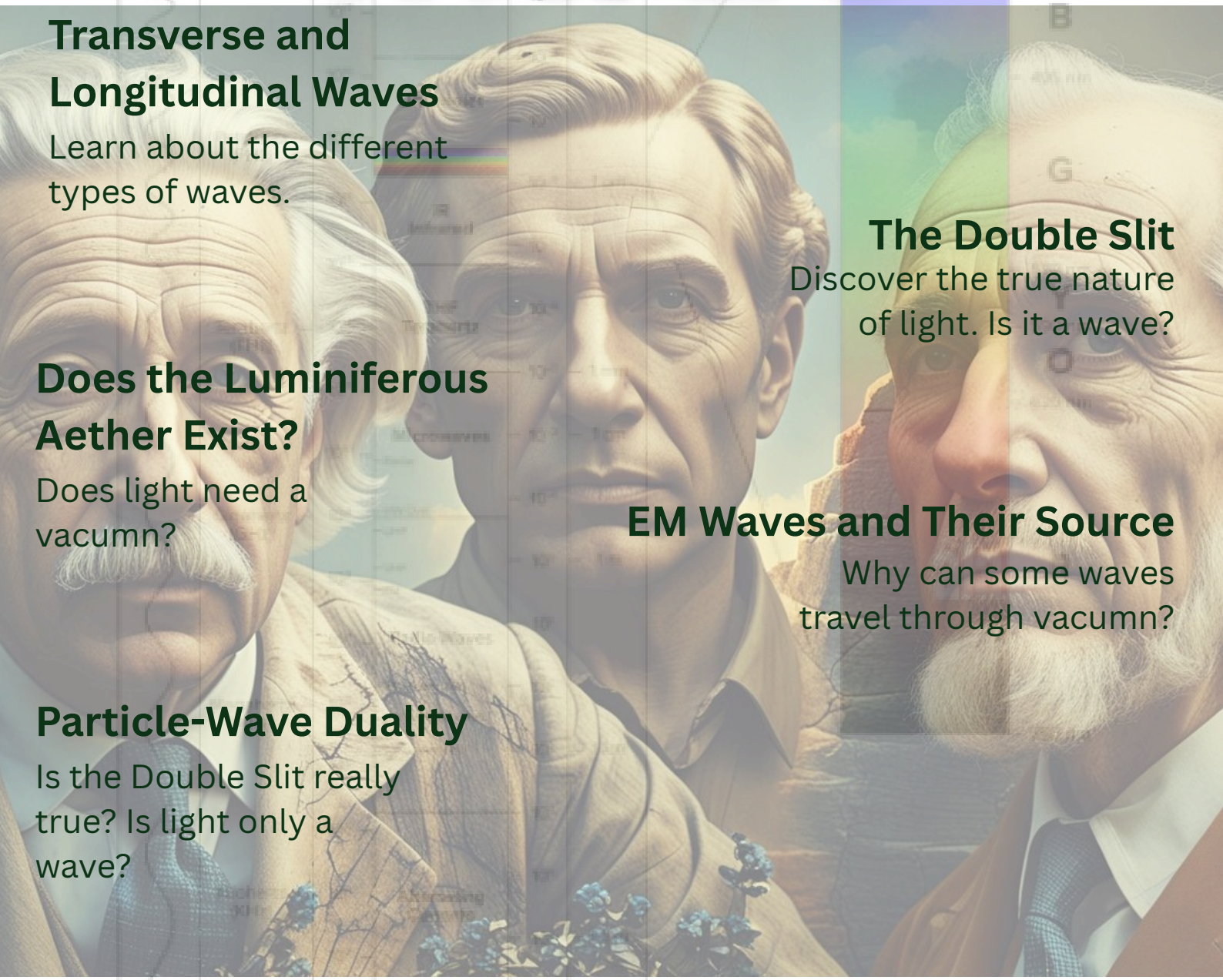
30 January, 2026

By Jian Shin

Whirling WAVES



Transverse and Longitudinal Waves

Learn about the different types of waves.

The Double Slit

Discover the true nature of light. Is it a wave?

Does the Luminiferous Aether Exist?

Does light need a vacumn?

