The photoelectric effect

The photoelectric effect, a landmark discovery in the realm of quantum mechanics, was first observed by Heinrich Hertz in 1887, and later thoroughly explained by Albert Einstein whose theoretical work on the phenomenon won him the Nobel Prize in Physics in 1921. This effect involves the emission of electrons from a material, typically a metal, when it absorbs light or more generally, electromagnetic radiation. Crucially, the photoelectric effect demonstrated the particle-like behavior of light.

Einstein proposed that light consists of quantized energy particles, or photons, whose energy depends on their frequency (not their intensity). When light strikes the surface of a metal, photons transfer their energy to electrons. If a photon's energy surpasses the material's work function — the minimum energy needed to dislodge an electron from the surface — an electron is ejected. Noteworthy is the fact that below the threshold frequency, corresponding to the work function, no electrons are emitted, regardless of the light's intensity. This contradicts classical wave theories which predicted that high intensity light should be able to eject electrons even at low frequencies.

Furthermore, the kinetic energy of the photoelectrons varies linearly with the frequency of the incident light and is independent of its intensity. The intensity of light, however, does influence the number of electrons liberated during the interaction.

This quantum behavior has profound implications, affirming the dual nature of light as both wave and particle and paving the way for the development of quantum physics. The photoelectric effect also has practical applications in various technologies such as photovoltaic cells, which convert light into electricity, and photoelectron spectroscopy, an analytical technique used to determine the composition and electronic structure of materials.