Suggested time allotment: 4 to 5 hours

MODULE 2

WAVES AROUND YOU

Waves occur all around you in the physical world. When you throw a stone into a lake, water waves spread out from the splash. When you strum the strings of a guitar, sound waves carry the noise all around you. When you switch on a lamp, light waves flood the room. Water, sound, and light waves differ in important ways but they all share the basic properties of wave motion. For instance, you can see water waves and surfers would say that they enjoy riding the waves. On the other hand, you don't see sound waves and light waves but you experience them in other ways. Your ears can detect sound waves and your skin can get burned by ultraviolet waves if you stay under the sun for too long.

A **wave** is a periodic disturbance that moves away from a source and carries energy with it. For example, earthquake waves show us that the amount of energy carried by a wave can do work on objects by exerting forces that move objects from their original positions. Have you personally experience an earthquake? How did it feel? Did you know that you can understand earthquakes by studying waves?

In this module, you would be doing three activities that would demonstrate the properties of wave motion. After performing these activities, you should be able to:

1. explain how waves carry energy from one place to another;
2. distinguish between transverse and longitudinal waves;
3. distinguish between mechanical and electromagnetic waves; and
4. create a model to demonstrate the relationship among frequency, amplitude, wavelength, and wave velocity.

Warm up. What are Waves?

Activity 1 will introduce you to different types of waves distinguished according to the direction of vibrations of particles with respect to the direction in which the waves travel. Activity 2 will give you a background of the terms and quantities used in describing periodic waves. Finally, Activity 3 will strengthen your understanding of the properties of waves and how they propagate.

Waving is a common gesture that people do to catch someone's attention or to convey a farewell.

Try to wave at your seatmate and observe the motion of your hand. Do you make a side-to-side motion with the palm of your hand? Do you do an up-and-down motion with your hand?

1. Describe your personal hand wave.

The repetitive motion that you do with your hand while waving is called a **vibration**. A vibration causes wave motion. When you observe a wave, the source is always a vibration.

2. Think of a still lake. How would you generate water waves on the lake?

Activity 1. Let's Make Waves!
What happens when waves pass by?

Objective

In this activity, you will observe and draw different types of waves and describe how they are produced. You will also describe the different types of waves.

Time Allotment: 30 minutes

Materials

- A rope (at least five meters long)
- A colored ribbon
- A coil spring (Slinky™)
- A basin filled with water
- A paper boat

Procedure

A. What are transverse waves?

1. Straighten the rope and place it above a long table. Hold one end of the rope and vibrate it up and down. You would be able to observe a **pulse**. Draw three sketches of the rope showing the motion of the pulse at three subsequent instances (snapshots at three different times). Draw an arrow to represent the direction of the pulse's motion.

Time 1

Time 2

Time 3

a. What is the source of the wave pulse?

b. Describe the motion of your hand as you create the pulse.

c. Describe the motion of the pulse with respect to the source.

You will now tag a specific part of the rope while making a series of pulses. A **periodic wave** can be regarded as a series of pulses. One pulse follows another in regular succession.

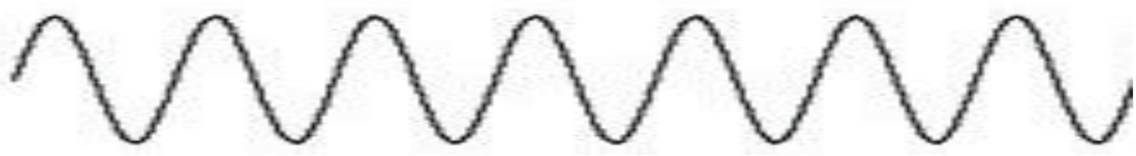


Figure 1. Periodic wave

Tie one end of the rope on a rigid and fixed object (e.g heavy table, door knob, etc).

Figure 2. Rope tied to a rigid object

Attach a colored ribbon on one part of the rope. You may use adhesive tape to fix the ribbon. Make a wave by continuously vibrating the end of the rope with quick up-and-down movements of your hand. Draw the **waveform** or the shape of the wave that you have created.

Ask a friend to vibrate the rope while you observe the motion of the colored ribbon. Remember that the colored ribbon serves as a marker of a chosen segment of the rope.

a. Does the wave transport the colored ribbon from its original position to the end of the rope?

b. Describe the vibration of the colored ribbon. How does it move as waves pass by? Does it move in the same direction as the wave?

