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# DEVELOPMENT OF A FAST-CHARGING HYBRID PORTABLE POWER BANK

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**Abstract**. The increasing reliance on laptops for both professional and personal activities has highlighted the limitations of existing portable power solutions, particularly in regions with unreliable access to electricity. This paper addresses the need for a reliable, portable, and universally compatible power bank specifically designed for laptops. The power bank integrates both DC charging and renewable solar energy, offering a hybrid solution that enhances user flexibility and independence from traditional power sources. The power bank prototype uses a series-parallel arrangement of lithium-ion batteries to generate a battery capacity of 20,000 mAh, a DC-DC buck-boost converter for voltage regulation, and a battery management system for thermal stability and output efficiency. The performance evaluation highlights charging efficiency of about 75% across various laptop models, output voltage stability within 10% fluctuation, and thermal control maintaining temperatures below 40 °C. Solar charging is more efficient but slow compared to DC charging, achieving full capacity in 12 hours under optimal sunlight. The developed power bank successfully charged laptops for an average of 2 hours and demonstrated compatibility with a range of devices. This innovative solution fills a critical gap in portable power technology and lays the groundwork for enhancements in weight, casing design, and device compatibility.

**Keywords**: Hybrid, Fast, portable, charger, bank

## 1. Introduction

The electronic devices that are mostly used in the modern day are mobile devices and computers, and these devices are becoming very reliable for human beings daily. While smartphones have been equipped to perform a wide variety of functions, these devices cannot be used to replace a general-purpose computer. Therefore, computers are still as vital as studies show that there are approximately 47.1% of households worldwide that own either a desktop or a laptop computer system (Marbin *et al.*, 2023). However, the reliance on electrical power presents a significant challenge, especially in regions with limited or unreliable access to electricity. In countries like Nigeria, millions of people lack access to reliable power sources, particularly in rural areas where electrification efforts are often inadequate.

Research showed that about 33.1% of the Nigerian population in rural areas still do not have access to electricity while about 14 percent of the country’s population in urban areas do not have access to electricity as well (Olaniyan *et al.*, 2018; Oladigbolu *et al.*, 2020; Olanrele *et al.*, 2020). Furthermore, electricity supply remains epileptic to those who do have access, regardless of location throughout the country, leading to frequent power outages that disrupt daily life and productivity (Agbeboaye *et al.*, 2019).

In response to these challenges, there has been a growing interest in alternative power solutions that can ensure uninterrupted usage of electronic devices. Power banks have become the most commonly used means for charging smartphones and other USB-powered devices in place of a power supply when the devices are low. Power bank technology enables users to extend the battery life of their devices without the need to always plug the devices directly to electricity supply, thereby enhancing the overall user experience (Divya *et al.*, 2018). However, power banks fall short when it comes to supplying the higher voltage and power demands of mobile PCs. Typically, mobile PCs require dedicated power sources with specific voltage and connector compatibility, making it challenging to find a one-size-fits-all solution.

A mobile PC is good enough for a person to work remotely with the provision of proper network connectivity and battery. Laptops provide us with the ability to fulfill our requirements on the job, thereby fulfilling life's necessities (Avinash *et al.*, 2021). A personal computer is designed to perform complex and resourceful tasks and therefore demands a higher voltage supply compared to the relatively modest needs of smartphones. The conventional power banks optimized for USB-powered devices are not equipped to meet the unique power demands of these powerful devices.

Moreover, the typical power output of conventional power banks is optimized for smartphones, falling short of the voltage required to efficiently charge and sustain the operation of laptops. As a result, users are left with limited options when it comes to portable power solutions for laptops, forcing users of these devices to rely on the traditional power supply with factory-specified chargers. This issue gives no room for flexible charging and often leads to avoidable downtime in the use of the laptops in the case of power outage.

Therefore, this study aims at providing a power bank that is compatible with a wide variety of laptops.

