Chap. 15
Waves

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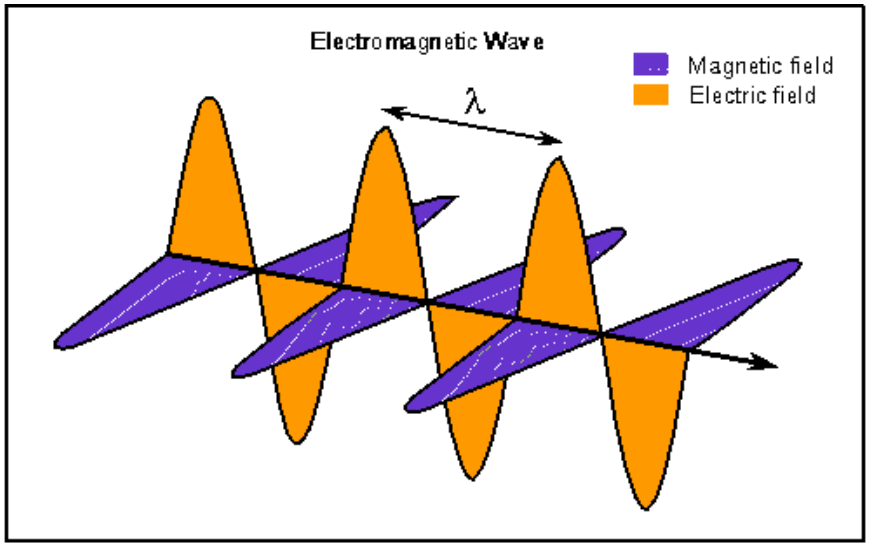
Learning Outcome

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

What is wave?

Water waves

Electromagnetic waves



Wave is …

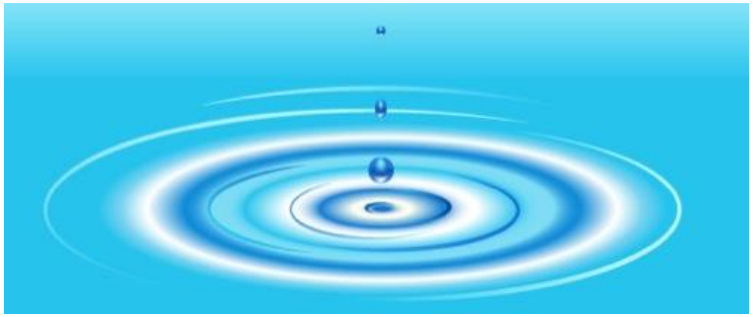
- a **disturbance** that moves. It is a method of **transferring energy**.

- It **carries energy without carrying matter**.
- No particle of the medium travels between the two points.
- Particles just oscillate in the medium their mean position with the **same frequency** as the source or origin of the wave.

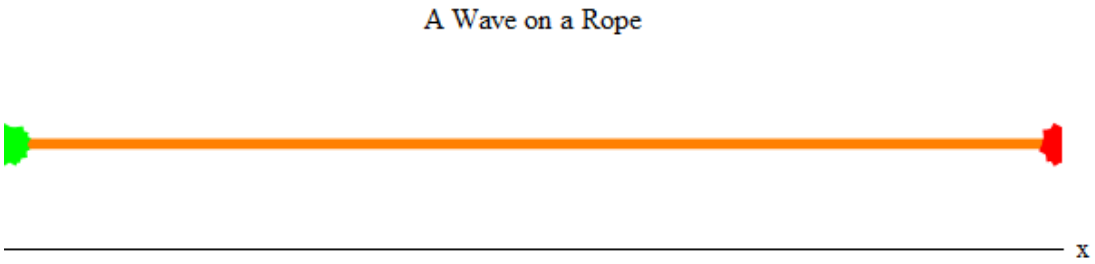
Waves: generation & transmission media

1. **Push a slinky spring forward & backward**

2. Throw a stone into a river – ripples moving outwards



3. Oscillate a rope upwards & downwards



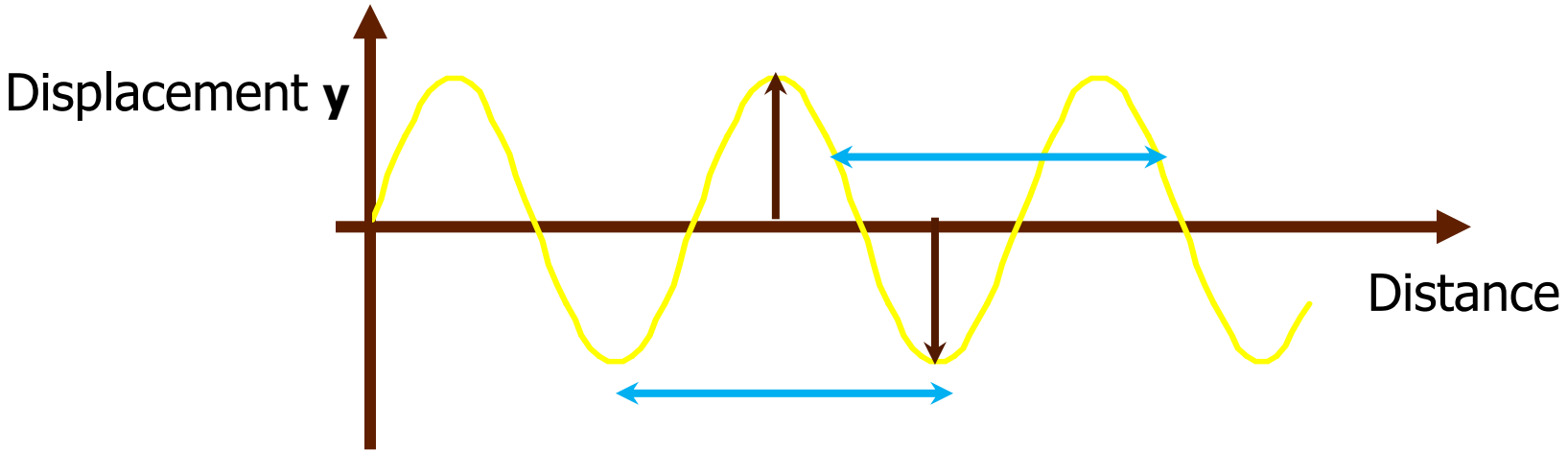
Learning Outcomes

(b) show an understanding of and use the terms displacement, amplitude, phase difference, period, frequency, wavelength and speed

