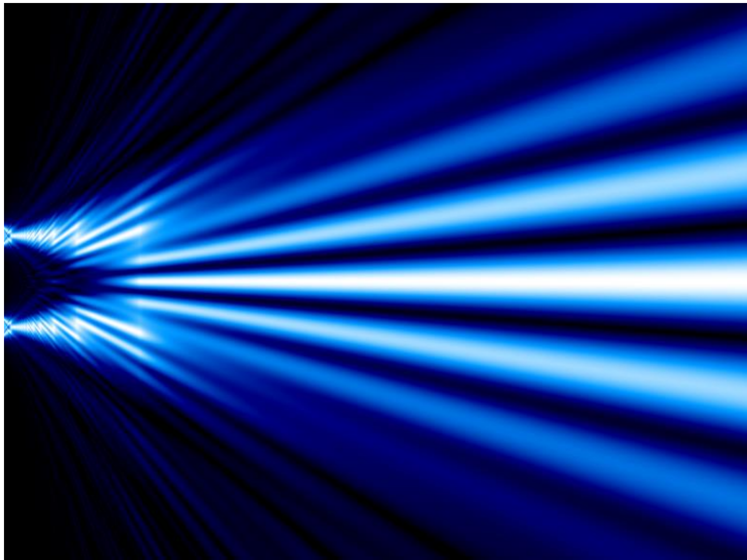
Waves & The Particle Nature of Light

2015 EdExcel A Level Physics
Topic 5

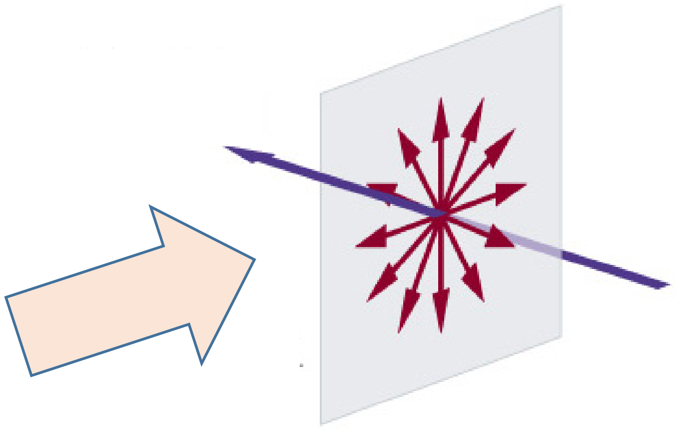
Polarisation and Diffraction

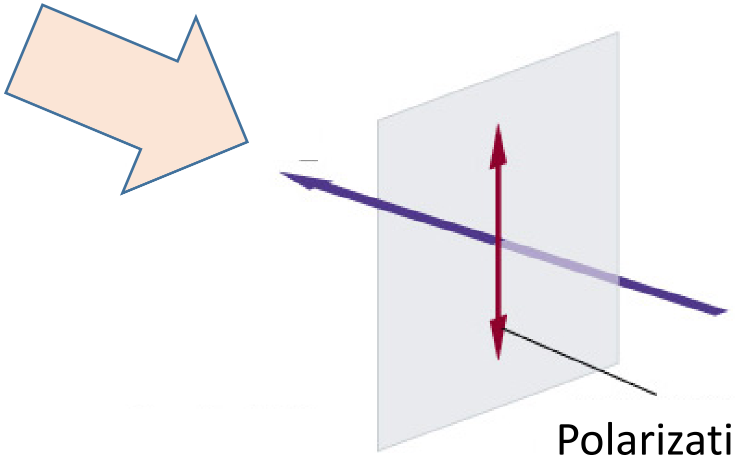


Physics Tutor Online

Polarization

- Polarization is a characteristic of all transverse waves.
- Oscillation which take places in a transverse wave in many different directions is said to be unpolarized.
- In a polarized transverse wave, oscillations take place in one direction only (the polarization direction).





Polarization

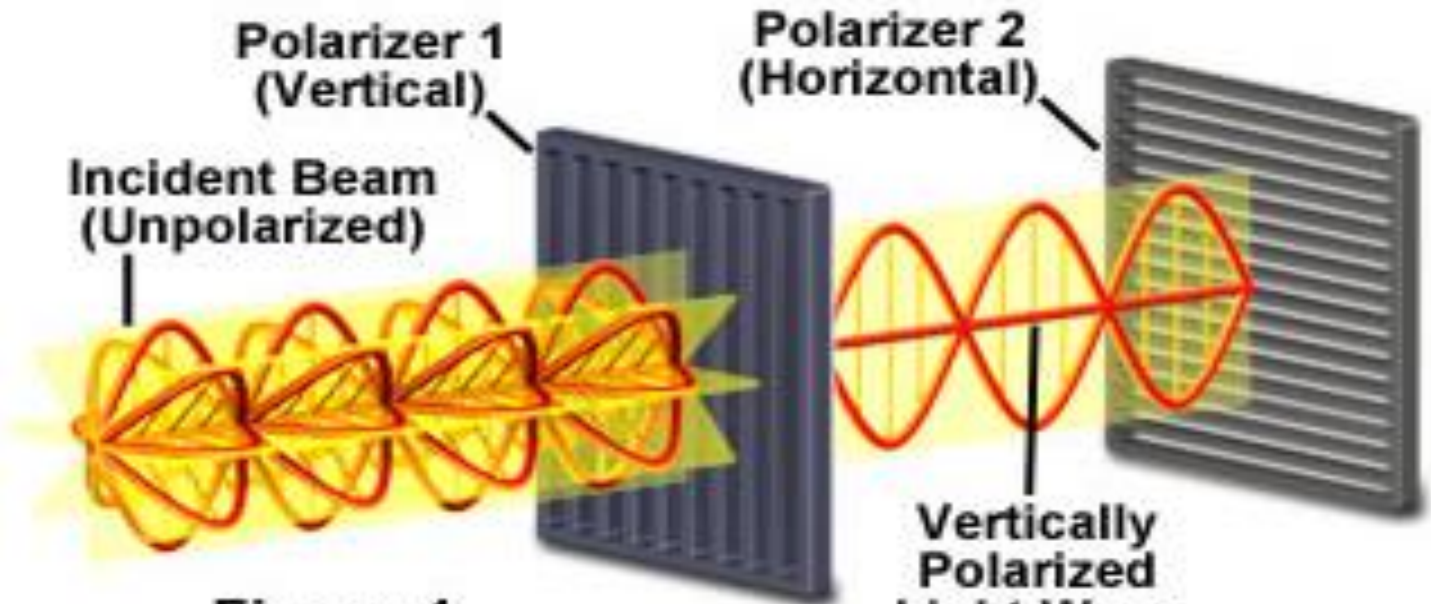
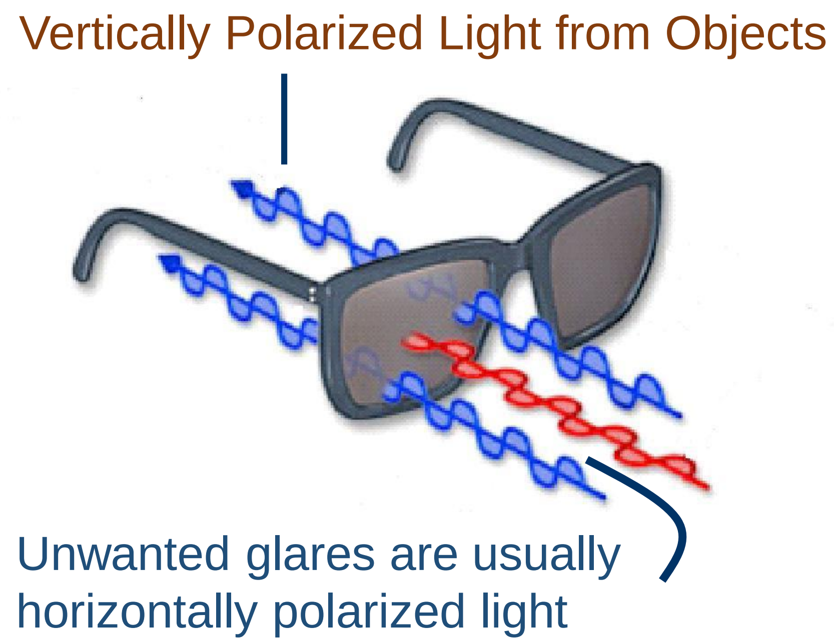


