4 Waves

4.1 Waves and Vibrations

Waves that pass through a substance are vibrations that pass through a substance, they are often referred to as **mechanical waves**. When waves progress through a substance, the particles of the substance vibrate in a certain way which makes nearby particles vibrate in the same way and so on.

- Sound waves
- Seismic waves
- Waves on strings

Electromagnetic waves are oscillating electric and magnetic fields that progress through space without the need for a substance - the vibrating **electric field** generates a vibrating **magnetic field**, which generates a vibrating electric field further away, and so on.

- Radio waves
- Microwaves
- Infrared radiation
- Light
- Ultraviolet radiation
- X-rays
- Gamma radiation

Longitudinal waves are waves which the direction of vibration of the particles is parallel to the direction in which the wave travels.

- Sound waves
- Primary seismic waves

Transverse waves are waves which the direction of vibration is perpendicular to the direction in which the wave travels.

- Electromagnetic waves
- Secondary seismic waves
- Waves on a string

Polarisation

Transverse waves are **plane-polarised** if the vibrations stay in one plane only. Otherwise if vibrations changes from one plane to another, then the waves are **unpolarised**.

Longitudinal waves cannot be polarised.

- If **unpolarised light** (e.g. light from a filament lamp) passes through a **polaroid filter**, the transmitted light is polarised.
  - The filter only allow through light which vibrate in a certain direction.
  - According to the alignment of its molecules.
- If unpolarised light is passed through **two polaroid filters**, the transmitted **light intensity** changes if one polaroid is turned relative to the other one.
  - The filters are said to be **cross** when the transmitted intensity is a minimum.
  - At this position, the polarised light from the first filter cannot pass through the second filter - as the alignment of the second filter is 90° to the first.

The **plane of polarisation** of an electromagnetic wave is defined as the plane in which the electric field oscillates.

Polaroid sunglasses reduces the glare of light reflected by water or glass.

- Light reflected by water or glass is **polarised**.
- The intensity of reflected light is reduced when it passes through the polaroid sunglasses.

4.2 Measuring Waves

- The **displacement** of a vibrating particle is its distance and direction from its **equilibrium position**.
- The **amplitude** of a wave is the **maximum displacement** of a vibrating particle.
  - Height of a wave crest for transverse waves.
- One **complete cycle** of a wave is from maximum displacement to the next maximum displacement.
- The **period** of a wave is the time for one complete wave to pass a fixed point.
- The **frequency** of a wave is the number of complete waves passing a point per second.
  - Or the **number of cycles of vibration** of a particle per second.

$$\text{Time period } T = \frac{1}{f}$$
$$\text{Wave speed } c = f\lambda$$

- The **phase** of a vibrating particle at a certain time is the fraction of a cycle it has completed since the start of the cycle.
- The **phase difference** between two particles vibrating at the same frequency is the fraction of a cycle between the vibrations of the two particles.

$$\text{Phase difference} = \frac{2\pi d}{\lambda}$$

4.3 Wave Properties 1

A **ripple tank** can be used to study wave properties - a shallow transparent tray of water with **sloping sides**, which prevent waves reflecting off the sides of tank.

- **Wavefronts** are lines of constant phase difference (crests).
- The direction in which a wave travels is at right angles to the wavefront.

Reflection

Straight waves directed at a certain angle to a hard surface **reflect off at the same angle** - the angle between the reflected wavefront and the surface is the same as the angle between the incident wavefront and the surface.

Also observed when a **light ray** is directed at a **plane mirror** - the angle between the incident ray and the mirror is equal to the angle between the reflected ray and the mirror.

Refraction

When waves pass across a boundary at which **wave speed changes**, the **wavelength also changes**. If the wavefronts approach at an angle to the boundary, they change direction as well as changing speed.

- Water waves in a ripple tank refracts when they pass across a boundary from deep to shallow water. Because they move more slowly in shallow water therefore changes direction.
- **Refraction of light** is observed when a light ray is directed into a glass block at an angle. The light ray changes direction when it crosses the glass boundary because it travels more slowly in glass than in air.

Diffraction

Diffraction occurs when waves **spread out after passing through a gap** or round an obstacle.

Can be seen in a ripple tank when straight waves are directed at a gap.

- The **narrower the gap**, the more the waves spread out.
- The **longer the wavelength**, the more the waves spread out.

Consider each point on a wavefront as a **secondary emitter of wavelets**

- The wavelets from the points along a wavefront **travels only in the direction which the wave is travelling**.
- The combine to **form new wavefronts** beyond the gap.