Photoelectric emission

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What is Photo-electric emission?

It is the emission of electrons from the surface of a material when light of suitable frequency falls on its surface. The emitted electrons are known as photoelectrons.

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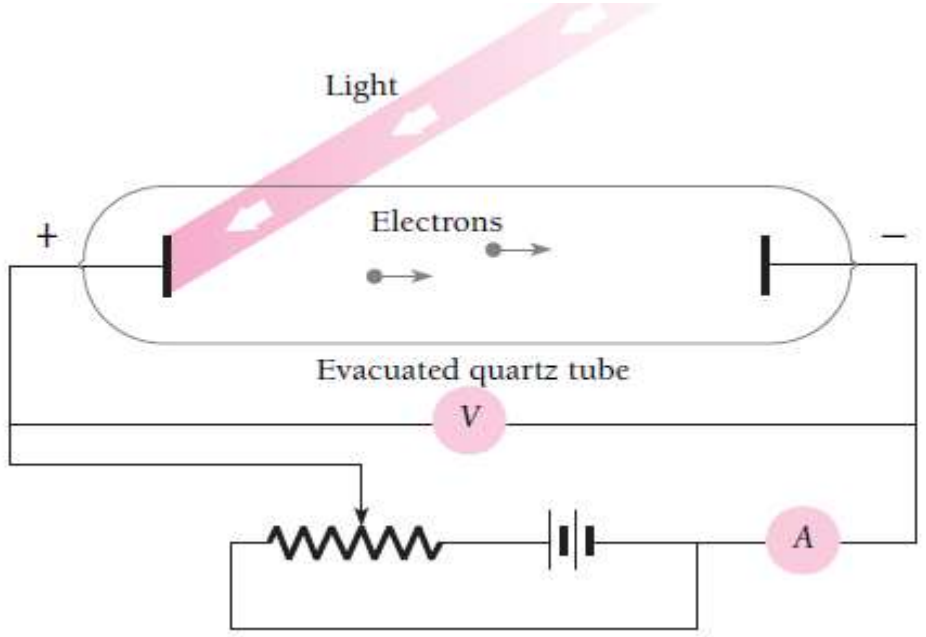
Experimental Setup

- The setup consists of an evacuated tube containing two electrodes connected to a source of variable voltage, with the metal plate whose surface is irradiated as the anode.
- Some of the photoelectrons that emerge from this surface have enough energy to reach the cathode despite its negative polarity, and they constitute the measured current, which is measured by the ammeter.

The slower photoelectrons are repelled before they get to the cathode. When the voltage is increased to a certain value V_0, *of the order of several* volts, no more photoelectrons arrive, as indicated by the current dropping to zero. This extinction voltage corresponds to the maximum photoelectron kinetic energy.



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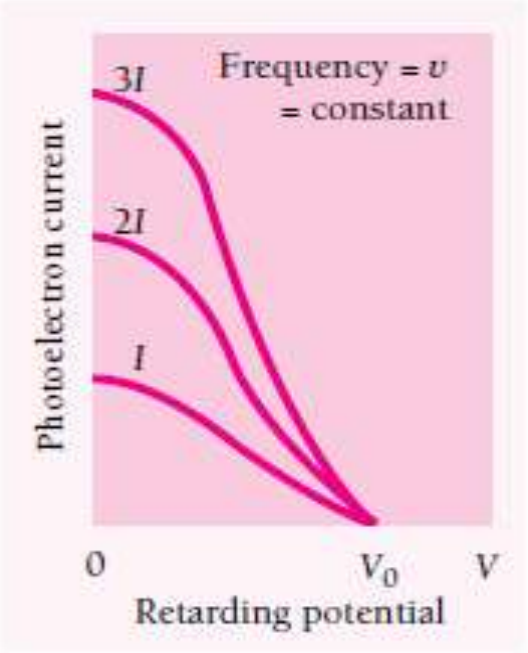
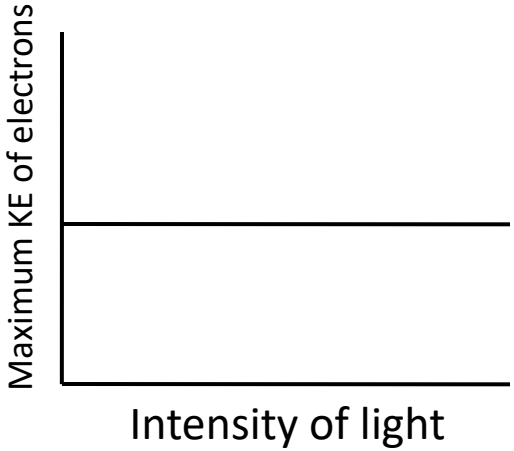
Observations and contradictions with classical Electromagnetic theory

