IB Physics Topic C2 The Wave Model; SL & HL

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1 Parts and Attributes of a Wave

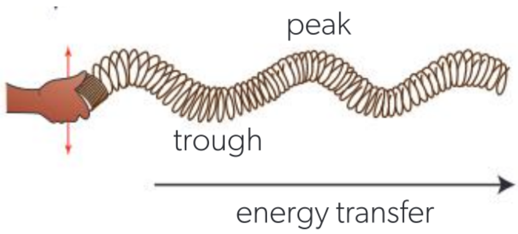

Figure 1: Transverse wave

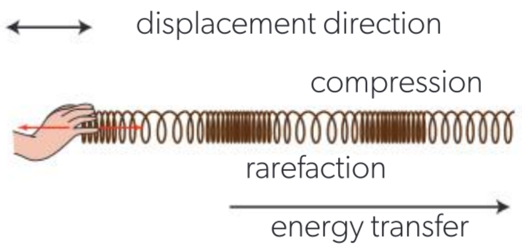

Figure 2: Longitudinal wave

A wave has the following attributes:

- Amplitude x_0: maximum displacement from the equilibrium position.
- Frequency f: number of oscillations per unit time.
- Time period T: time taken for one complete oscillation.
- Wavelength λ: distance between two consecutive points in phase.
- Wave speed v: speed at which the wave propagates.

These properties are linked by the following equation

$$v = \lambda f = \frac{\lambda}{T}$$
$$fT = 1$$

2 Graphing Waves

Transverse waves and longitudinal waves differ in their directions of energy transfer/particle movement:

- Transverse waves: perpendicular to the direction of wave propagation.
- Longitudinal waves: parallel to the direction of wave propagation.

2.1 Displacement-Time Graphs

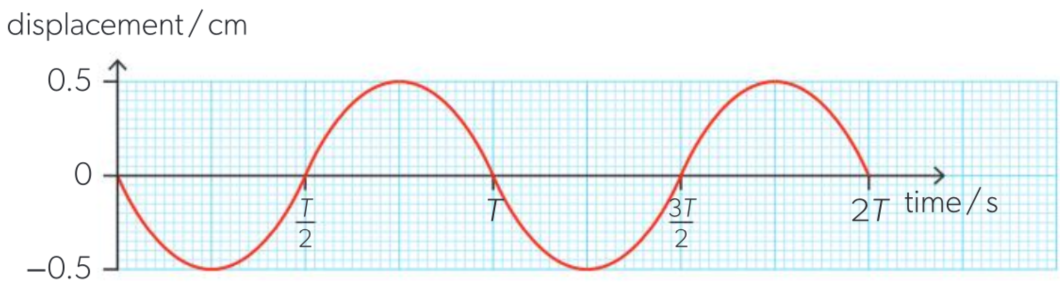

Figure 3: Displacement-time graph

This provides information about the movement of one particular particle on the wave, but it is also the same for every particle on the wave.

