# WAVES (Trilogy)

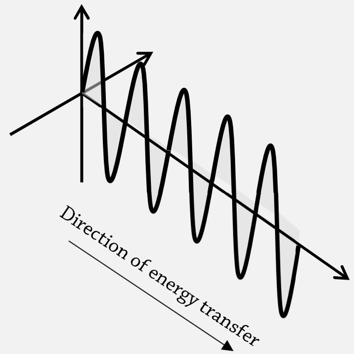
## TRANSVERSE AND LONGITUDINAL WAVES

A wave is the **transfer of energy** without the transfer of matter. Waves can be categorised into two types:

1. Transverse
2. Longitudinal

### Transverse waves

Transverse waves oscillate **perpendicular** to the direction of energy transfer.



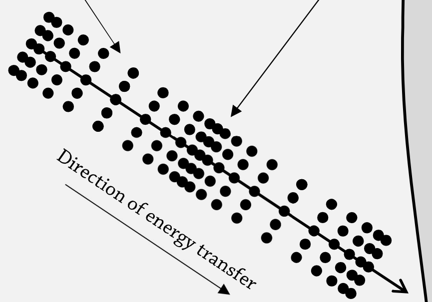

**EXAMPLE!**

- Ripples on the surface of water
- Electromagnetic radiation (light)
- Vibrations on a string (such as a guitar string)

### Longitudinal waves

Longitudinal waves oscillate **parallel** to the direction of energy transfer.

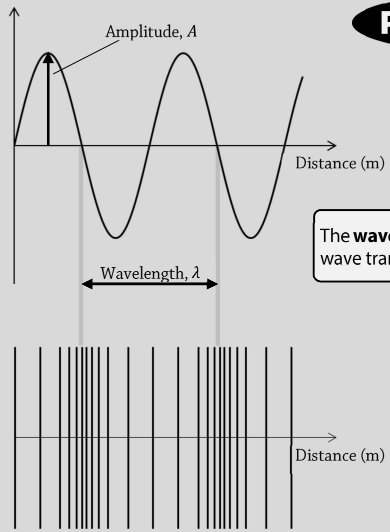
Areas where the density of particles is lower are called **rarefactions**, and where higher are called **compressions**.




**EXAMPLE!**

- Sound waves
- Vibrations through objects

## PROPERTIES OF WAVES




The **wavelength**, $\lambda$, of a wave is the length between two identical points on a wave. Measured in metres, $m$

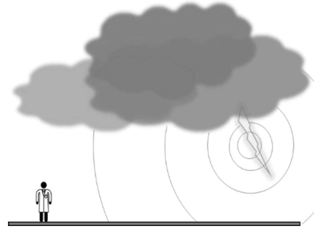
The **period**, $T$, of a wave is the time for one oscillation to occur. $period = \frac{1}{frequency}$ $\boxed{T = \frac{1}{f}}$ ES Measured in seconds, $s$

The **frequency**, $f$, of a wave is the number of oscillations that pass a point per second. $frequency = \frac{1}{period}$ $\boxed{f = \frac{1}{T}}$ ES Measured in Hertz, $Hz$

The **wave speed**, $v$, of a wave is how fast the wave transfers energy through the medium. $wave\ speed = frequency \times wavelength$ $\boxed{v = f\lambda}$ ! Measured in metres/second, $m/s$

**EXAMPLE!** i

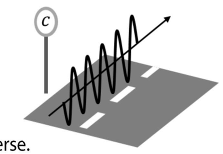
A lightning strike occurs an unknown distance away from an observer. The observer measures the frequency of the thunder as 140 Hz, and hears the thunder 5.4 s after seeing the lightning flash. Given the speed of sound in air is $v_{sound} = 330$ m/s, calculate the wavelength of the thunder and the distance the lightning strike occurred from the observer. (Assume the light instantly reaches the observer.)