### 1.1 Review of related works on power banks

Power banks are electronic devices that mainly contain batteries for storing electrical power and are used for recharging other electrical or electronic devices in the absence of power supply (Diao *et al.*, 2020). There is an increase in demand for a continuous supply of electronic devices such as phones and laptops as these devices help to keep one connected to the Internet at all times. It was estimated in 2019 that an average person spends approximately seven hours per day on the Internet (Czerniak *et al.*, 2021). This type of connection as well as other activities does not come cheap as it is very power-consuming and most devices do not have enough power to sustain them at maximum usage for a whole day (Pascal *et al.*, 2020). Users of electronic devices cannot always plug in their devices to sockets especially since the supply of electricity is inconsistent, as it is the case in a developing country like Nigeria. Thus, the power bank will be an effective and portable backup power supply.

Paco *et al*. (2023) designed a solar power bank for smartphones with the use of solar cells from discarded calculators to enable recycling and also reduce pollution. The output of the power bank was barely strong enough for standalone use but with the use of a DC-DC converter, the output of the power bank was sufficiently boosted to 5 V which was needed to charge smartphones.

The innovation of the DC-DC converter is a very important aspect in the design of power banks for laptops because more often than not, voltage output would have to be boosted to effectively and efficiently charge the laptop. Therefore, research into improvements of DC-DC converter circuits is also equally important. Effort in that direction include that of Callegaro *et al*. (2017) where a simple transition technique for non-inverting buck-boost converters was proposed. Also, Banaei and Bonab (2019) also researched on designs of an efficient non-isolated buck-boost converter.

Another aspect of importance is ways of improving the users' experience in relation power bank usage by making the recharging process as easy as possible. A noticeable effort in this regard borders on the introduction of wireless charging via the use of inductive coupling technology (Kweku, 2017; Sulaiman *et al.*, 2017; Sutar *et al.*, 2020). However, to make use of the wireless charging technology, there is a need to install extra coils in the charging device as well as the device to be charged, in this case, the power bank. This will lead to an increase in the complexity of circuit design, cost and reduce portability due to increase in weight. Therefore, unless there is a very simple and very cheap way to implement the wireless charging technology, it is considered unsuitable for design.

The design of a laptop power bank can be noted to be an improvement on the already improved design of a regular smartphone power bank except for some important upgrades. In the design of a power bank for laptops, some major criteria need to be considered from the manufacturer's side and the user's perspective. Such criteria include capacity, heat capacity, voltage and current requirements, and compatibility with a variety of laptops, etc. Okonkwo *et al.* (2023) researched and designed a microcontroller-based power bank for laptops that can be charged with conventional means only. The Arduino Uno microcontroller technology that was incorporated serves as the battery management unit and it helps to monitor overcharging, low voltage, normal controls as well as boost converter controls for auto adjustment depending on the load of the connected laptop.

There have also been lots of improvements in the use of solar energy to charge power banks for laptops. Johnson and Haskew (2018) designed a power bank that takes its input from solar source and has the capacity to adequately charge five laptops. However, the device had to be mounted outdoors and it is stationary. Therefore, it would require a considerable number of cables to power the laptops at indoor locations and it was not flexible. Similarly, Al-Talib *et al*. (2024) researched on the design of a power bank with charging based on clean renewable energy sources not just limited to solar energy but also wind energy as well.

Durganjali *et al.* (2022) also tried to improve on recharging speed of power bank technologies by attempting to replace lithium-ion batteries with super capacitors to take advantage of its quick charging and slow discharging feature and a display was also implemented using an Atmega microcontroller for monitoring. Supercapacitor battery technologies are well-established and widely used technology but it offers several disadvantages like weight, volume, large internal resistance, poor power density, and poor transient response.

This paper demonstrate the feasibility of designing a hybrid power bank capable of charging from both solar and grid power sources, with sufficient output to support laptop charging. Key findings revealed that integrating solar energy as a supplementary input can significantly improve flexibility and sustainability, especially in areas with unstable grid supply. The study also confirmed the effectiveness of using synchronous rectification and appropriate DC-DC converters for efficient power transfer. Overall, the research provided practical insights into component selection, power management, and system integration for portable, renewable-powered energy storage solutions tailored to laptop requirements.

