7 Waves

7.1 Progressive waves

Candidates should be able to:

1 describe what is meant by wave motion as illustrated by vibration in ropes, springs and ripple tanks

2 understand and use the terms displacement, amplitude, phase difference, period, frequency, wavelength and speed

3 understand the use of the time-base and *y*-gain of a cathode-ray oscilloscope (CRO) to determine frequency and amplitude

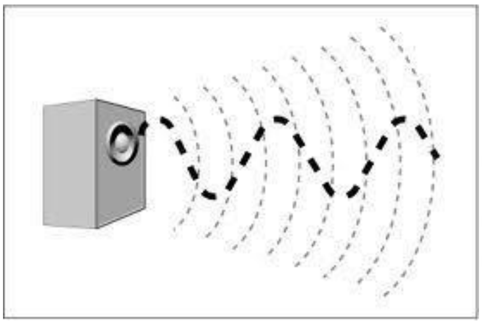
4 derive, using the definitions of speed, frequency and wavelength, the wave equation $v = f\lambda$

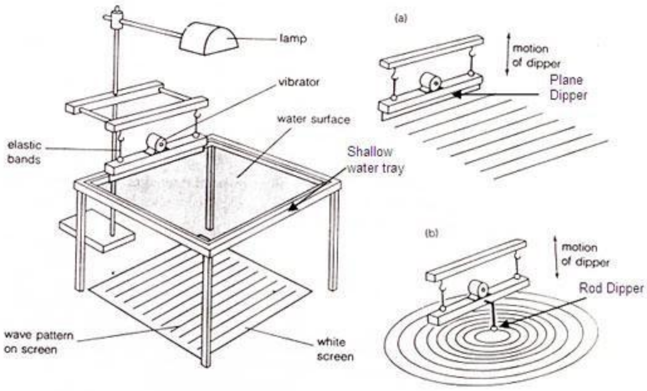
5 recall and use $v = f\lambda$

6 understand that energy is transferred by a progressive wave

7 recall and use *intensity* = *power*/*area* and *intensity* $\propto$ $(amplitude)^2$ for a progressive wave

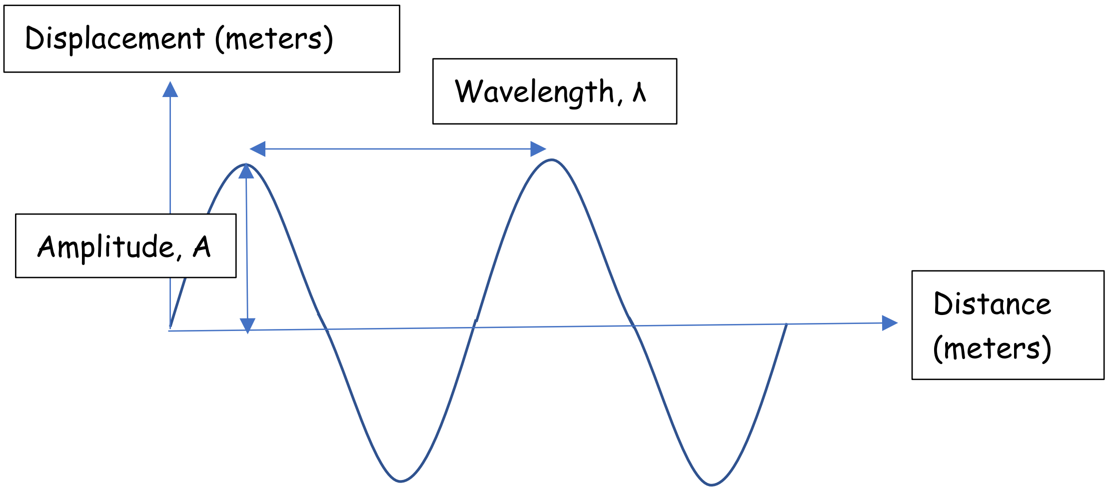
- Waves are created when particles oscillate or vibrate.
- **Energy** is transferred through these moving oscillations.



