

Research Article

The Mechanical Properties of Waves and Their Application

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Abstract

This study explores the captivating world of waves, focusing on their fundamental properties and diverse applications. At its core, a wave is a disturbance that propagates through a medium, transferring energy without permanently displacing the medium's particles. These disturbances can manifest in various forms, including changes in shape, pressure, the strength of electric or magnetic fields, electric potential, or even temperature. The magnitude of a wave is determined by its amplitude, with smaller amplitudes indicating smaller waves and larger amplitudes signifying more substantial ones. The wave's frequency, or the rate at which it oscillates, dictates its temporal behavior; lower frequencies correspond to slower wave motion. Notably, there is an inverse relationship between frequency and wavelength: as frequency increases, wavelength decreases proportionally. A common example of wave behavior is the visible light portion of the electromagnetic spectrum, where energy is carried in discrete packets called photons. Irrespective of type, waves invariably act as channels for energy transmission. Importantly, waves do not transport the medium itself; rather, they propagate through it, causing localized vibrations or oscillations as they serve as conduits for energy, rather than bulk movement of matter. In essence, a wave is initiated by a disturbance at its source, generating a pattern of oscillations that radiate outward, creating the impression of a traveling wave. By understanding these fundamental principles, we can unlock the potential of wave phenomena across a wide range of scientific and technological disciplines.

Keywords

Spectrum, Electromagnetic Radiation, Photon, and Elastic Deformation

1. Introduction

Waves, ubiquitous in nature and technology, are disturbances that propagate through a medium or space, transferring energy without net movement of the medium itself. Understanding their mechanical properties is crucial for numerous applications across diverse fields. This introduction explores key aspects of these properties and their practical significance. Properties of waves there are many properties that scientists use to describe waves they include amplitude, frequency, period, wavelength, speed, and phase each of these properties is described in more detail below.

1.1. Background of the Mechanical Wave

The study of mechanical waves has a rich history intertwined with the development of physics and engineering. A comprehensive background requires tracing its evolution through several key periods: Ancient Observations and Early Understanding (Pre-17th Century), Sound: Humans have long observed and utilized sound waves, although a scientific understanding was lacking. Musical instruments and the observation of echoes demonstrate an intuitive grasp of sound's properties, even without formal theories. Water Waves: The behavior of water waves, crucial for navigation and understanding coastal phe-

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nomena, was observed and empirically understood to some extent. However, a mathematical description was absent. Earthquakes: The destructive power of earthquakes was recognized in ancient civilizations, but the underlying physical mechanisms remained a mystery. The Scientific Revolution and the Birth of Wave Theory (17th-18th Centuries): Galileo (1564-1642): Made significant contributions to understanding the relationship between frequency and pitch in sound. He also conducted experiments on the speed of sound. Isaac Newton (1643-1727): His **Principia Mathematicae** laid the groundwork for classical mechanics, providing the mathematical framework for describing wave motion. He developed a theory of sound propagation, although it was not entirely accurate. Christian Huygens (1629-1695): Developed the Huygens-Fresnel principle, a crucial concept for understanding wave propagation and diffraction. This principle describes how every point on a wave front can be considered a source of secondary spherical wavelets. Development of Acoustics: The 18th century saw the beginnings of systematic studies of acoustics, including investigations into the properties of sound waves, musical instruments, and room acoustics.

The 19th Century: Consolidation and Expansion: Augustine-Jean Fresnel (1788-1827): Further developed the Huygens principle, providing a more complete explanation of diffraction. His work was crucial for understanding the wave nature of light. Joseph Fourier (1768-1830): Developed Fourier analysis, a mathematical technique for decomposing complex waveforms into simpler sinusoidal components. This is fundamental to understanding the harmonic content of waves. Lord Rayleigh (1842-1919): His monumental work, **The Theory of Sound**, provided a comprehensive and rigorous mathematical treatment of sound wave propagation and related phenomena. Understanding of Seismic Waves: The 19th century saw increasing efforts to understand earthquakes and the nature of seismic waves. Early seismographs were developed, allowing for the observation and analysis of these waves. 20th and 21st Centuries: Advanced Techniques and Applications: Development of advanced instrumentation: Sophisticated instruments for generating, detecting, and analyzing mechanical waves were developed, enabling precise measurements and detailed studies.