## 2. Design procedure of fast charging portable power bank (FCHPB)

This work aims to create a reliable and portable solution for charging laptops using renewable solar energy as well as DC charging. The proposed system is illustrated in the block diagram shown in Fig. 1. The power bank is designed with 10 units of 3.7 V Li-ion battery connected in series-parallel with a theoretical capacity of 20,000 mAh. The recommended input voltage range of 100 – 230 V AC power supply, an expected DC output voltage of 20 V and an output DC current of 3 A. The projected battery capacity is used to determine the amount of battery cells as well as solar panel cells that are needed. The design is sectioned appropriately. All necessary specifications are stated in Table 1.

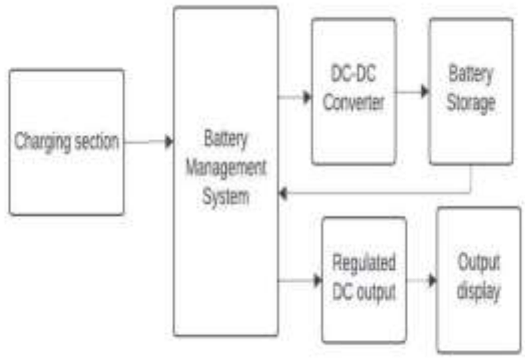


Fig. 1: A block diagram of the fast-charging hybrid 20 000 mAh, 20 V, 3 A power bank

Table 1: Specifications for the design of 20 000 mAh power bank

| Quantity | Specifications |
|---|---|
| Input voltage | 100 – 230 V AC |
| Output voltage | 20 V DC |
| Input current | 3 A |
| Output current | 3-5 A |
| Battery capacity | 20 000 mAh |
| Power rating | 60 W |

### 2.1. *The charging section of the FCHPB*

The required number of solar panels needed to effectively supply the power bank is determined based on the level of intensity or rays that are radiated to solar panel surfaces as well as the panels' efficiency of conversion.

To account for charging losses, a solar panel efficiency of 15% is assumed.

$$E = E_R V \tag{1}$$

Taking efficiency into account, (1) becomes

$$E = \frac{E_R V}{\eta} \tag{2}$$

where $E$ is the battery capacity, $E_R$ is the daily energy requirement, $V$ is the required voltage, $\eta$ is the solar panel efficiency. With appropriate assumptions of the power rating of a single solar panel cell, the required number of solar panel cells is then calculated.

$$N_s = \frac{E}{P_S} \tag{3}$$

where $N_s$ is the required number of solar panel cells, $P_S$ is the power rating of each cell.

The conventional charging of the power bank requires converting the usual available AC current to DC with the use of a rectifier, one that can handle the voltage 100 – 230V and current 3A requirements respectively. The rectifier circuit is fitted into the adaptive charger that is used for charging the device. Some important values that must be noted in rectifier circuits include the inductor sizing, the capacitor sizing and the filter capacitor rating.

The value for the appropriate filter capacitor to be used in the rectifier circuit is calculated and gives

$$C = \frac{I(1-coscos\,(\alpha))}{2f\Delta V} \tag{4}$$

where input current $I$ is given as 3A, α is the conduction angle 180°, $f$ is the frequency of AC input and it is a constant value of 50 Hz, $\Delta V$ is the allowable ripple voltage which is 5% of the peak voltage 230 V. The charging adapter features the rectifier circuit such that the output to the power bank port is DC. The power bank uses the same input port for both solar charging and AC-DC charging.