Figure 1

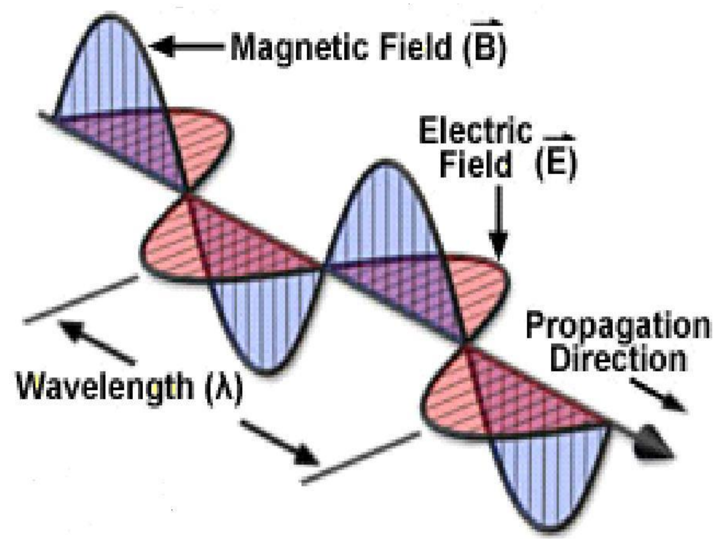
Action of Polaroid Sunglass

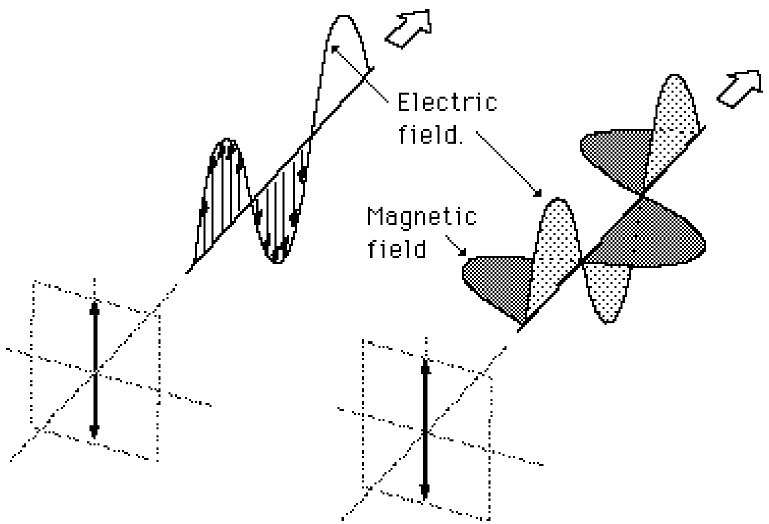
Light reflected from surfaces like a flat road or smooth water is generally horizontally polarized. This horizontally polarized light is blocked by the vertically oriented polarizers in the lenses.



Electromagnetic Wave

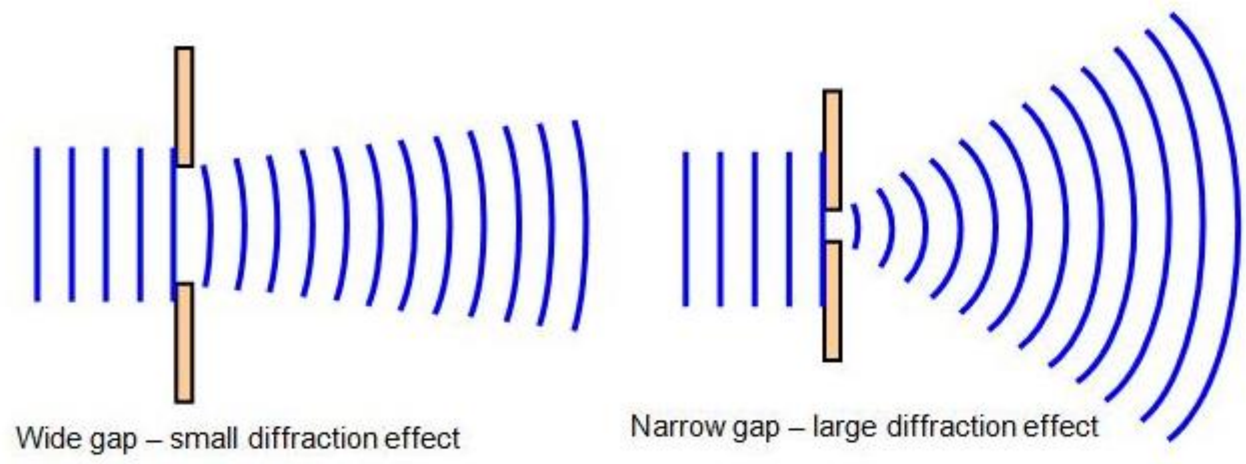
- Light is an electromagnetic wave.
- It consists of vibrations of electric field and magnetic field.
- The electric field and magnetic field are
- perpendicular to each other and in phase.
- EM wave is a transverse wave.
- The speed of EM wave is 3×10^8 ms^{-1}.