A disturbance that moves away from its source and spreads is called a wave. Although waves can move mass from one location to another, they can also move energy. Common examples of waves are light, sound, and ocean waves. Being mechanical waves, sound and water waves need a medium to pass through. The wave's speed is determined by the material characteristics of the medium it is traveling through, which can be a solid, liquid, or gas. But light isn't a mechanical wave; it can go across vacuums, like those seen in empty space. The water wave is a well-known wave that is simple to visualize. A boulder thrown into a pond or a swimmer continuously splashing the water's top are two examples of disturbances that occur in the water surface that cause waves. A disturbance in sound waves is brought about by a shift in air pressure; an instance of this is when the oscillat-

ing cone within a speaker produces noise. There exist other forms of disturbances associated with earthquakes, such as the disruption of the Earth's surface and pressure disturbances beneath the surface Alaji (2020). The easiest way to understand even radio waves is to compare them to water waves. Visualizing water waves can be helpful while studying other forms of waves, especially those that are not visible, because they are common and visible. Amplitude, period, frequency, and energy are properties of all waves, and we will talk about these in the next section. These are also characteristics of water waves.

Low Amplitude High Amplitude Low Frequency High Wavelength Low Wavelength High Frequency Note: As frequency goes up, wavelength goes down, electromagnetic Waves: Visible light is one example of electromagnetic radiation. Electromagnetic radiation is energy that travels via particles called photons. Different photons are associated with different wavelengths. In order of decreasing wavelengths, they are called radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays. Photons with shorter wavelengths carry more energy than do photons with longer wavelengths. Gamma rays are the highest energy photons, while radio waves are the lowest energy photons. Waves travel through materials as vibrations and transmit energy. All waves transmit energy, not matter, although nearly all waves travel through matter. Waves are created when a source material sets up wave-like disturbances that spread away from the source of the disturbance. This means, of course, that every wave starts somewhere Eke mini October 6, 2020 at 9:51 pm Thanks for write up. Where is the source of the wave below? Can you explain why the rope is creating a wave? Form? Waves can be compared by the way they behave. Waves have a repeating pattern that gives them a shape and length. These characteristics allow us to describe wave behavior, and, therefore, categorize waves with our descriptions. Waves change their behavior as they travel through different types of matter. To be able to use these wave properties, we must first understand how each wave is measured. Do you see any characteristics in the waving rope above that might help us describe a wave?

1. Amplitude: The height of a wave.
2. Wavelength: The distance between adjacent crests.
3. Trough: The lowest point of a wave.
4. Crest: The highest point of a wave.

Take a Closer Look Can you use the wave vocabulary to label the parts of the wave shown above?

1.2. Statement of the Problem

Wave behavior can be measured by the distance between peaks (wavelength), the size of the peak (amplitude), or the speed of the peaks (frequency). Sound and earthquake waves are examples of waves. These and other waves move at different speeds in different materials. Since earthquakes involve a variety of wave disturbances, including disturbances of the Earth's surface and pressure disturbances under the surface,

geologists mostly rely on physics to study earthquakes. Surface waves in an earthquake are comparable to surface waves in water. There are longitudinal and transverse components to the waves beneath the surface of the Earth. An earthquake's transverse waves are known as shear waves (S-waves) and longitudinal waves as pressure waves (P-waves). Different waves propagate at different speeds, and the stiffness of the material they are traveling through affects how quickly they do so. Granite experiences P-waves that travel at a substantially faster rate than S-waves during earthquakes.

All waves have

1. Frequency: The rate at which a vibration occurs that constitutes a wave.
2. Amplitude: the size of the peak of a wave
3. Wavelength: the distance between the peaks of a wave

Provide your child with a rope or string and a stationary object like a tree or doorknob. Your child's task will be to vary their arm movement to create waves of different amplitude, wavelength, and frequency. Ask your child to first create a wave with large amplitude, then a wave with small amplitude. Ask your child how he/she changed the arm movement to change the amplitude. Next, ask your child to create a wave with high frequency, then a wave with low frequency. Ask your child how he/she changed the arm movement to change the frequency.

1.3. Research Question

1. What happens to the amplitude of the waves?
2. Is this constructive or destructive interference?
3. What happens to the amplitude of the waves when there are two drips?
4. How does the application of in the surrounding area?
5. What to the control and keep about the wave?
6. What the evaluate frequency of the temperature?