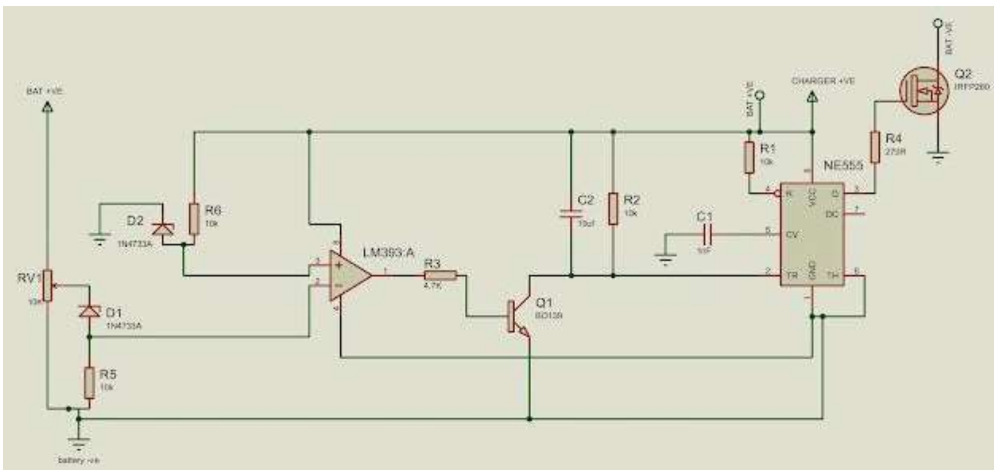


Fig. 2: Circuit diagram of the DC charging section of the 20,000 mAh, 20 V, 3 A power bank

*2.2. Battery management system of FCHPB*

The battery management section is handled by the XY PDS module which monitors the battery charging and usage levels, and boosts the voltage levels as required. Also, it is connected to a display system which displays the voltage and current output levels of the power bank. The system monitors the battery percentage levels using the divider rule. If two resistors $R_1$ and $R_2$ are considered and connected in series across a voltage supply $V_{in}$, if the output voltage $V_o$ is taken across $R_2$,:

$$V_o = V_{in} \frac{R_2}{R_1+R_2} \tag{5}$$

The required number of battery cells needed for the battery is determined as well as the battery capacity of the power bank. The batteries are arranged in a series-parallel connection. Therefore, the number of cells required in the series connection and the number of cells required in the parallel connection are determined.

Cells required in series

$$N_{cs} = \frac{V_o}{V_n} \tag{6}$$

cells required in parallel

$$N_{cp} = \frac{E}{E_s} \tag{7}$$

the required number of cells can then be computed by multiplying (6) and (7) to give

$$N_{bs} = N_{cs}N_{cp} \tag{8}$$

where $N_{cs}$ is the number of cells in series, $N_{cp}$ is the number of cells in parallel, $N_{bs}$ is the total number of battery cells.

Therefore, the appropriate number of required cells is derived from (8). These battery cells are made from 3.7 V lithium-ion batteries connected in series-parallel to generate an output voltage of 24 V and an output current of 3 A. The battery section is connected to the BMS which regulates the charging and discharging of the battery and monitors the battery health as well. The minimum and maximum input power required by the power bank and its minimum charge time are important. The rated power at input terminal is given as:

$$P_{in} = V_{AC} I_{AC} \tag{9}$$

where $P_{in}$ is the input power, $V_{AC}$ is the AC voltage, $I_{AC}$ is the AC voltage.

The output power to the load regulates and rectifies the DC output. The projected DC output power at the output supplied to the laptop is computed:

$$P_o = V_{DC} I_{DC} \tag{10}$$

where $P_o$ is the output power, $V_{DC}$ is the DC voltage, $I_{DC}$ is the DC voltage.

A specific high-current charger is designed to increase the charging current to the maximum to help speed up the charging process greatly. The corresponding charging time is

$$t = \frac{E}{I_{AC}} \tag{11}$$

where $E$ is the battery capacity, $t$ is the charging time.

*2.3 Output Section of FHPB*

The output section comprises an output port with a stable output of 60 W and a Type-C module which is varied as needed by the load (laptop). A DC-DC buck-boost converter is required to boost or step down the voltage as required by the load as well. The identification of the proper rating of the buck-boost converter circuit utilized is computed.

The DC charging circuit design is shown in Fig. 2 while the actual power bank framework with the required devices and its actual size are shown in the projected flowchart of the working system of the power bank in Fig. 3.

