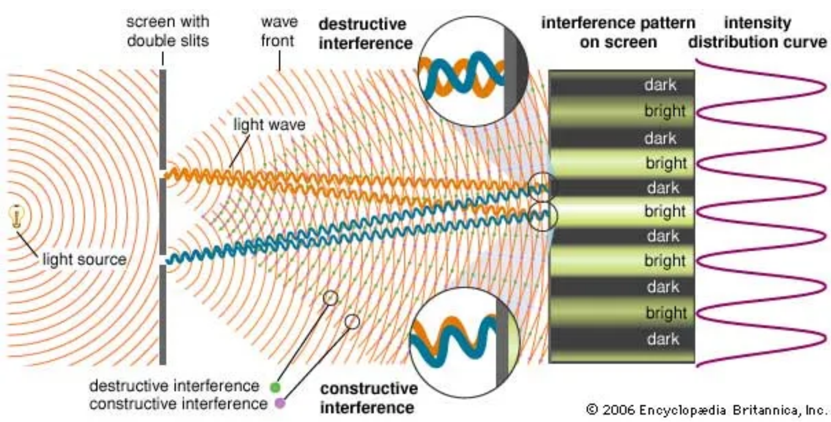
The Double-Slit Experiment

Imagine a wall positioned in front of you. On this wall, there are two narrow slits, and after this wall, there is another wall, but with no slits. Now, suppose you shoot tiny bullets from a pistol through these slits. These bullets, traveling through the two slits, will accumulate in two distinct clusters. But if we replace the bullets with tiny particles of light, called photons, the result is nothing like what classical physics would expect. Instead of two clusters, we see a series of bright and dark bars, like stripes painted across the wall. This is the setup of the double-slit experiment, one of the most puzzling and fascinating demonstrations in all of physics.

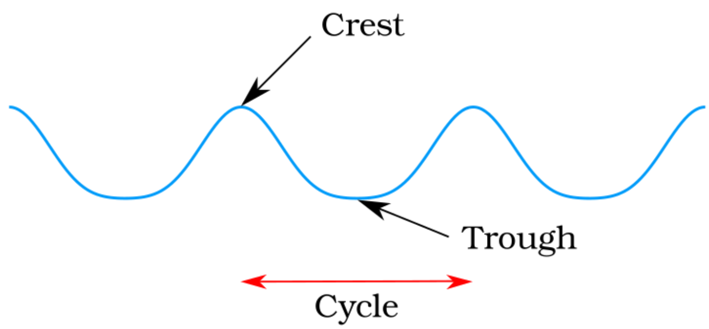
This double-slit experiment originated in 1801 with the first experiment conducted by Thomas Young, an English physicist. At the time, physicists wrestled with a fundamental question: Does light behave like a stream of particles or a wave? Nearly a hundred years earlier, Sir Isaac Newton had postulated that light behaved like particles. Due to his popularity and reputation, it was difficult for Thomas Young to present his theory on the wave nature of light. Nonetheless, Young's theory was still valid.

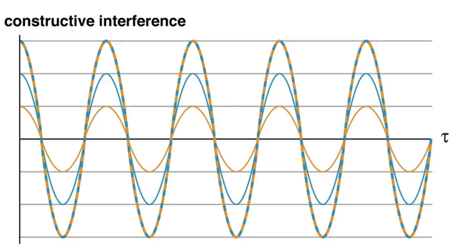
Thomas Young's test was fairly simple. He set up a wall with two narrow slits, similar to the bullet experiment, and shone light through it onto a second, uninterrupted wall.

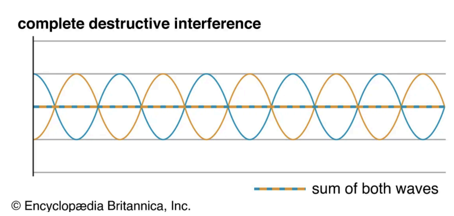


Young theorized that if light were to act like a particle, there would have been only two bright spots where photons accumulated. If light were to act like a wave, he declared, there would be repeating light and dark bars along the screen. As shown in the image, Thomas Young's theory was correct, demonstrating that light acts like a wave. Many physicists still opposed this theory. However, as later discovered, interference patterns say otherwise.

To understand interference patterns, let us examine two singular waves. Each wave will always have a crest, which is the top-most point of the wave, and a trough, the bottom-most point of the wave. However, when examining two waves, the alignment of the waves is key. If we look at the image with two waves, the position strongly affects the resulting wave's amplitudes. In the first example, since the crests and troughs of the waves match, the power of the wave compounds, creating a much larger wave. In the case of light, a stronger beam of light becomes visible on the screen, resulting from a phenomenon known as constructive interference. In the second example, the waves are opposite each other. When the crests and troughs of the waves completely oppose each other, the power of the wave reduces to zero. If these were light waves, it would mean that there would be darkness because of how the waves cancel each other out.





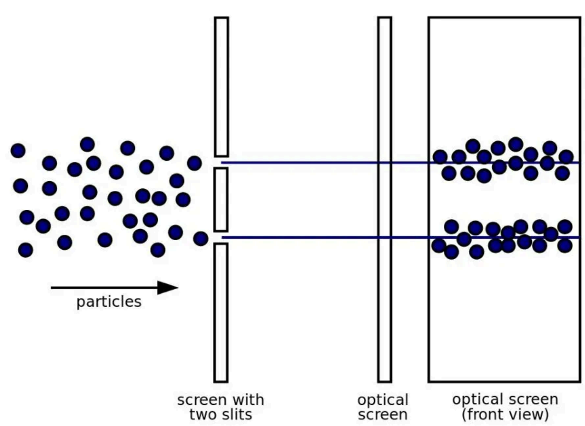


When we examine light behaving like waves, interference patterns occur in greater amounts. Circling back to the double-slit experiment, when we see a light bar, there is most likely a constructive interference pattern. However, when we see a dark bar, there is a high probability that it has been created by a destructive interference pattern. The repeating pattern of light and dark results from cycling constructive and destructive interference patterns from the light coming through the two slits

Let's picture another scenario. Instead of sending all of the light at once, what if we only send a couple of photons? What if we only send one at a time? At the time of Young's experiment, the technology to conduct this experiment was not available. It was not until the 20th century that physicists conducted a nearly identical experiment, with the modification of sending singular photons through the slits.

When physicists started sending one photon at a time, the photon acted like a particle. The photon hit the screen, creating only a single dot. However, as more and more photons were sent, the same pattern found in Young's experiment started to appear. Even when the photons were being sent one at a time, the same light and dark stripes appeared on a screen. From this experiment, physicists theorized that light acts like both a wave and a particle. This is known as the particle-wave duality of light, and it is a concept in quantum physics that is continuing to be researched and studied.

Scientists conducted the same experiment, but tried to measure through which slit each photon passes. This is done with the help of a beam of light near the slits. When the photon travels through the slit, the light beam will be disrupted, indicating the slit the photon passed through. As soon as the experiment was done, the screen looked like the image shown. The photons suddenly stopped acting like waves and began behaving like particles, creating two bright clusters of light. This act of measuring somehow changes the state of how



the photon behaves. This is known as the observer effect, another strange result of this demonstration.

Despite the double slit experiment's simplistic setup, it revealed some of the most profound scientific secrets. It was first demonstrated by Thomas Young that light acts like a wave. Light can also behave like a particle, as shown when photons are sent individually. Lastly, the observer effect demonstrated that the act of measuring itself had the power to alter experimental outcomes. Perhaps the most important lesson is that sometimes the most astounding discoveries come from the most basic experiments.

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