(c) deduce, from the definitions of speed, frequency and wavelength, the equation $v = f\lambda$

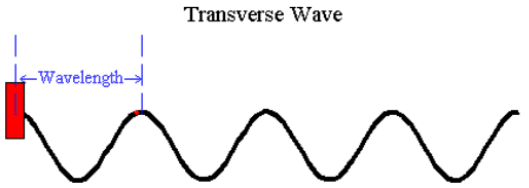
(d) recall and use the equation $v = f\lambda$

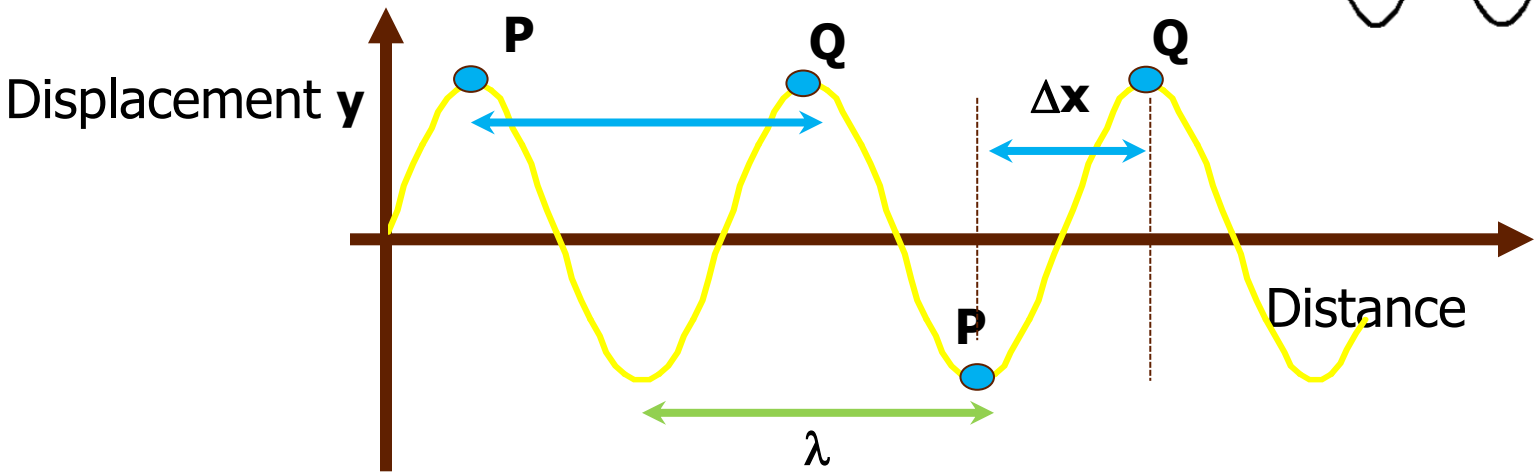
terms



1. Displacement of a particle, y is its instantaneous distance from the equilibrium position.
2. Amplitude of a wave, A is defined as the maximum displacement of a particle from its equilibrium position.
3. Wavelength of a wave, λ: distance between any two points on adjacent cycles, which are vibrating in phase.

terms





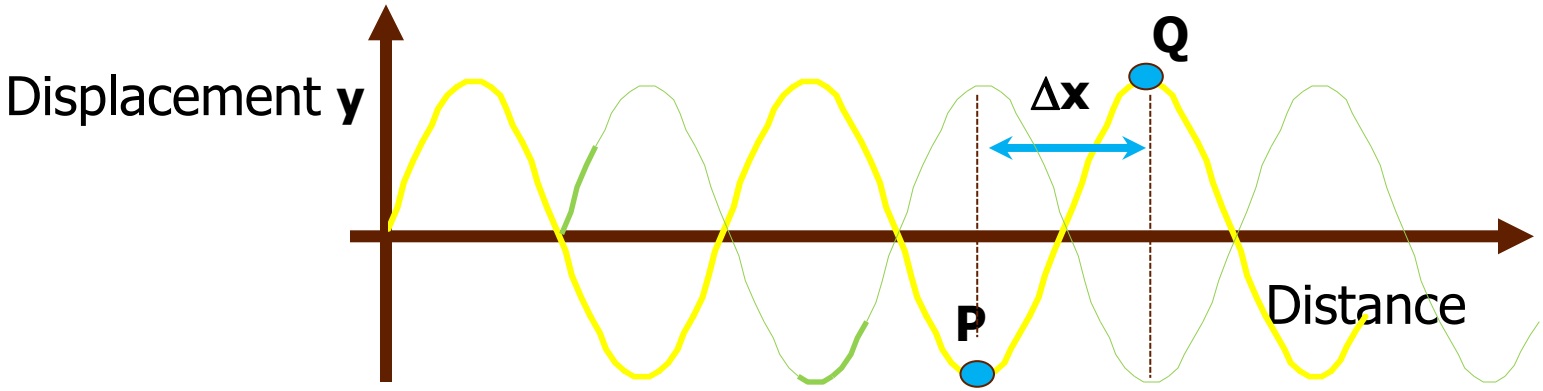
4. **Phase difference** ϕ between two points is the fraction of a cycle/oscillation a point has completed compared to another. The phase difference tells how much a point/wave is lagging or leading with respect to another.

