ASHESI UNIVERSITY COLLEGE

A DUAL ENERGY SOURCE LAMP FOR OFF-GRID PERSONS WITH LOW INCOME

B.SC. ELECTRICAL AND ELECTRONICS ENGINEERING

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ASHESI UNIVERSITY COLLEGE

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CAPSTONE PROJECT

Capstone Project submitted to the Department of Engineering, Ashesi University College in partial fulfilment of the requirements for the award of Bachelor of Science degree in Computer Engineering.

KOFI ANWEARA

2019

DECLARATION

I hereby declare that this capstone is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:

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I hereby declare that preparation and presentation of this capstone were supervised in accordance with the guidelines on supervision of capstone laid down by Ashesi University College.

Supervisor's Signature:

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Date: …………………………………………………………………………………………

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Abstract

In the off-grid communities in Ghana, most people depend on solar energy for electricity [1]. Some also depend on torch lights, candle lights or kerosene lamps to meet their lighting needs [2]. These lamps come with their own pros and cons. The solar lamps for instance, do not last for the entire night when in full usage though they are the cleanest of all. And since they are solar dependent, they become useless when there is no sun shine [3]. Hence, on the event of these solar lamps going off in the night, they leave users being stranded; especially when they need light urgently, things get worsen. People have worked on improving the battery capacity of such lamps for longer lasting [4]. However, the problem is that they would have to be charged for a longer time for longer discharging. This project therefore seeks to save solar lamps users from being stranded when their lamps go off in the night. It therefore focuses on providing an alternate means of recharging the lamp in that moment for usage. Hence this project modifies the already existing solar lamps by introducing a mechanical mechanism which enables users to mechanically recharge batteries for temporal use. The recharged lamp may light up for a little longer or a while depending on how much the user was able to charge the battery. But then the user can still go back and recharge it mechanically whenever he or she wants.

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Chapter 1: General Introduction

1.1 Background

The energy needs of humans are tied to their population and, as the population increases, the energy demand also increases. The strive to meet these energy needs of every generation has led to the discovery of quite several energy sources and has improved the existing once as well [5]. Aside of the demand for more energy which leads to discoveries, lack of efficiencies is also a factor. The major transition in the history of energy use was the harnessing of water and wind power which were used to run water wheels and windmills respectively [6]. The harnessing of water and wind today, has helped in the generation of electricity. Thermal power plants and others also evolved to supplement the power needs of the growing population. Mankind has passed through many stages in the upgrading of energy sources and today there are quite several energy sources which help in electricity generation [7]. These generated energies are then distributed to individuals for different purposes. The most common usage is for lighting. However, people who do not have access to the distributed energy tend to maneuver their way through to explore difference types of energy or ways of meeting their lighting needs. Today, most of these people depend on solar energy or lamps whilst a small percentage depend on dry cell lamps, candle lights or kerosene lamps for their lighting needs and other purposes [8].

1.2 Problem Definition

There are many sources of energy generation across the world however in Ghana, most of the energy comes from hydro, thermal and solar with the total generation capacity of 3,759 MW [1]. Despite these capacities, about 1.2 million people are off-grid. This population comprises of people who cannot afford and those who can but have no access to electricity at all. They therefore rely on either solar, fuel or dry-cell based lamps for their lighting [1]. These lamps also come with their own ups and downs. For instance, having to constantly replace dry cells or buy fuel to keep batteries charged become a challenge to those who are living below standard. Further, the solar which appears to be free and clean amongst the others, on a bad weather day, have its lamps charged poorly resulting in poor performance and might not last for a night [3]. So, on the event of users losing power in the night, they become stranded since the only source of recharging is the solar. They will have to endure the night irrespective of how much they need light. The same problem also arises for those who rely on dry cells and fuel but do not have reserves lack the means. They would have to equally endure darkness when they run out of energy. Further, aside the lighting, other people use these lamps for other purposes such as recharging mobile phones and when they run out of energy, all these activities also cease [9]. There is therefore the need for these lamp users to be saved from the plight of being stranded when their main source is down due to any reason.

1.3 Objective of the Project Work

Having identified the problem of people who are off-grid and therefore depend solely on lamps with low income as well, this project is therefore aiming at:

1. Providing a cheap and reliable lamp with a clean, independent, dual source of energy for people living off-grid; so that when one fails or is in short supply, the other can take over.
2. Providing a lamp with charging abilities to charge basic appliances such as mobile phone for people who are off-grid.
3. Providing a lamp that can change lighting colors to suit users' preference.

1.4 Motivation of Project Work

During my summer internship in 2017 at Burro Brand Ghana as a Research and Development intern, I had the opportunity to visit villages for research where I observed the electricity situation in those villages. I witnessed how people who are off-grid are struggling to meet their electricity needs. Those who rely on dry cell lamps must soon replace batteries for power supply. Likewise, with the fuel-based lamps. For solar lamps users, they suffer on days with bad weather since their lamps do not charge properly and they end up enduring the darkness till day break. Even on a good weather day, batteries charged do not last for the night. Having empathized with them, a lot of questions began running through my mind as a graduating engineer where I questioned myself what I could do to redeem these people from such a plight.

1.5 Research Methodology

Basically, the scientific methods of research are used to arrive at the research goals. The research methods include;

1. Defining and redefining the objective of the projects.
2. Review of pertinent literature.
3. Experimentation, simulation, data collection analysis; and
4. Software and Hardware designs and prototyping.

1.6 Research Facilities Used

The research facilities employed for this project work are;

1. Computer, internet and Library facilities at Ashesi
2. Ashesi ‘s Workshop and Electrical and Electronics Laboratory.

1.7 Scope of work

This project covers the design and construction of simple lamp a dual energy source with a mobile phone charging feature as a peripheral. The main components that would entail the design are cranking/gearing system, battery level indicator, LED lamp-head design, Voltage regulator and Charge controller.

1.8 Project Organization

The rest of the pages contain chapters of literature review on alternative source of energy, simple lamp designs, materials and methods employed in the project, implementation, result and analysis, recommendations and future works.

Chapter 2: Literature Review

2.1 Introduction

There are so many forms of energy namely electrical, solar, mechanical, wind energy etc. of which each of these has their own source. Some of these energies are intertwined, which means one might be converted to another as the law of conservation of energy states. For instance, solar energy can be converted to electrical and electrical to mechanical. Further, it is also possible to have two or more forms being converted to one form [10]. For example, wind and solar can be converted into electrical. So, having two or more forms with all these forms having the ability to be converted into one form, can make this converted form a reliable form. Because different forms are being converted into it. Despite all the numerous sources of energy available, there is a concept of “Free energy” as well, which refers to the idea of a system that can generate power by taking energy from a limitless source [11]. That is, this hypothetical device generates power free from the constraints of fuel, solar, and wind, but continue to produce energy for as long as the device remains active. The limitless source of energy is said to be as the result of the fact that this generator feeds on its own energy to generate energy and the excess is used externally [12]. Though this idea seems scientifically impossible, it worth reviewing as part of energy sources.

2.2 Sources of Energy

Energy sources are the places where energy could be obtained or that which can give energy [13]. Essentially, depending on the source, energy is categorized into two. Which are renewable and nonrenewable.

2.2.1 Renewable Energy Sources

Renewable resources are unlimited natural resources that can be replenished in a short period of time. Hence renewable energies are those generated from natural sources [14]. Examples of renewable energies include:

Solar energy which is essentially the conversion of sunlight into either directly using photovoltaics or solar panel. This is one of the best sources of renewable energy because it is the cleanest. It is environmentally friendly, as compared to fuel which when burnt pollutes the environment. [14]. There is also Wind energy; Over centuries ago, people harnessed wing energy for so many purposes. For instance, the ancient Egyptians used wind to sail ships on the Nile River. Later, people built wind mills to grind wheat and other grains. Today, wind energy is mainly used to generate electricity. The benefit of this type of energy source is that it is clean, does not emit gases such as NO_x, SO_2, CO, CO_2 [14]. Further, the next common type of renewable source of energy is Hydropower; Hydropower is also sometimes referred to as water power. It is the power derived from the energy of falling water or fast running water. The energy in this flowing water can be captured and converted into electrical energy [15].

Lastly but not the last type of renewable sources of energy is Geothermal energy. It is thermal energy generated and stored in the Earth and it is the energy that determines the temperature of matter. Geothermal heat is the only renewable energy source created naturally by the earth itself. [16] The process by which geothermal power is generated is by the transformation of the underground thermal energy to mechanical energy first, and it is then converted to electrical energy. [17]

2.2.2 Non-Renewable Energy

A non-renewable resource is a limited natural resource that cannot be replenished in a short amount of time at a scale comparable to its consumption. Few examples include:

Coal which is a burnable brownish-black sedimentary rock containing a very high amount of carbon and hydrocarbons. It is classified as a nonrenewable energy source since it takes millions of years to form [18]. Also, Petroleum; It is a naturally occurring liquid which is found below the surface of the Earth that can be refined into fuel. Petroleum is said to be a fossil fuel, because it is created by the decomposition of organic matter over millions of years [18]. And finally, Natural gas which consists of mostly of methane gas and it is found alongside coal beds and other fossil fuel deposits throughout the world [19].