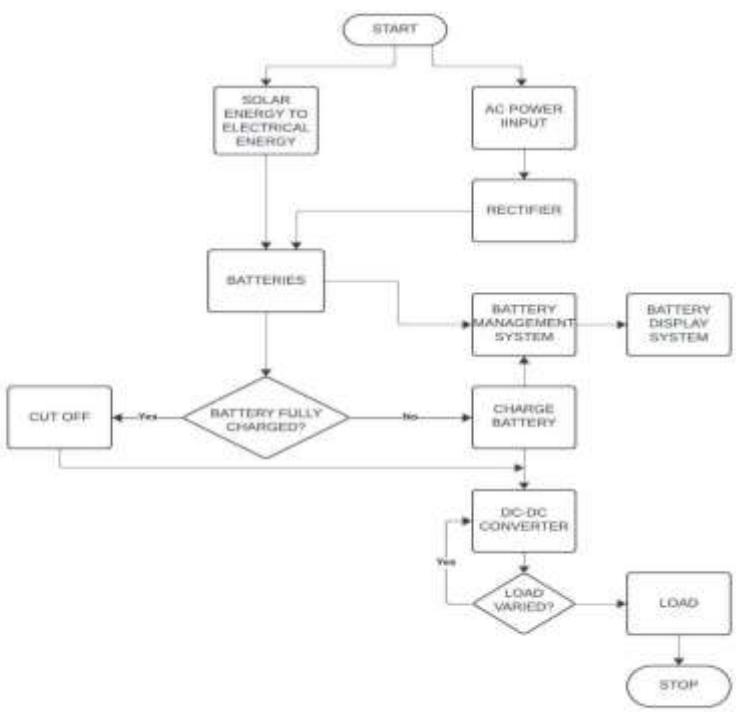

Fig. 3: Flowchart of the working principle of the hybrid 20 000 mAh, 19.5 V, 3 A Power bank

## 3. Results and Discussion of FCHPB

In this section, the results of the power bank prototype are presented and analyzed to assess the performance and effectiveness of the design. The main focus is on evaluating the charging process of the power bank using both solar and grid power. It also examines the power bank's ability to charge various laptops efficiently. Key performance metrics such as charging efficiency, voltage stability, and thermal are discussed in detail. Additionally, these evaluations aim to provide a comprehensive understanding of the power bank's operational capabilities, highlighting its strengths and identifying areas for potential improvement.

### *3.1 Performance evaluation of the FCHPB*

The power bank is tested under full load conditions to determine its effectiveness and efficiency. The key performance indicators that are monitored include the power bank charging time, output power efficiency, output voltage stability, actual battery capacity as well as heat dissipation. The power bank is designed with a capacity of 20,000 mAh, this is tested with multiple laptop models and with fast battery recharge using hybrid charging methods.

#### *3.1.1 Comparison between DC charging and solar charging with FCHPB*

The charging rate on comparison for the same amount of time (8 hours) is observed. It should be noted that the solar charging started at 8:00 am. The observations as presented in Table 2 shows that the DC charging rate is twice as fast as the solar charging rate.

Table 2: Comparison between DC charging and Solar charging rate

| Time (Hours) | DC Charging (mAh) | Solar Charging (mAh) | Remarks |
|---|---|---|---|
| 0 | 0 | 0 | Charging starts from 0% |
| 1 | 5,000 | 2,000 | Higher current with Type-C fast charging |
| 2 | 10,000 | 3,800 | Solar panel efficiency affects the charging rate |
| 3 | 15,000 | 5,500 | Solar charging slows as the sun's angle changes |
| 4 | 20,000 | 7,000 | Midday peak for solar charging |
| 5 | 20,000 | 8,200 | Solar charging continues |
| 6 | 20,000 | 9,000 | Solar charging continues |
| 7 | 20,000 | 10,000 | Solar charging slows due to evening light |
| 8 | 20,000 | 11,000 | Solar charging continues |

#### *3.1.2 Laptop charging time of FCHPB*

The results after testing showed that the power bank could charge a standard laptop with a 50 Wh battery from 0 to 100 % in approximately two hours. Fig. 4 shows the results of various charging times of laptop models of the same average battery capacities that are tested with the power bank. It is deduced from the observations that Apple and HP laptops charged considerably faster than the other laptop models that are tested and the average charging time for any laptop is approximately two (2) hours.

