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A PORTABLE WATER BOTTLE INTEGRATED WITH A SOLAR-RECHARGEABLE MINI FAN

A Mini Research Project
In Partial fulfillment of the Requirements for the course
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ABSTRACT

This project aimed to design and evaluate a Portable water bottle integrated with a solar-rechargeable mini fan to address the growing need for sustainable cooling and hydration solutions in response to rising temperatures. The device combines eco-friendly materials, energy efficiency, and ergonomic design to enhance user comfort, particularly in outdoor and high-temperature environments.

A developmental-experimental research design guided the prototyping and testing phases, assessing energy sustainability, user acceptability, and cooling efficiency under various environmental conditions. The system was developed using a solar panel, DC motor, and a food-grade water bottle, ensuring cost-effective portability. Key evaluations focused on material sustainability, charging reliability, and airflow performance. Experimental results demonstrated that the fan has 3 levels that suffice the needs of the user low power for longer usage, medium power for balance fan power and high power for hotter area but low time usage, while the solar charging system depends on the availability of the sun with full exposure of 8hrs of time at most. Additionally, user portability is attained when walking and climbing the stairs with its design, highlighting the system's effectiveness in improving personal comfort and hydration.

Despite limitations in material constraints, airflow optimization, and battery capacity, the prototype shows promising potential for advancing sustainable consumer products. These findings indicate that the developed system offers a viable solution for portable cooling and hydration. Future research should focus on enhancing energy storage, refining ergonomic design, and integrating advanced materials for broader applications in multifunctional consumer technology.

Keywords: portable cooling, solar-powered fan, hydration system, energy efficiency, ergonomic design, and sustainable consumer products.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The summer season of the Philippines is considered also a vacation season. Traveling and packing are made easier by the pleasant warmth of these months, which permits leisure activities to continue uninterrupted by unfavorable weather. Extreme heat was encountered in the Philippines in 2023; on April 21, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) recorded the year's maximum heat index, which was 48 degrees Celsius, or nearly half the boiling point of water. Dizziness, headaches, nosebleeds, and elevated blood pressure brought on by the hot heat led more than 500 kids and 100 teachers and staff from a Pasay City school to the clinic that same year (Tan,2024).

When your body lacks the water it needs to function, you become dehydrated. Water is essential for several functions, including as maintaining the proper balance of physiological chemicals, controlling body temperature, facilitating digestion, and distributing oxygen throughout the body (Inspira Health Network, 2022).

Due to the recent increased heat index, staying cool and hydrated is a must. This study aims to create a portable, energy-efficient device that gives relief from scorching heat and keeps you hydrated at the same time. The solar-powered, rechargeable mini fan integrated into a water bottle—a compact, eco-friendly device aimed at providing personal cooling and hydration on the go. This innovation addresses two concerns: heat stress and dehydration, particularly in places with limited access to cooling systems.

Furthermore, the product's design reflects the growing desire for multi-functional, space-saving electronics that fit modern lifestyles. With the growing popularity of outdoor activities, sports, and mobile work arrangements, a fan and water bottle in one equipment improves convenience and preparedness on hot days. Convenience and sustainability are combined in this dual-purpose design, which is especially helpful for those in warm regions, outdoor workers, athletes, and tourists.

1.2 Statement of the Problem

Portable fans are a popular choice for cooling. While they may have some drawbacks, most rely on non-rechargeable batteries or directed electricity, contributing to electronic waste and increasing carbon emissions. Many portable cooling devices also lack functionality, typically only providing air circulation without integrated features that help comfort or hydration. With the increasing concerns about environmental sustainability and efficiency of energy, there is a need to press for a compact, rechargeable and eco-friendly design that reduces the disposal of batteries and integrates renewable energy sources. A water bottle with a solar-powered/rechargeable mini fan built in may be a fantastic, environmentally responsible tool for on-the-go hydration and personal cooling.

This study aims to develop a solar-rechargeable portable fan, incorporating water storage to enhance usability while promoting sustainable energy practices.

This study aims to answer the following questions:

1. How can a portable fan be effectively designed and integrated into a water bottle?
2. How can the product be developed at a low cost?
3. How can the design balance compactness, water storage capacity, and ease of use for everyday portability?
4. What is the level of consumer acceptance for a multifunctional product that combines hydration and personal cooling, particularly in terms of design, usability, and perceived value?
5. To what extent does the prototype meet the criteria for an efficient and effective eco-friendly solution for portable cooling needs?
6. How does this design reduce electronic waste and minimize reliance on disposable batteries?

1.3 Objectives

The researchers of the study aims to meet the following objectives:

1. Design and develop a portable fan integrated with a water bottle powered by solar energy and rechargeable via USB.
2. Implement a low-cost design while maximizing efficiency and reliability.
3. Test and evaluate the performance, reliability, and practicality of the prototype in real-world conditions.
4. Determine the level of acceptability of the product among consumers.
5. Assess the overall effectiveness and energy efficiency of the product.
6. Promote environmental sustainability by integrating a reusable, solar-powered energy source to reduce dependence on disposable batteries and decrease electronic waste

1.4 Scope and Limitations

This study focuses on innovating the matter by bringing two things into one. Battling in day-to-day lives with the scorching heat with the help of this research, the water bottle with a fan powered by solar and also rechargeable, would be beneficial to people in summertime. To avoid dehydration and cool yourself with the help of a fan. This project study aims to explore the development of a portable and eco-friendly device by integrating a solar-powered rechargeable portable mini fan into a reusable water bottle. With the growing demand for multifunctional, energy-efficient, and sustainable solutions in everyday life, the project seeks to demonstrate how renewable energy sources can be harnessed in small-scale applications to enhance user comfort, especially in outdoor or travel settings. The goal is to create a simple, low-cost prototype that combines personal cooling and hydration into a single, compact unit. As it charges, energy is stored in the internal battery. When needed, the user can activate the fan with a switch on the cap. The fan provides a gentle airflow that helps cool the user, especially in warm environments. The battery powers the fan, and it can also be recharged using either solar energy or a USB cable connected to a power source. The design ensures that the electronic parts are securely sealed and kept separate from the water inside the bottle, maintaining safety and usability.

However, several limitations are acknowledged in this project. First, the prototype is not intended for large-scale manufacturing or commercial deployment, and therefore lacks industrial grade waterproofing, durability, and safety certifications. The airflow produced by the mini fan is minimal and suitable only for short term personal use. The rechargeable battery used in this project is basic and does not include advanced energy management systems such as overcharge or thermal protection. Thus, the study does not incorporate smart features like speed control, temperature sensing, or wireless connectivity due to budget and complexity constraints. While it benefits people, it also has another limitation to consider. Having taken into consideration the reliability of the solar energy will depend on the source of sun it could take. The energy efficiency would matter with sunlight for charging and for the fan to work with more efficient energy to be able to operate. Many functions also mean many components are needed, so the size of the project would also be taken into consideration, as it would affect the output of the project because it is a handheld device.

1.5 Significance of the Study

This study aims to make significant contributions across multiple industries by focusing on personal comfort, sustainability, and technical innovation.

To the field of green technologies. The inclusion of a solar-rechargeable system in the suggested device encourages the use of renewable energy sources, hence advancing eco-friendly technology. It demonstrates how green technology may be used to create practical, everyday items that reduce the consequences of high heat, particularly during the summer months.

To students, workers, and athletes. The device's dual functionality (hydration and portable chilling) provides convenience and better accessibility. It improves comfort in a variety of settings, particularly for people who spend a lot of time outside or in hot weather. Furthermore, its compact and user-friendly design promotes health and wellness while eliminating the need for several personal goods. Minimizing the cost for it will be customer-friendly and long-lasting technology.

To Future Researchers. This study may be used as a reference for future research into sustainable personal devices. It has the potential to inspire future innovations that include renewable energy, ergonomic design, and multifunctionality. Researchers may additionally expand on this study to increase efficiency, cost-effectiveness, or application.

CHAPTER II

LITERATURE REVIEW

2.1 Related Literature

Tumbler. You may be curious about the precise purpose of a tumbler; a tumbler is a multipurpose drinkware item that usually has a lid and occasionally a straw. Although there are various varieties of tumblers available, most of them are made to accommodate a range of liquids, from cold drinks like smoothies to hot ones like coffee. Their capacity to maintain beverages at the ideal temperature for extended periods of time is one of their best qualities, which makes them indispensable for leisure activities or lengthy commutes.

A variety of insulated tumblers from Corkcicle combine elegance and functionality to keep your drink just how you want it (Corkcicle, n.d.). In the mid-14c., "acrobat, one who performs feats of tumbling, etc.," an agent noun derived from tumble (v.). Compare a fem with the Old English tumbere, which means "tumbler, acrobatic dancer." early 15th-century tumblester, late 14th-century tumbester, and "female acrobatic dancer." The word "drinking glass" was first used in the 1660s to describe a glass that had a rounded or pointed bottom that would lead it to "tumble," making it impossible to put down until it was empty and inverted. As a component of a lock mechanism, a spring-latch from the 1670s keeps the bolt in place until a key releases it, guaranteeing that your drink will always be just the way you like it (Harper, n.d.).

Portable Mini Fan. The majority of customers like mini fans because of their portability and light weight. (Li et al., 2019). For people who need cooling in various places where central air is not an option, portable air coolers are excellent choices. They are perfect for people who enjoy traveling but still want to feel at ease wherever they go (EcoFlow, n.d.). Mini fans that run on batteries and USB have become increasingly popular due to the growing need for personal cooling solutions, especially in tropical and hot climates. Rechargeable system integration increases operational time and improves user convenience.

Solar Energy. Clean, sustainable energy has fueled the creation of cutting-edge technologies such as smart grids, renewable energy sources, and battery-powered electric cars (Zhou & Zhao, 2018). The creation of mobile technologies based on gadgets that consume a lot of energy but don't need to be constantly recharged from fixed sources (Czerniak, Gacek, & Szopa, 2021). Solar energy, generated from sunlight, is a sustainable renewable energy source that is environmentally friendly and inexhaustible. Every hour, the sunlight that arrives on Earth holds enough energy to satisfy global energy needs for an entire year. The greatest benefits of solar energy are that it is freely accessible to the general public and abundant in supply, especially when compared to the cost of different fossil fuels and oils over the last decade. Furthermore, solar energy demands significantly reduced labor costs compared to traditional energy generation methods (Shaikh et al., 2017).

