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In today’s world, we, scientists and students, all want to improve Quantum Physics by searching for new information. However, we must not forget how we managed to get to this point, and how it all started. So, we’re going to talk about the first ever Quantum Physics experiment, and how it helped, with the help of the scientists of the past, shape our perception of the universe and Physics, forever. So, we need to start from something simple. A single word

Light

What is light?

Light is the spectrum of electromagnetic radiation that is visible to the naked eye, ranging from 400 to 700 nm.

“Yeah, we know that. But how does it work?”

The nature of light has been a subject of debate for centuries. First Descartes assumed (although incorrectly) that light travels faster in denser mediums, based on the way that sound waves work, thus reaching the conclusion that light functions as a wave. Thus, light has to travel through a medium, right? But how does light then travel in space, since it’s a vacuum?

The two theories:

Wave?

Huygens, had suggested that light waves traveled through space mediated by the **ether**, an invisible weightless substance that exists throughout air and space. The search for ether was quite notable during the 19th century before being disproven. The ether theory lasted at least until the late 1800s, as evidenced by Charles Wheatstone's proposed model demonstrating that ether carried light waves by vibrating at an angle perpendicular to the direction of light propagation, and James Clerk Maxwell's detailed models describing the construction of the invisible substance.

Or Particle?

The **corpuscular theory of light** states that light is made up of small particles called "corpuscles" (little particles) which travel in a straight line with a finite velocity and possess momentum. This idea was based on an alternate description of atomism of the time period.

Isaac Newton laid the foundations for this theory through his work in optics. This early conception of the particle theory of light was a predecessor to the modern understanding of photons. This theory came to dominate the conceptions of light in the eighteenth century, displacing the previously prominent vibration theories, where light was viewed as "pressure" of the medium between the source and the receiver, first described by Descartes, and later refined by Huygens, while In part correct, being able to successfully explain refraction, reflection, rectilinear propagation and diffraction, the theory would fall out in the early nineteenth century, as the wave theory of light amassed new experimental evidence.

It’s a wave!!! (spoiler: it wasn’t)

Almost a hundred years after Newton and Huygens proposed their theories, English physicist Thomas Young performed an experiment that strongly supported the wave-like nature of light. Because he believed that light was composed of waves, Young assumed that some type of interaction would occur when two light waves met.

To test this hypothesis, he initially used a vertical surface containing a narrow slit to produce a continuous light beam (containing waves that propagate in phase) from ordinary sunlight. When the Sun's rays entered the slit, they spread out or diffracted to produce a single wave. Secondarily, he allowed the light to illuminate a second screen with two closely spaced slits. In that case, two additional sources of coherent light, perfectly in step with each other, are produced. Light from each slit traveling simultaneously to a single point halfway between the slits and the secondary surface.

The resulting waves reinforced each other to produce a much larger wave. However, if a point on either side of the central point is considered, then light from one slit must travel much farther to reach a second point on the opposite side of the central point. Light from the slit closer to this second point would arrive before light from the distant slit, so the two waves would be out of step with each other and might cancel each other to produce darkness.

(Of course today it is known that light acts as both waves and particles, but we're not going to analyze this in this presentation)

The Experiment in practice

Construction:

Materials:

- A small sheet of paper (preferably photographic paper)
- Scissors
- Tape (optional if other means of stability are used)
- Magnifying glass (optional if you think you have great vision)
- A cardboard cutter
- A laser (can be found even in a presentation controller)
- A stand for the laser and the paper, preferably made of wood, or by aligning holding stands, for stability and portability (can be found in a physics lab or at home)

CAUTION

Do not use the laser:

- **By pointing it at someone's eyes**
- **By not closing it when not using it**
- **By not placing it in a stable position**
- **If you have a cat in the room**

Setting up the model:

1. Make two parallel (!!!) small incisions in the colored area 1mm apart from each other (or closer if you are able to) using the cardboard cutter (use the magnifying glass for precision and a ruler to make them parallel)
2. Place the pointer in a stable place (even a tissue box) using the tape, in a way that the beam passes through the incision in a 90 degree angle
3. Use a piece of paper (or a wall) to display the result, and observe

Observation:

The light is spread out, but it appears in parallel “dots”, instead of a continuous line.

Thus, it appears that the light is making wave-like movements, indicating that it acts as a wave.

Results:

When light is passed through the incision, the beam spreads and becomes wider than expected. This important observation lends a significant amount of credibility to the wave theory of light. Like waves in water, light waves encountering the edge of an object appear to bend around the edge and into its geometric shadow—a region that is not directly illuminated by the light beam. The interference pattern also proves the particle nature of light, even though that wasn’t observed by Young himself, but rather was discovered by Heinrich Hertz in 1887 in the photoelectric effect and was explained by Albert Einstein in 1905, for which he was awarded the Nobel Prize.

Why is it a wave and not a particle? (like, can’t particles behave like that?)

If light consisted exclusively from classical particles, then the pattern’s size would depend on the size of the slit proportionally. However, as you can see, the opposite happens, and the beam is diffracted towards the outside. Thus, this means that light cannot exist only as particles, and that it needs to exist as waves too.

The significance of the experiment

The Double-Slit experiment provided important evidence for the wave-like nature of light and laid the foundation of Quantum Mechanics, which disproves the classical understanding of the world and dictates that particles behave differently depending on how they are observed, in a probabilistic nature.

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