1.4. Objectives

1. General objective of the wave

The general objective of the project to assess the mechanical Properties of wave and its application.

2. Specific objective the wave

- 1) The water drops hitting the surface at the same moment generate destructive interference, which keeps the water waves' amplitude constant.
- 2) The water drops hitting the surface simultaneously cancels out the amplitude of the waves due to destructive interference.
- 3) Because of constructive interference, which occurs when water drops strike the surface simultaneously, the amplitude of water waves stays constant.
- 4) As water drips simultaneously hit the surface, constructive interference causes the amplitude of the waves to quadruple.
- 5) To investigate the wave process in the environment
- 6) To evaluate the frequency of a wave is the number of

times

1.5. Significance of the Study

The significance of this project is to provide clear information about solar radiation,. Classification, factor affect, characteristics, effects and its benefits. It serves as are as a reference for researcher doing on the same topic. Another significance of this paper for students who take this course to get information for their preparation of exam and improving their knowledge.

1.6. Limitation of the Study

The study was not free from challenge and limitations. The researcher faced the following problems while conducted this study.

1. The study itself requires more time and money.
2. The study was conducted on limited number of respondents due to financial and time constraints.
3. The study was faced by lack of reference materials like text books and other information network as well as full willingness of the respondents.

2. Literature Review of the Project

2.1. Meaning and Ideas Related to Wave Length

The separation between two places that correspond on consecutive waves is known as the wavelength of a wave. Either two wave crests or two wave troughs can be used to measure this. In Physics, the Greek symbol lambda (λ) is typically used to indicate wavelengths [1-5]. Pulse Waves and Periodic Waves are in a wave pool, the waves are constant, but when you drop a pebble into the water, it might only cause a few waves before the disturbance subsides. A pulse wave is a quick disruption, like the pebble example, in which just one or a few waves are produced. Pulse waves are produced by explosions and thunderstorms [7-9]. A periodic wave is related to simple harmonic motion and repeats the same oscillation for multiple cycles, as in the case of the wave pool. Periodic waves because every particle in the medium to move back and forth through the same places on a regular basis, exhibiting basic harmonic motion. Consider the simplified water wave in Figure 1. This wave is an up-and-down disturbance of the water surface, characterized by a sine wave pattern. The uppermost position is called the *crest* and the lowest is the *trough*. It causes a seagull to move up and down in simple harmonic motion as the wave crests and troughs pass under the bird.

Types of Waves are Longitudinal Waves and Transverse Waves: Mechanical waves can be classified as either longitudinal or transverse depending on the kind of motion they produce. Recall that waves can be periodic in both transverse and longitudinal directions. When a transverse wave propa-

gates, the disruption is perpendicular to the wave's propagation direction. **Figure 2** Depicts a transverse wave example, with a woman moving a toy spring up and down, generating waves that propagate away from her in the horizontal direction while disturbing the toy spring in the vertical direction [11, 12].

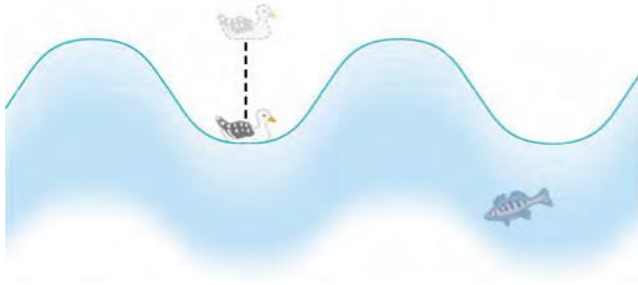


Figure 1. An idealized ocean wave passes under a seagull that bobs up and down simple harmonic motion.

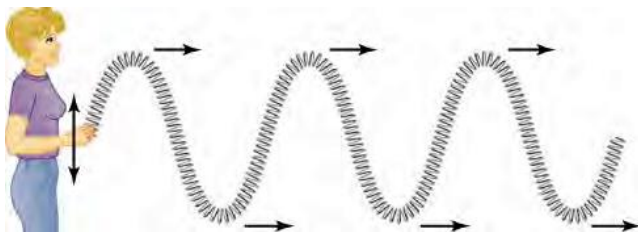


Figure 2. In this illustration of a transverse wave, the disturbance in the toy spring is vertically oriented while the wave propagates horizontally. On the other hand, the disturbance in a longitudinal wave is parallel to the direction of transmission. In **Figure 3**, a longitudinal wave is exemplified by the lady extending and then compressing the toy spring, causing a disturbance in the horizontal direction, which is also the direction in which the wave propagates.