B. What are longitudinal waves?

1. Connect one end of a long table to a wall. Place coil spring on top of table. Attach one end of the coil spring to the wall while you hold the other end.

Figure 3. Coil spring on a flat table with one end attached to a wall

Do not lift the coil spring. Ask a friend to vibrate the end of the coil spring by doing a back-and-forth motion parallel to the length of the spring. Observe the waves along the coil spring. Draw how the coil spring looks like as you move it back-and-forth.

2. Attach a colored ribbon on one part of the coil spring. You may use an adhesive tape to fix the ribbon. Ask a friend to vibrate the coil spring back-and-forth while you observe the motion of the colored ribbon. Remember that the colored ribbon serves as a marker of a chosen segment of the coil spring.

   a. Does the wave transport the colored ribbon from its original position to the end of the rope?

   b. Describe the vibration of the colored ribbon. How does it move as waves pass by?

C. What are surface waves?

1. Place a basin filled with water on top of a level table. Wait until the water becomes still or motionless. Create a wave pulse by tapping the surface of the water with your index finger and observe the direction of travel of the wave pulse. Tap the surface of the water at regular intervals to create periodic waves. View the waves from above and draw the pattern that you see. In your drawing, mark the source of the disturbance.

2. Wait for the water to become still before you place your paper boat on the surface. Create periodic waves and observe what happens to your paper boat.

   a. Do the waves set the paper boat into motion? What is required to set an object into motion?

   b. If you exert more energy in creating periodic waves by tapping the surface with greater strength, how does this affect the movement of the paper boat?

3. If you were somehow able to mark individual water molecules (you used a colored ribbon to do this earlier) and follow them as waves pass by, you would find that their paths are like those shown in the figure below.

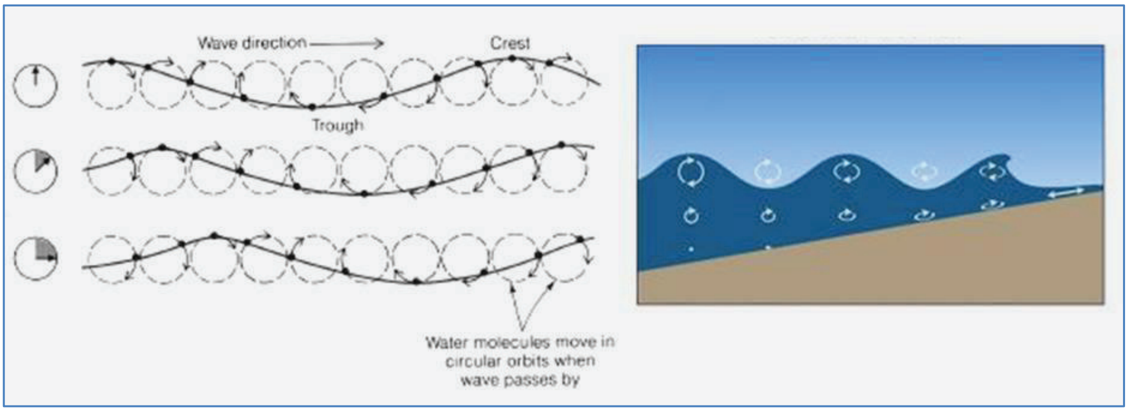


Figure 4. Surface waves

a. As shown in the figure, the passage of a wave across a surface of a body of water involves the motion of particles following a ___________ pattern about their original positions.

b. Does the wave transport water molecules from the source of the vibration? Support your answer using the shown figure.

D. Summary

1. Waves can be typified according to the direction of motion of the vibrating particles with respect to the direction in which the waves travel.

   a. Waves in a rope are called ____________ waves because the individual segments of the rope vibrate ____________ to the direction in which the waves travel.

   b. When each portion of a coil spring is alternatively compressed and extended, ____________ waves are produced.

   c. Waves on the surface of a body of water are a combination of transverse and longitudinal waves. Each water molecule moves in a _______________ pattern as the waves pass by.

2. How do we know that waves carry energy?

3. What happens when waves pass by?

Activity 2. Anatomy of a Wave
How do you describe waves?

Background

You had the experience of creating periodic waves in Activity 1. In a periodic wave, one pulse follows another in regular succession; a certain waveform – the shape of individual waves – is repeated at regular intervals.

