Section 1.1.1 – Properties of mechanical waves

Why study waves?

There are many Physics concepts that can be examined, and indeed explained, by the use of the wave model. So it is essential that a successful Physics student understands the basics of the wave model.

Key Definitions

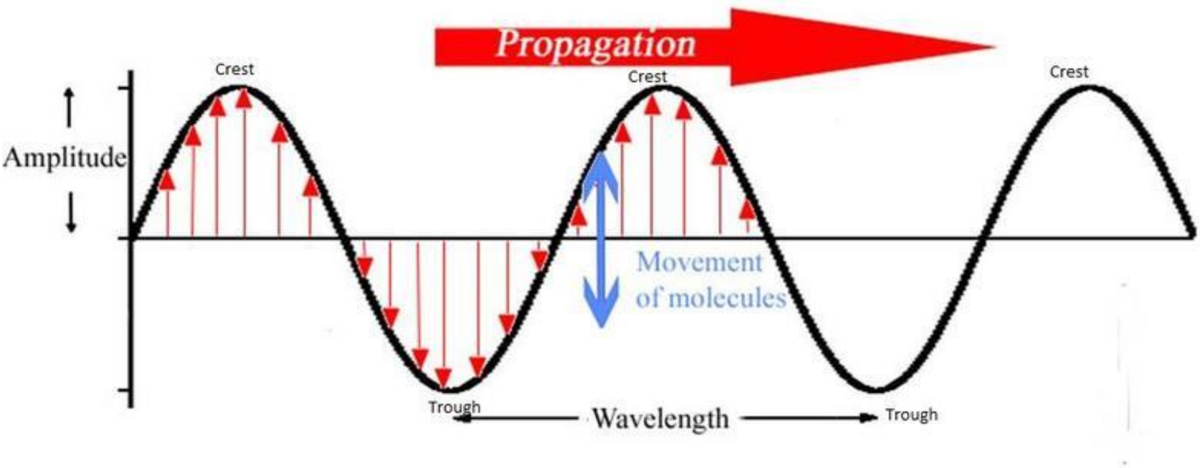
A **wave** is a disturbance which causes a transmission of **energy** from one location to another **without the net transfer of matter**.

A **medium** is the material that carries the wave

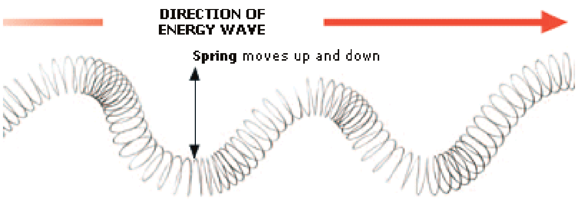
Wave Classifications

There are two main classifications of waves:
- Transverse waves
- Longitudinal waves

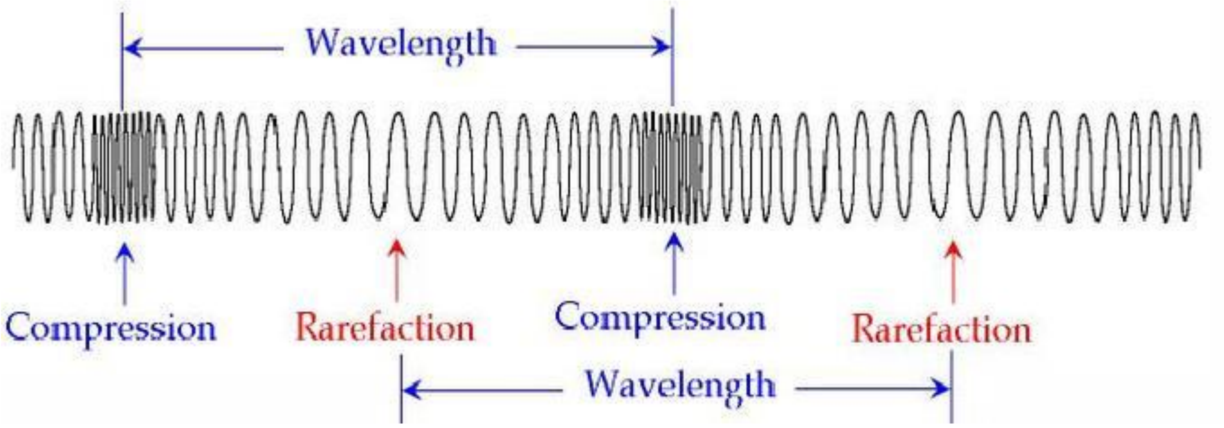
A **transverse wave** is defined as a wave whose oscillation is **perpendicular** (at right angles) to the direction of the wave's propagation (movement).



