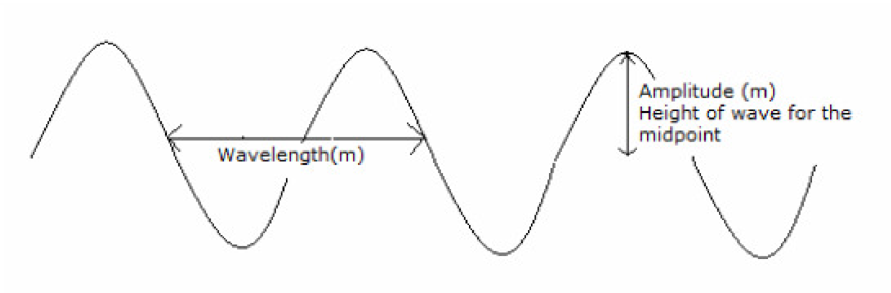
4.1 Kinematics of simple harmonic motion (SHM)

4.1.1 Describe examples of oscillations.

Examples of Simple Harmonic Motion include:
1. Simple spring oscillator
2. Pendulum for small angles of oscillation

4.1.2 Define the terms *displacement*, *amplitude*, *frequency*, *period* and p*hase difference*.

Displacement Distance from the equilibrium point



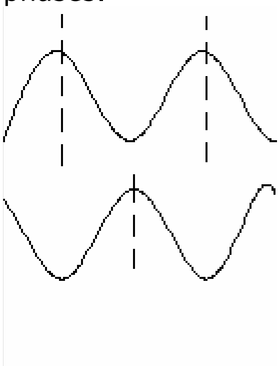
Amplitude The maximum value for displacement from the mid point.

Frequency (f): The number of oscillations per second measured in hertz (Hz) 1 Hz = 1 oscillation per second.

Period (T): The time taken for one oscillation measured in seconds.

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

Phase difference A way of comparing two oscillations by finding the difference between their phases.



The two waves shown have a phase difference of 180°. This means that the first wave is half a wavelength in front of the second one.

4.1.3 Define *simple harmonic motion* (*SHM*) and state the defining equation as $a = -\omega^2 x$.

For an oscillation to be described as Simple Harmonic:
- the force or acceleration is always directed to the centre of the motion.
- the force or acceleration is proportional to the distance from the centre of motion

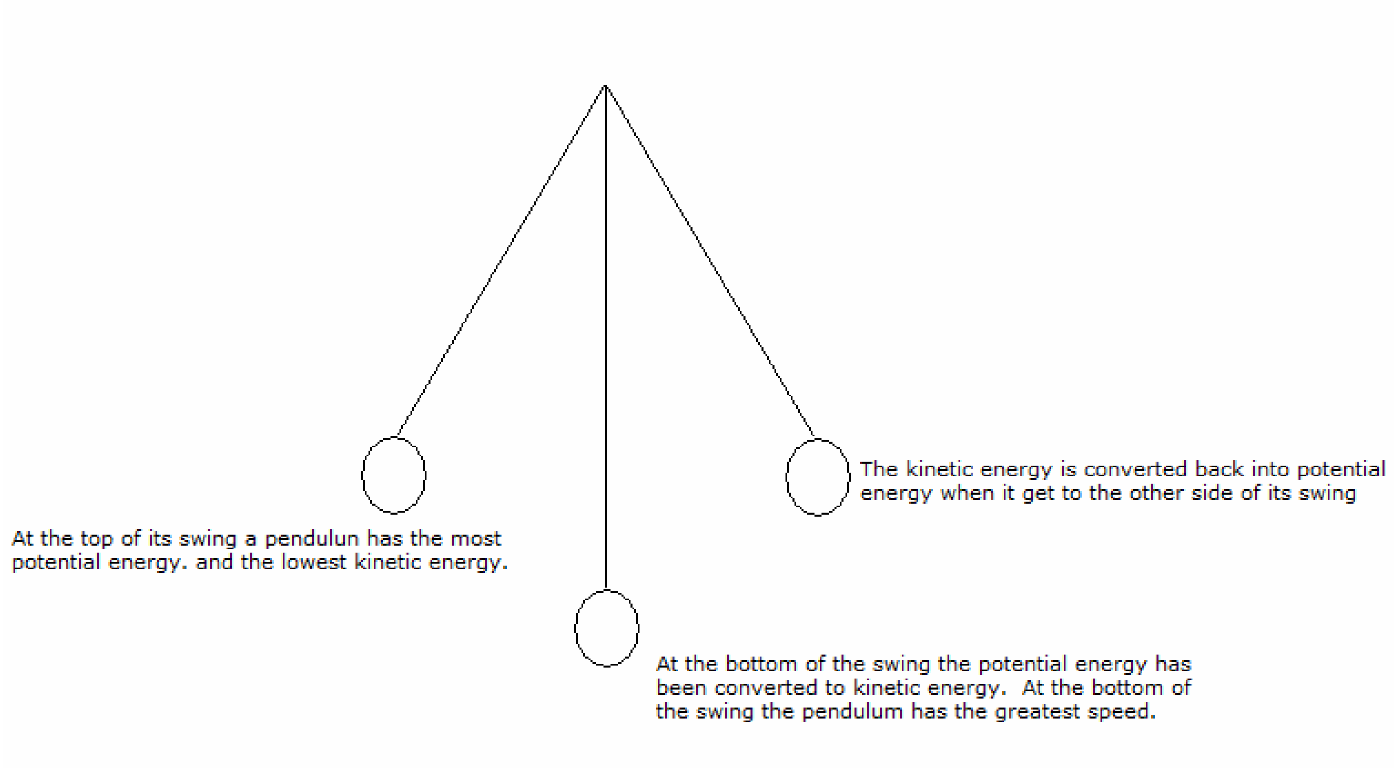
4.1.4 Solve problems using the defining equation for SHM.