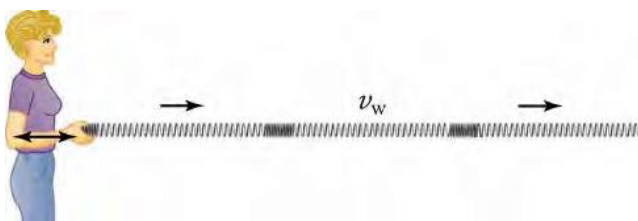


Figure 3. In this example of a longitudinal wave, the wave propagates horizontally and the disturbance in the toy spring is also in the horizontal direction.

Transverse waves are sometimes referred to as shear waves, and longitudinal waves are sometimes referred to as compression waves. Waves can be longitudinal, transverse, or a mix of the two. Both electromagnetic waves like visible light and the waves on musical instrument strings are transverse (see **Figure 3**). Both air and water have longitudinal sound waves. Periodic changes in pressure that are conveyed through fluids are their disturbances.

2.2. Introduction of Waves

There are some basic descriptors of a wave. Wavelength is the distance between two successive identical parts of the wave. Amplitude is the maximum displacement from the neutral position. This represents the energy of the wave. Prague April 23, (2020) is a wave transmitted by mechanical waves. Greater amplitude carries greater energy. Displacement is the position of a particular point in the medium as it moves as the wave passes. Maximum displacement is the amplitude of the wave. Frequency (f) is the number of repetitions per second in Hz, Period (T) is the time for one wavelength to pass a point. The velocity (v) of the wave is the speed at which a specific part of the wave passes a point. The speed of a light wave is c [8].

Types of Waves and Application

1. **Transverse Waves:** Waves in which the medium moves at right angles to the direction of the wave. Examples of transverse waves: Water waves (ripples of gravity waves, not sound through water), Light waves, S-wave earthquake waves, Stringed instruments and Torsion wave. The high point of a transverse wave is a crest. The low part is a trough.
2. **Longitudinal Wave:** A longitudinal wave has the movement of the particles in the medium in the same dimension as the direction of movement of the wave. Examples of longitudinal waves: Sound waves, P-type earthquake waves and Compression wave.

Parts of longitudinal waves: Particles in a compressed state are near to one another. When particles are dispersed, this is known as rarefaction. After learning about the many kinds of waves, let's watch the movie below to observe how the particles move within each form of wave: What does "transverse wave propagation along stretched string" mean, please?

1. **Mechanical waves:** a wave that requires a medium to stay in motion. This is exemplified by waves in water, sound, and slinkiness.
2. **Matter Waves:** Any moving object can be described as a wave. When a stone is dropped into a pond, the water is disturbed from its equilibrium positions as the wave passes; it returns to its equilibrium position after the wave has passed [9].
3. **Electromagnetic Waves:** These waves are disturbance that does not need any object medium for propagation and can easily travel through the vacuum. They are produced due to various magnetic and electric fields. The periodic changes that take place in magnetic and electric fields and therefore known as electromagnetic waves. The wind pushes up against the surface of the water and transfers energy to the water in the process [10].

2.3. Graphing a Wave

When drawing a wave or looking at a wave on a graph, we draw the wave as a snapshot in time. The vertical axis is the amplitude of the wave while the horizontal axis can be either

distance or time.

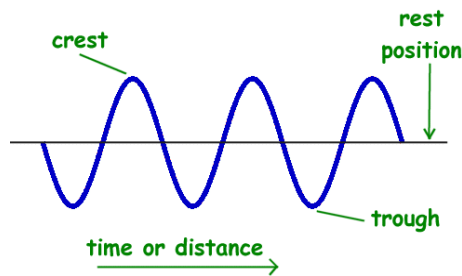


Figure 4. To determine a number of wave properties from the graph.

In this picture you can see that the highest point on the graph of the wave is called the crest and the lowest point is called the trough. The line through the center of the wave is the resting position of the medium if there was no wave passing through. We can determine a number of wave properties through the graph. The amplitude of a wave is a measure of the displacement of the wave from its rest position. The amplitude is shown on the graph below.

