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Study and Construction of a Purified Water Cooling and Heating System Using Peltier Module

A Thesis

By

Md. Nahid Islam	ID: ME 2103025013
Md. Ashraful Islam	ID: ME 2103025028
Tanzil Ahamed	ID: ME 2103025031
Kreshno Kumar Dash	ID: ME 2103025056
Mamun Molla	ID: ME 2103025070

Department of Mechanical Engineering
Sonargaon University (SU)

May, 2025

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Submitted by

Md. Nahid Islam	ID: ME 2103025013
Md. Ashraful Islam	ID: ME 2103025028
Tanzil Ahamed	ID: ME 2103025031
Kreshno Kumar Dash	ID: ME 2103025056
Mamun Molla	ID: ME 2103025070



Supervisor: Niloy Sarkar
Assistant Professor

SUBMITTED TO THE:

Department of Mechanical Engineering

SONARGAON UNIVERSITY (SU)

In partial fulfillment of the requirement for the award of the degree

Of

Bachelor of Science in Mechanical Engineering

May, 2025

APPROVAL

This is to certify that the project "Study and Construction of a Purified Water Cooling and Heating System Using Peltier Module", by Md. Nahid Islam (ID: ME 2103025013), Md. Ashraful Islam (ID: ME 2103025028), Tanzil Ahamed (ID: ME 2103025031), Kreshno Kumar Dash (ID: ME 2103025056), and Mamun Molla (ID: ME 2103025070), has been carried out under my supervision. The project has been completed in partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc.) in Mechanical Engineering in the year 2025 and has been approved as to its style and content.

Signature of the Supervisor

Niloy Sarkar

Assistant Professor

Department of Mechanical Engineering

Sonargaon University (SU)

LETTER OF TRANSMITTAL

April, 2025

To

Niloy Sarkar

Assistant Professor

Department of Mechanical Engineering.

Sonargaon University

Subject: Submission of Project Report**.**

Dear Sir,

We are pleased to submit the project report titled **"Study and Construction of a Purified Water Cooling and Heating System Using Peltier Module."** It was a great pleasure to work on such an important topic. This project has been completed under your supervision and in accordance with the requirements of Sonargaon University.

We hope that the project will be accepted by the concerned authority. We would be happy to provide any further explanation you may consider necessary in this regard.

Thank You

Sincerely yours,

Md. Nahid Islam
ID: ME 2103025013

Kreshno Kumar Dash
ID: ME 2103025056

Md. Ashraful Islam
ID: ME 2103025028

Mamun Molla
ID: ME 2103025070

Tanzil Ahamed
ID: ME 2103025031

DECLARATION

We do hereby solemnly declare that the work presented in this project report has been carried out by us and has not been previously submitted to any university or organization for the award of any degree or certificate.

We also hereby ensure that the work presented herein does not breach any existing copyright.

Furthermore, we undertake to indemnify the university against any loss or damage arising from a breach of the foregoing obligations.

Authors

Students Name & Signature

_____
Md. Nahid Islam

_____
Md. Ashraful Islam

_____
Tanzil Ahamed

_____
Kreshno Kumar Dash

_____
Mamun Molla

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ABSTRACT

This project introduces a compact and energy-efficient water purification system that utilizes a Peltier module for both cooling and heating. The system incorporates a single-stage filtration process using a ceramic filter to ensure clean, mineral-enriched water. A pump motor circulates the water through the system, while the Peltier module regulates the temperature via the thermoelectric effect. The hot and cold-water chambers are thermally managed using aluminum heat sinks to enhance performance. An ATMEGA328PU microcontroller monitors the temperature through sensors, enabling real-time adjustments and display.

The prototype consistently achieved heating and cooling within a temperature range of 18.8°C to 42.8°C in just 29 minutes. This system offers a sustainable solution for residential, office, and institutional use, providing purified water with user-defined temperature control. With low energy consumption, no moving parts, and simple operation, it demonstrates a promising application of thermoelectric technology in both water treatment and temperature regulation.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

Water is an essential resource for sustaining life, and ensuring access to clean and temperature-controlled water is crucial for both domestic and industrial applications. Traditional water heating and cooling systems rely on large-scale infrastructure, which can be inefficient and energy-intensive. To address this challenge, thermoelectric modules, specifically Peltier modules, offer a compact, energy-efficient solution for water heating and cooling. [1]

Peltier modules operate on the principle of the thermoelectric effect, where an electric current passing through a thermoelectric material creates a temperature gradient. This phenomenon allows for both cooling and heating within a single system, making it highly versatile for applications requiring temperature control. The use of Peltier modules for water purification and temperature regulation is gaining traction due to their reliability, solid-state operation, and ability to function without moving parts or refrigerants. [2]

This project aims to design and construct a purified water cooling and heating system utilizing Peltier technology. The system consists of a dual-chamber setup, where water is cooled and heated separately, controlled by digital temperature regulators. The purified water storage mechanism ensures that users have access to clean drinking water at their desired temperature. Additionally, the system is designed to be cost-effective and energy-efficient, making it suitable for residential, office, and laboratory environments.

By integrating filtration mechanisms, the system ensures that water is not only temperature-regulated but also free from contaminants. The implementation of this project contributes to advancing sustainable and eco-friendly solutions for daily water consumption needs. The findings and construction of this system can pave the way for further research into thermoelectric applications in water treatment and temperature management. This document outlines the methodology, construction, testing, and evaluation of the proposed system, ensuring a comprehensive understanding of its design and functionality. [3]

1.2 Objectives

Objectives of this project are:

- ❑ To study the working principles of water purification and Peltier modules.
- ❑ To design a combined hot and cooling water system.
- ❑ To assemble and implement the full system based on the circuit design.
- ❑ To collect performance and temperature data.
- ❑ To calculate COP and power consumption.

CHAPTER 2
LITERATURE REVIEW

2.1 Literature Review

The study of Peltier modules and their application in heating and cooling systems has gained significant attention in recent years. Several researchers have explored the working principles and efficiencies of thermoelectric devices for temperature regulation. Peltier modules operate based on the thermoelectric effect, where an electric current creates a temperature difference between two junctions, enabling precise heating and cooling applications. [5]

One of the primary advantages of Peltier modules is their compact size and the absence of moving parts, making them ideal for small-scale applications such as water purification and temperature management. Studies have shown that these modules can achieve efficient temperature control when integrated with proper heat dissipation mechanisms, such as heat sinks and forced-air cooling systems.

Research has also explored the integration of Peltier-based systems with microcontrollers for automated control, enhancing energy efficiency and operational reliability. Various studies have examined the feasibility of using thermoelectric cooling for potable water applications, demonstrating that it can effectively maintain optimal water temperatures while minimizing energy consumption. [6]

Additionally, the use of Peltier modules in heating applications has been investigated in studies focusing on their ability to provide precise temperature control in medical and industrial settings. Findings suggest that while these modules are highly effective for localized heating and cooling, their efficiency may be limited by external thermal conditions and power supply constraints.

Overall, the literature indicates that Peltier modules hold great potential for purified water cooling and heating applications. However, further research is required to optimize their performance and to integrate advanced materials for improved thermal conductivity. [6]

This literature review provides a foundation for understanding the role of Peltier modules in the proposed system and highlights their advantages over traditional methods.