2.2.3 Free Energy?

The concept of "Free energy" has always given rise to a lot of qualms in the sense that it gives an attempt to violate the laws of thermodynamics which seems ridiculous [12]. The problem arises from the fact that it is impossible to construct a perpetual motion device which is also the only hypothetical source to get free. [20]. Despite the clear scientific laws which attest to the fact that perpetual motion devices are impossible to construct, there are some people who strongly believe that it is possible. For instance, Lindemann P.A, one of the strong believers put it that if it was once said in the 100s, a man could travel by air it would have been ridiculed and nullified as being impossible or a fantasy. Most of these arguments are tied around the fact that in 1970 John Bedini, built a battery powered motor with a flywheel on the shaft of the motor. Though this device did not seem like a startling device, but the crunch is that the motor ran in his workshop for more than three years, keeping its battery fully charged during that time [21].

Generally, the two types of design that were reviewed are categorized into two.

The self-powered; These category of devices stores energy in a flywheel which is then used latter by the system. They also have at least two motors of which one serves as the prime-mover and the other serves as the generator. The fly wheel is mounted in between the shaft of both the generator and the motor. An external source of energy is supplied to the motor. Once the motor spins together with the flywheel, it picks up speed. As the flywheel picks up speed, the generator begins to generate power. The external source is quickly disconnected and since the flywheel has picked up speed it continues to spin the generator. The output of the generator is then connected to the motor which therefore powers the motor again and it continue to spin. Fig.2.3 depicts a simple model of the self-powered model.

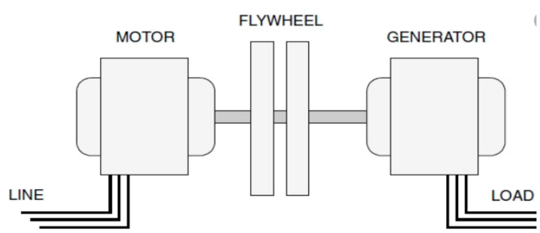


Fig. 2.3: A diagram of a self-powered model

The following equations from (2.1) to (2.9) gives the mathematical equations that governs such a model. For a motor

$$V_T = E_A + I_A R_A. \tag{2.1}$$

$$\tau = K\varphi I_A. \tag{2.2}$$

$$E_A = K\varphi\omega. \tag{2.3}$$

Where V_T is the terminal voltage across the terminals of the motor

E_A is the internal generated voltage

I_A is the armature current

R_A is the armature resistance,

τ. is the induced torque

K is the motor characteristics constant

φ. is the flux produced.

For the energy stored in a flywheel,

$$E_k = \frac{1}{2} I \omega^2 \quad (2.4)$$

where E_k is the energy stored in the flywheel

I is the inertia

r is the radius of the flywheel

m is the mass of the flywheel

$$I = \frac{1}{2} r^2 m \quad (2.5)$$

$$\omega = \sqrt{\frac{2E_k}{I}} \quad (2.6)$$

$$E_A = K\varphi \sqrt{\frac{2E_k}{I}} \quad (2.7)$$

$$E_A^2 = 2K^2 \varphi^2 \frac{E_k}{I}. \quad (2.8)$$

$$\frac{E_A^2}{\varphi^2} = 2K^2 \frac{E_k}{I}$$

$$I_A = \frac{V_T - E_A}{R_A}. \quad (2.9)$$

$$E_A^2 \propto E_k \ \ and\ E_k \propto \frac{1}{\varphi^2}.$$

Hence as the Energy of the flywheel increases, the flux decreases rapidly, and as the flux decreases, induce emf decreases and this causes a rise in the armature current. As indicated by equation (2.9) This effect results into an increase in torque induced and hence the motor speed increase which serves as the primover to the generator. As indicated by equation (2.2). The limitations of this type of model includes, flywheel comes to rest with time, it is also difficult to obtain maximum speed.

The second type that was considered was the magnetic based. This has eight bars of magnets arranged at equal distances at the rim of a circular disk and a ring magnet at the center of the disk. Fig.2.1.1 depicts how the magnets are configured.

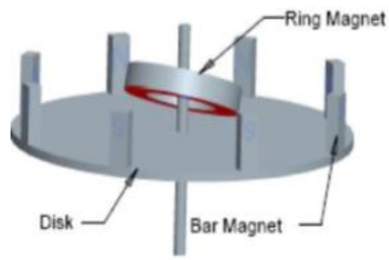


Fig .2.1.1: Arrangement of bar magnets with a with magnet at the center [22]

The first magnet located at the rim of the circular disk aligned aligns its north pole with axis of rotation and facing towards it. The magnet that follows is placed after 1/8th of the circumference is rotated by an angle of 45^{o} around z-axis such that after traveling half circumference, the magnet rotates through 180^{o} as in Fig 2.1.2. The input is ring magnet which has an inner and outer radius of 31.75 mm and 50.8 mm respectively as in Fig 2.1.3. This ring magnet is then placed at an angle between 30^{o}-40^{o} from the horizontal upper surface of the disk. The lower face of the ring magnet becomes the north Pole and the upper, face the South Pole or the vice versa. Hence the face of the bar magnet facing the ring magnet is such that there is a repulsive force between the two. The ring magnet is placed manually by rotating it around z-axis at an angle of 30^{o} -40^{o} to an axis parallel to the upper surface of the disk such that at any instant, there exists a repulsive force between a pair of bar magnets and the ring magnet. This therefore creates the spinning effect. Fig. 2.1.2 and Fig.2.1.3 depicts how the arrangements of these magnets are done.

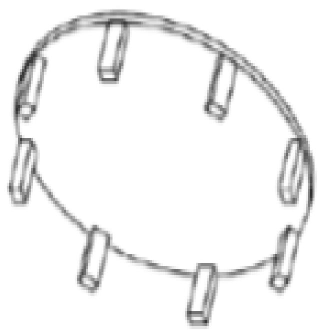


Fig 2.1.2: Risk with bar magnets [22]

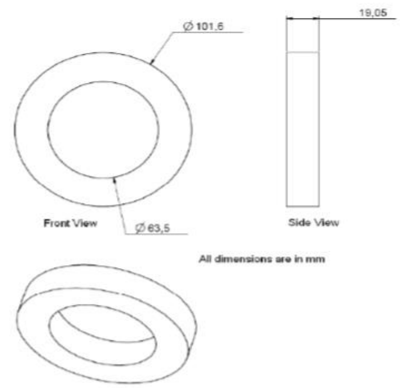


Fig 2.1.3: Ring magnet [22]

The limitations of this type of method are that the magnet gradually loses its strength over time and also speed depends on the strength of the magnet hence cannot be regulated.

2.2.4 Solar Powered Lamps

A solar lamp is sometimes called solar light or solar lantern. It comprises of an LED lamp, solar panels, battery, charge controller and there may also be an inverter. The lamp operates on electricity from batteries, charged using solar photovoltaic panel. [23]. The adequate amount of light is calculated using the Inverse Square Law. The inverse square law defines the relationship between the irradiance *I* from a point source and distance which states that the intensity per unit area *E* varies in inverse proportion to the square of the distance *d*. [3]

$$E = \frac{I}{d^2} \tag{2.1.1}$$

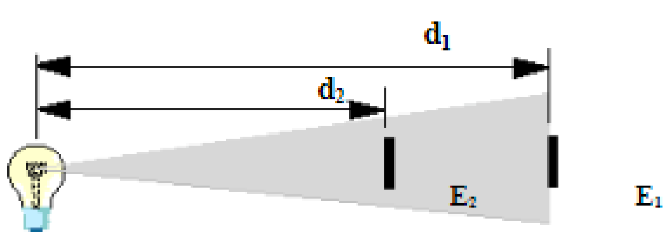


Fig.2.1.4: Diagram depicting the Inverse square law

For the total lumen output lm,

$$E(lmsr)\times\Omega(sr)=lm \tag{2.1.2}$$

Where
lm is lumen,
sr is steradian,
and Ω is the Solid Angle.

As the batteries serves as the power bank, battery sizing therefore becomes very necessary. In determining the right size of battery to be used the battery storage capacity S in ampere hours (Ah) may be estimated as:

$$S = \frac{W*h*N_s}{V_b*\eta_b*\eta_i}.$$

Where

W= power rating of CFL (in Watts), 5 watts

h= daily usage (in hours), 5 hours

NS= the number of days of storage (in days), 2 days

Vb= battery voltage (in volts), 12 volts

ηb= battery efficiency, assumed to be 90 %

ηi= inverter efficiency, assumed to be 85 %

Charge Controller also forms a vital component of solar lamps. It is designed to keep batteries from overcharging [24]. It therefore regulates the voltage and current coming from the solar panels going to the battery to ensure that overcharging does not occur. Hence the charge controller protects the battery from overcharge and disconnects the load to prevent deep discharge. The two commonly types of charge controllers used in today's solar power systems are pulse width modulation (PWM) and maximum power point tracking (MPPT) [24].

In PWM charge controller, the current which is from the solar panel tapers with respect to the battery's condition and recharging needs [24]. When the battery voltage reaches the set point of regulation, the PWM algorithm reduces the charging current slowly to avoid heating and gassing of the battery; yet charging continues to return the maximum amount of energy to the battery in the shortest time [25].

The MPPT breaks the higher solar panel voltage down to the charging voltage requirement of the battery. It therefore adjusts its input voltage to harness the maximum power from the solar panel which is then transformed to supply the varying voltage requirement of the battery plus load. Fig.2.1.5 depicts the general block diagram of a solar charge controller.

