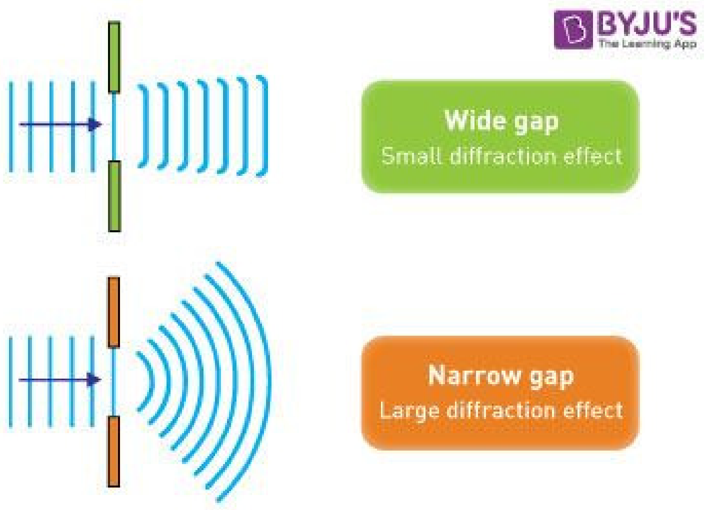
What is Diffraction?

Diffraction is defined as the bending of light around corners such that it spreads out and illuminates areas where a shadow is expected. In general, it is hard to separate diffraction from interference since both occur simultaneously.

When the double-slit in Young's experiment is replaced by a single narrow slit, a broad pattern with a bright region at the centre is seen. On both sides of the centre, there are alternating dark and bright regions. The intensity becomes weaker away from the centre. In this article, we discuss the single slit diffraction of light in a detailed manner.

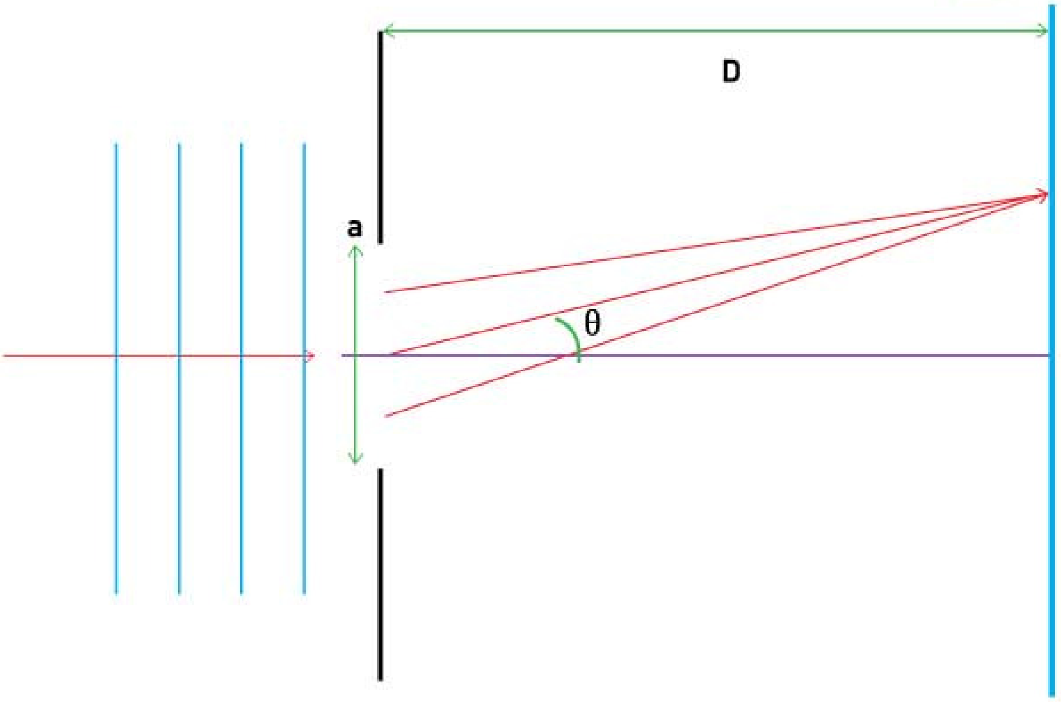
What is Single Slit Diffraction?

