Topic 11 - Wave Motion

A **progressive wave** is one that transfers energy from one point to another in the direction of wave propagation

- particles oscillate about their equilibrium positon

1 Wave terminology

- **Displacement** of a particle is the distance travelled in a specific direction from its equilibrium position
- **Amplitude, A** of a wave is the magnitude of maximum displacement of a particle from eqm position
- **Period, T** of a wave is the time taken for a particle to complete one oscillation
- **Frequency, F** is the numebr of oscillations per unit tiem made by a particle of a wave,

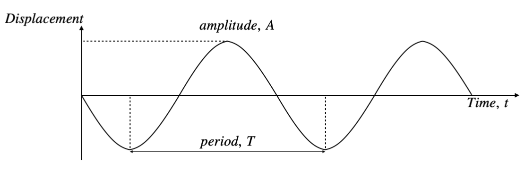
$$T = \frac{1}{f}$$

- **Wavelength** λ is the distance between two consecutive points which are in phase
- **Speed, v** is the distance travelled by a wave per unit time

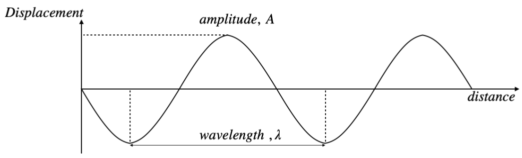
$$v = \lambda f = \frac{\lambda}{T}$$

- **Phase / Phase angle,** ϕ is a measure of the fraction of a cylce that has been completed by an on oscillating particle or by a wave.
- **Phase difference** between two partciles in a wave or between two waves at a point is the measure of the fraction of a cycle which one is ahead of the other
  - **In phase**: particles exercute the same motion at the same time, $\phi = 0$
  - **Out of phase**: partciles that are at different stages of motion
  - **Anti-phase**: execute motions that are out of phase by π rad
- **Wavefront** is a line or surface joining points on a wave that are in phase. Wave travels in a direction perpendicular to the wavefront

1.1 graphs of waves



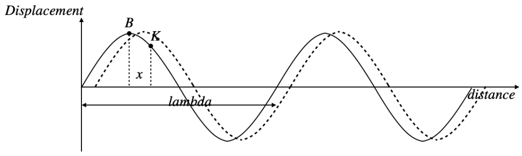
Displacemennt - time graph
graph represents displacement of **one** particle over time



Displacement - distance graph
graph represents the displacement of **all** particles at a particular instant

1.2 representation of phase difference

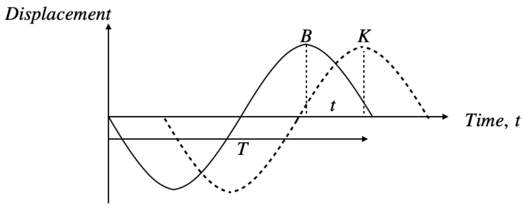
For a wave travelling to the right



Displacemennt - distance graph
B is on its way down and K is on its way up
K is lagging B by a phase differene of ϕ or (B is ahead of K by ϕ), $0 \leq \phi\pi$

$$\frac{x}{\lambda} = \frac{\phi}{2\pi}$$

$$\phi = 2\pi\frac{x}{\lambda}$$



Displacemennt - time graph
K is lagging B by a phase differene of ϕ or (B is ahead of K by ϕ), $0 \leq \phi\pi$

$$\frac{t}{T} = \frac{\phi}{2\pi}$$

$$\phi = 2\pi\frac{t}{T}$$

2 Wave Intensity

The **intensity** of a wave is defined as the rate of transfer of energy per unit area, where the area measured is perpendicular to the direction of energy transfer

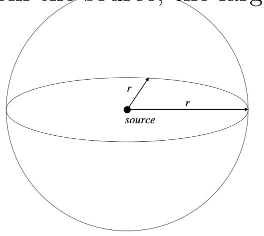
$$I = \frac{P}{S}$$

where P is the power of the source, and S is the surface area of the wave front

$$I = kA^2$$

2.1 Point source and inverse square

for a point source emitting waves that spread out radially, with a spherical wavefront, the further away from the source, the larger the area where energy is being distributed



$$I = \frac{P}{4\pi r^2}$$

Hence for a constant power, the inverse square law is known as

$$I = \frac{k}{r^2}$$

3 Transverse and longitudinal waves

A **transverse wave** is one in which particles oscillate in a direction perpendicular to the direction of energy transfer

A **longitudinal wave** is one in which the particles oscillate in a direction parallel to the direction of energy transfer

3.1 EM waves

Important properties

- Do not require medium to propagate, can move through vacuum
- EM waves travel at a speed of $c = 3.00 \times 10^8 ms^{-1}$ in vacuum
- EM waves are transverse waves and can hence be polarised

Radiation type	Radio	Microwave	Infrared	Visible	Ultraviolet	X-ray	Gamma ray
Wavelength (m)	10^3	10^{-2}	10^{-5}	0.5×10^{-6}	10^{-8}	10^{-10}	10^{-12}
Frequency(Hz)	10^4	10^8	10^{12}	10^{15}	10^{16}	$1o^{18}$	10^{20}

3.2 Sound waves

- **compression**: regions where particles are compressed together, regions of high pressure
- **rarefraction**: regions where particles are spread apart, regions of low pressure

4 polarisation

Polarisation is a phenomenon where the oscillations of the wave particles in a transverse wave are restricted to one direction only and this direction is perpendicular to the direction of wae propagation or energy transfer

- hence does not apply to longitudinal waves

4.1 Intensity

When unpolarised light is incident on an ideal polariser,

$$I = \frac{I_0}{2}$$

4.2 Malus' Law

Malus' Law states that the intensity of a beam of plane polarised light after passing through a plane polariser varies with the square of the cosine of the angle through which the polariser is rotated from the position that gives maximum intensity

$$I = I_0 cos^2\theta$$

When plane polarised light passes through a second polariser with its polarising axis at an angle of θ from the first polariser, the resultant amplitude is

$$A = A_0 cos\theta$$

Since

$$\begin{aligned} I &= kA^2 \\ &= k(A_0 cos\theta)^2 \\ &= kA_0^2 cos^2\theta \\ &= I_0 cos^2\theta \end{aligned}$$