جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

**College of Engineering**

**Department of Mechanical Engineering**

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# Senior Design Project Report

# Design of Mini Refrigerator

**In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering**


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***Abstract***

Refrigerators are considered to be an important household item that falls under the category of cooling appliances. The basic structure of the refrigerator consists of a thermally insulated compartment which through a proper mechanism lowers down the temperature inside it and transfers the heat from inside to the external environment. As it keeps the temperature lower so it is used to keep and store the food items which can be spoiled at ambient temperature.

Refrigerators in almost all the sizes are available at the market but they are restricted and limited for indoor usage only as they require electricity and are large. But presently, people are more inclined towards outdoor activities and they need to have a refrigerator to keep the essential items saved from spoilage and wastage. So, this project has designed a mini refrigerator that is powered through the batteries and is portable which can be easily used outdoors as well.

**Acknowledgments**

We are thankful to our supervisor, teachers, parents, and all the friends who supported us in completing this project. Without their support, it would not have been possible for us to complete this. We would like to extend our thanks and appreciation to Dr. Faramarz Djavanroodi, chair of the Mechanical Engineering Department at PMU, for his continued encouragement. Lastly, we thank our parents for the unceasing encouragement, support, and attention.

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## Chapter 1: Introduction

This chapter introduces the project. It further states the objectives of the project and specifications of all the related equipment and electronics to be used in its making. Lastly, it states the standards that are utilized while working on this project. Mini refrigerators are small in size, they can be kept anywhere and yet won't consume huge space. They are most suitable for small office spaces, dorm rooms, bedrooms. People with limited space often consider replacing a full-fledged refrigerator with a mini-fridge.

Most students have snack, and some regularly eat one or more meals each day in their room. Unless your diet consists of all packaged foods, you'll need a little fridge to store your perishable food and drinks.

### 1.1 Project Definition

The project under consideration is intended to design and construct a portable mini refrigerator that could be used at places where traditional and conventional refrigerators cannot be used. Refrigerators are considered to be an important household item that falls under the category of cooling appliances. The basic structure of the refrigerator consists of a thermally insulated compartment which through a proper mechanism lowers down the temperature inside it and transfers the heat from inside to the external environment. As it keeps the temperature lower so it is used to keep and store the food items which can be spoiled at ambient temperature. The refrigerators consist of different parts or components including the cabinets (inner and exterior), insulation inserted in between the two cabinets, the cooling system, fixtures, and the refrigerant. Cabinets are either made of aluminum or steel metal sheets and the exterior is usually plastic. Polyfoam or fiberglass is used as insulation which fills up space and gap between both cabinets. For refrigerant, freon is usually used which is trademarked by DuPont. It passes a nonflammable gas, which keeps the temperature low by undergoing the evaporation process repeatedly. Refrigerators in almost all the sizes are available at the market but they are restricted and limited for indoor usage only as they require electricity and are large. But presently, people are more inclined towards outdoor activities and they need to have a refrigerator to keep the essential items saved from spoilage and wastage. So, this project focuses on designing, constructing, and fabricating a mini refrigerator that would be powered through the batteries and is portable which can be easily used outdoors as well.

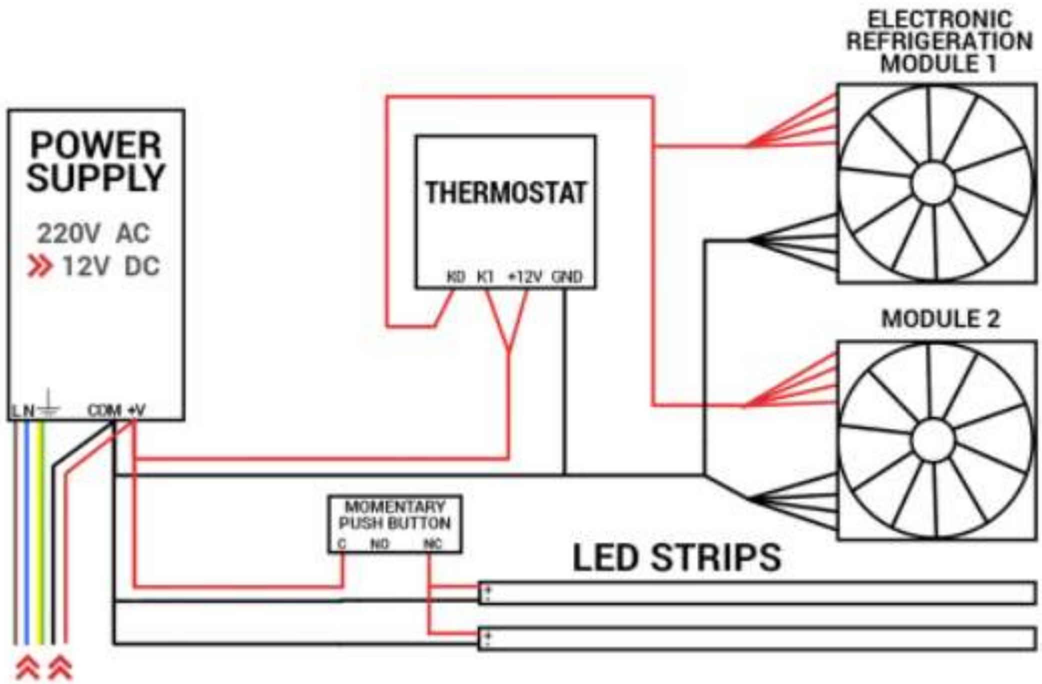
### 1.2 Project Objectives

The main objectives of the project are:

1. To design and construct a mini portable refrigerator that could be used to keep things cool while traveling or doing outdoor activities.
2. To study the vapor compression theory and related components to better understand the method to design the refrigerator.
3. To test run the refrigerator to see if it works as per the set theory and dynamics.

### 1.3 Project Specifications

The project intends to make a refrigerator and at the initial stage, the identification and planning of different electronics are made. The basic schematic diagram for the refrigerator is given below [Figure 1]:




The basic

Figure 1: Schematic Diagram of a Refrigerator

Figure 2: Vapor Compression Cycle DiagramFigure 3: Schematic Diagram of a Refrigerator

electronics which would be needed for the fabrication process of the refrigerator along with their specifications is given below:

Table 1: Specifications of electronics used

| **Essentials** | **Specifications** | **Diagram** |
|---|---|---|
| 2x electronic refrigeration modules | 12V 6A<br>Semiconductor cooling equipment |  |
| Thermostat | W1209 DC 12V -50 to +110<br>Temperature sensor control switch |  |
| AC to DC power supply | Ac 220V to DC 12V, 15Amps, 180W |  |

| | | |
|---|---|---|
| Cold white LED strip | 3M DC 12V, 43.2W, 180 SMD 5050 |  |
| Shrink tubes | Halogen-free heat shrink tubes |  |
| Power plug AC | AC 250V/10A IEC320 C14 |  |
| Aluminum channel holder | 50cm U/YW/V-Style |  |
| Self-adhesive rubber seal | 5M E type |  |

Other equipment to be used in the fabrication of the refrigerator are:

| | | |
|---|---|---|
| White sticker paper | Power plug 12v | Styrofoam |

| | | |
|---|---|---|
| Acrylic glass and aluminum tape | Momentary push button | Doorknobs (for setting the legs) |
| Medium-Density Fiberboard (MDF) | Aluminum handlebar (on lid) | Doorknobs (for setting the legs) |
| Styrofoam | Aluminum angles | Spray paint + clear coat |
| Wire terminals | | |

The main specifications of the project are:

Voltage: 12V DC

Current: 6 A

Power: 72 Watts

Weight:

Some of its marketing features are as follows:

- It is economical and easy on the budget
- It is energy efficient and uses less energy as compared to the conventional one
- It is lightweight and can be carried out easily
- It is Portable and mobile which makes it easy to use
- It is environment friendly as it reduces less heat and does not create the ozone layer
- It is safe and easy to use because of its features.

**a. Engineering standards:**

There are many codes and standards available that are appropriate for the use of electronics and related equipment while designing and fabricating refrigerators. Some of them which we are going to utilize in the making of this project are as follows:

- PR EN 13313 requires the involvement of competent engineers in the design, construction, and fabrication of refrigerators.
- BS EN 60335-2-24 states safety rules while making household and similar electrical appliances particularly refrigerators.