EM Waves and Their Source

Why can some waves travel through vacumn?

Particle-Wave Duality

Is the Double Slit really true? Is light only a wave?

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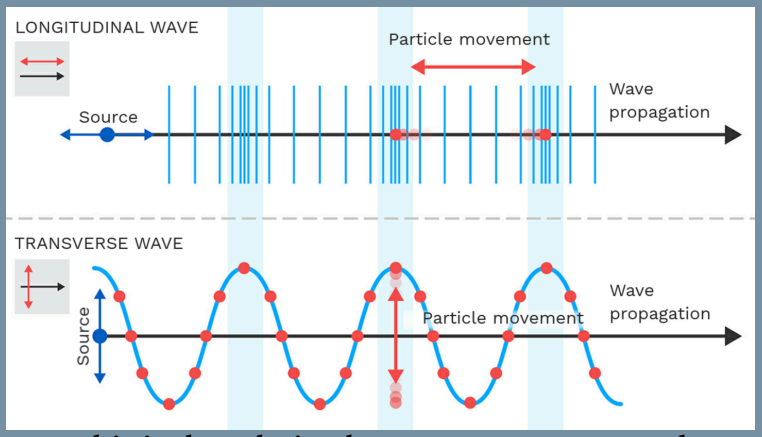
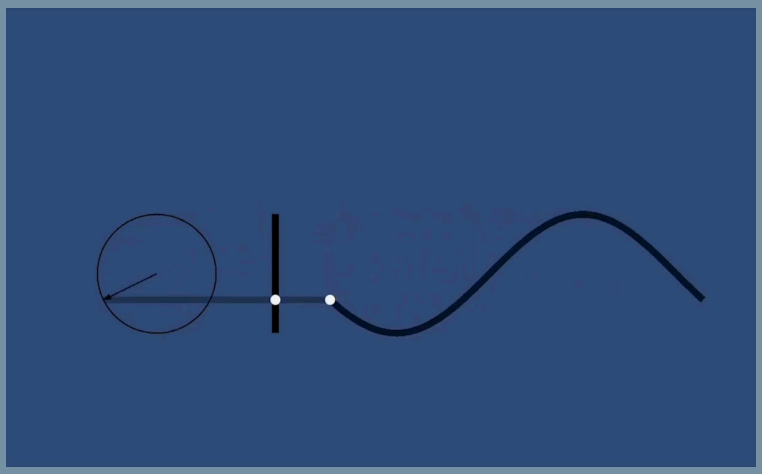
TRANSVERSE VS. LONGITUDAL



This is the relation between transverse and longitudinal waves.

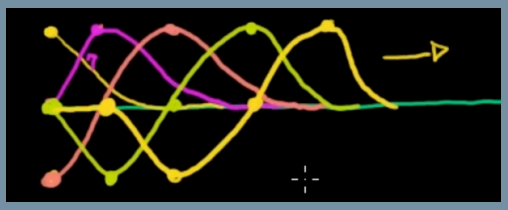


One round in the circle is one wave cycle.

You may think of ocean waves when someone says waves. But ocean waves are one of many waves. In this section, you will learn about the many types of waves: Transverse and Longitudinal waves.

Waves are a mechanical disturbance that propagates (spread, reproduce, or transmit something) through space. The medium (thing transmitting the energy made of mass) stays in the same place. Both have frequency, which is how many wave cycles pass through a fixed point per second. Frequency is measured in Hertz (Hz.) One wave cycle has the length of one wavelength λ. A wavelength is the distance from a crest (high point) to a crest, or a trough (low point) to a trough, and other parallel units. Another quality in common is a period, which is the time it takes for one wave cycle to pass a single point, so frequency and periods are related.