2.2 Displacement-Distance Graphs

2.2.1 Transverse Waves

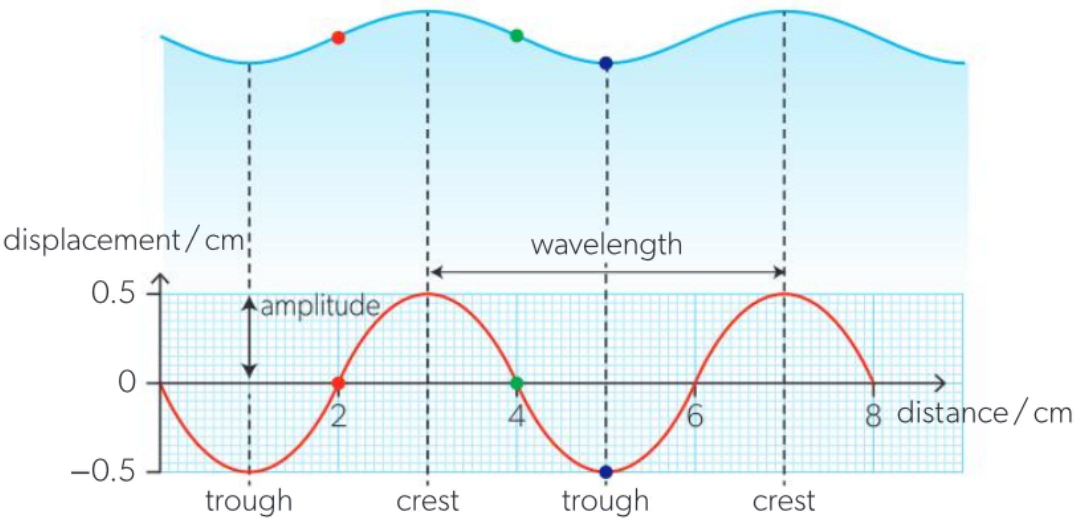

Figure 4: Displacement-distance graph for transverse waves

- This can be seen as a snapshot of the plot of the position of particles on the wave at a given instant.
- What cannot be inferred from the graph is the time period or frequency of the wave unless the wave speed is given.

2.2.2 Longitudinal Waves

Recall that particles in a longitudinal wave essentially move left and right.

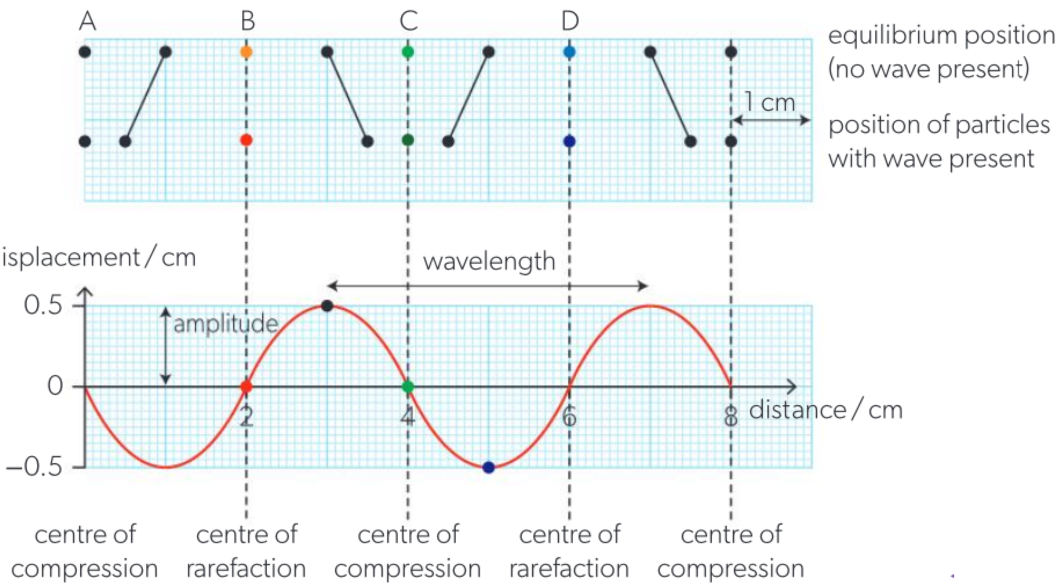

Figure 5: Displacement-distance graph for longitudinal waves

The second row reflects the actual position of the particles at this particular instant. Here is how the plot of them is obtained:

- For each point, find its corresponding point on the curve below.
- If the point is below the x-axis, the curve would have been displaced in the negative direction, that is, on the distance x axis, a movement to the left.
  - Take the second point in the top row as an example
  - Its corresponding point on the curve below is at -0.5.
  - This means that it is displaced by 0.5 units to the left, horizontally.
- If the point is above the x-axis, the curve would have been displaced in the positive direction, that is, on the distance x axis, a movement to the right.