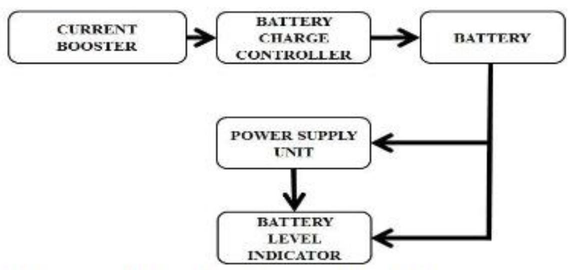


Fig. 2.1.5: Block diagram of charge controller [25]

Chapter 3: Design

3.1 Review of related work

With regards to simple lamps, people have come out with various kinds of lamps. A typical example is the gravitation powered light. With this type of lamp, the gravitational energy of a heavy object is converted to the electrical energy. According to [26], when a heavy object is dropped down from a higher position to a lower one, its potential energy is converted into kinetic energy and this energy is converted to electricity by using a synchronous motor. It was found that with increasing of the altitude of the load, the lighting time increases. However, if load increases, power production also increases, but the lighting time decreases.

Further, S. Mok [27] worked on a "Human powered generation" system of producing energy for simple devices. The principle behind the operation of such a system is quite very simple. It is either leg paddled or hand cranked. He found out that the Hand-crank generator normally generates very small power and commercially available products are essentially for charging mobile phones and LED lighting. According to S. Mok [27], the power ranges from less than one Watt to no more than a couple of few Watts. The Pedal Generator on the other hand, he presented that it is built from a bicycle stand and has a 500W neodymium magnet DC motor rated at 24 V and 2,000 rpm coupled to the rim of the bicycle stand. This makes the Pedal generator a bit more advance than that of the Hand-crank. Similarly, L. Linqiang et al. [28] exploited a mechanical hand crank device for charging mobile phones. This device converts mechanical energy into electrical energy which is used to charge the mobile phone. The device consists of a gear train and intermediate gears for the conversion of mechanical energy from the hand crank to electrical energy very efficient [28].

3.2 Design Decision

Table 3.6 gives a brief descriptions and features of what each intended design would be entailing.

Design No	Features
Design 1	Charging system for phone, Solar Energy dependent, Energy Boosting, one DC motor, 20W solar panel, voltage level indicator, 12V battery, user manual, voltage regulator, Charge controller, mechanical cranking feature, 1 lamp head with different lights
Design 2	DC motor, Wind energy dependent, two head lamps, manually/mechanically starting, multiple charging system, System weight 15kg, 200W, 4 wheels, 50m cable plug, spare parts for maintenance, user manual, fly wheel
Design 3	voltmeter, auto-starting, Energy dependent, Energy Boosting, three dc motors, 20kg, 200W, two sockets, flywheel energy storage.
Design 4	synchronous motor and a DC motor, two sockets, manually/mechanically starting, 20kg, 20W, 50m cable plug, spare parts for maintenance, user manual, 2 wheels

3.2.1 Pugh Matrix

The Pugh Chart below assesses the various design based on cost, usability, durability, feasibility, size, weight, output power, operation mode and portability. Each design is scored and the design with the highest score is chosen to be considered in the project

Table 3.1: Pugh matrix that scores each design against the given weight

Criteria	Weight	Design 1	Design 2	Design3	Design4
Cost	5	1	2	3	4
Usability	2	2	2	2	2
Durability	4	3	-2	-3	-4
Feasibility	7	5	3	2	4
Size	5	2	2	4	5
Output power	3	3	2	1	0
Operation mode	3	2	-1	-2	-3
Weight	2	-1	1	2	2
portability	2	-1	1	2	2
Total	33	16	10	9	12

From the Pugh matrix, the design with highest score is the design1. It has the highest scores of 16 which indicates that it is the best design amongst the rest in terms of cost, usability, durability, feasibility, size, weight, output power, operation mode and portability.

Chapter 4: Materials and Methods

4.1 Introduction

Materials and their availability are very important in this project. Some of these were gotten from the local market whilst others, from the international market. Although some of them were improvised, they did help to look at the project work from a different perspective. Essentially materials help in the fabrication of product.

4.2 Materials

The materials employed in this project are used to build a charging system, battery level indicator, phone charging spot, Lamp, solar panel, Casing and a flywheel

4.2.1 The generating Part Materials

The generating part is essentially the part responsible for the converting mechanical energy to electrical energy. The mechanical energy is supplied to the system when the solar is down. The converted energy is either used directly stored batteries for later use. The materials used to build the generating part include, 24V Johnson DC motor, Spur gears, 3D printer filament and a solar.

The Johnson motor is used as the motor generator in this project. It is coupled to the mechanical crank via gear train. Fig4.1 shows the image of the Johnson DC motor.

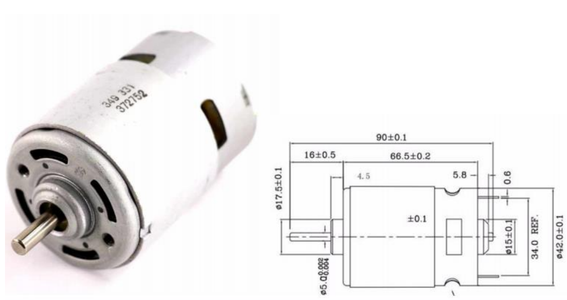


Fig.4.1 Johnson motor and its dimension

Table 4.1: gives the specifications of the Johnson Dc motor

Description	Value	Units
Nominal voltage	14.4	Volts
Wattage	100	Watts
RPM	16000	Rev/mins
Continuous Torque at 14.4V	1.9	Kg-cm
Stall Torque at 6V	9.8	Kg-cm
Dimensions:	90 x 44.5 (Dia.)	mm
mass	316	grams
No Load Current at 14.4V	1.8	A
Stall Current at 14.4V	49.5	A
Shaft Diameter Ø	5	mm
Shaft length	16	mm

The 3D printer filament is a thermoplastic feedstock for fused deposition modeling 3D printers. There are many types of filament available with different properties, requiring different temperatures to print. Filament is available in two standard diameters; 1.75 and 2.85 mm/3 mm [29]. Fig.4.2 is an image of different colors of 3D printer filament.

Fig.4.2: 3D filament, PL [29]

PLA 3D Printing Filament has the following properties:

- PLA filament is a stiff but brittle 3D printing material.
- Best used for cosmetic prints, prototypes, desk toys, low-stress applications.
- Best 3D printer material for beginners due to ease of printing and minimal warp.

The solar panel is used to harness the energy from the sun which by the help of the CS3 battery, this energy was stored. A solar panel works by allowing photons, or particles of light, to knock electrons free from atoms which thereby generate a flow of electricity [30]. Solar panels are made of many, smaller units called photovoltaic cells, linked together to make up a solar panel. Fig4.3 is a picture of the solar panel used in this project

Fig.4.3: Sun shine solar panel [30]

Table 4.1: gives the specifications of the Sun shine solar panel

Description	value	Unit
Amplitude	1.5	-
Energy per area	1000	W/m^2
Maximum power	20	W
Output tolerance	+/-5	%
Current at Pmax	1.14	A
Voltage at Pmax	17.5	V
Short circuit current	1.28	A
Open circuit voltage	22.05	V
Weight	2.5	kg
Dimension	470*350*23	mm
Maximum System voltage	1000	V, DC
Maximum series fuse rating	3	A

4.2.2 Battery and Charging System

The Battery is used to store electrical energy generated. In order to aid the storing up of the energy. The charging system built from resistors, Diodes, Relays, and ICs. The charging system is designed to automatically cut off supply when battery is fully charged. The solar panel also assists in the charging of the battery during the day time.

The CB3 battery serves as the power bank which is used to store energy from the solar. It also stores the electrical energy converted from the mechanical cranking. The CSB GP-1272F2 batteries are rechargeable, highly efficient and leak proof. It is specifically designed for highly efficient discharge application [31].

Fig.4.4: CS3 Battery [31]

Table 4.2: gives the specifications of the CS3 battery

Description	Value
Cells per unit	6
Voltage per unit	12V
Capacity	12 Ah @ 20hr-rate to 1.75V per cell @ 25°C (77°F)
Weight	Approx. 3.67kg. (8.09 lbs.)
Maximum discharge current	150/180A (5sec.)
Internal resistance	Approx. 16.7 mΩ
Operating Temperature Range	Discharge：-15℃~50℃(5°F~122°F) Charge：-15℃~40℃(5°F~104°F) Storage：-15℃~40℃(5°F~104°F)
Nominal operating temperature range	25°C ± 3°C (77°F ± 5°F)
Float Charging voltage	13.5 to 13.8 VDC/unit Average at 25°C (77°F)
Charging current limit	3.6 A
Terminal	F1/F2-Faston Tab187/250

4.2.3 Voltage Regulator

Any electrical device that helps to maintains the voltage of a power source within acceptable limits [32]. The voltage regulator is needed to keep voltages within the prescribed range that can be tolerated by the electrical equipment using that voltage. The voltage regulator is built in this project to keep the output voltage at constant value. This is to maintain constant brightness of lamb and also to aid in the charging of phones. Due to the fluctuating in the output of the voltage of the solar panel, a voltage regulator is also built to keep the output voltage constant and regulate the amount needed to charge the battery. The materials used in building up the voltage regulator are, resistors, LM7805, LM317T Capacitors (10uF, 1uF, 0.1uF), 100K variable resistor, heat sink and 100K resistor.

The LM7805 is a voltage regulator integrated circuit. It provides +5V regulated power supply. Capacitors of suitable values can be connected at input and output pins depending upon the respective voltage levels [33] . The image below is an LM7805 voltage regulator used in the project.