Most periodic waves have **sinusoidal** waveforms as shown below. The highest point and lowest point of a wave are called the **crest** and the **trough** respectively. The **amplitude** is the maximum displacement of a vibrating particle on either side of its normal position when the wave passes.

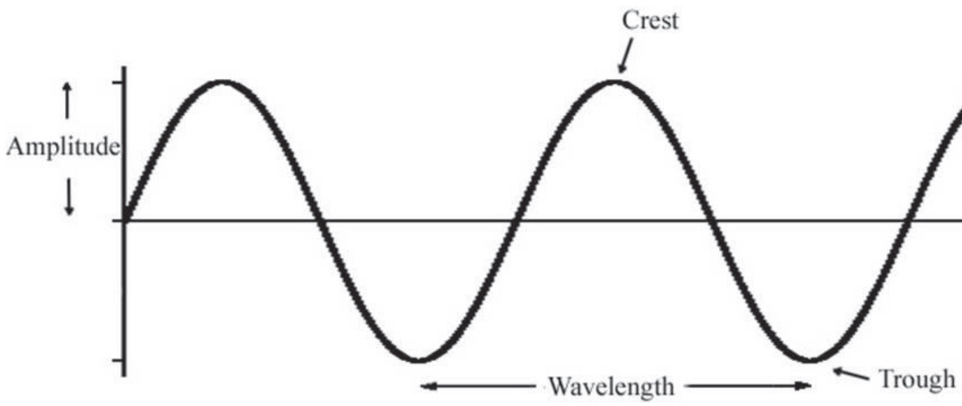


Figure 5. Sinusoidal wave

Objective

In this activity, you will identify the quantities used in describing periodic waves.

Time Allotment: 40 minutes

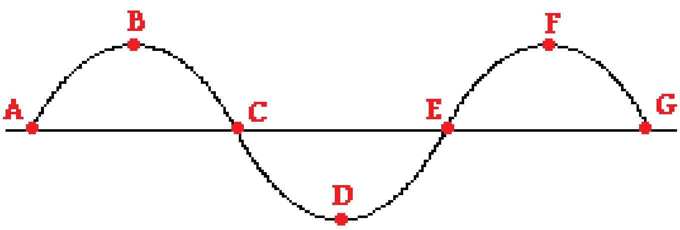
Materials

- A ruler
- A basin filled with water
- A rope (at least five meters long)
- A colored ribbon
- A watch or digital timer

Procedure

A. How can you measure the wavelength of a wave?

1. The **wavelength** of a wave refers to the distance between any successive identical parts of the wave. For instance, the distance from one crest to the next is equal to one full wavelength. In the following illustration, this is given by the interval B to F. Identify the other intervals that represent one full wavelength.



____

____

2. Place a basin filled with water on top of a level table. Wait for the water to become still. Create a vibration by regularly tapping the surface of the water with your index finger. You would be able to see the subsequent crest of the water waves.

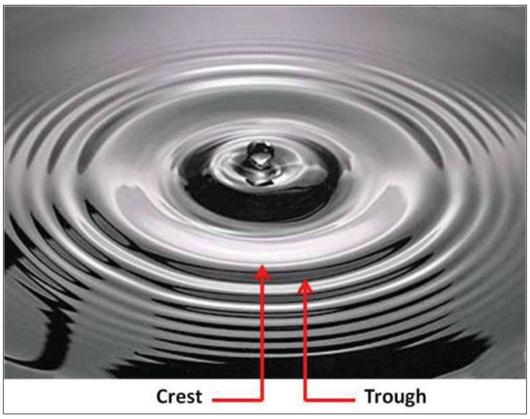


Figure 6. Crest and trough on a water wave

Draw the water waves as you see them from the top of the basin. Label one wavelength in your drawing.

3. Increase the rate of the vibrations you create by tapping the surface of the water rapidly. What happens to the wavelength of the waves? ____

Draw the water waves as you see them from the top of the basin. Compare it with your drawing in number 2.

B. How do you measure the frequency of a wave?

1. The **frequency** of a series of periodic waves is the number of waves that pass a particular point every one second. Just like what you have done in Activity 1, attach a colored ribbon on a rope to serve

as a tag. Tie one end of the rope on a fixed object and ask a friend to create periodic waves by regularly vibrating the other end of the rope.