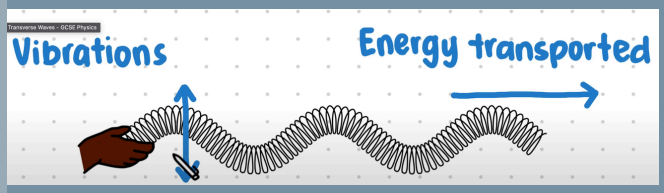
This diagram has demonstrated one wave cycle, with green being the whole wave cycle and the yellow with the arrow/right yellow being the wave cycle continuing to transfer energy. The video on the side is demonstrating a more easier-to-relate version, with one round on the circle being one wave cycle. This type of wave is a type of wave we'll talk about in a second. Another thing in common is amplitude, how strong the wave is, or the height of the wave. The amplitude is the length of the crest of the wave to the equilibrium, or middle neutral line. It is also the rest position of a wave.



This is one wave cycle.

First we will go over what we normally think of as waves. They have a crest and valley, and wavelength is easy to see. Think of it as a rope. You wave it up and down while it is tied to a wall. Then the matter, the rope, oscillates vertically, but never horizontally in perfect conditions. Perfect conditions are conditions with no friction, drag, and intermolecular forces are absent. It is hypothetical, but can be useful in situations like ours. The vibration also has to be consistent. In real life, some examples are the surface of water waves, or water ripples, and a guitar string that vibrates up and down. This is what a transverse wave looks like. Light waves look like transverse waves in a way that we will learn about soon.

On the other hand, a longitudinal wave is a wave made of compressions and expansions. The particles in the medium vibrate and compress parallel to the direction of the wave traveling. The wavelength is harder to figure out, it is the point from a compression to a compression and an expansion to an expansion. The number of waves passing a fixed point per second is called the frequency, same as transverse waves. Longitudinal waves can be represented as transverse waves with the amplitude of the representation being the density of the original longitudinal wave. Think of it as a slinky, being waved forward and backward. It is also the form of sound waves.



This is a transverse wave.

These are the very basic types of waves, and the basic explanation. Remember that transverse waves move up and down, while longitudinal waves move forward and backward. This information may be useful in the rest of the article and even in your life.

THE DOUBLE SLIT

Thomas Young's Double Slit Experiment

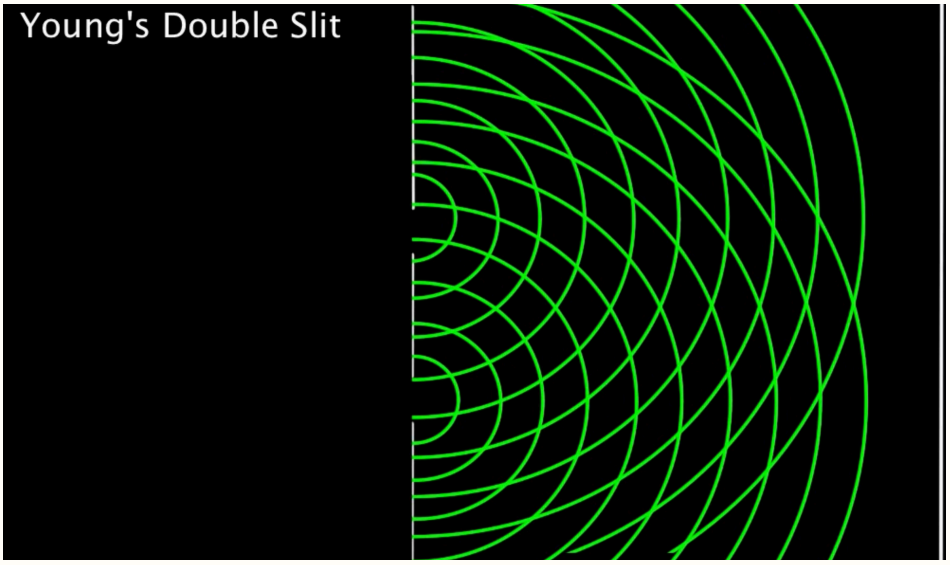
THE DEFINITIVE EXPERIMENT OF THE WAVE NATURE OF NIGHT

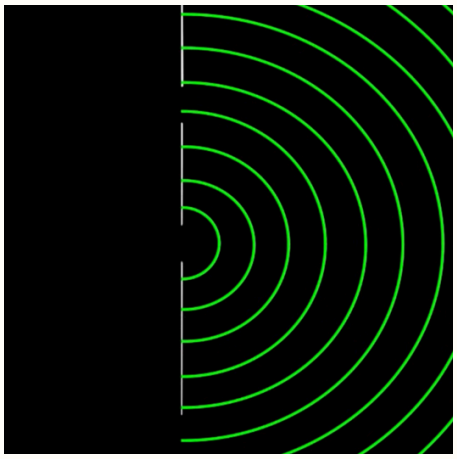
We always hear light, light. But is light a wave? The Double-Slit Experiment will prove whether light is a wave.