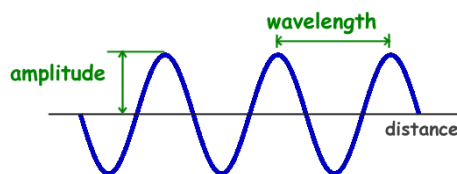


Figure 5. The amplitude is shown on the graph below.

Amplitude is generally calculated by looking on a graph of a wave and measuring the height of the wave from the resting position. The amplitude is a measure of the strength or intensity of the wave. For example, when looking at a sound wave, the amplitude will measure the loudness of the sound. The energy of the wave also varies in direct proportion to the amplitude of the wave [5] might find the below articles helpful: The wind pushes up against the surface of the water and transfers energy to the water in the process.

2.4. Wave Speed Formula

It is the total distance covered by the wave in a given time period. The formula for wave speed is given as,

$$\text{Wave Speed} = \text{Distance Covered} / \text{Time taken}$$

Properties of Waves

The prime properties of waves are as follows:

1. Amplitude – Wave is an energy transport phenomenon. Amplitude is the height of the wave, usually measured in meters. It is directly related to the amount of energy carried by a wave.

2. Wavelength – The distance between identical points in the adjacent cycles of crests of a wave is called a wavelength. It is also measured in meters.
3. Period – The period of a wave is the time for a particle on a medium to make one complete vibration cycle. As the period is time, hence is measured in units of time such as seconds or minutes.
4. Frequency – Frequency of a wave is the number of waves passing a point in a certain time. The unit of frequency is hertz (Hz) which is equal to one wave per second.

The period is the reciprocal of the frequency and vice versa.

2.5. Frequency and Period

The frequency of a wave is the number of times per second that the wave cycles. Frequency is measured in Hertz or cycles per second. The frequency is often represented by the lower case "f." The period of the wave is the time between wave crests. The period is measured in time units such as seconds. The period is usually represented by the upper case "T."

The period and frequency are closely related to each other. The period equals 1 over the frequency and the frequency is equal to one over the period. They are reciprocals of each other as shown in the following formulas.

$$\text{Period} = 1/\text{frequency or } T = 1/f$$

$$\text{Frequency} = 1/\text{period or } f = 1/T$$

2.6. Speed or Velocity of a Wave

Another important property of a wave is the speed of propagation. This is how fast the disturbance of the wave is moving. The speed of mechanical waves depends on the medium that the wave is travelling through. For example, sound will travel at a different speed in water than in air. The velocity of a wave is usually represented by the letter "v." The velocity can be calculated by multiplying the frequency by the wavelength.

$$\text{Velocity} = \text{frequency} * \text{wavelength or } v = f * \lambda$$

3. Materials and Methods

3.1. Project Design

This research paper uses the qualitative approach to research works. The qualitative approach is deployed to interpret and analyses data attempting to uncover the deeper meaning and significance of respondent's reflection.

3.2. Source of Data

The data will gathered from mechanical waves on the environmental manager and different reference and researcher, all helps are source data of this study and the

instrument of these data students are qualitative and quantitative instrument.

3.3. Population of the Study

The total populations of the study will all too female students and 4 physics education teachers.

3.4. Sample Size of Sampling Technique

From the total population of school the sample size include all sport science teacher, as they are purposeful for the study and 20 female students by using random sampling.

3.5. Data Collection Tools

The researchers will two ways of data collection tools. Questionnaire and observation.

3.6. Method and Procedures of Data Collection

The researcher would be developing questionnaires to obtain data from teachers and students. The questionnaires are appropriate and related with the concerned factor that affection female student's participation in physical education practical class. The researcher will select random sampling from method.

3.7. Method of Data Analysis

The data will analyses qualitatively and quantitatively. Finally, data were compared each other and possible result was interpreted in terms of percent to make over all conclusions and to give recommendation.

4. Result and Discussion

Standing Waves

There are moments when waves seem to just vibrate while standing still. These waves, which are referred to as standing waves, are created when two or more waves traveling in opposing directions superimpose. As the waves pass past one another, their disruptions accumulate. The two waves alternate between constructive and destructive interference if they have the same wavelength and amplitude. Figure 6 shows standing waves, which are produced by superposing two similar waves traveling in opposite directions.