2. You will count how many times the colored ribbon reached the crest in 10 seconds. You will start counting once the ribbon reaches the crest a second time. It means that one wave has passed by the ribbon's position. Ask another friend with a watch or a digital timer to alert you to start counting and to stop counting after 10 seconds. Record the results in Table 1.

3. It is also useful to consider the **period** of a wave, which is the time required for one complete wave to pass a given point. The period of each wave is

$$period = \frac{1}{frequency}$$

From the identified frequency of the observed periodic waves, the period can be calculated. For example, if two waves per second are passing by, each wave has a period of ½ seconds.

Table 1. Frequency and period of the wave

Number of waves (N cycles) that passed by the ribbon in 10 seconds	**Frequency** of the waves (N cycles/10 seconds)	**Period** of the waves (seconds)

The unit of frequency is the **hertz** (Hz); 1 Hz = 1 cycle/second.

4. If you increase the frequency of vibration by jerking the end of the rope at a faster rate, what happens to the wavelength? ______________________________

C. How do you measure the speed of a wave?

1. Using the rope with ribbon. Create periodic waves and estimate their wavelength. Count the number of waves that pass by the ribbon in ten seconds. Compute the frequency of the waves. Record the results in Table 2.

2. The wave speed is the distance traveled by the wave per second.

$$wave\ speed = distance\ traveled\ per\ second = frequency\ x\ wavelength$$

From the basic formula that applies to all periodic waves, you can see that wave speed, frequency and wavelength are independent of the wave's amplitude.

a. Using the data from number 1, calculate the wave speed of the observed periodic waves. Record the result in Table 2.

Table 2. The speed of a wave

Estimated wavelength (meters)	**Number of waves** (N cycles) that passed by the ribbon in 10 seconds	**Frequency** of the waves (N cycles/10 seconds)	**Wave speed** (meter/second)

Summary

1. What is the relationship between wave speed, wavelength and frequency?

2. Suppose you observed an anchored boat to rise and fall once every 4.0 seconds as waves whose crests are 25 meters apart pass by it.

   a. What is the frequency of the observed waves?

   b. What is the speed of the waves?

Activity 3. Mechanical vs. Electromagnetic Waves How do waves propagate?

Objective

In this activity, you will differentiate between mechanical waves and electromagnetic waves.

Time Allotment: 30 minutes

Materials

- Findings from Activity 1
- Chart of the electromagnetic spectrum

A. What are mechanical waves?

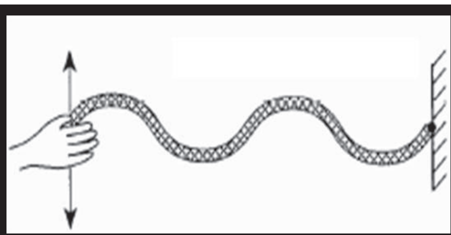
1. When you created waves using a rope in Activity 1 Part A, you were able to observe a moving pattern. In this case, the **medium** of wave propagation is the ***rope***.

   a. In Activity 1 Part B, what is the medium of wave propagation?

   b. In Activity 1 Part C, what is the medium of wave propagation?

2. The waves that you have created in Activity 1 all require a medium for wave propagation. They are called **mechanical waves**.

   a. How can you generate mechanical waves?



The medium of propagation for the wave shown above is the ***rope****.*

3. All three kinds of waves – transverse, longitudinal, and surface – are sent out by an earthquake and can be detected many thousands of kilometers away if the quake is a major one.

   a. What do you think is the source of earthquake waves?

   b. What is the medium of propagation of earthquake waves?

B. What are electromagnetic waves?

1. Energy from the sun reaches the earth through **electromagnetic waves**. As opposed to mechanical waves, electromagnetic waves require no material medium for their passage. Thus, they can pass through empty space. Locate the electromagnetic spectrum chart in your classroom. A smaller image of the chart is shown below. Identify the common name of each wave shown in the chart.

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________

2. The **electromagnetic spectrum** shows the various types of electromagnetic waves, the range of their frequencies and wavelength. The wave speed of all electromagnetic waves is the same and equal to the speed of light which is approximately equal to 300 000 000 m/s.