Integrated Portable Devices. The trend of multifunctional portable devices is increasing in popularity, combining multiple utilities in a single product. With the rise of smart electronic devices, there is a growing demand for portable and eco-friendly energy sources. A self-charging power unit combining a triboelectric nanogenerator (TENG) using silver nanowire-doped silicon rubber and a carbon cloth-based supercapacitor offers an efficient solution. The supercapacitor shows strong energy storage performance, while the TENG effectively captures energy from body movements and remains stable during extended use. This integrated system provides a reliable method for both energy harvesting and storage in electronic applications (Zhu et al., 2023).

Sustainable Energy Technologies. Portable Electronic Devices (PEDs) are increasing popularity. Various portable electronics devices are utilized on a daily basis, with smartphones being the finest example due to its attractive qualities such as light weight and compact size, which allow them to be conveniently taken around. The demand for more energy sources is rapidly increasing as a result of ongoing technological advancements. As portable electronic gadgets improve, there is an increasing demand for new types of energy. In the current circumstances, new breakthroughs are being made, and sustainable energy sources are gaining the lead. This research article provides an overview of various computer generations, including some developments, benefits, and concerns (Malini et al., 2024).

2.2 Related Studies

The investigatory project titled "A Portable Solar Powered Fan: An Investigatory Project on Developing an Efficient Solar Powered Fan" by students from Liceo de Cagayan University Junior High School presents a portable solar fan project that aims to provide relief from heat using solar power and to promote recycling and reusing of materials. The researchers designed a portable fan powered by a solar panel that is attached to a recycled plastic bottle. An old fan blade was attached to a DC motor placed inside the bottle. Wires connect the solar panel atop the bottle to the motor to power it using sunlight. The researchers concluded that solar energy is a clean, renewable source that can help reduce dependence on other energy sources. They recommend adding a rechargeable battery to store solar energy for use without sunlight.

According to an article "Solar-Powered Fan Cap for Outdoor Workers" by Mohapatra et al. (2020), researchers designed a solar powered cap to provide cooling for outdoor workers exposed to high temperatures. Field workers can manage heat stress with the help of adjustable headgear featuring a built-in fan and solar panel. The solar-powered fan lowered head temperature and greatly increased user comfort. This kind of effective and clever method of protecting the face from excessive heat is to use a solar cap with fan technology. Using a sun cap will allow one to fulfill their desire to use sustainable energy to cool off their face.

According to an article "Photovoltaic Bottle with Multiple Features Using Solar Module and USB Kit" by Telsang et al. (2024), in a study published by IEEE, investigates the design and performance of a multifunctional photovoltaic bottle that integrates transparent solar cells, a USB charging interface, and an internal water filtration system. This innovative device is engineered to harvest solar energy efficiently while also addressing basic utility needs such as mobile device charging and access to clean drinking water. The researchers focused on optimizing the device's design, carefully selecting materials to ensure functionality, durability, and sustainability. Through a series of experimental tests, the system's solar energy conversion efficiency and water purification capability were evaluated, demonstrating its viability for low-power electronic applications and environmental health. This photovoltaic bottle exemplifies a forward-thinking approach to renewable energy integration in everyday items. It not only supports sustainable energy practices but also enhances user mobility and access to essential resources, particularly in off-grid or emergency scenarios. The study highlights the device's role in promoting eco-friendly technology and underlines the broader impact of combining clean energy with portable utility solutions.

According to an article "Portable solar-powered dual storage integrated system: A versatile solution for emergency" by Muensuksaeng et al. (2022), develops a portable solar-powered system featuring a dual energy storage design to address the limitations of single-storage solar devices during emergencies caused by climate-related disasters. By integrating a supercapacitor and battery, the system ensures continuous power supply through two functional modes: Direct Mode, which uses the supercapacitor to stabilize fluctuating solar input, and Off-grid Mode, which combines both storage units for extended use in low light. A smart controller manages automatic mode switching based on solar irradiance levels (400–1000 W/m^2), while manual switching is also available for user control. Field tests under various weather conditions confirmed the system's reliability, demonstrating its ability to power both DC and AC loads, including an 80 W laptop with only a 20 W solar panel. This innovative system enhances energy resilience by providing clean, portable power for essential devices such as lighting and communication tools, thereby increasing survival chances during emergencies.

According to an article "Portable Solar Device" by Ghanade et al. (2023), examined the development of a Portable Solar Device as a sustainable alternative to fossil-fuel-based energy sources, emphasizing the growing relevance of solar energy in addressing environmental and energy access concerns. The device is designed to harness solar energy, convert it from DC to AC power, store it in batteries, and supply it to a variety of portable and off-grid electronic devices. Highlighting solar energy's renewable, non-polluting nature, the study presents the device as a practical solution for everyday and emergency use, particularly in outdoor settings. Its applications include charging flashlights, radios, televisions, and even vehicle batteries, making it a versatile tool for camping, travel, or remote areas lacking access to the electrical grid. This innovation supports the increasing demand for portable, clean energy technologies that align with sustainable development goals and modern mobile lifestyles.

According to an article "A review of rechargeable batteries for portable electronic devices" by Liang et al. (2019) provided an extensive review of rechargeable batteries as critical power sources for portable electronic devices (PEDs), emphasizing their central role in ensuring performance reliability and energy efficiency. As PEDs evolve into multifunctional, real-time communication tools, the demand for high-performance batteries has surged, driving continuous advancements in battery technology. The authors outlined the historical development of PEDs alongside key innovations in rechargeable batteries, focusing on four major battery types and their influence on device functionality and user convenience. Their review also explored emerging battery technologies and research directions aimed at achieving greater energy density, faster charging, improved durability, and sustainability. This work underscores the symbiotic growth of PEDs and energy storage solutions, highlighting rechargeable batteries as a cornerstone of portable technology's ongoing evolution.

According to a study titled "Development of a Solar-Powered Standing DC Fan Using Three-Phase Technology" by Ibrahim et al. (2016) examines the efficiency and design of a solar-powered fan, focusing on its mechanical performance, mobility, and energy saving. In order to achieve 85% energy conversion efficiency, the researchers created a 30-watt standing fan that is driven by an 80-watt photovoltaic (PV) module. The fan can run continuously for up to six hours at 500 rpm and 0.95 Nm of torque. In addition to highlighting solar energy's feasibility as a clean, renewable power source, the study suggests integrating batteries to improve usefulness in low-light situations.

According to a study titled "Cooling System Powered" by Solar University of Virginia, researchers worked on battery management, motor control, and circuit design while creating a solar-powered cooling system. In order to increase solar panel efficiency and battery storage capacity, the study describes power optimization techniques and component selection. Research shows that solar-powered fans can drastically cut down on electricity use, which makes them a sustainable substitute for traditional cooling systems (Tran, 2020).

The investigatory project titled "Portable Solar-Powered Fan in Saving Residents' Electricity" by Magboo & Cruz (2022) is a science investigatory project that investigates whether solar-powered fans may actually lower electricity consumption. A solar-powered portable fan system was created by the researchers, who also evaluated its environmental impact, efficiency, and user acceptability. Solar energy integration in consumer goods improves affordability and sustainability, according to the study's findings

Chapter III

RESEARCH METHODOLOGY

This chapter discusses the methodology used in this study. The sections of this chapter describe the research design, materials used (hardware), experimental procedures, data collection methods, and analytical techniques

3.1 Research Design

This research adopts a developmental-experimental design. This study aims to create, build, and assess a portable water bottle featuring a built-in mini cooling system that is powered by solar energy. The developmental phase of the research includes the actual building of the prototype using simple and easily obtainable electronic parts, whereas the experimental stage emphasizes evaluating the device's functionality, efficiency, and dependability in different scenarios.

The project aims to create a simple cooling system for hydration containers, targeting individuals often in warm environments such as athletes, outdoor workers, and travelers. This approach allows researchers to assess whether incorporating a small fan into a refillable water bottle can increase user comfort and improve the hydration experience by gently cooling the surrounding air.

The research process starts with the design and planning stage, where the circuitry and physical arrangement are envisioned, considering power needs, component sizes, and functionality. Subsequently, during the development stage, the prototype is put together according to the planned schematics. Following construction, the testing stage includes assessing the cooling impact, solar charging effectiveness, battery longevity, and the device's overall performance. Numerous tests are performed in various lighting and temperature settings to evaluate the mini fan's performance in practical situations.

3.2 Materials Used (Hardware)

The selection of materials was guided by the criteria of affordability, accessibility, energy efficiency, and environmental sustainability. The following components were used in the construction of the solar-powered cooling prototype:

- 5V Solar Panel (1-2W)

  The 5V solar panel is a compact photovoltaic device that converts sunlight into electrical energy, typically producing 5 volts at 1–2 watts. It is used to power low-energy devices or charge batteries in portable systems (Adafruit Industries, n.d.).
- TP4056 Charging Module (with protection)

  The TP4056 is a lithium-ion battery charger module that charges 3.7V cells through a 5V input. It features built-in protection against overcharging, over-discharging, and short circuits, making it suitable for portable power applications (WatElectronics, 2022).

- 18650 Lithium-ion Battery (3.7V)

  The 18650 lithium-ion battery is a high-capacity rechargeable battery with a nominal voltage of 3.7V. It is frequently used in DIY electronics, power banks, and flashlights due to its energy density and long cycle life (Ufine Battery, 2024)

- 18650 Battery Holder

  A battery holder for 18650 cells physically secures the battery and connects it to a circuit. It allows easy battery replacement and prevents short circuits by offering insulation and stable contact points (Components101, n.d.).

- Mini 5V DC Fan

  This is a small, direct current fan that runs on 5V power, often used to cool electronic components in compact devices. Its low power consumption and USB compatibility make it ideal for portable use (Electronics Hub, 2021).

- Switch

  A switch is an electrical component that opens or closes a circuit, enabling users to manually control power flow to components (All About Circuits, n.d.)

- 1N4007 Diode

  The 1N4007 is a general-purpose rectifier diode that permits current to pass in one direction only, protecting circuits against reverse polarity and used in AC-to-DC rectification (Circuit Digest, 2020)

- Wires and Soldering kit

  Wires provide electrical connectivity between components. A soldering kit, consisting of a soldering iron and solder, is used to permanently attach components by forming strong conductive bonds (SparkFun, n.d.).

- Resistor (220 Ohms)

  A 220-ohm resistor is a passive component that limits the amount of current flowing through a circuit, commonly used with LEDs to prevent damage from excess current (Electronics Tutorials, n.d.).

- LED (Green)

  The green LED is a light-emitting diode that glows green when a voltage is applied. It serves as a visual indicator for power status or device activity (All About Circuits, n.d.).

- Food Grade Tumblr

  A food-grade tumbler is a container made from non-toxic, BPA-free materials that are certified safe for storing beverages or consumables. It is often used to enclose or support electronic components in DIY projects (FDA, n.d.).

