FORM 4 SPM PHYSICS SHORTHAND NOTES
Chapter 5 Waves
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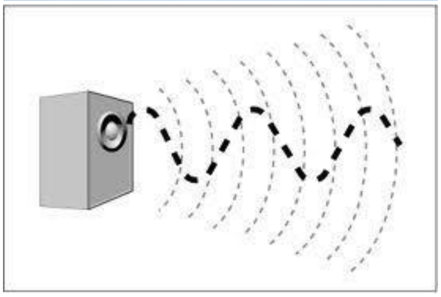
5.1 Fundamentals of Waves

Tick below what you think are waves.



Transverse waves: Particles vibrate perp*endicular/ along* the lines of motion and consists of a series of "peaks" and "valleys".

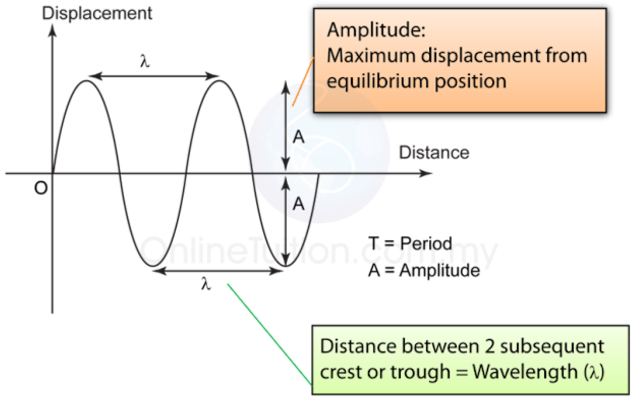
Longitudinal waves: Particles vibrate perp*endicular/ along* the lines of motion and consists of a series of compression and expansion.

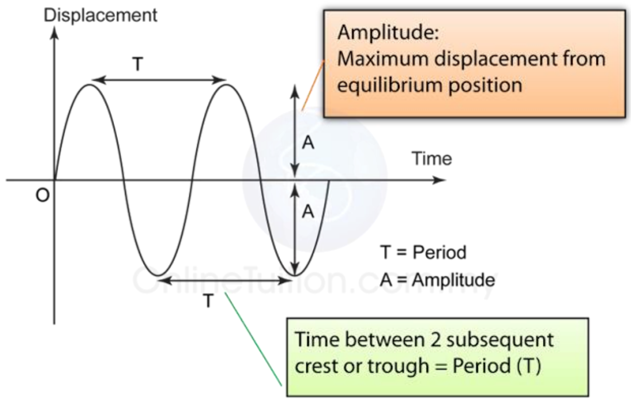
Revision:

1kHz = _____________Hz
1MHz = _____________Hz
1GHz = _____________Hz

If a wave starts from 0 meters and then moves up and down sinusoidally 5 times in 1 second. What is the period of the wave? What is the frequency of the wave? *Hint: Draw the wave out first!*

Ans:





Amplitude, *A*: The maximum displacement from the original position. The SI unit for amplitude is in **meters**.
Wavelength, λ: The horizontal distance between two points that are in phase. The SI unit for amplitude 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, the relationship between **frequency** and **period** is

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

The **speed** of the wave can be calculated from

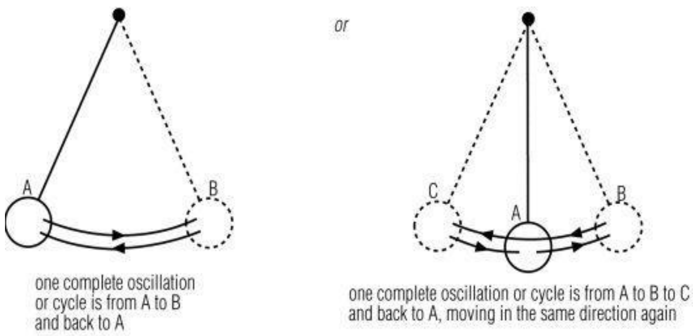
$$v = f\lambda$$

Where do waves come from?

Answer: Vibrations or oscillations.

An example for vibration is the way we speak. Your lung pumps the air and vibrates your vocal cords. This vibration is then "adjusted" by the larynx to fine tune the pitch and tone.

Examples of oscillating systems include a simple pendulum or a spring with a load on one end (watch videos).



Looking at the picture (right) above, can you tell me at which point/s is the amplitude of oscillation? *Hint: A, B or C*

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Suggest a way we find the period, *T*?

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What happens when I pull A even higher. What changes?