In 1801, English physicist Thomas Young conducted the definitive experiment to explain the wave nature of light. Light, especially a laser, would shine through 2 slits, or holes in a card, then the light would go through the slits. The slits were very small, so the laser could shine on both of them. The card absorbed most of the other light shone onto the card itself. The light shone onto the slits just simply went through. As one result, diffraction happened.

Diffraction is when waves pass through a slit and then tend to spread out. The smaller the difference between the wavelength and the length, the more noticeable the diffraction. →→→→→→

Another result, this time of diffraction, is that waves overlap. The light waves, coming out of the two slits, are not always together and add up. Theoverlapping causes a pattern of brightness. We call this interference. The waves are in phase, which is constructive interference (the strength of the light adds up) or out of phase, which is destructive interference (Which is when the strength of the light subtracts from each other.) But does interference have any pattern, or is it random? Let's think about it. The diffraction is in slits, so the waves





overlap. We already know this. If the overlapping has a pattern, which it does, the interference must have one too. We can spot the constructive interference when the peaks of the waves overlap, and trace the line of the peaks overlapping (from the source) to infinity (normally there is a detector screen to detect the pattern.)

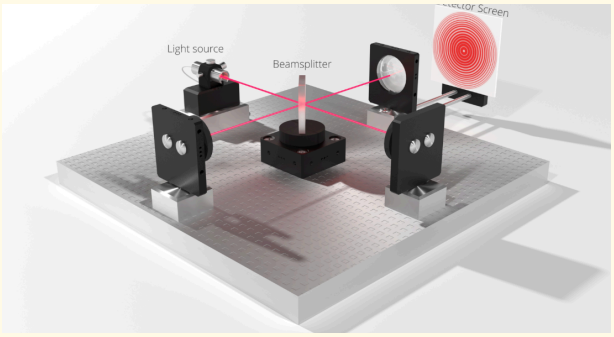
Finding the destructive interference is a bit harder. You have to trace where the peaks and the troughs align. This will be next to the bright spot. Make sure there is no other interference in between the two spots. When there is no other interferencebetween the two spots, the middle will be blended with brightness between the two spots.

Thomas Young's double-slit experiment was a big step forward in physics, but as diffraction shows that light is a wave, this created more problems in the theory of light, a problem chain reaction. How did this happen? Why was there a problem chain reaction? Well, light was a wave and space was a vacuum, with no medium. So how did light travel? Turn the page to find out.

DOES THE LUMINIFEROUS AETHER EXIST?

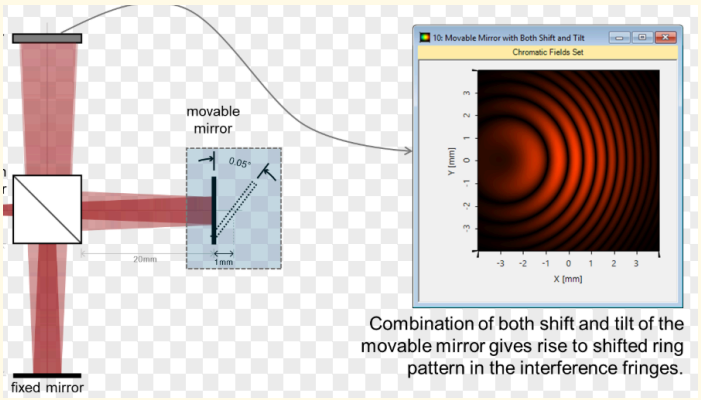
If light is a wave, then how does it travel through space? Space is a vacuum, so there is no medium. It only has 1 atom/m3. Physicists had some trouble finding out light's medium.

