SHIKSHA CLASSES

Subject : Physics **BOARD ANSWER PAPER** **Total Marks : 20**

Class : XII **14. Dual Nature of Radiation and Matter**

Section (A)

Q. 1. (a) Select and write the most appropriate answer from given alternatives in each sub-question. [5]

1. In Einstein's photoelectric equation, $E_K = hv - \phi$, E_K denotes

Ans : b) Maximum KE of emmited electron

2. The K.E. of most energtic photoelectron is 8×10^{-19}J. The stopping potential will be-

Ans : c) 5 Volt

K.E. = eV_0

$8 \times 10^{-19} = 1.6 \times 10^{-19} V_0$

$$V_0 = \frac{8 \times \cancel{10^{-19}}}{1.6 \times \cancel{10^{-19}}}$$

= 5 Volt

3. Photo electric effect is the emission of

Ans : b) Electrons

4. If the photoelectric work function for a metallic surface is 4.125 eV, the cut-off wavelength for photoelectric phenomenon for the surface is

Ans : d) 3000 A^0

Given, $W_0 = 4.125$ eV $= 4.125 \times 1.6 \times 10^{-19}$ J

$\therefore$ the photoelectric work function,

$$W_0 = h\nu_0 = \frac{hc}{\lambda_0}$$

$$\therefore \quad \lambda_0 = \frac{hc}{W_0}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{4.125 \times 1.6 \times 10^{-19}}$$

$$= \frac{6.63 \times 3}{4.125 \times 1.6} \times \frac{10^{-26}}{10^{-19}}$$

$$= 3.013 \times 10^{-7}\,\text{m}$$

$$\therefore \; 3.013 \times 10^{-7}\,\text{m} = 3013A^0 \approx 3000A^0$$

5. What happens to the magnetic moment if a hole is made at the centre of a bar magnet?

Ans : c) Not a change

(b) Very short answer type Question [2]

1) What is photoelectric effect?

Ans : Photoelectric Effect :

"The phenomenon of emmission of electrons from the metal surface when it is exposed to the light radiation of suitable frequency is known as photoelectric effect.

Cadmium, magnesium these metals shows photoelectric effect.

2) Calculate the frequency associated with a photon of energy 3.3×10^{-20}J.

Ans. : Given :

$E = 3.3 \times 10^{-20}$ J $V = ?$

$E = hV$

$$V = \frac{E}{h} = \frac{3.3 \times 10^{-20}}{6.6 \times 10^{-34}}$$

$$\boxed{V = 0.5 \times 10^{14} H_2}$$

Q. 2. Attempt any three . [6]

1. Define : a) Threshold frequency

b) Stopping potential

Ans : a) Threshold frequency : The minimum frequency at which photoelectron emission just begins is called threshold frequency.

b) Stopping potential : The negative potential given to the collector metal at which photoelectric current becomes zero is called stopping potential.

2. Calculate the energy of a photon in eV and in joule in a light of wavelength 5000 A^0.

Ans : **Given :** $\lambda = 5000\ A^0 = 5 \times 10^{-7}$ m

Solution : We know ,

$E = h\nu$

$$= \frac{hc}{\lambda}$$

$$E = \frac{6.63\times10^{-34}\times3\times10^{8}}{5\times10^{-7}}$$

$E = 3.978 \times 10^{-19}$ J

E in electron volt,

$$= \frac{3.978\times10^{-19}}{1.6\times10^{-19}} eV$$

$\therefore$ E = 2.486 eV

3. Sheet of silver is illuminated by monochromatic ultraviolet light of wavelength 1810 A^0. What is the maximum energy of the emitted electron? Threshold wavelength of silver is 2640A^0.

Ans : **Given :**

$$\lambda = 1810A^0 = 1810\times10^{-10} m$$

$$\lambda_0 = 2640A^0 = 2640\times10^{-10} m$$

$$E_{max} = ?$$

According to rinsteins photoelectric eq^n

$$E_{max} = h\nu - W_0 = h\nu - h\nu_0$$

$$= h\left[\frac{C}{\lambda} - \frac{C}{\lambda_0}\right] = hC\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$$

$$= 6.63\times10^{-34}\times3\times10^{8}$$

$$\left[\frac{1}{1810\times10^{-10}} - \frac{1}{2640\times10^{-10}}\right] J$$

$$= \frac{6.63\times3\times10^{-16}}{1.6\times10^{-19}}\left[\frac{2640-1810}{1810\times2640}\right] eV$$

After solving

$$\boxed{\therefore E_{max} = 2.16\ eV}$$

4) Explain the term wave particle duality?

Ans : **Wave-Particle Duality :** In its interaction with matter, light behaves as if it is made up of packets of energy called quanta. Later it was confirmed from other theoretical and experimental investigations that these light quanta can have associated momentum. Hence the question came up whether a particle can be associated with light or electromagnetic radiation in general. Particle nature was confirmed by Compton in 1924 in experiments on scattering of X-rays due to electrons of matter.

