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Using Human Kinetic Energy for Green Power Generation

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Abstract

The need for electricity is growing due to the rising population. The important way to address this issue is that human activity can contribute to the production of green energy through energy-based activities like the kinetic energy of humans. Walking is one activity that people can perform every day. In this project, we design a hands-on experiment that involves convert an unfamiliar from a mere pedestrian step does not need fuel input to produce electrical energy. This research uses CD-ROM was utilized to produce vertical motion (which represented compressive foot strike) and (3-6) volt DC generator. It was possible to convert the kinetic energy of a 750-gram particle into electrical energy (4 volts) and to convert the kinetic energy of a 780-gram particle into electrical energy (4.92 volts) and use this electrical energy to switch on a lamp (3volts). Also design an Automatic Traffic Light Controller 555 timer IC by using a LED to signify a light signal, which switches on by using a battery (9 V).

Key Words:

kinetic energy _ green energy _renewable source _ 555 timer IC _ light.

1. Introduction:

Historically, the metabolic energy utilized by plants and animals has been crucial in powering human societies. However, the recent shift towards fossil fuels has sparked environmental concerns, leading to a global push for clean energy alternatives. In today's world, the demand for energy is steadily increasing. It is becoming increasingly important to harness the wasted energy generated by individuals jogging or walking, particularly in densely populated countries. Energy harvesting systems that convert human motion into electrical energy have the potential for an indefinite lifespan when compared to traditional batteries. In certain low-power applications, motion harvesters could potentially charge or even replace chemical batteries. The exploration of harvesting energy from human body motion has gained momentum, highlighting the ability of human movements to generate kinetic energy. A method for repurposing the energy lost when a vehicle passes a speed breaker was demonstrated by (Barot *et al.*, 2017). Jerking typically produces a lot of energy, which may be quickly and effectively captured and transformed into electricity by utilizing a straightforward mechanism known as a roller mechanism (Notch type roller) (figure 1). The quantity of electricity produced is determined on the weight and number of vehicles that cross the speed breaker. Owing to the daily increase in the number of vehicles, this system can effectively meet the electricity needs of a small region and can be thought of as a little power plant for a single location.

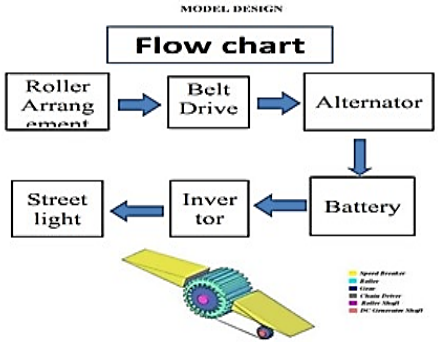
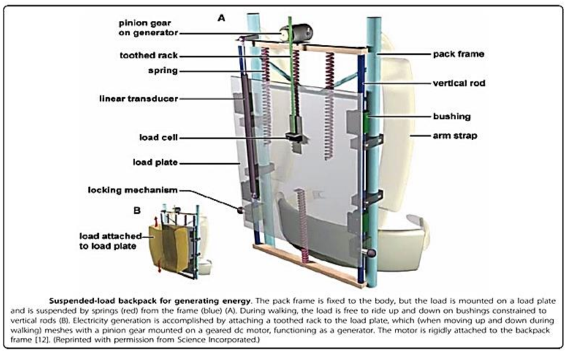


Figure (1). Design layout of the system Notch type roller.

The fundamental concepts behind the various human energy harvesting devices—such as piezoelectric, electromechanical, and friction-based processes—were delineated and utilized to categorize the devices now available in the market by (Lin *et al.*, 2023). Furthermore, a comprehensive analysis of key energy harvesting tactics has been conducted, including mode selection, efficiency enhancement, device miniaturization, and experiment assessment. It has also contrasted the distinctive features of several energy harvesting methods. They summarized the challenges these devices faced, which included integrating human biomechanics, achieving higher energy harvesting efficiency, facilitating micro-miniaturization, enabling composite designs, and exploring bigger applications. In addition, they laid the theoretical foundation and served as a roadmap for the future development of human motion energy collecting devices. The development of energy harvesting techniques in the 5G and IoT age was comprehensively reviewed by (Guo, X. *et al*, 2021), who included perspectives as well as specific operational principles, structural designs, and enhancement strategies. The quantity of energy recovered by the body and the degree of effort put out by the body during the walking motions examined by (Riemer & Shapiro, 2011). They found that during some walking motions, the muscles had to function as brakes, which releases energy into the environment. To overcome this, they created an energy–harvesting device (figure 2) that can act as a brake force during certain motion phases, enabling energy to be captured with little extra work. Based on published research findings and experimental data obtained from the gadget, they determined that energy harvesting can achieve up to 1 watt per kilogram of device weight. If someone was eighty kilograms in weight and moved at a speed of approximately 4 km/h, around 2 watts of power can be generated from the heel strike alone. Furthermore, for the device mounted on the joints that employs regenerative braking, the knees are identified as the most powerful generator of energy, producing about 34 watts, followed by the ankles contributing 20 watts.