2.2 Summary

The literature review highlights advancements in Peltier-based water cooling and heating systems, with a focus on efficiency improvements, energy optimization, and IoT integration. Future research aims to address existing limitations through the adoption of innovative techniques and advanced materials.

CHAPTER 3

HARDWARE ANALYSIS

3.1 Required Components List

Water Purifier Section:

1. Ceramic Filter
2. Mechanical float switch valves
3. Plastic Box

Cooling and Heating Section:

1. SMPS
2. Buck Converter
3. Pump Motor
4. Peltier Module
5. Heat Sink
6. Digital Temperature Meter

3.2 Ceramic Filter

A ceramic filter is a porous water filtration device that removes impurities and contaminants from water by using natural filtration mechanisms. These filters are widely used in water purification systems due to their efficiency, affordability, and ease of maintenance. Ceramic filters function by allowing water to pass through a network of microscopic pores while trapping suspended solids, bacteria, and other harmful microorganisms. The porous structure of ceramic material acts as a natural barrier, effectively removing particles larger than the pore size, typically ranging from 0.2 to 0.5 microns. Some ceramic filters are also coated with silver to enhance bacterial disinfection properties. [7]



Figure 3.l: Ceramic Filter

One of the key advantages of ceramic filters is their long lifespan. With proper maintenance, including periodic cleaning to remove accumulated impurities, these filters can last for several years. Additionally, ceramic filters do not require electricity, making them a sustainable and cost-effective solution for clean drinking water, especially in remote or underdeveloped areas. The integration of ceramic filters in water purification systems is beneficial for removing bacteria, sediment, and certain chemical contaminants. However, they may not effectively eliminate dissolved solids, heavy metals, or viruses, requiring additional filtration stages such as activated carbon or UV treatment for comprehensive purification. [8]

In the Peltier-based purified water cooling and heating system, the ceramic filter serves as a crucial component in ensuring water quality. It acts as a pre-filtration stage before the water undergoes temperature regulation, maintaining high purity levels and preventing contaminants from affecting system performance. The combination of ceramic filtration with advanced purification technologies enhances the overall efficiency and effectiveness of the water treatment process.

3.3 Mechanical float switch valves

Mechanical float switch valves are crucial components in water management systems, designed to regulate water levels in tanks, reservoirs, and purification systems. These valves operate based on a simple yet effective floating mechanism that rises or falls with the water level, automatically controlling the flow of water.



Figure 3.2: Mechanical float switch valves

The primary function of a mechanical float switch valve is to prevent overflow and maintain a steady water level. When the water level reaches a predetermined point, the float mechanism triggers the valve to either open or close, allowing or stopping water flow accordingly. This process ensures efficient water management without requiring electrical components, making it highly reliable and cost-effective. Mechanical float switch valves are typically made from durable materials such as stainless steel, brass, or high-quality plastic, ensuring longevity and resistance to corrosion. They are widely used in water filtration systems, agricultural irrigation, industrial applications, and household water tanks. [9]

One of the key advantages of these valves is their automatic operation, which minimizes human intervention and reduces the risk of water wastage. Additionally, they require minimal maintenance, as they do not rely on electrical power or complex control systems. In the Peltier-based purified water cooling and heating system, mechanical float switch valves play a vital role in maintaining an optimal water level within the system. By ensuring a consistent water supply, these valves contribute to the system's efficiency and longevity. [10]

They also help prevent dry running of the pump and protect components from potential damage due to fluctuations in water levels. Overall, integrating mechanical float switch valves into the water cooling and heating system enhances its reliability, sustainability, and ease of operation, making it an essential component in modern water management solutions.

3.4 Plastic Container Box

A plastic container box is an essential component used as a water tank in the Peltier-based purified water cooling and heating system. These containers serve as storage units for purified water, ensuring a continuous supply for the system's cooling and heating functions.



Figure 3.3: Plastic Container Box

Plastic water tanks are widely chosen due to their lightweight nature, durability, and resistance to corrosion. Unlike metal containers, plastic does not react with water, preventing contamination and ensuring the safety of stored water. High-density polyethylene (HDPE) or food-grade plastic is commonly used for water storage, as it is non-toxic and does not leach harmful chemicals into the water. [11]

The use of a plastic container box enhances the portability and adaptability of the system. Its design allows for easy installation and integration with components such as float switches, filters, and pumps. Additionally, plastic containers are cost-effective, making them a practical choice for small-scale water management solutions.

In this project, the plastic container box ensures that water remains uncontaminated while being efficiently cooled or heated. Proper insulation of the container helps maintain temperature levels, optimizing the performance of the Peltier module. By selecting a suitable plastic container, the system achieves a balance between affordability, efficiency, and safety in water storage and regulation. [12]

3.5 ATMEGA328PU Microcontroller

The ATMEGA328PU is an 8-bit microcontroller from Atmel's AVR family, widely used in embedded systems and microcontroller-based applications. It is the core microcontroller in the Arduino Uno board, making it a popular choice among hobbyists and engineers. The

microcontroller is based on the RISC (Reduced Instruction Set Computing) architecture, allowing it to execute instructions efficiently with minimal power consumption.



Figure 3.5: ATMEGA328PU Microcontroller

Key Features and Specifications

- CPU: 8-bit AVR
- Operating Voltage: 1.8V - 5.5V
- Flash Memory: 32 KB (for program storage)
- SRAM: 2 KB (for temporary data storage)
- EEPROM: 1 KB (for non-volatile data storage)
- Clock Speed: 16 MHz (when used with an external crystal)
- GPIO Pins: 23 (for digital and analog input/output operations)
- PWM Channels: 6 (used for motor control, LED dimming, etc.)
- Timers: 3 (for precise time-based operations)
- Communication: Supports UART, SPI, and I2C protocols

Applications

The ATMEGA328PU is extensively used in robotics, IoT (Internet of Things), sensor systems, industrial automation, smart home devices, and real-time data monitoring applications. It is ideal for low-power applications due to its power-saving sleep modes and efficient processing capability.

Working Principle

The microcontroller processes input signals from various sensors and controls output devices such as motors, LEDs, and displays. It follows a fetch-decode-execute cycle, where instructions stored in flash memory are read, interpreted, and executed sequentially. Its built-in analog-to-digital converter (ADC) enables it to process analog signals, making it suitable for interfacing with environmental sensors. [13]

Due to its cost-effectiveness, ease of programming, and compatibility with Arduino, the ATMEGA328PU remains one of the most widely used microcontrollers in embedded system development.

3.6 Switch Mode Power Supply (SMPS)

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power) to DC loads, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy.

A hypothetical ideal switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time (also known as duty cycles). In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.



Figure 3.9: SMPS

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor. Switched-mode power supplies are classified according to the type of input and output voltages.

The four major categories are:

- AC to DC
- DC to DC
- DC to AC
- AC to AC

A basic isolated AC to DC switched-mode power supply consists of:

- Input rectifier and filter
- Inverter consisting of switching devices such as MOSFETs
- Transformer
- Output rectifier and filter
- Feedback and control circuit

The input DC supply from a rectifier or battery is fed to the inverter where it is turned on and off at high frequencies of between 20 KHz and 200 KHz by the switching MOSFET or power transistors. The high-frequency voltage pulses from the inverter are fed to the transformer primary winding, and the secondary AC output is rectified and smoothed to produce the required DC voltages. A feedback circuit monitors the output voltage and instructs the control circuit to adjust the duty cycle to maintain the output at the desired level.