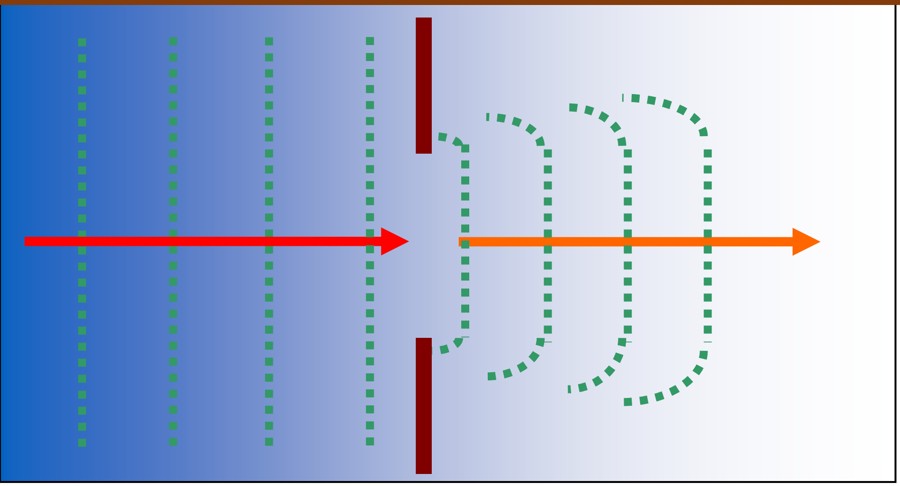
Diffraction

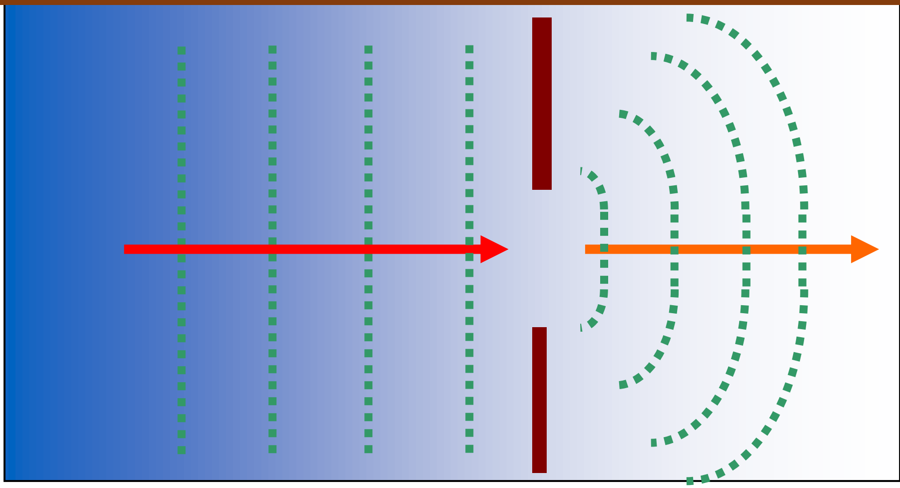
- Diffraction is the bending of a wave as it moves around an obstacle or passes through a narrow opening.
- The wave will try to curve around the boundary or outward through the opening due to friction.



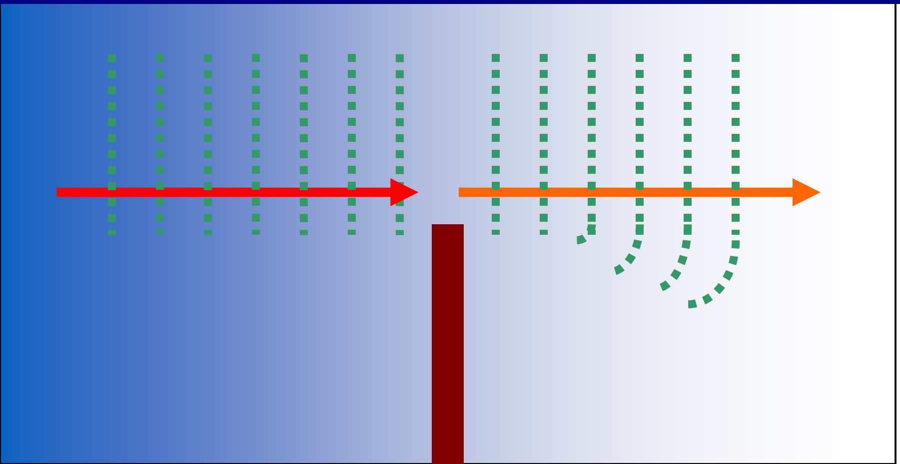
Diffraction cont.

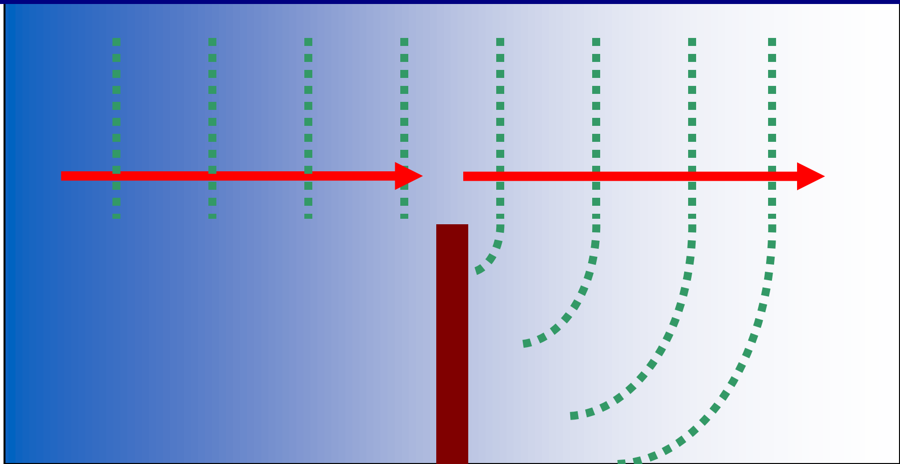
More diffraction if the size of the gap is similar to the wavelength