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The frequency does not change when we increase the swing height of the pendulum (increase its amplitude, A). The frequency of oscillation depends only on the length of the pendulum. Why? *natural frequency* of the pendulum is given by

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$$

Where l is the length of the pendulum and g is gravitational constant *(Note: this formula is not examinable in SPM but is examinable in STPM and A-levels)*.

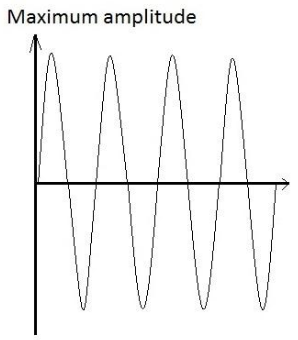
5.2 Damping and Resonance

The **natural frequency** of a system is the frequency of the system, which oscillates freely without an *external force*.

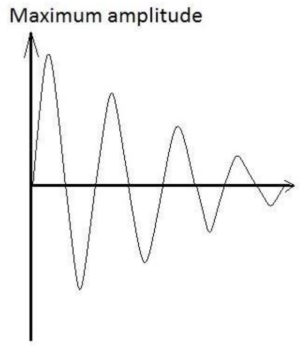
After a while, the pendulum will stop oscillating due to damping. **Damping** is the decrease of a system's amplitude due to wasted energy as heat. There are two types of damping: external and internal.

External damping: Air resistance.
Internal damping: Extension and compression of the molecules of a system.

The figure below shows a normal or forced oscillation

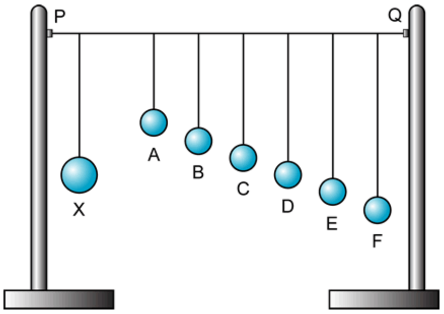


If we add a bit of damping to the system above, the oscillation will then look like this



How do you keep the pendulum oscillating?
By continuously applying a force to the pendulum.

Such a motion is called **forced oscillation**. When the frequency of the external force is the same as the system, the system will oscillate with the largest possible amplitude. This is called **resonance**.



If we pull oscillate pendulum X which pendulum will oscillate with the biggest amplitude? Why? Why? *Hint: Pendulum X is the external driving force.*

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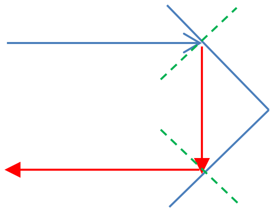
5.3 **Reflection of Waves**

Waves show the following four main phenomena: **reflection, Refraction, diffraction,** and **interference**.

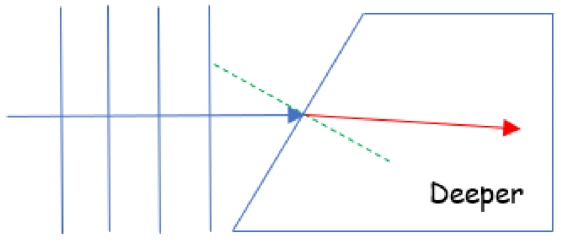
Reflection: Change of direction when it collides with a reflective barrier.



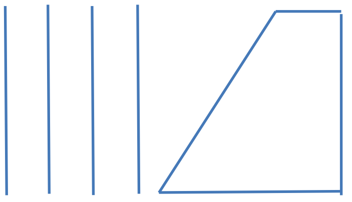
5.4 **Refraction of Waves**

Refraction: Change of direction when it goes through a change of medium. E.g. Water waves change direction when there is a change in the speed of the water. The speed of the water changes when there is a change in the depth of the water. From deep to shallow waters the wave's speed *increases/ decreases* as the wavelength becomes shorter. From shallow to deep waters the wave's speed *increases/ decreases* as the wavelength becomes longer (*Hint: recall* $v = f\lambda$). Refraction occurs when the direction of motion is *not perpendicular* to the border between the deep and shallow regions. E.g. tsunami

Hint: *1) Draw a line representing the direction of the wave propagation.*
2) Draw the normal line.

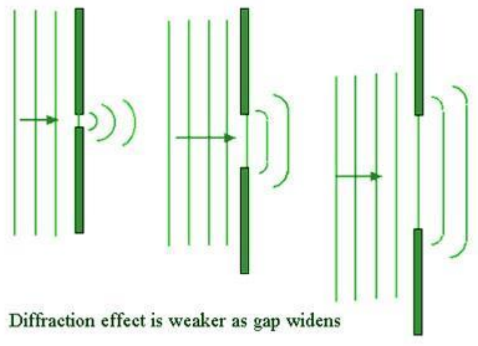


Try this refraction problem!



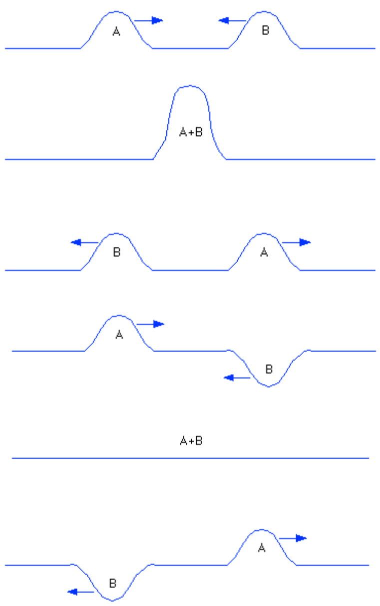
5.5 Diffraction of Waves

Diffraction: Spreads when it passes through an opening or an edge. Diffraction increases when the size of the gap decreases, or the wavelength of the waves increases. E.g. Sea coves



5.6 Interference of Waves

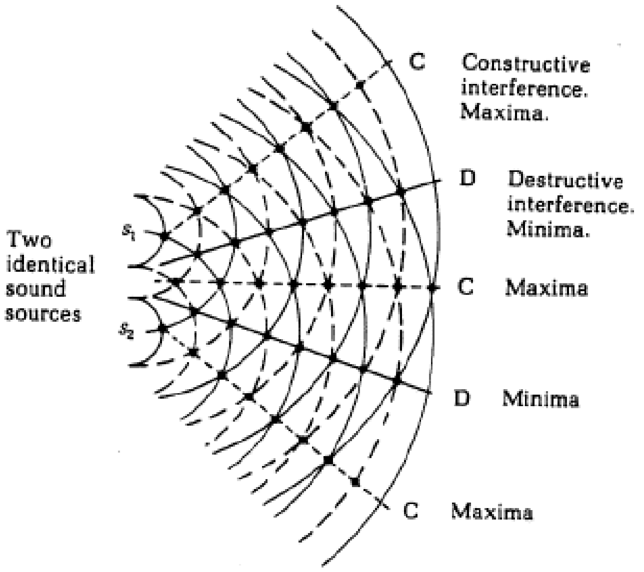
Interference: Interference of waves is the *superposition* of waves from two *coherent* sources. The principle of superposition states that when two or more waves pass through each other, the net displacement at a given point is equal to the vector sum of the displacement of the individual waves. What this means in layman terms is…



There are two types of interference:
Constructive interference: A crest meets another crest or a trough meets another trough.
Destructive interference: A crest meets a trough. Think of it as canceling each other out at that point.

In the previous diagrams, which are constructive and which are destructive?

The following diagram shows the interference of two water ripples.



Maxima or **antinodal** lines are lines where *constructive interference* occurs. **Minima** or **nodal** lines are lines where *destructive interfer*
ence occurs.

The distance between two successive *antinodal* lines or *nodal* lines can be calculated using:

$$x = \frac{\lambda D}{a}$$

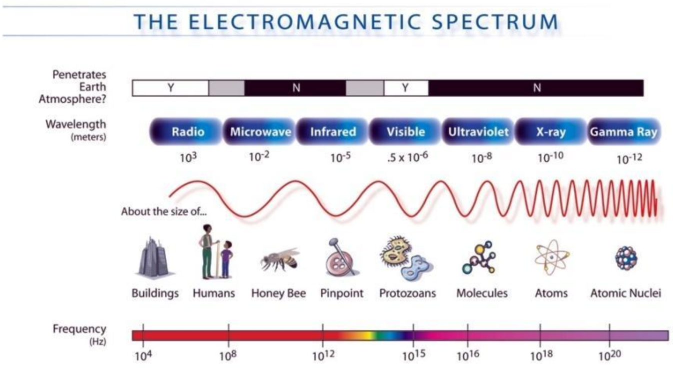
Where x is the distance between two successive lines
a is distance between two *coherent* sources of waves
D is the distance from the waves sources to the line PQ where x is measured

A quick summary of what occurs in each of the **four phenomena** you have learned so far.

Reflection	Refraction	Diffraction	Interference
Direction change	Speed change	Spreading of waves	Constructive
	Wavelength change		Destructive
	Direction change		

5.7 Electromagnetic Waves

Electromagnetic waves are transverse waves. It consists of electric field and magnetic field components. It can propagate without the need for a medium to carry it, unlike mechanical waves (e.g. water). The speed at which electromagnetic waves travel is $3x10^8$ 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 seven types of waves in the electromagnetic spectrum.



Mnemonic time!

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