i. $v = f\lambda$
$\lambda = \frac{330}{140} = 2.4$ m

ii. $s = vt$
$s = 330 \times 5.4 = 1.8$ km away

## ELECTROMAGNETIC RADIATION



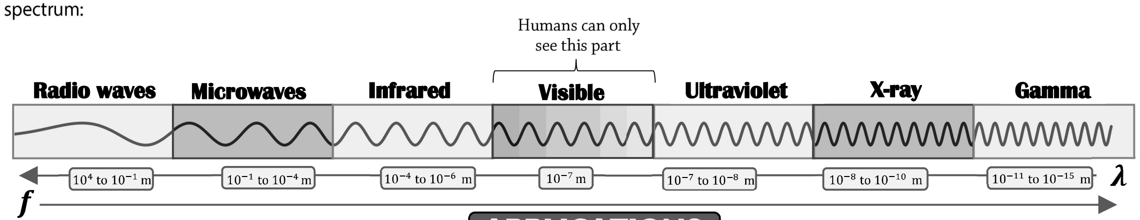

Electromagnetic (EM) radiation, also known as light, is a **transverse** wave that travels through the electromagnetic field. All light travels at the **same speed** in a vacuum (i.e. in space):

$$c = 3.0 \times 10^8 \text{ m/s}$$

Nothing can travel faster than light. You could say that the speed of light in a vacuum, $c$, is the speed limit of the universe. As this speed is a constant, the wave equation becomes

$\lambda$ ⇧ $f$ ⇩ $\boxed{f = \frac{c}{\lambda}}$

So, as the wavelength increases, the frequency decreases, and vice versa. The variation of wavelength with frequency of light leads to the EM spectrum:




### APPLICATIONS

**Radio waves**
- Television and radio
- Longest wavelength / smallest frequency

**Microwaves**
- Satellite communications
- Most fibre-optic communications
- Cooking food

**Infrared**
- Remote control (e.g. TV remote)
- Electrical heaters
- Cooking food
- Infrared cameras

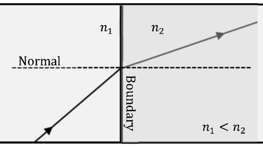
**Visible**
- Some fibre-optic communications
- Visual perception by living organisms

**Ultraviolet**
- Suntanning
- Crime scene investigation
- Energy-efficient lamps

**X-ray**
- Medical imaging /treatment
- Analysing molecular structure of materials

**Gamma**
- Medical treatment
- Released from nucleus (as in nuclear fission)
- Shortest wavelength / largest frequency

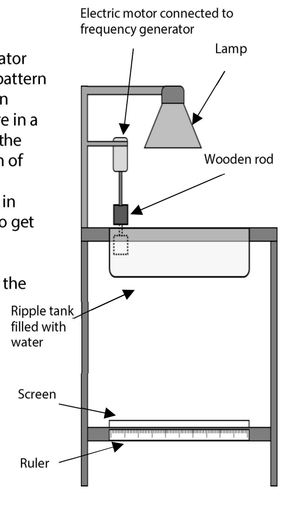
When a light ray transmits through a boundary, it refracts. Its direction of propagation bends towards / away from the normal of the boundary, depending on whether the relative refractive index is high/low.




## Investigating the frequency, wavelength and speed of waves using a ripple tank

### Method

1. Fill the water level of the ripple tank to around 5 mm
2. Turn on the lamp and frequency generator
3. The bottom of the tank is clear, so the pattern of the wave is projected onto the screen below. Count how many peaks there are in a given distance. Divide this distance by the number of peaks to get the wavelength of the wave.
4. Count how many peaks pass one point in 10 seconds. Divide this number by 10 to get the frequency of the wave.
5. Adjust the frequency of the frequency generator to another value, and repeat the steps above

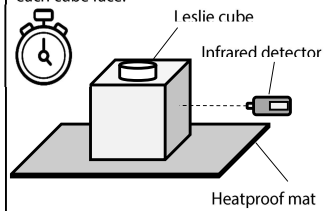



### Analysis

1. Plot wavelength against the inverse of frequency
2. Draw a line of best fit and calculate its gradient
3. The gradient of the line is equal to $gradient = wave\ speed$
4. Compare this wave speed value to typical speeds of water waves

## Investigating the amount of infrared radiation emitted from different surfaces

Cover each side of a Leslie cube with a different material to be investigated. Then fill the Leslie cube with hot water. At regular time intervals (measured using a stopwatch) measure the amount of infrared radiation being emitted from each cube face.




**Independent variable**
Material used

**Dependent variable**
Intensity of infrared radiation emitted (W/m²)

**Control variables**
Temperature throughout water, distance of detector from cube face, time between measurements