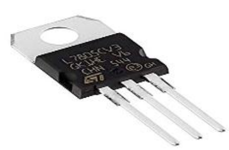


Fig 4.5: LM7805 Voltage Regulator [33]

Table 4.3: gives a brief specification of the LM7805 voltage regulator

Description	Value	Unit
Output voltage tolerance	+/-4	%
Operating temperature	-40 to 125	C
Input voltage	5 to 18	V
Output voltage	4.8 to 5.2	V
Dropout Voltage	2.0	V
Peak Current	2.2	A
Short circuit current	230	mA

The LM317T is monolithic integrated circuits which are designed to supply at least 1.5 A of load current with an output voltage adjustable over a range of 1.2 to 37 V range. This electrical component also has built in current limiting and thermal shutdown which makes it essentially blow-out proof [34]. Fig. 4.6 is an image of LM317T

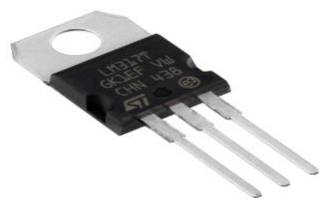


Fig.4.6: LM317T, Adjustable Voltage Regulator

The following are the Key Features of the LM317T

- Output voltage range: 1.2 to 37 V
- Output current in excess of 1.5 A
- 0.1% line and load regulation
- Floating operation for high voltages
- Complete series of protections: current limiting, thermal shutdown and SOA control.

4.2.4 The Lamp Head

The lamp head is created from a Compact disc with LEDs and a printed 3D model. The Compact disc served as a reflecting surface which reflects the light to a distance. Below is an image of the compact disc.

Fig.4.7: Compact Disc

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons [35]. These LEDs serves as the source of light. They are glued to the surface of the Compact disc to illuminate the surface of the disc for brighter light. Some also serves as indicators. Fig.4.8 is an image of an LED

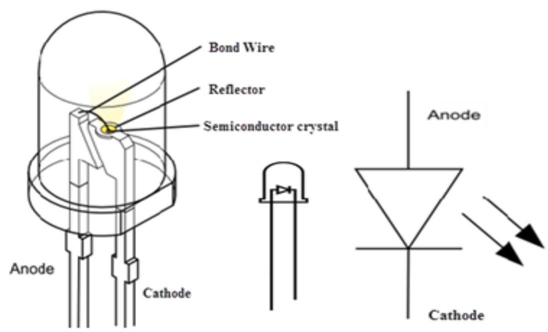


Fig.4.8: A light Emitting Diode [35]

Table 4.4: gives the specifications of the various LEDs used.

Color of LED	Description	Forward voltage drop typical (V)	Viewing Angle	Max forward current(A)	Typical luminous intensity
White	3mm	3.1	60	25	700 mCd (@20mA)
Red	5mm	2.1	60	25	275 mCd (@20mA)
Blue	3mm	2.1	60	25	500 mCd (@20mA)

4.2.5 Charge Controller

A charge controller regulates the rate at which electric current is added to or taken from electric batteries [25]. It therefore prevents overcharging and may protect it against overvoltage, which can affect the battery performance or lifespan, and may pose a safety risk as well. The individual components use to achieve this are LM3914, LED, 12V Relay, SCR, NPN transistors, Resistor (1K,10K, 200K), NE555, and diodes (1N4001)

The LM3914 is a special type of monolithic integrated circuit that detects analog voltage levels and drives 10 LEDs, providing a linear analog display. A single pin changes the display from a moving dot to a bar graph. The Current drive to the LEDs is regulatable and programmable, disregarding the need for using resistors [36]. Fig4.9 is an image of LM3914N-1

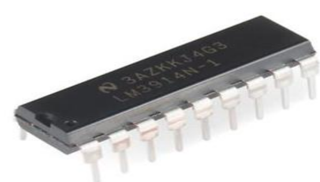


Fig.4.9: LM3914N-1, Voltage level indicator.[31]

The following are the key features of an LM3914N-1

- Drives LEDs, LCDs or Vacuum Fluorescents
- Bar or Dot Display Mode Externally Selectable by User
- Expandable to Displays of 100 Steps
- Internal Voltage Reference from 1.2V to 12V
- Operates with Single Supply of Less than 3V
- Inputs Operate Down to Ground
- Output Current Programmable from 2 mA to 30 mA [36]

Relays are switches that open and close circuits electromechanically or electronically. They control one electrical circuit by opening and closing contacts in another circuit. When a relay's contact is normally open (NO), there is an open contact when the relay is not energized, and it closes when energizes. Also, when its contact is Normally Closed (NC), there is a closed contact when the relay is not energized, and it opens when energized. In either case, applying electrical current to the contacts will change their state [37].

Generally, relays are used to switch smaller currents in a control circuit. Fig.4.1.1 depicts an image of a 12 V Relay.

Fig.4.1.1: 12V Relay [37]

The 555 timer IC is an integrated circuit used in a variety of timer, pulse generation, and oscillator applications [38]. They can produce accurate time delays or oscillation with precision in timing. In the time-delay or mono-stable mode of operation, the timed interval is controlled by a single external resistor and capacitor network. In the a-stable mode of operation, the frequency and duty cycle can be controlled independently with two external resistors and a single external capacitor. Below is an image of an NE555 timer.

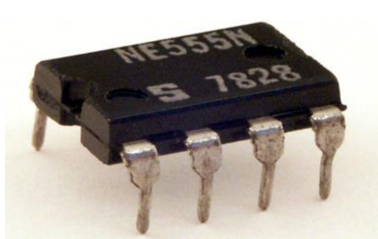


Fig 4.1.2: NE555 IC [38]

Below are the key features of the NE555 IC

- Timing from Microseconds to Hours
- Astable or Monostable Operation
- Adjustable Duty Cycle
- TTL-Compatible Output Can Sink or Source Up to 200 mA

4.3 Hardware Designs and Construction

In the hardware design, the various physical components and their relationships are identified. Schematics were designed in software such as Kicad and Multism. After simulation, they were built by bringing all the required components together. Aside the circuitry, Solidworks is also used to design other tangible parts of the product. Fig 4.3.0 is the block diagram which depicts the various stages and how the individual components are connected.

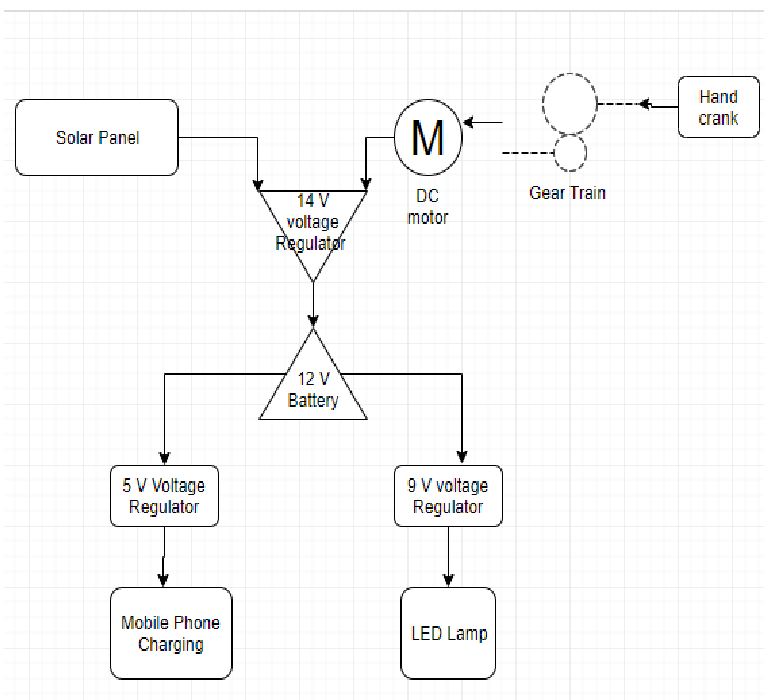


Fig.4.1.3: Block diagram of a dual energy source lamp

4.3.1 The Adjustable Voltage Regulator

The adjustable voltage regulator is built purposely to regulate the voltage from the solar panel at 14.4V. The maximum voltage of the panel is 20.5V and it can go as low as 5V depending on the intensity of the sun. The components used in this design are LM317T,1$K\Omega$ and 10KΩ. Fig 4.1.3 is a schematic diagram of the voltage regulator.

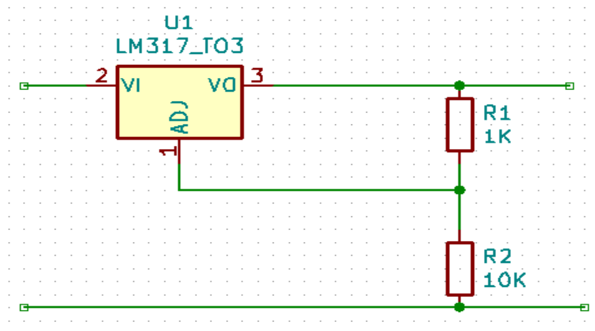


Fig .4.1.4: Variable voltage regulator circuit diagram

The principle behind how the adjustable voltage regulator works is that the voltage across the feedback resistor R1 has is a constant 1.25V reference voltage, V_{ref} produced between the "output" and "adjustment" terminal. The adjustment terminal current is a constant current of 100uA. Since the reference voltage across resistor *R1* is constant, a constant current *i* will flow through the other resistor R2, resulting in an output voltage, V_{out} . In calculating for the resistor values, V_{out} and R_1 specified. Using these values, R_2 is then calculated. [34]

$$V_{out} = 1.25\left(1 + \frac{R1}{R2}\right). \qquad (4.1)$$

$Required \quad V_{out} = 14.4.$

$Assume\ R1 = 1K.$

$then\ R2 = 10K.$

4.3.2 The Pulse Generator

The pulse generator is used to control the lighting effect of head lamp. Below is a pulse generator with adjustable duty cycle made with the 555 timer IC. The circuit is an astable multi-vibrator with a 50% pulse duty cycle. The circuit is set up in a way that it puts the NE555 timer in an astable mode (that is connecting pin2 to pin6). The astable mode makes the NE555 timer to trigger itself, generating a stream of pulses if it still receives power. The components that were used include NE555 IC, Potentiometer (100KΩ), Capacitors (0.01uF, 0.1uF) and 10KΩ resistor. Fig 4.1.5 is a circuit diagram of the pulse generator built.