- Silicon Boot

  A silicone boot is a flexible sleeve or cover that fits over the bottom of a tumbler or electronic component housing. It improves grip, reduces noise, and protects surfaces from scratches or heat (Makerflo, n.d.)

- Electrical Tape

  Electrical tape is an adhesive PVC tape used to insulate electrical wires and prevent short circuits. It is also used for color-coding and organizing wiring systems (3M, n.d.).

Table 1. *List of Components and Their Costs*

COMPONENTS	QUANTITY	COST
5V Solar Panel (1–2W)	1	Free (Recycled)
TP4056 Charging Module (with protection)	1	53.00
18650 Lithium-ion Battery (3.7 V)	1	100.00
18650 Battery Holder	1	30.00
Mini 5V DC Fan	1	Free (Recycled)
Switch	1	10.00
1N4007 Diode	1	6.00
Wires, Soldering Kit,	Various	30.00
Resistor (220 Ohms)	1	5.00
LED (Green)	1	5.00
Food Grade Tumblr	1	200.00
Silicon Boot	1	26.00
Electrical Tape	1	45.00
TOTAL		**505.00**

The project utilized various materials to develop a compact and cost-efficient system, with a total expenditure of PHP 505.00. Key components included a TP4056 charging module with protection (PHP 53.00), a 18650 lithium-ion battery (3.7V) (PHP 100.00), and an 18650-battery holder (PHP 30.00), ensuring stable power storage. Additionally, a 1N4007 diode (PHP 6.00), a 220-ohm resistor (PHP 5.00), and a green LED (PHP 5.00) supported electrical functionality. The system incorporated a switch (PHP 10.00), various wires, a soldering kit, and electrical tape (PHP 30.00) for connectivity and assembly. A food-grade tumbler (PHP 200.00) served as the primary housing for components, complemented by a silicon boot (PHP 26.00) for enhanced durability. Additional electrical tape (PHP 45.00) reinforced the setup. Recycled materials, including a 5V solar panel (1–2W) and a mini 5V DC fan, were repurposed at no cost, contributing to sustainability efforts. These components collectively supported the development of an efficient, low-cost prototype designed for practical implementation.

3.3 Experimental Procedures

The study followed a step-by-step approach for assembling, testing, and evaluating a portable water bottle equipped with a solar-powered mini fan. The primary objective was to assess the system's efficiency in delivering sustainable airflow for user comfort, ensuring compactness and energy efficiency in its design.

3.3.a Material Preparation and Circuit Planning

Before assembly, all required electronic and non-electronic components were gathered and inspected for functionality and safety. A schematic diagram was created to guide wiring and component placement, ensuring proper integration of:

- 18650 lithium-ion battery to store power.
- 5V solar panel as the primary renewable charging source.
- TP4056 charging module for controlled battery charging and management.
- Mini 5V DC fan to provide cooling airflow.
- Switch and LED indicator for operational monitoring.

Voltage ratings were checked to prevent overloading or short-circuiting, and safety measures—such as wearing gloves and working in a ventilated space—were followed during soldering (Bhatt & Bhatt, 2020).

3.3.b Charging System Assembly

The core charging mechanism was constructed by:

- Connecting the solar panel to the IN+ and IN− terminals of the TP4056 charging module.
- Integrating a 1N4007 diode in series to prevent reverse current flow from the battery.
- Placing the 18650 battery into its holder and linking it to the BAT+ and BAT− terminals of the TP4056 module, respecting polarity.
- Testing the Type-C USB charging input as an alternative power source, verifying compatibility with a power bank or USB adapter (Sharma et al., 2021).

3.3.c Integration of the Fan and Indicator

To ensure proper airflow and monitoring, the following steps were executed:

- Connecting the mini 5V DC fan to the battery output through a switch, enabling manual control.

- Wiring a 220-ohm resistor in series with a green LED, placed parallel to the fan, acting as an operational indicator.
- Soldering all joints securely and covering exposed wires with electrical tape or heat-shrink tubing for insulation (Park & Kim, 2018).

3.3.d Installation into the Water Bottle

Once the circuitry was finalized, components were carefully embedded into the bottle:

- A hole was cut into the cap to securely fit the fan, with additional ventilation slots for improved airflow.
- The internal circuit, including the battery, TP4056 module, and wiring, was mounted inside the cap using adhesive or custom supports to prevent displacement.
- The switch and LED indicator were positioned on the outer cap surface for easy access and monitoring (Li et al., 2022).

3.3.e Initial Testing and Verification

To ensure proper functionality, a series of preliminary tests were conducted:

- Placing the solar panel under direct sunlight for 2–3 hours and monitoring TP4056 LED charging indicators.
- Activating the switch to power the fan and verify airflow strength.
- Checking the LED indicator to ensure it illuminated when the fan was active.
- Using a USB Type-C charger to test alternative charging when solar power was insufficient (Garcia & Zhou, 2023).

3.3.f Performance Assessment

The fully charged system underwent extended testing to evaluate operational efficiency:

- Measuring fan runtime per full battery charge.
- Assessing airflow effectiveness by observing the movement of a small piece of paper placed in front of the fan.
- Testing the system in shaded environments to examine solar panel performance in low-light conditions.

- Conducting environmental stress tests by placing the device in a warm location and recording cooling performance variations (Chen & Wei, 2020).

3.3.g Troubleshooting and System Refinement

If inconsistencies arose, necessary adjustments were made by:

- Using a multimeter to check connections and ensure correct voltage flow.
- Replacing any faulty components and refining the circuit layout for better efficiency.
- Reconfiguring wiring paths to stabilize fan operation and improve energy management (Singh & Patel, 2021).

All observations, including charging time, fan duration, and user feedback, were recorded. This documented data provided the foundation for analyzing the system's overall efficiency and performance, which was later integrated into the results and discussion section.

3.4 Data Collection Methods

This project uses a hands-on, experimental approach to evaluate the performance, efficiency, and user-friendliness of a portable water bottle with a solar-powered mini fan. The system was designed to provide sustainable airflow while maintaining compactness and energy efficiency (Bhatt & Bhatt, 2020).

3.4.a How Data Was Collected

A. Observation and Prototype Evaluation

Researchers conducted direct observation during the assembly and testing phases to monitor:

- Solar charging duration in direct sunlight.
- Operational runtime of the fan after a full battery charge.
- Response of the switch and LED indicator during activation (Hassan et al., 2018).

These observations helped assess the device's functionality under different conditions, ensuring each component performed as expected.

B. Performance Testing

To evaluate the system's effectiveness, researchers measured:

- Fan runtime per full charge cycle.

- Charging speed comparison between solar power and USB charging.
- Airflow strength, tested using a lightweight object placed near the fan (Garcia & Zhou, 2023).

Multiple trials were conducted to confirm reliability and consistency across different environments.

By integrating these data collection techniques, researchers obtained both quantitative measurements and qualitative insights, supporting improvements in design, functionality, and user experience (Singh & Patel, 2021).

3.5 Analytical Techniques

This system was developed to ensure efficient, reliable, and functional performance in delivering portable cooling and hydration through a Portable Water Bottle with an Integrated Solar-Powered Mini Fan. Several techniques and considerations were applied for data analysis, performance evaluation, and system diagnostics to achieve accurate and effective results. The core components of the system are described below:

1. **Solar Charging System**

   The 5V solar panel serves as the device's primary renewable energy source, converting sunlight into electrical energy to charge the 18650 lithium-ion battery. Its efficiency depends on sunlight exposure, panel orientation, and ambient conditions (Naguit et al., 2025).

2. **Battery Storage and Charging Regulation**

   The 18650 lithium-ion battery provides portable power for extended fan operation. To regulate charging, the TP4056 charging module ensures safe power management, preventing overcharging and voltage fluctuations, while enabling USB and solar charging compatibility (Ibrahim et al., 2016).

3. **Fan Cooling Mechanism**

   The mini 5V DC fan delivers airflow for personal cooling. It is activated via a manual switch, allowing users to control airflow intensity. The fan runtime depends on the battery charge level, ensuring sustained operation in various environmental conditions (Naguit et al., 2025).

4. **User Control and Monitoring**

   The system features a switch and LED indicator to provide clear feedback on device operation. The LED light signals charging activity and fan activation, offering users a visual confirmation of functionality (Ibrahim et al., 2016).

5. **Structural Integration and Ergonomic Design**

The electronic components are securely housed within a food-grade water bottle, maintaining compactness and portability. The bottle cap is modified to accommodate the fan, ensuring efficient airflow without compromising usability (Naguit et al., 2025).

3.5.a Analytical Techniques in Action

1. **Solar Charging Efficiency:**

   The solar panel's performance was assessed by measuring charging duration in direct sunlight and low-light conditions, recording battery voltage before and after each cycle. A comparative analysis of solar vs. USB charging helped determine the most efficient method (Bhatt & Bhatt, 2020). These evaluations ensured optimal energy utilization and identified power inconsistencies affecting performance.

2. **Battery Performance and Power Management:**

   The TP4056 charging module was examined for stability and regulation, tracking battery discharge rates during continuous fan operation and monitoring voltage fluctuations under different load conditions. The diode's role in preventing reverse current flow was tested to minimize power loss (Sharma et al., 2021). These measures maintained steady energy consumption, prevented system failures, and prolonged battery life.

3. **Fan Airflow and Cooling Efficiency:**

   The mini 5V DC fan was analyzed for airflow strength and energy efficiency. Runtime per full charge was recorded to ensure consistent airflow, while object movement near the fan provided a practical cooling measurement. Environmental tests in shaded and high-temperature areas assessed its thermal regulation effectiveness (Park & Kim, 2018), optimizing the system for user comfort in diverse settings.

CHAPTER IV

DESIGN AND IMPLEMENTATION

The portable water bottle with a mini fan powered by solar is a system that is a handheld device for a day living. Used in a summertime to take advantage of the abundance of sunlight. Implementing a sustainable energy used and cost-effective device to lessen the burden in bring many things every, and put in to one functional device. Design for portability and sustainability.

4.1 Detailed Description of the System Design

TP4056: Battery Charging Controller

Manages charging of the battery from the solar panel. The core chip that manages the charging process (constant current/constant voltage). The module regulates charging current and voltage, and includes protection circuits for overcharge, over-discharge, and short circuit (Addicore, n.d.).