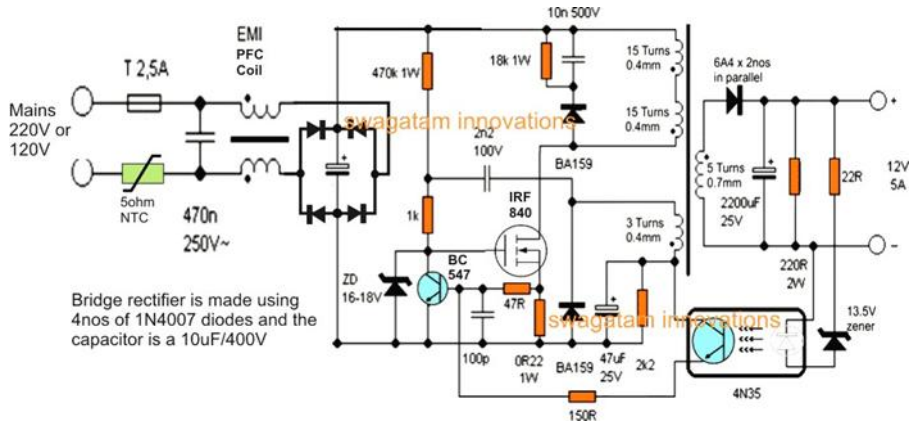


Figure 3.7: SMPS Circuit

Basic working concept of an SMPS

A switching regulator does the regulation in the SMPS. A series switching element turns the current supply to a smoothing capacitor on and off. The voltage on the capacitor controls the time the series element is turned. The continuous switching of the capacitor maintains the

voltage at the required level.

Design basics

AC power first passes through fuses and a line filter. Then it is rectified by a full-wave bridge rectifier. The rectified voltage is next applied to the power factor correction (PFC) pre-regulator followed by the downstream DC-DC converter(s). Most computers and small appliances use the International Electrotechnical Commission (IEC) style input connector. As for output connectors and pin outs, except for some industries, such as PC and compact PCI, in general, they are not standardized and are left up to the manufacturer. [14]

The input DC supply from a rectifier or battery is fed to the inverter where it is turned on and off at high frequencies of between 20 KHz and 200 KHz by the switching MOSFET or power transistors. The high-frequency voltage pulses from the inverter are fed to the transformer primary winding, and the secondary AC output is rectified and smoothed to produce the required DC voltages. A feedback circuit monitors the output voltage and instructs the control circuit to adjust the duty cycle to maintain the output at the desired level.

Advantages of switched-mode power supplies:

- Higher efficiency of 68% to 90%
- Regulated and reliable outputs regardless of variations in input supply voltage
- Small size and lighter
- Flexible technology
- High power density
- Disadvantages:
- Generates electromagnetic interference
- Complex circuit design
- Expensive compared to linear supplies

Switched-mode power supplies are used to power a wide variety of equipment such as computers, sensitive electronics, battery-operated devices and other equipment requiring high efficiency. Linear voltage IC regulators have been the basis of power supply designs for many years as they are very good at supplying a continuous fixed voltage output. Linear voltage regulators are generally much more efficient and easier to use than equivalent voltage regulator

circuits made from discrete components such a zener diode and a resistor, or transistors and even op-amps.

These two types of complementary voltage regulators produce a precise and stable voltage output ranging from about 5 volts up to about 24 volts for use in many electronic circuits.There is a wide range of these three-terminal fixed voltage regulators available each with its own built-in voltage regulation and current limiting circuits. This allows us to create a whole host of different power supply rails and outputs, either single or dual supply, suitable for most electronic circuits and applications. There are even variable voltage linear regulators available as well providing an output voltage which is continually variable from just above zero to a few volts below its maximum voltage output.

Switch Mode Power Supply

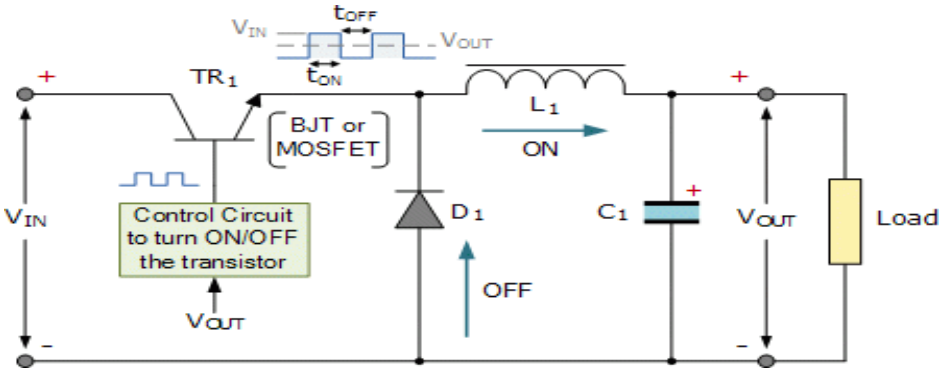


Figure 3.8: SMPS Circuit Connection

Most d.c. power supplies comprise of a large and heavy step-down mains transformer, diode rectification, either full-wave or half-wave, a filter circuit to remove any ripple content from the rectified d.c producing a suitably smooth d.c. voltage, and some form of voltage regulator or stabilizer circuit, either linear or switching to ensure the correct regulation of the power supplies output voltage under varying load conditions. Then a typical d.c. power supply would look something like this:

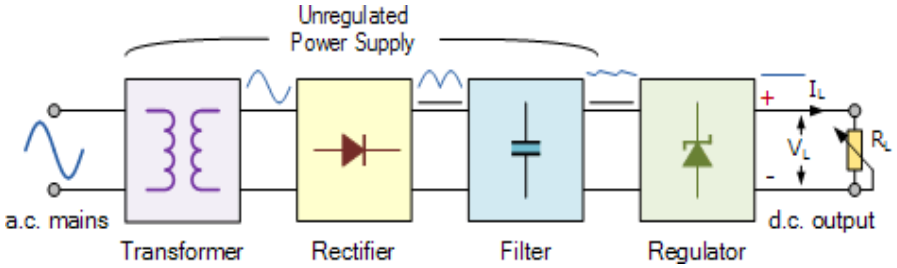


Figure 3.9: DC Power supply way

These typical power supply designs contain a large mains transformer (which also provides

isolation between the input and output) and a dissipative series regulator circuit. The regulator circuit could consist of a single Zener diode or a three-terminal linear series regulator to produce the required output voltage. The advantage of a linear regulator is that the power supply circuit only needs an input capacitor, output capacitor and some feedback resistors to set the output voltage.

3.7 Buck Converter

A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while drawing less average current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). It is called a buck converter because the voltage across the inductor “bucks” or opposes the supply voltage.