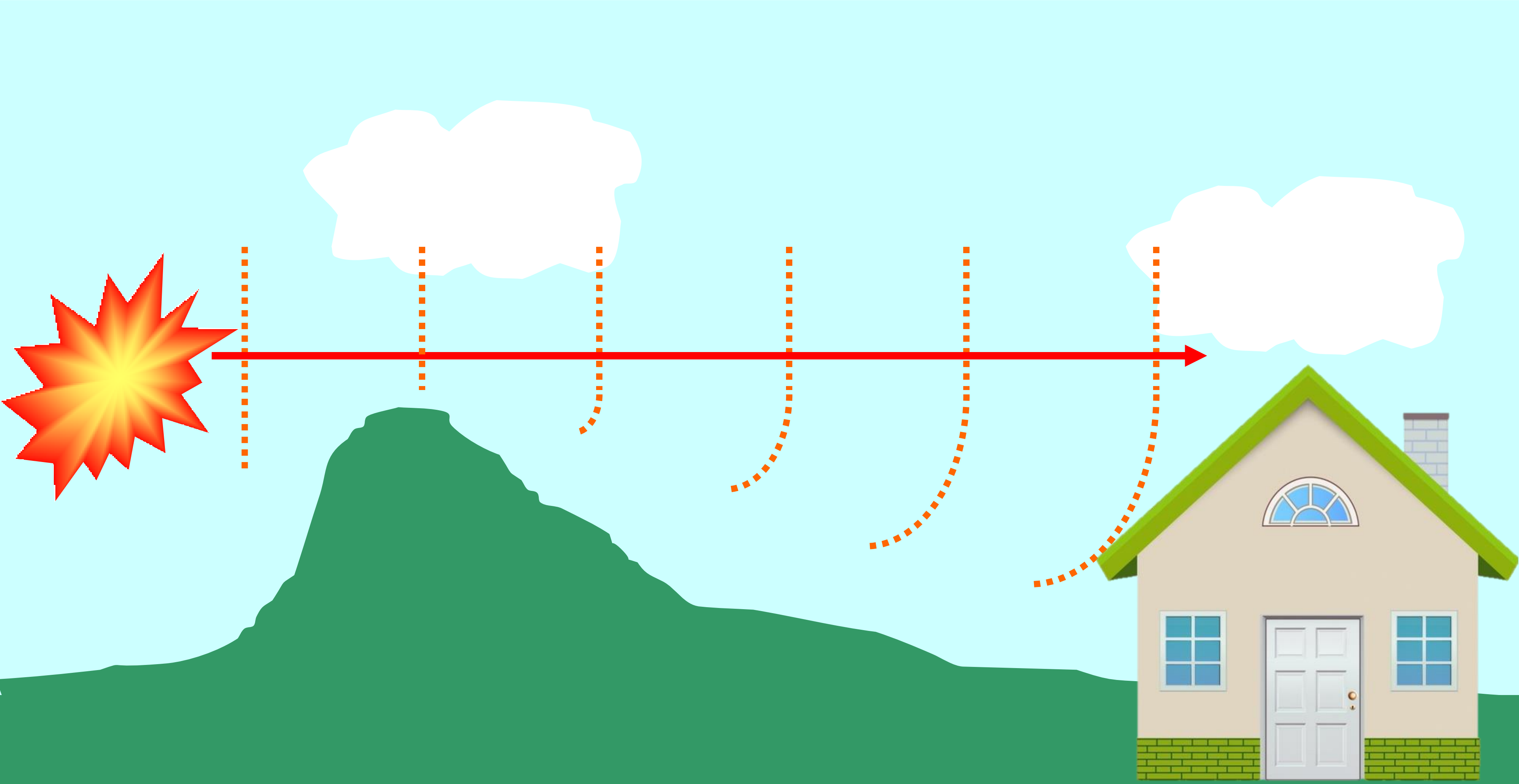


More diffraction if wavelength is increased (or frequency decreased)