Suspended-load backpack for generating energy. The pack frame is fixed to the body, but the load is mounted on a load plate and is suspended by springs (red) from the frame (blue) (A). During walking, the load is free to ride up and down on bushings constrained to vertical rods (B). Electricity generation is accomplished by attaching a toothed rack to the load plate, which (when moving up and down during walking) meshes with a pinion gear mounted on a geared dc motor, functioning as a generator. The motor is rigidly attached to the backpack frame [12]. (Reprinted with permission from Science Incorporated.)

Figure (2). Energy–harvesting device.

The most recent advancements in technology and materials used for efficiently harnessing mechanical human energy were focused by (Haq,2019). his goal was to drive implanted medical devices, providing a significant solution for energy harvesting in both *in–vitro* and *in–vivo* environments. He discussed various studies that detail a systematic approach to monitoring the health of the biological host using materials like Lead Zirconate Titanate (PZT) and its nano composites. For health monitoring applications, he used the Electro–Mechanical Impedance (EMI) technique with piezo patches, highlighting its sensitivity and advantages compared to current methods. His Researcher included a comparison of recent experimental and numerical studies utilizing finite element modelling systems with PZT patches bonded to specimens to simulate healing progress during or post–surgery. Additionally, he addressed challenges in implementing these technologies with these materials in medical sensors and harvesters, offering potential solutions. An itemized analysis of power generation capabilities is conducted, exploring various studies on smart nano composites and piezo. The discussion focused on their biocompatibility and lower modal frequency ranges compared to other devices, aiming to assist researchers worldwide in creating more efficient self–powered, flexible, ultra–thin implantable electronic devices in the field of biomedical sciences. A prototype wearable electronics system that included high–performance apparel with an integrated energy collecting technology to transform the mechanical energy of human movements into electrical energy are created by (Kukle, *et al*, 2023) . Within the parameters of the study, a system was created and incorporated into apparel that had been altered using sol-gel technology for both indoor and outdoor use. This system allowed for the determination of human physiological and/or environmental factors and the transmission of data. While the hydrothermal treatment method preserves the functionality of the energy harvesting system's generated flat inductive elements, other components of the smart clothing system—particularly the electro-conductive yarns—rapidly lose their electrical conductivity. To safeguard the embedded wearable electronics, the knitwear was adjusted to extend the interval between washing cycles. Additionally, the impact of surface modification with sol-gel on wearing comfort was evaluated figure (3,4).

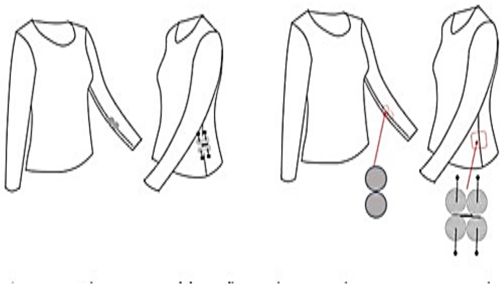


Figure (3). Placement of four flat inductive elements connected in sequence and magnets embedded in the sleeve of the shirt and moving relative to inductive elements when the wearer marches.

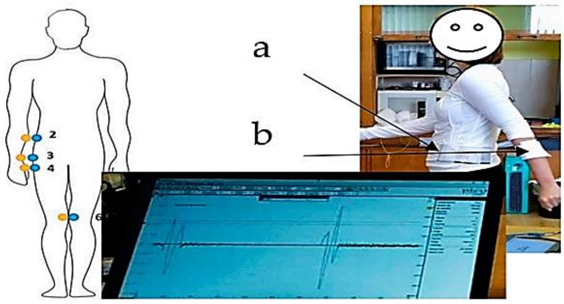


Figure (4). Selected locations of the electromagnetic energy converter components and testing. (a) Placement of flat inductors; (b) placement of permanent magnets. Chosen position of energy converter and its components and (3, 4, 6) other possible positions.