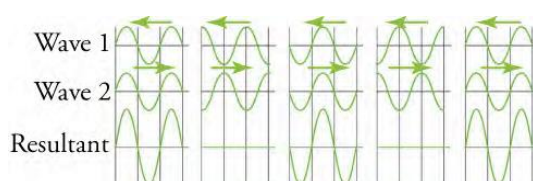


Figure 6. To determine standing waves.

5. Conclusion and Recommendation

5.1. Conclusion

This study determined that mechanical waves, such as water, seismic, and sound waves, necessitate a medium for their transmission. Unlike these, light is capable of traveling through a vacuum, thus classifying it as a non-mechanical wave. A pulse wave, characterized by a brief disturbance, consists of one or more crests. Notably, periodic waves and simple harmonic motion are fundamentally intertwined. The direction of disturbance in a longitudinal wave is parallel to its direction of propagation, whereas in a transverse wave, the disturbance is perpendicular to its direction of travel. Wavelength, as we've defined and measured, represents the spatial distance between two corresponding points on successive cycles of a wave, often measured between two crests or two troughs. In physics, the Greek letter lambda (λ) commonly denotes wavelength. Waves transport varying amounts of energy, with energy content being directly proportional to a wave's amplitude, which is the wave's height, measured in meters. Put simply, a wave is a disturbance that propagates outwards from its source.

5.2. Recommendation

Aside from rare seismic events like tsunamis, wind is the primary driver behind the formation of most large ocean waves. The process begins with wind transferring its energy to the water's surface. Stronger winds impart more energy, leading to the creation of larger waves. As waves grow taller, they present a larger surface area to the wind, resulting in a positive feedback loop where more energy is transferred from the wind to the water. Severe storms, with their powerful winds, therefore become the origin of large, energetic waves that emanate outward. The energy transferred from wind to water is directly related to wind speed, and this energy transfer is amplified as the surface area of the developing waves increases. Consequently, the most intense storms generate the most dramatic waves, characterized by their large size and extensive reach across the ocean surface. While lunar tides also play a role in wave generation, they are not the primary source of large wind driven waves. It's worth noting that the complexity of real ocean waves goes beyond a simple sinusoidal model. Ocean waves are better described as orbital progressive waves, where surface water particles move in circular paths as they move from crest to trough and back again, and continuously generating new waves. Finally, the phenomenon of shoaling occurs when wave energy is compressed into smaller volumes as the water depth decreases near the shoreline, leading to a dramatic increase in wave height.

Abbreviations

v	Velocity
f	Frequency
T	Time
λ	Lambda

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Author Contributions

Takele Teshome Somano is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts interest.

References

- [1] Anushkapriya (2022) afternoon on the waves for write up it was very helpful.
- [2] Arush (2019) water particles at the surface follow a circular path from the crest to the trough of the passing text book physics A. A.
- [3] Alaji (2020) the Supper notes I need full notes of waves of the mechanical waves.
- [4] Deepa (2020) at 1:03 pm A wave is defined as a disturbance or variation that transfers energy progressively from point to point in a medium and that may take the form of elastic deformation or of a variation of pressure, electric or magnetic intensity, electric potential, or temperature.
- [5] Deepa 2021 at 3:08 pm Hi, You might find the below articles helpful: The wind pushes up against the surface of the water and transfers energy to the water in the process.
- [6] Deepa July 26, 2022 at 10:07 am A detailed explanation regarding transverse wave propagation along a stretched string is given on the following page, please check:
<https://byjus.com/physics/transverse-waves/>
- [7] Devapujabindhu (2022) Please could you explain about “transverse wave propagation along stretched string?”
- [8] Khandelwal, M. (2013). Correlating P-wave velocity with the physico-mechanical properties of different rocks. *Pure and Applied Geophysics*, 170, 507-514.
- [9] Altindag, R. (2012). Correlation between P-wave velocity and some mechanical properties for sedimentary rocks. *Journal of the Southern African Institute of Mining and Metallurgy*, 112(3), 229-237.
- [10] Ishika Rathore (2023) please, explain chapter simple harmonic motion and wave motion.
- [11] Pragun April 23, (2020) at 6:59 pm what is a wave transmitted by mechanical waves?
- [12] Yohuno Isaac November 12, 2020 at 2:14 pm I really appreciate the teaching.