Progressive Waves

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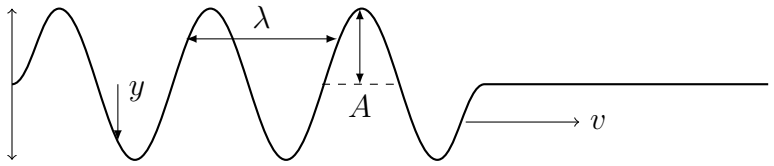
All waves transfer energy from one point to another without there being any transfer of matter between the points. We shall mainly deal with waves which are advancing in a fixed direction, known as *progressive* or *travelling waves*[1].

Waves come in two main types: mechanical and electromagnetic. Mechanical waves require a material medium for their propagation, e.g. water waves, acoustic waves, waves in stretched strings. Electromagnetic waves, on the other hand, require no medium, and can travel in a vacuum (indeed, their progress is impeded to some degree by the presence of matter). They form a continuous electromagnetic spectrum of waves, including light, radio waves and X-rays.

Definitions

These definitions refer to mechanical waves which involve the disturbance of particles (whereas electromagnetic waves can be viewed as a disturbance of electric and magnetic fields). The particles are displaced from their mean positions as the wave motion travels past them. Consider regular waves on a string which are moving from left to right and imagine a snapshot of these waves at one instant in time:



At this instant, each small segment of the string is displaced either upwards or downwards, and it will oscillate (change regularly between two extremes) as each 'crest' and 'trough' passes.

- **Displacement** y – the distance of a particle from its mean position

[1]The other kind, where waves are reflected at boundaries so that advancing and returning waves are superimposed, are known as stationary waves.

- **Amplitude** A – the maximum displacement of a particle
- **Wavelength** λ – the shortest distance between two particles which are at the same point in their oscillation and moving in the same direction (i.e. shortest distance between two particles which are in phase)
- **Frequency** f – the number of waves passing a point per second, or the number of oscillations of any particles per second
- **Speed** v – If f waves are emitted each second, each with a wavelength λ, then the wave speed is given by

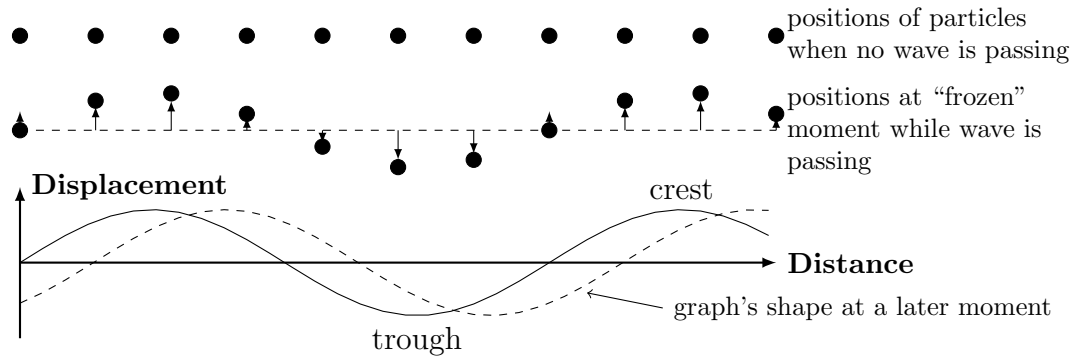
$$v = f\lambda.$$

Longitudinal and transverse waves

In all waves, the wave motion is a disturbance which is passed along from one position to another. Usually this motion is repeated over and over, and oscillations occur periodically to and fro from a mean position.

Transverse waves

Waves in which the oscillations occur in a direction perpendicular to the direction of wave movement, e.g. water waves (oscillation of particles) and electromagnetic waves (oscillation of fields).



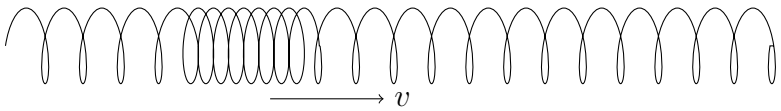
Displacement/distance graph for particles in a transverse wave at two instants

The *crest* is where the wave causes maximum positive displacement, and the *trough* is where the wave causes maximum negative displacement. The crest and troughs of some waves, e.g. water waves, can be seen as they travel.

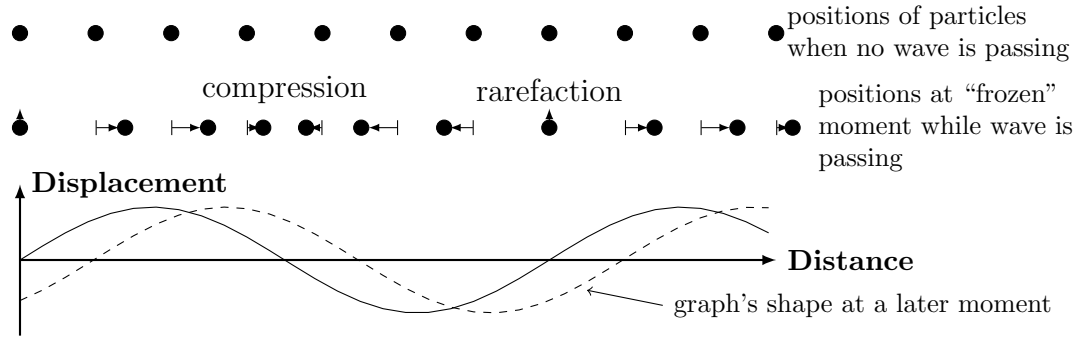
Longitudinal waves

Waves in which the oscillations are in the same direction as the direction of wave movement, e.g. waves on a spring. These are all mechanical waves, meaning that it is the particles of a

substance which are displaced.



A good example of longitudinal waves is that of sound. Such a waves consists of areas where the particles are closer together (and have higher density or—in a gas—pressure) which are known as *compressions*, and areas where the particles are further apart (thus having lower density) called *rarefactions*.



Displacement/distance graph for particles in a longitudinal wave at two instants