DUAL NATURE OF RADIATION

EXPERIMENTAL STUDY OF PHOTOELECTRIC EFFECT

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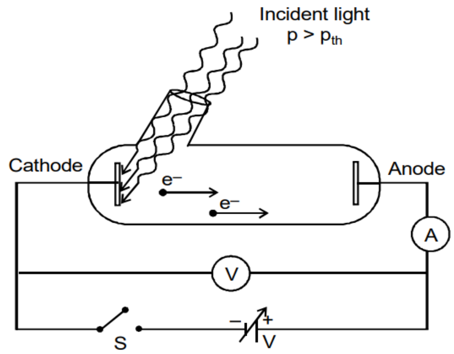
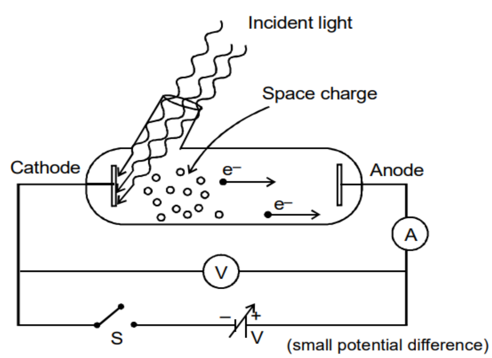
Investigations involving the photoelectric effect are conducted within a discharge tube apparatus, as depicted in the accompanying diagram. The cathode of the discharge tube is composed of a metal that demonstrates the photoelectric effect and serves as the focal point of the experimentation process.



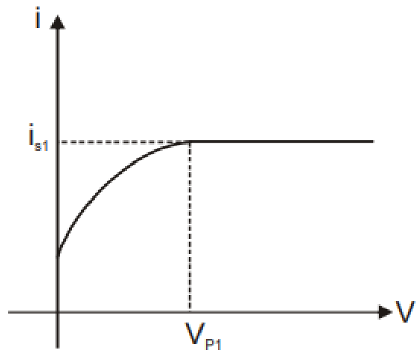
A discharge tube is supplied with a high voltage via an adjustable voltage source. In this setup, a voltmeter and an ammeter are connected to gauge both the potential difference across the electrodes and the photoelectric current, respectively. Light of a frequency exceeding the threshold frequency of the cathode metal is directed onto the cathode, prompting the emission of photoelectrons from its surface. These photoelectrons subsequently traverse the space to reach the anode, thus forming the photoelectric current, which is quantified by the ammeter's reading.

Commencing the experiment involves the closure of switch S. At the outset, the variable battery source is configured to have zero potential. Interestingly, even with the variable source initially set at zero potential, the ammeter will register a certain level of current. This phenomenon occurs because, due to their initial kinetic energy, some electrons manage to traverse the distance and reach the anode, thereby inducing a minimal current flow.

However, it's important to acknowledge that a significant portion of the ejected electrons possesses relatively low kinetic energies. These electrons congregate outside the cathode, giving rise to a cloud of negative charge, which is referred to as a "space charge," as depicted in the accompanying diagram.

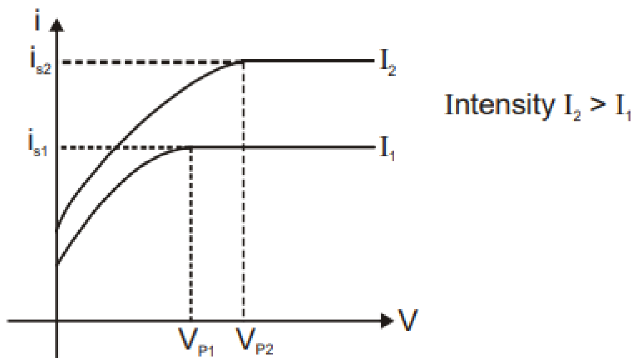


As the potential difference applied across the discharge tube is incrementally augmented using the variable source, the positive potential of the anode commences the process of attracting electrons from the space charge. With the progressive elevation of the potential difference, the space charge diminishes, and concomitantly, the photoelectric current within the circuit experiences an increase. This phenomenon is also depicted in the graphical representation illustrating the relationship between current and potential difference, as displayed in the provided figure.



As delineated in the graph, it's observable that with an increase in the potential difference, the current within the circuit also rises. However, at a higher voltage denoted as V_{P1}, the space charge ceases to exist. At this voltage, the anode is capable of attracting even the slowest electrons, those with zero kinetic energy, which were initially emitted by the cathode. Consequently, all the electrons emitted by the cathode are now directed toward the anode. Any further escalation in the potential difference will no longer have an impact on the number of electrons reaching the anode. This behavior is depicted in the provided figure, wherein the current within the circuit stabilizes beyond V_{P1}. This constant current is referred to as saturation current, denoted as I_s. The potential difference at which the current reaches saturation,V_{P1} is termed the "pinch-off voltage."

Now, in a scenario where the frequency of the incident light remains constant and its intensity is further augmented, the quantity of incident photons surges. This, in turn, leads to an increase in the number of ejected photoelectrons, consequently causing a rise in the current within the circuit. Under these conditions, at a higher incident light intensity, the current does not saturate at the potential difference V_{P1}. This occurs because the elevated electron emission results in a more substantial space charge, preventing its disappearance at V_{P1}. To attract all the electrons that have been emitted from the cathode, a greater potential difference is necessitated. This is evident in the accompanying figure, where at the higher intensity denoted as I_2 (where $I_2 > I_2$), the current saturates at a higher potential difference value V_{P2}.



Beyond V_{P2}, it becomes apparent that all the electrons expelled from the cathode successfully reach the anode, leading to a saturation of the current, designated as I_{s2}, due to the greater number of electrons. Additionally, an observation that can be made from the provided figure is that even when the potential difference (V) is at zero, the current remains relatively high when exposed to high-intensity incident radiation. This phenomenon arises because, at the outset, there is a higher quantity of electrons possessing elevated kinetic energies, which allows them to penetrate the space charge and ultimately reach the anode.