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

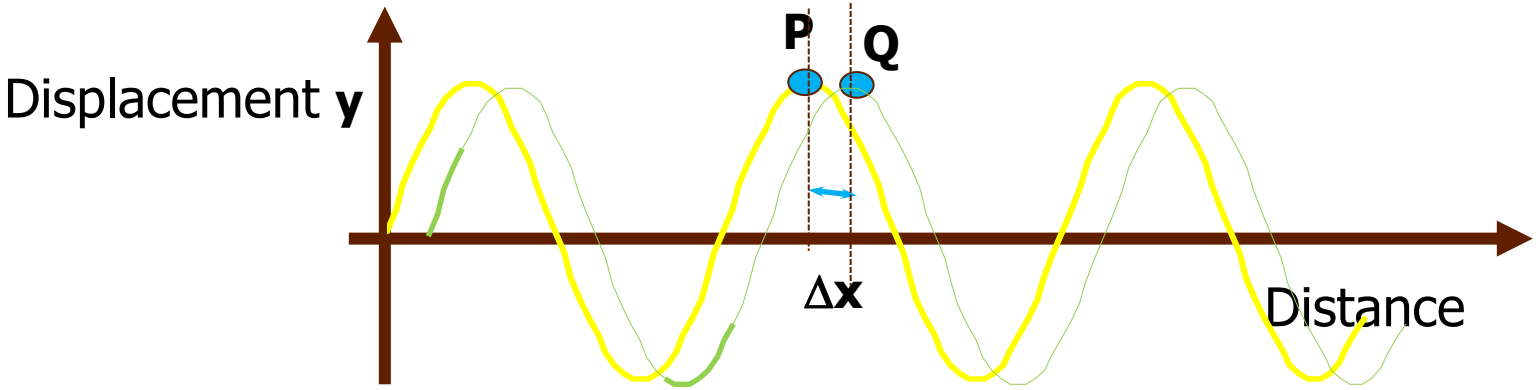
ϕ = 2π when $\Delta x = \lambda$
P has completed one oscillation when Q is about to oscillate (in-phase)

ϕ = π when $\Delta x = \lambda/2$
P has completed half an oscillation when Q is about to oscillate (antiphase)

Phase difference $\phi = \frac{2\pi}{\lambda}\Delta x$



4. **Phase difference** ϕ between two points on a wave or between crests of two waves of the same frequency travelling in the same medium.



These two waves are Out of phase by ϕ

Terms

1. Period, T: time between one wave crest and the next arriving at the same point. OR time take for a point to complete one oscillation/cycle.
2. Frequency of a wave, f : the number of wave crests passing a given point per unit time OR The number of complete cycles of an oscillating particle per unit time
3. Wave Speed, v: the rate at which energy is transferred along the propagation of waves.

   v = distance moved by a crest after one period / period

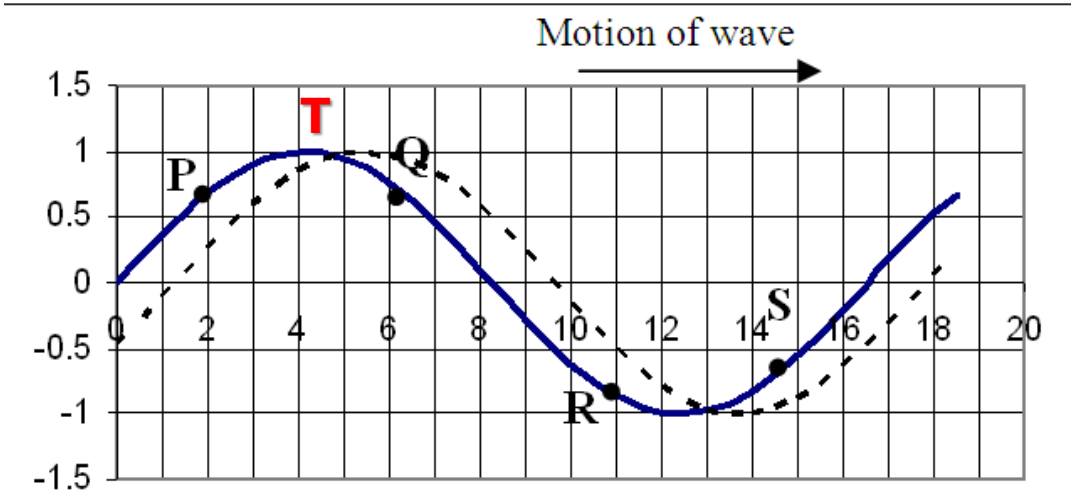
   $= \lambda / T = f\lambda$ as $1/T = f$

The speed depends on the properties of medium in which wave is propagating.

Question:

White light has a range of wavelength from 400nm to 700 nm. Determine the range of frequencies for white light.