4.1.5 Apply the equations $v = v_0 \sin \omega t$, $v = v_0 \cos \omega t$, $v = \pm\omega\sqrt{(x_0^2 - x^2)}$, $x = x_0 \cos \omega t$ and $x = x_0 \sin \omega t$ as solutions to the defining equation for SHM.

4.1.6 Solve problems, both graphically and by calculation, for acceleration, velocity and displacement during SHM.

4.2 Energy changes during simple harmonic motion (SHM)

4.2.1 Describe the interchange between kinetic energy and potential energy during SHM.



4.2.2 Apply the expressions $E_K = \frac{1}{2}m\omega^2(x_0^2 - x^2)$ for the kinetic energy of a particle undergoing SHM, $E_T = \frac{1}{2}m\omega^2 x_0^2$ for the total energy and $E_P = \frac{1}{2}m\omega^2 x^2$ for the potential energy.

4.2.3 Solve problems, both graphically and by calculation, involving energy changes during SHM.

4.3 Forced oscillations and resonance

4.3.1 State what is meant by damping.

Damping is a force that is always in the opposite direction to the direction of motion of the oscillating particle and that the force is a dissipative force**.**

4.3.2 Describe examples of damped oscillations.

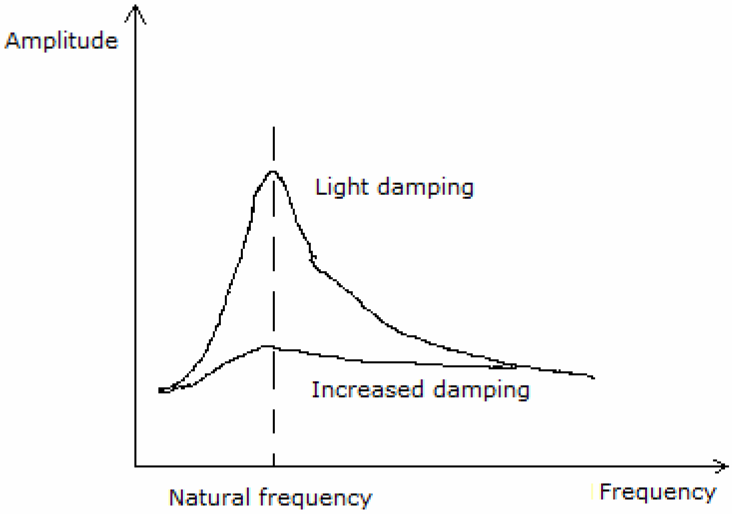
This happens on cars in their suspensions, when it vibrates the damper tries to reduce the number of oscillations, to reduce the possible effects. On a piano the pedals reduce the oscillations of the springs of the piano. One pedal reduces the damping and one cuts completely the oscillations.

