Wave-Particle Duality: Double-Slit Experiment

GRADES 9-12

The human eye can only see a small portion of the range of radiation given off by the objects around us. We call the entire range of radiation the ***electromagnetic spectrum***. The part of the spectrum that we can see is called ***visible light***. There are many forms of light making up the electromagnetic spectrum that are not visible to the human eye. Radio waves, infrared waves, visible light, ultra-violet light, x-ray, and gamma-ray radiation are all forms of light that make up the electromagnetic spectrum.

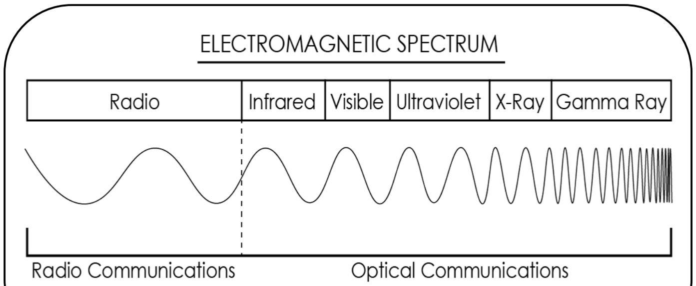

Figure 1: A chart of the electromagnetic spectrum.

To create and use everyday items such as lasers, microscopes, microelectronics, and x-rays, we first have to understand how light functions. Light functions as both a wave and a particle - this means that it has ***wave-particle duality.*** The word duality comes from the root word dual, which means both. Light travels between two distances like a wave, but it exchanges energy with matter like a particle. How do we know that light has wave-particle duality, and why is this important to know?

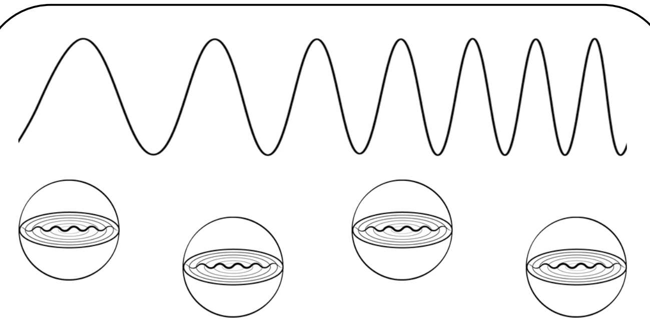

Figure 2: Light behaves as both a wave and a particle.

When we conduct experiments in the lab that attempt to measure the path light takes when it travels from one point to another, we find that light behaves like a wave. However, when we conduct experiments in the lab that attempt to measure the energy of light when it interacts with matter, we find that light behaves as a particle. We call a light particle a ***photon***. A photon is a tiny packet of pure energy that has no charge, no mass, and travels at the speed of light.

All types of electromagnetic radiation have wave-particle duality, not just visible light. NASA uses the radio and optical parts of the electromagnetic spectrum to send messages between Earth and space. Understanding the wave properties of electromagnetic radiation helps NASA predict how signals will travel from one point to another. Understanding the particle properties of electromagnetic radiation helps engineers design transmitters, which send signals, and receivers, which detect signals.
Transmitters and receivers play a key role in space communications.

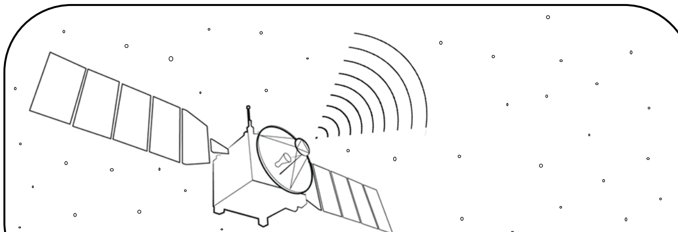

Figure 3: NASA uses radio waves to communicate in space.