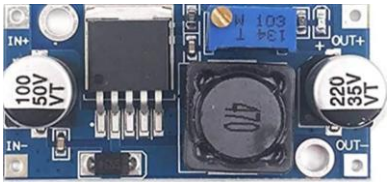


Figure 3.10: DC -DC Buck Converter

DC-DC Buck Converter Step Down Module LM2596 Power Supply is a step- down(buck) switching regulator, capable of driving a 3-A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3 V, 5 V, 12 V, and an adjustable output version. The LM2596 series operates at a switching frequency of 150kHz, thus allowing smaller sized filter components than what would be required with lower frequency switching regulators.

Specifications of DC-DC Buck Converter Step Down Module LM2596 Power Supply:

- Conversion efficiency: 92%(highest)
- Switching frequency: 150KHz

- Output ripple: 30mA9maximum)
- Load Regulation: ± 0.5%
- Voltage Regulation: ± 0.5%
- Dynamic Response speed: 5% 200uS
- Input voltage:4.75-35V
- Output voltage:1.25-26V(Adjustable)
- Output current: Rated current is 2A, maximum 3A (Additional heat sink is required)
- Conversion Efficiency: Up to 92% (output voltage higher, the higher the efficiency)
- Switching Frequency: 150KHz
- Rectifier: Non-Synchronous Rectification
- Module Properties: Non-isolated step-down module (buck)
- Short Circuit Protection: Current limiting, since the recovery
- Operating Temperature: Industrial grade (-40 to +85) (output power 10W or less)

3.8 Pump Motor

This is a low cost, small size Submersible Pump Motor which can be operated from a 2.5 6V power supply. It can take up to 120 liters per hour with very low current consumption of 220mA. Just connect tube pipe to the motor outlet, submerge it in water and power it. Make sure that the water level is always higher than the motor. Dry run may damage the motor due to heating and it will also produce noise.



Figure 3.11: Pump Motor

Feature:

- Operating Current: 130 ~ 220mA
- Flow Rate: 80 ~ 120 L/H

- Maximum Lift: 40 ~ 110 mm
- Continuous Working Life: 500 hours
- Driving Mode: DC, Magnetic Driving
- Material: Engineering Plastic
- Outlet Outside Diameter: 7.5 mm
- Outlet Inside Diameter: 5 mm

3.9 Peltier Module

A Peltier cooler, heater, or Thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current.



Figure 3.12: Peltier Cooler

The TEC1-12706 40x40 mm Thermoelectric Cooler 0~6A Peltier Module is the simple application of Peltier Thermoelectric Effect. Thermoelectric coolers also are known as TEC or Peltier Module create a temperature differential on each side. One side gets hot and the other side gets cool. Therefore, they can be used to either warm something up or cool something down, depending on which side you use. You can also take advantage of a temperature differential to generate electricity.

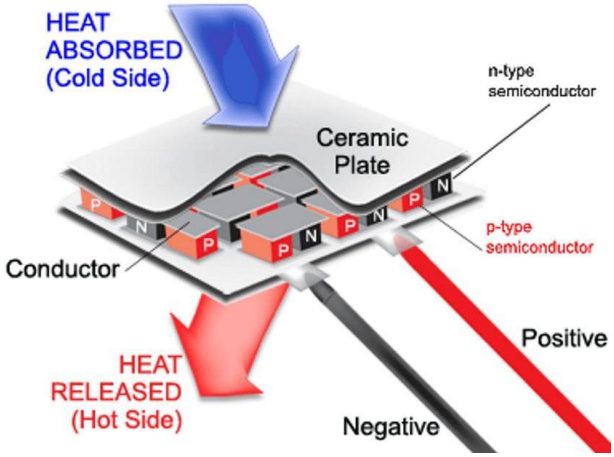


Figure 3.13: Construction of Peltier

Two unique semiconductors, one n-type and one p-type, are used because they need to have different electron densities. The semiconductors are placed thermally in parallel to each other and electrically in series and then joined with a thermally conducting plate on each side. When a voltage is applied to the free ends of the two semiconductors there is a flow of DC current across the junction of the semiconductors causing a temperature difference. The side with the cooling plate absorbs heat which is then moved to the other side of the device where the heat sink is. Thermoelectric Coolers, also abbreviated to TECs are typically connected side by side and sandwiched between two ceramic plates. The cooling ability of the total unit is then proportional to the number of TECs in it. This Peltier works very well as long as you remove the heat from the hot side. After turning on the device, the hot side will heat quickly, the cold side will cool quickly. If you do not remove the heat from the hot side (with a heat sink or other device), the Peltier will quickly reach stasis and do nothing. We recommend using an old computer CPU heatsink or another block of metal to pull heat from the hot side. We were able to use a computer power supply and CPU heat sink to make the cold side so uncomfortable we could not hold our finger to it.

A Thermoelectric cooling (TEC) module is a semiconductor-based electronic component that functions as a small heat pump. By applying the DC power source to a TEC, heat will be transferred from one side of the module to the other. It creates a cold and hot side. They are widely used in industrial areas, for example, computer CPU, CCDs, portable refrigerators, medical instruments, and so on. Also Known as Thermoelectric cooling modules, Thermoelectric modules, Peltier modules, Thermoelectric cooling module.

Key Features and Specifications

- Thermoelectric device based on the Peltier effect.
- Creates a temperature differential between two surfaces.
- Can be used for both cooling and heating by reversing current polarity.
- Compact and solid-state, with no moving parts.
- Requires proper heat dissipation for effective operation.
- Available in various sizes, such as 40x40 mm modules.
- Capable of reaching temperatures between -40°C to 85°C depending on power and heat dissipation.
- Commonly used in cooling systems, portable fridges, and temperature regulation applications.
- Efficient when combined with heat sinks to prevent overheating.
- Operates on DC voltage, typically 12V for common modules like TEC1-12706.

3.10 Heat Sink

A heat sink (also commonly spelled heat sink) is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device's temperature. In computers, heat sinks are used to cool CPUs, GPUs, and some chipsets and RAM modules. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light emitting diodes (LEDs), where the heat dissipation ability of the component itself is insufficient to moderate its temperature.



Figure 3.14: Heat Sink

Feature:

- Aluminum Water Cooling Block for CPU Heat sink Cooler Peltier Plate 80x40x12mm
- Internal flow channel extrusion forming
- Brazing parts into a whole
- Leak rate of less than 5X10-6 mbar.l/s parts
- Internal fin thickness 0.5 mm
- Connection: 9 mm ID tubes
- Processing: vacuum aluminum brazing
- Surface treatment: silver oxidation
- Applicable to computer CPU water, industrial inverter driver, laser head cooling, industrial control cabinet cooling, and Thermoelectric Cooler
- Size:80 (D) x 40 (W) x 12 (H) MM

3.11 Push Button Switch

The Push Button Switch - Small (4Pin) is a compact and versatile electronic component commonly used in various circuit applications. It features four pins, typically arranged in a 2x2 configuration, and operates in a momentary manner, meaning it closes the circuit when pressed and opens it once released.

The 4-pin design offers additional functionality compared to traditional 2-pin push-button switches. The four pins generally include two pairs of contacts: one pair for the normally open (NO) state and another pair for the normally closed (NC) state. This allows for more versatile control in electronic projects, enabling different behaviors, such as toggling between on/off states or creating more complex input systems.