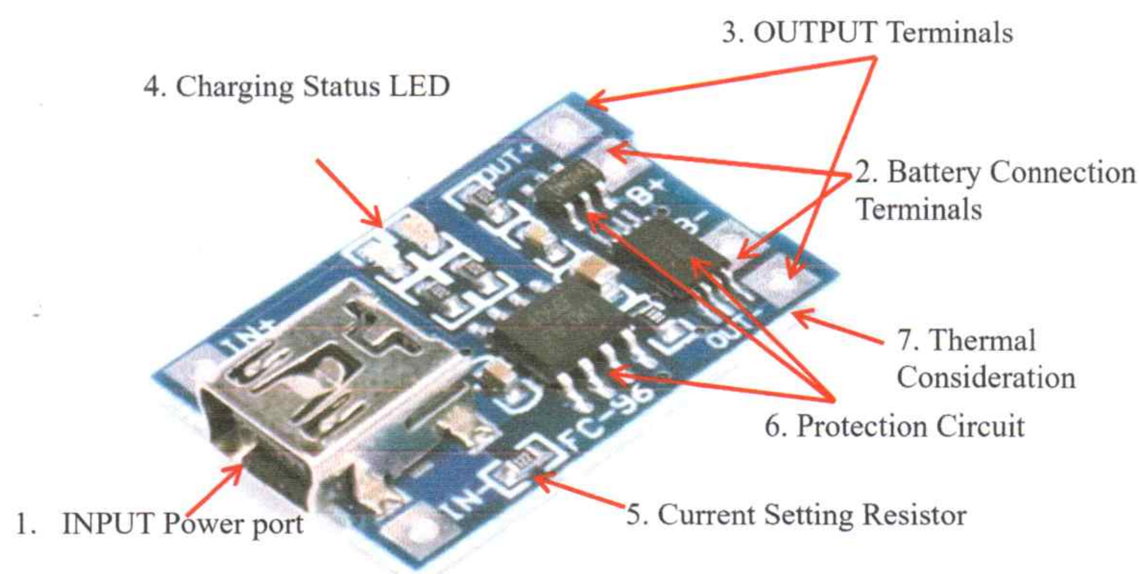

Figure 1. TP4056 Charging Module

PARTS

1. **Input Power Port (Micro USB / 5V Input)** - Usually has a Micro USB port for 5V input.
2. **Battery Connection Terminals (B+/B-)-B+ (Positive)** – Connects to the + terminal of the Li-ion/Li-Po battery. B- (Negative) – Connects to the - terminal of the battery.

3. **Output Terminals (OUT+/OUT-)** - Provides 5V output (when input power is connected) or battery voltage (when unplugged). Used to power external circuits.
4. **Charging Status LEDs** - Red LED Indicates charging in progress. Blue LED Indicates charging complete (turns on when battery is fully charged).
5. **Current Setting Resistor** - A resistor 1.2KΩ by default for 1A charging. Can be replaced to adjust charging current.
6. **Protection Circuit (DW01A + FS8205)-DW01A** – Battery protection IC (prevents overcharge, over-discharge, and short-circuit). FS8205 – Dual MOSFET for discharge control.
7. **Thermal Considerations** - The TP4056 can get warm during charging. Serve as a heat sink.

5v Solar panel: Energy input

It charges the battery from the solar energy into electrical energy via TP4056 to power the system during the day. Lightweight and portable, so you can take it with you wherever you go (Pagaria, 2022).

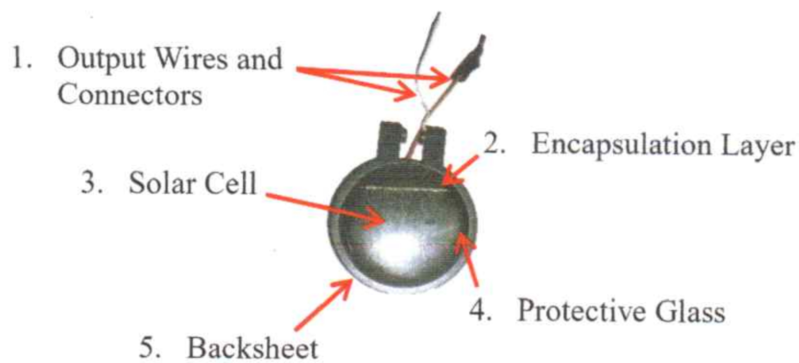

Figure 2. 5v Solar panel

PARTS

1. **Solar Cells (Photovoltaic Cells)**
   a. Function: Convert sunlight into electricity (DC power).
   b. Material: Usually polycrystalline or monocrystalline silicon.
   c. Voltage & Current:
      i. Each cell produces ~0.5V (multiple cells are wired in series to reach 5V).
      ii. Current depends on size (e.g., 100mA–1A for small panels).
2. **Protective Glass or Plastic Cover**
   a. Function: Shields solar cells from weather (rain, dust, UV rays).
   b. Material: Tempered glass or transparent polycarbonate.

3. **Encapsulation Layer (EVA or Resin)**
    a. Function: Seals and protects solar cells from moisture and mechanical damage.
    b. Material: Ethylene Vinyl Acetate (EVA) or epoxy resin.
4. **Backsheet (Rear Protective Layer)**
    a. Function: Insulates and protects the backside of the panel.
    b. Material: Polymer-based (e.g., Tedlar) or aluminum foil.
5. **Output Wires & Connectors**
    a. Function: Delivers power to devices or batteries.
    b. Common Types:
        i. Bare wires (for direct soldering).

Battery 18650 2000mah: Energy storage

It stores the converted solar energy and supplies all the components in the system when the solar power is unavailable (IndiaMART, n.d.).

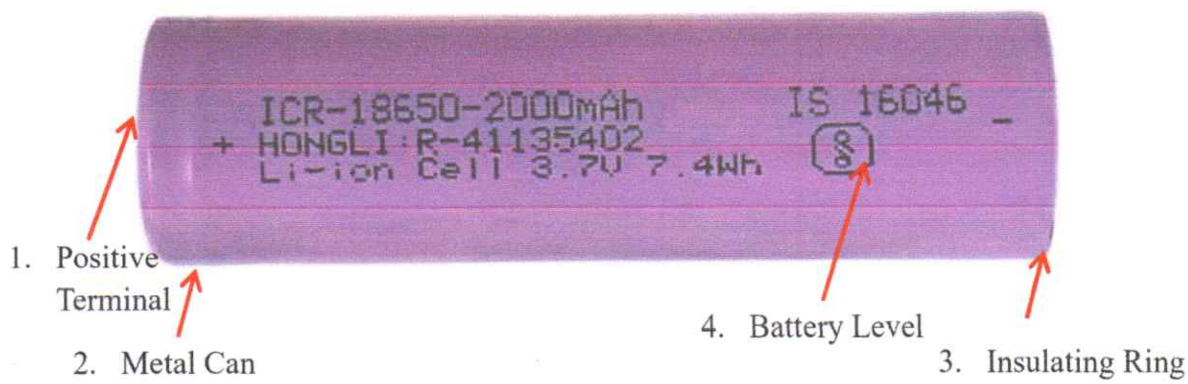

Figure 3.a. External Components of 3.7v battery 18650

PARTS -

External Components

1. **Metal Can (Casing)**
    a. Material: Steel or aluminum.
    b. Function: Protects internal components and acts as the negative.
2. **Positive Terminal (Cap)**
    a. Material: Steel with aluminum coating.
    b. Features:
        i. Raised button top.
        ii. Includes a venting mechanism safety feature.
3. **Insulating Ring (Gasket)**
    a. Material: Plastic or polyethylene.
    b. Function: Prevents short circuits by separating the positive cap from the negative casing.

4. **Battery Label**
    a. Printed Info: Voltage 3.7V nominal, capacity 2000 mAh.

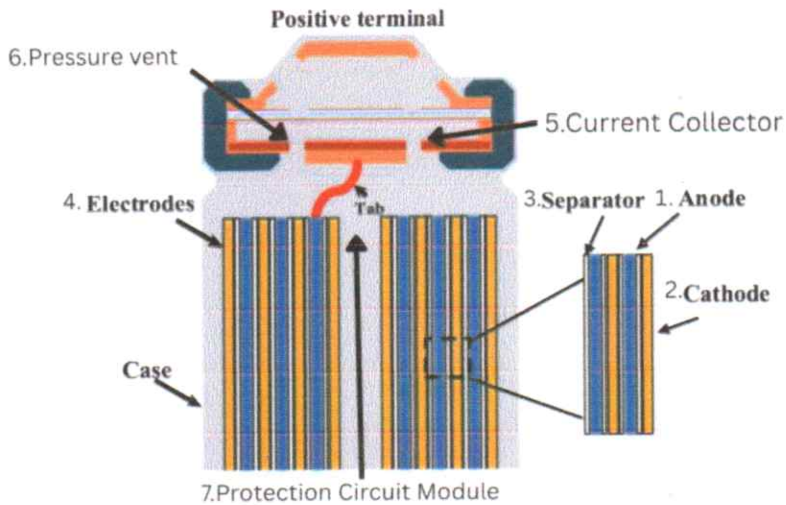

Figure 3.a. Internal Components of 3.7v battery 18650

PARTS

Internal Components

1. **Anode (Negative Electrode)**
    a. Material: Graphite-coated copper foil.
    b. Function: Stores and releases lithium ions during discharge.
2. **Cathode (Positive Electrode)**
    a. Material: Lithium metal oxide.
    b. Function: Receives lithium ions during charging.
3. **Separator**
    a. Material: Porous polyethylene (PE) or polypropylene (PP).
    b. Function: Prevents physical contact between anode/cathode while allowing ion flow.
4. **Electrolyte**
    a. Composition: Lithium salt in an organic solvent.
    b. Function: Conducts ions between electrodes.
5. **Current Collectors**
    a. Anode Collector: Copper foil.
    b. Cathode Collector: Aluminum foil.
6. **Pressure Vent (Safety Feature)**
    a. Function: Releases gas if internal pressure rises.
    b. Prevents: Explosion by breaking the circuit in overpressure scenarios.
7. **Protection Circuit Module (PCM)**
    a. Functions: Prevents overcharge (>4.2V), over-discharge (<2.5V), and short circuits.
    b. Uses a DW01A IC + MOSFETs for control.

5v DC Fan: Airflow for the fan

A little electronic gadget that runs on 5 volts of direct current (DC) electricity is called a 5V DC fan. When a 5V power source is attached to it, a motor with fan blades placed on it rotates. These fans are available in a range of sizes and types; centrifugal blowers and axial fans are popular choices. The output load that is powered by the battery or via solar input. Runs when the switch is turned on and power is available (Mifra Electronics, n.d.).