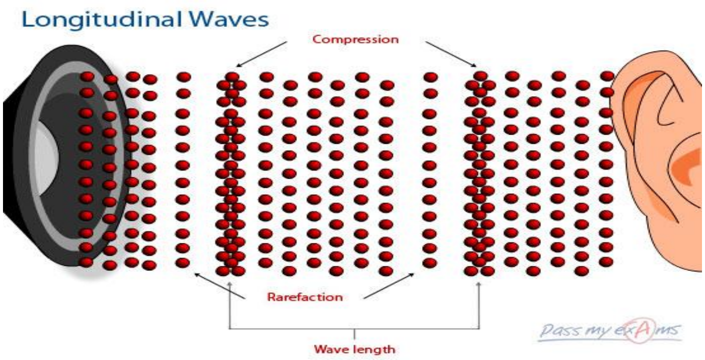
Example.1
Examples of transverse waves are a "flick" along a spring, or the disturbance along water waves. Light waves can also be explained using the transverse wave model.



Whereas, a **longitudinal waves** (also known as a compressional wave) is defined as a wave whose oscillation is **parallel** to the direction of propagation (movement).

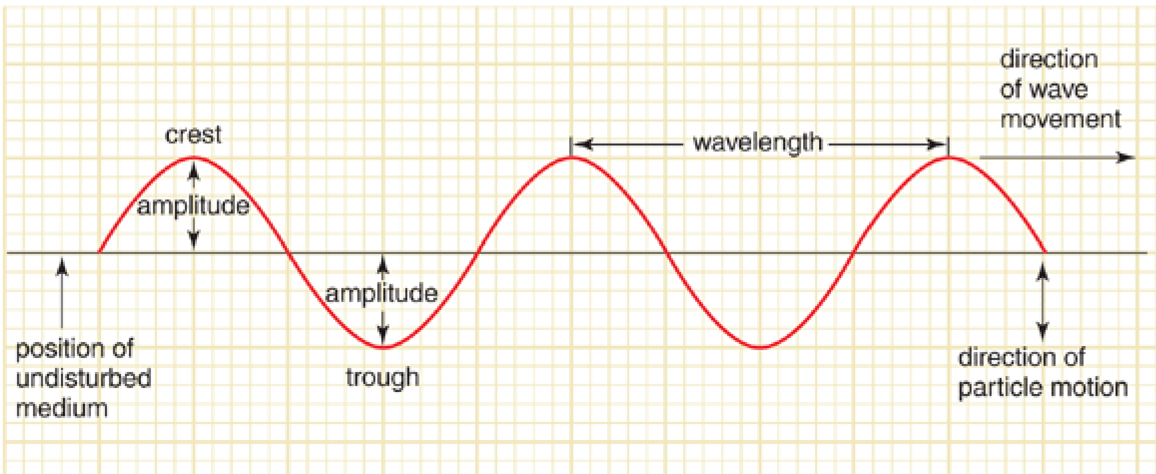


Example.2
Examples of longitudinal waves are a compression along a spring, or a primary wave formed by seismic activity. Sound waves can also be explained using the longitudinal wave model.



Properties of Waves

The following figure highlights several key measureable properties of waves:



Vertical Analysis of a transverse wave

Particles within a medium start at an **equilibrium** or **rest point**. It's only when the disturbance of a wave arrives that the particles will move vertically upwards or downwards, **perpendicular** to the direction of wave propagation.

The wave **crest** represents the largest **amplitude** from the rest point in the **positive direction.** The waves **trough** represents the largest **amplitude** from the rest point in the **negative direction.**

Amplitude Is the size of the wave.
It is the maximum displacement for a particle from its rest position.
Measured in meters.

Horizontal Analysis of a transverse wave

Whilst particles within a medium move vertically up and down, the actual **wave disturbance** itself travels in a **horizontal direction.**

Wave signal graphs can either display length (m) or time (s) upon the horizontal axes.

Wavelength (λ) The distance between two repeating points upon a wave cycle.
Typically measured between crest to crest or trough to trough.
Measured in meters.

Period (T) The time between two repeating points upon a wave cycle.
The amount of time one cycle or an event takes.
Measured in seconds.