Figure 3.15: Push Button Switch

These small push button switches are commonly used in Arduino projects, DIY electronics, and other embedded systems, often serving as input devices to trigger actions like activating

LEDs, motors, or other components. Due to their small size, they can be integrated easily into tight spaces or compact designs, making them ideal for projects with limited space.

The 4Pin push button switch is widely used in devices such as remote controls, alarms, and small control panels. It’s durable, reliable, and simple to wire, making it a great choice for anyone building projects that require basic user interaction or simple circuit control.

3.12 Digital Temperature Meter

A thermometer is a device that measures temperature or a temperature gradient (the degree of hotness or coldness of an object). A thermometer has two important elements: a temperature sensor (e.g. the bulb of a mercury-in-glass thermometer or the pyrometric sensor in an infrared thermometer) in which some change occurs with a change in temperature.



Figure 3.16: Digital Temperature Meter

Thermometers are widely used in technology and industry to monitor processes, in meteorology, in medicine, and in scientific research. Some of the principles of the thermometer were known to Greek philosophers of two thousand years ago.

As Henry Carrington Bolton (1900) noted, the thermometer's "development from a crude toy to an instrument of precision occupied more than a century, and its early history is encumbered with erroneous statements that have been reiterated with such dogmatism that they have received the false stamp of authority." The Italian physician Santorio Santorio (Sanctorius, 1561-1636) is commonly credited with the invention of the first thermometer, but its standardization was completed through the 17th and 18th centuries.

In the first decades of the 18th century in the Dutch Republic, Daniel Gabriel Fahrenheit made two revolutionary breakthroughs in the history of thermometry. He invented the mercury-in-glass thermometer (first widely used, accurate, practical thermometer) and Fahrenheit scale (first standardized temperature scale to be widely used).

Specification

- Temperature range: -50~ +110℃
- Using environment: Temperature: -5~ +50℃ Humidity: 5%~80%
- Accuracy: ±1℃
- Size: 47*28*14mm

CHAPTER 4
METHODOLOGY

4.1 Methodology

The methodology for constructing the purified water cooling and heating system using a Peltier module follows a structured approach. The system consists of key components such as a Peltier module, ceramic water filter, heat sink, pump motor, IC ATMEGA328PU Microcontroller, SMPS power supply, and temperature sensors. The Peltier module serves as the core of the system, utilizing the thermoelectric effect to either cool or heat the water based on user input.

The process begins with water being filtered through a ceramic filtration system to remove impurities. The filtered water is then circulated through the system by a pump motor, ensuring a continuous supply. The Peltier module is activated based on temperature requirements, cooling or heating the water efficiently. A heat sink dissipates excess heat to maintain system stability. The IC ATMEGA328PU Microcontroller controls the system, receiving real-time data from temperature sensors and adjusting operations accordingly. A digital temperature display provides real-time monitoring. The system is powered by an SMPS power supply, ensuring consistent voltage levels. The final prototype was tested under various conditions to evaluate efficiency, energy consumption, and performance. Data was recorded at different time intervals to analyze temperature variations and optimize functionality.

4.2 Block Diagram

A block diagram visually represents the components and flow of a system, providing a clear overview of its functioning. In the case of the water heating and cooling system using a Peltier module, the diagram includes key elements such as the Peltier Module, Power Supply, Water Pump, and Temperature Sensors. The Power Supply drives the Peltier module, which is responsible for heat transfer for both cooling and heating. Temperature Sensors monitor the water temperature, feeding data to a Controller Unit that adjusts the system's operation. The diagram helps visualize the interaction between components for efficient temperature regulation.

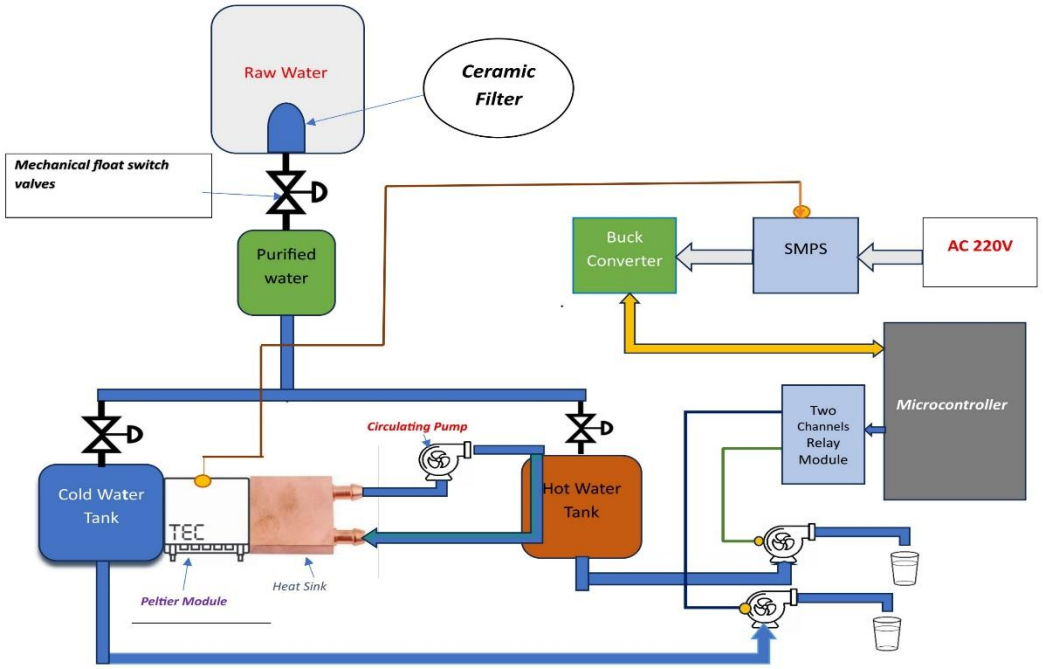


Figure 4.1: Block Diagram

4.3 Project Design 2D and 3D Model

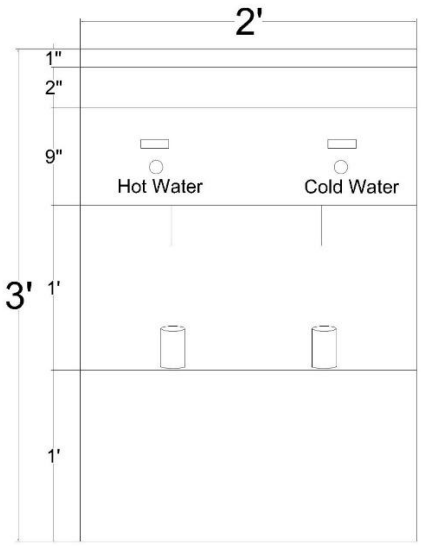


Figure 4.3: 2D Model

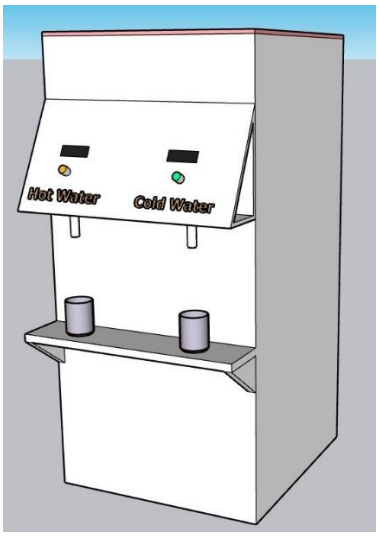


Figure 4.3: 3D Model

4.4 Complete Project Prototype Image:



Figure 4.2: Complete Project Picture (Front View)



Figure 4.3: Complete Project Picture (Side View)

4.5 Working Principle

A pump motor that enables the constant circulation of water throughout the system starts the operation. Water flows through every step of the purifying process thanks to this pump motor. The water goes through a ceramic filter in the first step. The purpose of this filter is to rid the water of germs, sediments, and bigger particles. It serves as an initial defense against impurities. The water is filtered using activated carbon after passing through a ceramic filter. Because of its adsorption capabilities, activated carbon is well-known for enhancing the taste and purity of water by eliminating organic molecules, pollutants, and unwanted odors.