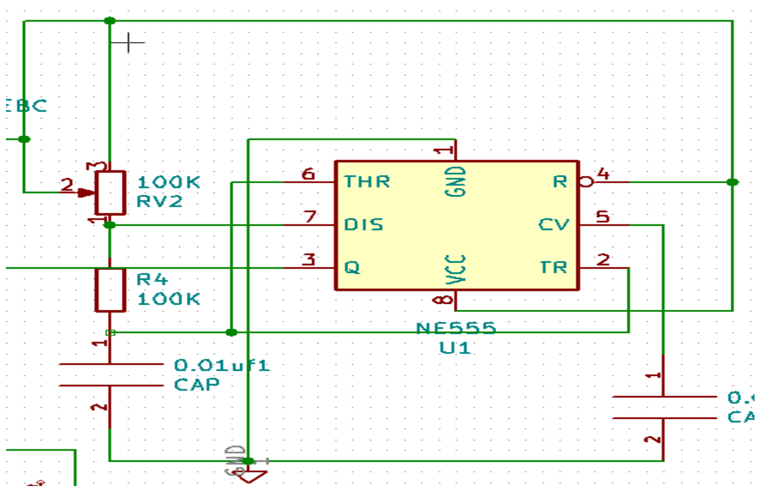


Fig 4.1.5: Pulse generator

To determine the resistor and capacitor values for the circuit, the following equations were employed

$$T = t_c + t_d \tag{4.2}$$

$$t_c = 0.69(R_4 + RV2) * C1. \tag{4.3}$$

where T is the period,

t_c is the ON time

t_d is the OFF time

$when\ t_c = 2s\ , R_4 = 10K\ , C1 = 0.1\mu F$, RV2 is then tuned to 13K.

$$t_d = 0.69 R_4 * C1. \tag{4.4}$$

Based on the design, it was required that the system switch on for 2 seconds and off for 2 seconds. Hence total time is 4s. therefore the frequency is given by

$$f = \frac{1.44}{(R_4 + RV2)C1} \approx \frac{1}{T} = \frac{1}{4} = 0.25Hz. \tag{4.5}$$

How the Pulse Generator works is that, the trigger pin (pin 2) is connected directly to C1. In the monostable circuit, the timer is triggered by a switch that short-circuited the voltage applied to pin2. In the astable circuit, the timer is triggered when the capacitor discharges once the voltage across the capacitor drops to 1/3 Vcc, pin 2 triggers the timer to start another cycle. The frequency can be altered by changing the resistor or capacitor values.

4.3.3 Charge Controller

The charge controller as explained earlier is made of LM317T, General purpose diodes, LM7805, Thyristor, LEDs, Resistors (100K, 18K, 4.7K), Potentiometer(100K), Transistors (BC538 K7K), 12 V Relay, NE555. Fig4.1.5 is the schematics of the Charge Controller

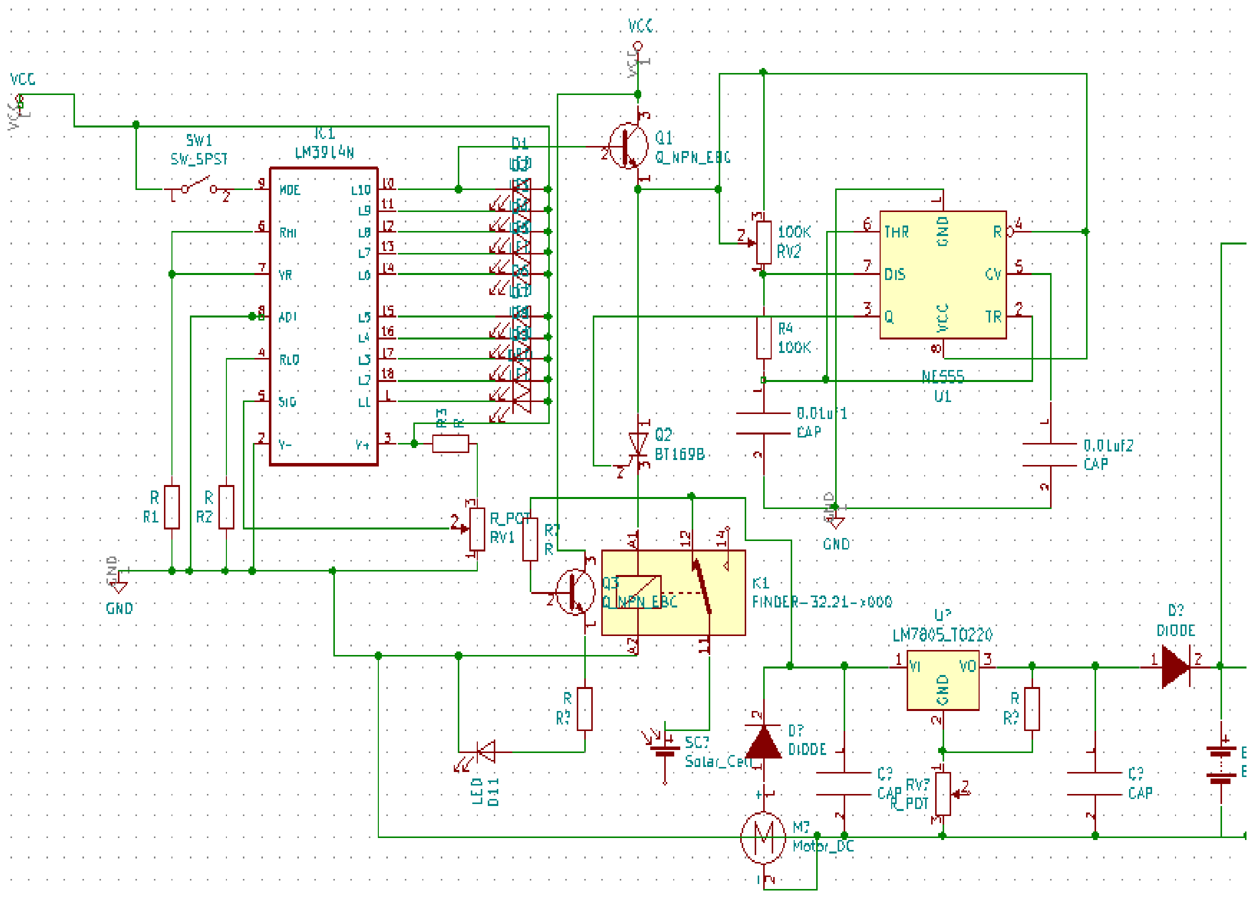


Fig.4.1.6: Automatic charge controller circuit diagram

The LM3914 is responsible for sensing the voltage level of the Battery. When the battery is below a certain threshold, the relay is energized and power flows from the solar panel to the battery thereby charging it. Further, the batter is full the LM3914 would again sense this and as a special LED is turned on, it concurrently triggers NE555. The NE555 therefore introduces a delay into the process. This is to prevent the battery from stopping charging immediately when it indicates full level. The pulse from NE555 is used to fire an SCR which in turns energizes the relay. The energizing of the relay cuts the power to flow to the battery. Also, the LM317T is regulates the voltage from the solar panel(20V) to 14V which is used to charge the battery.

4.3.4 Switch Control Circuit.

The Switch Control Circuit is made to control the switching of the different types of lights at different times. It is designed in such a way that when one switch is in operation, the others are disengaged even when pressed. It is made of three 12 V relays, three switches and six general purpose diodes. The relays do the switching whilst three of the diodes do protect the relays from reverse current. The remaining three also help to direct current in a desired path.

Fig.4.1.6 is the schematic diagram of the Switch Control circuit.

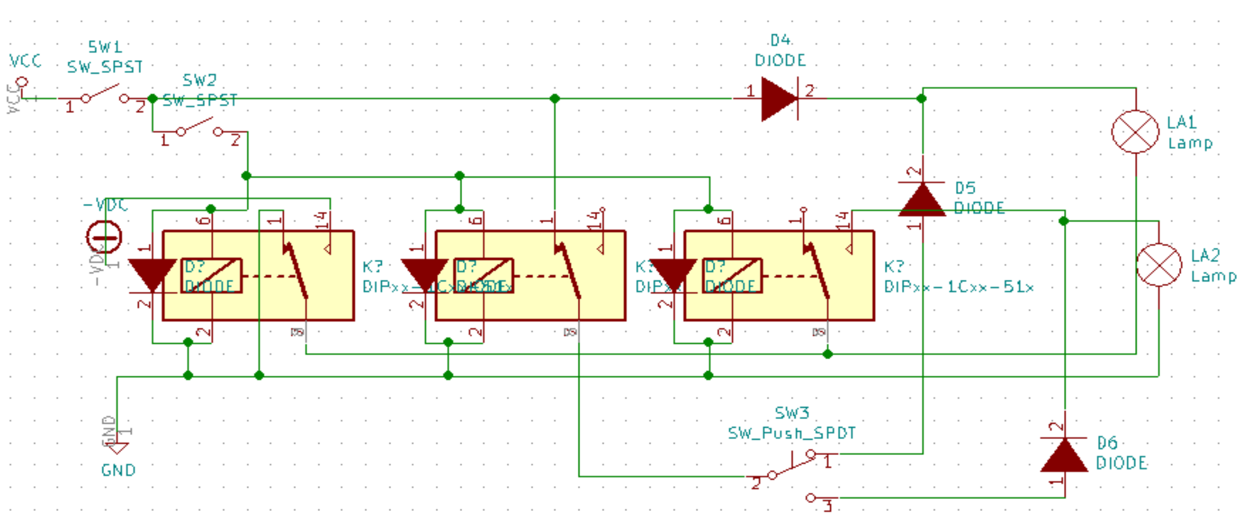


Fig. 4.1.7: Switch control circuit diagram

In Fig.4.1.6, sw1 is the main switch and so when it is closed, sw3 can turn either LA1 or LA2 on. However, when sw2 is switched on, the coil of relay 2 is energized which disengages sw3 completely from the main source. Hence no matter what is done to sw3, nothing happens. But at relay one, one energized, the ground pin is disengaged and get connected to the pulse from the pulse generator. At the same time, relay3 is also energized which reverses the connection at LA2. This enables both LA1 and LA2 to come on alternatively without having to press any switch.

