CHAPTER 13

Mechanical waves

CONTENTS

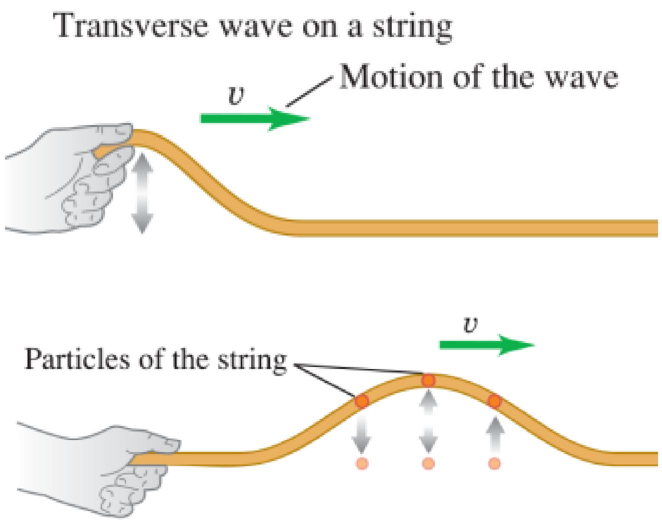
1. TYPES OF MECHANICAL WAVES

- A mechanical wave is a disturbance that travels through a medium from one location to another location without transporting matter (only transport energy)
- Example of mechanical waves: seismic waves, tsunami waves, sound waves, water waves, oscillation of a rope (or spring)…

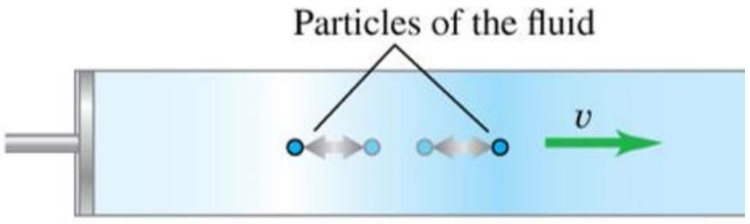
- Three types of mechanical waves can be introduced:

A. Transverse waves: In this type of wave, the particles of medium vibrate about their mean position perpendicular to direction of wave motion.

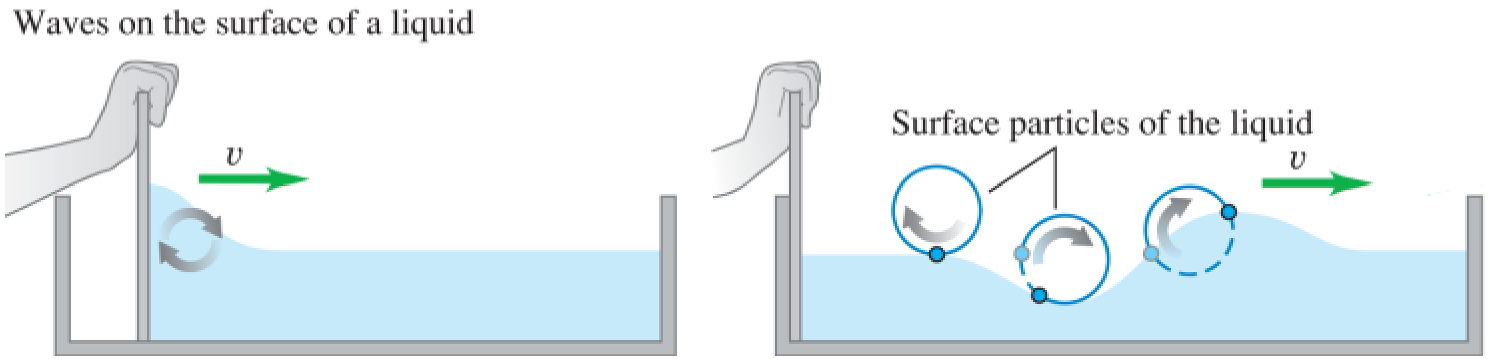
Examples: waves on strings, seismic S-waves, vibrations in a guitar string…



B. Longitudinal waves: In this type of wave, the movement of the particles is parallel to the motion of the energy, i.e. the displacement of the medium is in the same direction in which the wave is moving. Examples: vibration in spring, sound waves, pressure waves, tsunami waves...