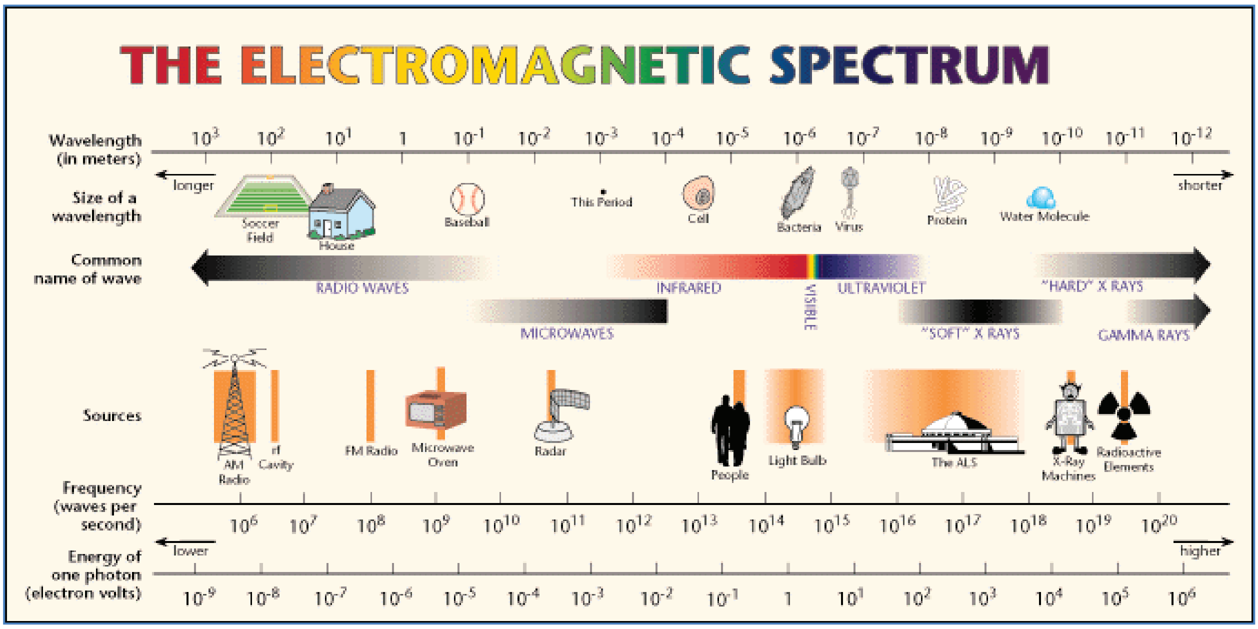


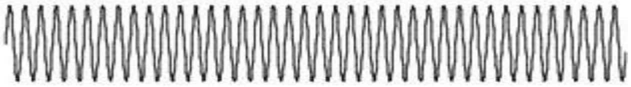
Figure 7. The electromagnetic spectrum

a. Examine the electromagnetic spectrum.

1. Describe the relationship between frequency and wavelength of each electromagnetic wave.

2. Draw waves to represent each electromagnetic wave. Your illustrations must represent the wavelength of a wave relative to the others. For instance, gamma rays have a very small wavelength compared to the other waves in the spectrum.

1. <u>Gamma Rays</u>



2. __________
3. __________
4. __________
5. __________
6. __________
7. __________

b. The Sun is an important source of ultraviolet (UV) waves, which is the main cause of sunburn. Sunscreen lotions are transparent to visible light but absorb most UV light. The higher a sunscreen's solar protection factor (SPF), the greater the percentage of UV light absorbed. Why are UV rays harmful to the skin compared to visible light?

Compare the frequency and energy carried by UV waves to that of visible light.

C. Summary

1. Mechanical waves like sound, water waves, earthquake waves, and waves in a stretched string propagate through a _______________ while __________________ waves such as radio waves, visible light, and gamma rays, do not require a material medium for their passage.

Review. Waves Around You

The activities that you have performed are all about wave motion or the propagation of a pattern caused by a vibration. Waves transport energy from one place to another thus they can set objects into motion.

What happens when waves pass by?

Activity 1 introduced you to transverse waves, longitudinal waves, and surface waves. You observed the motion of a segment of the material through which the wave travels.

1. Transverse waves occur when the individual particles or segments of a medium vibrate from side to side perpendicular to the direction in which the waves travel.

2. Longitudinal waves occur when the individual particles of a medium vibrate back and forth in the direction in which the waves travel.

3. The motion of water molecules on the surface of deep water in which a wave is propagating is a combination of transverse and longitudinal displacements, with the result that molecules at the surface move in nearly circular paths. Each molecule is displaced both horizontally and vertically from its normal position.