In the single-slit diffraction experiment, we can observe the bending phenomenon of light or diffraction that causes light from a coherent source interfere with itself and produce a distinctive pattern on the screen called the **diffraction pattern**. Diffraction is evident when the sources are small enough that they are relatively the size of the wavelength of light. You can see this effect in the diagram below. *For large slits, the spreading out is small and generally unnoticeable.*

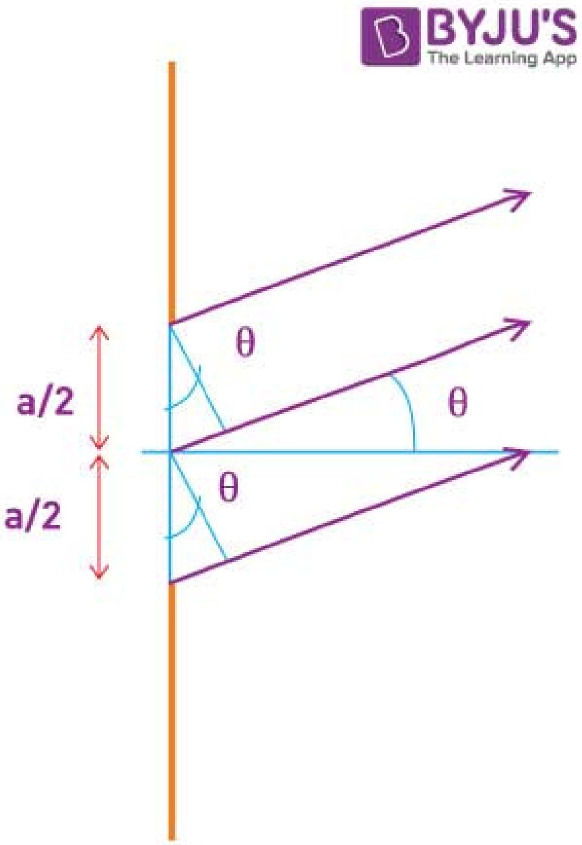


Single Slit Diffraction Formula

We shall assume the slit width a << D. x`D is the separation between slit and source.



We shall identify the angular position of any point on the screen by ϑ measured from the slit centre which divides the slit by $a/2$ lengths. To describe the pattern, we shall first see the condition for dark fringes. Also, let us divide the slit into zones of equal widths $a/2$. Let us consider a pair of rays that emanate from distances $a/2$ from each other as shown below.



The path difference exhibited by the top two rays shown is:

$$\Delta L = a/2 \sin\Theta$$

Remember that this is a calculation valid only if D is very large. For more details about the approximation check out our article on the Young's Double Slit experiment.

We can consider any number of ray pairings that start from a distance a2 from one another such as the bottom two rays in the diagram. Any arbitrary pair of rays at a distance a2can be considered. We shall see the importance of this trick in a moment.
For a dark fringe, the path difference must cause destructive interference; the path difference must be out of phase by $\lambda/2$. (λ is the wavelength)
For the first fringe,

$$\Delta L = \lambda/2 = a/2 \sin\Theta$$

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

For a ray emanating from any point in the slit, there exists another ray at a distance $a/2$ that can cause destructive interference.
Thus, at **θ = sin−1λ/a**, there is destructive interference as any ray emanating from a point has a counterpart that causes destructive interference. Hence, a dark fringe is obtained.

For the next fringe, we can divide the slit into 4 equal parts of a/4 and apply the same logic. Thus, for the second minima:

$$\lambda/2 = a/4 \sin\Theta$$

$$2\lambda = a\sin\Theta$$

Similarly, for the **nth fringe**, we can divide the slit into 2n parts and use this condition as:

$$\mathbf{n\lambda} = a \sin \theta$$

The Central Maximum

The maxima lie between the minima and the width of the central maximum is simply the distance between the 1st order minima from the centre of the screen on both sides of the centre.