4.3.4 Lamp Head

The lamp head is made of 3D printed model modeled from Solidworks, LEDs and a compact disc (CD). The LEDs are carefully and equally spaced on the surface of the CD. Opposite ones are 1inch apart whilst adjacent ones are 1.5inches apart. Holes were drilled into the CD and the LEDs were inserted into them. Cables were carefully passed and soldered to the appropriate LEDs. The Blue LEDs were connected in parallel likewise the White LEDs. Fig 4.1.6a and Fig4.1.6b are images displaying the back and front sides of the LEDs displaying on a CD.

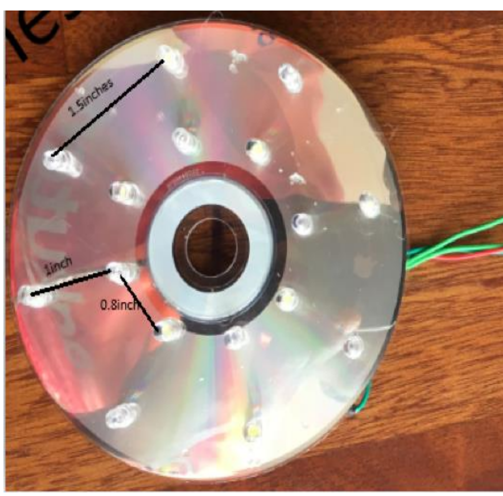


Fig.4.1.7a: Front view of Compact disk

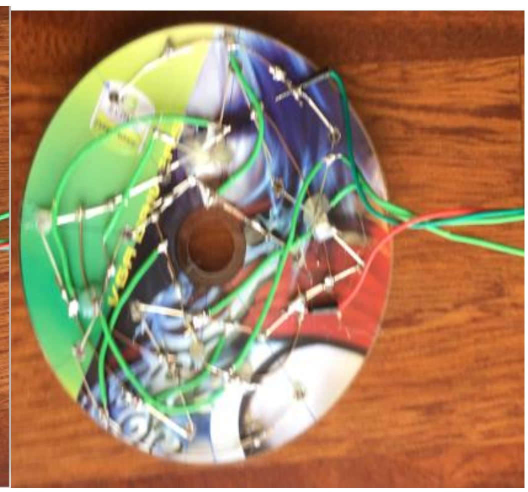


Fig4.1.7b: Back side of Compact disk

The 3D Torch Head Model was designed with Solidworks with the dimensions 4.8inches (for inner diameter) 5inches (outer diameter)

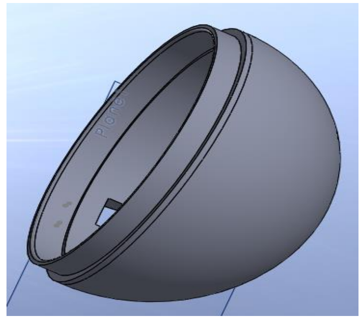
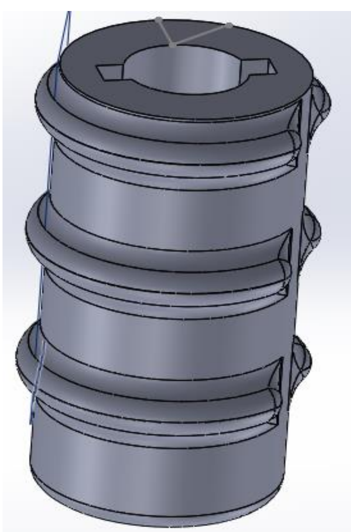
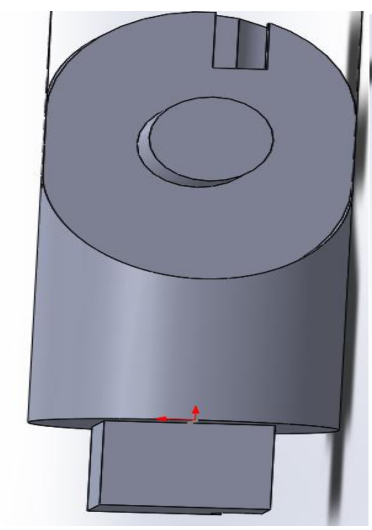


Fig4.1.8: Solidworks model of Torch head

The Torch Neck give support to the main head. It comprises of three different parts which come together to form a solid figure. On which the main head rest upon. Fig.4.1.8b and Fig.4.1.8c fit together in a way to allow up and down movements of the main head. When they sit on Fig .4.1.8a, the base part of it enables it to rotate of its axis. So, when they do support the main head, they enable it to move up, down, left and right.





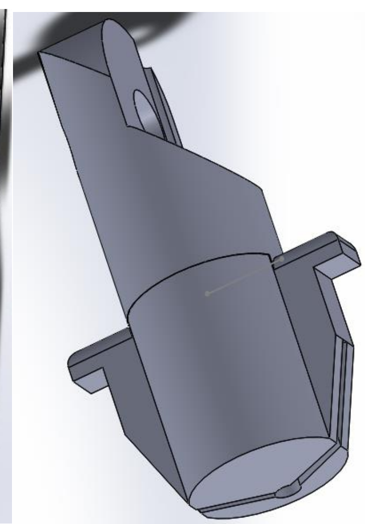


Fig .4.1.9a: Main neck

Fig.4.1.9b: Right-neck knob

Fig.4.1.9c: Left-neck knob

4.3.5 The 3D Base Support

The 3D Base Support provides a surface to hold the neck. It also serves as the main body as it contains circuitries for regulating the lighting effects of the LEDs and charging of cell phones. It is made of two dependent bodies which are joined to take care of that function. It also contains three switches, one for turning the charger on and the other two for either turning on white light or combination of white and blue. Fig.4.2.9a and show the two sets of components that form the base.

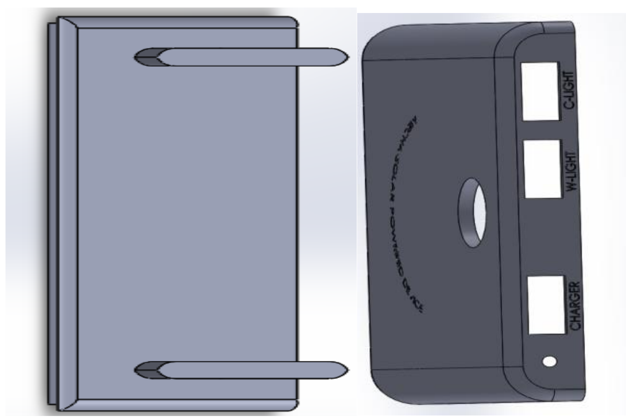


Fig.4.2.1: Solidworks model of Lower base support (left) and Upper base support (right)

4.3.6 The Gear Train

A Gear Train is basically a mechanical system formed by mounting gears on a frame, so the teeth of the gears engage each other. The gear teeth are usually designed to ensure that the pitch circles of engaging gears roll on each other without slipping. This provides a smooth transmission of rotation from one gear to the next. In this project seven gears were used to build the gear train. Each was modeled in Solidworks and printed out. It compromises of three kinds of gears of which the difference is based on the number of teeth and sized. The driven gear is fixed to another of 36 which forms a compound gear. Therefore, for each compound gear, the side with the 12 teeth serves as the driven gear whereas the side with 36 serves as the driver gear. To find the gear ratio, the teeth of the driven gear is found and that of the driver as well. Hence it is given as in the equation. (4.6)

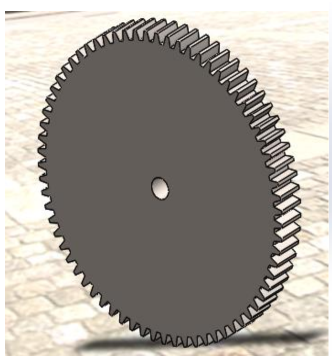
$$Gear\ Ratio = \frac{\text{teeth of driven gear}}{\text{teeth of driver gear}}. \tag{4.6}$$

$$therefore\ \frac{12}{70} \times \frac{12}{36} \times \frac{12}{36} \times \frac{12}{36} = 0.006349.$$

So, this is the speed reducing factor. However, an increase speed is rather desired. Hence the speed increasing factor is the inverse of the speed reducing factor.