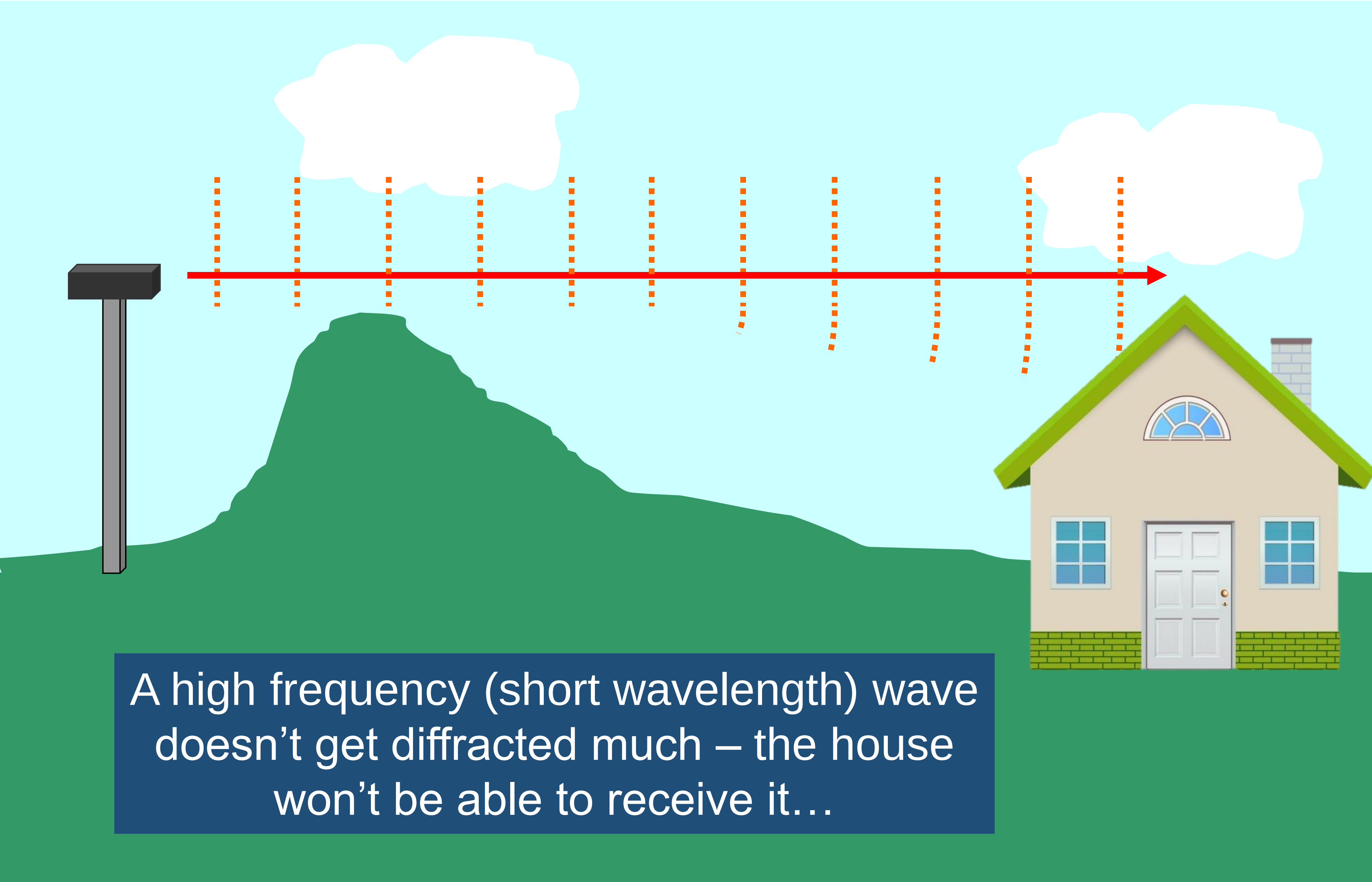


Diffraction of Sound



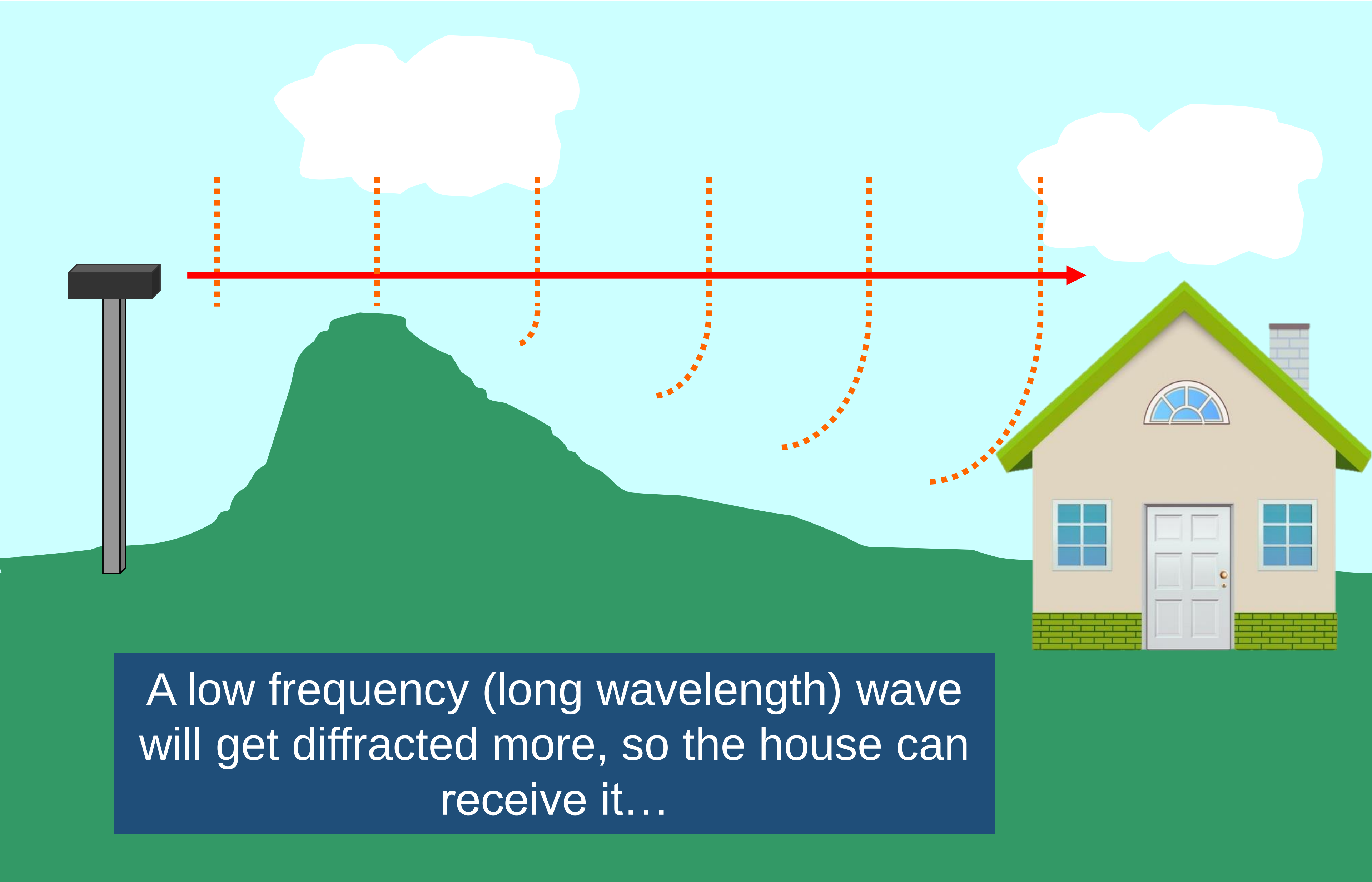
The explosion can't be seen over the hill, but it can be heard. We know sound travels as waves because sound can be refracted, reflected (echo) and diffracted.

