Diffraction

We classically think of light as always traveling in straight lines, but when light waves pass near a barrier they tend to bend around that barrier and become spread out. The definition of diffraction is the spreading of waves as they pass through or around an obstacle. More specifically when applied to light, diffraction of light occurs when a light wave passes by a corner or through an opening or slit that is physically the approximate size of, or even smaller than that light's wavelength.

Diffraction is the spreading out of waves as they pass through an aperture or around objects. It occurs when the size of the aperture or obstacle is of the same order of magnitude as the wavelength of the incident wave. For very small aperture sizes, the vast majority of the wave is blocked. For large apertures the wave passes by or through the obstacle without any significant diffraction.

In an aperture with width smaller than the wavelength, the wave transmitted through the aperture spreads all the way round and behaves like a point source of waves (they spread out below).

This is shown in the diagram below:

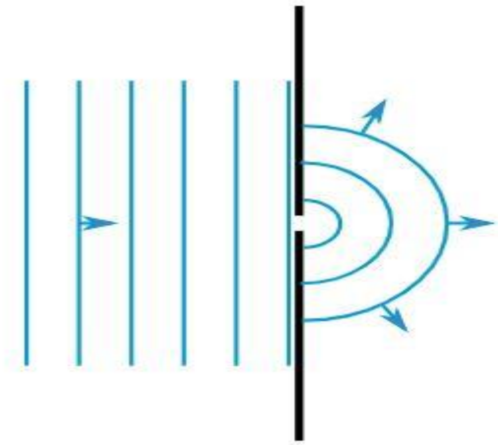

Figure 1: Single slit diffraction when a wave passes through an aperture with width smaller than the wavelength (d, is less than, lambda,$d<\lambda$). For a significant amount of the wave to pass through, the aperture must be close to the size of the wavelength

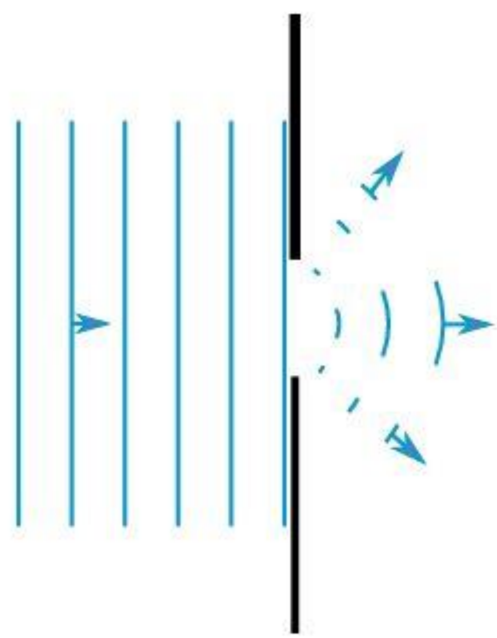

Figure 2: Diffraction pattern for a single slit of width larger than the wavelength (d, is greater than, lambda,$d>\lambda$)

The diffraction pattern made by waves passing through a slit of width a,a (larger than lambda,λ) can be understood by imagining a series of point sources all in phase along the width of the slit. The waves moving directly forward are all in phase (they have zero path difference), so they form a large central maximum.

Figure 3: Waves passing straight through the slit.
If the wave travels at an angle theta,θ from the normal to the slit, then there is a path difference x,x between the waves produced at the two ends of the slit.

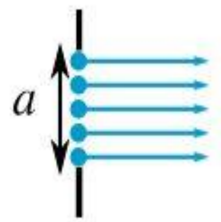

Figure 3: Waves passing straight through the slit.

If the wave travels at an angle theta ,θ from the normal to the slit, then there is a path difference x, between the waves produced at the two ends of the slit.

$$x = a\ \sin\theta$$

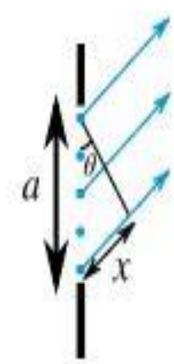

Figure 4: Waves passing through the slit at an angle theta,θ.

The path difference between the top and middle waves is then

$$. \ x' = 2a \sin\theta$$

If the path difference between the top and middle waves is 2λ, then they are exactly out of phase and cancel each other out. This happens to all consecutive pairs of waves (the ones produced by the second source from the top and the second source past the middle etc.) at this angle, so there is no resultant wave at this angle. Thus, a minimum in the diffraction pattern is obtained at

$$\lambda = a \sin\theta$$

Now the slit can be divided into four equal sections and the pairing of sources to give destructive interference can be repeated for the top two sections, which is identical to the result of pairing off matching sources in the bottom two sections. In the case, we obtain for a minimum (since every pair of waves we consider will destructively interfere due to our choice of geometry and pairing), to give

$$2\lambda = 4a \sin\theta$$

We can then divide the slit aperture into six equal sections, and pair off sources in the top two divisions, then the middle two divisions, and then the bottom two, to give destructive interference for every matched pair. The minima of intensity are obtained at angles.;

$$n\lambda = a \sin\theta$$

where,n is an integer left bracket, 1, comma, 2, comma, point, , right bracket,(1,2,...), but not n, equals, 0,$n=0$. There is a maximum of intensity in the centre of the pattern. This process only gives the positions of the minima, does not work for positions of the maxima, and so does not give the intensities of the maxima.

These results lead to the diffraction pattern minima shown below, which can be represented as a graph of intensity of the diffracted wave against angle. See a level 6 section for an explanation of this diffraction pattern using phasors.

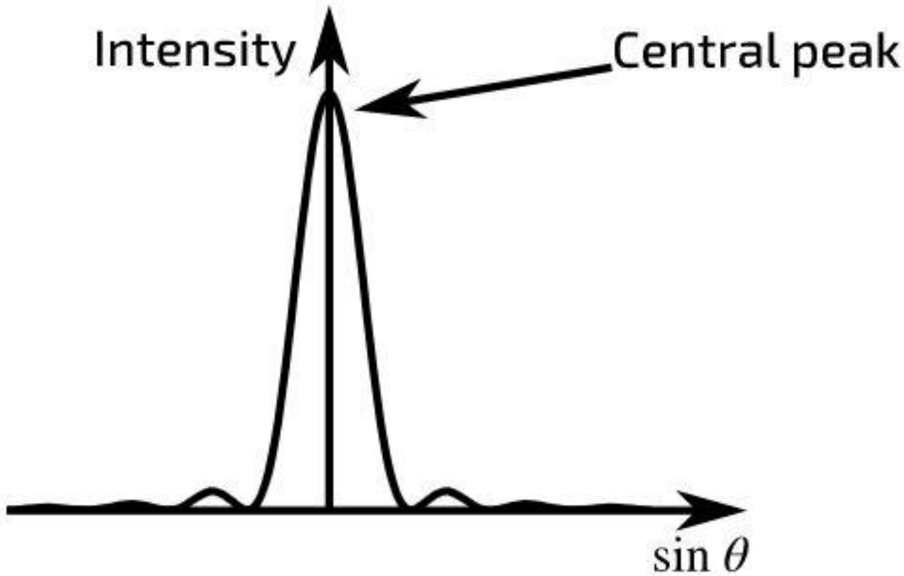

Figure 5: Single slit diffraction pattern.

Properties

diffraction, the spreading of waves around obstacles. Diffraction takes place with sound; with electromagnetic radiation, such as light, X-rays, and gamma rays; and with very small moving particles such as atoms, neutrons, and electrons, which show wavelike properties