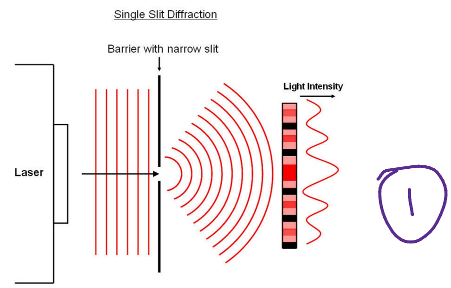
Diffraction, Two Source Interference, Gratings

10 December 2019 08:44



Waves spread out when they go through a gap, or a hit a corner. Happens most when $\lambda \approx$ gap width. This occurs because Huygens' Principle. If you are a keen bean then then the first 4 or 5 minutes of this video https://www.youtube.com/watch?v=41GP7VCY86g are excellent (but not really on the syllabus)

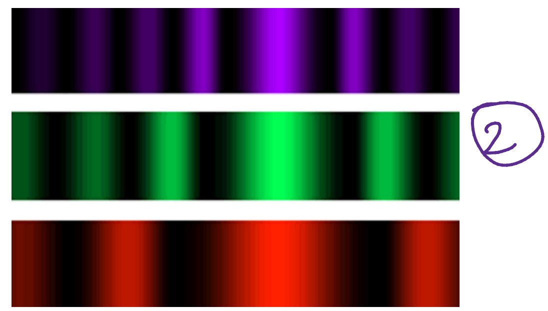
Once you are aware of these effects look out for them - especially when you go near a lake, river, sea. You can easily see the wave properties in action - and they can be quite beautiful.

Single Slit

At a single slit, where λ is about slit width you will see a diffraction pattern as in diagram 1

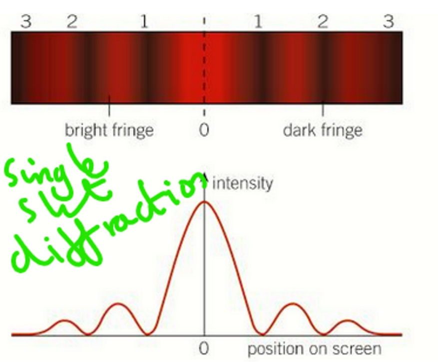
You get a wide, central maximum, surrounded by a symmetrical pattern of dark and bright fringes which are narrower. These bands are caused by interference/superposition

- Bright fringes - constructive interference
- Dark fringes are destructive interference.



If you since different wavelengths through the single slit you get something like the image 2. See how larger λ are diffracted most.

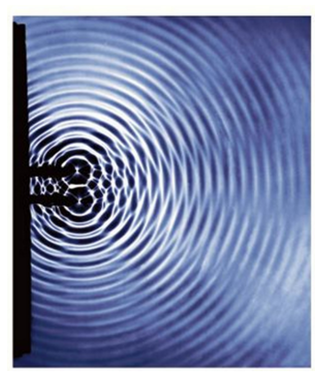
If you shone white light through you'd see a central white max, surrounded by coloured fringes as the different wavelengths are diffracted by different amounts.

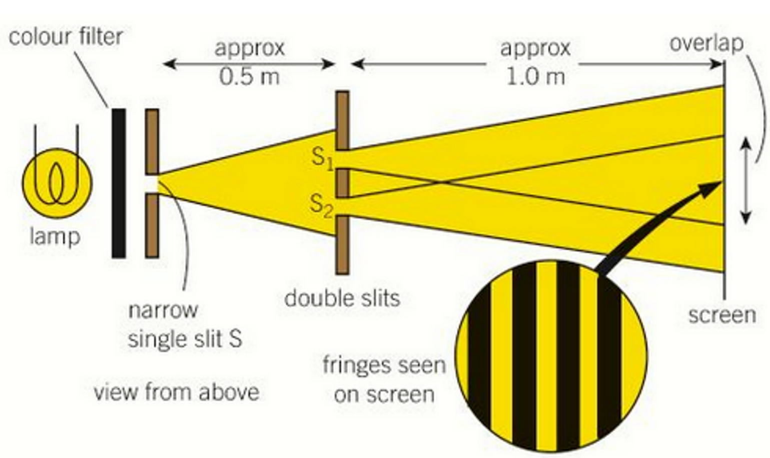


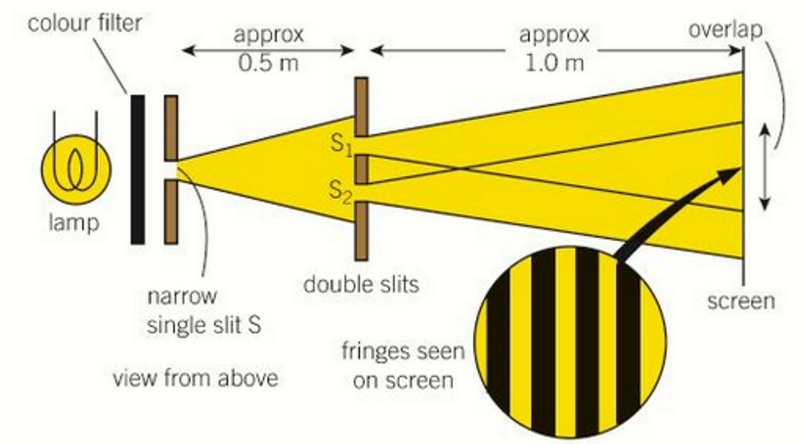
Two Source Interference

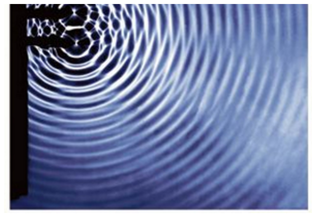
You can get this effect in several ways. Young's Double Slit, two loudspeakers etc

A coherent source is one where the waves are of the same frequency, and with the a constant phase difference. Of course the laser is the best example of this, and if it crops up you will most likely get asked about safety - ie don't look into the laser!



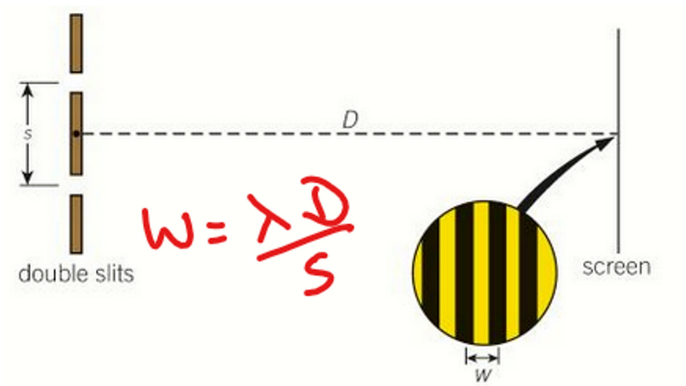






In this image of Young's Double slits a filter is used to create a narrower band of λ. This is then passed through a single slit which acts to create a coherent source which then hits the double slit. Diffraction occurs at S1 and S2 and these waves then interfere at the screen leading to a set of fringes that are symmetrical about the midline.

Fringe spacing is the distance from the center of a dark fringe (a minimum) to the center of the next one. (or from adjacent bright fringes). But usually you would measure across a series of fringes and divide by the number of fringes you counted to get the fringe spacing - this reduces the uncertainty (and takes account of the fact that the fringes aren't always the same size...)

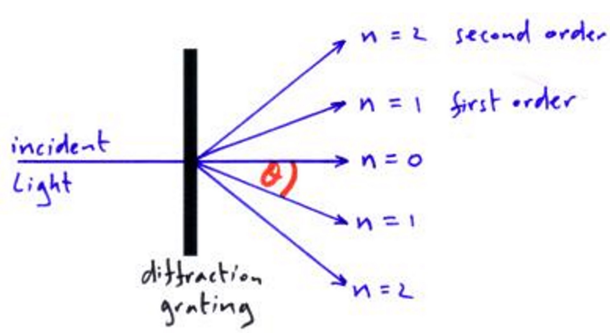


If you look in the internet for images of the diffraction pattern produced it can be confusing - you will see images with different sized fringes.... This can be due to the use of a single slit that is too wide (remember the single slit can be used to create a coherent light source which is then incident on the double slit). The effect is that the pattern is degraded. With a laser you get clear, equally spaced, well defined fringes.

Young's Double Slit is so famous because it showed light can be diffracted and interfere - both wave properties. The Rock Star Scientist of the time, Newton, had suggested that light was a particle....