As a general rule of thumb:

- The centers of rarefraction and compression are at the roots of the curve.
  - If gradient at a root is positive (increasing), then, it is a center of rarefraction.

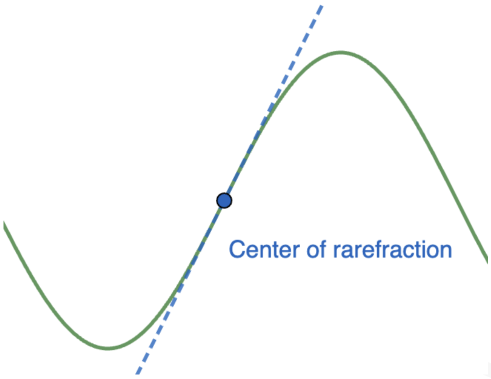

Figure 6: Center of rarefraction

  - Inversely, if the gradient at a root is negative (decreasing), then, it is a center of compression.

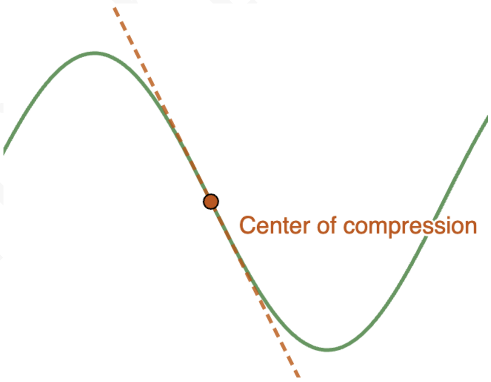

Figure 7: Center of compression

More observations:

- Neither rarefraction nor compression occurs at the peaks.