Innovative wearable energy harvester technology has been developed to utilize the movements of human joints for electricity generation, as demonstrated by (Li *et al*, 2018). This new technology involves placing two flexible harvesters on the knees and elbows to extract kinetic energy from the human body, as shown in (Figure 5). By partaking in regular low-frequency limb activities like walking, jogging, and running, this technology effectively and consistently produces electricity at around 4.0 V. The study introduces a unique wearable energy harvester that utilizes a piezoelectric cantilever to convert the body's low-frequency movements into high-frequency electrical energy. An electromagnetic energy harvester which size of an AA battery were designed to turn the motion of human limbs into electrical energy (Zhao *et al* ,2019). The designed 3D-printed tube completely covered in coils allows a permanent magnet that is cylindrical to move freely within it. The device's external measurements are 44 mm in height and 14 mm in diameter (figure 6). Leg swing action produced 4.2 mW of power at a typical walking frequency of 1 Hz. In the realm of human energy harvesting, the related power density of 0.62 mW cm^{-3} was very high. The aim of this research project is to use human movement energy to create electrical energy when crossing pedestrian bridges throw navigating bumpy surfaces. It is possible to use this electrical energy to illuminate traffic signals, roads, and pedestrian crossings.

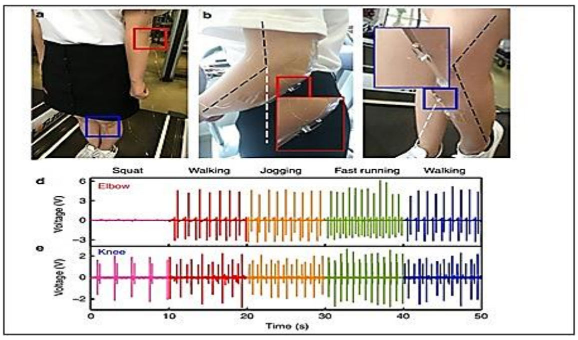


Figure (5). a Photograph showing a practical wearable application where two flexible harvesters are attached on a human elbow and knee. b, c Magnified views of the devices on the elbow and knee, respectively. d, e Test results for the voltage waves generated from the devices on the elbow and knee, respectively. The generated results are, sequentially, from joint bending (only for knee), walking, jogging, fast running, and walking again.

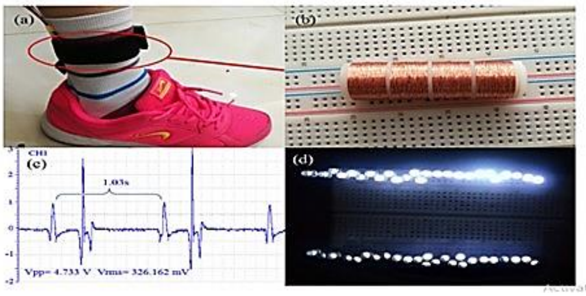


Figure (6). The human motion harvester fixed at the ankle (a) when walking normally at 1 Hz. (b) The harvester, (c) the voltage waveform and (d) 50 lighted commercial LEDs.

2. The Theoretical Framework

The theme of our graduation project is using human motion to create green energy. We design a hands-on experiment that involves convert an unfamiliar from a mere pedestrian step does not need fuel input to produce electrical energy.

Mechanical energy of the human body can be converted to electric energy through various methods that involve the generation of mechanical motion, which is then transformed into electricity. The first electrical generator that could supply industry with power was the dynamo. The dynamo transforms mechanical rotation into direct current by using electromagnetic principles. A dynamo is made from a stationary component that produces a steady magnetic field (Demirel, 2012).

A device that transforms mechanical energy into electrical energy is a DC generator.

whereas dc generator consists of:

Stator magnets: they are basically electromagnets with such an arrangement, so the adjacent poles have opposite polarity, they perform the function of producing the magnetic field.

Armature: it is a system of conductors or coil which is free to rotate on the supported bearings, the armature consists of various parts:

•Armature core: it is made up of high permeability thin silicon content steel laminations.

Additionally, the core's outside circumference contains spaces for armature windings.

•Armature windings: it is generally made up of copper wires and is wound over the armature core.

commutators: is cylindrical in shape and is made of copper, it performs two basic functions:

•One being, Collecting the current from the armature conductor.

•And another being, converting the alternating current of the armature into the unidirectional current in the external circuit with the help of brushes.

brushes: they are usually made of carbon or graphite, and the main function of brushes is to collect current from moving commutator.

shaft: is a rotating part of dc motor. We obtain the final output in the form of mechanical energy from the shaft (Settar, *et al*,2018).