### *3.1.3 Load test of FCHPB*

The power bank is subjected to a full load test under a period of two hours where the voltage readings of the power bank at battery terminals are observed by a voltmeter. The output voltage and current to load (laptop) are also observed on the LED display unit and the results are given in Table 3. It can be deduced from the results that the battery terminals produce an average voltage of 12.5 V. This voltage is then supplied to the DC-DC converter, which steps it up to the required level of 20 V. The output readings observed on the LED display also confirmed that the output is at the appropriate voltage and current levels needed to charge the laptop, thus demonstrating the power bank efficiency under full load conditions.

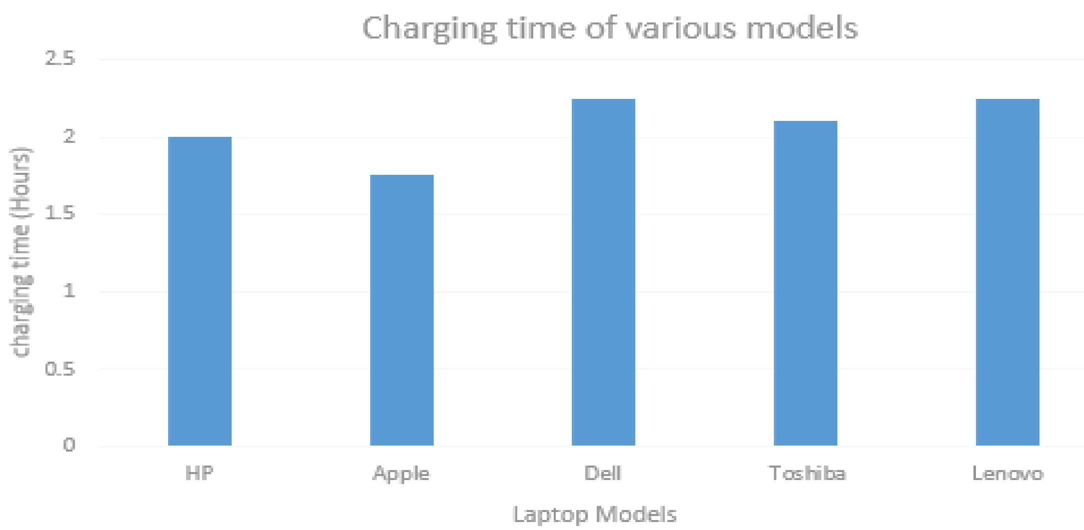


Fig. 4: Charging periods of various laptop models

Table 3: Observation for Load test for 2 hours

| Time (minutes) | Voltmeter Reading at Battery Terminals (V) | Current output reading on LED display(A) | Voltage output reading on LED display (V) |
|---|---|---|---|
| 0 | 12.6 | 2.97 | 20.0 |
| 15 | 12.55 | 3.01 | 19.9 |
| 30 | 12.53 | 2.98 | 19.8 |
| 45 | 12.50 | 3.03 | 19.7 |
| 60 | 12.47 | 3.02 | 19.6 |
| 75 | 12.47 | 3.00 | 19.5 |
| 90 | 12.44 | 3.02 | 19.5 |
| 105 | 12.41 | 3.02 | 19.5 |
| 120 | 12.35 | 3.05 | 19.3 |

### *3.1.4 Thermal management of FCHPB*

The temperature of the power bank is recorded during the charging and discharging cycles. The built-in cooling components effectively maintained the temperature within safe operating limits. The values of the temperature variations of the power bank over a four-hour usage period are given in Fig. 5. It can be concluded that the power bank's temperature increased with prolonged use but remained within safe limits, with the ambient temperature at 30°C and a peak temperature of 40°C during maximum usage, ensuring it did not overheat.

### *3.2 Discussion of FCHPB*

The results from the experimental tests demonstrate that the power bank is both functional and effective. The key parameters such as output voltage stability, charging time, and ambient temperature during operation are measured. The use of a DC-DC buck-boost converter ensured that the power bank consistently met the voltage and current requirements for charging mobile PCs. Furthermore, the charging time is effectively reduced, and the power bank maintained safe operation without overheating, staying below 40°C even under load for 4 hours.