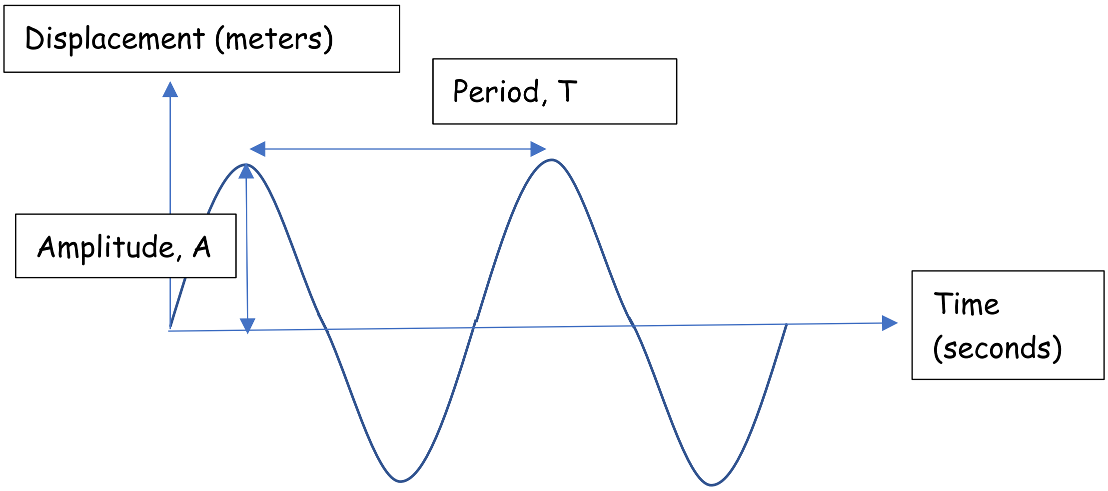


- You can represent waves on **two** types of plots:

1) Displacement-distance plot



2) Displacement-time plot

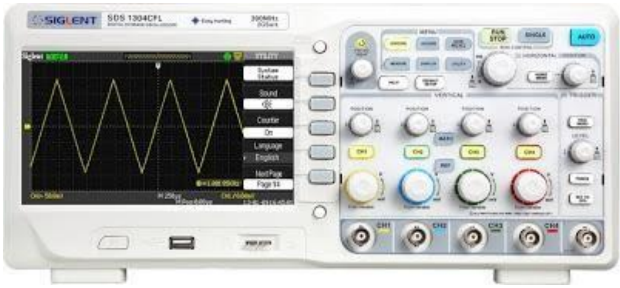


- Below are some terminology for waves:
- **Amplitude, *A***: The maximum displacement from the original position. The SI unit for amplitude is in meters.
- **Wavelength, *λ***: The horizontal distance between two **wave fronts**. The SI unit for wavelength is in meters
- **Period, *T***: Time taken for the wave to complete a cycle or return to its original displacement. The SI unit for periods is seconds.
- **Frequency, *f***: The number of complete cycle's in a second (How many times did the wave go up, down and up again or down, up, and down again in 1 second). The SI unit for frequency is hertz (Hz) OR seconds^{-1}.

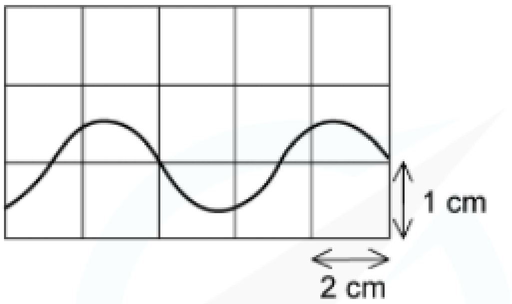
- Hence, relationship between **frequency** and **period** is

$$f = 1/T$$

- A cathode ray oscilloscope (CRO) can be used to display the waveform of electrical signals.



- Below is an example of a CRO display with the x-axis being time and y-axis being voltage



- The period of the wave can be determined from the time based (how

Worked example

Assuming from the diagram above each cm represent 1 second, find the frequency of the wave

- Wave equation is given by

$$v = f\lambda$$

Here v is the speed of the wave, f is the frequency of the wave and λ is the wavelength of the wave

Derivation for the equation above

- Progressive waves transfer **energy**.
- The amount of energy passing per unit time (P) through a unit of area (A) is the intensity, I of the wave

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

- The area the wave passes through is perpendicular to the direction of its velocity
- The intensity of a progressive wave is also proportional to its amplitude squared and frequency squared