4. While energy is transported by virtue of the moving pattern, it is important to remember that there is not net transport of matter in wave motion. The particles vibrate about a normal position and do not undergo a net motion.

How can you describe waves?

In Activity 2, you have encountered the important terms and quantities used to describe periodic waves.

1. The crest and trough refer to the highest point and lowest point of a wave pattern, respectively.

2. The amplitude of a wave is the maximum displacement of a particle of the medium on either side of its normal position when the wave passes.

3. The frequency of periodic waves is the number of waves that pass a particular point for every one second while the wavelength is the distance between adjacent crests or troughs.

4. The period is the time required for one complete wave to pass a particular point.

5. The speed of the wave refers to the distance the wave travels per unit time. It is related to the frequency of the wave and wavelength through the following equation:

$$wave\ speed = frequency\ x\ wavelength$$

How do waves propagate?

Finally, Activity 3 prompted you to distinguish between mechanical and electromagnetic waves.

1. In mechanical waves, some physical medium is being disturbed for the wave to propagate. A wave traveling on a string would not exist without the string. Sound waves could not travel through air if there were no air molecules. With mechanical waves, what we interpret as a wave corresponds to the propagation of a disturbance through a medium.

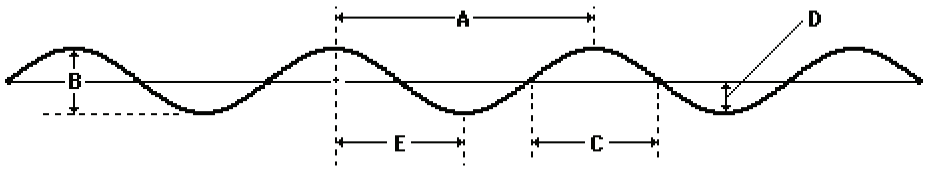
2. On the other hand, electromagnetic waves do not require a medium to propagate; some examples of electromagnetic waves are visible light, radio waves, television signals, and x-rays.

Up Next. Light

In the next module, you would learn about visible light, the most familiar form of electromagnetic waves, since it is the part of the electromagnetic spectrum that the human eye can detect. Through some interesting activities, you would come across the characteristics of light, how it is produced and how it propagates. You would need the concepts that you learned from this module to fully understand and appreciate the occurrence of light.

Pre/Post Test

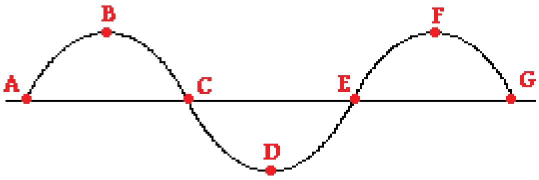
Consider the diagram below to answer questions 1 and 2.



1. The wavelength of the wave in the diagram above is given by letter ______.

2. The amplitude of the wave in the diagram above is given by letter _____.

3. Indicate the interval that represents a half wavelength.



   a. A to E
   b. B to F
   c. A to B
   d. C to E

4. A pulse sent down a long string eventually dies away and disappears. What happens to its energy?
   a. The energy disappears with the wave.
   b. The energy is remains along the length of the string.
   c. The energy is transferred from the wave to the environment.
   d. The pulse does not carry energy.

5. Mechanical waves transport energy from one place to another through
   a. Alternately vibrating particles of the medium
   b. Particles traveling with the wave
   c. Vibrating particles and traveling particles
   d. None of the above

6. In a transverse wave, the individual particles of the medium
   a. move in circles
   b. move in ellipses
   c. move parallel to the direction of travel
   d. move perpendicular to the direction of travel

7. The higher the frequency of a wave,

a. the lower its speed
b. the shorter its wavelength
c. the greater its amplitude
d. the longer its period

8. Of the following properties of a wave, the one that is independent of the others is its

a. amplitude
b. wave speed
c. wavelength
d. frequency

9. Waves in a lake are 5.00 m in length and pass an anchored boat 1.25 s apart. The speed of the waves is

a. 0.25 m/s
b. 4.00 m/s
c. 6.25 m/s
d. impossible to find from the information given

10. Energy from the sun reaches the earth through

a. ultraviolet waves
b. infrared waves
c. mechanical waves
d. electromagnetic waves

References and Web Links

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