STOPPING POTENTIAL AND SATURATION CURRENT IN PHOTOELECTRIC EFFECT

Photoelectric effect - Effect of potential applied

In the photoelectric effect, electrons are emitted from a material's surface when it is illuminated with light. When an external potential is applied to the material, it can affect the emission of electrons in various ways.

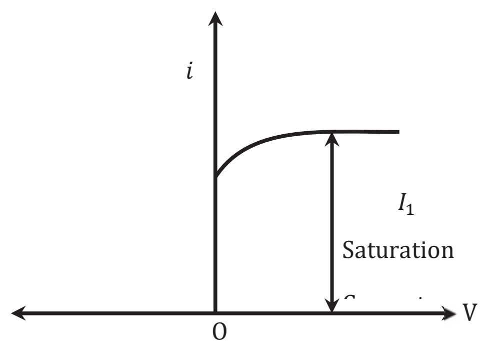
One significant aspect is the stopping potential, which represents the minimum potential difference required to halt the emission of photoelectrons. By adjusting this applied potential, one can control the flow of emitted electrons, thereby influencing the intensity or rate of the photoelectric effect.

Additionally, the applied potential can also affect the kinetic energy of the emitted electrons. Increasing the potential difference can accelerate the emitted electrons, leading to higher kinetic energies. Conversely, decreasing the potential can reduce the kinetic energy of the emitted electrons.

Overall, studying the effect of potential applied in the photoelectric effect provides insights into the behavior of electrons in materials under the influence of external electric fields and is crucial for understanding and manipulating this phenomenon in various applications.

Saturation current

Once all the photoelectrons emitted reach plate A, the current attains its maximum value, referred to as the saturation current.



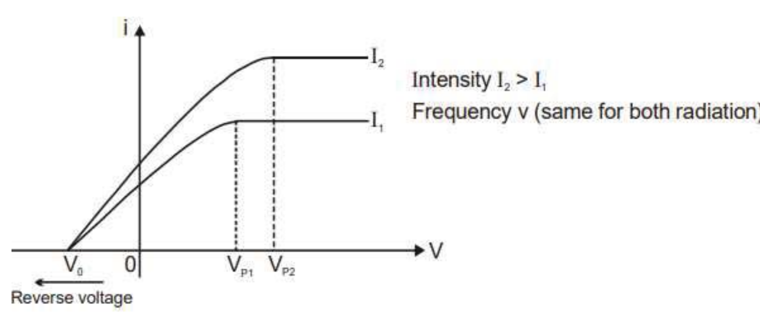
If we examine the positive aspect of the potential, we notice the potential for an increase in current. However, beyond a certain threshold of potential increase, the rise in current halts. This capped current value is known as the saturated current.

This occurs because, initially, only a portion of the electrons emitted from the surface at zero voltage reached the other plate, while others did not. As we increment the potential, gradually those electrons which initially did not reach the other plate also begin to do so. Eventually, when all the emitted electrons successfully reach the other surface, regardless of further increases in potential, the number of electrons reaching the other plate remains constant.

Stopping Potential

When the polarity is reversed, electrons experience deceleration within the discharge tube. As the reverse potential difference is amplified, fewer electrons reach the anode, causing a decline in the photoelectric current within the circuit. This phenomenon is depicted in the accompanying diagram, illustrating the change in current as voltage across the discharge tube increases in the opposite direction.

It is noted that at a particular reverse voltage, designated as $V0$V0, the circuit's current becomes zero. This voltage signifies the moment when the faster electrons emitted from the cathode are decelerated and halted just prior to reaching the anode.



The voltage V_0 can be determined by plugging in $vf=0$ into equation (1), which is derived from the correlation between stopping potential and the kinetic energy of electrons.

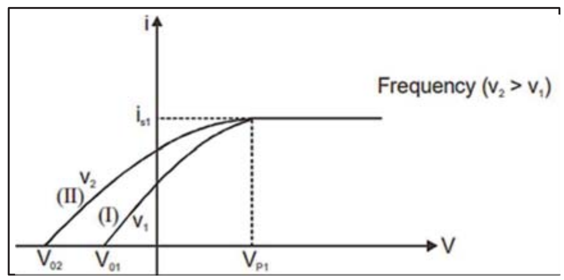
$$\frac{1}{2}mv^{2_0}_{max}$$

$$eV_0 = \frac{1}{2}mV^2_{max}$$

$$V_0 = \frac{\frac{1}{2}mv^2_{max}}{e} \quad \text{... (2)}$$

$$V_0 = \frac{hv-\phi}{e} \quad \text{... (3)}$$

In the depicted graph, it is noted that the curves plotted for two distinct intensities, I_1 and I_2, exhibit identical values for V_0. In both scenarios, the current is interrupted at the same reverse potential V_0. This observation can be elucidated by equations (2) and (3), which suggest that V_0 depends solely on the maximum kinetic energy of ejected electrons. This energy, in turn, is dictated by the frequency of light and remains unaffected by its intensity. Consequently, in the aforementioned graphs where the incident light frequency is consistent, the value of V_0 remains constant. This reverse potential difference V_0, where the fastest photoelectron is halted and the circuit's current becomes zero, is termed the cutoff potential or stopping potential.



When repeating the experiment while maintaining a constant number of incident photons and increasing the frequency of the incident light, the resulting graph depicting the variation of current with voltage can be illustrated, as shown in the accompanying figure.

The graph represents two incident light beams, labeled with distinct frequencies v_1 and v_2, while maintaining an equal photon flux. As the number of ejected photoelectrons remains consistent for both instances of incident light, the pinch-off voltage (V_{01}) and saturation current remain identical. However, due to the differing kinetic energy of the fastest electron in the two scenarios resulting from different frequencies, the stopping potential varies. In graph II, where the frequency of the incident light is higher, the maximum kinetic energy of the photoelectrons is also increased, necessitating a higher stopping potential. Therefore, V_{01} and V_{02} can be expressed as follows:

$$V_{01} = \frac{hv_1-\phi}{e} \quad \text{... (4)}$$

$$V_{02} = \frac{hv_2-\phi}{e} \quad \text{... (5)}$$

Typically, for a particular metal with a work function designated as ϕ, if V_0 denotes the stopping potential for incident light with frequency vv, the relationship is stated as follows:

$$eV_0 = hv - \phi$$

$$eV_0 = hv - hv_{th} \quad \text{... (6)}$$

$$V_0 = \left(\frac{h}{e}\right)v - \frac{hv_{the}}{e} \quad \text{... (7)}$$

Equation (7) demonstrates that the stopping potential V_0 shows a linear relationship with the frequency vv of the incident light. This correlation between the stopping potential and frequency is illustrated in the accompanying figure. Equation (6) can be rewritten as:

$$\frac{1}{2}mv^{2_0(V-V_{th})}_{max} \quad \text{... (8)}$$

Equation (8) is identified as Einstein's equation for the Photoelectric Effect, establishing a direct relationship between the maximum kinetic energy, stopping potential, frequency of incident light, and the threshold frequency.

This equation stands as a fundamental expression capturing the complex interaction among these variables within the framework of the photoelectric effect.