C. Surface waves (combination of transverse and longitudinal): The displacements of the medium have both transverse and longitudinal components.



Example 11.1: Answer Check

1. Which of the following is a mechanical wave?

A- Radio waves	**B-** X-rays	**C-** light waves	**D- sound waves**	**E-** microwaves

2. The medium of a mechanical wave can be a

A- gas	**B-** liquid	**C-** solid	**D- all of the above**	**E-** none of the above

3. Types of mechanical waves include

A- longitudinal waves	**B-** transverse waves	**C-** surface waves	**D- all of the above**	**E-** none of the above

4. Examples of mechanical waves include all of the following except

A- ocean waves	**B-** waves in a rope	**C-** sound waves	**D-** seismic waves	**E- electromagnetic waves**

5. Mechanical waves in which particles of medium vibrate about their mean position perpendicular to direction of wave motion are called:

A- longitudinal waves	**B- transverse waves**	**C-** surface waves	**D-** sound waves	**E-** light waves

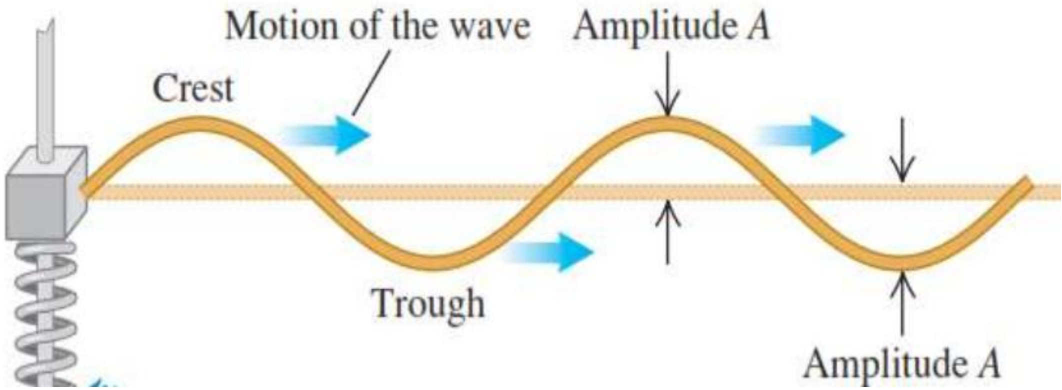
6. Mechanical waves in which particles of medium vibrate about their mean position parallel to the motion of the energy are called:

A- longitudinal waves	**B-** transverse waves	**C-** surface waves	**D-** sound waves	**E-** light waves

2. PERIODIC WAVES

- **If we give the free end of the string a periodic motion (Simple harmonic motion, SHM) , then each particle in the string also undergoes periodic motion as the wave propagates, and we have a <u>periodic wave</u>. This wave is a symmetrical sequence of crests and troughs which represents the maximum displacement of the particles of the wave undergoing a periodic motion.**

- **Any periodic wave can be represented as a combination of sinusoidal waves.**

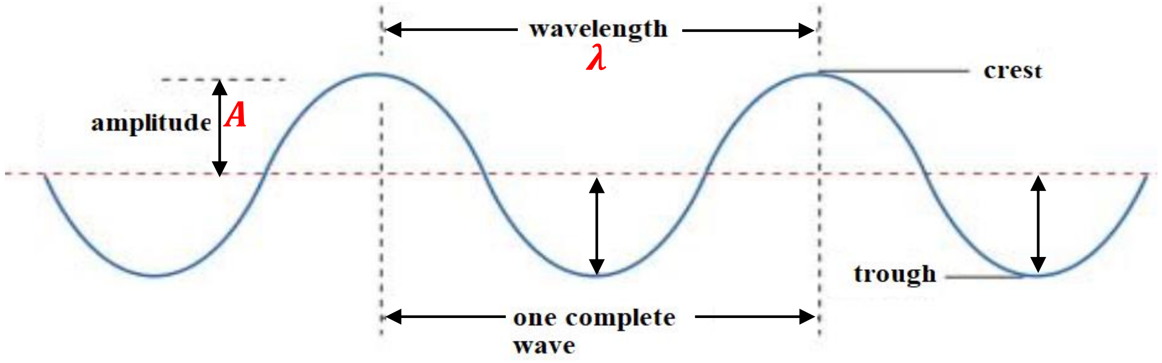


- **We can characterize periodic wave by five parameters:**

a- amplitude A:

The amplitude, measured in meters m, of the wave is the maximum displacement (top of a crest or the bottom of a trough) of the wave from its equilibrium from rest. Its one half the height difference between a crest and a trough.

