Newton vs. Huygens

Advanced

- As we learned in High school, **Isaac Newton** (1643 - 1727), the science hero of the 17th century, propagated the view that *light consists of small particles or corpuscles*.
  - He based his book „Opticks or a treatise of the reflections, refractions, inflections and colours of light“ on this point of view, and since he didn't do so badly, it was far from obvious that he should be wrong.
  - For example, he deduced that white light consists of of colored light (corpuscles of different sizes) that get separated in a prism or generally in glass. Prior to his insight, everybody believed that glass somehow changed the light. Based on this he not only explained the nature of a rainbow but also concluded that a telescope based on mirrors should be superior to one with lenses because of their "chromatic aberration" (he did not use this term, of course). He even built a prototype of a mirror based telescope but, bad luck, it wasn't better than the lens telescopes of his times because his mirror suffered from spherical aberration.
  - He knew that his corpuscle model could not (easily) explain some known effects around interference or polarization tied to birefringence (first described in 1669 by **Erasmus Bartholin**) but so what. There was a lot of other stuff in the 17th century that had not yet been satisfactorily explained.
- **Huygens** (1629-1695), a Dutch mathematician, physicist and so on, formulated the **Huygens principle**, nowadays better known as **Huygens–Fresnel principle**, and generally argued that light consists of waves.
  - **Augustin-Jean Fresnel** (1788 – 827), was a French engineer who contributed significantly to the establishment of the theory of wave optics long after Huygens, so from my point if view it is OK to just call it Huygens principle.
  - Huygens experimented with Icelandic crystals (calcite) that showed double refraction (birefringence) and explained it with his wave theory and polarized light. Based on his insights he also constructed and made better lenses and thus microscopes, telescopes and so on. Moreover, he made seminal contributions to mechanics and was instrumental in early probability theory.
  - He fought Newton tooth and nail about the nature of light. He lost the fight. Newton appealed to the "Royal Society", the topmost authority in those bygone times, and **1715** it ruled that Newton's point of view was the correct one. This was not as stupid as it appears now. Huygens, as we know now, was right but could not really prove his assertions then. For that another **75** years needed to pass.
- Enter **Thomas Young** (1773 - 1829). While he started as a physician, he mutated and became a true physicist early in life and proved beyond doubt that *light is a wave*.
  - Somewhat ironically, it weren't only the seminal **double slit interference experiments** done around 1802 but also the explanation of "**Newton rings**" that convinced all and sundry that light is a wave and *not* a particle.
  - Young did not just establish the wave nature of light but contributed to many other aspects of physics or, as we would call it now, materials science. "**Young's modulus**", for example, is named after him for good reasons. Moreover, he was also instrumental in deciphering hieroglyphic and other forgotten scripts.
- So Newton was wrong - or was he? Enter **Albert Einstein** (1879 - 1955). In **1905**, the "annus mirabilis", he postulated the **photon**, a kind of light *particle*, to explain the photo electric effect (that should get him his one Nobel prize in 1921). He also published the special theory of relativity in this year and the explanation of Brownian motion, i.e.. the atomic theory of diffusion. By the way, he received his Ph.D. (Dr. degree) a year later in **1906**.
  - So light is now a particle once more? Of course meanwhile we know better. We know since **Louis-Victor Pierre Raymond duc de Broglie** (1892 - 1987) established in **1924** that particles are also waves, that there is no such thing as a pure wave or a pure particle.
  - There are only "things" described by a *wave function* that comes out as a solution of the Schrödinger equation (or the more general equations of quantum (field) theory). There are no problems anymore, except that explaining that to somebody not used to quantum theory is like explaining color to the blind, symphonies to the deaf, reason to a lawyer, conservation laws to an economist or truth to a theologian. It's tough.
  - We also know now how we might simplify and approximate the problem at hand by looking at the "thing" either as a pure particle or a pure wave.