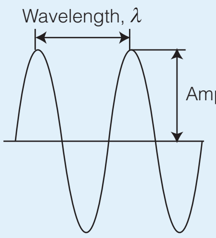
The chemist's toolkit 11 Waves

A wave is characterized by its **wavelength**, λ (lambda), the distance between consecutive peaks of the wave and its **amplitude**, A, the maximum displacement (see the first sketch). The mathematical form of a stationary wave in the x-direction is

$$\psi(x) = A\sin(2\pi x/\lambda) \quad \text{Wave in the } x\text{-direction}$$



If this wave is travelling to the right (positive x) at a speed v, the height of the wave at a certain point oscillates between A and $-A$. Its **frequency**, ν (nu), is the rate at which the height returns to its initial value. Frequency is reported in hertz, Hz, with 1 Hz = 1 s^{-1} (that is, 1 cycle per second). The wavelength and frequency of the wave are related by:

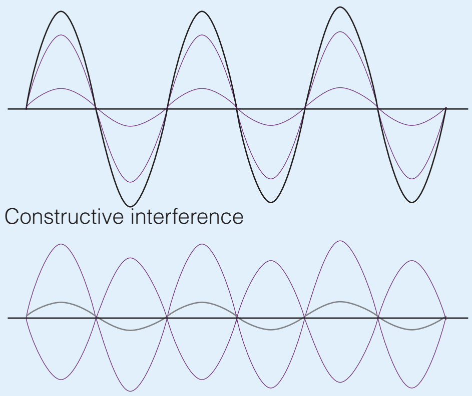
$$\lambda\nu = v \quad \text{The relation between wavelength and frequency}$$

It is also common to describe a wave in terms of its **wavenumber**, $\tilde{\nu}$ (nu tilde), which is defined as

$$\tilde{\nu} = \frac{1}{\lambda} = \frac{\nu}{v} \quad \text{Wavenumber [definition]}$$

Thus, wavenumber is the reciprocal of the wavelength and can be interpreted as the number of wavelengths in a given distance.

A characteristic property of waves is that they interfere with one another, which means that they result in a greater amplitude where their displacements add and a smaller amplitude where their displacements subtract (second sketch). The former is called **constructive interference** and the latter **destructive interference**.



The regions of constructive and destructive interference show up as regions of enhanced and diminished amplitude. The phenomenon of **diffraction** is the interference caused by an object in the path of waves and occurs when the dimensions of the object are comparable to the wavelength of the radiation.

Electromagnetic radiation consists of oscillating electric and magnetic disturbances that propagate as waves. The two components of an electromagnetic wave are mutually perpendicular and are also perpendicular to the direction of propagation (see sketch). Electromagnetic waves travel through a vacuum at a constant speed called the **speed of light**, c, which has the defined value of exactly $2.997\,924\,58 \times 10^8$ m s^{-1}. In a medium of refractive index n_r, the speed of propagation is reduced to c/n_r. For air, n_r = 1.0; for water n_r = 1.3. The frequency (and therefore the colour) when light enters a medium is unchanged but the wavelength is increased from λ to $n_r\lambda$. Note that the refractive index depends on the frequency. Light, which is electromagnetic radiation that is visible to the human eye, has a frequency range from 700 THz (violet light, 420 nm in a vacuum) to 450 THz (red light, 700 nm in a vacuum).