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Physics
Teach Yourself Series
Topic 11: Properties of mechanical waves(Unit 4)

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Contents

What you should know 3
As it appears in Unit 4 3
Mechanical waves 3
As it appears in Unit 4 3
Characteristics of waves 3
Wave equation 4
Review Questions 5
Transverse and Longitudinal waves 6
As it appears in Unit 4 6
Longitudinal waves 6
Transverse waves 6
Review Questions 6
Doppler Effect 6
As it appears in Unit 4 6
Review Question 6
Diffraction of Waves 6
As it appears in Unit 4 6
Review Questions 6
Standing Waves, Harmonics & Resonance 6
As it appears in Unit 4 6
Superposition 6
Standing waves 6
Harmonics on strings 6
Resonance 6
Review Questions 6
Solutions to Review Questions 6

What you shouldknow

As it appears in Unit 4

- explain a wave as the transmission of energy through a medium without the net transfer of matter
- distinguish between transverse and longitudinal waves
- identify the amplitude, wavelength, period and frequency of waves
- calculate the wavelength, frequency, period and speed of travel of waves using: $v = f\lambda = \frac{\lambda}{T}$
- explain qualitatively the Doppler effect
- Describe diffraction as the directional spread of various frequencies in terms of different gap width or obstacle size, including the significance of the magnitude of the $\frac{\lambda}{w}$ ratio;
- explain resonance as the superposition of a travelling wave and its reflection, and with reference to a forced oscillation matching the natural frequency of vibration.
- analyse the formation of standing waves in strings fixed at one or both ends

Mechanical waves

As it appears in Unit 4

Characteristics of waves

Waves are defined as disturbances that travel through a medium without carrying any of the medium along with them.

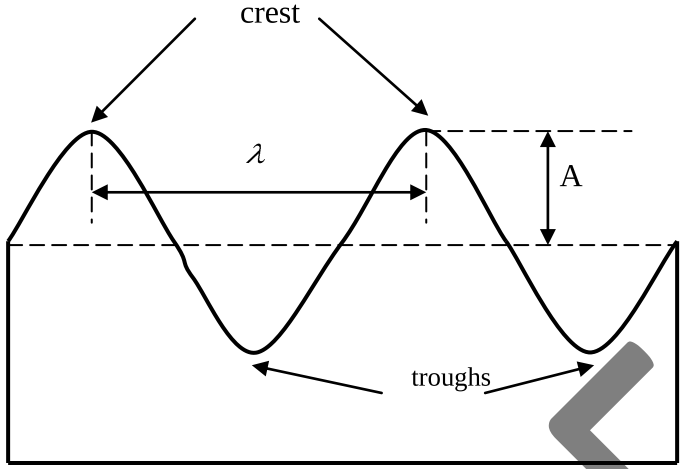
The substance through which the wave travels is called the **medium**. The medium itself is not changed as a result of the wave motion.

Waves can be classified as ***mechanical*** or ***electromagnetic*** waves.Mechanical waves, such as water waves or sound waves need a medium to travel through. But electromagnetic waves can travel through vacuum as well.

Waves that repeat themselves at regular intervals are called **periodic or continuous** waves

A source of energy is needed to create such waves.

The ***amplitude, A,*** of a wave is the ***maximum displacement*** of the particles of the medium from their rest position.



The ***frequency (f)*** of a wave is the number of waves generated per second, or the number of waves passing a given point per second.Frequency is measured in hertz (Hz).

The ***period,T,*** of a waveis the time it takes before a wave repeats itself.It is also the time for a complete oscillation of a particle of the medium to occur.Period is measured in seconds (s).

The period and frequency are related $f = \frac{1}{T}$

The ***speed***, *v*, of a waveis the rate at which a wave covers distance. Speed is measured in metre per second (ms^{-1}).

The ***wavelength*** , λ , is the distance that one wave covers before it repeats itself. The ***wavelength*** is also the distance between two consecutive crests or troughs.Furthermore it is also the distance travelled by the wave in one period.Wavelength is measured in metre (m).

