Power Generation Through Simulated Ocean Waves

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Abstract

This quantitative research study explores the practicality of converting ocean wave energy into electrical energy. An experimental analysis of a buoy’s motion was conducted to determine the dependence of the buoy’s motion to wavelength, wave speed, amplitude, and period. An acrylic tank measuring 12 x 13 x 48 inches was used to simulate Connecticut shoreline wave parameters. A motor was used to oscillate a flat plate through the tank’s water to produce waves, converting the motor’s rotatory motion into linear motion. A 0.26 kg spherical buoy of radius 1.80 inches was placed in the tank to determine its buoyant force under varying wave parameters. After observing the oscillatory motion of the buoy, data was gathered on the buoyant force. In addition, a sine function was extrapolated to fit the data, resulting in regressions (R^2) of at least 0.93. Furthermore, these findings were used to explore designs for generating electricity by utilizing the buoyant force to drive magnets through a copper coil, capitalizing on Faraday’s law. This research opens the door for a better understanding of generating renewable and environmentally friendly energy.

Methods

Flat Plate wave generators are used to produce deep water waves where the orbital particle motion decays with depth and there is negligible motion at the bottom.

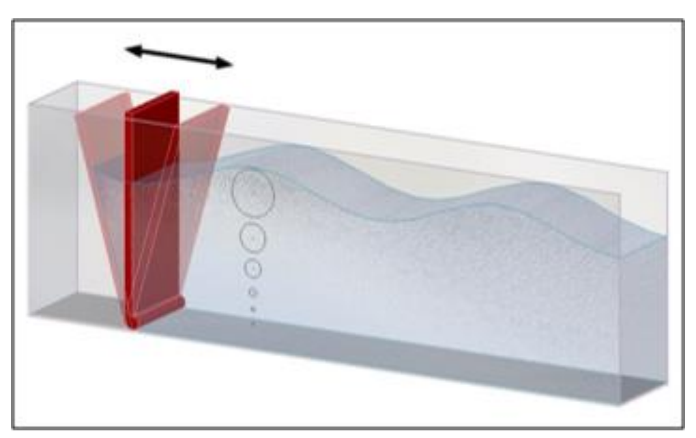


Figure 1: Flat plate wave generators to generated deep water waves [4]

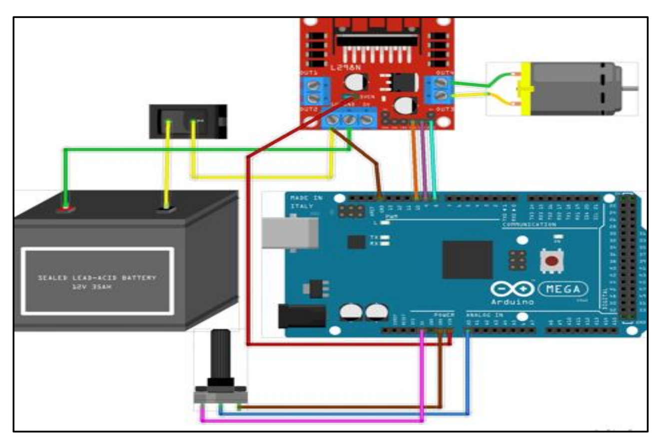
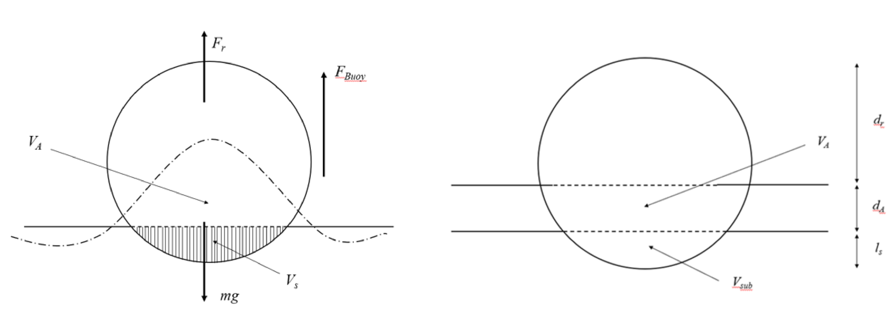


Figure 2: Flat plate wave generators to generated deep water waves [7]

The motor circuitry breadboard controlled the motor to drive the flat plate through the acrylic tank, creating waves, composed of the following: L298N board, 12 volts DC motor, DC 12 volts lead-acid battery, Arduino MEGA 2560 Rev3, and a potentiometer.