The electrical energy from the generator is used to light a lamp (3)V.

The 555-timer integrated circuit (IC) is used to create the traffic light circuit.

In a circuit of traffic light: breadboard is a plastic board with holes that let you plug in and connect various electronic components.

555 timer IC: traffic light is designed with two timer ICs 555 and three LED indicators, this circuit drives three LEDs with different time delay to provide stop, wait, and go signals on road.

Capacitors: to even out supply voltage variations that could interfere with the timer's ability to function.

Resistors: are predominantly used to lower the flow of current, divide voltages, block transmission signals, and bias active elements.

wires: to connections.

Theory of working traffic lights by using 555 timer IC Figure (7).

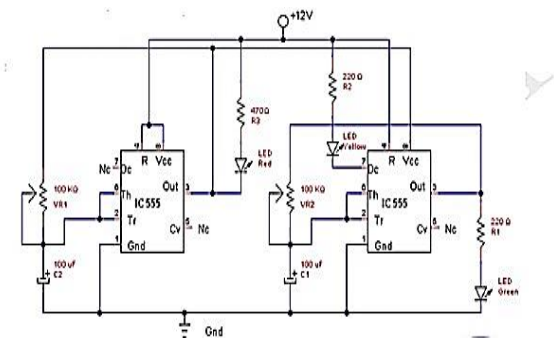


Figure (7) Circuit diagram for traffic light controller.

The red LED is wired so that it will only light on when the first 555 timer IC's output voltage is at zero volts. This occurs as a result of the red LED's other terminal being linked to a positive voltage. When the second 555 timer IC's output is at a positive voltage, the green LED lights on, and the yellow LED turns on when the second 555 IC is in discharge mode.

The output of the first 555 timer IC will be in the on state as soon as the circuit is powered on because the voltage at PIN-3, or the trigger pin, is less than one-third of the supply voltage. The green light turns on when the second 555 timer IC is activated, but the red LED is still off.

The output of the second 555 timer IC shuts off and the yellow LED illuminates due to the discharge pin being triggered. The capacitor of the IC slowly charges until it reaches a threshold value, which is equal to two thirds of the supply voltage.

Normally, the green and yellow LEDs would switch on simultaneously. However, the voltage across the capacitor of the first 555 timer IC reaches two thirds of the supply voltage before the capacitor of the second 555 timer IC does. As a result, the output of the first 555 timer IC switches off, turning off the yellow LED and turning on the red LED (Sandhya, Mahesh & Arunraj,2022).

3.Methods of Research and the tools used Tools:

CD-ROM (represented compressive foot strike).

DC Generator

Connecting wires

Electric lamp

Multimeter

Bread board

555 IC timer

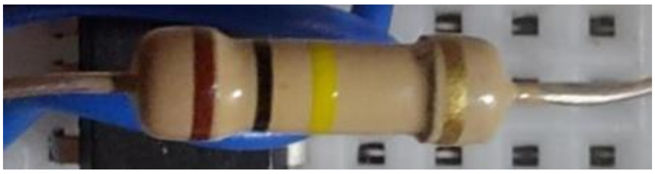
Capacitors (100 uf)

Resistors

330 ohm resistor

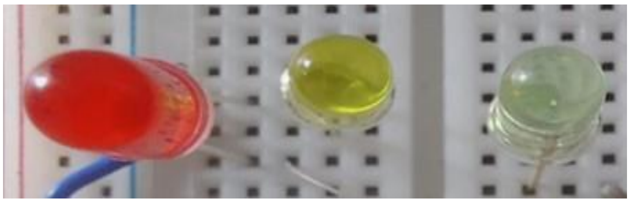
47 k resistor

100 k resistor



Connecting wires of traffic lights system

lamps of traffic lights



Battery (9)V

Methods:

To convert kinetic energy from human footsteps into electrical energy using a DC generator, we follow these steps:

-DC generator: A DC generator has ranging between (3 -6) Volts was used in this experiment. These generators typically have a rotating shaft that can convert mechanical energy into electrical energy.

-Footstep Mechanism: It create a footstep device that is triggered by a person walking on the ground. This mechanism is intended to provide linear motion, but in our tiny designer, the CD-ROM was utilized to produce vertical motion (which represented compressive foot strike)

-Mechanical Conversion: The rotating shaft of the DC generator Connected to a mechanism that converts the linear motion of footsteps into rotational motion such as gears.