Diffraction depends on frequency



A high frequency (short wavelength) wave doesn’t get diffracted much – the house won’t be able to receive it…

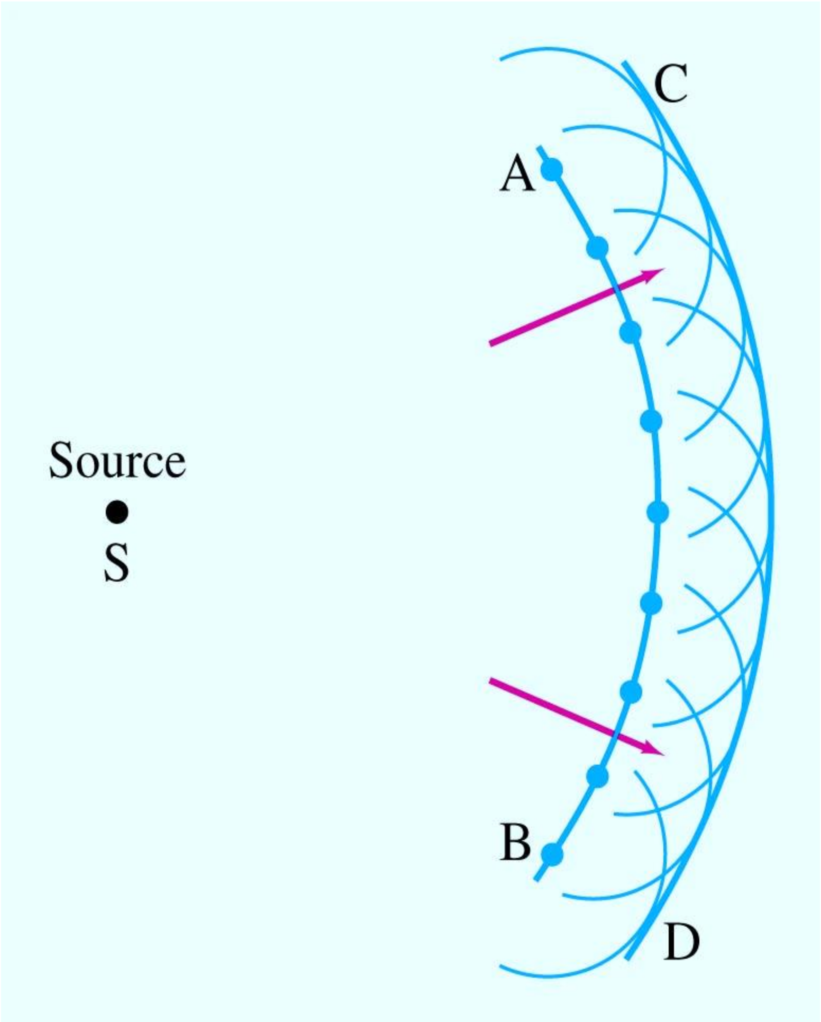
Diffraction depends on frequency cont.



Huygens’ Principle

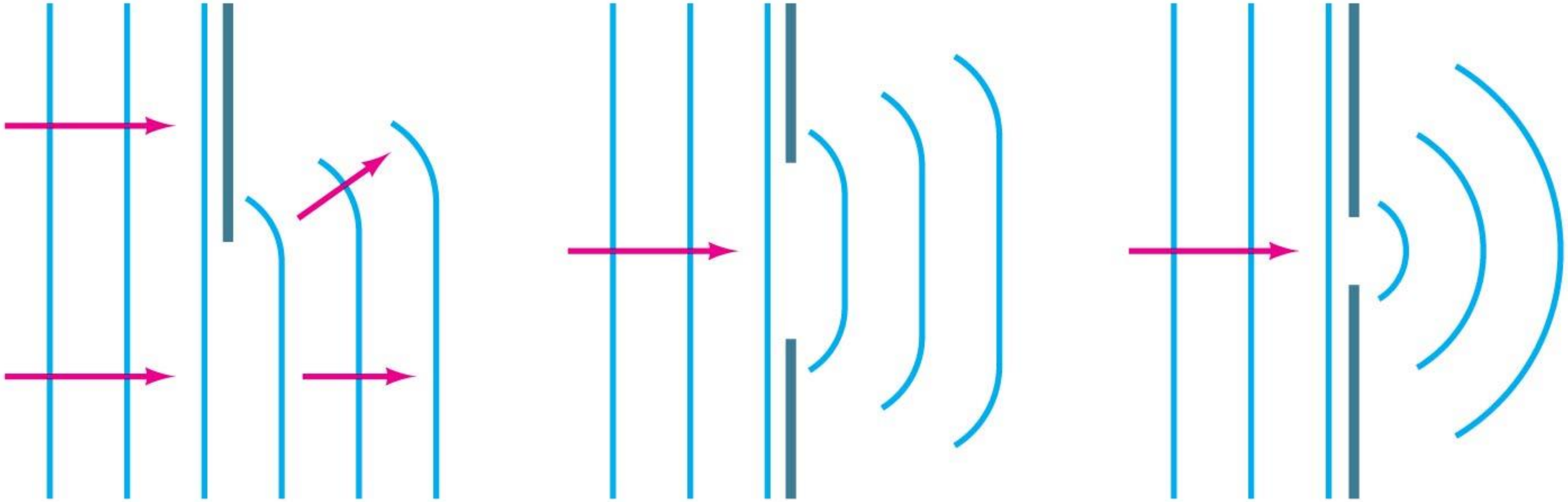
Huygens proposed that every point on the wave front of a wave was a source of a spherical wave.