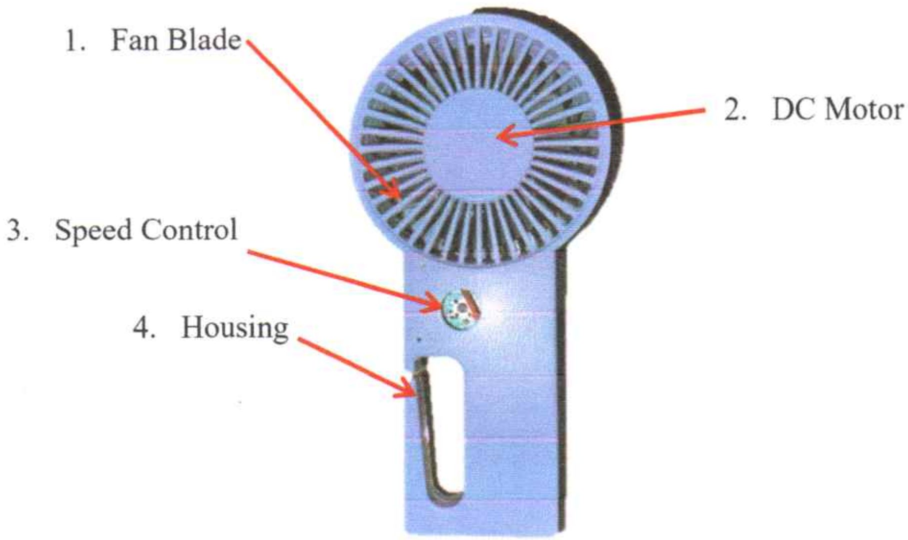

Figure 4: 5v DC fan

PARTS

1. **Fan Blades**
    a. Material: Plastic or lightweight metal
    b. Function: Spins to create airflow
    c. Design: 4 blades small, efficient for low power
2. **DC Motor**
    a. Type: Usually 5V–12V DC motor (small, low power)
    b. Function: Converts electricity into spinning motion
3. **Speed Control**
    a. Multi-Speed Button – Adjusts fan speed (Low/Med/High)
4. **Housing (Frame & Body)**
    a. Material: Plastic, ABS, or metal mesh
    b. Function: Protects internal parts & directs airflow

IN4007 Diode: Prevents reverse current

Is a rectifier diode with a plastic casing that has been molded. The rectifier diode has a low forward voltage drop and a high current capacity (Element14 Philippines, n.d.). Serves as a protection of the flow of from the solar panel or the battery from reverse voltage that can damage components. Placed in series between the solar panel and charging module.

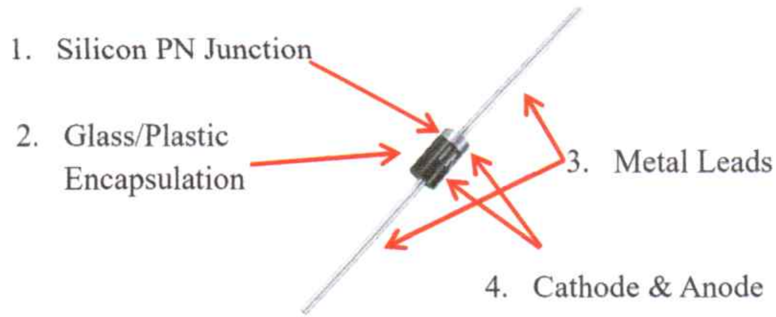

Figure 5: IN4007 Diode

PARTS

1. **Silicon PN Junction**
   a. Material: Silicon (for high efficiency & temperature stability)
   b. Function: Allows current flow in one direction only (forward bias) and blocks reverse current.
2. **Cathode & Anode (Terminals)**
   a. Cathode (–): Marked with a band/line on the diode body.
   b. Anode (+): Unmarked side current enters here in forward bias.
3. **Glass / Plastic Encapsulation**
   a. Material: Typically, glass (DO-41 package) or epoxy.
   b. Function: Protects the semiconductor from damage.
4. **Metal Leads (Wire Terminals)**
   a. Material: Tinned copper or steel.
   b. Function Soldered into circuits for electrical connection.

LED: Indicator light

A semiconductor device known as a light-emitting diode (LED) releases light when an electric current passes through it. Light is produced when electrons recombine with holes in an LED when current flows through it. LEDs permit current flow in a forward direction while blocking it in a reverse direction (BYJU'S, n.d.). Indicator for power status of fan when in use.

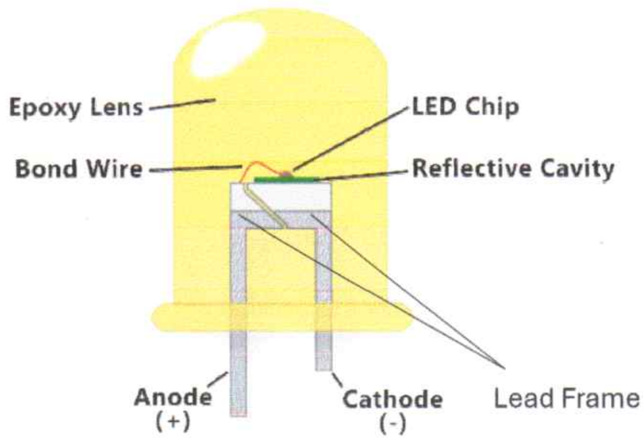

Figure 6: LED

PARTS

1. Semiconductor Chip/ LED Chip (Light-Emitting Layer)
    a. Material: Gallium Arsenide (GaAs), Gallium Phosphide (GaP), or Indium Gallium Nitride (InGaN)**
    b. Function: Emits light when electrons recombine with holes.
2. Anode (+) & Cathode (–) Terminals
    a. Anode (+): Longer lead (must connect to positive voltage).
    b. Cathode (–): Shorter lead (connects to ground) or flat edge on the LED casing.
3. Epoxy Lens / Case
    a. Material: Clear or diffused epoxy resin.
    b. Function:
        i. Protects the semiconductor.
        ii. Focuses/scatters light (diffused LEDs have a frosted look).
4. Reflector Cup/ Cavity (Inside Housing)
    a. Material: Plastic or metal.
    b. Function: Directs light forward for better brightness.
5. Bond Wire (Gold or Aluminum)
    a. Function: Connects the semiconductor to the leads.
6. Lead Frame (Metal Base)
    a. Function: Provides structural support & electrical connection.

220k Resistor: Current Limiting for the LED

A resistor is a passive electrical component with the primary function to limit the flow of electric current (EE Power, n.d.). Limiting the current and prevent the LED from burning out.

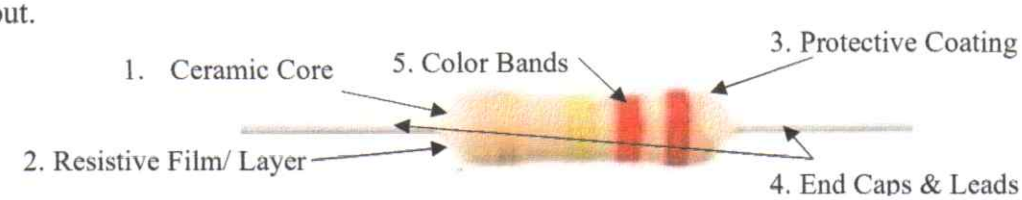

Figure 7: Resistor 220k

PARTS

1. Ceramic Core (Substrate)
    a. Material: High-purity alumina (Al_2O_3) or ceramic.
    b. Function: Provides mechanical strength and heat resistance.
2. Resistive Film/Layer
    a. Material: Carbon film, metal film, or thick metal oxide.
    b. Function: Determines resistance value (220KΩ in this case).
3. Protective Coating
    a. Material: Epoxy resin or vitreous enamel.
    b. Function: Shields the resistive layer from moisture and damage.
4. End Caps & Leads
    a. Material: Tinned copper or nickel-plated steel.
    b. Function: Electrical connection points (soldered to circuits).
5. Color Bands (Identification)
    a. 4-Band
    Example
    (220KΩ ± 5%):
    Red (2) – Red (2) – Yellow ($\times 10^4$) – Gold (±5%)
    *(Calculates to $22 \times 10^4 = 220{,}000\Omega = 220K\Omega$) *.

Switch: Manual control

It is used to start or stop device powered by electricity (Cambridge University Press, n.d.). Used to turn the fan on and off. conserving power and allowing user control

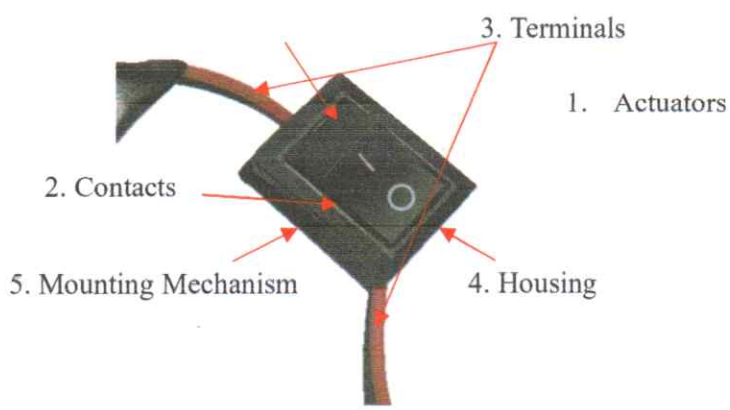

Figure 8: Switch

PARTS

1. **Actuator**
    a. Function: The part you press, flip, or slide to turn the switch on/off.
    b. Types: Rocker (flat paddle)

2. **Contacts**
    a. Fixed Contacts: Stationary metal terminals (connected to wires).
    b. Moving Contacts: Metal parts that touch/separate to close/open the circuit.
3. **Terminals**
    a. Input (Line) & Output (Load): Where wires attach.
    b. SPST Example: 2 terminals (ON/OFF).
4. **Housing**
    a. Material: Plastic
    b. Function: Protects internal parts and insulates against shocks.
5. **Mounting Mechanism**
    a. PCB Mount: Pins for soldering to circuit boards.

Chassis: Body of the tumbler

Tumblers are an excellent way to keep hot beverages hot and cold beverages chilled. Professionals who wish to sip water, tea, or coffee for extended periods of time will love them. An excellent tumbler will keep your drink at the perfect temperature for you to enjoy, whether you're on the road, working on a challenging task, or attending a long meeting (Craft Clothing, n.d.).