- Connect the DC Generator: When a generator is exposed to rotation motion, it can convert mechanical energy into electrical energy through the phenomenon of electromagnetic induction by:

–Rotating Magnetic Field: The generator consists of a rotor (the rotating part) and a stator (the stationary part). The rotor is equipped with a set of magnets or electromagnets, while the stator contains a set of conductive coils or windings. As the rotor rotates, it creates a rotating magnetic field around the stator.

–Electromagnetic Induction: When the rotating magnetic field passes through the conductive coils of the station, it induces a changing magnetic flux in the coils, a changing magnetic field induces voltage in the coils.

–Generation of Electricity: The induced voltage in the stator coils drives an electric current to flow through them. This current represents the conversion of mechanical energy into electrical energy.

–Utilization of electrical energy: The electrical energy generated by the direct current generator can be used to operate the connected electrical load. For example, if you plug in a light bulb, it will light up when footsteps generate enough electrical energy. Electrical energy can also be stored in batteries used to power the traffic signal system.

Traffic lights system:

The turn on a traffic lights system was designed (figure 8) using a battery, breadboard, capacitor, 555 timer IC, and resistors, as the following these steps:

–Gather the Components: Collect the battery, breadboard, capacitor (100uF), 555 timer IC, resistors (330 ohms, 47k, 100k), and connecting wires.

Set up the Breadboard: Place the breadboard on a flat surface, then:

–place one 555 timer IC into your breadboard.

–connect the positive rail with pin8 of the IC using a connecting wire, and do the same with the negative but connect it to the negative rail to pin 1.

–connect pin 4 and 8 with a connecting wire of IC.

–connect pin 2 and 6 with a connecting wire of the IC.

–Take your 100–k resistor and connect pin 3 and 6of the IC.

–Connect 100uf capacitor to pin2 and the negative rail.

–Place other 555 timer onto the breadboard.

–Connect pin 3 of the first IC to pin 8 of the second IC with connecting wire.

–Connect pin 1 of the second IC to the negative rail (–) using connecting wire.

–Connect pin 2 and pin 6 of the second IC using connecting wire.

–Take 47 k resistor and connect pin 3 and pin 6 of the second IC.

–Connect pin 4 to the positive rail (+) using connecting wire.

–Connect positive lead of the 100 uf capacitor to pin 2 of the second IC and the negative rail (–).

–Place red LED into the breadboard link. And Place yellow LED in parallel with the red LED but the negative lead of the yellow LED in a separate pin.

–Connect the positive leads of the LEDS with the positive rail (+).

–Connect pin 3 of the first IC to the cathode of the red LED using connecting wire and a 330-ohm resistor.
–Connect pin 3 of the first IC with the connecting wire.
–Connect A 330-ohm resistor to the connecting wire and the negative lead of the red LED.
–Connect the negative lead of the yellow LED to pin 7 of the second IC using connecting wire and A 330-ohm resistor.
first: place connecting wire from the negative lead of the yellow LED .
second: connect 330-ohm resistor to the wire and pin 7).
–Place green LED, then Connect pin 3 of the second IC to the positive lead of the green LED using connecting wire.
–Connect the negative lead of the green LED to the negative rail (–) using A 330-ohm resistor.
–Finally, connect 9V battery with two wires: the black (negative) to (–) rail and the red (positive) to (+) rail.

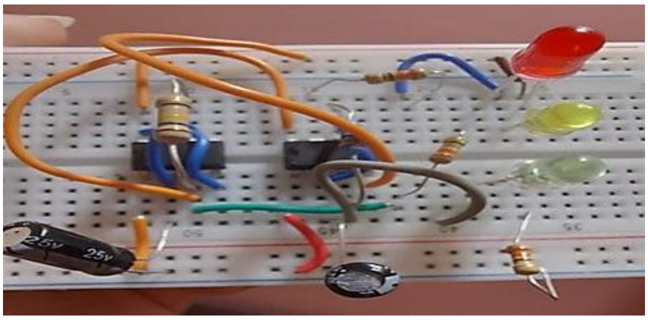


Figure (8) Traffic lights system

4. Results of Research

We use DC generator to generate electrical energy from the motion of human body (kinetic energy).(figure 9).