The resultant wave is determined by adding all the waves from the point sources



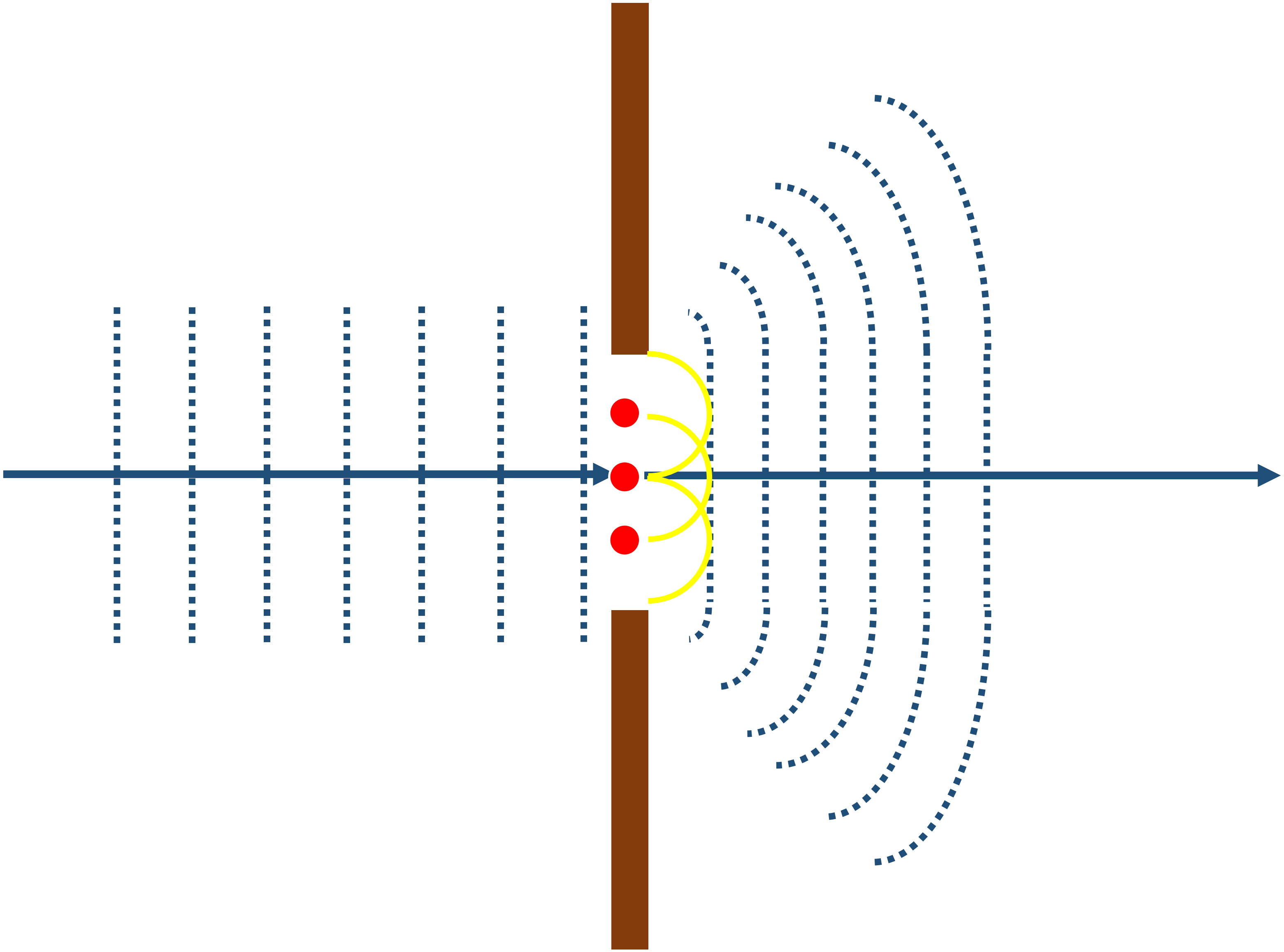
Huygens’ Principle and Diffraction

Huygens’ principle is consistent with diffraction:



(a) (b) (c)

Example of using Huygens' Construction

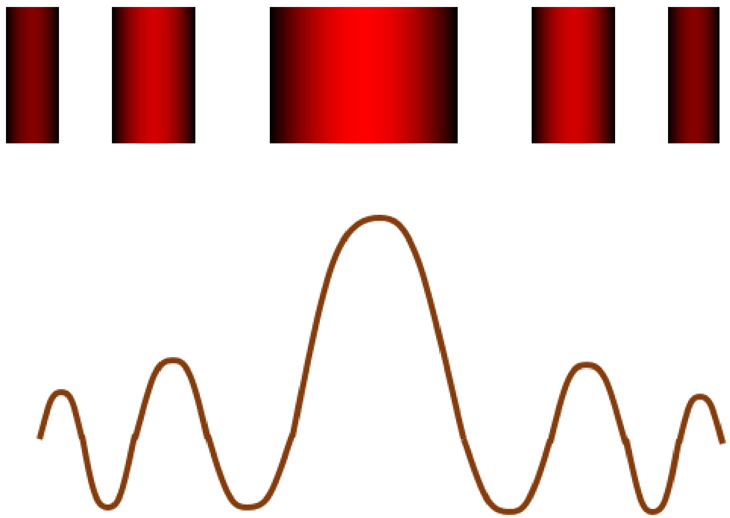


Diffraction by a Single Slit or Disk

Light will also diffract around a single slit or obstacle.

The resulting pattern of light and dark stripes is called a diffraction pattern.

This pattern arises because different points along a slit create wavelets that interfere with each other just as a double slit would.