Young's double slit experiment showed that light was a wave, but light traveled through space, which had no medium. This presented a problem, so a hypothetical medium of light was proposed; Luminiferous aether, also known as ether or aether. The aether theory said that an aether was



stationary, so light could travel through space. But mass, like earth, also travels, so it has to be frictionless. Since it was stationary, and light used it as a medium, it would have an effect on light, like light friction, but called aether wind.

Using a Michelson Interferometer, which consists of a laser, two mirrors, one detector screen, and a beam splitter, which is something that lets a



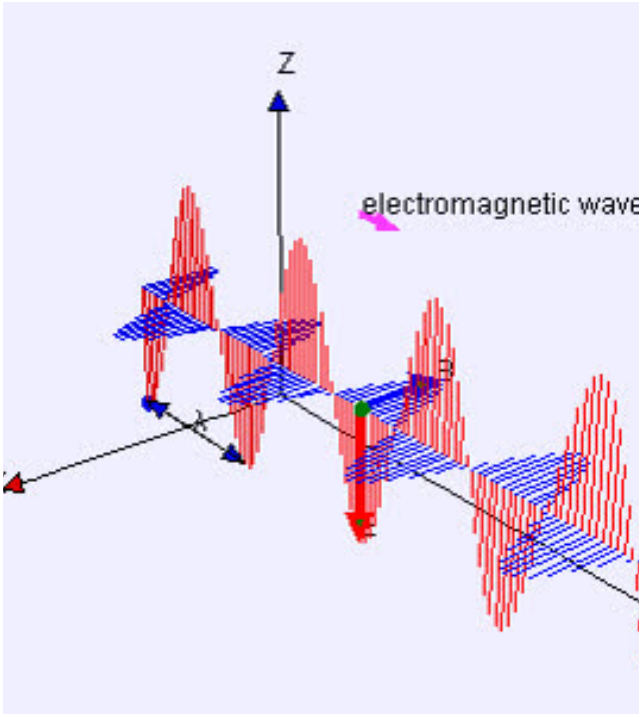
Combination of both shift and tilt of the movable mirror gives rise to shifted ring pattern in the interference fringes.

fraction of the light shone on it through and the other fraction gets reflected. The components were positioned so that the laser shone light onto a 45˚ tilted beam splitter, and that beam splitter made the light shine onto the two mirrors. This reflected the light back and the beam splitter would reflect the two beams into the detector.

The perpendicular paths of light meant that aether wind would disturb one beam more than the other and the timing would defocus the light on the detector. But, when the experiment was run, there was no significant difference between the two beams of light. This meant the aether did not exist. Then how did light travel? This question will be answered in the next chapter.

To sum up, every small flaw that you do not understand can turn into a lasting debate. We can inquire more about our interests and question necessary things to lead information to justice and tell the truth.

EM WAVES AND THEIR SOURCE



This is what a EM wave looks like.

Some waves don't need a medium to travel! A vacuum is a place completely devoid of matter, such as space, but certain types of waves traveling there are still possible. One of these types of waves are Electromagnetic (EM) waves, which have many special qualities that are different to most waves.

First, we will need to understand the natural sources of EM waves to fully understand their being. For all charged particles, there is an electric field around them. Electric fields are a field of material that can create magnetic force, since magnetism and electricity are related. Positive electric fields have outward propagation, while negatively charged particles have inward propagation of the electric field. Meanwhile, wires with electricity flowing create magnetic fields. These two types of fields interact with each other to make EM waves.

Second, if the charged particle accelerates, then the electric field must adapt to the acceleration particle, which creates a disturbance, a wave. The mathematical definition of acceleration is ΔvΔt, or vf-vo/t, where Δ is the change of something in physics, v is velocity, a vector, or speed (something that has magnitude and direction), and t is time. In the other equation, t is time again, but vf is the original velocity, while vo is the new velocity within the timeframe t. Vectors have arrows over them in equations. So, this must be the formula for average acceleration, o aavg. But meanwhile, let us know that ΔE□→ΔB□→ΔE□and so on (E□ is electric field, B□ is magnetic field), due to electromagnetism (electricity and magnetism are tangible with each other.) If the charged particle accelerates, it will create a change in magnetic field, which oscillates the magnetic and electric fields. This oscillation of magnetic and electric fields makes a wave pattern, turning out to be a wave. These waves are called EM waves because they are made of oscillating electric and magnetic fields, and only oscillating electric and magnetic fields.