Velocity and displacement of particles in the medium of wave propagation



	displacement	movement
P	upwards	
Q		upwards
R	downwards	
S		downwards
T		

Learning Outcomes

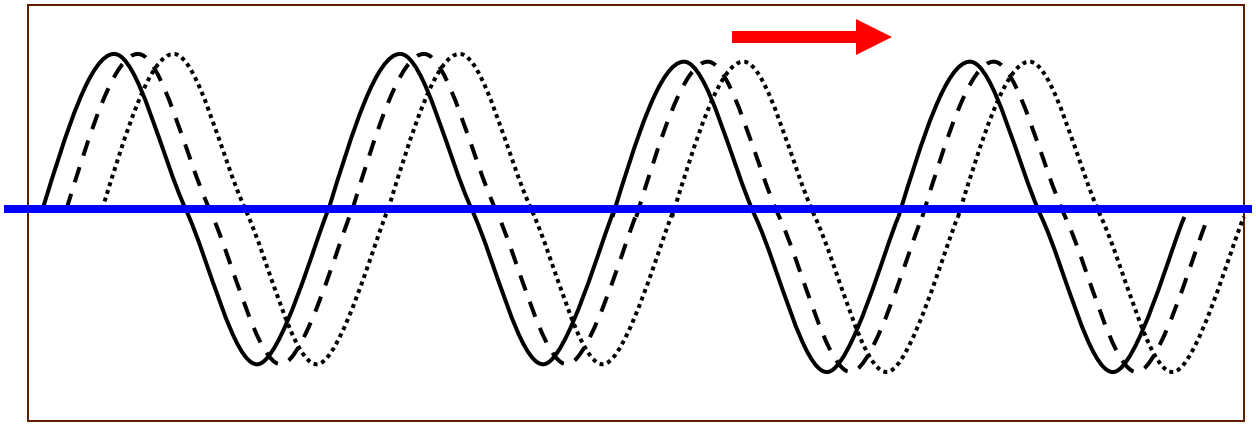
(e) show an understanding that energy is transferred due to a progressive wave

(f) recall and use the relationship $\textit{intensity} \propto (\textit{amplitude})^2$

(g) compare transverse and longitudinal waves

(h) analyse and interpret graphical representations of transverse and longitudinal waves

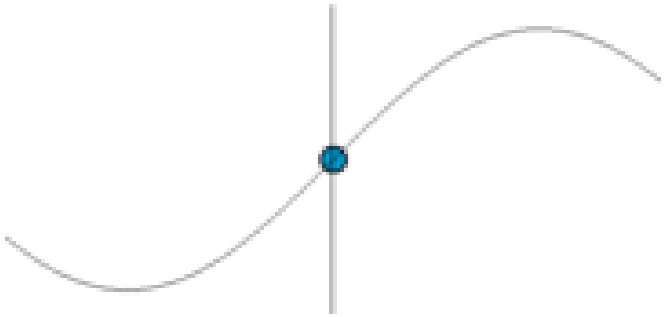
Progressive waves

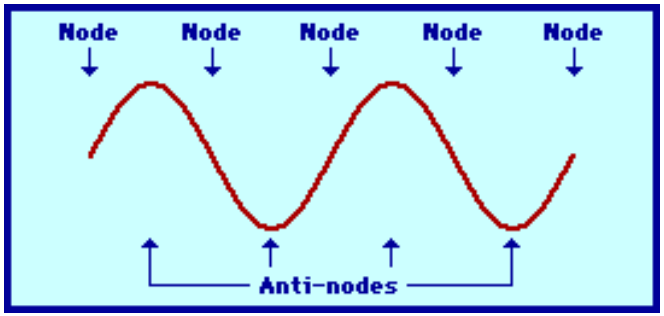


- **Energy is transferred** from the source outwards
- The wave profile can be seen to move/advance in the direction of propagation of the wave, with the speed of the wave
- Every point along the direction of propagation is displaced
- The oscillation of the particles in a progressive wave are of the same amplitude and frequency at different distant.
- Neighbouring points are not in phase

distinguish between

Electromagnetic waves	mechanical waves
doesn't need a medium to travel – vacuum	needs a medium





Progressive waves	stationary waves
Wave profile is advancing Energy is transferred along the propagation of waves	Wave profile is not moving Energy is confined between two nodes

Intensity I

The rate of transfer of energy per unit area normal to the direction of propagation of the waves. $\mathbf{I} = \frac{energy}{time \times area}$; unit Wm^{-2} .

It is directly proportional to the square of wave amplitude *A* but inversely proportional to the square of distance from the source *r*.

$I \propto A^2$ and $I \propto 1/ r^2$

intensity

Intensity	Amplitude
I	A
?	2A
2I	?

$I \propto A^2$

$I = k A^2$

$I' = k (2A)^2$

$= k\, 4A^2$

$= 4\, I$

$I = k A^2$

$2I = k\, 2A^2$

$= k (\sqrt{2}A)^2$

OR

$2I = k A'^2 - (1)$

$I = k A^2 - (2)$

$A' = \sqrt{2}A$

Try this:

Two waves, P and Q, of the same frequency are travelling in the same medium. The amplitude and intensity of wave P are A and I respectively. The amplitude of wave Q is ½ A. Determine the intensity of the resultant wave, in terms of I, when P and Q meet

(i) in phase

(ii) antiphase

Questions

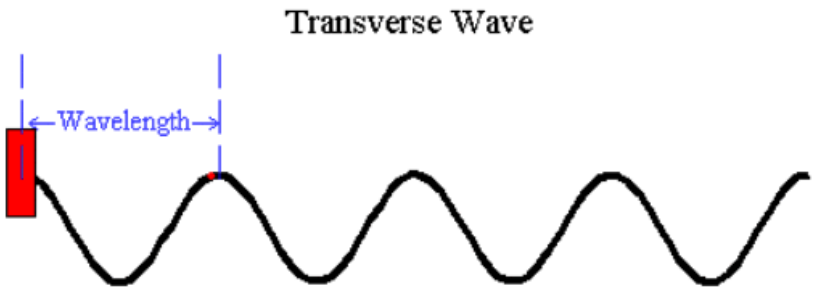
1. At a distance of 15 m from a point source of waves the amplitude of a wave is 3.2 mm and it has an intensity of 6.4×10^{-3} Wm^{-2}. Determine the intensity of the waves at distances of 40 m and 120 m from the source. [9e-4, 1e-4]

2. A point source of sound emits energy equally in all directions at a constant rate and a person 8 m from the source listens. After a while, the intensity of the source is halved. If the person wishes the sound to seem as loud as before, how far he is now from the source? [5.66 m]

Longitudinal & Transverse waves

- **Longitudinal waves**

- **transverse waves**



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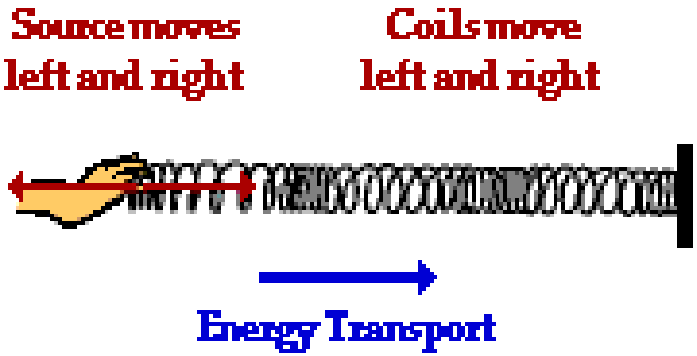
http://www.cbu.edu/~jvarrian/applets/waves1/lontra_g.htm
http://members.aol.com/nicholashl/waves/movingwaves.html
http://www.gmi.edu/~drussell/Demos/waves/wavemotion.html

distinguish between

Transverse waves	Longitudinal waves
➢ A wave which is propagated by oscillations **perpendicular** to the direction of motion of the wave	➢ A wave which is propagated by oscillations occur in the same direction of (**parallel to**) the motion of the wave.
➢Electromagnetic wave	➢Sound waves
➢Water wave	
➢Can be polarised	➢Can not be polarised

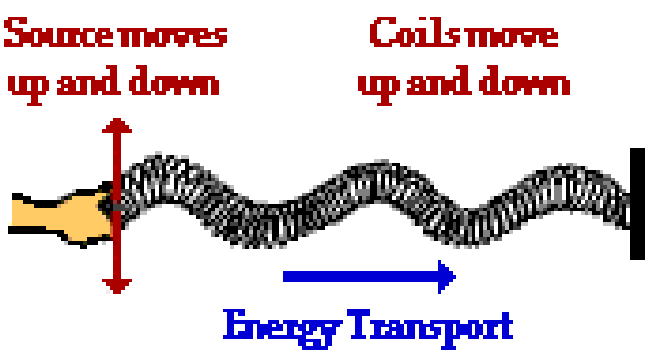
Longitudinal & Transverse waves

Longitudinal wave



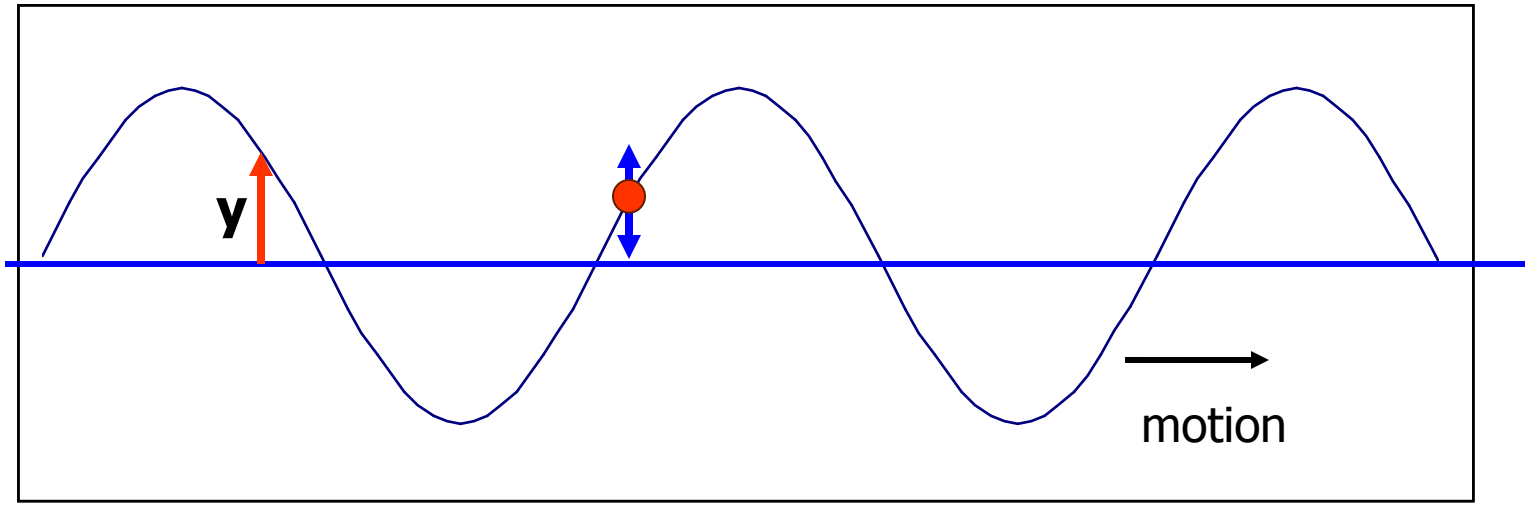
- Slinky spring is pushed forwards and backwards at a constant rate.
- A series of **rarefactions** and **compressions** occurs.