4.3.3 State what is meant by natural frequency of vibration and forced oscillations.

The natural frequency is the frequency that an object will oscillate at if it if moved from its equilibrium position and released. When a guitar string of a certain length is plucked it vibrates at a certain frequency.

Objects can also be made to oscillate by an external force. This is known as forced oscillation.

4.3.4 Describe graphically the variation with forced frequency of the amplitude of vibration of an object close to its natural frequency of vibration.



4.3.5 State what is meant by resonance.

If an object is forced to oscillate at its natural frequency resonance will occur. Resonance results in oscillations of a very large amplitude.

4.3.6 Describe examples of resonance where the effect is useful and where it should be avoided.

Resonance can be a serious problem. When designing an aeroplane wing care must be taken that it will not resonate in flight.

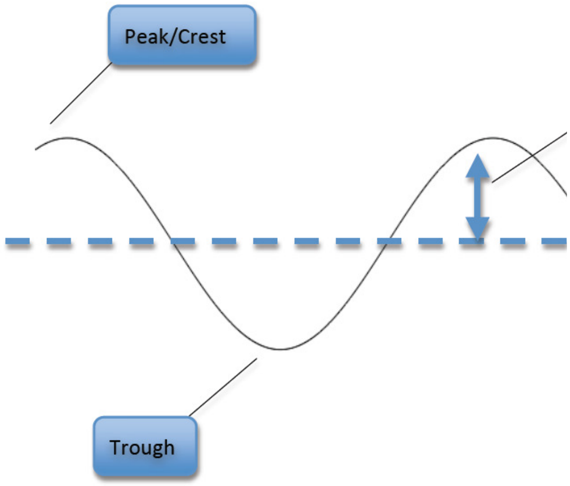
4.4 Wave characteristics

4.4.1 Describe a wave pulse and a continuous progressive (travelling) wave.

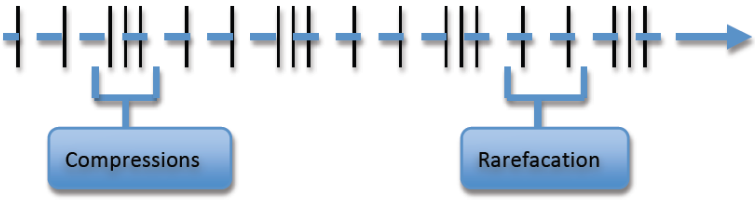
4.4.2 State that progressive (travelling) waves transfer energy.

Waves transfer energy with no net movement in the medium they travel through**.**

4.4.3 Describe and give examples of transverse and of longitudinal waves.



Above is a diagram of a transversal wave. Transverse waves can be defined by the fact that they oscillate at right angles to the direction of energy transfer. Examples of such waves are ripples in the water of a pond, and vibrations along a taught rope.



Above is a diagram of a longitudinal wave. Examples of such waves are sound waves and compression waves down a spring. Note that these waves do not oscillate perpendicular to the ray or direction of energy transfer.

4.4.4 Describe waves in two dimensions, including the concepts of wavefronts and of rays.

There are some important aspects of all waves which can be studied using the above.

- Wave fronts – These are the movement of the wave pattern, i.e. when the curve is going up, or going down. The wave fronts highlight the parts of the waves which are moving together.
- Rays – the rays highlight general direction of the wave and therefore the direction of the energy transfer.