A spherical buoy was incorporated in the system to understand the buoyant force created by the waves.



$$\sum F = \mathrm{ma}$$

$$\cancel{-mg + F_r} + F_{Buoy} = ma_B$$

$$F_{Buoy} = m\frac{d^2 A_{Buoy}}{dt^2}$$

By solving the differential equation, the amplitude $A_{Buoy(t)}$ relative to time could be solved for.

Final Design

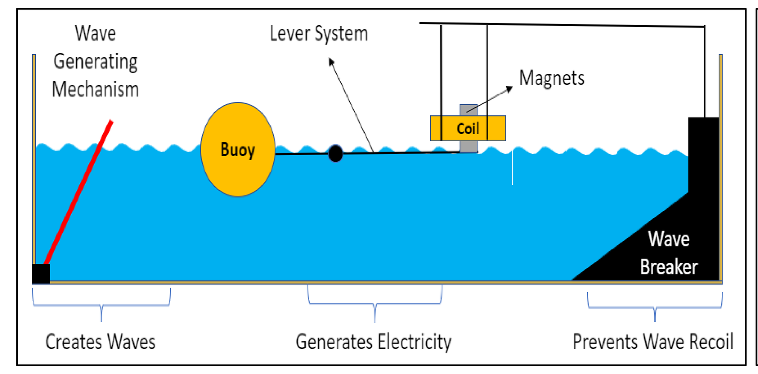


Figure 3: System design overview: (1) Wave Generating Mechanism (2) Lever System (3) Wave Breaker.

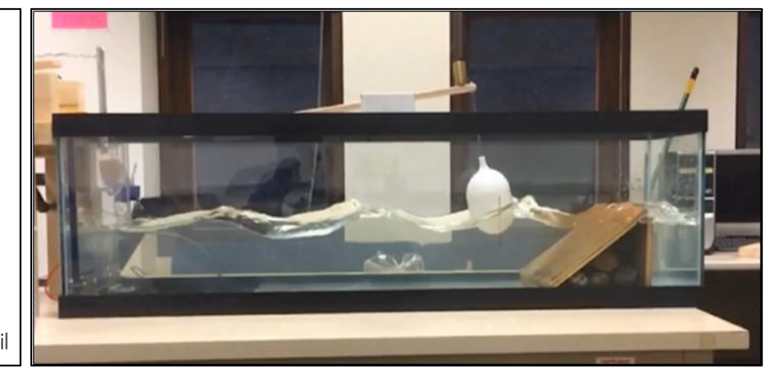
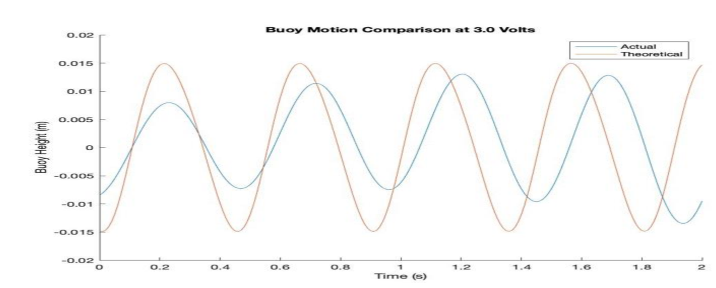


Figure 4: Actual experimental apparatus used to analyze the motion of a buoy

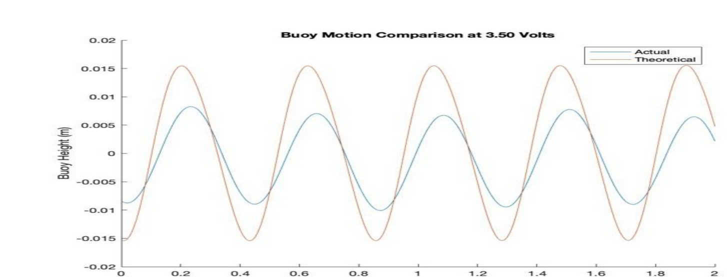
The final design is composed of two components: The wave generation mechanism and the design for the power generation mechanism. A complete model for the wave generation mechanism was constructed and designed an apparatus to output a voltage from the wave generation mechanism. The entire system operates by using a motor to oscillate a flat plate (far left) at different speeds. This speed is controlled through pulse width modulation (PWM) from an Arduino board and a potentiometer. As the waves interact with the buoy, a buoyant force is produced by the waves, oscillating the buoy vertically. This force drives the lever mechanism, with the buoy (left) and propelling magnets through copper coils (right). As the generated waves reach the far end of the tank, the waves break on the wave breaker.