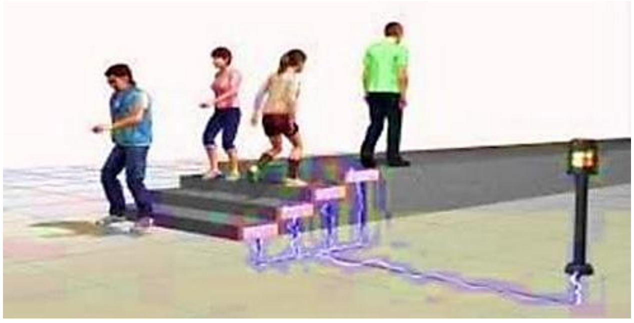


Figure (9) represents the idea of the project convert kinetic energy (human activity as walking) into electrical energy.

Generators use the principles of electromagnetic induction to transform mechanical and kinetic energy (from rotation) into electrical energy. We use DC generators to create electrical energy from the motion of the human body (kinetic energy). Generators are essential for the production and distribution of electricity because they can convert energy according to the laws of electromagnetic, namely Lenz's Law and Faraday's Law of Induction .

–Force:
To calculate the force exerted by a mass of 750 grams (0.75 kilograms) according to Newton's second law of motion, we will use the formula: $F = m \times g$ $F = 0.75$ kg x 9.8 m/s^2 $F = 7.35$ newtons.
Therefore, the force exerted by a mass of 750 grams (0.75 kilograms) due to gravity on earth is approximately 7.35 newtons.

To calculate the force exerted by an average human body (mass =77 kgm=77 kg) according to Newton's second law of motion, we can use the formula: F=m×a

where: F is the force (N), m is the mass of the object (kg) (slope) , a is the acceleration (in meters per second squared, m/s^2) Figure(10).

In this case, assuming we want to calculate the force required to accelerate the human body (or the force exerted due to gravity), we can use the acceleration due to gravity ($\approx 9.8 m/s^2$ $g \approx 9.8\ m/s^2$)

F=m×g substituting the values m & g

$F=77\ kg \times 9.8\ m/s^2$ F=754.6 newtons

Therefore, the force exerted by the weight of an average human body (mass 77 kg) due to gravity is approximately 754.6 newtons.

This calculation represents the gravitational force acting on the body, which is equivalent to the body's weight. Note that this force is the force due to gravity (weight) and not the force exerted by muscles for movement or other activities, which would depend on various factors including muscle contraction and biomechanics (Liu,2019).

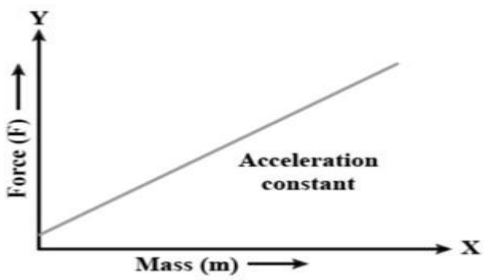


Figure (10): The relationship between Force and mass.

Measuring electromagnetic induction from generators involves detecting and quantifying the electrical output generated by the generator due to the changing magnetic fields and motion of conductive components. Here are the steps and methods typically used to measure electromagnetic induction from generators.

The force required to make the generator work (i.e., to rotate the rotor) is not directly determined by the voltage output (V) measured from the generator. Instead, the force required to rotate the rotor and generate electricity depends on the mechanical power input required to overcome resistance (including friction and magnetic forces) within the generator.

– Voltage (Electrical) and Power:

Definition: Voltage (V) is the electrical potential difference or electromotive force (emf) that drives the flow of electrical current.

Mathematical Relationship: Power (P) in an electrical circuit can be calculated using. voltage (V) and current (I): P=V×I where:

P is power (in watts, W), V is voltage (in volts, V), I is current (in amperes, A)(figure11).

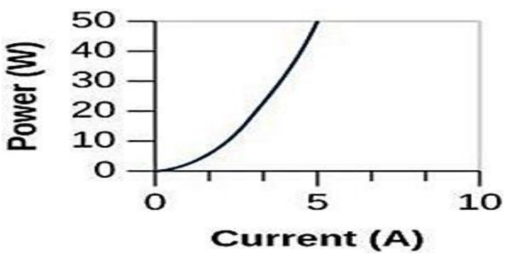


Figure (11) the relationship between electrical current and power.

–DC generator

Faraday's laws of electromagnetic induction. EMF Equation of a DC Generator. The EMF equation for DC generator is expressed as:

E= (PØNZ)/60A

E _Generated EMF across any parallel path

P – Total number of poles in the field.

N – Rotational speed of armature (rpm).

Z – Total number of armature conductors in field.