4.4.5 Describe the terms crest, trough, compression and rarefaction.

In the above we have seen various terms to describe features of waves, and below is a definition for these:

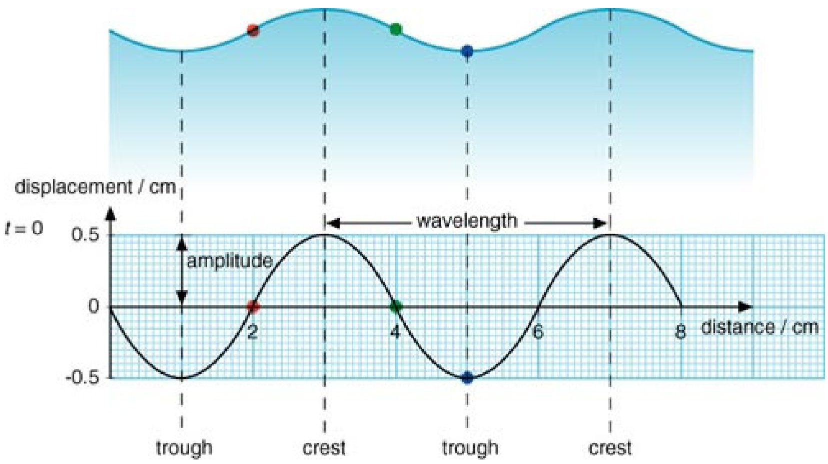
- Crest – This is the highest point the wave oscillates, it is the top of the wave. This is a feature of a transversal wave.
- Trough – The trough is the lowest point to which the wave oscillates, in other words it is the bottom of the wave. Again this is only a feature of transversal waves.

- Compressions – This is the point in a longitudinal wave where everything is bunched together, i.e. there is high pressure.
- Rarefacations – This is the point where all the points are far apart and there is low pressure.

4.4.6 Define the terms *displacement*, *amplitude*, *frequency*, *period*, *wavelength*, *wave speed* and *intensity*.

Amplitude	The amplitude is a measure of the maximum displacement of the wave. If there is no energy loss this value is constant.
Period	This is the time taken for one complete oscillation in seconds; this is also referred to as the periodic time.
Frequency	This is the number of oscillations that take place in one second, this is measured in hertz. 10Hz would mean that a wave is oscillating 10 times a second.
Wavelength	This is the shortest distance between one oscillation this can be the distance between any two points as long as the two points are in the same position.
Wavespeed	This is the speed (in ms^{-1}) at which the oscillation pass a stationary point.
Intensity	The intensity is the power per unit area that is absorbed by the observer. In English this is the power that the wave carries per oscillation to say as such, and is proportional to the square of the amplitude.

4.4.7 Draw and explain displacement–time graphs and displacement–position graphs for transverse and for longitudinal waves.

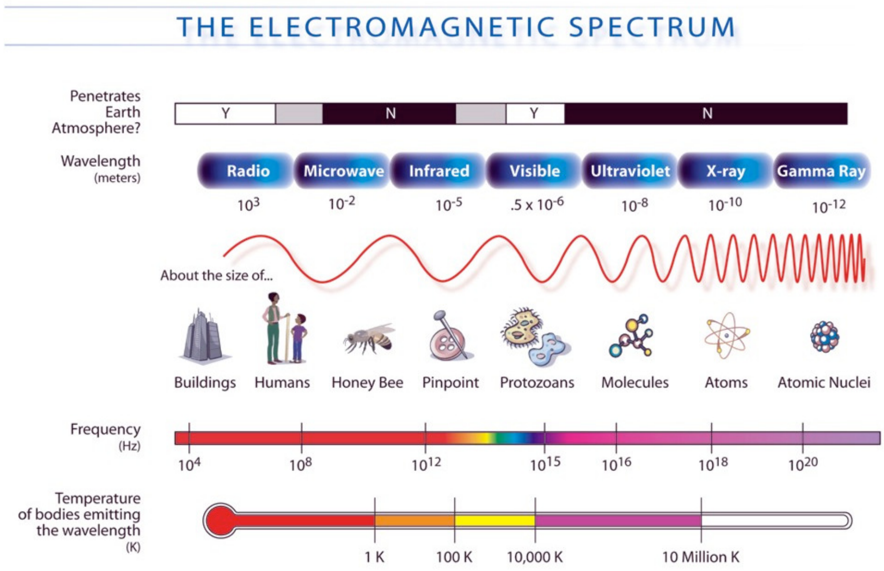


4.4.8 Derive and apply the relationship between wave speed, wavelength and frequency.

Wave Speed (ms^{-1}) = Frequency (Hz) x wavelength (m)

$$v = f\lambda$$

4.4.9 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 in the electromagnetic spectrum.