The device is developed using 10 Li-ion batteries arranged in a series-parallel configuration and connected to the buck-boost converter, thereby providing an output range of 5 –20 V and 2 – 5 A through the type-C port, with a maximum power output of up to 100 W. For small devices, the USB port offers a maximum power output of 36 W. Additionally, a solar panel of 40 W rating is incorporated as an alternative charging source for use in the absence of an electricity supply.

The measured weight of the power bank is 1.008 kg, indicating that the power bank is portable and convenient to use. It also features a display interface that shows variations in output voltage and current depending on the connected device. During testing, the hybrid power bank successfully charged a standard laptop rated at 50 Wh in approximately 2 hours and a smartphone rated at 15 Wh in less than 2 hours, demonstrating its compatibility with multiple device types.

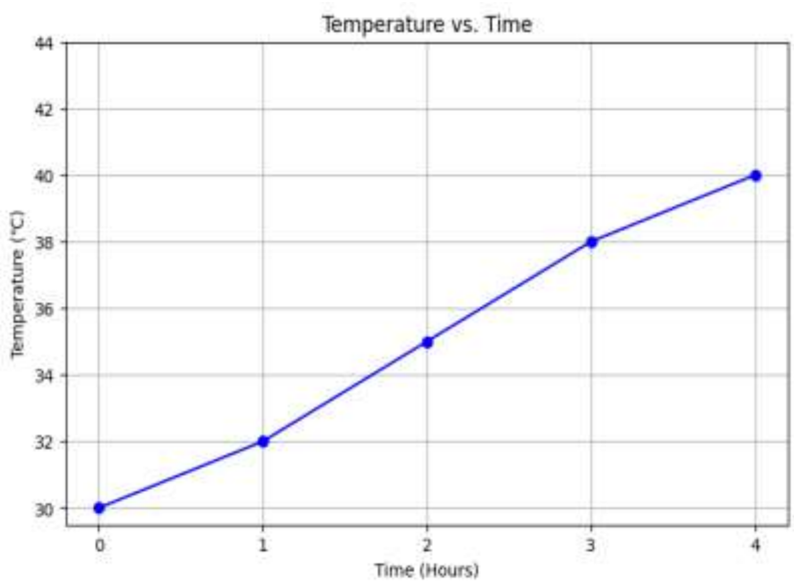


Fig. 5: A line graph showing the temperature variation over a 4-hour operation period

## 4. Conclusion of FCHPB

The power bank development can be considered to be successful, achieving the majority of the objectives outlined in the initial stages. The final product demonstrated an efficient, reliable, and moderately compatible solution for charging laptops, particularly in scenarios where access to traditional power sources is limited. However, despite its success in many areas, the power bank did not fully meet all its intended objectives. While it does provide a reliable and efficient charging solution for laptops, it is only capable of doing so when the laptop being charged is equipped with

a Type-C input port. This limitation reduces the overall versatility, as the power bank is initially designed to be compatible with various laptop models regardless of input type.
Moreover, an additional input port is integrated for smaller devices such as smartphones, allowing simultaneous charging of both laptop and smartphone. This dual-functionality adds a level of flexibility and convenience, demonstrating that the design is adaptable for use with multiple devices. In terms of efficiency, the power bank achieved a charging rate of 60 W, with an output voltage of 20 V and an output current of 3 A. These specifications reflect its ability to charge laptops efficiently, although future designs could benefit from further optimization to increase compatibility across a broader range of devices.

## 5. Recommendations for FCHPB

While the power bank performed well, there are many areas for future improvement. Future iterations could focus on reducing the weight of the power bank without compromising on capacity. The designed power bank only functions effectively with the type-C output and therefore it is only limited to charging newer laptop models with a type-C input port. This does not meet up with the intended standards of the power bank that is meant to charge multiple laptops at the same time regardless of the output type. Therefore, the most notable improvements can be made here to make the power bank much more compatible.
Provision can also be made for a higher-rated solar panel to speed up charging speed via solar energy. A solar panel rated 100 W would cover up the substantial time difference between DC charging and solar charging.

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