From the wavelength (λ) and period (T), other quantities can be calculated.

$$f = \frac{1}{T} \quad or \quad T = \frac{1}{f}$$

Frequency (f) A measure of how many times per second an event happens
Measured in Hertz (Hz)
A frequency of 50 Hertz, represents 50 cycles/repeats per second

NB: The period of a wave is the reciprocal of its frequency:

Example.3

A wave signal was a period of 20 ms. Calculate the waves frequency.

T = 20 ms
= 20×10^{-3} s
f = ?

$$f = \frac{1}{T}$$

$$f = \frac{1}{20 \times 10^{-3}}$$

= 50 Hz

Example.4

Several insects can beat their wings at an amazing frequency of 2000 Hz. What period of time exists between each individual wing cycle?

f = 2000 Hz
T = ?

$$T = \frac{1}{f}$$

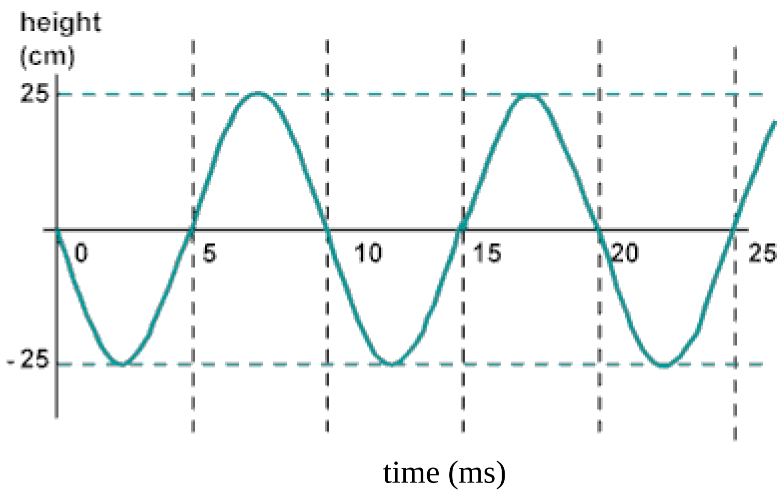
$$T = \frac{1}{2000}$$

$$= 0.0005 \text{ sec or } 0.5 \text{ ms}$$

Example.5

Examine the below wave cycle graph. Determine its:

i. Amplitude
ii. Period
iii. Frequency



Solutions

i. From off the graph it can be seen that the wave has an amplitude of 25 cm.
(ie. maximum vertical displacement from the initial rest point)

ii. From off the graph the time between two repeating points/events on the wave is 10 ms.

iii. f = ?
T = 10 ms
= 10×10^{-3} sec

$$f = \frac{1}{T}$$

$$f = \frac{1}{10 \times 10^{-3}}$$

$$= 100 \text{ Hz}$$

Wave speed (v) The speed that the wave travels. It is not the speed of the particles. Measured in ms^{-1}.

$$v = \frac{\lambda}{T} = \lambda f$$

Example.6

A tenor saxophone is used to generate a wave form of frequency 500 Hz. Given that the speed of sound in air at room temperature is 345 ms^{-1}, calculate sound waves wavelength.

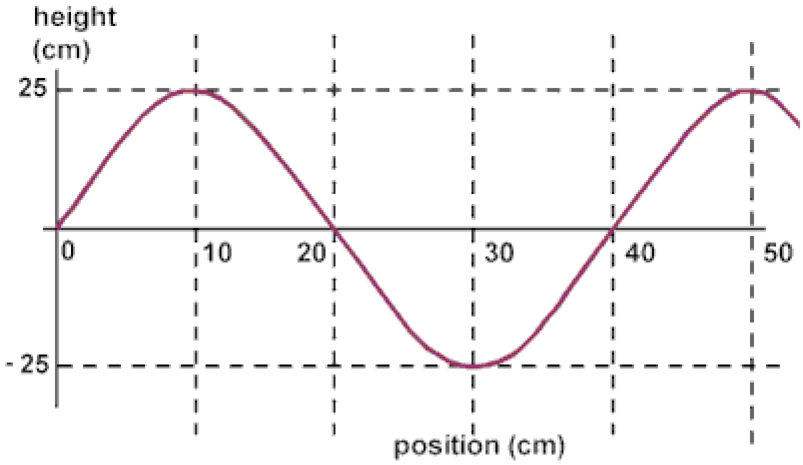
f = 500 Hz
v = 345 ms^{-1}
λ = ?