That is $\frac{1}{0.006349} = 157.5$

Below are the individual gears that were put together to form the gear train. The first gear (driver gear) has 70 teeth and the driven gear (third gear) has 12 teeth. The second gear is also a driver gear with 36 teeth. All the gears have the same thickness 0.5inch to enable compatibility



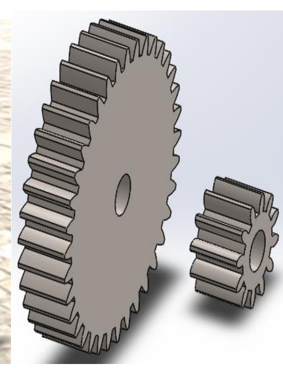
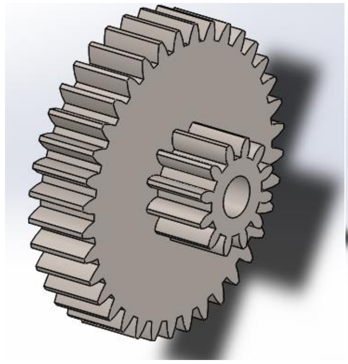


Fig.4.2.2a: Driver gear, 70teeth

Fig.4.2.2b: Driver (36 teeth) and driven (12 teeth) gears



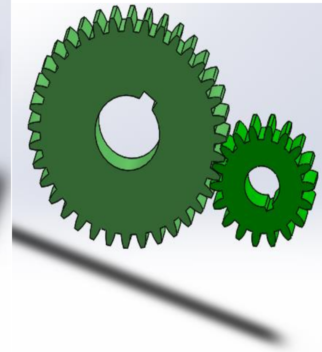


Fig.4.2.3a: Solidworks model of Compound gear   Fig.4.2.3b: Driver and driven gear

The gear train is made up of three compound gears, one 70teeth gear and one 12 teeth.

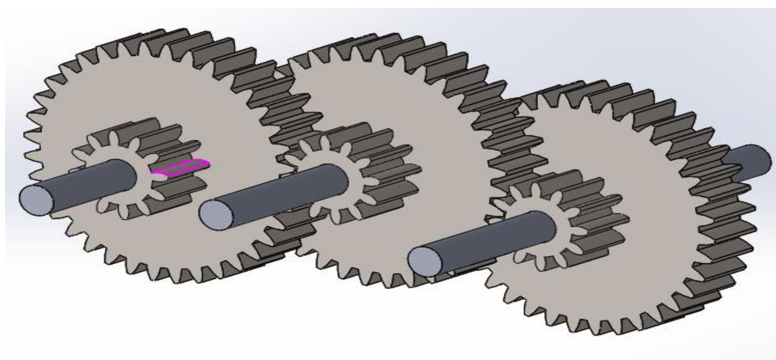


Fig .4.2.4: Solidworks model of the Gear train

For the gear train to have a less friction movements, the shafts connecting the gears were passed through bearings. Fig.4.2.4 is an image of the type of bearings used.

Fig.4.2.5: An angular contact bearing and its socket

After putting all the gears and bearings together, Fig.4.2.5 is an image of the Gear train formed

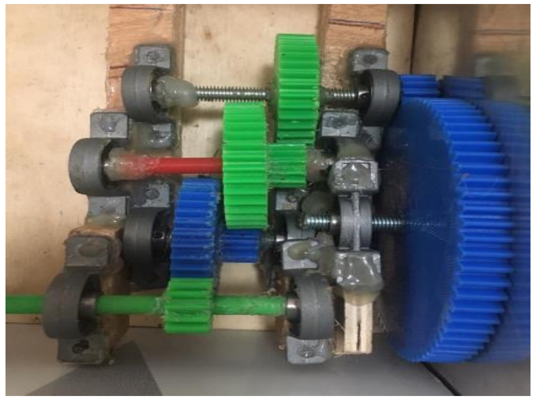


Fig.4.2.6: Gear Train

4.3.8 The Components Case

The Component case is designed to house the gear train, the battery, the DC motor and other circuitries. It has a wooden base, aluminum sides and an alucobond top. It has the dimensions of $9 \times 8 \times 6.5 inches$.

Fig 4.2.7: The Components case

4.3.9 Assemblage Product

The product is basically broken into three parts. The mechanical generation unit, the solar generating unit and the head lamp and charging unit.

The mechanical generation unit contains the gear train, the crank shaft, 12 V battery, 12V DC motor and 14 V regulation block. This is where the mechanical energy generated by cranking (with the aid of the gear train) is converted to electrical energy by the 12 V DC motor, then regulated by the 14 V regulation block and is then stored in the 12 V batter. Fig.4.2.5 is an image depicting the mechanical generation unit

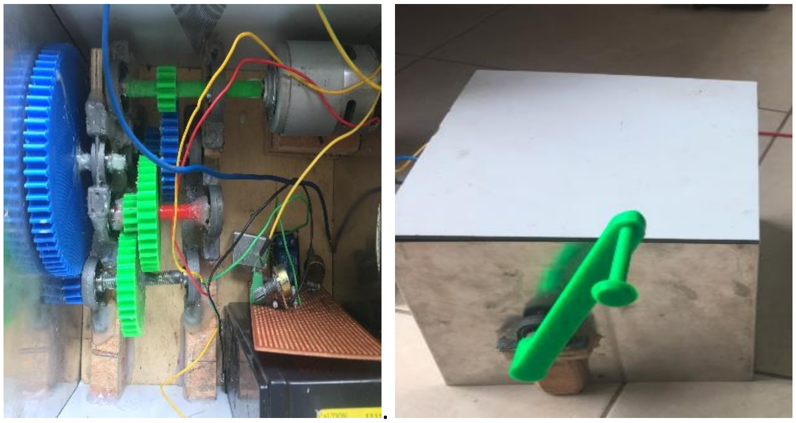


Fig.4.2.8: Internal(left) and external(right) view of the Mechanical generating unit

The Solar Generating Unit apparently is made up of only the solar panel and it however, works with some of the components in the Mechanical Generating Unit. It converts the solar energy into electrical energy which is regulated by the 14 V regulation block and then used to charge the 12 V battery. Fig. 4.2.9 is an image of the solar generation unit.

Fig.4.2.9: Solar Generating Unit

The Head Lamp and Charging Unit contains the LED lights, 5 V and 9 V regulation block, Relays switch control block. The 5 V regulation block regulates the 12 V from the battery to 5 V which is channeled via the USB port for mobile phone charging. The 9 V regulation block also regulates the 12 V from the battery to 9 V which is used to power the LED lights. Fig.4.3.1 depicts the Head Lamp and Charging Unit.

Fig.4.3.1: Front (right) and Back (left) view of the Head Lamp and Charging Unit.

After successfully manufacturing of each component, the individual components were brought together. Fig 4.3.2 is an image of the complete product.

Fig .4.3.2: A Complete Assemblage of Product.

4.4.1 Circuitry

This section contains images of all the circuits built on PCB for the projects. Fig.4.3.3 is a PCB circuit of the Switch control, 5 V and 9 V voltage regulator. Fig4.3.4 is a PCB of Voltage level indicator, charge controller and a 14 V voltage regulator.

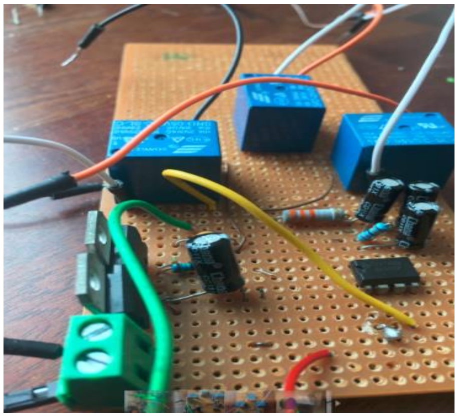


Fig.4.3.3: A PCB circuit of the Switch control, 5 V and 9 V voltage regulator.

Fig.4.3.4: A PCB of voltage level indicator, charge controller and a 14 V voltage regulator.

Chapter 5: Results and Analysis

5.1 Introduction

In this chapter, individual parts are put together to form the complete product. Various test relating to the product are done and the appropriate values are read to enable the specifications of the product.

5.2 Solar Panel Voltage Readings

The efficiency of a solar panel mostly depends on the maximum sunlight it receives. As such it became necessary to determine the maximum and minimum voltage the solar panel could deliver on a typical day. This will therefore inform how efficient the product would be. In order to find these voltages, the solar panel is put under the sun during the day and voltage readings are taken at a regular time interval (1 hour) with the help of a voltmeter. The duration of the experiment for each day was 5 hours. It started from 11am to 4pm

Table 5.1: contains data obtained from testing the Solar Panel

Days	Voltage (V) at t=0	Voltage (V) at t=1	Voltage (V) at t=2	Voltage (V) at t=3	Voltage (V) at t=4	Average Voltages
Day1	16.90	17.10	19.80	17.8	17.02	17.72
Day2	15.80	17.50	18.10	19.5	16.80	17.54
Day3	16.50	16.09	17.95	18.05	18.80	17.48
Day4	16.89	17.60	19.80	18.08	16.96	17.87
Day5	15.99	17.99	18.60	17.88	17.01	17.49

From Table 5.1, it can be seen the voltages of each day at a particular time differs from the other in an ununiform order. The average voltages are around 17.62. This therefore implies that on an average day, the voltage that the panel can produce is 17.62. Fig.5.2 a graph that plotted the average voltages versus days.