Wave equation

It is an important relation between the speed, frequency and wavelength of a wave.

$$v = f\lambda$$

v is the speed of the wave, expressed in (ms^{-1})

f is the frequency of the wave, expressed in (Hz)

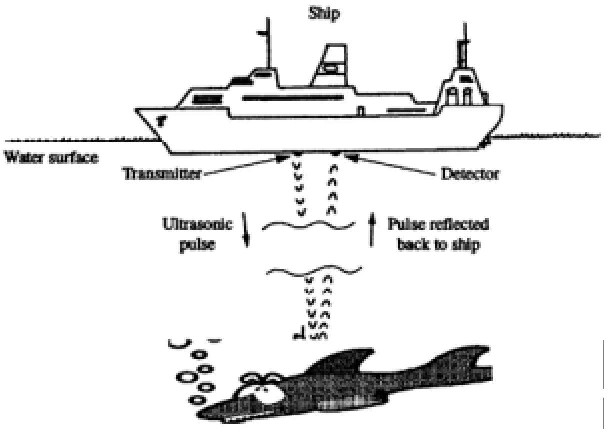
λ is the wavelength of the wave, expressed in (m)

The***wave equation*** is true for all types of waves.

Review Questions

Question 1

The diagram shows a ship using an Echo locator (SONAR) to find a school of fish. The pulsed wave is transmitted from the ship, reflected off the school and picked up by a receiver



The time taken to receive the echo is 0.2s after transmission. Calculate how deep the ship has to lower its fishing nets to catch the school if the speed of sound in water is 1300 ms^{-1}.

Solutions to Review Questions

1. $v = \frac{d}{t}$
   $1300 \times 0.1 = \text{distance}$
   $\text{distance} = 130 \text{ m}$

2. **a.** $\lambda = 0.8 \text{ m}, \text{ amplitude} = 15 \text{ cm}$

   b. B-not moving, C-down, D-not moving, E-up

   c. $v = f\gamma$
   $f = \frac{12}{0.8} = 15 \text{ Hz}$
   $T = \frac{1}{f} = \frac{1}{15} = 0.067s$

3. $T = \frac{8}{16} = 0.5 \text{ s}$
   $f = \frac{1}{T} = \frac{1}{0.5} = 2 \text{ Hz}$

4. $v = f\lambda$
   $200 = 500 \times \lambda$
   $\lambda = 0.4 \text{ m}$

5. Longitudinal wave – particle movement is left and right and wave movement is right.

6. Transverse wave – particle movement is at right angles to the wave movement.

7. B.

8. The 150 Hz sound

   $f = 150 \text{ Hz}, \lambda = \frac{340}{150} = 2.27 \text{ m}$
   $\frac{\gamma}{w} \approx 7.3 \ \therefore \text{significant diffraction}$

   $f = 800 \text{ Hz}, \lambda = \frac{340}{800} = 0.425 \text{ m}$
   $\frac{\gamma}{w} < 1 \ \therefore \text{some diffration but less than for the 150 Hz sound.}$

9.

a. 0.34 m

$$\lambda = \frac{v}{f} = \frac{340}{1000} = 0.34 \text{ m}$$

b. Yes, because $\frac{\lambda}{w} \geq 1$, there is significant diffraction.

10.

a. 0.68 m

First harmonic: $\lambda_1 = 2L = 2 \times 0.34 = 0.68$ m

b. 0.23 m

second overtone = third harmonic

$$\lambda_3 = \frac{2L}{3} = \frac{2 \times 0.34}{3} = 0.23 \text{m}$$

c. 0.17 m

$$\lambda_4 = \frac{L}{2} = \frac{0.34}{2} = 0.17 \text{ m}$$

d. This situation involves resonance. 550 Hz $\times$ 4 = 2200 Hz. It corresponds to the fourth harmonic of the forcing vibration by the 550 Hz.

11. For a vibrating object fixed at one end, the second overtone is the fifth harmonic.

$$\lambda_5 = \frac{4L}{5} = \frac{4 \times 0.48}{5} = 0.384 \text{ m}$$