DUAL NATURE OF RADIATION

EINSTEIN'S PHOTOELECTRIC EQUATION: ENERGY QUANTUM OF RADIATION

EINSTEIN'S PHOTOELECTRIC EQUATION

In accordance with Einstein's theory regarding the photoelectric effect, when a photon undergoes an inelastic collision with an electron, the photon is either entirely or partially absorbed by the electron. Consequently, if an electron within a metal absorbs a photon containing energy, it utilizes this energy in the following manner:

A portion of the energy, denoted as Φ0, is expended to liberate the surface electron from the metal. This is referred to as the "work function" of the material. The remaining energy manifests as the kinetic energy (K) possessed by the emitted photoelectrons.

Einstein's Photoelectric Equation elucidates the following concepts: The frequency of the incident light exhibits a direct proportionality to the kinetic energy of the electrons, while the wavelengths of the incident light exhibit an inverse proportionality to the kinetic energy of the electrons.

If $\gamma = \gamma_{th}$ or $\lambda = \lambda_{th}$ then $v_{max} = 0$.

$\gamma < \gamma_{th}$ or $\lambda > \lambda_{th}$: There will be no emission of photoelectrons.

The term "intensity" in the context of radiation or incident light pertains to the quantity of photons within the light beam. Higher intensity implies a greater number of photons, and conversely, lower intensity implies fewer photons. It's important to note that intensity is unrelated to the energy of individual photons.

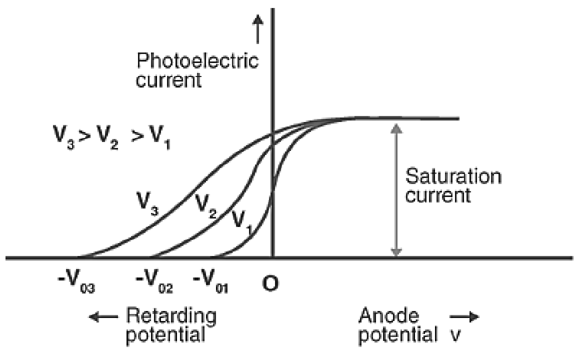
Consequently, when the intensity of the radiation is elevated, the rate of photon emission also increases, but this change in intensity does not result in any alteration of the kinetic energy of electrons. As the number of emitted electrons rises, the value of the photoelectric current similarly increases.

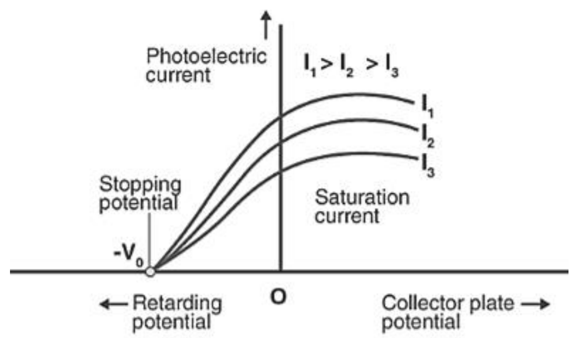
DIFFERENT GRAPHS OF PHOTOELECTRIC EQUATION

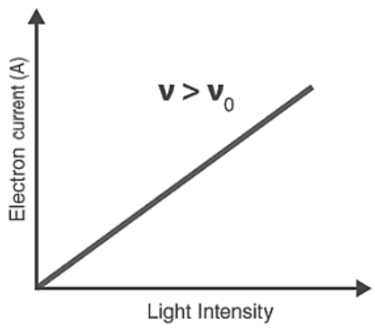
Graphs showing the relationship between various parameters in the photoelectric effect can be categorized as follows:

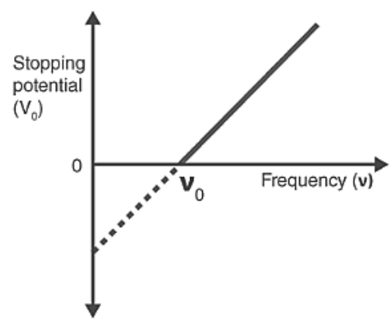
- Photoelectric current as a function of retarding potential.
- Photoelectric current as a function of different intensities of light.
- Electron current versus the intensity of incident light.
- Stopping potential versus the frequency of the incident light.

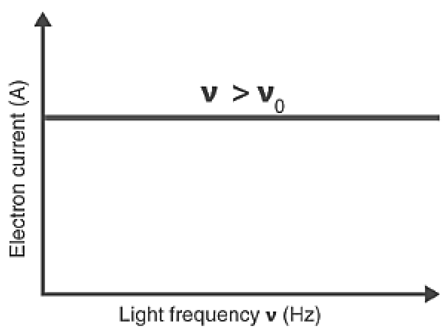
- Electron current in relation to the frequency of the incident light.
- Electron kinetic energy versus the frequency of the incident light.