- Within experimental accuracy (~10^{-9} s) there is no time lag between the arrival of light and emission of photoelectrons from the metal surface. However, because the energy in an em wave is supposed to be spread across the wavefronts, a period of time should elapse before an individual electron accumulates enough energy (several eV) to leave the metal.
- An intense beam of light yield more photoelectrons than a dim light of the same frequency. EM theory on the other hand predicted greater energies of photoelectrons with more intense light





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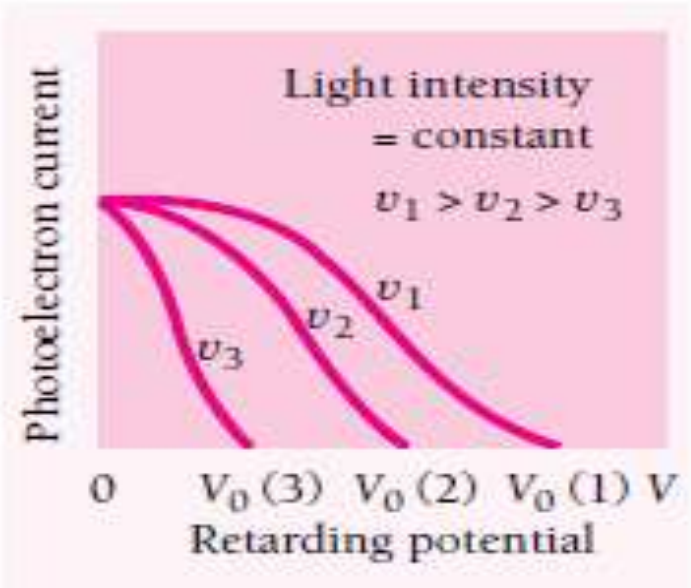
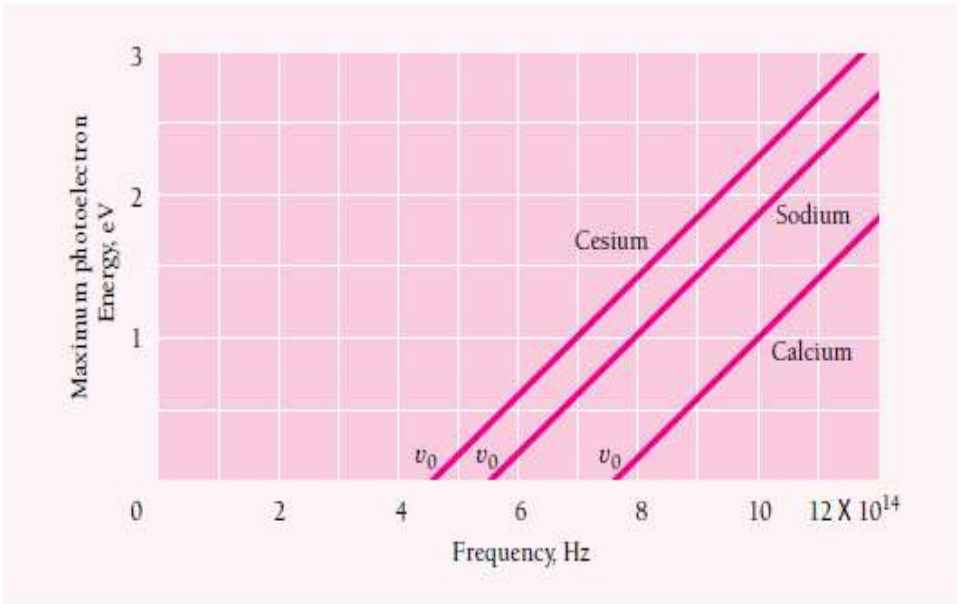
Observations and contradictions with classical Electromagnetic theory