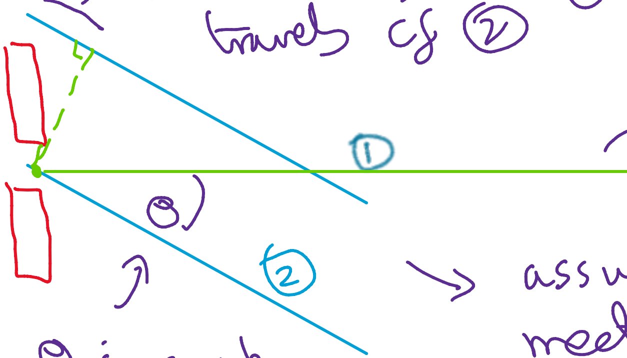
Diffraction Gratings

With a larger number of slits you get basically the same pattern as with the double slit, just the bright fringes are narrower, and further apart.



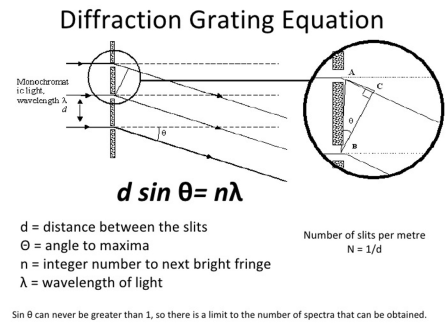
You need to be able to derive the formula for gratings. Its not difficult. It is a question of grasping the fact that two rays from adjacent slits travel different distances when they arrive at the screen,

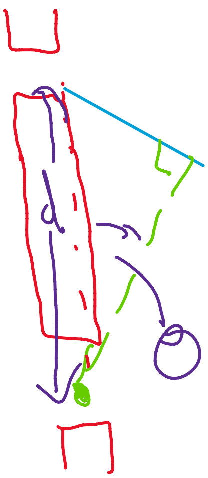
extra distance (1) travels cf (2)



θ is angle to the fringe

→ assume rays meet.... ie they "are parallel" and "not parallel" at the same time





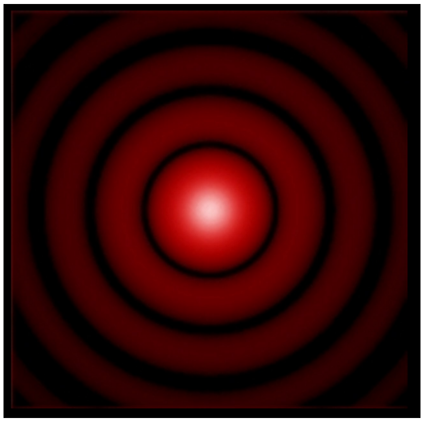
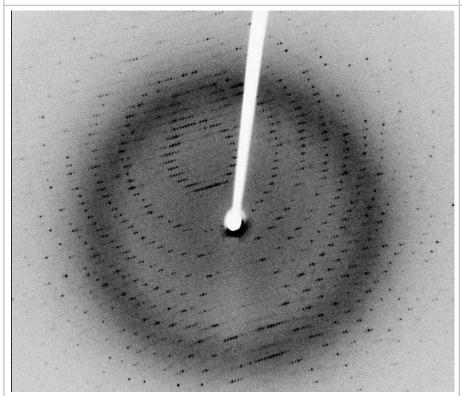
The slit spacing is d which is the hypotenuse .... the extra distance is ∴ $d \sin \theta$ for the first fringe, $2d \sin \theta$ for the second.

This leads to $n\lambda = d \sin \theta$

Diffraction gratings are fab because you can get very clearly defined bright fringes that are well separated. So shine a light source, say from a distant star into one and you will see the emission spectra - a series of bright lines. From this you can work out what elements are emitting the light, and hence what the star is made of.

Diffraction is also used to look at atomic/molecular structure - the regular lines of atoms in a crystal acts as a grating. Interestingly if we fire electrons at such materials we get diffraction patterns, suggesting that particles have wave properties.

Some Extra Stuff - because its fab!

	Here is a single colour of light going through a pin hole. Quite, quite beautiful
	X ray diffraction pattern of a enzyme - the x rays diffraction around the structure, and from the image that structure can be determined. Clever stuff