



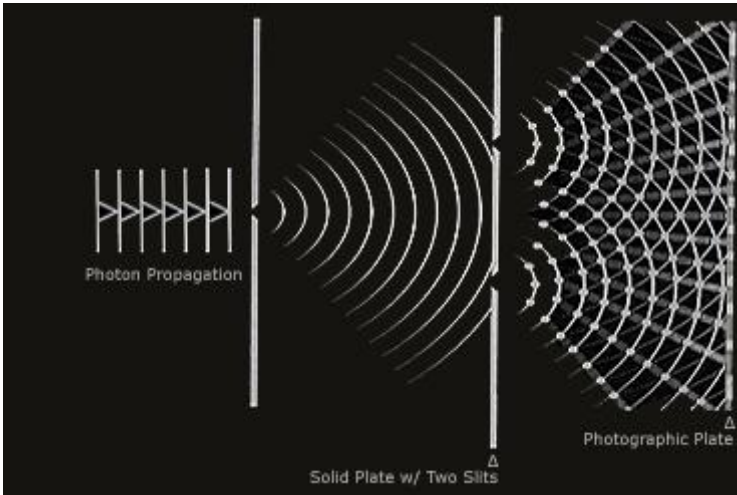
<http://micro.magnet.fsu.edu/primer/java/interference/doubleslit/>

The Most Beautiful Experiment

Quantum physics informs us that a system exists in superposition — that is, in all possible states — until we observe that it is only in one specific state.

According to a 2002 poll of Physics World readers, the “most beautiful experiment” in physics is one that simply and elegantly demonstrates how observation affects quantum systems: The double slit experiment. The double slit sets aside causality, determinism, and the notion that reality is “out there” as it blurs the line between the observer and the system being observed.

In the double slit experiment, a series of single photons (light particles) are fired at a solid plate that has two slits. On the other side of the solid plate, a photographic plate is set up to record what comes through those slits.



The question: What will we see on the photographic plate?

The answer: If one neglects to observe which slit a photon passes through, it appears to interfere with itself, suggesting that it behaves as a wave by traveling through both slits at once. But, if one chooses to observe the slits, the interference pattern disappears, and each photon travels through only one of the slits.

The formation of the interference pattern requires the existence of two slits... But how can a single photon pass through two slits simultaneously? At that point, we are forced to consider each photon as a wave that travels through both slits... Or we have to think of the photon as splitting and going through each slit separately — and wondering how the photon “knows” a pair of slits is coming.

The only solution is to abandon the idea of a photon — or any other quantum system — as having a location in spacetime until it is observed.

Thomas Young's Double Slit Experiment

In 1801, an English physicist named Thomas Young performed an experiment that strongly inferred the wave-like nature of light. Because he believed that light was composed of waves, Young reasoned that some type of interaction would occur when two light waves met. This interactive tutorial explores how coherent light waves interact when passed through two closely spaced slits.