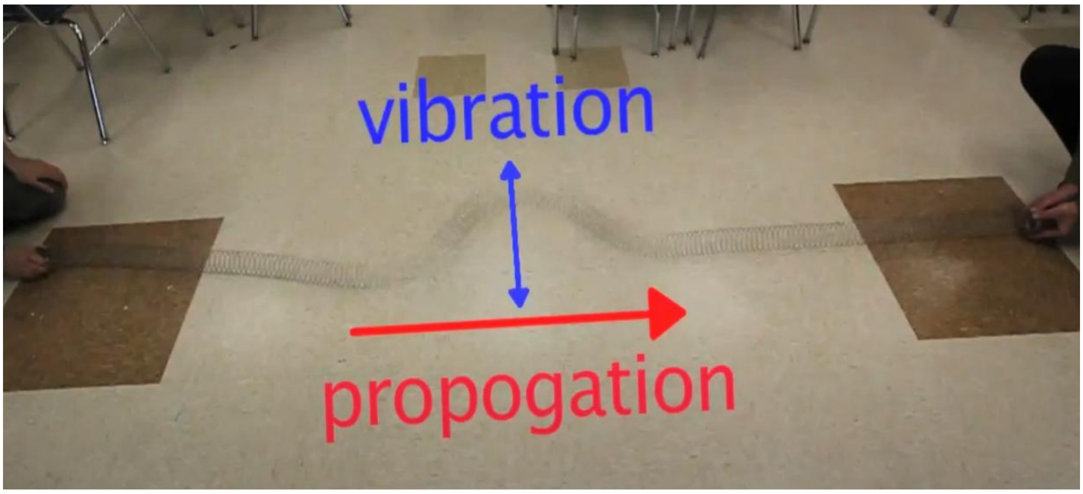
$$\boldsymbol{I \propto A^2}$$

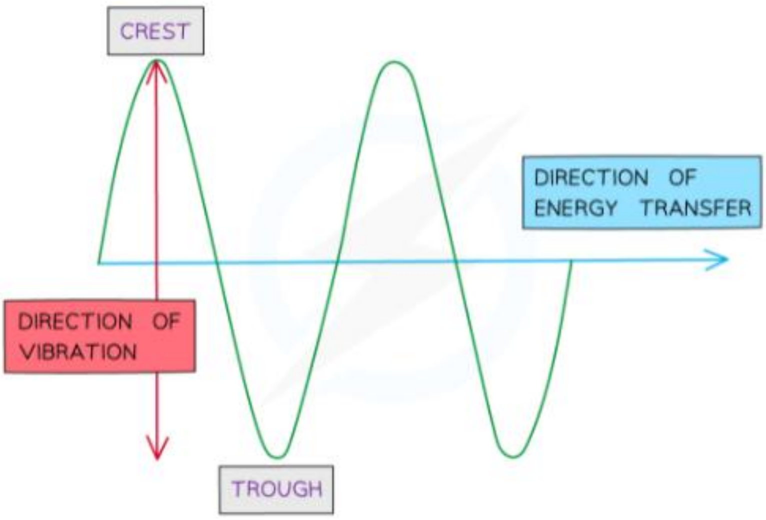
$$\boldsymbol{I \propto f^2}$$

7.2 Transverse and longitudinal waves

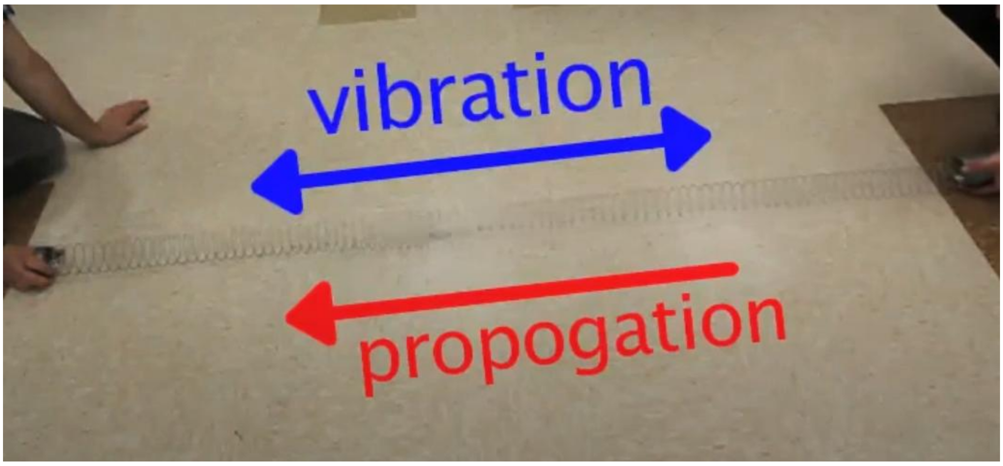
Candidates should be able to:	
1	compare transverse and longitudinal waves
2	analyse and interpret graphical representations of transverse and longitudinal waves

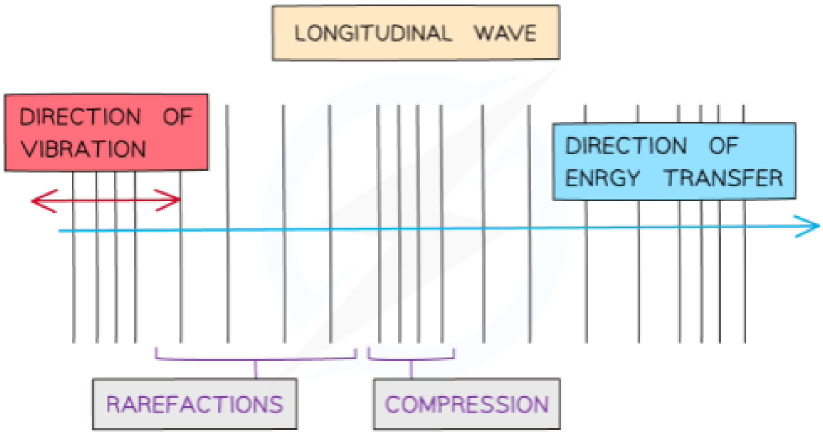
- **Transverse waves** are waves where the particles vibrate **perpendicular** along the lines of motions and consists of a series of "crest" and "troughs".
- Examples include electromagnetic waves, water ripples and vibration on a guitar string.
- **Longitudinal waves** are waves where the particles vibrate **along** the lines of motion and consist of a series of compression and expansions (rarefractions).
- Examples include sound waves.
- Visual and graphical representation of transverse waves





- Visual and graphical representation of longitudinal waves


vibration
propogation


LONGITUDINAL WAVE
DIRECTION OF VIBRATION
DIRECTION OF ENRGY TRANSFER
RAREFACTIONS
COMPRESSION

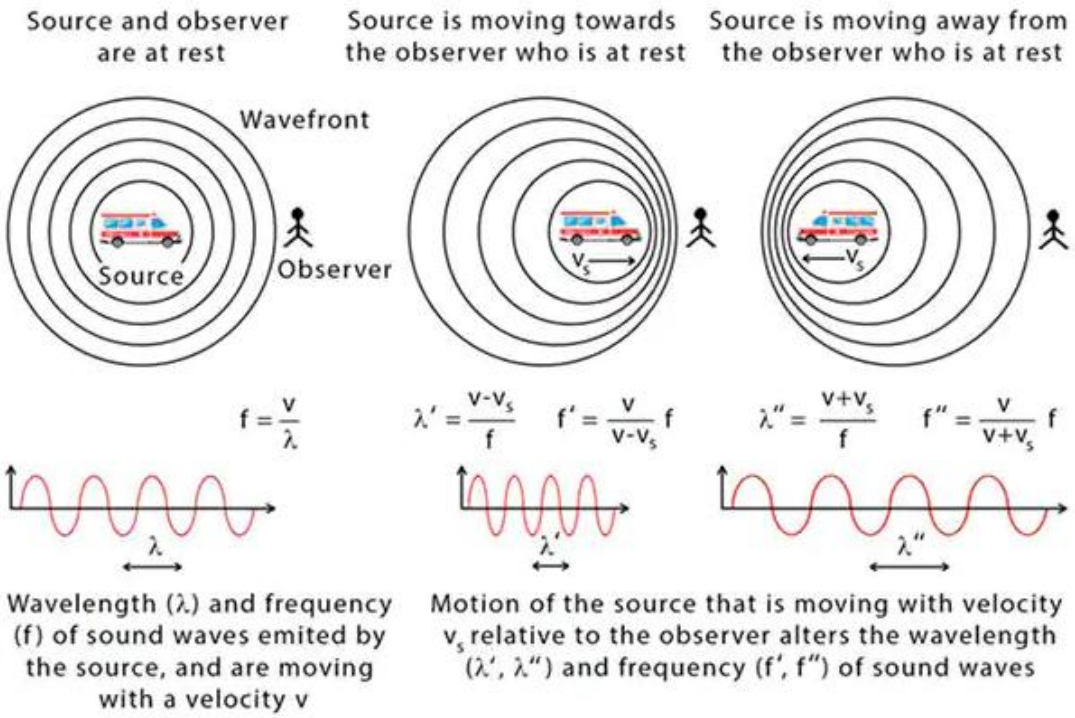
7.3 Doppler effect for sound waves

Candidates should be able to:

1 understand that when a source of sound waves moves relative to a stationary observer, the observed frequency is different from the source frequency (understanding of the Doppler effect for a stationary source and a moving observer is not required)

2 use the expression $f_o = f_s v / (v \pm v_s)$ for the observed frequency when a source of sound waves moves relative to a stationary observer

- The sound of a siren changes as it moves closer or further from you.
- This phenomenon is due to the **doppler effect**.
- When the observer and the source sound are both stationary, the waves are at the same frequency for both observer and source.



- Here f' is the observed frequency, f is the frequency from the source, V is the wave velocity and V_s is the source velocity.

7.4 Electromagnetic spectrum

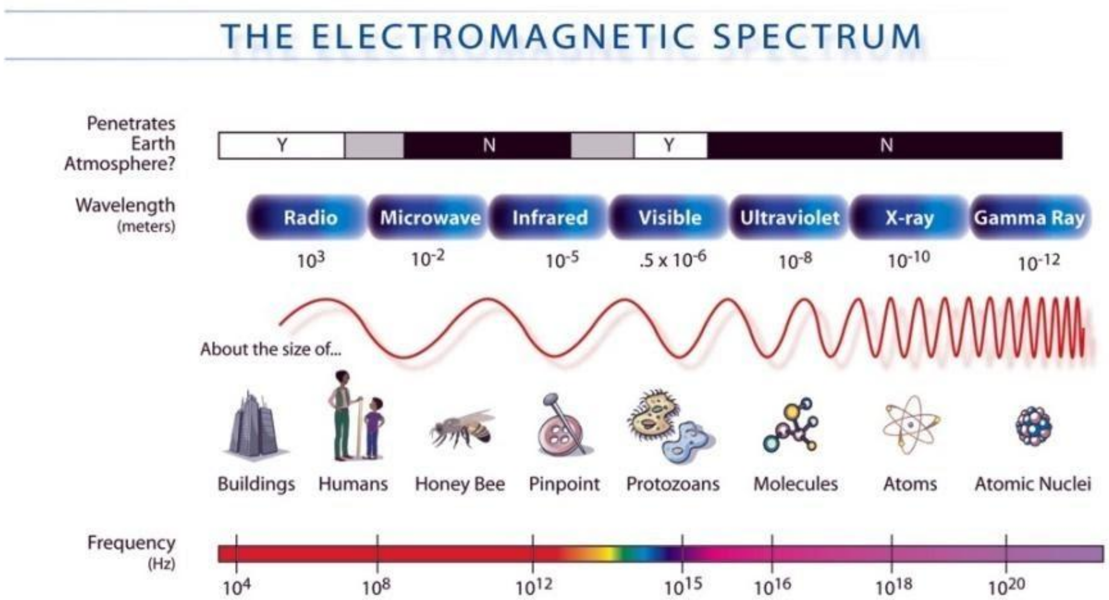
Candidates should be able to:

1 state that all electromagnetic waves are transverse waves that travel with the same speed *c* in free space

2 recall the approximate range of wavelengths in free space of the principal regions of the electromagnetic spectrum from radio waves to γ-rays

3 recall that wavelengths in the range 400–700 nm in free space are visible to the human eye

- Electromagnetic waves are transverse waves.
- It consists of electric field and magnetic field components.
- It can propagate without the need of a medium to carry them unlike mechanical waves.
- The speed that electromagnetic waves travel at is 3×10^8 ms^{-1}
- If this number seems familiar it's because that's the speed of light. Light is a wave or more specifically an electromagnetic wave.
- There are 7 types of waves in the electromagnetic spectrum.



