELECTRIC COOLING CELL BASED ON PELTIER MODULE , May 14 – 17, 2018, Paper #28, pp. 381–384, doi: 10.21495/91-8-381.
5. YU. G. GUREVICH, J. E. VELAZQUEZ-PEREZ, Peltier Effect in Semiconductors, 03 April 2014, Citations: 12.
6. Nakul Mahalle, Lalit Gabhane , Jayshri Lanjewar , Urvashi Dhanre , Sandesh Ughade , Washimraja Sheikh , Dipak Hajare, Nehal Jadhao, Nitinkumar Padghan, Development of Solar Based Heating and Cooling System Using Thermo-Electric Module, International Journal of Innovations in Engineering and Science, Vol. 3, No.10, 2018, e-ISSN: 2456-3463
7. K. M. Kretzschmar, Douglas Robert Wilkie, The use of the Peltier effect for simple and accurate calibration of thermoelectric devices, Published:19 August 1975, Royal Society, Volume 190, Issue 1100.
8. D.M. Rowe, Recent developments in thermoelectric materials, University of Wales Institute of Science & Technology, Volume 24, Issue 2, 1986, Pages 139-162, online 8 August 2003.
9. Chao Wang, Yi Niu , Jing Jiang , Yide Chen , Hanqing Tian , Rui Zhang , Ting Zhou , Junfeng Xia , Yan Pan , Shuangyin Wang, Hybrid thermoelectric battery electrode, Volume 45, March 2018, Pages 432-438, 16 February 2018.
10. https://www.matweb.com/search/datasheet_print.aspx?matguid=db0307742df14c8f817bd8d62207368e

11. https://www.matweb.com/search/datasheet.aspx?MatGUID=abc4415b0f8b490387e3c922237098da
12. M. N. Ramesh (2000) Effect of cooking and drying on the thermal conductivity of rice, International Journal of Food Properties, 3:1, 77-92, DOI: 10.1080/10942910009524617
13. LI Chun-xiang， FANG Da-ming， CHEN Wei， PANG Ke， LI Guang， ZHAO Jian-xin， ZHANG Hao. Thermal and Dielectric Properties of Cooked Rice[J]. FOOD SCIENCE, 2011, 32(3): 103-107.