Results

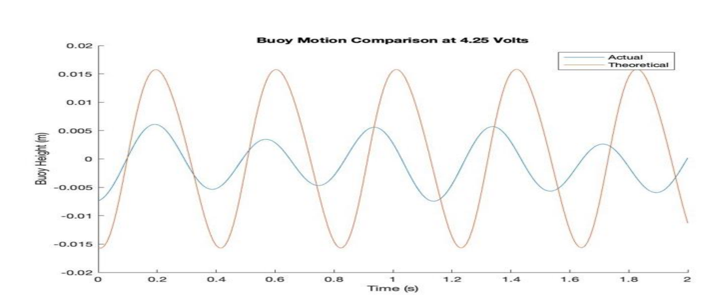
From the results in the three graphs it can be deduced that the theoretical approximation overestimated the buoy’s amplitude response to the waves. This overestimation occurrence is due to the assumptions 1-3 as previously defined. Another aspect that is apparent is the experimental curves deviate farther from the theoretical approximation of the buoy’s motion as voltage is increased to operate the motor. This is linked to the fact that as the voltage increased, it became challenging to use Tracker to record the buoy changes in height relative to time because the visual representation of the buoy’s motion on the software became difficult to analyze.



Graph 1: Buoy Actual & Theoretical Height vs Time comparison at 3.0 Volts from the potentiometer



Graph 2: Buoy Actual & Theoretical Height vs Time comparison at 3.5 Volts from the potentiometer



Graph 3: Buoy Actual & Theoretical Height vs Time comparison at 4.25 Volts from the potentiometer

Discussions & Conclusion

From using the periods (Δt) from the experimental results of the buoy’s oscillatory motion, (neglecting resistances due to motion) the generated voltage can be predicted using the parameters: following

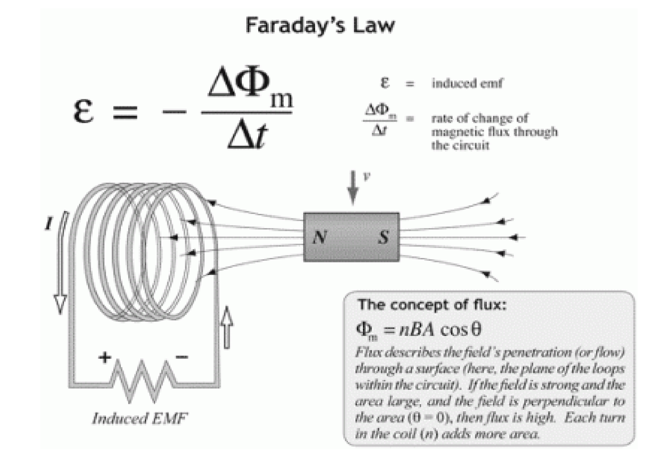


Figure 5: Faraday’s Law with concept of flux. [8]

$$V_{Gen,Act,Max} = -\mathbf{N} * \frac{\Delta(\mathbf{B}*\mathbf{A})}{\Delta t}$$

N = 100 turns (Arbitrary selection)

B = 7.4 Telsa (5x) Neodymium Magnetic field)

A =1.2E-3 m^2 (Area of coil corresponding to magnets diameter)

t = buoy’s period

- $V_{3\,V,\,Max} = 2.0\ \mathrm{V}$
- $V_{3.5\,V,\,Max} = 2.1\mathrm{V}$
- $V_{4.25\,V,\,Max} = 2.2\ \mathrm{V}$

It is imperative to understand that the theoretical voltage generated is solely a prediction for the maximum amount of voltage capable of being produced with the given parameters according to FDL. Neglecting resistance due to magnetic forces from electromagnetic induction with copper coils and magnets, the weight of the power generation mechanism, and resistances due to motion, the prediction overestimates the generated voltage. The instant these resistances are considered the time (Δt) will increase, instantaneously decreasing the voltage generated. For power generation to be considered, the next steps for this experiment would be to assign a load to our system and improve the amount of power generated.

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