Photoelectric Effect-Tutorial 1 Solution

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1. *In a photoelectric effect experiment, excited hydrogen atoms are used as light source. The light emitted from this source is directed to a metal of work function Φ. In this experiment, the following data on stopping potentials (V_s), for various Balmer lines of hydrogen, is obtained.

$$n=4 \rightarrow n=2, \text{ transition line}: V_S = 0.43\text{ V}$$
$$n=5 \rightarrow n=2, \text{ transition line}: V_S = 0.75\text{ V}$$
$$n=6 \rightarrow n=2, \text{ transition line}: V_S = 0.94\text{ V}$$

a) What is the work function Φ of the metal in eV?
b) What is the stopping potential (in Volts) for Balmer line of the shortest wavelength?
c) What will be the photocurrent corresponding to Paschen series (ending in $n = 3$) transitions?

(a) $h\nu - \phi = eV_s$

(4→2 trans.)

$$13.6\left(\frac{1}{4}-\frac{1}{16}\right) - \phi = 0.43\text{eV}$$

$$\phi = 13.6 \times \frac{3}{16} - 0.43 = 2.55 - 0.43 = 2.12\text{ eV}$$

(b) Shortest wavelength Balmer lines : $\infty \rightarrow 2$ transition

$$eV_s = 13.6\left(\frac{1}{4}\right) - 2.12 = 1.28\text{eV}$$

$$V_s = 1.28\text{V}$$

(c) For paschen series no photo $e^{\ominus}$ would be emitted as highest energy photon ($\infty \rightarrow 3$ transition) has energy

$$E = 13.6\left(\frac{1}{9}\right) = 1.51\text{eV} < \phi \ (= 2.12\text{ eV})$$

Hence photo current = 0

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2. In an experiment on photoelectric effect of a metal, the stopping potentials were found to be 4.62 V and 0.18 V for $\lambda_1 = 1850$ Å and $\lambda_2 = 5460$ Å, respectively. Find the value of Planck's constant, the threshold frequency and the work function of the metal.

Sol^n

$$\left.\begin{aligned} \frac{hc}{\lambda_1} - \phi &= eV_1 \\ \frac{hc}{\lambda_2} - \phi &= eV_2 \end{aligned}\right\}$$ Solve & obtain h & ϕ

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3. A monochromatic light of intensity 1.0 μW/cm^2 falls on a metal surface of area 1 cm^2 and work function 4.5 eV. Assume that only 3% of the incident light is absorbed by the metal (rest is reflected back) and that the photoemission efficiency is 100 % (i.e. each absorbed photon produces one photo-electron). The measured saturation current is 2.4 nA.

(a) Calculate the number of photons per second falling on the metal surface.

(5)

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   (a) Calculate the number of photons per second falling on the metal surface.

   (b) What is the energy of the incident photon in eV ?

   (c) What is the stopping potential ?

(a) $I_s = e \cdot n_{photo\, e^-} / s = e \cdot 0.03\, n_{photons}/s$

$2.4 \times 10^{-9} = 1.6 \times 10^{-19} \times 0.03 \times n_{photons}/s$

$\boxed{n_{photons}/s = 5 \times 10^{11}}$

(b) Power = Intensity × Area = Total energy falling on the surface per unit time

$\Rightarrow 1\mu W/cm^2 \times 1cm^2 = E_{photon} \times n_{photons/sec}$

$\Rightarrow 10^{-6} = E_{photon} \times 5 \times 10^{11}$

$\Rightarrow E_{photon} = 0.2 \times 10^{-17}\, J = \frac{0.2 \times 10^{-17}}{1.6 \times 10^{-19}}\, eV = \frac{100}{8}\, eV$

