Ishaan Patel

Light: Wave or Particle?

S.No.	Properties of Light	Particle Theory	Wave Theory	Result: Particle/Wave
1.	Rectilinear Propagation	Light must consist of particles that move a very high speed since the light travels in a straight line. Regular objects such as a ball would curve under the influence of gravity, while a faster object such as a bullet would curve less. Since light does not seem to curve, the speed must be extremely high. The mass of the particles must be very low since light does not seem to exert any force or pressure.	This theory explains light as wave fronts perpendicular to the paths of the light rays. A new spherical wavelet is created from a point on the wavefront. The tangents of all of the new wavelets (creating an envelope) would be the new wave front a certain amount of time later. Light rays just indicate the direction of motion.	For this property of light, I think that the particle theory is best explained, and that light is a particle.
2.	Reflection	Light obeys the laws of motion if perfectly elastic collisions occur between the surface and the particles in the light. In a situation where the surface is facing the vertical direction, the horizontal velocity of the light does not change as the angle of incidence equals the angle of reflection. However, the vertical velocity is reversed. The magnitude of the velocity stays the same.	Whenever a wavefront strikes a reflective surface, the wave reflects. The point at which the wavefront hits the reflective surface becomes a source for new spherical wavelets. The common tangent for all of these new wavelets forms the reflected wavefront. The tangent is reflected because wavelets form at different times. For example, if wavefronts hit a reflective surface at an angle, not all points of the wavefront will hit the reflective surface at the same time. The wavelets that form first have travelled further than the ones that formed later, hence the tangent is directed at a reflected angle.	I think that the wave theory best explains reflection and that light is a wave.
3.	Refraction	Newton thought that particles of light travel faster in mediums such as water, than air. He stated that when light travels faster, its path will bend towards the normal, which explains refraction in water, or any other medium other than air. The reason he thought that light travels faster in water was like gravity and that the water attracted light particles. This causes them to accelerate and speed up.	The wave theory suggests that the light bends towards the normal during refraction since its speed will be slower in the new medium. A wavelet moving in the first medium would travel a further distance than a wavelet traveling inside a more optically dense medium such as water. This causes the wave fronts to travel slower. Therefore, they bend towards the normal.	I think that the wave theory best explains refraction and that light is a wave.

4.	Diffraction	Newton stated that when diffraction happens, the wave spreads around the obstacle in different directions. Seeing as light does not go around corners like waves do, light must be a particle. Newton also stated that any traces of light moving around obstacles (or around the openings of slits) must be from reflections at the edges of the slit, and not the bending of light waves (diffraction).	Points on the wavefront that pass the opening act as sources of new spherical wavelets that propagate away from the source. Newton claimed that if light was a wave, the diffraction should be more visible. Diffraction becomes easily visible when the aperture or the slit sizes are comparable to the wavelength of the light. Young's double slit experiment demonstrates diffraction and interference when a pattern of bright and dark spots is visible. Another experiment proving diffraction is "Poisson's bright spot" where the light diffracting around the edges of a small solid object should interfere constructively to produce a bright spot in the center of the diffraction pattern. This is impossible according to the particle theory of light.	I think that the wave theory best explains diffraction and that light is a wave.
5.	Dispersion	Red light refracts least, and blue-violet light the most. Newton stated that the mass of the light particle varied with color. Red light particles have more mass than violet, causing them to deflect less when crossing the border into another material such as a prism. When he stated the above, he assumed light particles experience a force of the same amount when crossing a border. What differs among them is their inertia. Red light would be more resistant to the change in motion compared to violet light.	Each color of light has its own wave frequency. Colors with a shorter wavelength will deviate more from their original path when going through a prism. A light wave travelling through a transparent material is absorbed by an atom of that material causing its electrons to vibrate. If the frequency of the light wave does not match the resonance frequency of the vibrating electrons, it is re-emitted at the same frequency. This process repeats with other atoms of the material. This process slows down higher frequency waves (violet) more than low frequency waves (red). This means the index of refraction depends on frequency and is more for violet light. Therefore violet light bends towards the normal more.	I think that the wave theory best explains dispersion and that light is a wave.
6.	Interference	Newton's particle theory of light does not adequately support interference.	Young's double slit experiment proves that light is a wave. A light source is shone on two very small slits (comparable to the wavelength of the light) and diffraction occurs at both slits. When the two waves start to overlap, constructive and destructive interference occur. In this experiment, constructive interference causes bright bands and destructive interference causes dark bands. This phenomenon proves that light is a wave.	The wave theory best explains interference of light, so judging from this phenomenon, light must be a wave.

7.	Polarization	Newton's particle theory of light does not adequately explain polarization of light. As an example, there is no particle theory explanation that states why polarizers block light.	Electromagnetic waves are produced by vibrating electric charges. Electromagnetic waves that traverse in only one plane of vibration, whether if it is vertically, horizontally, or diagonally. Waves that vibrate in multiple planes of vibration are unpolarized. These waves are created by electric charges vibrating in many directions. One way light can be polarized is by a filter that blocks certain planes while letting specific ones through. Reflection off a non-metallic surface can also polarize light. The glare produced by reflection on water is mostly polarized parallel to the water's surface. Polarization can also occur during refraction, in a plane perpendicular to the surface of the medium.	The wave theory describes this phenomenon of light better. The particle theory cannot be applied here.

Conclusion:

Light must be a wave and a particle at the same time. The reason for this is that light exhibits wave-like properties as well as properties of a particle. In this assignment, most of the phenomena listed above could be explained well by waves and a couple by particles. This means that it would be a wave. However outside of this assignment, there is another phenomenon that can only be explained by the particle theory, the photo-electric effect. Due to this duality of light between waves and particles, light can be either depending on what is being observed. For example, light must be a wave when talking about polarization because particles cannot get blocked by the chemical composition of polarizers, while light acts like a particle (known as photons) when it transfers energy onto surfaces such as metal into its atoms causing electrons to eject off the surface. As Neil Bohr stated in his principle of complementarity, one must use either the wave or particle theory when applying to a specific experiment but should use both when trying to understand the nature of light. On its own, neither theory fully explains the nature of light.

Links:

- http://hyperphysics.phy-astr.gsu.edu/hbase/mod1.html
- https://www.olympus-lifescience.com/en/microscope-resource/primer/lightandcolor/interference/
- https://www.physicsclassroom.com/class/refrn/Lesson-4/Dispersion-of-Light-by-Prisms
- https://www.youtube.com/watch?v=N3levs4TzTA
- https://www.physicsclassroom.com/class/light/Lesson-1/Polarization#:~:text=Polarized%20light%20waves%20are%20light,of%20methods%20of%20polarizing%20light.
- http://galileo.phys.virginia.edu/classes/609.ral5q.fall04/LecturePDF/L20-LIGHTII.pdf
- https://www.youtube.com/watch?v=h1tflE-L2Dc
- https://www.khanacademy.org/science/ap-chemistry/electronic-structure-of-atoms-ap/bohr-model-hydrogen-ap/a/photoelectric-effect
- https://www.edu.gov.mb.ca/k12/cur/science/found/physics30s/topic2_2.pdf