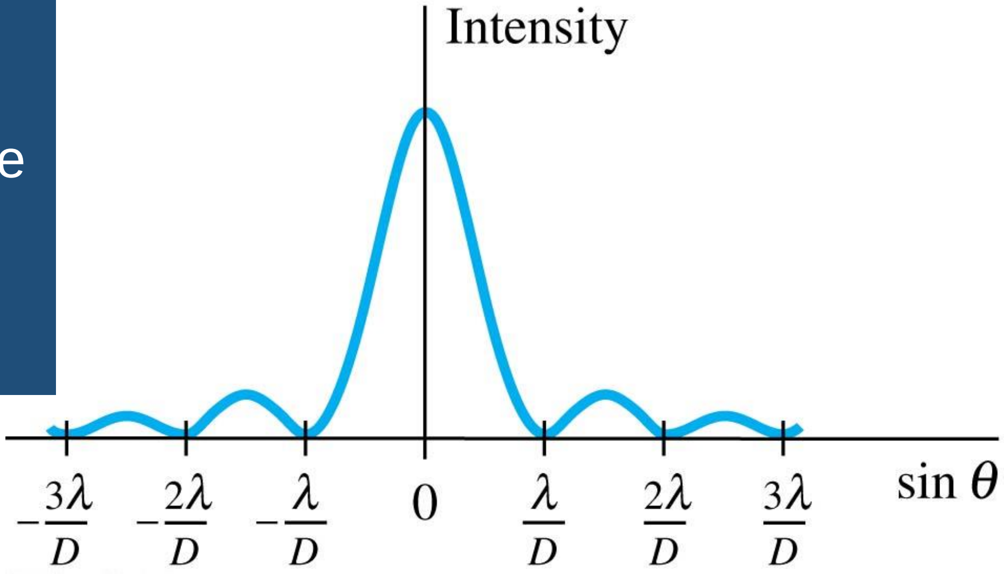


Diffraction by a Single Slit or Disk

The minima of the single-slit diffraction pattern occur when

$$d \sin\theta = n\lambda \qquad n = \pm 1, \pm 2, \pm 3, \cdots,$$

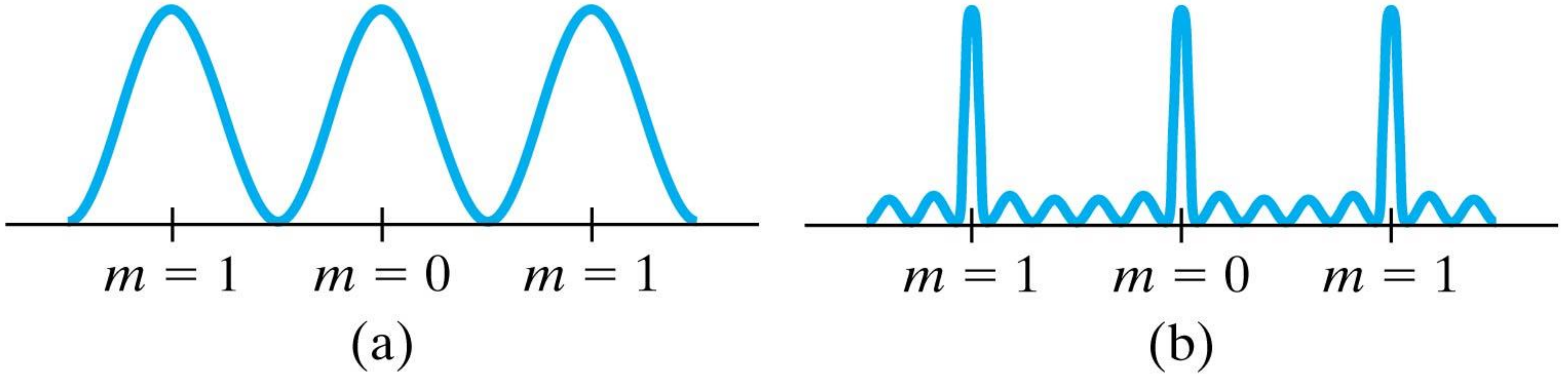
where n = the order of the bright spot, λ is the wavelength of the light, d is the slit separation and θ is the angle between the bright spot and the original angle.



Diffraction Grating

A diffraction grating consists of a large number of equally spaced narrow slits or lines. A transmission grating has slits, while a reflection grating has lines that reflect light.

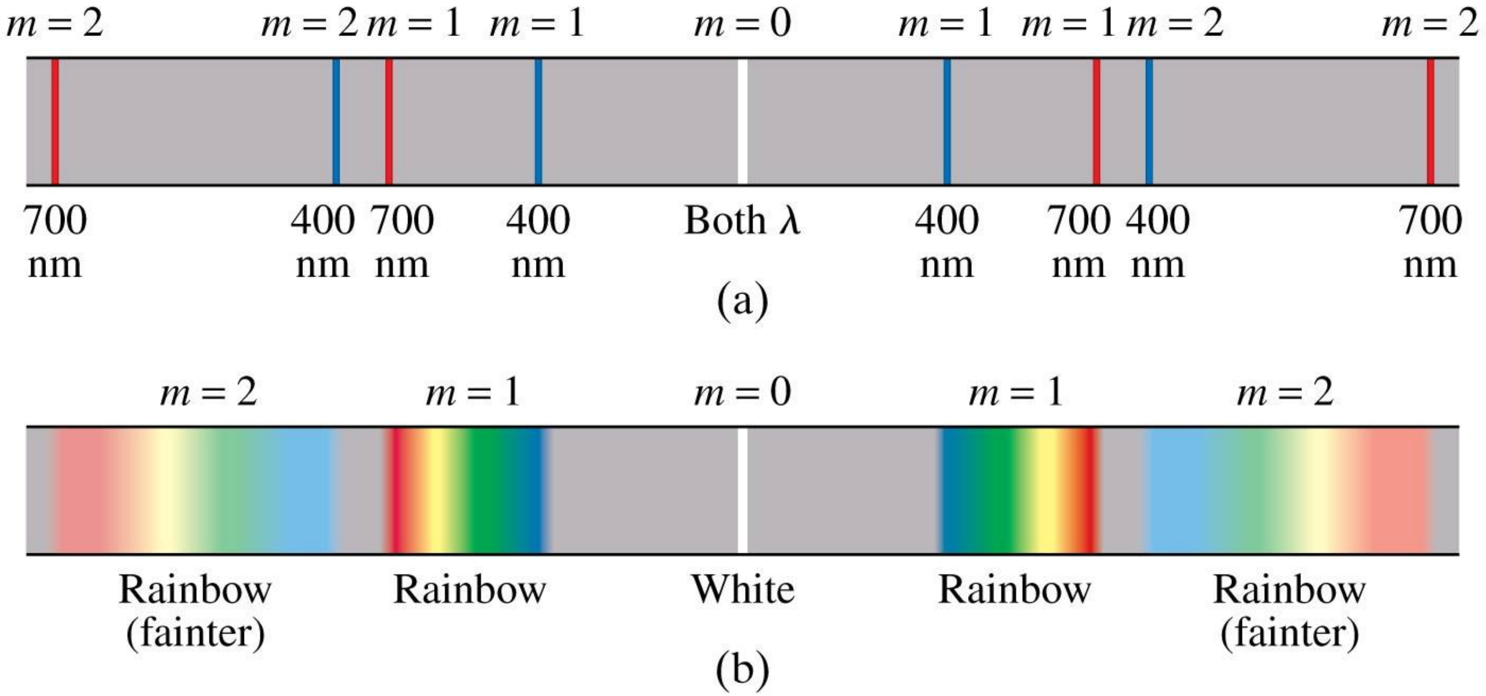
The more lines or slits there are, the narrower the peaks.



Diffraction Grating cont.

The maxima of the diffraction pattern are defined by

$$\sin\theta = \frac{m\lambda}{d}, \quad m = 0,\ 1,\ 2,\ \cdots$$



Example

When a grating with 300 lines per mm is illuminated normally with a parallel beam of monochromatic light a second order principle maximum is observed at 18.9^0 to the straight through direction. Find the wavelength of the light.

Solution:

Example

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Solution:

300 lines per mm is 3.00×10^5 lines per metre and therefore the spacing

$d = 1/3.00 \times 10^5 m$

A second order maximum means n=2

Using $n\lambda = d \sin\theta$

$$\lambda = \frac{1}{2 \times 3 \times 10^5} x \sin 18.9 = 5.40 x 10^{-7} m$$

Practice Questions

1) In the diagram above, the angle between the second bright red line and the centre is 2^{o}. If red light has a wavelength of 630nm what is the slit separation?

2) Another double slit of separation 200μm has blue light shone on it. Calculate the angle to the third bright spot if blue light has a wavelength of 400nm.

Core Practical 8 – Wavelength of laser light

Task: how can you measure the wavelength of laser light using a diffraction grating and this equation?

$n\lambda = d\sin\theta$