$= 12.5 eV$

(c) $eV_s = E_{photon} - \phi = (12.5 - 4.5) eV$

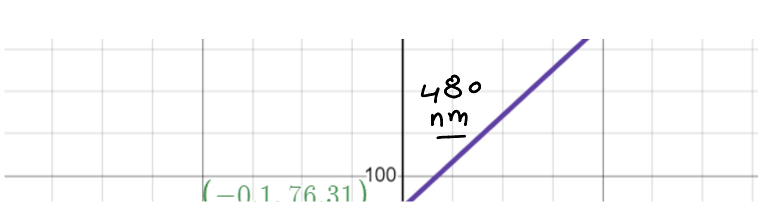
$\boxed{V_s = 8V}$

(4)

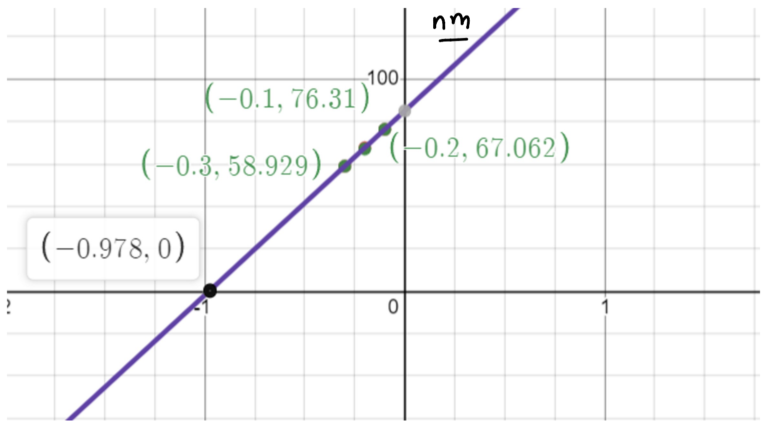
In a photoelectric experiment, a photocathode is illuminated separately by two light sources of same intensity but different wavelengths, 480 nm and 613 nm. The resulting photocurrent is measured as a function of the potential difference (V) between the cathode and the anode. Observed photocurrent for three values of V is given below

V	current (nA)	
	480 nm	613 nm
−0.1	76.3097	64.7039
−0.2	67.6194	44.4078
−0.3	58.9291	24.1118

(4)



Here looking at the values of 480 nm & 613 nm wavelength lights, we can observe that the



wavelength lights, we can observe that the photo current varies linearly with the reverse potential.

To get a feel of the curve, you can look at the graph for 480 nm light.

Here the photo current becomes 0 at potential $V = -0.978\ V$ = stopping potential

stopping potential is numerically equal to the max kinetic energy of photoelectron

$$\Rightarrow \quad \phi = \frac{hc}{\lambda} - K_{max}$$

$$= 2.583\,eV - 0.978\ eV = 1.605\ eV = \frac{hc}{\lambda_c} \Rightarrow \boxed{\lambda_c = 772.42\ nm}$$

(b) $K_{max} = 0.978\ eV$

$K = \frac{K_{max}}{2} = 0.489\,eV$

$$\frac{hc}{\lambda'} = \phi + K = 1.605\,eV + 0.489\ eV = 2.09\,eV$$

$$\boxed{\lambda' = 592.16\ nm}$$

(c) DIY

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5. Light of wavelength 2000 Å falls on a metal surface. If the work function of the metal is 4.2 eV, find the kinetic energy of the fastest and the slowest emitted photoelectrons. Also find the stopping potential and cutoff wavelength for the metal.

Fastest emitted photo $e^{\ominus}$ $\rightarrow$ Takes up all the extra energy of photon

$$KE_{max} = \frac{hc}{\lambda} - \phi \simeq 2\,eV$$

Slowest emitted photo $e^{\ominus}$ $\rightarrow$ Looses all its energy in collisions & comes out with zero kinetic energy

$$\boxed{KE_{min} = 0}$$

$$\phi = \frac{hc}{\lambda_{cutoff}} \Rightarrow \boxed{\lambda_{cutoff} \simeq 2950\,\text{Å}}$$

$$eV_s = K_{max} \Rightarrow \boxed{V_s \simeq 2V}$$