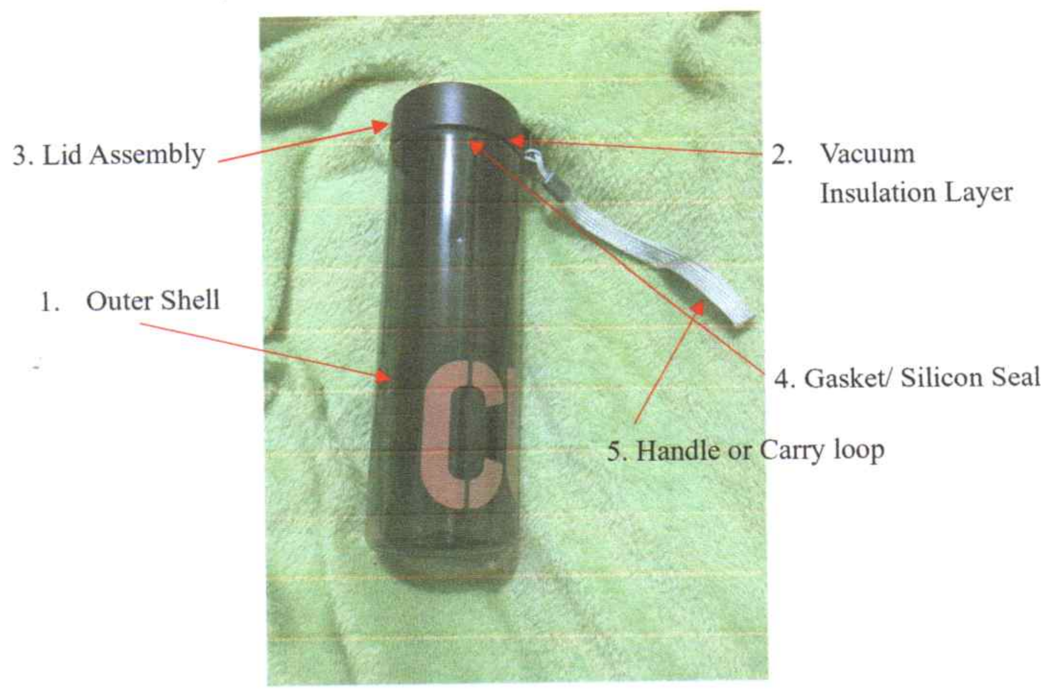

Figure 9: Tumbler

PARTS

1. **Outer Shell**
    a. Material: Stainless steel (most common), plastic, or aluminum.
    b. Function: Protects the inner layers and provides structure.

2. **Vacuum Insulation Layer**
    a. Function: A sealed airless space between inner and outer walls that blocks heat exchange.
3. **Lid (Cap) Assembly**
    a. Types:
        i. Screw-on lid
    b. Material: Plastic
4. **Gasket/Silicone Seal**
    a. Function: Prevents leaks when the tumbler is closed.
5. **Handle or Carry Loop**
    a. Function Makes the tumbler easier to carry.
    b.

Silicon Boots: Removable Top

Designed to protect your water bottles' bottoms from normal wear and tear (AquaFlask NZ, n.d.). Used to remove and attach the solar, fan and battery or the whole electrical system that runs the entire system.

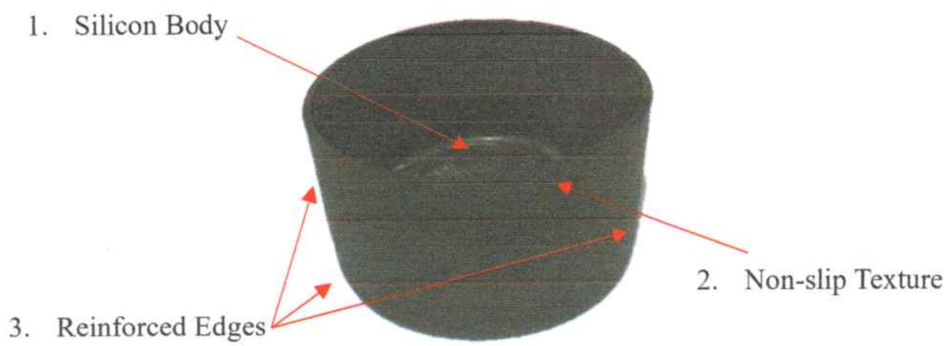

Figure 9: Silicon boot

PARTS

1. Silicone Body (Main Cover)
    a. Material: Soft, flexible silicone rubber (heat-resistant up to ~200°C).
    b. Function: Provides shock absorption, insulation, and grip.
2. Reinforced Edges (Rim/Seams)
    a. Function: Prevents tearing and improves durability.
3. Non-Slip Texture (Grip Pattern)
    a. Design: Raised dots, ridges, or matte finish.
    b. Purpose: Enhances grip.

Electrical tape: Prevents current to short

An electrical tape that is responsive to pressure and is used to insulate electrical wires and other electrically conducting materials. Also used to hold parts together.

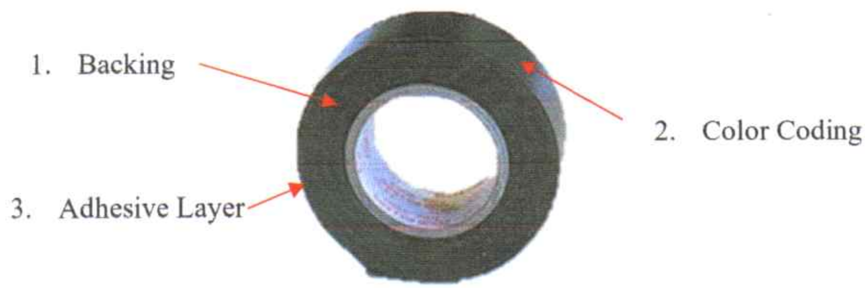

Figure 10: Electrical tape

PARTS

1. Backing (Base Material)
   a. Material: Vinyl and rubber
   b. Function: Provides flexibility, insulation, and durability.
2. Adhesive Layer
   a. Material: Rubber-based or acrylic glue.
   b. Function: Sticks to wires and itself without leaving residue.
   c. Temperature Range: Typically -18°C to 105°C.
3. Color Coding
   a. Black – General insulation

4.2 Circuit Schematics

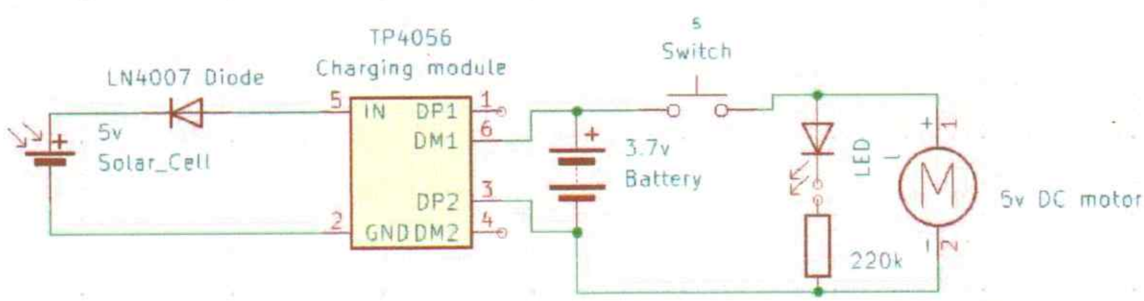

Figure 11: Schematic Diagram

4.3 Simulation

1. **Charging**
    a. During the daylight, the solar panel supplies 5v to the TP4056, which controls the charging to the battery. It can also charge directly to the outlet if sunlight is not available.
    b. A LN4007 diode prevents backflow of from the battery into the solar panel
2. **Powering Device**
    a. When the switch is turned on, the battery powers the 5v fan and LED. From electricity stored in the battery via Solar energy or direct electricity.
3. **Indicators**
    a. The LED lights up to show the device is turned on.
    b. The charging LED indicators on TP4056: blue for charging green for full charge.
4. **Water storage**
    a. Stores water in a bamboo, easy to acquire and reproduce.
5. **Fan power**
    a. The fan has 3 levels of power to suffice your needs from low to medium and maximum power.
6. **Storage**
    a. System storage designed to put all working parts together in one place. Water storage for access to water and freshening through air flowing from the fan.

Figure 12: Parts of the Prototype

IMPLEMENTATION STEPS

Step 1: Solar Charging via TP4056

Connect +ve of the solar panel to the IN+ of the TP4056. Connect –ve of the solar panel to IN– of TP4056. TP4056 will regulate charge to the 3.7V battery safely.

Step 2: Battery to Load (Motor + LED)

Connect the B+ and B– terminals of TP4056 to the battery. Use OUT+ and OUT– of TP4056 to power your load (motor and LED).

Step 3: Add a Switch to Control Power

Place the switch between OUT+ of TP4056 and the rest of the circuit (motor and LED), so turning the switch ON allows current to flow.

Step 4: Connect Motor and LED in Parallel

From the switch output: Connect to one leg of the LED in series with the 220kΩ resistor (used to limit current to the LED — although this value is quite high; 220Ω would be more typical). Connect also to one terminal of the 5V motor.

Step 5: Add Diode Protection

Place the 1N4007 diode in series with the motor's +ve input, with the cathode (striped end) facing the motor. This prevents reverse current into the circuit when power is off.

Step 6: Making holes

Drilling holes in the storage bottle for the led indicator, switch and the type C USB.

Step 6. Putting together

After connecting ang soldering the wirings. Putting together the wirings and its components to the cup of the tumbler which it is designed. And also, the solar and the fan outside.

CHAPTER V

RESULTS AND DISCUSSION

This chapter presents the results of the system's functional and performance tests, as well as the interpretation of findings based on testing data. The performance of the integrated solar-charging fan water bottle was evaluated under various conditions to assess its cooling effect, energy efficiency, and reliability.

5.1 Results

Table 2. Summary of Charging Testing Results

Lighting Condition	Average Solar Current (mA)	Charging Time – Trial 1	Trial 2 Duration	Trial 3 Duration	Average Charging Time
Direct sunlight	300 mA	8.2 hrs	7.8 hrs	8.5 hrs	8.2hrs
Cloudy	100 mA	24 hrs	26 hrs	22 hrs	24 hrs
Indoor	<50 mA	Failed	Failed	Failed	N/A

Table 2. Depicts the trials of the charging time of the 5V solar panel under direct sunlight, cloudy, and indoor charging capabilities. The energy that can be stored will depend on the availability. The charging time can be calculated with this formula:

$$Avg. Charging\ Time = \frac{Trial\ 1 + Trial\ 2 + Trial\ 3}{3}$$

The battery capacity is constant at 2200mAh, and the current value depends on the sunlight availability. The average time to charge the battery in 3 different observations for direct sunlight the average time to charge the battery is in 8hrs for full sun, no shading, for cloudy conditions, it takes 1 day, which is intermittent charging. While doing indoor errors to gather solar energy because of the low solar energy.