- ISO/TC 86/SC 1 states safety and environmental requirements for refrigerating systems
- ISO/TC 86/SC 4 states testing and rating of refrigerant compressors

## 1.4 Applications

The portable mini refrigerator can be used as:

- Storing and keeping the perishable items like food and beverages cold
- Keeping the medicine cold while traveling or at small places
- Storing and keeping the beauty Care products cold during travel or at small salons etc.
- Saving the electricity and space yet storing the items efficiently
- Storing the items at workshops or camper van
- Replacing the big size high-voltage refrigerator to avoid and save energy wastage

## Chapter 2: Literature Review

This chapter states the research and review on literature regarding the related projects and performs a comparative analysis. It also states how this project differs from those mentioned in the literature review.

### 2.1 Project background

Generally, refrigeration is the most reliable method of getting the right temperature for keeping the perishable things fresh and cool hence saved from getting spoiled and bacterial growth. A refrigerator does this by lowering down the temperature as compared to the ambient temperature. A refrigerator falls under the category of cooling appliances which works on two basic laws of physics: first, the flow of heat goes from the warmer material to cooler material only, and second, when the pressure of gas decreases, the temperature also decreases. Back before 1748, when there were no refrigerators, icehouses were used to provide cool storage for food and other items. Then, in 1748, William Cullen at the University of Glasgow, Scotland demonstrated the first-ever artificial refrigerator which was later designed by Oliver Evans in 1895 which was further developed by James Harrison in 1857 which was based on the vapor compression concept which is still used in all the refrigerators.

The main components and parts of a refrigerator include a compressor, capillary tube which is an expansion valve, condenser, and an evaporator. The compressor works like a pump and increases the pressure of the liquid inside the refrigerator through pulling in the air whereas the capillary tube meters the refrigerant flow from the condenser to the evaporator. The condenser diffuses the heat which is extracted from the interior of the system and the evaporator works to keep the inside cool as a result of the vapor compression process. Through a complete circuit, these parts are joint, and evaporation of liquid takes place which helps in achieving the lower temperature inside the refrigerator.

Refrigerators in almost all the sizes are available at the market but they are restricted and limited for indoor usage only as they require electricity and are large. But presently, people are more inclined towards outdoor activities and they need to have a refrigerator to keep the essential items saved from spoilage and wastage. So, this project focuses on designing, constructing, and fabricating a mini refrigerator that would be powered through the batteries and is portable which can be easily used outdoors as well.

## 2.2 Previous Work

Almost in all places like homes, hotels, events, etc., people prefer chilled and cold water, drink, and fruits which have given rise to the use of refrigerators [1]. To the date, the refrigerators use a vapor compression system which is the basic mechanism of the refrigerators. "In this system, the working fluid is a vapor. It readily evaporates and condenses or changes alternately between the vapor and liquid phases without leaving the refrigerating plant" [2 and 3]. During the phase of evaporation, the refrigerant while passing through the evaporator cools down the inside of the cabinets as well as absorbs the heat, and later on, that heat is converted into the liquid to vapor. [4]. As far as the portable refrigerators for household are concerned, they are small in sizes having "horsepower ratings of between 1/20 and ½ hp, normally of the hermetically sealed type." They usually consume about 90W to 600W electrical energy while running and are designed to perform satisfactorily in environments at up to 43$^{o}$C. [1]

The authors used the same vapor-compression concept and made a refrigerator that can be used either for heating or for cooling with the main application of cooling. It can also be used a temperature controller. The refrigerator has no moving parts and uses a thermoelectric approach which reduces the use of electricity. That refrigerator utilizes the pettier effect and maintains the temperature of 3oC to 23oC. [5]

The size of components that are used to design and construct a refrigerator is determined based on heat load particularly the size of the compressor because it has the main duty to handle the heat and lowering down the temperature. According to ASHRAE, good conservation measures can minimize the amount of energy consumed by a refrigerator [4]. The main beneficiary of such refrigerators is the food industry which can save perishable food items for a longer period of time with lesser cost.

Different methods can be used to fabricate the refrigerator including icebox, cold air systems vapor-compression. The latter method is widely used for the fabrication of refrigerators, air-conditioning systems, and heat pumps. "It consists of four processes: Isentropic compression in a compressor; Constant-pressure heat rejection in a condenser; throttling in an expansion device;

and Constant-pressure heat absorption in an evaporator [1]. The figure [Figure 2] below describes this process where the cycle is operated in two pressures high and low. The section line from state 4-1 is low pressure and state 2-3 is high pressure for the system. [1]

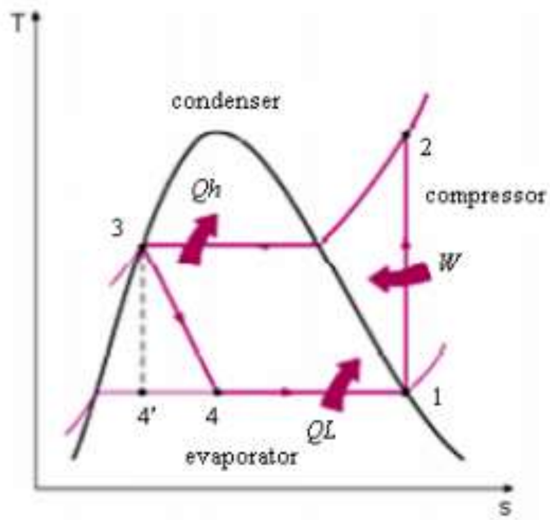



Figure 4: Vapor Compression Cycle Diagram

## 2.3 Comparative Study

The authors developed a DC portable refrigerator with the aim and objective to store the food and perishable items particularly medicines. The project was based on a vapor-compression system which is explained before in this chapter. The main components of the refrigerator were a condenser, a compressor, a capillary tube, and an evaporator. The project was focused on their length and at the end of the project, the length of the capillary tube was 2.84 meters, a condenser is 12.39 meters, and an evaporator is 9.25 meters. A small DC refrigerator has been tested but cannot work properly because of the electronic unit problem. [6]

The authors of a study improved the efficiency of a portable refrigerator by using the outside cold air. They explored that the highest energy consumption stage is the usage phase and it is in the form electricity running the compressor 80-90% of the time so they introduced the sheer volume technique to reduce the power consumption but the research has some limitations like it can also be used in the kitchen with modifications for the energy-efficient environment and at places with cold climates. [7]

The authors of another study developed a mini mobile refrigerator that was developed to store medicines, vaccines, food materials without electricity. They made a solar portable fridge that was eco-friendly. the refrigerator was successfully operated both in AC and DC power supply environment. The results have shown reliable figures throughout the year and the lowest temperature that it could obtain was 6 Celsius degree with a COP1 of 5.89. [8]

The review of another study showed that the authors worked to design and develop a portable refrigerator particularly for home use. The design and mechanism were based on a vapor compression system and it used tetrafluoroethylene (R134a) refrigerant. The maximum volume it could accommodate was 0.041m2 and it could achieve the temperature of 7 Celsius degree. The body was made up of steel plates and plastic foam was used for insulation purposes. At the end of the fabrication, the test was run and results showed that the refrigerant was wet vapor and the coefficient of performance was calculated as 7.81. The heat rejected by the condenser and work is done on the compressor were obtained as 176.81 kJ/kg and 20.07 kJ/kg which was quite a good output. [1]

The project under consideration is different from the above-stated projects concerning a few points: It is positioned as a desktop refrigerator (horizontal top-lid) as against the tower one which would increase its efficiency by keeping the coolness inside it every time it is opened. Also, it reaches the lower temperature in lesser time than in the projects which is 6 Celsius degree in 30 minutes when there is nothing in it and takes a bit longer when something is inside there. It is energy efficient as compared to those refrigerators that are mentioned above. In one of the projects mentioned, there was an operational issue because of unit disturbance which is not the case here. This project works very well and is well functional.

[1] COP stands for Coefficient of Performance and indicates the efficiency of heating and cooling machines.

## Chapter 3: System Design

In this chapter, we will focus on various parameters that are required in the design and fabrication of a mini portable refrigerator.