Transverse Wave

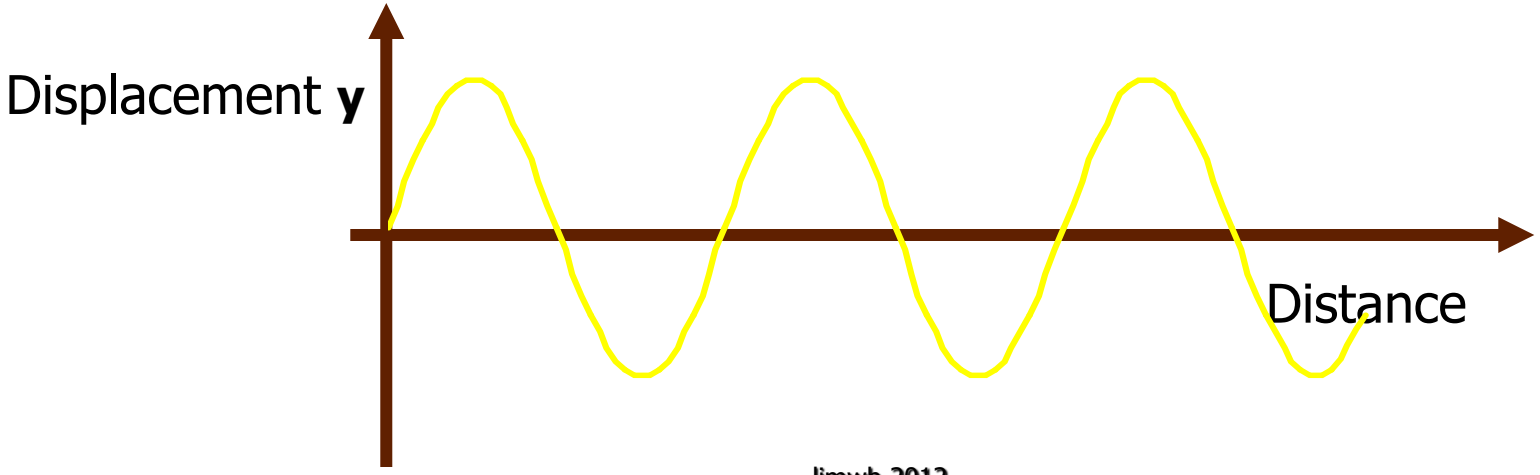


- A spring is tied at one end and the other end is moved continuously up and down.
- A waveform is exhibited on the spring.

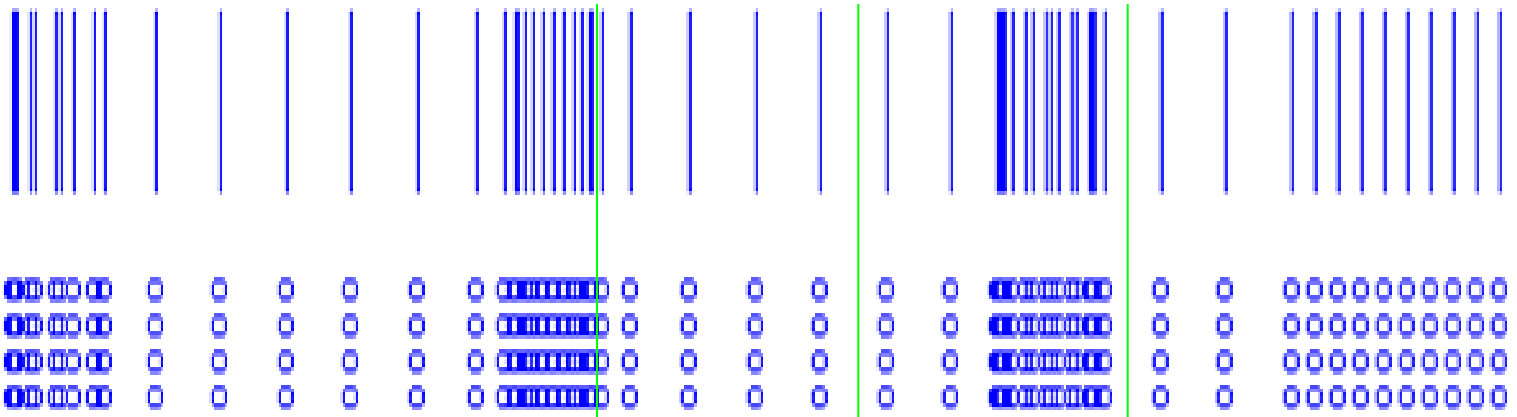
Represent wave motion as a sine function – Transverse waves