Table 3. Runtime Performance at Varying Fan Speeds

Speed level	Trial 1	Trial 2	Trial 3	Avg. Runtime
Low	240	235	245	240 min
Medium	130	125	245	130 min
High	75	80	70	75 min

This dataset compares the runtime of a 5V DC fan at different speed settings. Table 3. presents the values gathered in testing the run time of the fan 3 times to get the average run time of the three levels, namely low, medium, and high. Powered by the 2200 mAh battery.

Current draws speed from 3V:80mA low speed, medium speed 4V:150mA, and High speed 5V:250mA. These values are attained by the formula:

$$Avg. Run\ Time = \frac{Trial\ 1 + Trial\ 2 + Trial\ 3}{3}$$

Low speed is the best for energy efficiency but provides weaker airflow. Medium speed optimal for moderate cooling with reasonable battery life. High speed delivers maximum airflow but drains the battery quickly. The level of power depends on the needs of the user. Prioritize low speed for extended usage in a lower temperature area. Use high speed for rapid cooling when runtime is less critical, when going places that are hot in a short amount of time. Medium speed offers a trade-off between airflow and battery life suitable for a long-lasting battery with a minimum speed not too low not too high just enough to satisfy your needs.

Test Parameters

1. **Weight & Dimensions:**
   - **Capacity:** 800ml
   - **Weight (Empty):** 400g
   - **Weight (Filled):** 1100g (800ml water + tumbler)
   - **Dimensions:** 8cm diameter × 22cm height
2. **Test Scenario:**
   - **Handheld Use:** Walking, jogging, stairs

Table 4: Comfort and Stability Ratings During Various Activities

Activity	Trial 1 Rating	Trial 2 Rating	Trial 3 Rating	Average Rating (1-5)
Walking	5	4	5	4.7
Jogging	3	3.5	1	2.5
Stairs	5	5	5	5

The portability of the tumbler is tested in 3 different activities, as shown in Table 4. Tested with the tumbler filled with water and the components together. The tumbler tested in the first activity in the first trial has a firm grip, which is why it rates 5 and slightly changes to 4 because of slight slipperiness and the time it carries the tumbler, which affects it. In activity 2, the tumbler shows a low rating, which is not ideal for running, as it is rated the lowest in all the activities, because of the sweat. In the last activity, the portability of bringing the tumbler is somewhat the same as walking, just a slight difference.

5.2 Discussions of Findings

*1. **How can a portable fan be effectively designed and integrated into a water bottle?***

The portable fan can be effectively designed into the water bottle, as shown in Table 4, The portability of the tumbler and the fan is tested in different activities. Also, Table 3 shows the run time of the fan with the power it can put in different run times. Depending in your needs of the fan efficiency.

*2. **How can the product be developed at a low cost?***

The system used affordable, readily available components such as a mini 5V fan, a lithium-ion battery, and a small solar panel, contributing to a budget-friendly prototype. The fan and panel were chosen not for premium performance but for a balance of function and cost-efficiency. The use of recycled or standard bottles and minimal electronics ensured that development costs were kept low without compromising on usability or safety, as verified by the results in Table 2, 3 and 4.

*3.**How can the design balance compactness, water storage capacity, and ease of use for everyday portability?***

The prototype maintained its function as a water bottle while incorporating a fan and solar unit in a non-intrusive manner. According to Table 4, the components operated reliably in this compact configuration. Successful integration without affecting water storage capacity or comfort in handling suggests that careful layout and component positioning can support a balance between compactness and portability for daily use.

4. What is the level of consumer acceptance for a multifunctional product that combines hydration and personal cooling, particularly in terms of design, usability, and perceived value?

Although consumer testing data were not included, Table 2 implies high usability due to the 5v solar capabilities in sunny days consistent operation and recharge performance. The solar panel's ability to recharge in outdoor settings (Table 3) adds value for users in travel or outdoor environments.

5.To what extent does the prototype meet the criteria for an efficient and effective eco-friendly solution for portable cooling needs?

Table 2 shows that the solar panel reliably charged the battery under full sunlight in 8 hours, which aligns well with eco-friendly objectives by harnessing renewable energy. Combined with the fan's performance (Table 3), the system meets basic cooling needs without dependency on grid electricity or disposable power sources, supporting its effectiveness as a green solution.

6. How does this design reduce electronic waste and minimizes reliance on disposable batteries?

As shown in Tables 2 and 3, the use of a rechargeable battery charged via a solar panel eliminates the need for single-use batteries, directly addressing concerns of electronic waste. This approach promotes reusability and sustainability, key aspects of reducing environmental impact in portable electronics.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the final conclusions drawn from the results and findings of the study, as well as practical recommendations based on the performance and feedback regarding the prototype. The development of a portable water bottle integrated with a solar-rechargeable mini fan was guided by the goal of providing a sustainable, user-friendly solution for hydration and personal cooling, especially in hot environments like the Philippines.

6.1 Conclusions

This chapter presents a detailed summary of the project's key outcomes, the insights derived from its development, and the challenges encountered throughout the process. The following points highlight the major conclusions drawn from the project:

1. A fully functional prototype of a portable water bottle integrated with a solar-rechargeable mini fan was successfully developed.
2. The device combines hydration and personal cooling in a single, compact, and portable unit.
3. It features a mini fan mounted on top of the bottle's cup, with three speed settings (low/medium/high) to adjust airflow based on user comfort.
4. A small solar panel positioned beside the fan allows recharging using sunlight, promoting clean energy use.
5. The system includes a 3.7V rechargeable battery that powers the fan when solar energy is unavailable.
6. A Type-C charging module provides an alternative charging method when sunlight is insufficient.
7. A built-in LED indicator shows whether the device is turned on or off, enhancing usability.
8. A main switch controls the entire electrical system, ensuring efficient power management.
9. The unit remains lightweight and easy to carry, despite the integration of electronic components.
10. It is effective in hot, sunny outdoor environments, especially where traditional power sources are unavailable.
11. Demonstrates practical application of green technology, using affordable and accessible components.
12. Validates that sustainable and functional products can be built with existing technologies.
13. Limitations include limited performance in low-light conditions, reduced solar charging on cloudy days or indoors, and lack of airflow adjustability beyond fixed speed modes.
14. Durability can be improved by using higher-grade materials, although this may increase production costs.
15. Future improvements may include compact ergonomic design, weatherproofing, longer battery life, or smart charging features.

16. Overall, the project shows strong potential for commercial use in daily life and emergency scenarios, offering a sustainable and innovative solution for hydration and cooling.

6.2 Recommendations

Based on the findings, conclusions, and limitations observed in the prototype, several improvements are suggested to enhance the product's efficiency, user experience, and long-term practicality. The following recommendations are proposed:

1. Upgrade to more efficient or larger solar panels to collect more energy, especially during short or low-sunlight hours.
2. Add a feature that adjusts fan speed depending on battery percentage to maximize usage time and avoid sudden shutdowns.
3. Use a higher capacity than of 3.7V battery to store more power, extending fan operation on cloudy days or indoors.
4. Upgrade the charging module to support fast charging when using electrical outlets.
5. Seal the wiring, switch, and battery compartment to prevent water damage during outdoor use or cleaning.
6. Apply insulating materials around the bottle to help maintain the temperature of the water inside to hot or cold.
7. Create a basic mobile app or screen interface that shows battery level, fan status, and solar input for user convenience.
8. Redesign the device so that components (fan, battery, solar panel) can be easily replaced or repaired if damaged.
9. Use a non-slip grip or handle to make the bottle easier and more comfortable to carry during travel or outdoor activities.
10. Include basic electrical safety components like fuses or overcharging protection circuits to prevent overheating or short circuits.
11. Design the fan so it can be folded or detached when not in use, improving portability and reducing the risk of breakage.
12. Prioritize sustainable materials in production to align with the project's green technology goals.
13. Test the product with actual users and collect feedback on usability, comfort, and performance to guide future improvements.
14. Prepare a simplified, cost-effective version of the prototype that maintains core features but is optimized for commercial manufacturing.

APPENDICES

APPENDIX A
COMPUTATIONS OF DATA

FOR TABLE 2

$$Avg.Charging\ Time = \frac{Trial\ 1 + Trial\ 2 + Trial\ 3}{3}$$

Direct Sunlight (300 mA)

$$Avg.Charging\ Time = \frac{8.2 + 7.8 + 8.5}{3}$$

$$Avg.Charging\ Time = 8.2\ hrs$$

Cloudy (100 mA)

$$Avg.Charging\ Time = \frac{24 + 26 + 22}{3}$$

$$Avg.Charging\ Time = 24\ hrs$$

Indoor ($<$50 mA)

$$Avg.Charging\ Time = N/A$$

FOR TABLE 3

$$Avg.Run\ Time = \frac{Trial\ 1 + Trial\ 2 + Trial\ 3}{3}$$

Low

$$Avg.Run\ Time = \frac{240 + 235 + 245}{3}$$

$$Avg.Run\ Time = 240\ min$$

Medium

$$Avg.Run\ Time = \frac{130 + 125 + 245}{3}$$

$$Avg.Run\ Time = 130\ min$$

High

$$Avg.\,Run\,Time = \frac{75 + 80 + 170}{3}$$

$$Avg.\,Run\,Time = 75\,min$$

FOR TABLE 4

$$Avg.\,Rating\,(1-5) = \frac{Trial\,1 + Trial\,2 + Trial\,3}{3}$$

Walking

$$Avg.\,Rating\,(1-5) = \frac{5 + 4 + 5}{3}$$

$$Avg.\,Rating = 4.7$$

Jogging

$$Avg.\,Rating\,(1-5) = \frac{3 + 3.5 + 1}{3}$$

$$Avg.\,Rating = 2.5$$

Stairs

$$Avg.\,Rating\,(1-5) = \frac{5 + 5 + 5}{3}$$

$$Avg.\,Rating = 5$$

APPENDIX B
PROJECT DOCUMENTTION

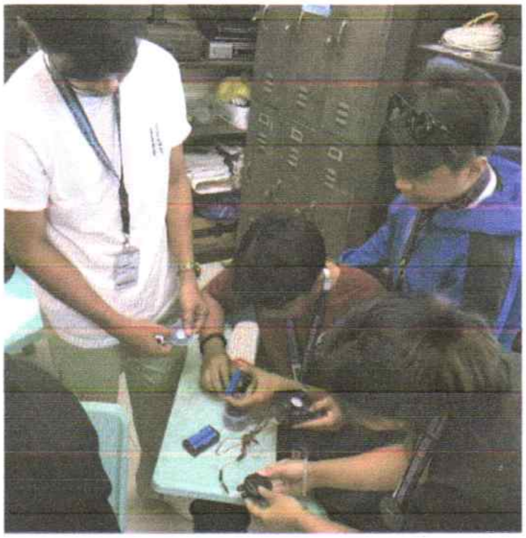

Figure 14. Gathering the Parts needed for the Prototype.