Displacement-position graph



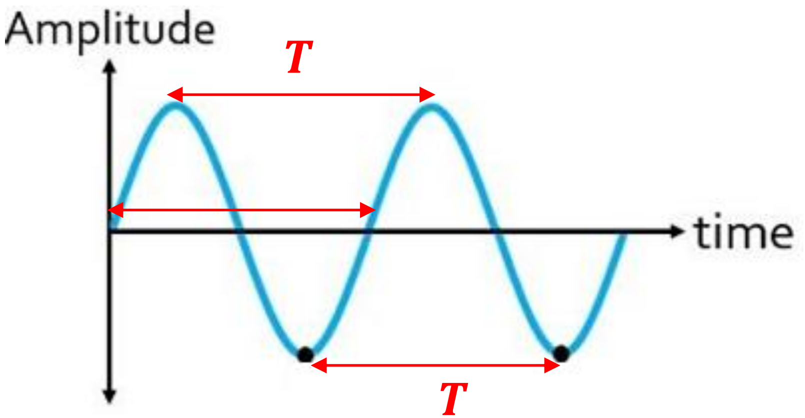
b- wavelength λ :

The wavelength λ of a periodic wave, measured in meters m, is the length of one complete wave pattern (the distance over which the wave's shape repeats). It is the distance between consecutive corresponding points of the same phase on the wave, such as two adjacent crests, troughs, or zero crossings.

c- period T :

The wave period is the amount of time it takes to complete one wave cycle. Displacement-time graphs can be used to display the period of the wave T

Displacement-time graph



d- Wave frequency f :

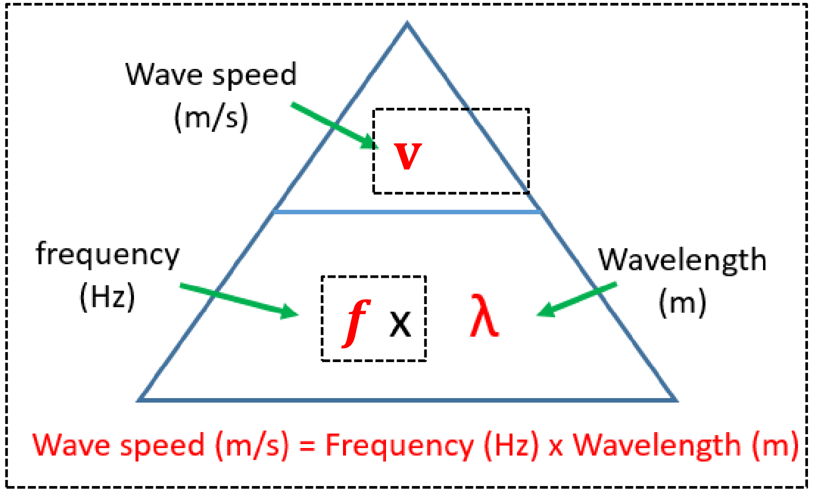
Wave frequency f is the number of waves that pass a fixed point in a given amount of time:

$$f = \frac{1}{T}$$ (The SI unit of the wave frequency is the hertz (Hz))

e- Wave speed v :

The wave speed v is a measure of the total distance travelled by the wave in a given time. Wave speed is the product of the frequency f and the wavelength λ :

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



Example 11.2:

1. An object attached to the one end of spring makes 20 vibrations in $10\ s$, what is its period?

$$\text{Period} = \frac{\text{time taken}}{\text{number of vibrations completed}}, \quad T = \frac{10}{20} = 0.5\ s$$