In this experiment you will use a thumbtack, a piece of paper, and a laser pointer to observe how light propogates, or travels, and interacts with matter. Visually you will be able to see the laser beam produce ***interference patterns*** on the wall. In some regions, their peaks will align, and the strength of each wave will add and produce brightness. In other regions, their crests will be completely misaligned and cancel each other out entirely, which results in darkness.

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Procedure Instructions

1. Fold the sheet of cardstock paper in half, then unfold it so you can stand it upright on a table. Place the paper on the table ten feet away from a flat wall in a dark room.

2. Poke two tiny holes next to each other in the center of the paper with the thumb tack as shown in Figure 4.

3. Use tape to mount your laser pointer to a stable object, like a stack of heavy books. Place the mounted laser and books on the table so that the paper is between the wall and the laser, as shown in Figure 6.

4. Adjust the angle of your laser so the light passes through the holes in your paper and onto the wall.*

When the laser, paper, and wall are correctly aligned you will see interference patterns appear on the wall (Figure 5).

***Warning: Never directly aim laser beam towards your eyes or the eyes of others.**

Materials

- Laser pointer
- Thumb tack
- Tape
- Table
- White cardstock
- A flat wall in a dark room

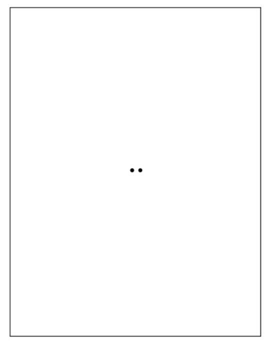

Figure 4

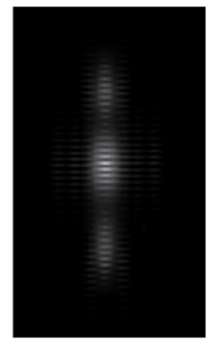

Figure 5

If you shine a laser pointer through two side-by-side holes, you might expect to see two spots of brightness on the wall side-by-side. However, if the holes are spaced closely enough, you will see lines of darkness across a bright spot, as seen in Figure 5. This is because light travels through both slits simultaneously, and when light waves emerge from each of the side-by-side holes, they interfere with each other and create a pattern of bright and dark lines. Interference occurs when two waves collide. In some regions, their peaks will align, and the strength of each wave will add together and appear bright. In other regions, their peaks will be completely misaligned and cancel each other out entirely, which results in darkness.

If you cover up one hole, the interference pattern across the bright spot will disappear - instead you would see a bright spot with no interference pattern. Most people would guess that shinig a laser through two holes would produce a bright spot instead of thinking would produce an interference pattern of bright and dark lines.

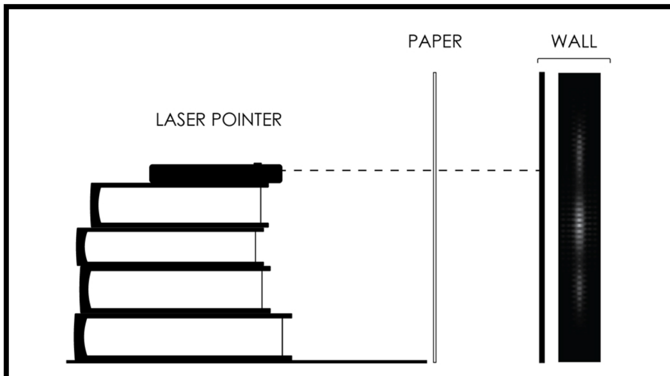

Figure 6: This image demonstrates the correct table set up for a doube-slit experiment.

To view the particle-like properties of light, perform the double-slit experiment in a very dark room, turn down the brightness of the laser to a very low level, and use a high-speed camera to record the light hitting the wall. You will see single tiny "blips" of bright spots appear on the wall. The individual spots of light on the wall are due to the particle nature of light. If all of the camera images were summed together, the tiny bright spots would produce the bright lines of the interference pattern, seen in Figure 5, due to the wave-like nature of light.