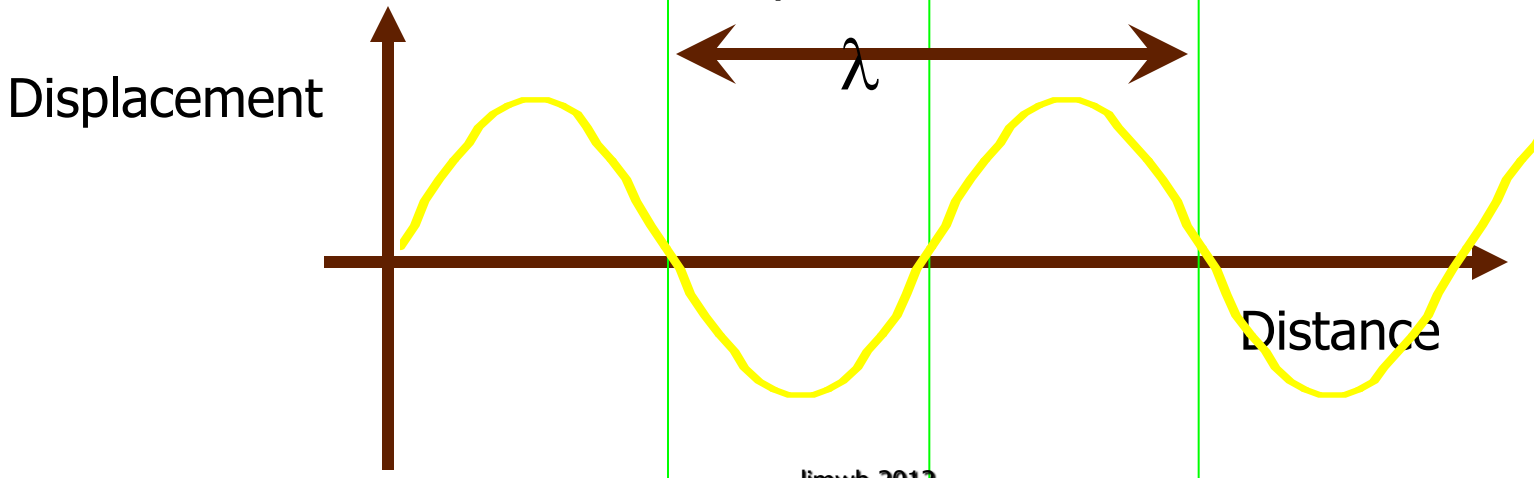
- Displacement is measured from its equilibrium position



Represent wave motion as a sine function – Longitudinal waves



- Displacement of a particle is measured from the equilibrium position of the particle
- A series of rarefactions and compressions occurs.



Learning Outcomes

(i) show an understanding that polarisation is a phenomenon associated with transverse waves

(j) determine the frequency of sound using a calibrated c.r.o. *

(k) determine the wavelength of sound using stationary waves #

(l) state that all electromagnetic waves travel with the same speed in free space and recall the orders of magnitude of the wavelengths of the principal radiations from radio waves to γ-rays.

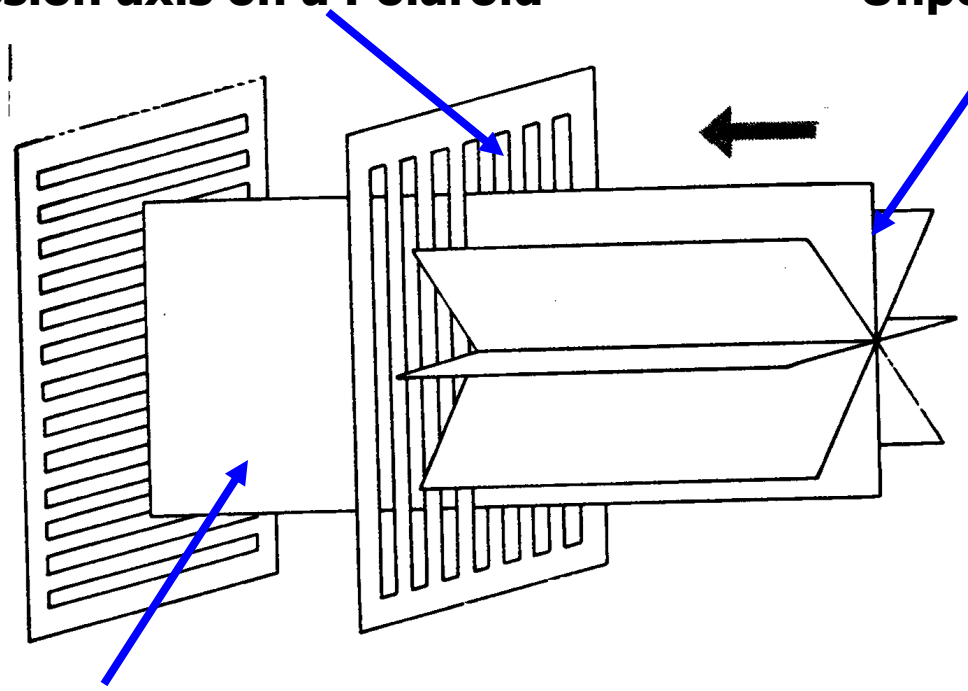
Polarisation

- The restriction of the propagation of waves to a certain plane.

Vertical transmission axis on a Polaroid

Unpolarised light waves

Intensity of light after passing through the second Polaroid?



Restriction of waves to travel on the vertical plane.

It is the property **exhibited by _____ waves only**

Effects of polarisation with light.

- Sunglasses
- Car windscreens
- Polarisation by reflection - glare/shine off roads
- Polarisation of scattered sunlight
- Stresses in materials
- Liquid crystal displays on a calculator
- Laptop displays

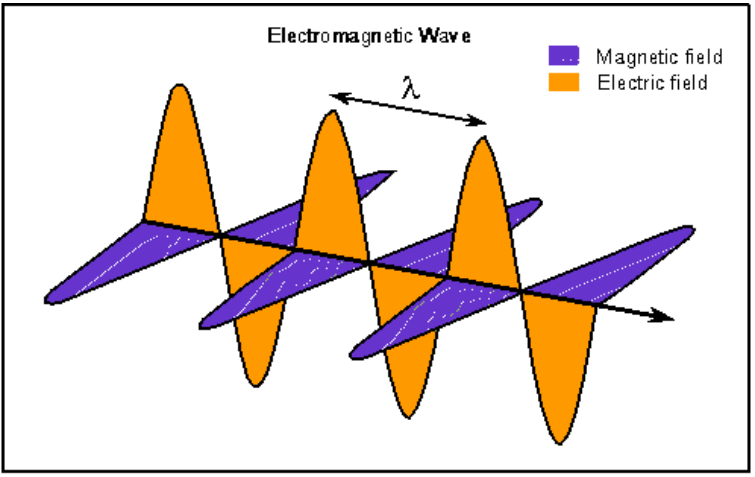
websites

Polarisation of waves (sunglasses)