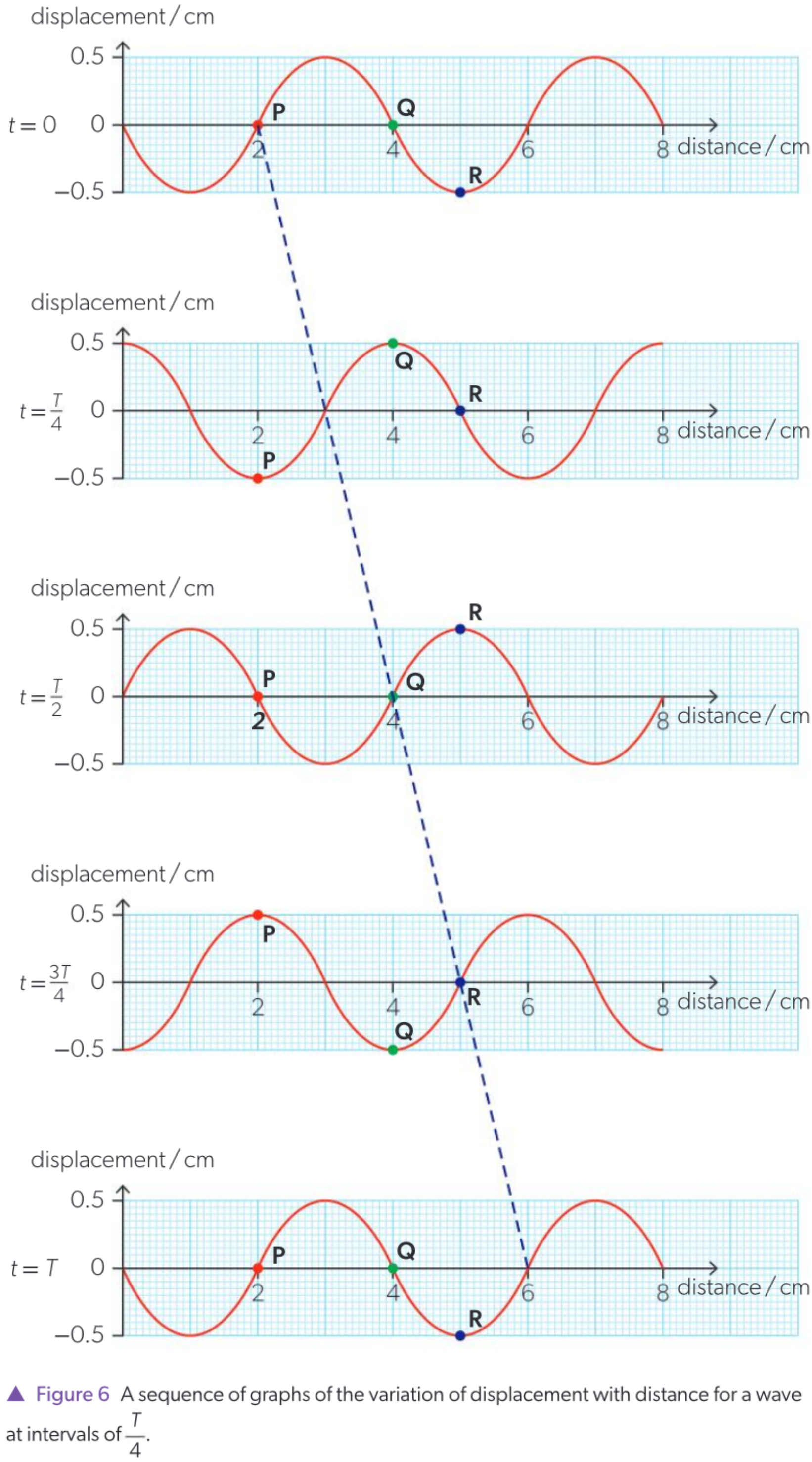

Figure 8: A sequence of snapshots

3 Mechanical Waves

Mechanical waves can be both transverse and longitudinal. They require a medium to propagate through.

- Gases and liquids cannot support transverse waves due to the lack of a restoring force, but solids can transmit both wave types due to strong atomic bonds.

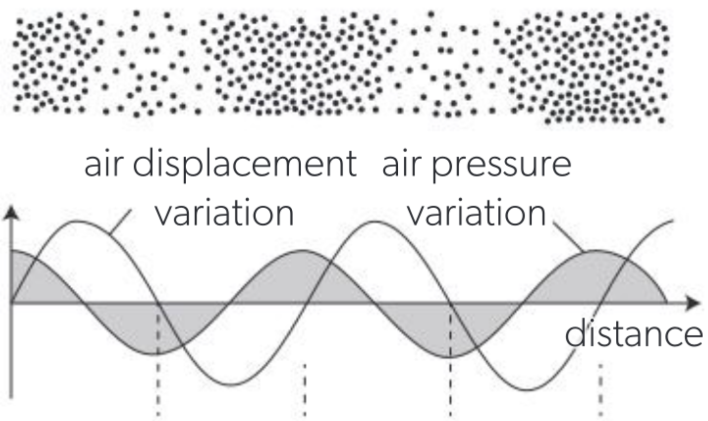

Figure 9: Sound wave

Sound from a smartphone loudspeaker creates alternating high- and low-pressure regions in the air, which travel as a longitudinal wave to the listener's ear. These pressure variations correspond to compressions and rarefactions in the wave. As the wave spreads out, its amplitude decreases due to energy loss, partly from heating the air.

Each adjacent pair of compressions and rarefactions is a quarter of a wavelength away, or $\frac{\pi}{2}$ out of phase.

