Modern Physics
(Lec-6)

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OUTLINES

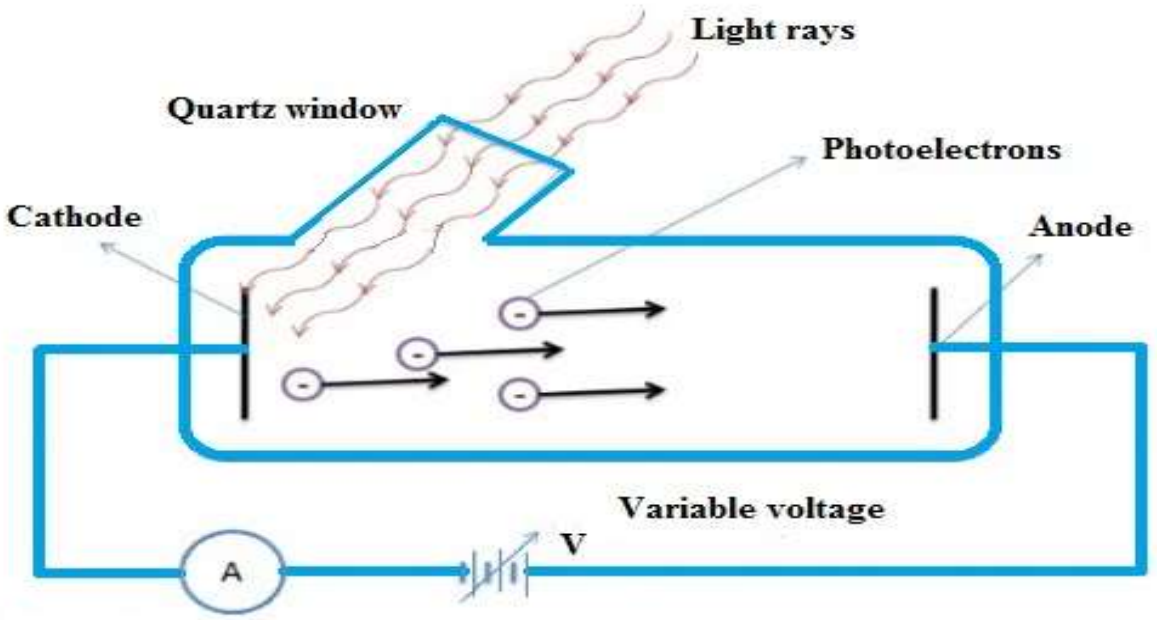
- Determination of Maximum Kinetic Energy of Electron
- Determination of Planck's constant
- Mathematical Problems

Determination of Maximum Kinetic Energy of Electron:

An experimental arrangement for observing the photoelectric effect is illustrated in figure below. Light falling on a metal surface can release electrons, which travel to the collector. The maximum kinetic energy of the electrons is determined by applying a negative potential to the collector that is just enough to repel the most energetic electrons. This potential, called the stopping potential V_0, is determined by increasing magnitude of the voltage until the ammeter current drops to zero. At this point the maximum kinetic energy K_{max} is just equal to the energy eV_0 used to repel the most energetic electrons.

Thus,

$$K_{max} = eV_0 \ldots\ldots\ldots\ldots (2)$$



Determination of Planck's constant:

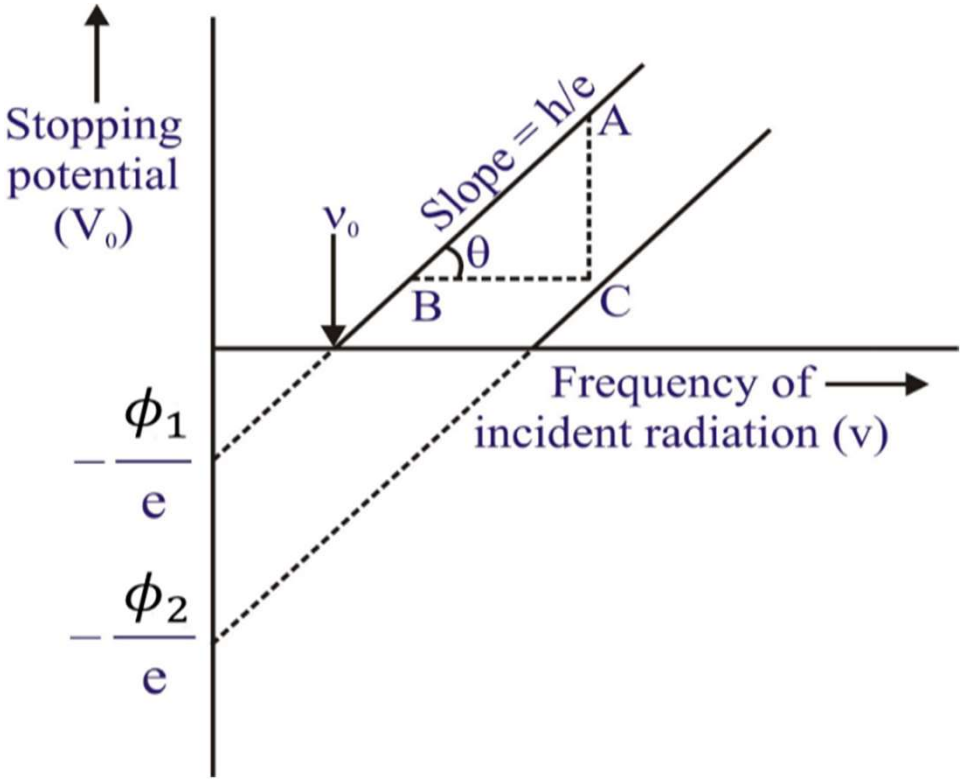
From equation (1) and (2) we get,

$$h\nu = eV_0 + \phi$$

$$eV_0 = h\nu - \phi$$

$$V_0 = \frac{h}{e}\nu - \frac{\phi}{e} \ldots\ldots\ldots (3)$$

If we measure the stopping potential for different frequencies of light and plot them in a graph, we will find a straight line.



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The x intercept of this graph indicates the value of cutoff frequency.
From y intercept we will get the value of work function for a particular material.
The slope of this graph is, h/e.

$$\text{i.e. } slope = h/e$$

$$\therefore h = slope \times e$$

Problem: A light source of wavelength λ illuminates a metal and ejects photoelectrons with a maximum kinetic energy of 1 eV. A second light source with half the wavelength of the first ejects photoelectrons with a maximum kinetic energy of 4 eV. Determine the work function of the metal.

Solution:

We know,

$$h\nu = K_{max} + \phi$$
$$\Rightarrow K_{max} = h\nu - \phi$$
$$\therefore K_{max} = \frac{hc}{\lambda} - \phi \ldots\ldots\ldots (1)$$

Let λ_1 and λ_2 be the wavelengths of the light emitted by the first and second sources, respectively, and let K_1 and K_2 be the maximum kinetic energies of the corresponding photoelectrons. It follows from eqn. (1).

$$K_1 = \frac{hc}{\lambda_1} - \phi \ldots\ldots\ldots (2)$$
$$K_2 = \frac{hc}{\lambda_2} - \phi \ldots\ldots\ldots (3)$$

Here, $\lambda_2 = \frac{\lambda_1}{2} \Rightarrow \lambda_1 = 2\lambda_2$

CONT…

Now from (2),

$$K_1 = \frac{hc}{2\lambda_2} - \phi$$

$$2K_1 = \frac{hc}{\lambda_2} - 2\phi \ldots\ldots\ldots (4)$$

From (3)-(4),

$$K_2 - 2K_1 = -\phi + 2\phi$$

$$\Rightarrow \phi = 4 - 2 = 2\ eV \qquad (Ans)$$

Problem-1: A photoelectric surface has a work function of 4eV. What is the maximum velocity of Photoelectrons emitted by light of frequency 10^{15} Hz incident on the surface?

Problem-2: Find the maximum velocity of photo-electrons emitted by radiation of frequency 3×10^{15} Hz from a photoelectric surface having a work function 4.0 eV.

Problem-3: The wavelength of light falling on the surface of a metal of work function 2.3 eV is 4300 A^0 with what velocity the electron will be emitted?

Problem-4: Calculate the threshold frequency and corresponding wavelength of radiation incident on a certain metal whose work function is $3.31 \times 10^{-19}\ J$. Given Plank's constan= $6.63 \times 10^{-34}\ JS$

Problem-5: The stopping potential for electrons emitted from a metal due to photoelectric effect is found to be 1V for a light of 2500 A^0. Calculate the work function of the metal in eV.

Problem 6: The work function for tungsten metal Is $4.52\ eV$.(a) What is the cutoff wavelength λ_c for tungsten? (b) What is the maximum kinetic energy of the electrons when radiation of wavelength 198 nm is used? (c) What is the stopping potential in this case?