Name: _____ Period: _____ Date: _____

An Evolving Understanding of the Nature of Light

A	Experimenting with sunlight entering through small opening in a tent, one can observe that blocking any part of the path from the opening to a chair or from the chair to your eye would eclipse your vision of the chair. From similar observations, الحسن بن الحسن بن الهيثم و علي، (also known as Alhazen) around the year 1011 concluded light does not originate in the eye, but rather that light is a particle that is emitted from things like the sun or fire that then travel and bounce off objects, like chairs, in all directions. Those light particles that travelled from the sun and bounce off the chair to then enter your eye are what allow you to see the chair.

Y	If you had a pen laser and pull out a single strand of your hair, you could observe that if you aim the laser right at the hair, it will cast an unexpected shadow. You would see the laser dot shrink a bit and a band of bright then dark then bright then dark lines spread from the laser dot. So, it appears that the light acts like the waves we sent down our slinkies. In that case, when both crests are on the same side of the slinky they constructively interfere and grow bigger (in the case of the laser and hair this would be one of those bright spots) and when the crests are on opposite sides of the slinky they deconstructively interfere, momentarily canceling out (this would be one of those dim spots). Based on this evidence and more, in 1801 Young concluded that light must be a wave.

N	Imagine a bright sunny day at the beach. If you stand with your back to the sun, you can see your shadow near-perfectly trace an outline of your legs. However, if you stand in the ocean, you would notice that when a water wave travels past your legs, it immediately curves around them. In 1670, Isaac Newton collected data on light in similar situations and observed that light did not seem to curve around objects. He concluded that therefore light must be a particle, not a wave that would curve and spread out.

D	Think of this fairly common situation: a group of people are all looking out a window from different perspectives. It can be observed that light from different objects in this situation must intersect and travel through each other to reach all the different peoples' eyes spread around near the window. Based on similar evidence, in 1630, Descartes reasoned that if light were a particle, it would hit and bounce off other light particles. Since light from different objects appears to travel "through" other light, he concluded light must be a wave.

E	Just recently, we have studied and observed that solar cells transform light energy into electrical energy. One observation we made was that the more sunlight that hit the cell, the more electricity was generated. However, it was surprising to a student that no amount of red light would produce electricity by one of our solar cells, but that dim green light did produce electricity. After testing the solar cell further, green and every color of light beyond it in the rainbow -- that is, green light and every higher frequency of light, produced electricity, but no frequency of light below green did. In 1905, Einstein also observed a similar effect in metals and concluded that light could not be a pure wave that can constructively add up its energy. He reasoned that it must at times act like a particle that either has the critical energy and is individually absorbed or does not individually have the critical energy and therefore cannot absorbed.

1. After reading all the pieces of evidence, place a brief description of each piece of evidence on the timeline below; if it supports a wave model of light place it above the line and if it supports a particle model of light place it below the line.

Wave Model

Particle Model

2. Why do you think people went back and forth about which model of light was best?

3. A historical note: the situation that Einstein studied involved shining higher and higher energy (that is, frequency or equivalently color) light on a metal plate and observing at a certain energy level of light that electrons started flying off the metal plate. Because only light with this energy level or above generated electricity, it made sense to call this discovery *the photoelectric effect*, which roughly translates as light → electricity. Additionally, the fact that two pieces of low energy light, even when constructively adding their energies together, did not generate electricity provided the undeniable evidence that light, while often behaving as a wave, must at times act like a particle that is sometimes absorbed and sometimes not absorbed, depending on if it individually has the critical energy. This finding that light must at times be a particle meant we needed a name for a particle of light. What name do you think was given to a particle of light? Hint: all particle names in physics end in -on.

4. What is a new good name for our current best understanding that light is neither actually a wave or particle but something else, but that something else always acts as either a wave or a particle?

5. In order to honor that light is neither truly a pure wave or a pure particle, but also at any given moment does act as like a wave or a particle, the name historically given was actually a phrase: the *wave / particle duality*. In the following situations, indicate which aspect of the duality would best model how the light is behaving in that situation.	wave model	particle model
Red, green, and blue light are fairly harmless but even just a little higher-energy UV light can damage your DNA, sometimes leading to skin cancer.		
Your eyeball bends all colors of light to focus an image on your retina.		
Only certain colors (energies) of light can be utilized by plants to photosynthesize sugars.		
Looking and tilting the bottom of a DVD under sunlight you will see it create a band of of light with all		

the colors of the rainbow.		
Challenge Question: research polarized sunglasses that selectively allow light through.		