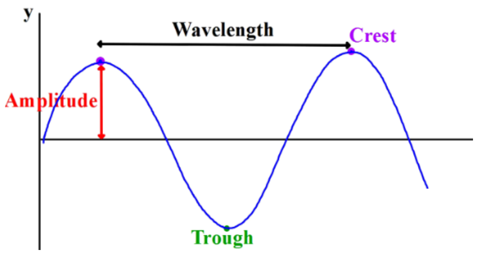
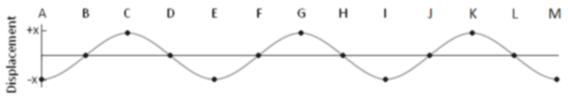
Subject: A-level Physics	Topic: Waves	Year Group: 12

Waves basics

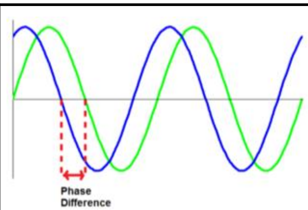
1	A wave is a periodic disturbance in a material or in space that transfers energy from one place to another.
2	
3	In the diagram above the horizontal black line is the equilibrium position.

Phase difference

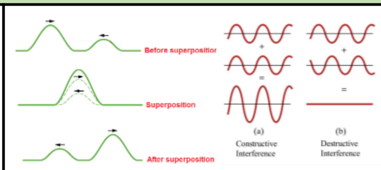
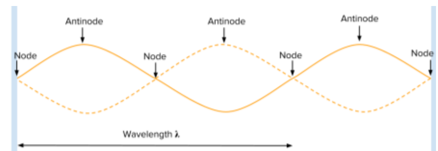
1	The phase difference between two points on a wave is the difference in their positions in the wave's cycle.



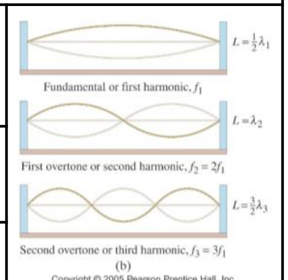
	B	C	D	E	F	G	H	I	J	K	L	M
Phase Difference from A (radians)	½π	1π	1½π	2π	2½π	3π	3½π	4π	4½π	5π	5½π	6π
Phase Difference from A (degrees)	90	180	270	360	450	540	630	720	810	900	990	1080

2	The phase difference between two waves is how much one wave lags behind the other.	
3	Phase difference is measured in degrees, radians or fractions of a cycle.	
4	In a stationary wave all points between consecutive nodes are vibrating in phase as they all reach their maximum displacement at the same time.	

Stationary waves basics

1	**Principle of superposition-** when similar waves meet the total displacement is the vector sum of the individual displacements.	
2	If both waves have the same sign displacement constructive interference occurs.	
3	If one wave has a positive displacement and the other has negative displacement then destructive interference occurs.	
4	When two progressive waves of the same frequency travel in opposite directions they superpose to produce a stationary wave. This happens when a progressive wave is made to reflect back on itself.	
5	Stationary waves store energy (rather than transmit it). 	

Stationary waves on a string

1	Since the string is fixed at both ends, the ends cannot vibrate. Therefore nodes form at the ends.	
2	The frequencies at which the stationary waves are produced are called harmonics.	
3	The lowest frequency at which a standing wave is formed is called the first harmonic. It has an antinode at the centre.	
4	**1st harmonic** - there is ½ a wavelength on the string so λ = 2l. The frequency is given by, f = c/2l	
5	The frequency of the 2nd harmonic is twice the first and so on.	

Key equations

1	Wave speed	$c = f\lambda$
2	Time period	$T = \frac{1}{f}$
3	Frequency of first harmonic	$f = \frac{1}{2l} \times \sqrt{\frac{T}{\mu}}$

Key Vocabulary

1	Progressive wave	A wave which transfers energy from one point to another.
2	Stationary wave	A non-progressive formed when two progressive waves of the same frequency travel in opposite directions and *superpose*.
3	Transverse	A type of wave where the oscillations are perpendicular to the direction of wave travel.
4	Longitudinal	A type of wave where the oscillations are parallel to the direction of wave travel.
5	Wavelength	The length of one cycle or the distance travelled by a wave in one period of oscillation.
6	Amplitude	The maximum displacement from the equilibrium position.
7	Frequency	The number of waves passing a point each second.
8	Time period	The time taken for one complete cycle.
9	Node	Points on a stationary where the displacement is zero.
10	Antinode	Points on a stationary wave where the displacement is maximum.
11	Principle of superposition	When similar waves meet the total displacement is the vector sum of the individual displacements.

Beckfoot

Subject: A-level Physics	Topic: Waves	Year Group: 12

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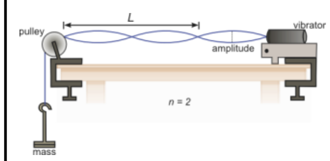
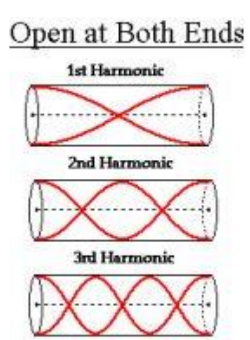
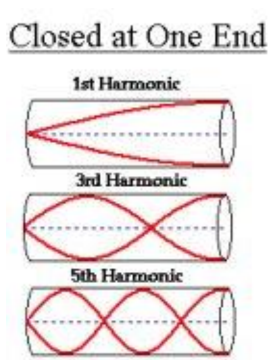
Stationary waves required practical

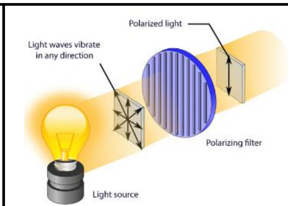
1	This setup can be used to produce stationary waves on a string. It can be used to verify that the frequency of the 1st harmonic is given by, $f = \frac{1}{2l} \times \sqrt{\frac{T}{\mu}}$	

2	Independent	Length of string between pulley and vibrator.
	Dependent	Fundamental frequency (measured from signal generator).
	Control	Mass per unit length of string.

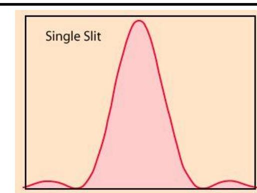
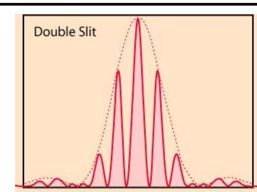
Stationary waves in pipes

1	Blowing into a pipe (e.g. flute) causes the air in it to vibrate. Sound waves reflect from both the closed and open ends of a pipe, resulting in a stationary wave in the pipe.	
2	Nodes are always found at the closed ends of pipes. Antinodes are always formed at the open ends of pipes.	
3		

Polarisation

1	Only **transverse waves** can be polarised.	
2	Transverse waves have oscillations that are perpendicular to the direction of wave travel. There are an infinite number of ways this can happen.	
3	A polarising filter allows waves only with oscillations in a certain plane to pass through.	
4	Polarising filters can be used to reduce glare e.g. in sunglasses.	
5	TV signals are also transmitted as polarised waves. The alignment of the receiving aerial must match the polarisation direction of the transmitted wave.	

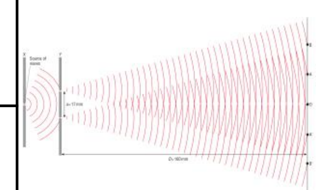
Diffraction

1	Diffraction is most noticeable when the aperture is a similar size to the wavelength of the wave.	
2	The diffraction of light through a single slit produces this pattern. The central maxima is twice as wide and much more intense than the other maxima. The smaller the gap, the wider the central maxima.	
3	This is the diffraction pattern of light when passed through a double slit.	
4	When white light passes through the slit, rather than monochromatic light, each colour diffracts a different amount which leads to a rainbow effect in all but the central maximum.	

Key Vocabulary

1	Polarised wave	A transverse wave whose oscillations are confined to one plane.
2	Diffraction	The spreading out of a wave after passing through an aperture or around an obstacle.
3	Monochromatic	Radiation of a single frequency / wavelength.
4	Coherent	Two sources of waves are **coherent** if they have the same frequency, are polarised in the same plane and they maintain a constant phase difference.
5	Constructive interference	Interference between waves that results in an increase in amplitude.
6	Destructive interference	Interference between waves that results in a decrease in wave amplitude.
7	Path difference	How much further one wave has travelled than the other.

Interference

1	When the path difference from the two sources is a full number of wavelengths (nλ where n is an integer) you get constructive interference e.g. at B.	
2	When the path difference is a half, 1.5, 2.5 number of wavelengths, (n+0.5)λ, you get destructive interference e.g. at A.	
3	To demonstrate a clear interference pattern you need to use a coherent source such as a laser.	
4	Laser safety	Never shine the laser towards anyone or towards reflective surfaces. Always display a warning sign on the door. Turn it off when it is not needed.