### 3.1 Design Constraints and Design Methodology

For the proper thermoelectric module, design selection for the specific application requires an evaluation of the total system in which refrigeration is used. As for general applications, it can be done by using standard module configurations, while in many cases, the need for special design is mandatory to meet electrical, mechanical, and many other requirements. The basic design of the refrigerator is based on the Vapor Compression System which is shown below in Figure:

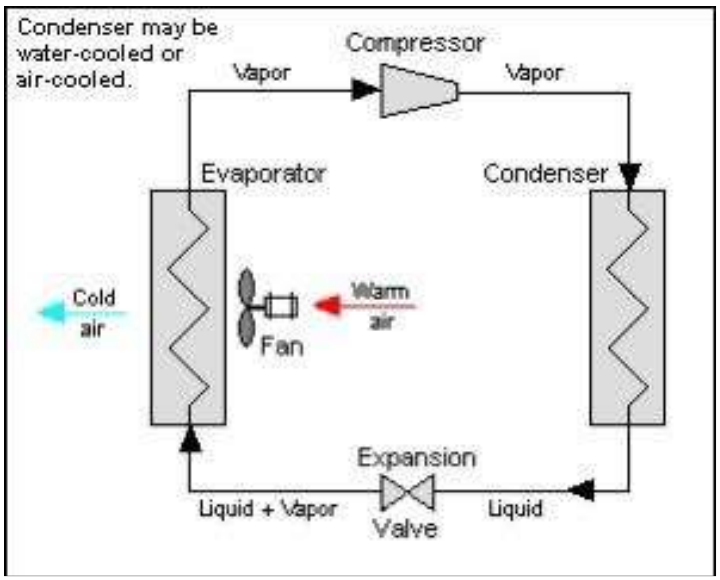



Figure 3: Typical Single-stage Vapor Compression Refrigeration

While working on the project, there are certain constraints that we had to face. The detail of the constraints is given below:

#### Geometrical Constraints:

Refrigeration has three main categories, namely: Domestic Refrigeration; Industrial Refrigeration; and Commercial Refrigeration. The limitations in refrigerators are mainly due to the specifications in size, capacity, area, and capacity that limits the design of any machine. The same happened with the design of the refrigerator while designing that. Besides these limitations, there is the inaccessibility of a 12V DC compressors, Second most important is the inaccessibility of a polyfoam that is the most important element for insulation and the third is lack of workshop tools for machining.

**Environmental Constraints:**

When we talk about cooling systems, conventionally they use compressors and working fluids to transfer heat for refrigeration. In this process, thermal fluid is absorbed, and the working fluid is released which is the environmental constraints. However, in this mini portable refrigerator, no such fluids become a part of the environment and no ozone is made as general. it uses Peltier model coolers that to offer several benefits over conventional systems. They are entirely solid-state devices, with no moving parts, reliable, and quiet. They can be extremely compact, much more so than compressor-based systems.

**Social Constraints:**

These refrigerators are very friendly as it has no moving parts and is one of the solid-state heat pumps. There are very few components in these refrigerators due to which it is convenient and can be carried outside easily. This model of refrigeration is a beneficial alternative as it can use waste electricity for further cooling applications and meeting our present energy challenges. Further, the absence of moving parts makes them rugged, reliable, and quiet.

**Economic Constraints:**

During the process of manufacturing refrigerators, fins are used that are the surfaces extended from an object to increase the rate of heat transfer to the surroundings by enhancing the convection process. By adding the fins surface area is increased and it is an economical solution to the heat transfer problems. To maximize heat transfer density shape of the fins must be optimized. This can be possible when space and materials used for finned surfaces are constraints.

**Safety Constraints:**

No flame source, toxic or propane source used. This runs on 12 V but compressor system can leak freon which is one of the side effects of it when heated. Besides this absorption system can use propane which is also harmful if leaked.

### 3.2 Engineering Design Standards

Engineering standards should be followed in each component of our system. In this section, we described the main components that have been selected for our project.

| **Components** | **Engineering Standard** |
|---|---|
| Screw | ASME |
| Fans | AMCA |
| Alternator | Delco-Remy |
| Battery | RESNA |

### 3.3 Theory and Theoretical Calculations

Initially, we set the initial temperature of the refrigeration box as 32 degrees Celsius and observed the cooling rate for 45 minutes and after 45 minutes, the refrigeration process starts working gradually in such a way that its temperature starts decreasing up to 22 degree Celsius after 45 min.

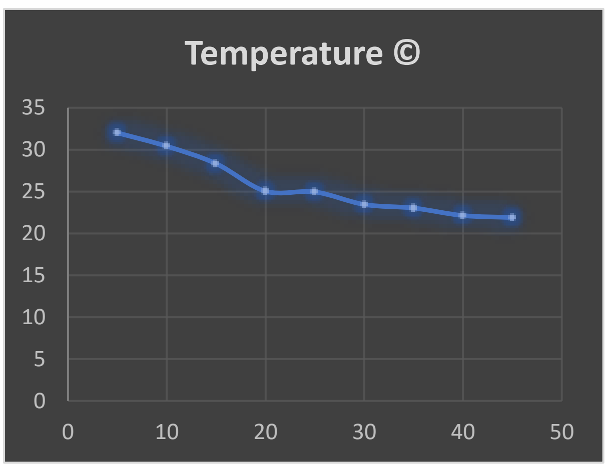



Figure 4: Temperature Vs. Time

Theory underuse in this system manufacturing was the vapor compression Model theory and Peltier effect. The governing equations used in this process are identical to the adiabatic inlet and outlet region of the capillary tube. Where the mass, momentum, and conservation equations are as follows.

$$\frac{\dot{m}_r}{A_{ct}} = G_{ct} = \text{const}$$

$$\frac{-dp}{dx} = \frac{f\upsilon G_{ct}^2}{2D_{ct}} + G_{ct}^2 \frac{d\upsilon}{dx}$$

$$\frac{dh}{dx} = \frac{-G_{ct}^2}{2} \frac{d(\upsilon^2)}{dx}$$

Here our concern is to deal with the governing equations used in the heat exchanger regions. So in that case mass, momentum, and conservation equations for the capillary tube are used. Similarly for suction line and energy equations for the heat exchangers, six number of governing equations are as follows:

$$\frac{\dot{m}_r}{A_{ct}} = G_{ct} = \text{const}$$

$$\frac{\dot{m}_r}{A_{sl}} = G_{sl} = \text{const}$$

$$\frac{-dp}{dx} = \frac{f\upsilon G_{ct}^2}{2D_{ct}} + G_{ct}^2 \frac{d\upsilon}{dx}$$

$$\frac{dh}{dx} + \frac{G_{ct}^2}{2} \frac{d(\upsilon^2)}{dx} = cp_{sl} \frac{dT_{sl}}{dx}$$

$$\dot{m}_r cp_{sl} \frac{dT_{sl}}{dx} = -h_{sl} \pi D_{sl} (T_w - T_{sl})$$

$$h_{ct} \pi D_{ct} (T_{ct} - T_w) - h_{sl} \pi D_{sl} (T_w - T_{sl}) = 0$$

Also, the thermodynamics properties for the two-phase region are calculated for both liquid and vapor phases

$$h = (1 - x) h_f + x h_g$$

$$s = (1 - x)s_f + xs_g$$

$$\upsilon = (1 - x)\upsilon_f + x\upsilon_g$$

### 3.4 Product Subsystems and selection of Components

The chief thermoelectric (TE) material design method was that introduced by A.V. Ioffe, guiding to semi-conducting 23 compounds such as Bi2Te3, which is used in thermoelectric refrigerators even today. In recent years there has been increased interest in the application of thermoelectric to electronic cooling, accompanied by efforts to improve their performance through the development of new bulk materials and thin-film micro coolers. The usefulness of thermoelectric materials for refrigeration is often characterized by the dimensionless product, ZT, of the thermoelectric figure of merit Z and temperature T. The expression for the thermoelectric figure of merit is given by:

$$\boldsymbol{z = \frac{\alpha}{\rho k}}$$

Where $\rho$ = Electrical Resistivity

k= thermal conductivity

P and N-type material have different figures of merit and are averaged to determine materials' overall quality.