Beneficial minerals are released into the water via the system's mineral sand balls. By introducing necessary minerals, this mineralization stage improves the water's overall quality. By aiding in the adsorption of particular contaminants, these elements complete an additional layer of thorough water purification. The Peltier Module, a thermoelectric device with dual heating and cooling capabilities, is the central component of the system. The Peltier Module modifies its operation based on the desired water temperature. It delivers heat to the water when heating is needed and absorbs heat from the water when cooling is needed. The Peltier Module produces heat throughout the cooling process, which must be released. To effectively dissipate this heat and avoid overheating, a specialized heat sink is incorporated into the system, guaranteeing the Peltier Module's longevity and optimum performance. The system's user interface allows users to customize the water temperature to their liking. Based on these parameters, the Peltier Module modifies its function to provide accurate and adaptable temperature control.

4.6 Cost Analysis:

Table 1: Cost Analysis.

No	Product Name	Specification	Qty	Unit Price	Total Price	Market Price
01.	Water Purifier	Multi Cartridge	1	1500	1500	
02.	Water tap		2	100	200	
03.	IC	AT mega 328P	1	650	650	
04.	SMPS	12V	1	990	990	
05.	Buck Converter	LM2596	1	120	240	
06.	Pump Motor	12V DC	3	150	450	
07.	Peltier Module	TEC-1 12706	1	250	250	
08.	Heat Sink	80*40*12	2	520	1040	
09.	Temperature Meter		3	150	450	
10.	Others				1500	
Total =					7270/=	12,000/=

CHAPTER 5
RESULT AND DISCUSSION

5.1 Visual Test

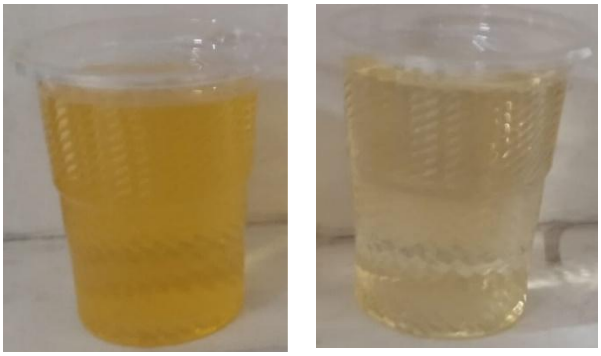


Figure 5.1: Before and After Water Purification

5.1 Data Analysis

Observation-I:

Table No. 1: Time duration VS. Cold water temperature

SL	Time (Min)	Normal Temp.	Cold Temp.
1	0-0	26.3° C	26.3° C
2	0-1	26.3° C	26.3° C
3	1-2	26.3° C	25.9° C
4	2-3	26.3° C	25.5° C
5	3-4	26.3° C	25.1° C
6	4-5	26.3° C	24.7° C
7	5-6	26.3° C	24.2° C
8	6-7	26.3° C	23.8° C
9	7-8	26.3° C	23.3° C
10	8-9	26.3° C	23.0° C

Table No. 2: Time duration VS. Hot water temperature

SL	Time (Min)	Normal Temp.	Hot Temp.
1	0-0	26.3° C	26.3° C
2	0-1	26.3° C	26.9° C
3	1-2	26.3° C	27.8° C
4	2-3	26.3° C	28.4° C
5	3-4	26.3° C	29.1° C
6	4-5	26.3° C	29.8° C
7	5-6	26.3° C	30.5° C
8	6-7	26.3° C	31.2° C
9	7-8	26.3° C	31.8° C
10	8-9	26.3° C	32.5° C

SL	Time (Min)	Normal Temp.	Hot Temp.	Cold Temp.
1	0-0	26.3° C	26.3° C	26.3° C
2	0-1	26.3° C	26.9° C	26.3° C
3	1-2	26.3° C	27.8° C	25.9° C
4	2-3	26.3° C	28.4° C	25.5° C
5	3-4	26.3° C	29.1° C	25.1° C
6	4-5	26.3° C	29.8° C	24.7 C
7	5-6	26.3° C	31.8° C	24.2 C
8	6-7	26.3° C	32.5° C	23.8 C
9	7-8	26.3° C	31.8° C	23.3 C
10	8-9	26.3° C	32.5° C	23.0° C

Observation-II

Table No. 3: Time duration VS. Cold water temperature:

SL	Time (Min)	Normal Temp.	Cold Temp.
1	9-10	26.3° C	22.7° C
2	10-11	26.3° C	22.3° C
3	11-12	26.3° C	22.0° C
4	12-13	26.3° C	21.8° C
5	13-14	26.3° C	21.5° C
6	14-15	26.3° C	21.2° C
7	15-16	26.3° C	21.0° C
8	16-17	26.3° C	20.8° C
9	17-18	26.3° C	20.6° C
10	18-19	26.3° C	20.3° C

Table No. 4: Time duration VS. Hot water temperature:

SL	Time (Min)	Normal Temp.	Hot Temp.
1	9-10	26.3° C	33.1° C
2	10-11	26.3° C	33.7° C
3	11-12	26.3° C	34.3° C
4	12-13	26.3° C	34.9° C
5	13-14	26.3° C	35.3° C
6	14-15	26.3° C	35.9° C
7	15-16	26.3° C	36.6° C
8	16-17	26.3° C	37.1° C
9	17-18	26.3° C	37.6° C
10	18-19	26.3° C	38.1° C

SL	Time (Min)	Normal Temp.	Cold Temp.	Hot Temp.
1	9-10	26.3° C	22.7° C	33.1° C
2	10-11	26.3° C	22.3° C	33.7° C
3	11-12	26.3° C	22.0° C	34.3° C
4	12-13	26.3° C	21.8° C	34.9° C
5	13-14	26.3° C	21.5° C	35.3° C
6	14-15	26.3° C	21.2° C	35.9° C
7	15-16	26.3° C	21.0° C	36.6° C
8	16-17	26.3° C	20.8° C	37.1° C
9	17-18	26.3° C	20.6° C	37.6° C
10	18-19	26.3° C	20.3° C	37.1° C

Note: Each Data has been taken after 1 minutes

Observation-III

Table No. 5: Time duration VS. Cold water temperature:

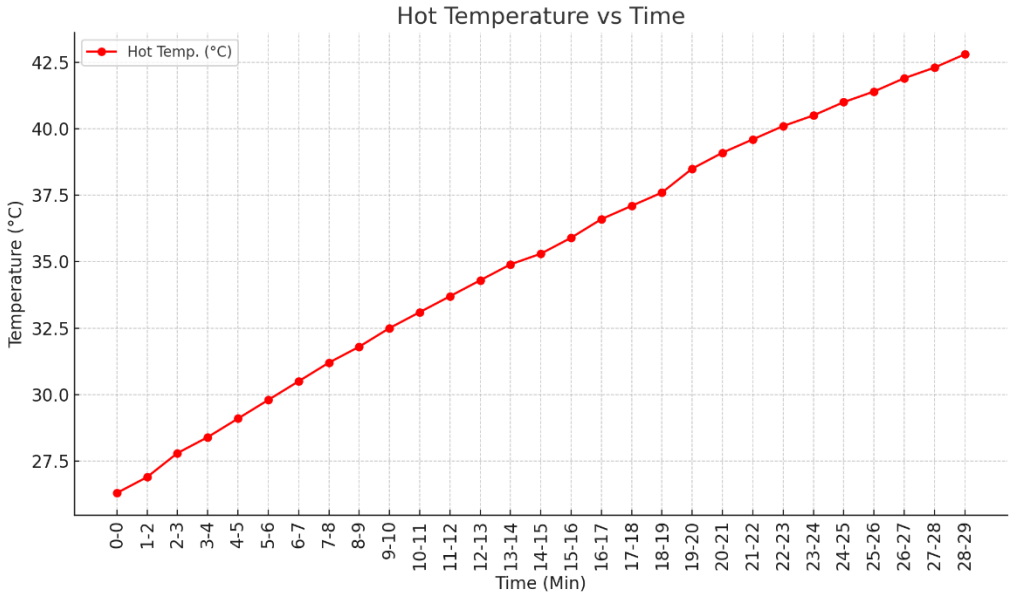
SL	Time (Min)	Normal Temp.	Cold Temp.
1	19-20	26.3° C	20.2° C
2	20-21	26.3° C	19.9° C
3	21-22	26.3° C	19.8° C
4	22-23	26.3° C	19.6° C
5	23-24	26.3° C	19.5° C
6	24-25	26.3° C	19.3° C
7	25-26	26.3° C	19.2° C
8	26-27	26.3° C	19.1° C
9	27-28	26.3° C	18.9° C
10	28-29	26.3° C	18.8° C

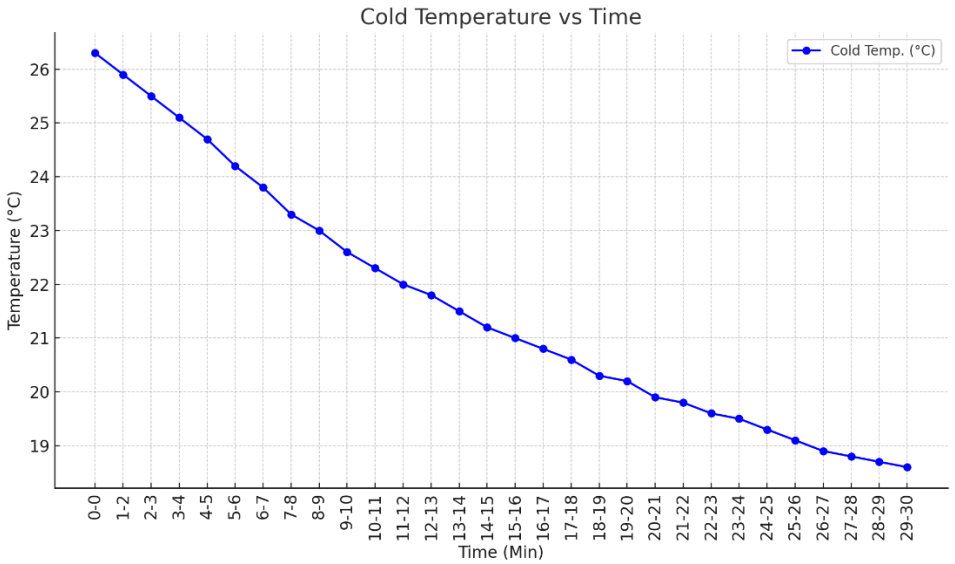
Table No. 6: Time duration VS. Hot water temperature.

SL	Time (Min)	Normal Temp.	Hot Temp.
1	19-20	26.3° C	38.6° C
2	20-21	26.3° C	39.1° C
3	21-22	26.3° C	39.6° C
4	22-23	26.3° C	40.1° C
5	23-24	26.3° C	40.5° C
6	24-25	26.3° C	41.0° C
7	25-26	26.3° C	41.4° C
8	26-27	26.3° C	41.9° C
9	27-28	26.3° C	42.3° C
10	28-29	26.3° C	42.8° C

SL	Time (Min)	Normal Temp.	Cold Temp.	Hot Temp.
1	19-20	26.3° C	20.2° C	38.6° C
2	20-21	26.3° C	19.9° C	39.1° C
3	21-22	26.3° C	19.8° C	39.6° C
4	22-23	26.3° C	19.6° C	40.1° C
5	23-24	26.3° C	19.5° C	40.5° C
6	24-25	26.3° C	19.3° C	41.0° C
7	25-26	26.3° C	19.2° C	41.4° C
8	26-27	26.3° C	19.1° C	41.9° C
9	27-28	26.3° C	18.9° C	42.3° C
10	28-29	26.3° C	18.8° C	42.8° C

Note: Each Data has been taken after 1 minute.





Given the following experimental parameters:

- Water Volume: 1580 mL 1.58 L = 0.00158 m^3
- Density of Water: 1000 kg/m^3
- Mass of Water: $M_w = \rho \times v$ =1000× 0.00158 = 1.58 kg
- Sp. Heat Capacity of Water: C_P = 4200 J / kg^0k.
- Raw Water Temperature (T) = 26.3^0C = 299.3 ^0k
- Cooling Temperature ($T_{2)}$): 18.8^0C = 291.8 ^0k
- Heating Temperature (T_2): 43.2^0C = 316.2 ^0k
- For Cooling: ΔT =(299.3 - 291.8) = 7.5^0k
- For Heating: ΔT =(316.2 -299.3) = 16.9^0k

Power Input:

- Voltage = 12V
- Current = 6A
- Power = 12×6 = 72 w
- Time = 30 minutes = 1800 seconds
- Cooling Effect (Q_C):
- Q_C = msΔT = 1.58 × 4200 × 7.5 = 49770 J
- Heating Effect (Q_h):
- Q_h = msΔT = 1.58 × 4200 × 16.9 = 112148.4 J
- Work Input (W):
- W = 72 W ×1800 scc
- W = 129600 J

Hot and Cold Chamber (The volume of both chambers is equal):

The Hot and Cold-Water Chamber dimensions are below.

D = 120 mm
R = 120/2 = 60mm = 0.060m
H =140 mm = 0.140m

Chamber Volume, V = $\pi r^2 h$
=$(3.1416 \times (0.060)^2 \times 0.140) m^3$
= 0.00158 m^3

Mass of Water in the Chamber,
m = ρV
= 1000 × .00158 = 1.58 kg

(i) Raw Water Box = Length × width × Depth Or initial Water, L = 340mm = 0.340m W = 242mm = 0.242m D = 183mm = 0.183m Volume = $(0.340 \times 0.242 \times 0.183) m^3$ = 0.0151 m^3 Mass of Water in the Chamber, m = ρV = 1000×.0151 =15.1 kg	(ii) After Purified Water Reserve tank, V= $\pi r^2 h$ D = 120 mm r = D/2= 66 mm = 0.066 m H =140 mm = 0.140m Volume, V= $\pi r^2 h$ = $(3.1416 \times (0.066)^2 \times 0.215) m^3$ =0.00294 m^3 Mass of Water in the Chamber, m = ρV = 1000 × .00294 =2.94 kg

Load Calculation

Here,

Q=Heat Energy absorbed

M = Mass of the substance

Specific heat capacity

ΔT= Change of the temperature

T_1=26.3+273=299.3K

T_2=42.8+273=315.8K

Heating Power Q_h= msΔT

$=(1.58 \text{ x } 4200 \text{ x } (T_2 - T_1)$

$=(1.58 \text{ x } 4200 \text{ x } (315.8 - 299.3)$

$=109494 j/30Min$

$=60.83$ Watt

Cooling Power: Q_c= msΔT

$=(1.58 \text{ x } 4200 \text{ x } (T_2 - T_1)$

$=(1.58 \text{ x } 4200 \text{ x } (299.3 - 291.8)$

$=49770 \text{ j}/30Min$

$=28$Watt

The coefficient of performance of the module in heating & cooling modes is given by the equation below:

$$\boldsymbol{COP_h = \frac{Heating\ Power}{Electric\ \ Power\ Input} = \frac{Q_h}{vI} = \frac{60.83}{12\times6} = 0.84}$$

$$\boldsymbol{COP_c = \frac{Cooling\ Power}{Electric\ \ Power\ Input} = \frac{Q_c}{vI} = \frac{28}{12\times6} = 0.38}$$

Total Coefficient of Performance Is Calculated by This Formula:

$$\boldsymbol{COP_t = COP_h + COP_c = 0.84+0.38 = 1.22}$$

Technical Specification:

Rated Voltage = 220-240V

Rated Frequency = 50 Hz

Heating Power = 60.83 Watt

Cooling power = 28 Watt

Hot Water > 42.8°C

Cold Water > 18.8°C

5.2 Result

After all goals and plans were met, we built our project. At last, we launch our initiative. We start this project by building our project circuit with enough equipment. Everything is operating smoothly thanks to our precise plan and execution.

Result on Observation-I

The cold-water temperature begins at 26.3°C and steadily decreases to 23.0°C, over a 9-minute period, indicating the system's efficient cooling performance. The Peltier module effectively transfers heat, maintaining a consistent drop in temperature. Meanwhile, the hot water temperature starts at 26.3°C and increases to 32.5°C, demonstrating the system's capability to provide hot water on demand. Both cooling and heating processes are well-regulated, with the system successfully controlling water temperature to meet user preferences, offering an efficient and reliable temperature management solution.

Result on Observation-II

In Observation-II, the cold-water temperature decreases from 22.7°C to 20.3°C, over a 10-minute period, showcasing the system's efficient cooling capabilities. The steady reduction in temperature indicates the successful functioning of the Peltier module, effectively maintaining the cold water at a lower temperature. On the other hand, the hot water temperature starts at 33.1°C and increases steadily to 37.1°C, indicating the system's ability to heat water effectively. Both cooling and heating processes work efficiently, providing users with consistent temperature control for their water needs.

Result on Observation-III

In Observation-III, the cold-water temperature gradually decreases from 20.2°C to 18.8°C, over a 10-minute period, indicating the system's continued efficiency in cooling the water. The steady reduction in cold water temperature reflects the consistent performance of the Peltier module in lowering the water temperature. Meanwhile, the hot water temperature rises from 38.6°C to 42.8°C, demonstrating the system's effective heating capabilities. Both processes of cooling and heating show smooth and predictable behavior, confirming the system's reliability in providing temperature-controlled water for user preferences.

5.3 Advantage

Our initiative undoubtedly has many benefits, some of the most significant of which are listed below:

- Comprehensive Water Treatment.
- Temperature Control.
- Improved Water Taste and Odor.
- Health Benefits
- User-Friendly Interface
- Efficient Water Circulation
- Innovation in Water Treatment

5.4 Application

Our project has many application areas and actually we need to use it in many places to verify the exact person which have the proper access. Some of the application areas of the project has been pointed out below:

- Residential Use.
- Office Environments.
- Healthcare Facilities.
- Educational Institutions
- Emergency and Disaster Relief
- Research Laboratories.

5.5 Limitation

It is a demo project so we found some limitation. In future we will work for reduce this kind of limitation. These limitations are –

- Energy Consumption.
- Initial Cost.
- Maintenance Requirements.
- Limited Temperature Range.
- Dependence on Ambient Temperature.
- Water Flow Rate.

5.6 Discussion

Of course, let's take a closer look at the theoretical features of the Peltier Module Water Cooling and Heating Water Purifier System. The thermoelectric Peltier Module is the central component of the system. The See beck effect, which produces an electric current when there is a temperature differential across the module, is the theoretical underpinning of thermoelectricity. To maximize the Peltier Module's performance, it is essential to comprehend the fundamentals of thermoelectric heating and cooling. For the Peltier Module to operate correctly and last a long time, efficient heat transfer and dissipation are crucial. To guarantee optimum performance, the design and material selection for the heat sink are guided by the theoretical elements of heat transfer mechanisms, such as conduction and convection. Each filtration stage's theoretical underpinnings support the water treatment process as a whole. Important theoretical ideas include the ion-exchange capabilities of zeolite and silica gel, mineralization with mineral sand balls, and the adsorption qualities of activated carbon. For the removal of bigger particles, the physical barrier qualities of the ceramic filter are also essential.

CHAPTER 6
CONCLUSION

6.1 Conclusion

- The system cools water from 26.3 °C to 18.8 °C in 30 minutes, with a cooling rate of about 0.25 °C per minute. It heats water from 26.3 °C to 43.2 °C in 30 minutes, at a heating rate of roughly 0.57 °C per minute. Power consumption averages around 60.83 watts during operation. The coefficient of performance (COP) for heating is 0.84, and for cooling is 0.38. The thermoelectric system provides eco-friendly heating and cooling without using CFCs or other harmful gases.

6.2 Future Scope

The model can be improved by making some changes in the program and components. Some suggestions are given below-

- **Integration of Smart Technologies:** Using smart technologies, such Internet of Things (IoT) connectivity, could allow the water purifier system to be monitored and controlled in real time.
- **Nanotechnology in Filtration:** Investigating how nanotechnology might be incorporated into filtration components could improve the system's capacity to eliminate even tinier impurities and particles, therefore enhancing the quality of the water.
- **Advanced Filtration Materials:** More sustainable and efficient water purification may result from research into cutting-edge filtration materials, such as bio-inspired materials.

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