Ø– Magnetic flux produced per pole.

A – number of parallel paths in the armature.

Working Principle of a DC Generator. A DC generator operates on the principle of Faraday's laws of electromagnetic induction. According to Faraday's law when a conductor is moved in a magnetic field) an EMF is induced in the conductor.

If conductor is guided with a closed path, the current will get induced.

The direction of the induced current changes as the direction of movement of the conductor changes. The voltage difference across a resistor (figure 12)

V=IR where I= current

R= resistance V= voltage difference

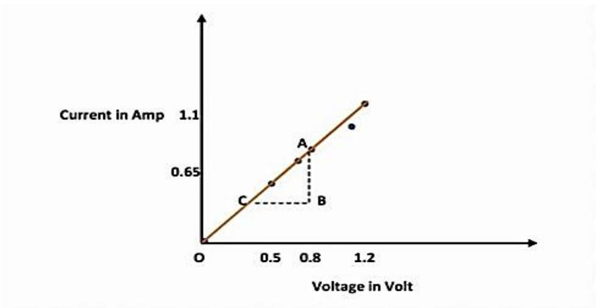


Figure (12): The relationship between the voltage and the electrical current.

–Then we use Fleming right hand rule.

to determine the direction of current in the coil in the DC generator as the following Figure (13).

Figure (13) Fleming's right–hand rule.

Then we use Lenz rule to determine the direction of emf that opposes the direction of magnetic flux figure (14).

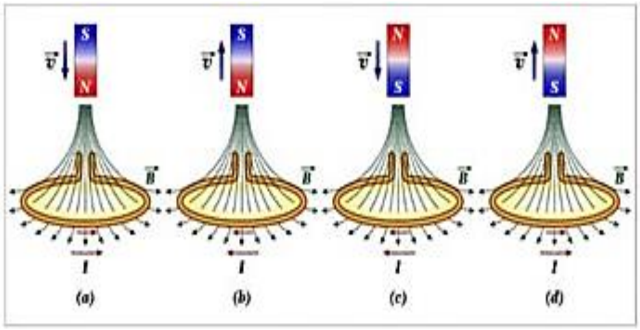


Figure (14): Lenz rule.

– Duration of LED's lighting in traffic light circuit (Sandhya, Mahesh & Arunraj,2022).

T= 0.7 RC

T: – time in seconds

R: – resistance in ohm

C: – capacitance in sec /ohm

T= 0.7(330) × (100×10^{-6}) = 0.023sec.

5.interpretation of Results

The scientific idea of our project is achieved through the movement of individuals on artificial bumps on the roads and pedestrian bridges, and these roads are equipped with artificial bumps within the circuits designed to transform the human kinetic energy into electrical energy.

This scientific idea was realized in this project that uses a basic drive mechanism (a CD-ROM), reverses its operation, and converts it to a DC generator. It is then connected to a led. When the CD moves, the kinetic energy of each step results in force, which causes the moving part to descend and cuts the magnetic field in the generator, causing an induced electromagnetic field emf.

The forces that generate kinetic energy were represented by a 750-gram body, and the voltage that was produced was 4 volts. The forces that generate kinetic energy rise as the particle weight does. With 780 grams in the body, the voltage is 4.92 volts.

As represented in Figure (15,16).

Note: We can utilize a DC generator (9 V) if one is available to charge the battery used in the traffic light system. We are unable to charge a battery at 9 volts since the generator type employed in this study to convert mechanical energy to electrical energy is only capable of producing (3-6) volts.

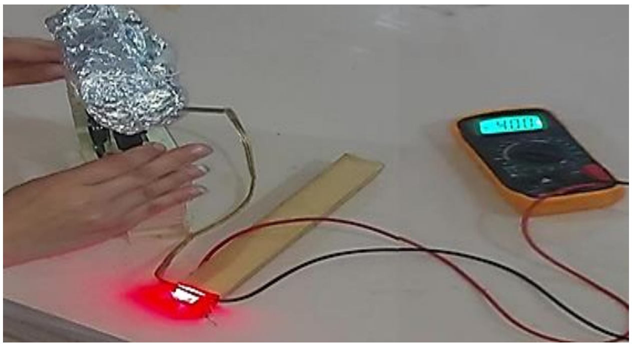


Figure 15: reading of voltameter of 750 gram.