2. If the time period of a wave is $4\ s$, what is the frequency of the wave?

$$f = \frac{1}{T} = \frac{1}{4} = 0.25\ \text{Hz}$$

3. An ocean wave usually occurs at a frequency of $0.2\ \text{Hz}$. What is the period of each wave?

$$T = \frac{1}{f} = \frac{1}{0.2} = 5\ s$$

4. If a wave has a frequency of $5\ \text{Hz}$ and wavelength of $1.5\ m$, what is its speed ?

$$\text{v} = f\lambda = 5 \times 1.5 = 7.5\ m/s$$

5. A wave is travelling at a speed of $12\ m/s$ and has a frequency of $5\ \text{Hz}$, what its wavelength?

$$\text{v} = f\lambda \implies \lambda = \frac{\text{v}}{f} = \frac{12}{5} = 2.4\ m$$

Example 11.3: Answer Check

1. The SI unit of frequency is

A- m/s	**B-** s	**C-** Hz	**D-** s/Hz	**E-** $m.s$

2. The distance between adjacent crests or troughs is known as

A- amplitude	**B-** wave speed	**C-** wave energy	**D-** wavelength	**E-** wave medium

3. the distance from wave's rest to its crest is called

A- amplitude	**B-** wavelength	**C-** frequency	**D-** trough	**E-** wave period

4. The number of waves that pass a fixed point in a given amount of time is called

A- amplitude	**B-** wavelength	**C-** frequency	**D-** trough	**E-** wave period

5. The highest point of the wave is called:

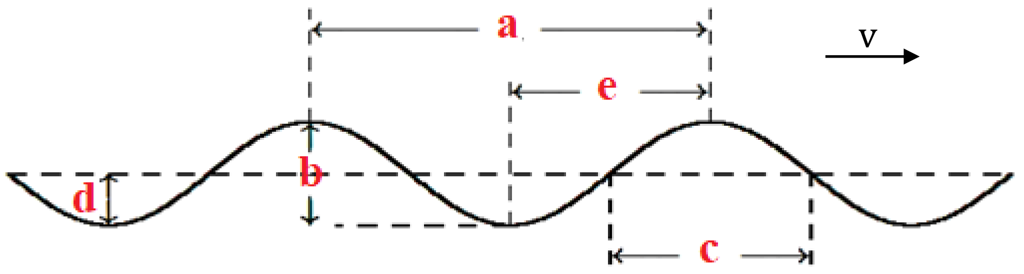
A- trough	**B-** wavelength	**C-** frequency	**D-** amplitude	**E-** crest

6. The lowest point of the wave is called:

A- trough	**B-** wavelength	**C-** frequency	**D-** amplitude	E- crest

7. A wave is traveling toward the right as shown in the diagram below. Which letter correctly labels the amplitude of this wave?

A- a
B- b
C- c
D- d
E- f

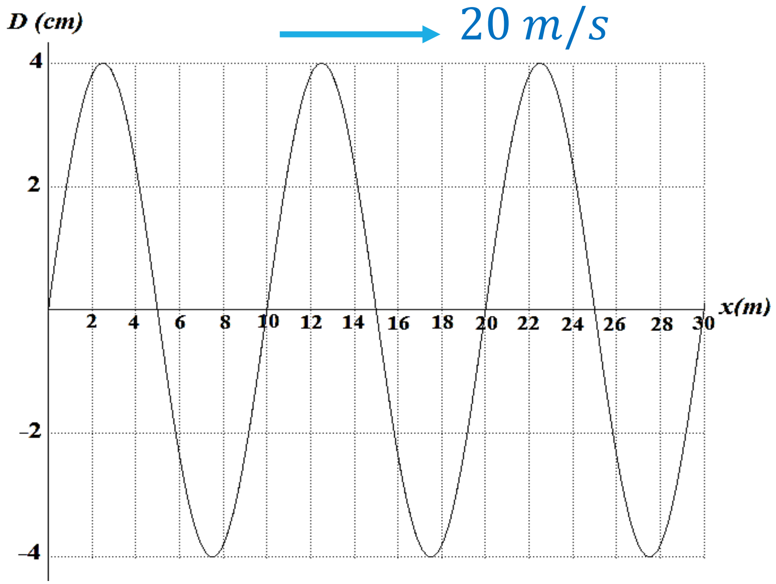


8. Which letter correctly labels the wavelength of the wave in the diagram above (Question# 7)?

A- a	**B-** b	**C-** c	**D-** d	**E-** e

9. A mechanical wave is travelling to the right at $20\ m/s$ as shown in the diagram below. How many completed waves are shown in this diagram?