At this moment, you might be wondering, what do oscillating electric and magnetic fields look like? These EM waves are transverse waves, so their direction of movement is perpendicular to the direction of their travel, while E□ and B□ are perpendicular to each other. So, the image would have waving, or oscillating E□ and B□ would be perpendicular to it, but both are at a 90˚ angle to the direction of travel. The next step for humans new to EM waves is to figure out how to make them. In nature, the acceleration of a charged particle makes them, so humans made a thing called oscillators, which oscillate charged particles such as electrons to make Δ\vec{E}, which sets up the oscillating chain reaction we talked about earlier. To send signals, people chose to control a specific property of the wave, such as AM, or Amplitude (height of wave) Modulation (to change or edit) and FM, Frequency (measured in Hz) Modulation. These are two types of common radios. The numbers on the wheel represent frequencies or amplitudes in numbers. Turning the wheel changes the receiver's receiving qualities and what they measure.

As you can see, sometimes physics is out of the ordinary. There can be bizarre relationships with motion and waves, and in the future, I hope we and all recognize this hard work put in by engineers and physicists and help them in their process of advancing technology, but even more important, remember to always stay curious!

PARTICLE-WAVE DUALITY

THE THEORY BEHIND QUANTUM PARTICLES

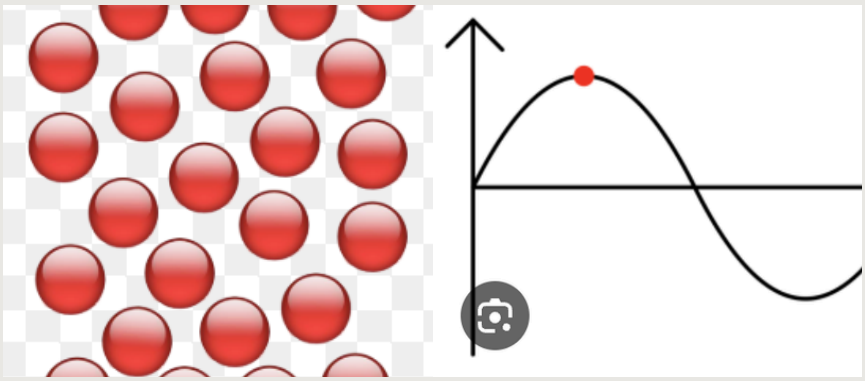
WHAT IS PARTICLE-WAVE DUALITY?

Waves, as we learned, have specific features of their own. But are they only for a wave? Wave properties can be applied to waves, but it turns out specific objects have similar properties.

To review, waves are a mechanical disturbance that propagates (spread, reproduce, or transmit something) through space, as we learned in the first chapter. They carry energy from one place to another, since they are a disturbance. They are used for radio, as we learned in the beginning, FM (Frequency Modulation) and AM (Amplitude Modulation). Another use is ultrasonic cleaning, like electric toothbrushes, and imaging. All waves also have momentum, *p*, even those without mass. We'll learn about that in a moment.

Particles, on the other hand, c or energy (mass and energy are interchangeable, $E=mc^2$.) In a field of study called particle physics, these particles make up atoms, the small things that make up our world. They have momentum, and yes, momentum that we cannot feel, if it is not a cluster of atoms. These particles, such as electrons (we learned about it in EM waves) can image many things, including rooms and people.

But how does this explain that it is not only waves with wave properties, but that particles can be so too? To understand particle-wave duality, you need to understand that. To understand phenomena, you need to accept some unnatural things. We will go through this in the most natural way possible, but even then it may be confusing.