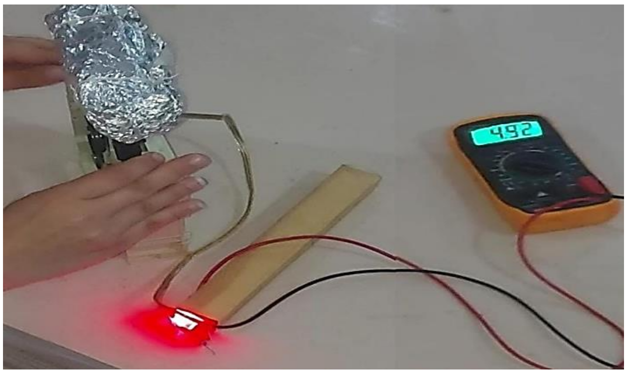


Figure 16: reading of voltameter of 780 gram.

6. Conclusion

The practical implementation of the graduation project yielded results in converting human kinetic energy into electrical energy. A model was created to apply Newton's and Faraday's laws to the concept. Utilizing a 3-6-volt DC generator, the output registered at 4 volts with a 750-gram weight and 4.92 volts with a 780-gram weight. The model, designed to validate the scientific hypothesis, successfully powered a 3-volt LED bulb. Additionally, a design was proposed for a self-sufficient traffic lights system powered by a 9-volt battery. It is hoped that relevant authorities will implement this project in high-traffic public areas, such as roads, pedestrian bridges, official organizations .... etc. Where artificial speed bumps equipped with closed circuits can transform the energy of human footsteps into renewable electricity.

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References and Sources

Barot, V., Kadia, A., Rabari, C., Patel, A., Patel, J., & Viranchi, M. (2017). Power

Generation Using Kinetic Energy of Vehicles. Research gate. https://doi.org/DOI:10.21884/IJMTER.2017.4117.U2BB9

Demirel, Y. D. (2012). Energy Conversation (pp. 229-303). ResearchGate https://doi.org/DOI:10.1007/978-1-4471-2372-9_7

Guo, X., Liu, L., Zhang, Z., Gao, S., He, T., Shi, Q., & Lee, C. (2021). Technology Evolution from Micro-scale Energy Harvesters to Nanogenerators. Journal of Micromechanics and Microengineering. https://doi.org/DOI 10.1088/1361-6439/ac168e

Haq, M. (2019). Application of Piezo Transducers in Biomedical Science for Health Monitoring and Energy Harvesting Problems. Mater. Res. Express, 9. https://doi.org/DOI 10.1088/2053-1591/aaefb8

Kukle , S., Blums, J., Kataševs, A., Bak, I., ans, V. J., evs, I. G., Ecka, G. T., Zelca , Z., & Okss, A. (2023). Development of an Energy Harvesting System for the Conversion of Mechanical Energy of Human Movement into Electrical Energy and Its Integration into High Performance Wearable Clothing. Processes. https://doi.org/10.3390/pr11113056

Li, K., He, Q., Wang, J., Zhou, Z., & Li, X. (2018). Wearable Energy Harvesters Generating Electricity from Low-Frequency Human Limb Movement. Microsystems & Nanoengineering. https://doi.org/DOI 10.1038/s41378-018-0024-3

Lin, W., Wei, Y., Wang, X., & Zhai, K. (2023). Study on Human Motion Energy Harvesting Devices: A Review. Machines, 11. https://doi.org/10.3390/machines11100977

Liu, X. (2019). Revisiting Newton's Second Law of Motion. ResearchGate July 30, Tuesday, 2019. https://doi.org/DOI:10.13140/RG.2.2.25238.91204

Riemer, R., & Amir Shapiro, A. (2011). Biomechanical Energy Harvesting from Human Motion: Theory, State of The Art, Design Guidelines, and Future Directions. Journal of Neuro Engineering And Rehabilitation.http://www.jneuroengrehab.com/content/8/1/2

Sandhya, K., Mahesh, B. V.& Arunraj, M. (2022). Automatic Traffic Light Controller. IJISET - International Journal of Innovative Science, Engineering & Technology, 9, 132–136.

Settar, S., Khalid, G., & Mayyada, S. (2018). Analysis Study in Principles of Operation of DC Machine. Journal of Advanced Research in Dynamical and Control Systems., 10, 2323–2329. https://www.researchgate.net/publication/329280723

Zhao, X., Cai, J., Guo, Y., Li, C., Wang, J., & Zheng, H. (2018). Modeling and Experimental Investigation of an AA-Sized Electromagnetic Generator for Harvesting Energy from Human Motion. Smart Materials and Structures. https://doi.org/10.1088/1361-665X/aacdc4