A- 1
B- 2
C- 3
D- 4
E- 5



Explanation: One complete wave cycle is referred to as a wavelength

10. The amplitude A of the wave in the diagram above (Question #9) is

A- $2\ cm$	**B-** $4\ cm$	**C-** $5\ m$	**D-** $8\ cm$	**E-** $10\ m$

11. The wavelength λ of the wave in the diagram above (Question #9) is

A- $2\ cm$	**B-** $4\ cm$	**C-** $5\ m$	**D-** $8\ cm$	**E-** $10\ m$

12. The frequency f of the wave in the diagram above (Question #9) is

A- 0.5 Hz	**B-** 2 Hz	**C-** 6 Hz	**D-** 8 Hz	**E-** 12 Hz

Explanation:

10- The amplitude is the distance from wave's rest to its crest (or trough): $A = 4\ cm$

11- The easiest way is to consider that the wavelength is the distance from the origin to the second zero crossing: $\lambda = 10\ m$

12- The frequency:

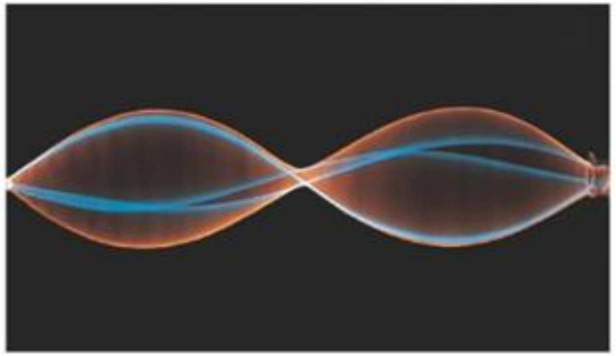
$$\text{v} = f\lambda \Longrightarrow f = \frac{\text{v}}{\lambda} = \frac{20}{10} = 2\ \text{Hz}$$

3. STANDING WAVES ON A STRING

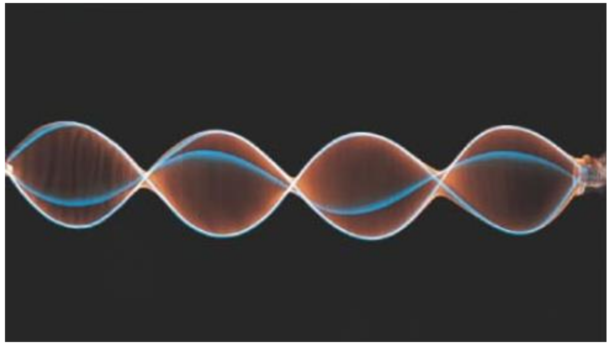
- **The standing waves are formed by the superposition of two harmonic waves of equal amplitude and frequency travelling through the medium in the opposite direction. The standing waves are also known as stationary waves. These waves are localized and not progressive, hence the name stationary waves.**

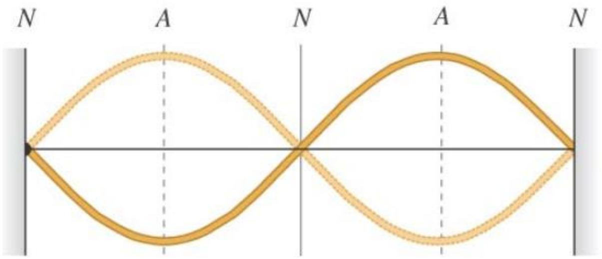
- **Standing waves are characterized by nodes and antinodes. The amplitude of vibration of the particle is maximum at the antinodes and minimum at the nodes. The vibration within a string can produce a variety of patterns. Each pattern corresponds to the vibration that takes place at a particular frequency and it is called harmonic**

String is one wavelength long



String is two wavelengths long





N = **nodes:** points at which the string never moves

A = **antinodes:** points at which the amplitude of string motion is greatest