In 1900, Max Planck was studying thermal radiation (hot objects produce Electromagnetic waves), but he couldn't explain why classical physics (physics before Einstein) predicted infinite amounts of energy in the form of EM waves. Infinite amounts of energy did not appear in experiments, though. This resulted in Planck resorting to a mathematical trick to understand the mathematics behind it. The trick was that he said there were imaginary oscillators (we learned about oscillators in the previous chapters) in everything, and the frequency of the oscillation changes as the temperature changes.The oscillators had a small amount of energy (that was the smallest amount of energy possible), quanta (plural for quantum), like waves being 1, 2, or 3 centimeters high, but never 3.5 centimeters high. This was because quanta were the smallest unit. He then would get rid of the oscillators and whatever other unwanted products. Planck then used the trick to make the equation $E=hv$, where E is the energy of one quanta, and h is a constant,$6.626x10^{-34}$, and v is the frequency. You might be thinking, why didn't Planck get rid of h and the oscillators? He did want to get rid of unnecessary products, after all.

This is because this mathematical model requires the conditions to operate, even if real life is different. Planck thought his trick was incorrect, though, and hoped someone would create a mathematical explanation without a trick in desperation, but the theory sunk in. Five years later, Albert Einstein explained the Photoelectric Effect (photo=photon, a word for light quanta, and electric=electron, a charged particle), an effect where electrons come out when light is shone on a sheet of metal. f light is made of photons (or quanta) then it must have energy and momentum (momentum is transit of energy), which causes electrons from the atoms to be knocked loose from the metal, by the momentum. Lasers are also made in a similar way as light gets knocked loose from atoms (mass and energy are interchangeable, light is a form of energy) and bounced around mirrors to make the photons straight and the concentrated light shines out the remaining hole, which is what we see. This leads to the conclusion that EM waves are "quantum particles", a type of particle, not waves nor particles. They behaved with both states of energy combined in one.

All in all, particles and waves are not so different after all, they can be joined by quantum particles. Particles and waves are important because they are one of the fundamentals of modern physics and waves.

CITATIONS

Transverse vs. Longitudinal waves:

Launchpad Learning: https://www.youtube.com/watch?v=vjlitABDL_U

Shutterstock: https://www.shutterstock.com/image-vector/exploring-transverse-waves-observing-crests-thoughts-2446097175?trackingId=020ec4dc-2670-4118-9c27-6ce85dc0d9f1

Physics Stack Exchange: https://physics.stackexchange.com/questions/175771/how-do-waves-have-momentum

The Double Slit:

Khan Academy 3: https://www.khanacademy.org/science/ap-physics-2/x0e2f5a2c:waves-sound-and-physical-optics/x0e2f5a2c:diffraction-and-interference-of-light/v/youngs-double-split-part-1

Chad Orzel, 2009, How to Teach Quantum Physics to Your Dog, Scribner

The Luminiferous Aether:

Quora: https://www.quora.com/How-does-a-wave-have-momentum-without-having-mass

Youtube: https://www.youtube.com/watch?v=M3GQM7tuq2w

Britannica: https://www.britannica.com/science/Michelson-Morley-experiment

BYJU's: https://byjus.com/physics/michelson-morley-experiment/

EM Waves and Their Source:

Khan Academy waves 2: https://www.khanacademy.org/science/ap-physics-2/x0e2f5a2c:waves-sound-and-physical-optics/x0e2f5a2c:electromagnetic-waves/v/electromagnetic-waves-and-the-electromagnetic-spectrum

Britannica: https://www.britannica.com/science/electromagnetic-radiation

National Inventors Hall of Fame: https://www.invent.org/blog/trends-stem/difference-between-am-fm

Particle Wave Duality:

BBC Bitesize Waves: https://www.bbc.co.uk/bitesize/topics/zm9mxbk/articles/ztmsp4j#z6fhtrd

Brittanica Search: https://www.britannica.com/search?query=use+of+waves

Chad Orzel, 2009, How to Teach Quantum Physics to Your Dog, Scribner

Khan Academy Waves: https://www.khanacademy.org/science/highschool-physics/x6679aa2c65c01e53:electromagnetic-radiation/x6679aa2c65c01e53:wave-behaviors-of-em-radiation/v/electromagnetic_waves

Khan Academy waves 2: https://www.khanacademy.org/science/ap-physics-2/x0e2f5a2c:waves-sound-and-physical-optics/x0e2f5a2c:electromagnetic-waves/v/electromagnetic-waves-and-the-electromagnetic-spectrum