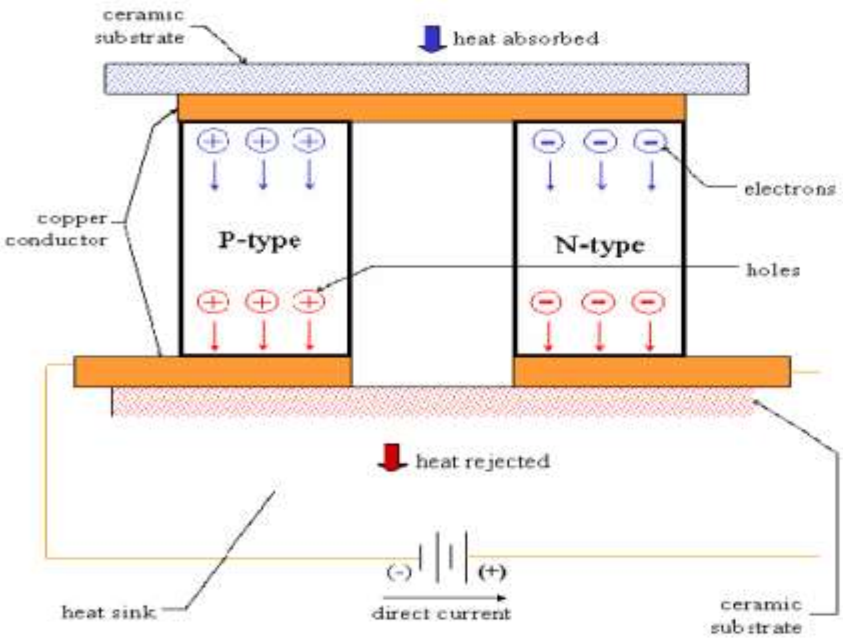



Figure 5: Heat Transfer mechanism using sub-systems

**Thermoelectric Module:**

Bismuth telluride is a material that is taken for the thermoelectric cooler module. The characteristics of a 127 couple, 6 A Bismuth Telluride module. This module involves Direct Current (D.C) device. Specified thermoelectric module action is valid in case of a Direct Current (D.C) power supply is used. Thermoelectric module degradation due to the ripple can be approximated by

$$\frac{\Delta T'}{\Delta T} = \frac{1}{1 + \frac{N^2}{2}}$$

Aluminum is used as the material used for a Heat sink, to keep it in contact with the hot side of the thermoelectric module. Heat sink normally is mediated stages in the heat removal process whereby heat flows into a heat sink and then is transferred to an outward medium. Depending on the size of the refrigerator mostly used heat sinks contain free, forced convection and fluid cooled. There is a contact of the cold side that is made of aluminum with the cold side of the thermoelectric module. The hot side of a thermoelectric module is typically sited in contact with the object that needs to cool. The spacer block is used to make sure an appropriate air gap among the object being cooled and the heat sink. In addition to these, a fan is used to transfer the heat from one side to another. In thermoelectric refrigeration, fins are also connected to the fans for more cost-effective. The rate of cooling depends on the surface area of the fin exposed to surroundings. In the thermoelectric refrigerator, the fins are used on the cold side as well as the hot side.

Figure 6: Cooling fan and Fins used

The temperature sensor gives us the data about the cooling rate of the box and it is used to calculate the efficiency of the device. Considering the dimensions of the box as 28cmX45.5cm and the top side has a length of 41cm. as far as its capacity and volume is concerned, the figure below describes it well:

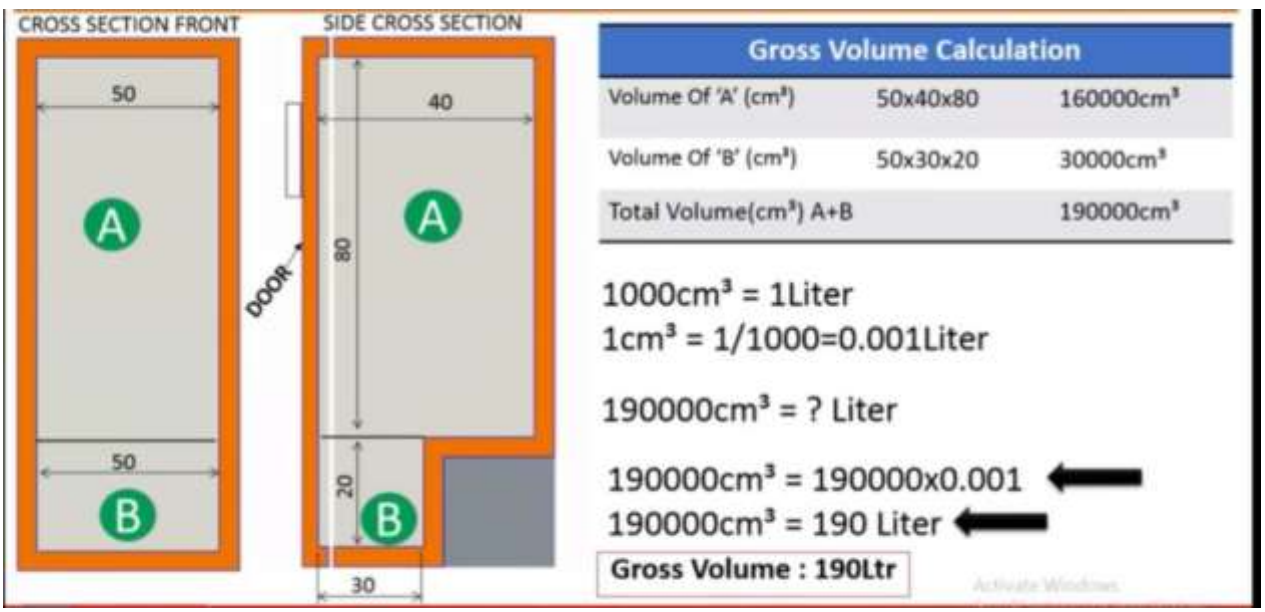



Figure 7: Gross Volume of Refrigerator

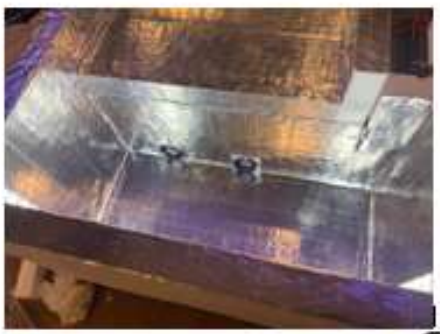
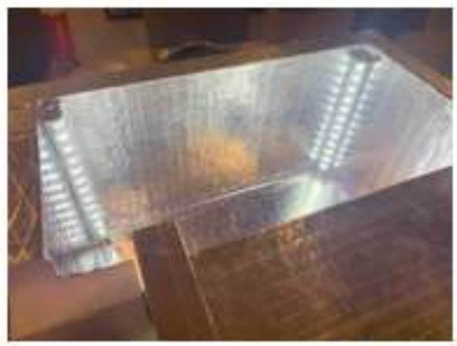
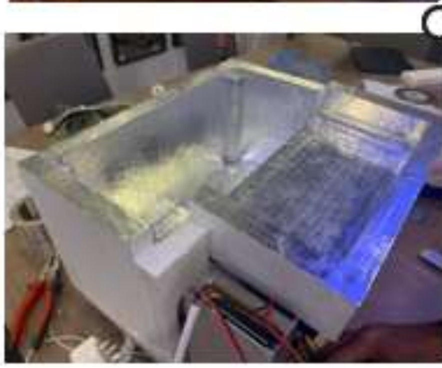
### 3.5 Manufacturing and assembly (Implementation)

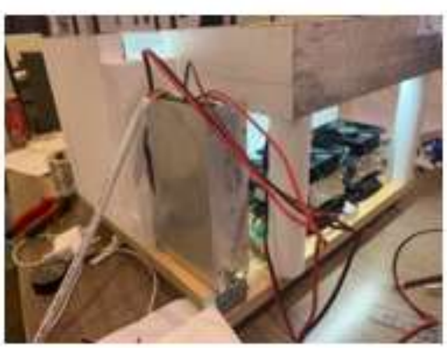
**Firstly, a Refrigeration chamber is made for which** a box for a purpose of refrigeration is made with insulation on both sides. An aluminum sheet of thickness 1mm is used on the outer side of the insulation. The backside of this box is created in a proper dimension to fit the fin fan assembly in it. Also, fins are attached to fans and the whole assembly is attached at the back of the refrigeration chamber. After the alignment of fans in that, some holes in a Styrofoam were made where they would enter the main compartment. Peltier Module is attached to the surface of the fin. Care should be taken that the module is free of dirt and oily materials using alcohol or similar materials. After that, a space for a snack shelf was made and holes were cut for the fans to properly fit in. for the lightning, LED channels were made using a tiny piece of Styrofoam to cover the top and white LED strips were used for this purpose. For the taping purposes, the aluminum tape was used because it looks better, and it is heat reflecting. After that cable spacing was made and the thermostat was hooked up. 12V DC power supply is used in this process, where both the fans and the module is attached to the circuit controller using wires. After hooking up everything to the battery, a push-button was made. After that, the exterior is made with acrylic glass and a scoring knife was used to cut that in straights. In the ned, denting painting is made. The images below describe the step by step manufacturing of a mini portable refrigerator.