THE ELECTROMAGNETIC SPECTRUM
Penetrates Earth Atmosphere?
Y
N
Y
N
Wavelength (meters)
Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray
10^3
10^{-2}
10^{-5}
$.5 \times 10^{-6}$
10^{-8}
10^{-10}
10^{-12}
About the size of...
Buildings
Humans
Honey Bee
Pinpoint
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^4
10^8
10^{12}
10^{15}
10^{16}
10^{18}
10^{20}
Temperature of bodies emitting the wavelength (K)
1 K
100 K
10,000 K
10 Million K

4.5 Wave properties

4.5.1 Describe the reflection and transmission of waves at a boundary between two media.

At a boundary between two media, two things happen:

- Reflection: In this case the law of reflection applies incident angle = reflected angle when measured from the normal (an imaginary line at right angles to the surface).
- Refraction: In this case the wave is refracted towards the normal entering a slower medium and away from the normal entering faster medium.

4.5.2 State and apply Snell's law.

4.5.3 Explain and discuss qualitatively the diffraction of waves at apertures and obstacles.

Diffraction is when the wave spreads out after passing through a narrow opening.

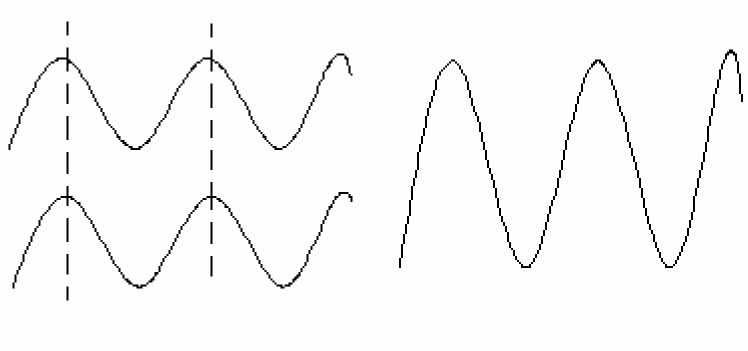
In general, diffraction is greatest when the size of the opening is of the same order as the wavelength.

4.5.4 Describe examples of diffraction.

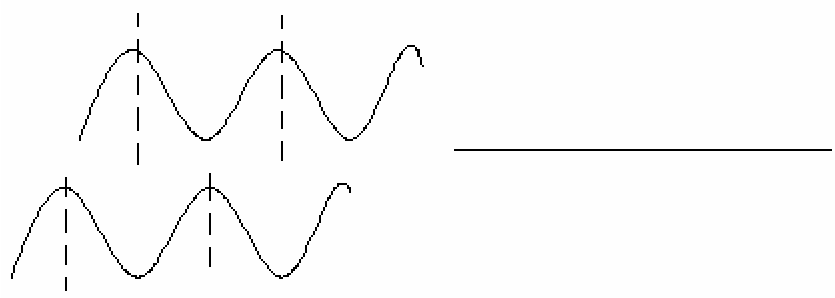
- Waves in the harbour, ocean waves diffract through the harbour opening and spread out.
- FM radio can be heard for a few meters after the tunnel opening as the signal diffracts through the opening.
- Light rays diffract around your hair so people with long floppy fringes can see diffraction patterns in bright weather.

4.5.5 State the principle of superposition and explain what is meant by constructive interference and by destructive interference.

Superposition is when two waves meet and effect each other.
The principle of superposition states that two waves add up in a vector fashion as follows:



This is called constructive interference and happens when the two waves are in phase.
path difference = $n\lambda$



This is called destructive interference and happens when the waves are out of phase.
Path difference = $(n+\frac{1}{2})\lambda$

4.5.6 State and apply the conditions for constructive and for destructive interference in terms of path difference and phase difference.

4.5.7 Apply the principle of superposition to determine the resultant of two waves.