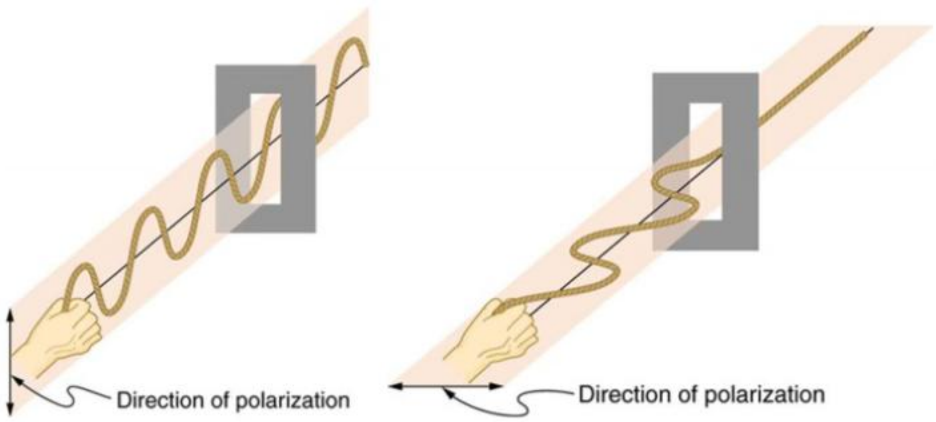
7.5 Polarisation

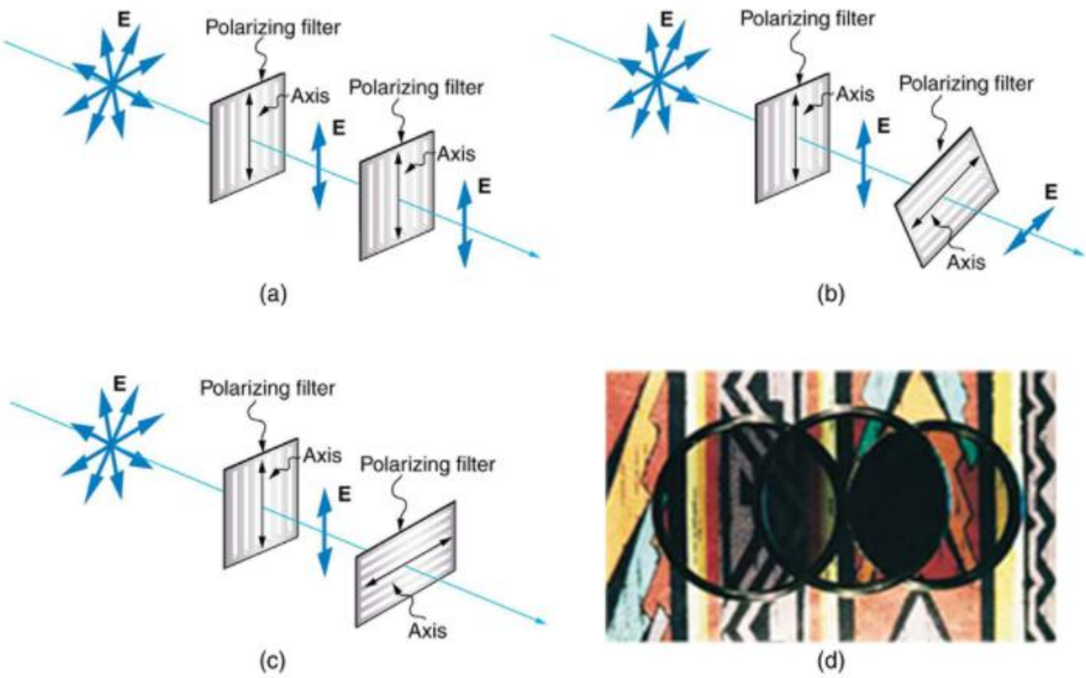
Candidates should be able to:

1 understand that polarisation is a phenomenon associated with transverse waves

2 recall and use Malus's law ($I = I_0 \cos^2\theta$) to calculate the intensity of a plane-polarised electromagnetic wave after transmission through a polarising filter or a series of polarising filters (calculation of the effect of a polarising filter on the intensity of an unpolarised wave is not required)

- Only transverse waves can be polarized.
- Polarization means that vibrations are restricted to one direction.
- Waves can be polarised through a polariser or polarising filter.
- Example polaroid sunglasses.





- Polarising a wave reduces its amplitude.
- Malus' Law is used to find the intensity of light after passing through a number of filters.

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

Here I is the remaining intensity (W m^{-2}), I_0 is the original intensity, θ is the angle between polarised light and transmission axis (degrees)

Angle of transmission axis θ / degrees	Direction of transmission axis	$\cos^2\theta$	Transmitted intensity I / W m−2	Max or min light intensity transmitted
0		1	I_0	Max
180				
90		0	0	Min
270				