The position of the minima given by y (measured from the centre of the screen) is:

$$\tan\theta \approx \theta \approx y/D$$

For small ϑ,

$\sin \theta \approx \theta$

⇒ $\boldsymbol{\lambda} = a \sin \theta \approx a\theta$

⇒ $\boldsymbol{\theta} = y/D = \lambda a$

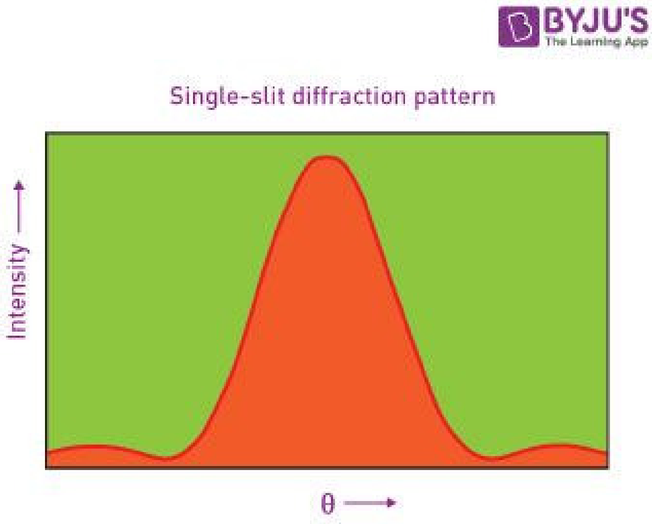
⇒ $\mathbf{y} = \lambda D a$

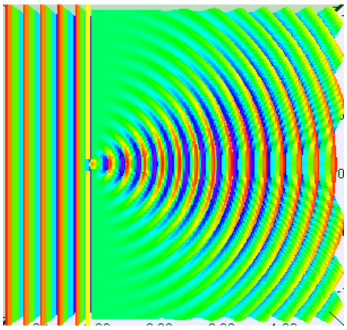
The width of the central maximum is simply twice this value

⇒ **Width of central maximum** = 2λDa

⇒ **Angular width of central maximum** = 2θ = 2λa

The diffraction pattern and intensity graph is shown below.





What is Polarization?

Polarization, in Physics, is defined as a phenomenon caused due to the wave nature of electromagnetic radiation. Sunlight travels through the vacuum to reach the Earth, which is an example of an electromagnetic wave. These waves are called electromagnetic waves because they form when an electric field interacts with a magnetic field. You will learn more about that later in the article, but now for some recap. In the chapter on waves, you learned about two types of waves, transverse waves, and longitudinal waves.

Transverse waves

Transverse waves are waves, i.e. movement of the particles in the wave is perpendicular to the direction of motion of the wave. For example, the ripples when you throw a stone in water. Longitudinal waves are when the particles of the medium travel in the direction of motion of the waves. For example, the motion of sound waves through the air.

Light is the interaction of electric and magnetic fields traveling through space. The electric and magnetic vibrations of a light wave occur perpendicularly to each other. The electric field moves in one direction and magnetic in another though always perpendicularly. So, we have one plane occupied by an electric field, the magnetic field perpendicular to it, and the direction of travel which is perpendicular to both. These electric and magnetic vibrations can occur in numerous planes. A light wave that is vibrating in more than one plane is known as unpolarized light. The light emitted by the sun, by a lamp or a tube light are all unpolarised light sources. As you can see in the image below, the direction of propagation is constant, but the planes on which the amplitude occurs is changing.

The image here shows its various types:

The other kind of wave is a polarized wave. The polarization of light or any other wave refers to the removal of all but one plane so that the vibrations of the wave occur on only one plane. In the image above, you can see that a linearly polarized wave vibrates on only one plane. The process of transforming unpolarized light into the polarized light is known as polarization. The devices like the purple blocks you see are used for the polarization of light.

Types of Polarization

Following are the three types of polarization depending on the transverse and longitudinal wave motion:

- Linear polarization
- Circular polarization
- Elliptical polarization

Linear Polarization

In linear polarization, the electric field of light is limited to a single plane along the direction of propagation.

Circular Polarization

There are two linear components in the electric field of light that are perpendicular to each other such that their amplitudes are equal, but the phase difference is $\pi 2$. The propagation of the occurring electric field will be in a circular motion.

Elliptical Polarization

The electric field of light follows an elliptical propagation. The amplitude and phase difference between the two linear components are not equal.

Methods used in the polarization of light

There are a few methods used in the polarization of light:

- Polarization by Transmission
- Polarization by Reflection
- Polarization by Scattering
- Polarization by Refraction