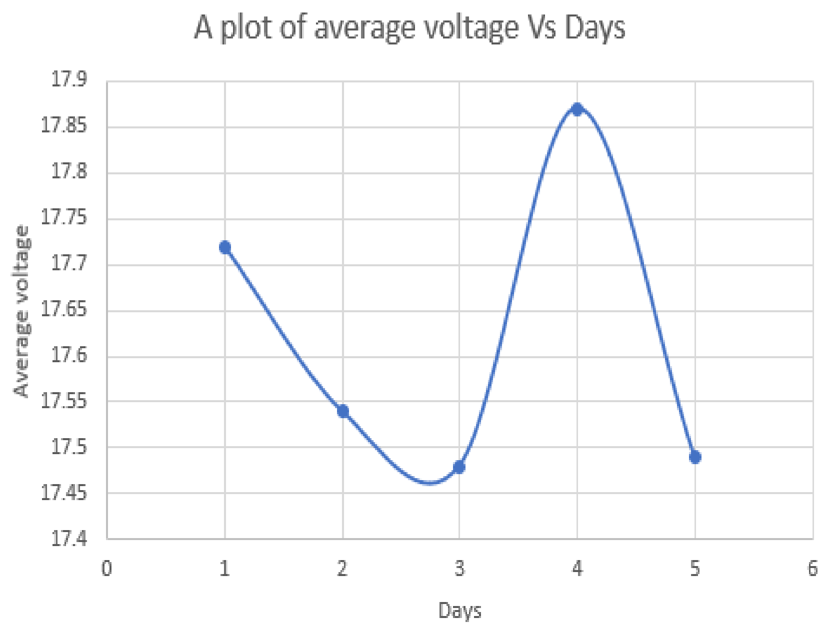


Fig.5.2: A graph of average Voltage Vs Days

5.3 Battery Life (Draining and Recharging)

The detection of the battery life is very important because it gave the sense of how long the battery can take to recharge and how long it will take to get drained when all the functionalities are turned on and when each is on.

5.3.1 Charging via Solar Panel

Charging via Solar occurs during the day time when the sun is in full operation. To term the rate of charging, the voltage level of the battery was tested at 20 minutes time interval. And it was observed that the total time it took to charge was 1hour 50minutes.

Table 5.2: A table of the values obtained from the experiment

Days	Voltage at t=1	Voltage at t=2	Voltage at t=3	Voltage at t=4	Voltage at t=5	Voltage at t=6	Voltage at t=7	Voltage at t=8
Day1	5.6	6.2	7.01	8.31	9.2	10.4	11.6	12.5
Day2	6.7	7.9	8.8	9.95	10.69	11. 9	12.8	
Day3	8.3	9.5	10.6	11.9	12.98			
Day4	9.2	10.90	11.89	12.99				

From Table 5.2, depending on the initial voltage level of the battery, the battery takes a certain length of time to charge.

5.3.2 Charging via Cranking

Charging via cranking is when the solar panel channel is being disenabled and the crank is cranked to recharge the battery. This done when the battery is low and yet no or too little solar energy is available to recharge it. Depending on how fast the crank is turned, a certain level of voltage is generated which in turns, charge the battery. However, due to the gear train inculcated in the system, one does not have to turn the crank at extremely high speed. Absolute consistency in turning does not also a matter that much, however it must be cranked in a way to generate a voltage that falls within a given range of voltages at which the output would be constant. To generate 24 V DC, the motor must be turned not less than 6000rpm. However, this has been made easier by the help of the gear train. The gear train enables one to crank 38 rpms ant it is amplified to 6000 rpm at the motor side. The following mathematical equations shows how the 38rpm cranking corresponds to 6000 rpm

Motor speed = 6000 rpm

Gear amplification factor = 157

$$\text{Therefore cranking speed} = \frac{\text{Motor speed}}{\text{Gear amplification factor}} = \frac{6000}{157} \approx 38\ rpm \qquad (5.1)$$

Table 5.3: Data obtained from applying different cranking speed

Force Applied(N)	**Cranking Speed(rpm)**	**Generated voltage(V)**	**Regulated voltage (V)**
4	40	26.2	14.41
4	38	23.4	14.40
4	34	21.3	14.40
4	30	20.4	14.40
4	28	18.78	14.40

5.3.3 Charging Dynamics

The charging dynamics talks about how the cranking speed is related to charging rate.

Table 5.4: Gives the breakdown of how the charging occurred at times when cranking.

Initial battery voltage(V)	**Cranking time (mins)**	**Cranking speed range (rpm)**	**Battery voltage level(V)**
5.6	5	30 to 40	7.3
5.6	10	30 to 40	8.8
5.6	15	30 to 40	10.9
6.3	5	30 to 40	7.9
6.3	10	30 to 40	9.1
6.3	15	30 to 40	11.3
4.2	5	30 to 40	5.7
4.2	10	30 to 40	7.2
4.2	15	30 to 40	9.3

5.3.3 Battery Draining Rate

The battery draining deals with how long the battery can survive when it is fully loaded partly loaded and quarterly loaded. The fully loaded here is when the two lights are on and there is a phone charging as well. Partly loaded is when two of the functionalities are in operation. Lastly when one of the functionalities are in operation then, it is said to be quarterly loaded.

Table 5.5: Shows how the voltage of the battery drops under different conditions

Functionality	**Duration (mins)**	**Initial voltage level**	**Final voltage**
Fully loaded	10	12	10.7
Fully loaded	20	12	9. 3
Fully loaded	30	12	7.8
Partly loaded	10	12	11
Partly loaded	20	12	10.8
Partly loaded	30	12	9.2
Quarterly loaded	10	12	11.6
Quarterly loaded	20	12	11
Quarterly loaded	30	12	10.2

5.3.4 Total Weight and Cost of the Device

The total weight of the system was determined by putting the entire device of the system on a balance. Total weight = 10.40 kg . Table 5.6 gives the cost and quantity of materials used. The prices of the materials were taken from Alibaba.com

Table 5.6: Cost and quantity of material used.

Material	Quantity	Cost ($)/piece	Cost($)
LED	16	0.025	0.4
Diodes	6	0.1	0.6
LM317T	1	0.35	0.35
LM7805	2	0.1	0.2
Resistor	9	0.02	0.18
Capacitor	4	0.2	0.8
Relays	4	0.17	0.17
NE555 IC	1	0.2	0.2
Bearings	10	0.2	2
DC motor	1	3.5	3.5
Solar Panel	1	8.5	8.5
12 V Battery	1	4.9	4.9
Potentiometer	2	0.058	0.116
Transistor	1	0.2	0.2
Terminal block	2	0.015	0.3
3D filament	1	7.5	7.5
Cables	3yards	1.5	4.5
Total			29.266

Table 5.6 shows that; the total cost of the product is $29.266. This amount though it is higher, but it is relatively lower as compared to other Lamps in the market which might not even have the features compared to this one.

Chapter 6: Conclusion and Recommendation

6.1 Introduction

Generally, the project has been very successful despite the difficulties and other unanticipated issues that came up. For instance, software simulations gave a perfect result but when the actual circuitries were built, they did not function as expected. A lot of adjustments were needed to be made to cater for these contingencies. However, with determination and perseverance there has been a head way. Everything worked together for a good purpose and at the end of the project, lessons have been learnt. The rest of this chapter is dedicated to discussing the limitations, lessons learnt and the future works of this project.

6.2 Limitations

The device works well. All the desired functionalities are working as designed. However, some of the functionalities do not function to expectation. For instance, the battery takes a quite a shorter time to run low. It is suspected that the strength of the battery is low since the system designed has no problem. Also because of the attempt to increase speed extremely at each crank, this has caused a significant increase in torque. The crank is very difficult to crank since more force is required to generate the required torque for the expected voltage. Further, the device is bulky which makes it difficult to handle. There are a lot of unwanted spaces within the casing of the system. These spaces make the whole system unreasonably big. Aesthetically, the device does not look that much appealing since it was designed and implemented as a protype. The qualities of the LEDs used are also very poor this affected the brightness level. Also, the cost of the product is not cheap as expected though it is relatively cheaper than others in the market. And lastly, the device made provision for charging only smart phones and it also takes on at a time.

6.3 Future Work

Having identified the limitations of this device, it will therefore be ideal when all those limitations are suggested as work to be considered in the future. But before, this product needs to be tested by the persona for the necessary feedback to be inculcated for the betterment of the device. The size needs to be worked in order to save materials and make it handleable as well. Lower voltage ratings with higher bright quality LEDs are recommended to be considered in future works. Further, larger size gears need to be considered in reducing the amount of force required to produce the torque required for the maximum voltage generation. The length of the cranking shaft is also an alternative in reducing the applied force whilst maintaining the same torque. Since the longer the shaft, the smaller the force.

6.4 Conclusion and Lessons Learnt

The project has come far with its own downs and ups which brought their own lessons as well. New Softwares such as KiCad and Multism were learnt. They are circuitry simulation tools which can equally develop PCBs. Further, solidworks skills have been enhanced. Through series of experimentations, data analyzing skills and experiments structuring have equally been improved.

In conclusion, the dual energy source lamp is a very simple, reliable and useful device designed purposely for people in the rural areas with low income level and are off grid. This device is to provide them lighting and charging abilities. The goal of this project was to save solar lamps users from being stranded in the event of the solar lamp running low when there is no sunshine to recharge. The mechanical feature therefore becomes very useful since the existing solar lamps, some does not last for the night depending how it is used. But with a Dual energy source lamp, one does not have to worry about usage, because once the battery goes off, it can be recharged at any point in time when the user is willing to mechanically crank it. It has been made very efficient and simply to use, and hence does not require any special skills to be operated.

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