$$v = \lambda f$$
$$\lambda = \frac{v}{f}$$
$$= \frac{345}{500}$$
$$= 0.69 \text{ m}$$

Example.7

Examine the below wave cycle graph. Given the frequency of this wave is 500Hz, calculate the waves:

i. Amplitude
ii. Wavelength
iii. Speed



Solutions

i. From off the graph it can be seen that the wave has an amplitude of 25 cm.

ii. From off the graph the distance between two repeating points/events on the wave is 40 cm.

iii. v = ?
f = 500 Hz
λ = 40 cm

$$v = \lambda f$$
$$= 0.40 \times 500$$
$$= 200\ ms^{-1}$$

Exam Styled Questions

Questions 1 to 5 relate to the following information.

Question 1

A stretched spring, attached to two fixed ends, is compressed on the right end and then released, as shown in Figure 1. The resulting wave travels back and forth between the two fixed ends until it comes to a stop.

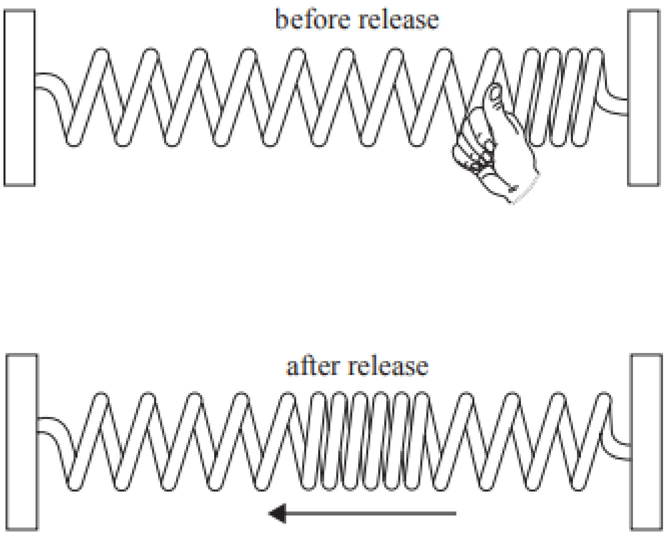


Figure 1

This wave is best seen as an example of:

A. a transverse wave.
B. a longitudinal wave.
C. diffraction.
D. an electromagnetic wave.

B	Vibration is along direction of the wave

The following information relates to Questions 2 and 3.

A loudspeaker producing a sound of constant frequency of 512 Hz is placed in a room, as shown in Figure 2. The speed of sound in air in the room is 330 ms^{-1}.

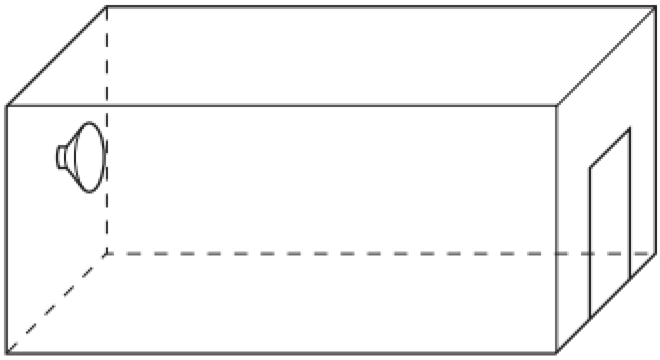


Figure 2

Question 2
Which of the following best gives the wavelength of the sound?

A. 0.33 m
B. 0.64 m
C. 1.55 m
D. 1.69 m

B	Using $v = \lambda f \quad \therefore \lambda = \frac{v}{f} = \frac{300}{512} = 0.64\ m$

Question 3
Which of the following statements best describes the behaviour of air immediately in front of the speaker?

A. It is moving away from the speaker at 330 ms^{-1}.
B. It is moving away from the speaker at 512 ms^{-1}.
C. It is oscillating vertically 512 times per second.
D. It is oscillating horizontally 512 times per second.

D	Sound is a longitudinal pressure wave.

A loudspeaker on a school oval is emitting a constant volume sound equally in all directions. The frequency of the sound is 100 Hz. Take the speed of sound to be 340 ms^{-1}.

Question 4

Which of the following is the best estimate of the wavelength of the sound?

A. 1.7 m
B. 3.4 m
C. 100 m
D. 340 m

B	Using $v = \lambda f \quad \therefore \lambda = \frac{v}{f} = \frac{340}{100} = 3.4\,m$