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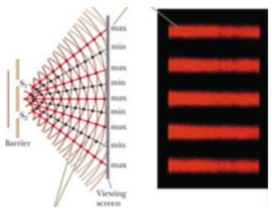
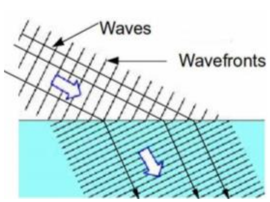
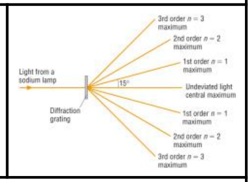
Young's double slit

1	Young's double slit experiment demonstrates two source interference with light by shining a light source (e.g. a laser) through a double slit. The pattern produced is shown here.	
2	It can be shown that, $w = \frac{\lambda D}{s}$	w = fringe spacing D = distance between slits and screen s = spacing between slits
3	The required practical on Young's double slit experiment requires you to use the above formula to determine the λ of a laser.	
4	Independent	Distance between slit and screen.
	Dependent	Fringe spacing
	Control	Spacing between slits
5	To reduce percentage uncertainty in measurements of w you would measure the distance between many fringes then divide by the number of fringe widths between them.	

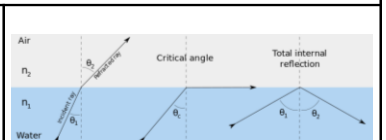
Refraction

1	Waves travel more slowly in optically dense mediums.	
	When a wave slows down the wave fronts get closer together, meaning the wavelength is reduced.	
	The frequency is unchanged as this is determined by the source.	
2	Rays of light refract towards the normal when they slow down and away from the normal when they speed up.	
3	The higher the refractive index, the more optically dense the material and the more refraction.	
4	The refractive index of air is usually taken to be 1.	

Diffraction gratings

1	Diffraction gratings contain lots of equally spaced slits.	
2	They produce very sharp interference patterns, allowing for more accurate measurements.	
3	The interference pattern produced has a line of maximum brightness at the centre called the zero order line. The lines either side are called first order lines and so on.	
4	$d \sin\theta = n\lambda$	d = distance between slits θ = angle between incident beam and nth maximum n = order of maximum
5	d = 1 metre / number of slits in a metre	
6	The required practical on diffraction gratings requires you to use the above formula to determine the λ of a laser.	

Optical fibres

1	Optical fibres are long, very thin solid cylinders of glass or transparent polymer.	
2	The fibres used in communications are made up of two layers of glass. The inner layer (core) is where the light is transmitted and the outer layer (cladding) protects the cable.	
3	Light passes through the fibre using total internal reflection.	
4	When light travels into a less optically dense medium it is refracted away from the normal (shown here).	
5	As θ_1 increases, so does θ_2 until the light ends up being refracted along the boundary. The angle of incidence at which this happens is called the critical angle.	
6	If you increase the angle of incidence further still no light escapes from the medium, the light is totally internally reflected.	

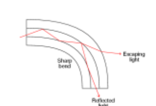
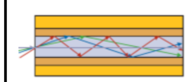
Key equations

1	Young's double slit	$w = \frac{\lambda D}{s}$
2	Diffraction grating	$d \sin\theta = n\lambda$
3	Refractive index	$n = \frac{c}{c_s}$
4	Snell's law	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
5	Critical angle	$\sin\theta_c = \frac{n_2}{n_1}$

Key Vocabulary

1	Refraction	The change in direction of a wave due to a change in wave speed as it travels between materials.
2	Refractive index	The ratio of the speed of light in a vacuum, c, to the speed in the substance, c_s
3	Critical angle	The angle of incidence above which all the light is totally internally reflected.

Signals in optical fibres

1	Absorption is where some of the signal's energy is absorbed by the material of the fibre, resulting in a reduced signal amplitude.	
2	If a fibre is bent too sharply it will alter the angle the ray makes with the normal. It can mean the light strikes the cladding at less than the critical angle and leaves the fibre.	
3	Modal dispersion - Rays enter the fibre at different angles and therefore take different paths, meaning each ray takes a different time to leave the fibre. The signal is spread out by the time it reaches the receiver. Solution: use a narrower fibre or use a core and cladding of similar n.	
4	Chromatic dispersion – A material's n varies with λ meaning white light splits into a spectrum. Solution: use monochromatic light.