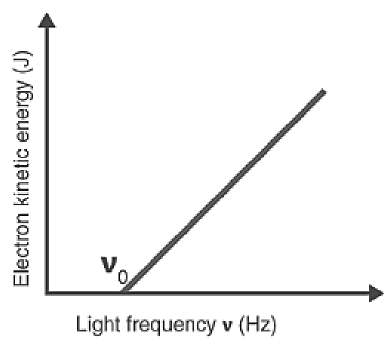


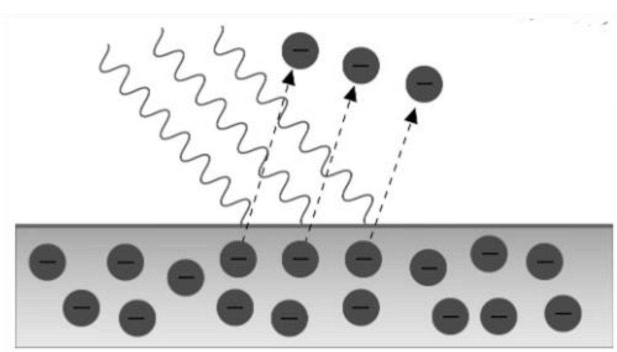












The photoelectric effect is a phenomenon characterized by the emission of electrons from the surface of a metal when it is exposed to light of a specific frequency. The initial observations of the photoelectric effect were made in 1887 by Heinrich Hertz and were later documented by Lenard in 1902. However, neither of these early observations could be adequately explained by Maxwell's electromagnetic wave theory of light. It is noteworthy that Hertz, who had previously demonstrated the wave theory of light, did not further investigate the matter, believing that it could be accounted for within the framework of wave theory. Nevertheless, the wave theory failed to address the following aspects of the phenomenon:

As per the wave theory, energy is assumed to be evenly spread throughout the wave front, and its magnitude is solely linked to the beam's intensity. This would suggest that the kinetic energy of electrons should rise in tandem with the intensity of the incident light. However, it was observed that the kinetic energy of the emitted electrons remained unaffected by variations in light intensity.

According to the wave theory, it is postulated that light of any frequency should possess the capability to dislodge electrons. However, it was observed that electron emission only transpired for frequencies exceeding a certain threshold frequency (ν0). Under the wave theory's premise, lower-intensity light should eventually release electrons as they accumulate enough energy to be ejected. Nevertheless, the emission of electrons was spontaneous, occurring irrespective of how minimal the intensity of the light was.

Here is a table featuring links to other experiments associated with the photoelectric effect:

EINSTEIN'S EXPLANATION OF PHOTOELECTRIC EFFECT

Einstein successfully addressed this issue by adopting Planck's groundbreaking concept that light could be viewed as composed of discrete particles known as quanta or photons. The energy conveyed by each individual light particle (photon) is contingent upon the frequency (ν) of the light, as depicted in the following equation:

$E = h\nu$

Where h = Planck's constant = 6.6261×10^{-34} Js.

As light is composed of photons, Einstein postulated that when a photon strikes the surface of a metal, all of the photon's energy is transferred to the electron.

A portion of this energy is utilized to liberate the electron from the hold of the metal atom, while the remaining energy is transferred to the ejected electron as kinetic energy. Electrons emanating from within the metal surface experience a reduction in kinetic energy upon their ejection. However, those electrons situated at the surface retain all the kinetic energy imparted by the photon and possess the highest kinetic energy.

This relationship can be expressed mathematically as follows:
Energy of a photon = Energy needed to release an electron (work function) + Maximum kinetic energy of the electron.

$E = W + KE$
$h\nu = W + KE$
$KE = h\nu - w$

For the threshold frequency, denoted as ν_0, electrons are merely expelled without possessing any kinetic energy. Below this frequency, electron emission does not occur. Consequently, the energy of a photon with this specific frequency must be equivalent to the work function of the metal.

$w = h\nu_0$

Hence, the equation for the maximum kinetic energy can be expressed as:

$KE = \frac{1}{2mv^2{}_{max}} = h\nu - h\nu_0$

$\frac{1}{2mv^2{}_{max}} = h\,(\nu - \nu_0)$

The stopping potential is given by $ev_0 = \frac{1}{2mv^2{}_{max}}$

Therefore, Einstein successfully elucidated the Photoelectric effect by considering the particle-like behavior of light.

The following video provides a concise overview of the photoelectric effect: