Introduction to the physics of waves

Concept of disturbance

1. Definition

A **disturbance** is any temporary, local change in the physical characteristics of an environment.

2. Nature of the disturbance

- A disturbance is said to be **mechanical** when it modifies the medium directly.
- A disturbance is said to be **electromagnetic** (EM) when it modifies the magnetic and electric fields prevailing within the medium.

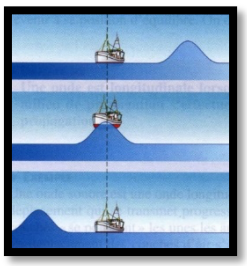
Note: In a vacuum, only EM disturbances (like light) can exist.
Only material media (such as air) can undergo mechanical disturbance

Propagation of a disturbance

1. Definition

When a disturbance propagates (i.e. when it moves away from its source), it forms a progressive wave.

Note: A mechanical disturbance will form a mecanical wave. An EM disturbance will form an EM wave.
The medium in which the wave propagates is called medium of propagation.



2. What does a wave carry?

A wave consists in the propagation of a disturbance in a medium, without the medium itself moving. Therefore, a wave **doesn't carry matter**.
However, a wave can act on the medium of propagation, which requires energy. Therefore, a wave **carries energy**.

3. Nature of a wave

A disturbance propagates in all available directions.

- When the disturbance can only travel along one unique direction, the wave is said unidimensional (1D).

Ex: Vibration on the cord of a guitar

- When the disturbance can travel in the 2 directions of a plane, the wave is said to be bidimensional (2D).

Ex : A wave at the surface of the water

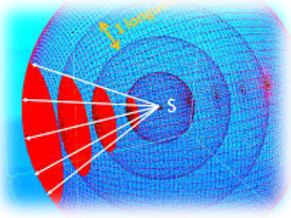
- When the disturbance can travel in the 3 directions of space, the wave is said to be tridimensional (3D).

Ex: Sound in air

Note: Whatever the nature of a wave, its propagation is studied in 1 direction only, called the direction of propagation.

4. Concept of wavefront

The **wavefront** is the set of points in the propagation medium at which the same disturbance is maximal.



5. Propagation speed of a wave

For a disturbance travelling at constant speed:

$$\mathbf{v = \frac{SM}{\tau}}$$

with S the source of the disturbance, M the point where the disturbance is studied and τ the time taken by the disturbance to propagate from S to M.

Note: The propagation speed of a wave depends on the nature of the medium of propagation.
The propagation speed of an EM wave in vacuum is the highest possible speed than can be reached by anything. It is called celerity, c.

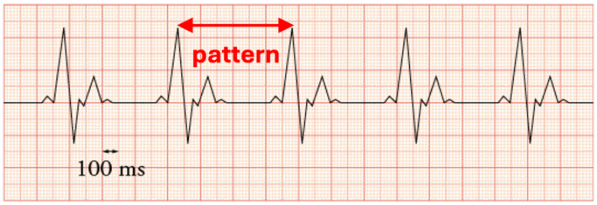
$$c = 3.00 \times 10^{8}\ m.s^{-1}$$

Periodic travelling waves

1. Definition

A phenomenon is **periodic** when it repeats identically at constant time intervals.

Ex : Electrocardiogram



This phenomenon is periodic: the same pattern repeats itself regularly in time.

2. Features of a periodic wave

a. Temporal periodicity

The time interval between 2 wavefronts at a point in space is called **timeperiod**, and is noted **T**.

Note:

- *Frequency, f, is also often used. It corresponds to number of timeperiods per unit time. It is measured in hertz (Hz) when time is in seconds (s).*

$$\mathbf{f(Hz) = \frac{1}{T(s)}}$$

- *The timeperiod of a wave only depends on the source of the disturbance, and doesn't depend on the medium through which it propagates.*

b. Spatial periodicity

When a wave has a timeperiod T, a disturbance has travelled a distance **λ = vT** when the next disturbance is created. This distance λ is called **wavelength**. It is the **space-period** of the wave. 2 consecutive wavefronts are separated by distance λ.

Note: The wavelength depends on the propagation speed of the wave, therefore on the nature of the medium of propagation, and on the timeperiod of the wave, therefore on the source of the disturbance.

c. Concept of double periodicity

A periodic wave is defined by both its timeperiod T and its wavelength λ.
It is said to have a **double periodicity**.