- http://www.colorado.edu/physics/2000/applets/polarized.html
- http://physics.gac.edu/~chuck/PRENHALL/Chapter%2025/AABXTEP0.html

(Rotated Polaroid)

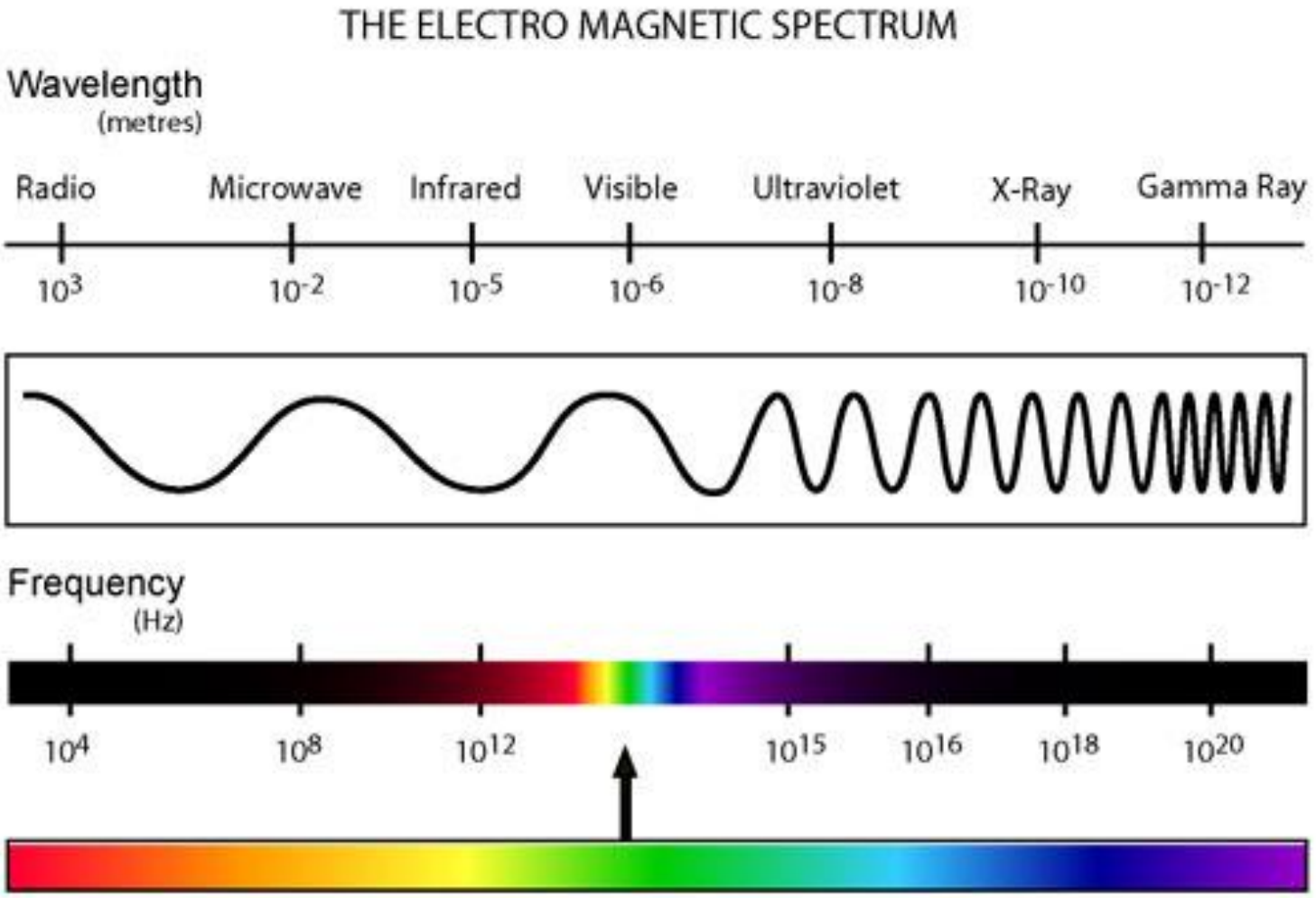
- http://www.colorado.edu/physics/2000/applets/lens.html



Electromagnetic (EM) waves

- EM waves are _____ waves with the vibrations of an _____ **field and a** _____ **field** occurring at _____ **angles** to each other and in any plane at right angles to the direction of travel of the wave.
- _____ **medium** is required
- All travel with same speed in vacuum i.e._____

Electromagnetic waves



There is no sharp division in term of wavelength or frequency to group these 7 categories of EM waves. But, they are categorized according to how they are produced.

Electromagnetic waves

Waves	Range of frequency	Range of wavelength	Source	Detection
1. radio waves		10^{-1} - 10^{3}	Electrons oscillated by electric field in aerial	Resonance in tuned electrical circuits (radio receiver)
2. micro waves		10^{-2} – 10^{-4}	klystron oscillators	
3. infrared		10^{-4} – 10^{-6}	Hot solid	Skin as heat Thermopile
4. visible light		10^{-6}	Sun	Eye Thermopile
5. ultraviolet		10^{-7} – 10^{-9}	High temperature solids and gases	Fluorescence Photoelectric cell
6. *x*-rays		10^{-8} – 10^{-11}	Bombarding metal target with high energy electrons	Geiger Muller tube Ionisation Photographic film Phosphorescence (e.g. ZnS)
7. gamma		$<10^{-9}$	Energy released from the nucleus of atoms in radioactivity	