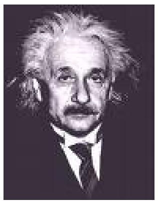
Categories
Issues
November/December 2008
November/December 2007
September/October 2008
May/June 2008
March/April 2008
Podcasts
Videos
Subscribe

Light Is Not What You Think

by **Megan Rulison**
Scope Correspondent



Think you know Albert Einstein? Most people can pick the head of unruly white hair out of a lineup or name his illustrious theory. But did you know the physics celebrity did not receive his Nobel Prize for relativity? Rather, Einstein was awarded the highest honor in science in 1921 for his explanation of a strange little phenomenon called the photoelectric effect.

This peculiar interaction occurs when light hits a metal plate and electrons are ejected from its surface. Scientists have observed this quirky but common event since at least 1839, but it was not until Einstein pooled the work of others with his own heretical view of nature that the significance of the phenomenon was recognized. His explanation of the photoelectric effect knocked classical physics aside without apology and proceeded to alter our understanding of the nature of light.

Heinrich Hertz was one of the first on record as dazzled by the photoelectric effect. While investigating electromagnetism in 1887, Hertz noticed he could get a long spark to jump between brass coils under ultraviolet (UV) light, but after blocking the UV rays by placing a dark case over the experiment (to better see the flash of light), he saw the spark diminish. As with most anomalies, the scientist had no idea what was going on but did not investigate the matter further.

Next up to the plate was J. J. Thompson. This Nobel laureate deduced that a metal plate exposed to UV light was actually emitting negatively charged particles (the same material in Hertz's spark). Thompson and others imagined that the waves of UV light were shaking the atoms of metal hard enough that some particles flew off, like waves in a pond upsetting a flock of geese. Thompson called the escaping particles "corpuscles." They are better known today as electrons.

Three years later, Philipp Lenard, a former assistant of Hertz's, set out to measure the energy of electrons emitted during the photoelectric effect. By steps he moved a lamp closer and closer to a piece of metal, then recorded the energy and the number of electrons emitted for each increase in the intensity of the light. According to Thompson, as the light became stronger, it should have shaken the atoms faster and faster, causing electrons to rocket off the metal with higher and higher energies. But to Lenard's shock and confusion, the electrons ejected by the various intensities of light all came out with the exact same energy. The only difference in each trial was the number of electrons ejected from the metal. The reigning theory of light couldn't explain this phenomenon. At the beginning of the twentieth century, light was known to be composed of waves. Beams of light interfere with each other like sound waves, and they bend around objects like water flowing around a curve. No one doubted that light was made of waves. But suddenly, it wasn't acting like that at all.

Enter Einstein, our rebel with a cause, into the fray. In a deft act of synthesis, Einstein married Lenard's puzzling results to the strange math of a German physicist. Max Planck had been commissioned by an electric company to figure out how to get the most light from a light bulb using the least amount of energy. Frustrated with his calculations, Planck found that by imagining light as little particles instead of waves, his mathematics worked perfectly. At the time, Planck regarded his assumption as simply a mathematical shortcut, but Einstein became convinced that Planck's fanciful lumps of energy were a worldly reality.

Imagine Einstein at age 26, not yet white-haired, sitting down with paper and pen to write about light. He has no powerful lamps or sheets of metal in front of him, no instruments to measure energy or coils to create sparks. He simply scribbles out fifteen pages of equations and arguments. He concludes, in essence, "Light is not what you think it is."

Based on Planck's lumps of energy and the results of the photoelectric effect, Einstein proposed that light exists as "quanta," little packets of energy later called photons. When a photon of light hits a metal plate, it knocks into an electron, like a bowling ball catching a single pin. Increasing the intensity of light increases the number of photons hitting the metal— adding more lanes with more bowlers. But it does not change the energy of any single electron; more pins will be knocked away, but none will fly away faster.

The energy of an emitted electron has only to do with the energy of the photon that crashes into it. A high-energy photon packs a lot of power— a ball whipped quickly down the lane that blasts a pin backwards.

Photons with very low energies, no matter what the number, are like balls rolled softly by a three year old; if they're lucky enough to reach a pin, they may jiggle it but not knock it down. In the photoelectric effect, the energy of emitted electrons depends only on the energy of the individual photons that hit them. That dependency cannot be explained by waves.

But Einstein's photon revolution didn't catch on easily. Experiments done by earlier physics giants, such as Thomas Young, Michael Faraday, and James Clerk Maxwell, had proved beyond a doubt that light was composed of waves. Today, we can only conclude that light is somehow both a wave and a particle, or appears to be one or the other depending on how we look at it. Don’t worry if that’s not satisfying, most scientists are in the same boat, including Einstein. Nineteen years after his explanation of the photoelectric effect, he wrote, “There are therefore now two theories of light, both indispensable and—as one must admit today in spite of twenty years of tremendous effort on the part of theoretical physicists—without any logical connection.”

Tags: Albert Einstein, Heinrich Hertz, J.J. Thompson, photoelectric effect