➢The higher the frequency of light, the more the energy photoelectrons have.





➢For each metal there exists a critical frequency ν_0 below which no photoelectric emission is observed. This critical frequency ν_0 is characteristic of each particular metal.

These observations also could not be explained by classical EM theory.

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Explanation by Quantum Theory

Einstein proposed that light is concentrated in small packets of energy or photons. Each photon of light of frequency ν has the energy hν, the same as Planck's quantum of energy.

Einstein gave explanation of photoelectric effect with the Hypothesis that "Energy was not only given to em waves in separate quanta but was also carried by the waves in separate quanta."

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Explanation by Quantum Theory

The experimental observations follows directly from the Einstein's hypothesis of quantization of light

(1)Because energy of em wave is concentrated in photons, each photon interacts with one electron and there should be no delay in the emission of photoelectrons.

(2)All photons of same frequency *have the same energy, so increasing the intensity of a monochromatic light* beam will increase the number of photoelectrons but not their energies.

(3)The higher the frequency , the greater the photon energy *hv and so the photoelectrons possess more energy*.

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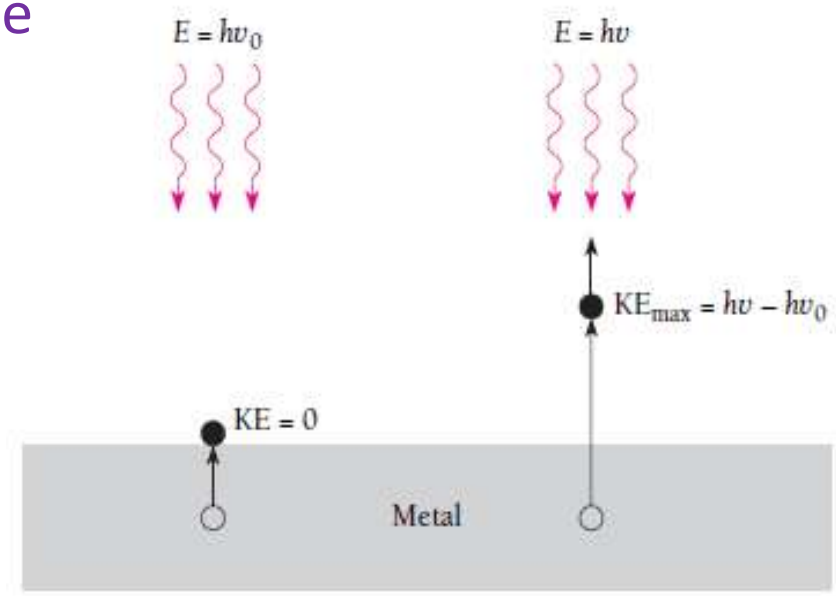
Einstein's Photoelectric Equation

The minimum energy required for an electron to escape from a particular metal surface is called the work function of the metal, and is related to ν_0 by the formula

Work function $\phi = h\nu_0$



Total incident photon energy must equal to the sum of work function of the metal and KE_{max} of the electron. i.e.

$h\nu = KE_{max} + \phi$

Substituting for Work Function $\phi = h\nu_0$,

$h\nu = KE_{max} + h\nu_0$

$KE_{max} = h\nu - h\nu_0 = h(\nu - \nu_0)$

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Thank You

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