Figure 8: Initial & progress steps of manufacturing Refrigerator








## Chapter 4: System Testing and Analysis

### 4.1 Experimental Setup, Sensors and data acquisition system

We make use of different sensors in the Mini Refrigerator.

Figure 9. Refrigerator in process

- Proximity Sensor

Figure 10. Proximity Sensor

- Temperature Sensor

Figure 11. Temperature Sensor

**Location of the Sensors and their uses:**

**Temperature sensor**

- Temperature sensor is used inside the Refrigerator,
- It is used to monitor the temperature of the mini refrigerator.

We use **Pt1000 sensor** and it's the second most common type of the platinum resistance thermometer. It can sense temperature up to
1000°C and it has a resistance of 1000 ohms (Ω).

**Proximity Sensor**

- It is you to detect if the refrigerator dour is one or close
- It is located at the inside door of the refrigerator

**Proximity sensor** is able to sense the existence of any nearby objects without any physical Contact. It often emits a beam of the electromagnetic radiation (infrared) for instance) and look for the change in field or return signal.

## 4.2 Results, Analysis and Discussion

While making the practical model, we had some goals to test our project, perform analysis and see its performance. So, conduct an experiment, get the results and conclude our project.

**Experimental Setup:**

We had the goal to see the effect of the temperature difference by changing the voltage and see the effect of the Peltier effect with the passage of time.
Mini Refrigerator is coupled with the heat pipe. Hot side of the Peltier is coupled with that of heat pipe.  Cold side of the Peltier is equipped with a compact heat sink. There was an air duct that was responsible for drainage of air from cold side. Multipoint recorder is used in this used experiment. Infrared thermal imager is used to monitor running state of experiment. (1)

Figure 12. Experimental Setup

**Results and Analysis:**

Relationship of the cooling produced and voltage is show in the figure below:

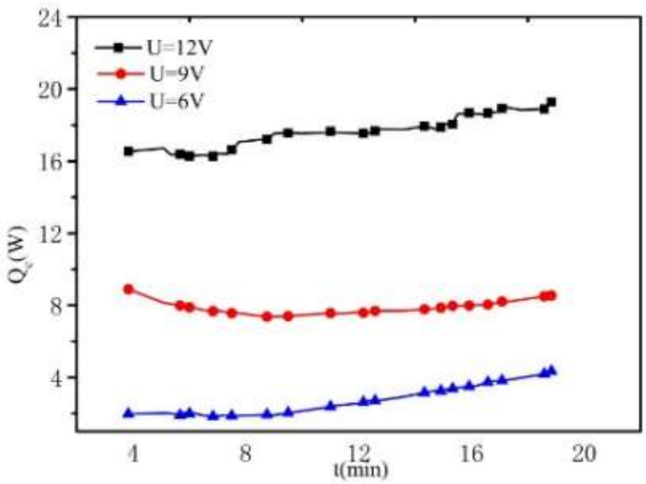



Figure 13. Cooling load Vs Time

It can be seen from the graph that cooling production increases with the increase in the working time and then tends to stabilize. It can be seen that when the working voltage is 12V, then cooling production is largest. When the cooling production was below 9V then working condition show the red line and the cooling production is lower than that of 12V. And when the voltage is below the cooling production is the lowest. (2)

Graph below shows the relationship between temperature difference and time.

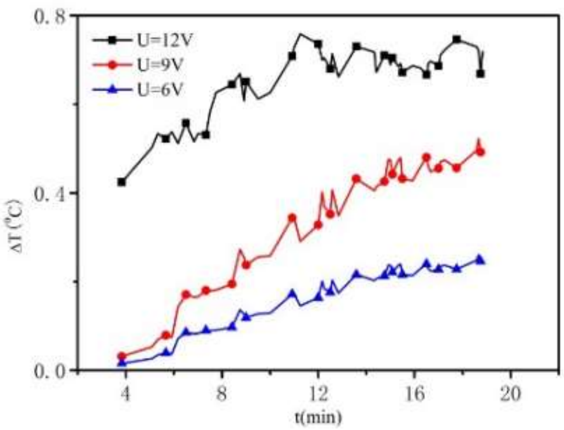



Figure 14. Temperature difference Vs time

The graphs show that the temperature difference is also the function of the voltage with respect to the time.
For higher voltage the value of temperature difference is also high and with the passage of time, temperature difference also increases.

**Design process of the Peltier:**

The choice of Peltier is also important; there are a number of the Peltier available in market with different specifications and dimensions as shown in the figure below.

| Part Number | Data obtained at hot plate temperature Th=27°C | | | | Dimension AxBxH mm |
|---|---|---|---|---|---|
| | Imax (amps)) | DTmax(°C) | Vmax (Volts)) | Qmax (watts)) | |
| TEC1-01703 | 3.3 | 70 | 1.90 | 3.90 | 15x15x4.8 |
| TEC1-03103 | | | 3.50 | 7.20 | 20x20x4.8 |
| TEC1-07103 | | | 8.60 | 16.40 | 30x30x4.8 |
| TEC1-12703 | | | 15.0 | 29.30 | 40x40x4.8 |
| TEC1-01704 | 3.9 | 70 | 2.00 | 4.00 | 15x15x4.7 |
| TEC1-03104 | | | 3.66 | 7.30 | 20x20x4.7 |
| TEC1-07104 | | | 8.40 | 16.70 | 30x30x4.7 |

Figure 15. Showing different Peltier and their specifications

The choice of the right Peltier depends on many factors. Design process of the Peltier involves followings factors:

- Heat load estimation of the object to be cooled.
- Defining the temperature range for the working of object and that of heat sink
- Chose Peltier which meets the specifications
- Chose it according to the suitable power range required
- Chose fan for the heat sink
- Chose right heat sink for the Peltier element. **(3)**

We make choice of the Peltier having:

- Voltage 12 volts
- Power 72W

**Chapter 5: Project Management**

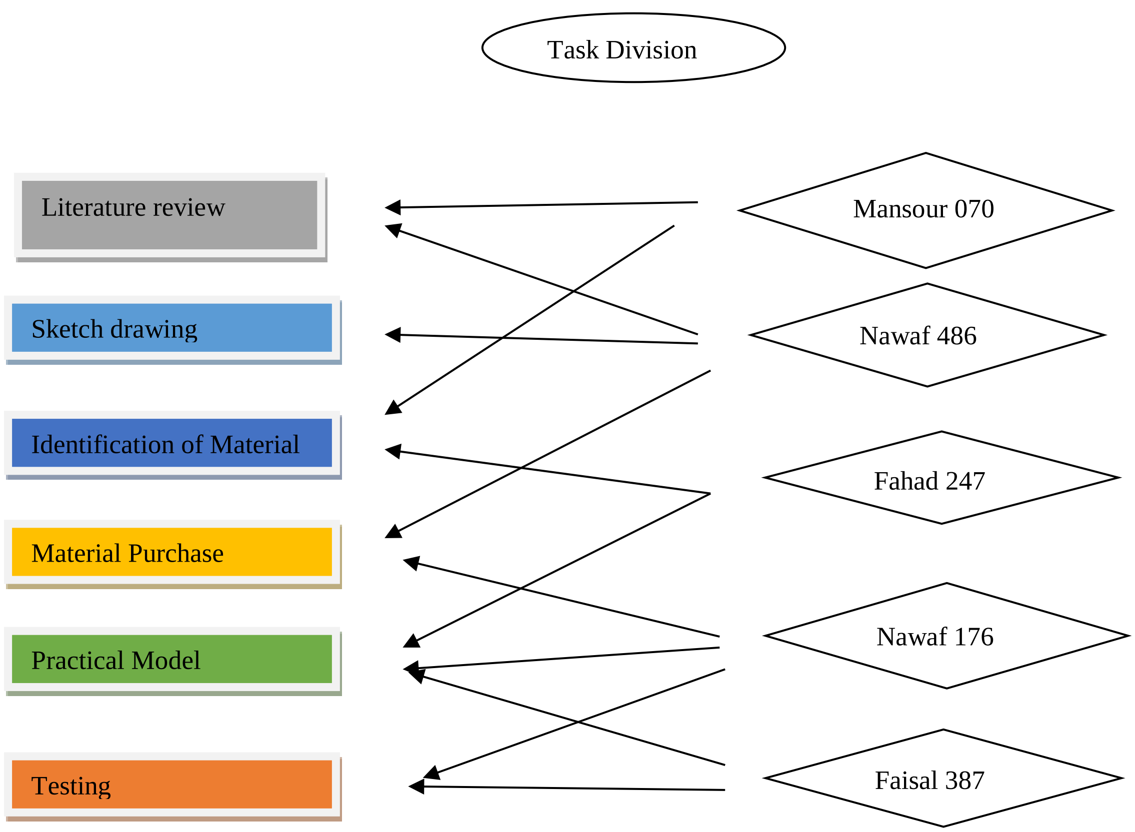
**5.1 Project Plan**

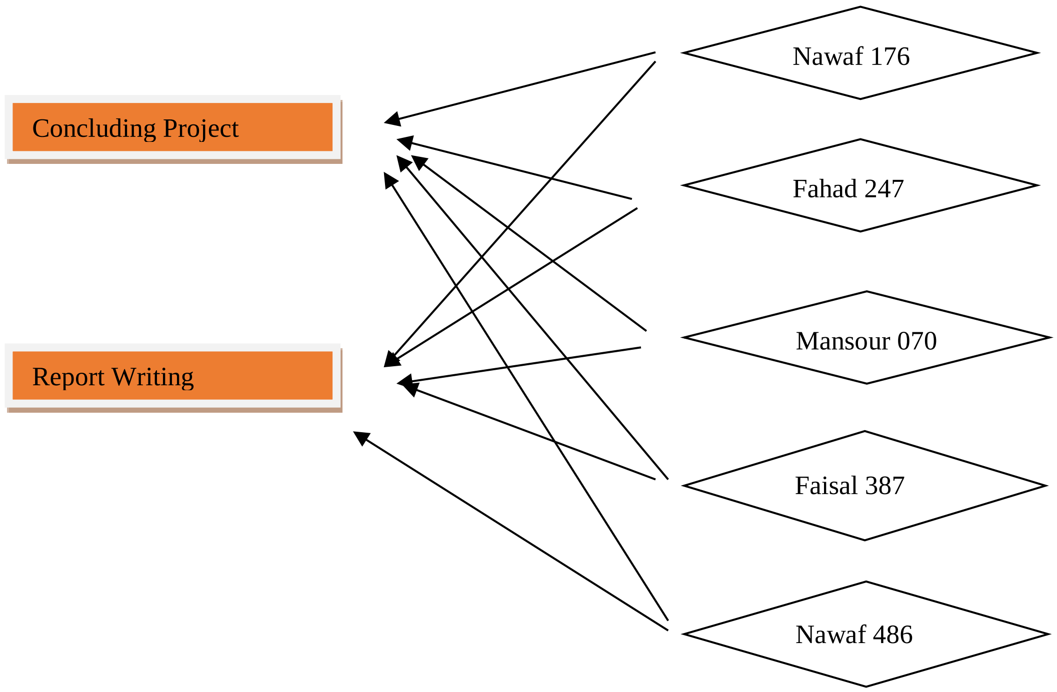
**Break Down of Tasks**:

We have divided the task into 8 tasks

- Literature review for methodology
- 3D modeling
- Identification of appropriate material
- Purchasing of the material
- Making practical model
- Make experimental setup
- Concluding the project
- Report writing

**Map tasks to team members.**



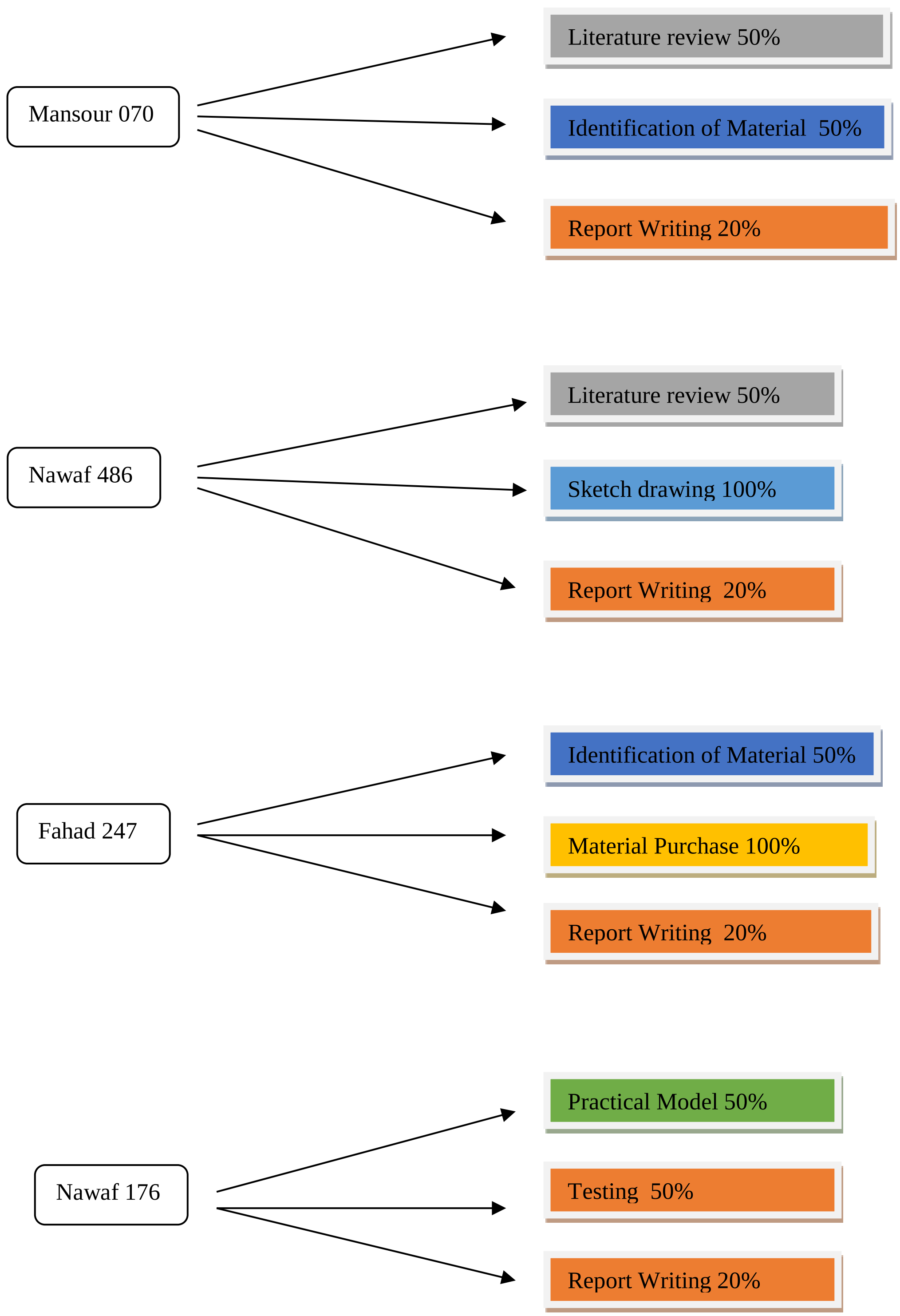

Concluding Project
Report Writing
Nawaf 176
Fahad 247
Mansour 070
Faisal 387
Nawaf 486

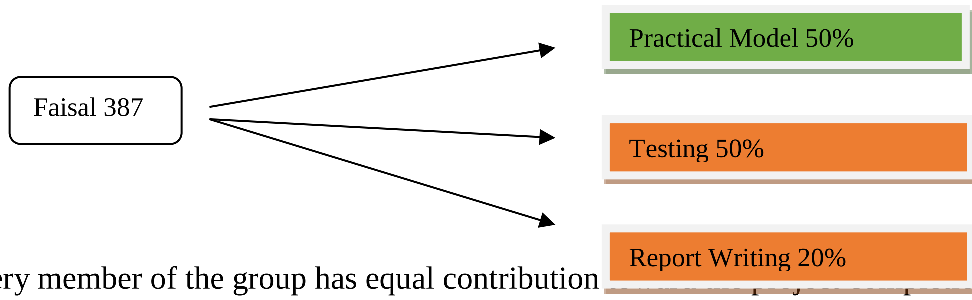
**Time duration table of each task:**

**Table 5.1: Time duration table of tasks**

| Task | August | September | October | November | December |
|---|---|---|---|---|---|
| Task 1 | Literature review | | | | |
| Task 2 | | Modeling | | | |
| Task 3 | | Material Identification | | | |
| Task 4 | | | Material Purchase | | |
| Task 5 | | | | Practical Model | |
| Task 6 | | | | | Testing |
| Task 7 | Report Writing | | | | |

**5.2: Contribution of members: (out of 100%)**






Almost every member of the group has equal contribution n.

## 5.3 Project Execution Monitoring

**Project Execution performs following activities:**

- We met advisor for the selection of semester project
- Then we have Literature review
- Then, we select the Mini Refrigerator Project.
- Study literature review for the selection of methodology
- Then, we plan to do the project into 3 parts (Analytical Calculations, 3D modeling and Practical Model)
- Then, we apply the suitable Methodology for making practical model
- Then, we get Approval of the method from advisor
- Then, we make a detailed research for appropriate selection of Material
- Then, we had Meeting with the advisor for the approval of Material
- Then, we make a market visit for purchase of Material
- Then, we had a Meeting for practical model making
- Then, we make the Practical Model
- Meeting of all members with advisor for testing criteria
- Then, we perform the testing
- Conclude the project
- Report writing

## 5.4 Challenges and Decision Making

**Challenges Faced:**

- Problems with team members not cooperating/meeting.

  - All the group members do their best for this project and cooperate with each other's for their assigned tasks.

  - Each member did his assign task and also help in others task too.
- Problems or delays in procuring required parts/components/tools.
  - The major reason for delay in this project was the procurement of the materials. It was task assigned to the member 3 but knowing the difficulty level member 3 and 4 also help him for the purchasing of required parts, components and tools which were being used during the making of the practical model of the project.
- Problems with equipment or components not working or malfunctioning.
  - Major problem we face was the selection of the right material because we waste much of our money buying useless components and waste of the material whole making a practical model makes budget of our project high.

**Decision Making:**

I learn a lot regarding decision making from this project. We were having much options and methodologies to put for the project, and choosing best one gave me confidence. Staring from choice of project ad project members, going to choose the project, then methodology, purchase of material and their identification, whole project was having much options and ways for solution but finding a perfect solution was problem gave me a lot regarding decision making.

- Decision while choosing my part for the project which a I could do the best
- Decision while choosing the team members.
- Assigning of the right task to the right person
- Choose of appropriate for methodology for the project
- Choosing right material for the project
- Choosing best test criteria.

This project was full of challenges, starting form searching for best methodology to the testing criteria. So, choice of the best available option gave you confidence. We get help from some seniors, research papers, journals, web sites and so to find out best possible opportunity and to conclude our project in the best way.

## 5.5 Project Bill of Materials and Budget

**BOM**:

Bill of Materials of this project is following, which indicate the expected cost of the project.

**Parts and Tools Required**

**Parts used in this project are:**

- **2x Thermo electric cooler**
- **Acrylic sheet**
- **aluminum**
- **LED**
- **Arduino Nano**
- **Dc jack**
- **12v power supply**
- **Rocker switch**
- **Shrink tubes**
- **Styrofoam**
- **40*50cm pdf wood**

**Tools required:**

**Tools required for this project are following:**

- **Dremel Workstation**
- **Tools box**
- **Jigsaw for wood**
- **Glue gun**
- Acrylic glass cutter

Table5.2: Bill of Material of Project

| | Unit | Unit price | Total quantity | Total price | |
|---|---|---|---|---|---|
| Thermoelectric cooler | No. | 35$ | 2 | 70$ | |
| ARRYLIC SHEET | 12x12 sheet | 11$ | 5 | 55$ | |
| Arduino Nano | No. | 10$ | 1 | 10$ | |
| Relay Module | No | 5$ | 1 | 5$ | |
| LED | No. | 3$ | 2 | 6$ | |
| **aluminum** | No. | 5$ | 2 | 10$ | |
| Power supply | No. | 20$ | 1 | 20$ | |
| Rocker Switch | No. | 2$ | 1 | 2$ | |
| Dc jack | No. | 1$ | 1 | 1$ | |
| Super glue | No. | 3$ | 2 | 6$ | |
| Glue stick | No. | 1$ | 3 | 3$ | |
| Jigsaw | No. | 20$ | 1 | 20$ | |
| Dremel Workstation | No. | 30$ | 1 | 30$ | |
| Acrylic cutter | No. | 15$ | 1 | 15$ | |
| Glue gun | No. | 10$ | 1 | 10$ | |
| Tools box | No. | 25$ | 1 | 25$ | |
| Styrofoam | No. | 25$ | 1 | 25$ | |
| | | | | 313$ | |

Project was expected to have a budget of 250$ but after purchasing thing went to some higher price than we were expecting to be so it went to almost 275$ in the start then there were some minor expenses which cost almost 50%, these are mentioned as miscellaneous expenses in the BOM. There were some material losses a due to the miscalculations for the first time, which we have to buy again. These expenses added to the original and make it 400$. Major expenses are from the purchase of the tools for making the project.

## Chapter 6: Project Analysis

### 6.1 Life-long Learning

Major learning from this project is:

- It gave me the vast idea of energy conversion system.
- This project gave me a great understanding of the manufacturing process.
- Implementation of my technical knowledge into real life problem.
- It makes me learn to tackle engineering problems.

- It makes me able to apply engineering knowledge for the selection of the right material for specific use.
- It makes me learn team work.
- It makes me learn skills related to the project management and time management.
- Working in group make me learn team work.

In all these learning from the project we get help from the internet (scientific topics, research topics, journal papers). We also get help from the books related to this topic. Also, some seniors and electronics department fellows help us in learning all above. (4)

## 6.2 Impact of Engineering Solutions

Impacts of the project:

- It requires low maintenance cost.
- It is low in cost, so it affordable and have essential features.
- Low electricity consumption; make it economical in term of service too.
- This project contains a solution of the energy crisis.
- It has a great engineering impact that we can make you of the mechanical energy for heating cooling or vice versa. So, it gives a big use of the law of energy transformation.
- Thermo electric conversion used to pump heat in the opposite direction of the natural heat flux.

## 6.3 Contemporary Issues Addressed

**Our project has addressed the following issues:**

- A mini refrigerator occupies a small space, so it comes as a problem solver for the people having almost not vacant place for freezer in offices and so.
- It has addressed the issue of high maintenance cost
- It has addressed the high electricity usage issue.
- It is portable and you can even carry it with you in cars for trips.
- Modern vehicle is now making use of mini refrigerators in cars.
- It has low environmental effects unlike other refrigerators.

## Chapter 7: Conclusion and Future Recommendations

### 7.1 Conclusion

While working on the project, we learned many new things and developed the skills required to conduct research, practical work, and report writing. As a result of all these learnings, we became more confident in our field. The project of manufacturing a mini-refrigerator was very interesting to perform as we set the objectives which were quite realistic like we wanted to develop a refrigeration system that could be used to keep things cool while traveling or doing outdoor activities while keeping their size small and portable and we achieved this task.

We observed the Peltier effect and vapor compression effect practically. The refrigerator worked well but it has a limitation that it took much time to cool and besides that, it remained cool for a longer time. It was not although energy-efficient to the extent we wanted it to be. In addition to this, we learned many other skills like marketing, buying the essential things while considering the budget, working in a group, and communicating with all the parties involved in the projects. It gave us a vast idea of the energy conversion system and gave us a great understanding of the manufacturing process. We learned 3D modeling Software and grabbed the knowledge of how to convert your CAD model into the practical.

### 7.2 Future Recommendations

The developed refrigeration system is functional as per the batteries and electricity or power availability which makes it restricted in use so new research and project can be made while considering other options like heat, solar system, etc. The project can be made in a better manner if it is made through a thick and high aluminum pipe material as it would speed up the heating process of the refrigerator so that it may become cool earlier than now. It is also recommended to see the alternates for compressors as this would reduce the cost of the system and would increase its capacity.

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| | SDP – WEEKLY MEETING REPORT |
|---|---|
| | Department of mechanical Engineering<br>Prince Mohammad bin Fahd University |

| SEMESTER: | FALL | ACADEMIC YEAR: | 2020-2021 |
|---|---|---|---|
| PROJECT TITLE | Design Mini Refrigerator | | |
| SUPERVISORS | Dr. Panos Sphicas | | |

**Month 1: September**

| ID Number | Member Name |
|---|---|
| 201600176 | Nawaf al Shihry |
| 201600247 | Fahad al Ghamdi |
| 201600070 | Mansour al Tubayyeb |
| 201600387 | Faisal al Qahtani |
| 201500486 | Nawaf al Qahtani |

**List the tasks conducted this month and the team member assigned to conduct these tasks**

| # | Task description | Team member assigned | Progress 0%-100% | Delivery proof |
|---|---|---|---|---|
| 1 | Planning and Designing of the prototype | ALL | 100% | |
| 2 | Manufacturing and Assembling of the prototype | ALL | 90% | |
| 3 | Chapter 1 and 2 | ALL | 100% | |
| 4 | Chapter 3 | ALL | 100% | |

**List the tasks planned for the month of October and the team member/s assigned to conduct these tasks**

| # | Task description | Team member/s assigned |
|---|---|---|
| 1 | Gathering the materials for the project | ALL |
| 2 | Chapter 3: System Design | ALL |
| 3 | Acrylic glass design print | ALL |
| 4 | Testing the Refrigerator model | ALL |
| 5 | Chapter 1: Introduction- Project Objectives and Chapter 2: literature review | ALL |

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

| **Outcome MEEN4:** an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts | | | | |
|---|---|---|---|---|
| **Criteria** | **None (1)** | **Low (2)** | **Moderate (3)** | **High (4)** |
| MEEN4A. Demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental and societal context | Fails to demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts | Shows limited and less than adequate understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts | Demonstrates satisfactory understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts | Understands appropriately and accurately the engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts |

| **Outcome MEEN5:** an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives | | | | |
|---|---|---|---|---|
| **Criteria** | **None (1)** | **Low (2)** | **Moderate (3)** | **High (4)** |
| MEEN5A: Ability to develop team work plans and allocate resources and tasks | Fails to develop team work plans and allocate resources and tasks | Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks | Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks | Properly and efficiently makes team work plans and allocate resources and tasks |
| MEEN5B: Ability to participate and function effectively in team work projects to meet objectives | Fails to participate and function effectively in team work projects to meet objectives | Shows limited and less than adequate ability to participate and function effectively in team work projects to meet objectives | Demonstrates satisfactory ability to participate and function effectively in team work projects to meet objectives | Function effectively in team work projects to meet objectives |

| | | | | |
|---|---|---|---|---|
| MEEN5C: Ability to communicate effectively with team members | Fails to communicate effectively with team members | Shows limited and less than adequate ability to communicate effectively with team members | Demonstrates satisfactory ability to communicate effectively with team members | Communicates properly and effectively with team members |

**Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)**

| # | Name | Criteria (MEEN4A) | Criteria (MEEN5A) | Criteria (MEEN5B) | Criteria (MEEN5C) |
|---|---|---|---|---|---|
| 1 | Nawaf al Shihry | 4 | 4 | 4 | 4 |
| 2 | Fahad al Ghamdi | 4 | 4 | 4 | 4 |
| 3 | Mansour al Tubayyeb | 4 | 4 | 4 | 4 |
| 4 | Faisal al Qahtani | 4 | 4 | 4 | 4 |
| 5 | Nawaf al Qahtani | 4 | 4 | 4 | 4 |

| | SDP – WEEKLY MEETING REPORT |
| --- | --- |
| | **Department of mechanical Engineering**<br>**Prince Mohammad bin Fahd University** |

| SEMESTER: | FALL | ACADEMIC YEAR: | 2020-2021 |
| --- | --- | --- | --- |
| PROJECT TITLE | Design Mini Refrigerator | | |
| SUPERVISORS | Dr. Panos Sphicas | | |

| ID Number | Member Name |
| --- | --- |
| 201600176 | Nawaf al Shihry |
| 201600247 | Fahad al Ghamdi |
| 201600070 | Mansour al Tubayyeb |
| 201600387 | Faisal al Qahtani |
| 201500486 | Nawaf al Qahtani |

**List the tasks conducted this month and the team member assigned to conduct these tasks**

| # | Task description | Team member assigned | Progress 0%-100% | Delivery proof |
| --- | --- | --- | --- | --- |
| 1 | Finishing the project | ALL | 100% | |
| 2 | Banner | ALL | 100% | |
| 3 | brochures | ALL | 100% | |
| 4 | Finishing chapter 3 | ALL | 100% | |

**List the tasks planned for the month of November and the team member/s assigned to conduct these tasks**

| # | Task description | Team member/s assigned |
| --- | --- | --- |
| 1 | Final testing of the project | ALL |
| 2 | Chapter 4: System Testing and Analysis | ALL |
| 3 | Chapter 5: Project Management | ALL |
| 4 | Chapter 6: Project Analysis | ALL |
| 5 | Chapter 7: Conclusion and Recommendation | ALL |

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

| **Outcome MEEN4:** an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts | | | | |
|---|---|---|---|---|
| **Criteria** | **None (1)** | **Low (2)** | **Moderate (3)** | **High (4)** |
| MEEN4A. Demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental and societal context | Fails to demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts | Shows limited and less than adequate understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts | Demonstrates satisfactory understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts | Understands appropriately and accurately the engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts |

| **Outcome MEEN5:** an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives | | | | |
|---|---|---|---|---|
| **Criteria** | **None (1)** | **Low (2)** | **Moderate (3)** | **High (4)** |
| MEEN5A: Ability to develop team work plans and allocate resources and tasks | Fails to develop team work plans and allocate resources and tasks | Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks | Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks | Properly and efficiently makes team work plans and allocate resources and tasks |
| MEEN5B: Ability to participate and function effectively in team work projects to meet objectives | Fails to participate and function effectively in team work projects to meet objectives | Shows limited and less than adequate ability to participate and function effectively in team work projects to meet objectives | Demonstrates satisfactory ability to participate and function effectively in team work projects to meet objectives | Function effectively in team work projects to meet objectives |

| | | | | |
|---|---|---|---|---|
| MEEN5C: Ability to communicate effectively with team members | Fails to communicate effectively with team members | Shows limited and less than adequate ability to communicate effectively with team members | Demonstrates satisfactory ability to communicate effectively with team members | Communicates properly and effectively with team members |

**Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)**

| # | Name | Criteria (MEEN4A) | Criteria (MEEN5A) | Criteria (MEEN5B) | Criteria (MEEN5C) |
|---|---|---|---|---|---|
| 1 | Nawaf al Shihry | 4 | 4 | 4 | 4 |
| 2 | Fahad al Ghamdi | 4 | 4 | 4 | 4 |
| 3 | Mansour al Tubayyeb | 4 | 4 | 4 | 4 |
| 4 | Faisal al Qahtani | 4 | 4 | 4 | 4 |
| 5 | Nawaf al Qahtani | 4 | 4 | 4 | 4 |

| Gannt Chart | | |
|---|---|---|
| Tasks | Start Date | Days to complete |
| **INITIATION** | 5/9/2020 | 5 |
| **Kick off meeting** | 10/9/2020 | 2 |
| **Gantt Chart** | 10/9/2020 | 2 |
| **Project Definition** | 1/10/2020 | 1 |
| **Project Objectives** | 1/10/2020 | 1 |
| **Project Specification** | 1/10/2020 | 1 |
| **Application** | 5/10/2020 | 1 |
| **PLANNING** | 8/10/2020 | 2 |
| **Literature review** | 8/10/2020 | 3 |
| **Project Background and History** | 15/10/2020 | 7 |
| **Previous Work** | 17/10/2020 | 2 |
| **Parts** | 20/10/2020 | 10 |
| **Midterm Presentation** | 29/10/2020 | 1 |
| **Design Methodology** | 1/11/2020 | 10 |
| **Components** | 4/11/2020 | 12 |
| **Implementation** | 7/11/2020 | 14 |
| **SYSTEM TESTING ANALYSIS** | | |
| **Subsystem1** | 10/11/2020 | 10 |
| **Subsystem2** | 21/11/2020 | 10 |
| **Results** | 25/11/2020 | 1 |
| **Discussion** | 1/12/2020 | 3 |
| **PROJECT MANAGEMENT** | | |
| **Project Plan** | 5/9/2020 | 2 |
| **Contribution of Team Members** | 10/9/2020 | 93 |
| **Project Execution Monitoring** | 10/9/2020 | 93 |
| **Project Bill of Materials and Budget** | 8/10/2020 | 45 |
| **PROJECT ANALYSIS** | 8/10/2020 | 33 |
| **Life Long Learning** | 15/10/2020 | 5 |
| **Impact of Engineering Solutions** | 3/12/2020 | 5 |

| | | |
|---|---|---|
| **Contemporary Issues Addressed** | 3/12/2020 | 5 |
| **CONCLUSION & RECOMMENDATIONS** | | |
| **Conclusions** | 16/12/2020 | 1 |
| **Future Recommendations** | 17/12/2020 | 1 |
| **REFERENCES** | | |
| | | |

# FINAL IMAGES OF THE PROJECT