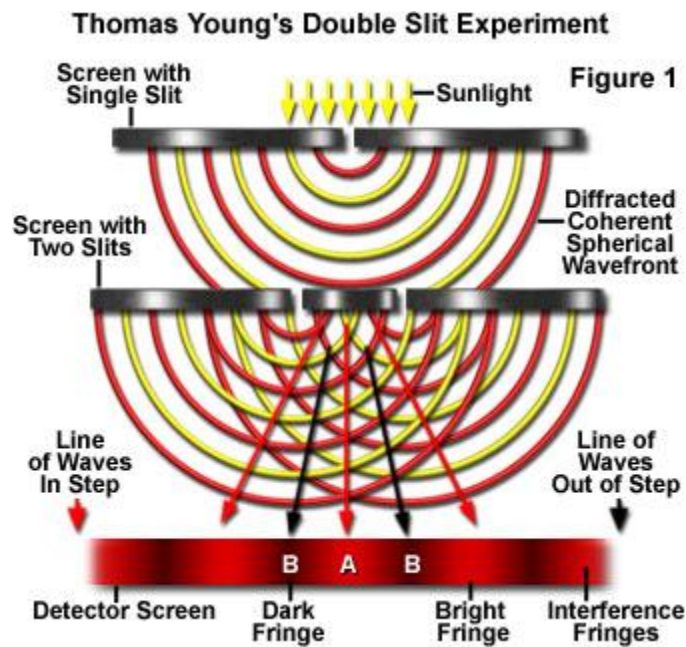


The tutorial initializes with rays from the sun being passed through a single slit in a screen to produce coherent light. This light is then projected onto another screen that has twin (or double) slits, which again diffracts the incident illumination as it passes through. The results of interference between the diffracted light beams can be visualized as light intensity distributions on the dark film. The slider labeled **Distance Between Slits** can be utilized to vary the distance between the slits and produce corresponding variations in the interference intensity distribution patterns.

Young's experiment was based on the hypothesis that if light were wave-like in nature, then it should behave in a manner similar to ripples or waves on a pond of water. Where two opposing water waves meet, they should react in a specific manner to either reinforce or destroy each other. If the two waves are in step (the crests meet), then they should combine to make a larger wave. In contrast, when two waves meet that are out of step (the crest of one meets the trough of another), the waves should cancel and produce a flat surface in that area.

In order to test his hypothesis, Young devised an ingenious experiment. Using sunlight diffracted through a small slit as a source of coherent illumination, he projected the light rays emanating from the slit onto another screen containing two slits placed side by side. Light passing

through the slits was then allowed to fall onto a screen. Young observed that when the slits were large, spaced far apart and close to the screen, then two overlapping patches of light formed on the screen. However, when he reduced the size of the slits and brought them closer together, the light passing through the slits and onto the screen produced distinct bands of color separated by dark regions in a serial order. Young coined the term **interference fringes** to describe the bands and realized that these colored bands could only be produced if light were acting like a wave.



The basic setup of the double slit experiment is illustrated in Figure 1. Red filtered light derived from sunlight is first passed through a slit to achieve a coherent state. Light waves exiting the first slit are then made incident on a pair of slits positioned close together on a second barrier. A screen is placed in the region behind the slits to capture overlapped light rays that have passed through the twin slits, and a pattern of bright red and dark interference bands becomes visible on the screen. The key to this type of experiment is the mutual coherence between the light waves diffracted from the two slits at the barrier. Although Young achieved this coherence through the diffraction of sunlight from the first slit, any source of coherent light (such as a laser) can be substituted for light passing through the single slit.

The coherent wavefront of light impacting on the twin slits is divided into two new wavefronts that are perfectly in step with each other. Light waves from each of the slits must travel an equal distance to reach point **A** on the screen illustrated in Figure 1, and should reach that point still in step or with the same phase displacement. Because the two waves reaching point **A** possess the necessary requirements for constructive interference, they should add together to produce a bright red interference fringe on the screen.

In contrast, neither of the points **B** on the screen is positioned equidistant from the two slits, so light must travel a greater distance from one slit to reach point **B** than from the other. The wave emanating from the slit closer to point **B** (take for example the slit and point **B** on the left-hand side of Figure 1) does not have as far to travel to reach its destination, as does a wave traveling from the other slit. As a consequence, the wave from the closest slit should arrive at point **B** slightly ahead of the wave from the farthest slit. Because these waves will not arrive at point **B** in phase (or in step with each other), they will undergo destructive interference to produce a dark region (interference fringe) on the screen. Interference fringe patterns are not restricted to experiments having the double slit configuration, but can be produced by any event that results in the splitting of light into waves that can be canceled or added together.

The success of Young's experiment was strong testimony in favor of the wave theory, but was not immediately accepted by his peers. The events in place behind phenomena such as the rainbow of colors observed in soap bubbles and Newton's rings (to be discussed below), although explained by this work, were not immediately obvious to those scientists who firmly believed that light propagated as a stream of particles. Other types of experiments were later devised and conducted to demonstrate the wave-like nature of light and interference effects. Most notable are the single mirror experiment of Humphrey Lloyd and the double mirror and bi-prism experiments devised by Augustin Fresnel for polarized light in uniaxial and birefringent crystals. Fresnel concluded that interference between beams of polarized light could only be obtained with beams having the same polarization direction. In

effect, polarized light waves having their vibration directions oriented parallel to each other can combine to produce interference, whereas those that are perpendicular do not interfere.