4 E.M. Waves

All E.M. waves share the following properties:

- Are transverse
- Can travel through a vacuum
- Travel at the speed of light $c = 3.00 \times 10^8 \mathrm{m\,s^{-1}}$ in a vacuum
- Consist of oscillating electric and magnetic fields perpendicular to each other and the direction of wave propagation

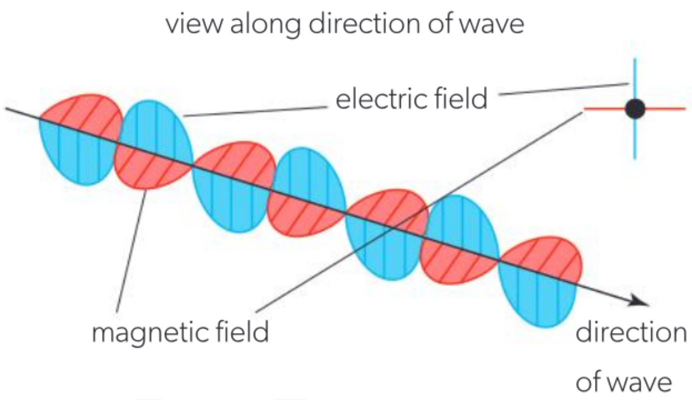

Figure 10: E.M. wave

- They are generated when accelerated electrons or other charged particles emit photons due to energy changes.
- Like all waves, they have frequency and wavelength; however, only the wavelength changes in different media, while frequency remains constant.

4.1 The E.M. Spectrum

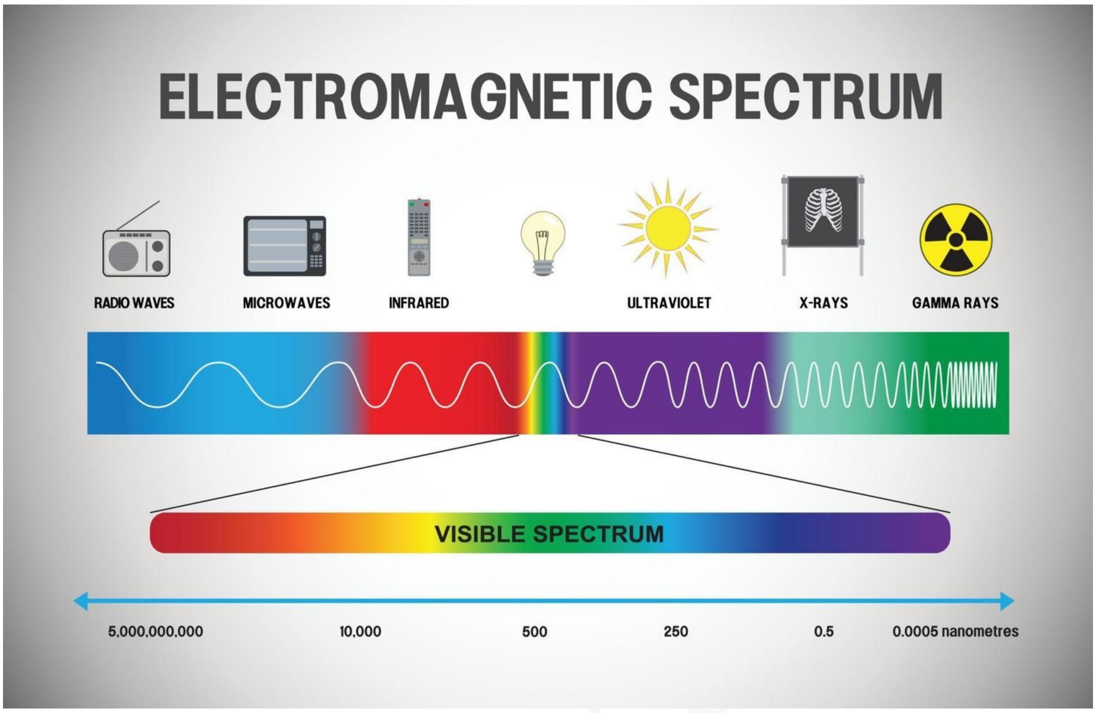

Figure 11: E.M. spectrum