This figure shows the process of gathering the parts needed for the prototype. In this step, necessary components are collected and prepared for assembly. These parts include the mini fan, solar panel, rechargeable battery, charging module, wires, switch, and tools to help assemble the prototype. Each item is checked for quality and compatibility to ensure smooth integration during the construction process.

Figure 15. Assembling the Internal Parts of the Fan.

This figure shows the process of assembling the internal parts of the fan. This step involves carefully connecting the small DC motor to the fan blades and securing it inside the bottle cap or designated fan housing. The motor is then linked to the rechargeable battery and connected to the small solar panel through wiring, ensuring proper polarity for power flow. Each component is fixed firmly in place to prevent movement and ensure stability during use.

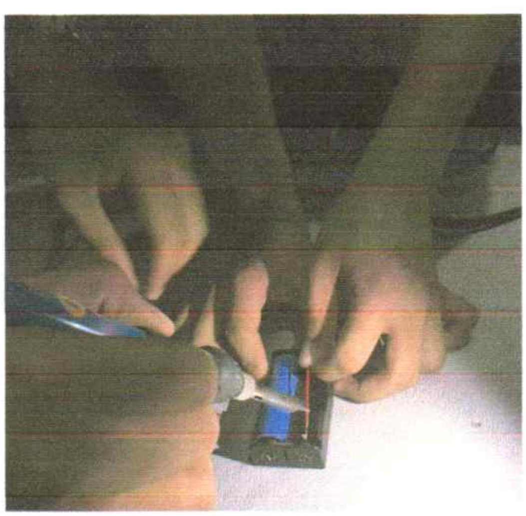

Figure 16. Soldering the Battery.

This figure illustrates the process of soldering the battery. In this step, the battery terminals are carefully connected to the corresponding wires using a soldering iron and solder. This creates a strong, stable electrical connection between the battery, the charging module, and the fan.

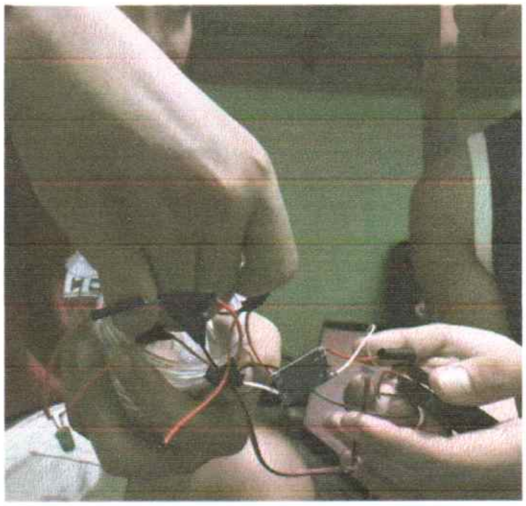

Figure 17. Wiring and Integration of Mini Fan.

This figure illustrates integrating essential electronic parts for the solar-rechargeable mini fan project such as, TP4056 charging module, a green LED, red and black connecting wires, and a plastic container that serves as the main body of the fan. This stage highlights the connection and testing of the circuit before final installation.

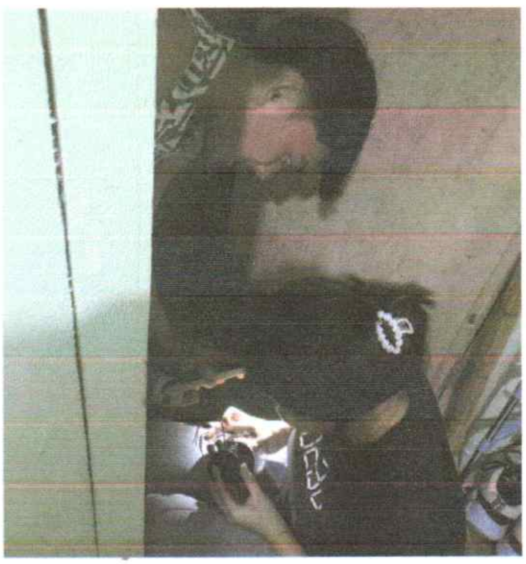

Figure 18. Installment of the Solar Panel

This figure illustrates the installment of the solar panel on the portable water bottle. In this step, the solar panel is securely attached to the outer surface of the bottle, usually on the lid, where it can receive maximum sunlight exposure. The panel is connected to the internal wiring that links it to the rechargeable battery and the fan system.

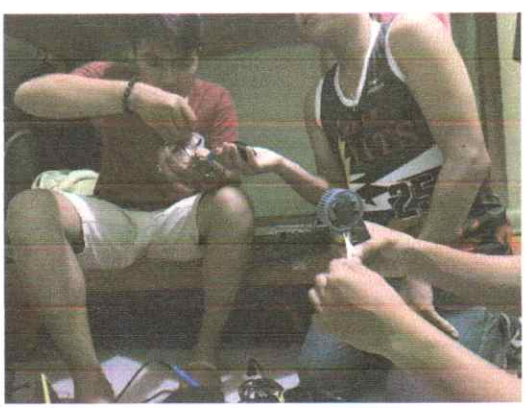

Figure 19. Connecting the Fan to the Solar Panel

This figure shows the direct connection of the mini fan to the solar panel through appropriate wiring. The purpose of this step is to power the fan using energy harnessed from sunlight. Proper polarity and secure connections are ensured to allow the solar panel to drive the fan efficiently during daylight conditions.

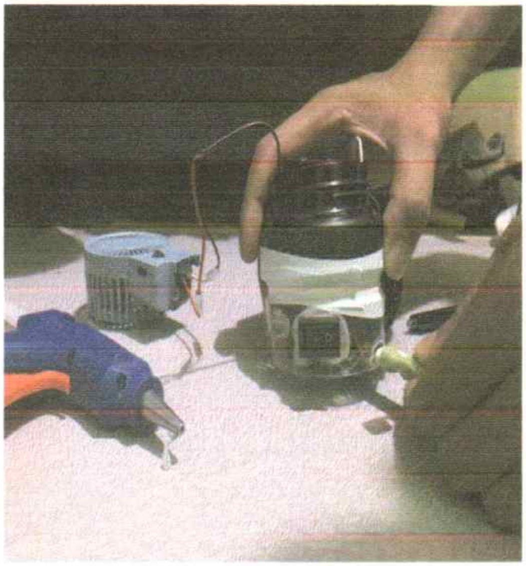

Figure 20. Testing the Charging Module

This figure shows the testing of the charging module of the battery. In this step, the solar panel is exposed to a light source to verify if it successfully charges the rechargeable battery through the connected charging module. An indicator is used to check if current is flowing and the battery is receiving power. This process ensures that the charging system is working properly and that the battery can store enough energy to power the fan.

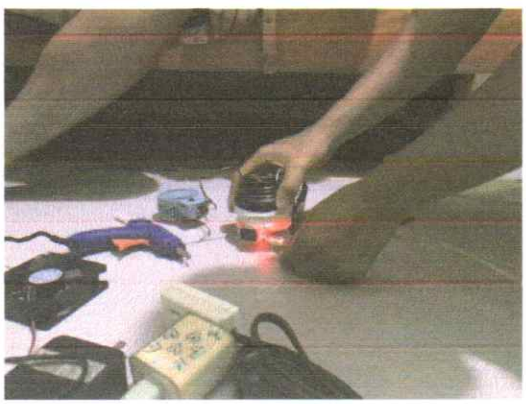

Figure 21. Red Light Indicator – Charging in Progress

This figure shows the charging module with a red light illuminated, indicating that the rechargeable battery is actively charging. The red light serves as a visual confirmation that power is being supplied from the solar panel to the battery.

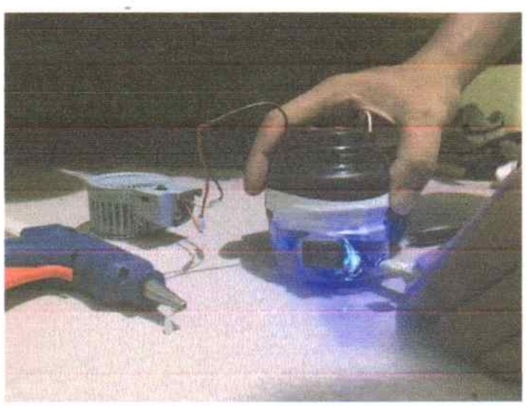

Figure 22. Blue Light Indicator – Fully Charged

This figure displays the charging module with a blue light turned on, signifying that the battery is fully charged. The blue light confirms that the charging process is complete and the battery is ready for use.

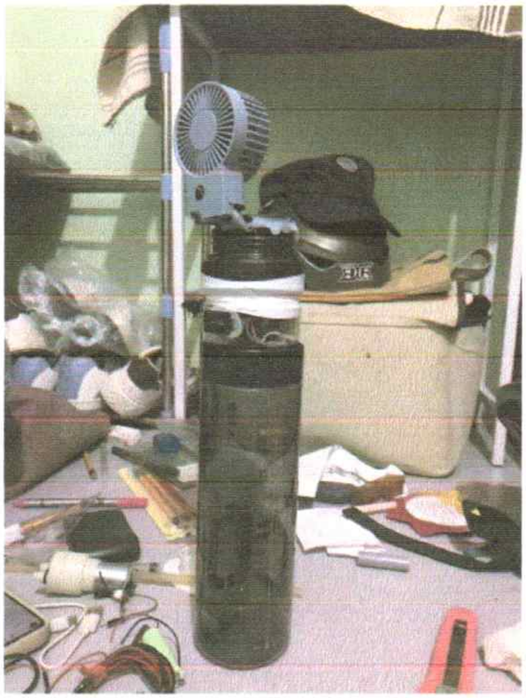

Figure 23. Fitting the Tumbler to the Fan Unit

This figure shows the process of checking whether the tumbler properly fits with the mini fan unit. The tumbler is aligned and tested against the fan's structure to ensure compatibility and stability. It is essential to confirm that the components are securely attached and the design is suitable for combined use as a portable hydration and cooling device.

Figure 24. Creating the Final Prototype

This figure illustrates the creation of the final prototype of the portable water bottle integrated with a solar-rechargeable mini fan. In this stage, all components such as the water bottle, solar panel, battery, internal wiring, and fan are fully assembled and tested for functionality. The entire system is enclosed securely, ensuring that all parts are properly fitted and the device is safe for use. Final adjustments are made to improve stability, appearance, and performance. This step completes the construction process, resulting in a fully functional and portable prototype that provides both hydration and personal cooling.