Compton showed that photon has an associated momentum along with the energy it carries. All photons of electromagnetic radiation of a particular frequency have the same energy and momentum. Photons are electrically neutral and are not deflected by electric or magnetic fields. Photons can have particle-like collisions with other particles such as electrons. In photon – particle collision, energy and momentum of the system are conserved but the number of photons is not conserved. Photons can be absorbed or new photons can be created. Photons can transfer their energy and momentum during collisions with particles and disappear. When we turn on light, they are created. Photon always moves with the speed of light, it is never at rest. Mass of a photon is not defined as we do for a particle in Newtonian mechanics. Its rest mass is zero (in all frames of reference).

Effects of wave nature of light were seen in experiments on interference or diffraction when the slit widths or the separation between two slits are smaller than or comparable to the wavelength of light. If the slit width is large or the spacing between slits is more, the interference or diffraction patterns will not be same and the wave nature will not be so obvious.

Section (C)

Q. 3. Attempt any one question. [3]

1. Derive de-Broglie wave equation for a particle of mass (m) moving with velocity V.

Ans : In 1924, Prince Louis de Broglie proposed, on the basis of the symmetry existing in nature, that if radiation has dual nature - sometimes wave nature dominates and sometimes particle nature.

Consider a wave having frequency and wavelength λ, and proposed a relation to connect these with the particle properties, energy E and momentum p the momentum p carried by a photon of energy E is given by $p = \frac{E}{c}$ ---(i)

Which is valid for a massless particle travelling with the speed of light C, according to Einstein theory of relativity, using Einstein's relation in eq^n (i)

$$p = \frac{E}{c} = \frac{hv}{c} = \frac{h}{\lambda} \qquad \text{---(ii)}$$

De broglie proposed that a moving material particle of total E and momentum p has associated with it a wave analogous to a photon. Thus frequency and wavelength of a wave associated with a material particle, of mass m moving with a velocity 'v' are given as

$$v = E / h \text{ and}$$

$$\lambda = h / p = h / mv \text{ ---(iii)}$$

He referred these waves associated with material particles as *matter waves*. The wavelength of the matter waves, given by Eq. (iii) is the momentum, Broglie wavelength.

For a particle of mass m moving with a velocity 'v', the kinetic energy

$$E_K = \frac{1}{2}mv^2 \text{ or } v = \sqrt{\frac{2E_K}{m}}$$

Thus, $$\lambda = \frac{h}{mv} = \frac{h}{m}\sqrt{\frac{m}{2E_K}} = \frac{h}{\sqrt{2mE_K}}$$

For a charged particle q, through a potential difference V, the work done is qV. This provides kinetic energy. Thus $E_K = qV$.

$$\therefore \lambda = \frac{h}{\sqrt{2mE_K}} = \frac{h}{\sqrt{2mqV}}.$$

This relation holds for any charged particles like electron, proton or even charged ions where m corresponds to the mass of the charged particle.

2. The photoelectric workfunction of metal is 4.2 eV. If the stopping potential is 3V. Find the threshold wavelength and the maximum kinetic energy of emitted electrons.

Ans: Given data :

$W_0 = 4.2 \text{ eV} = 4.2 \times 1.6 \times 10^{-19} \text{ J} = 6.72 \times 10^{-19} \text{ J}$

$V_0 = 3V$

We know, $W_0 = \frac{hc}{\lambda_0}$ $\qquad \lambda_0 = \frac{hc}{W_0}$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{6.72 \times 10^{-19}}$$

$= 2.959 \times 10^{-7}$ m $\qquad \lambda_0 = 2959 \text{ A}^0$.

Also, Maximum kinetic energy of emitted electrons,

$(K.E.)_{max} = eV$

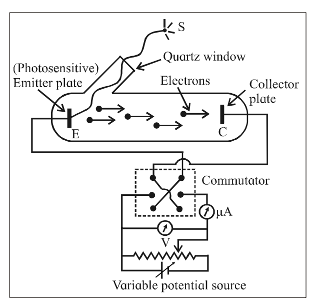
$= 1.6 \times 10^{-19} \times 3 \qquad = 4.8 \times 10^{-19}$ J.

Section (D)

Q.4. Attempt any one question. [4]

1) a. Explain the effect of potential and frequency of light on photoelectric current.

Ans :



Schematic of experimental set-up for photoelectric effect.

Effect of potential on photoelectric

Current - when suitable frequency of light fall on photosensative electrode 'C'. Photoelectrons are emitted, thuse electrons get accelerated towards electrode A which is positive potential w.r. to the electrode 'C' and gives the current called photoelectric current.

For fixed frequency and fixed intensity of light, photoelectric current increases with increases in potential applied to plate 'A'.

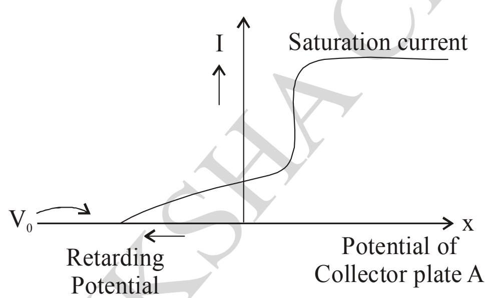
Photoelectric current has maximum value this maximum current is known as saturation current. Saturation current will not increase with increase in positive potential of plate A, the negative potential applied to plate 'A' is increased to a certain value V_0, for which no photo-electrons reach the plate A thus, at this potential, photoelectric current is zero the minimum negative potential (V_0) applied to plate or anode A for which photoelectric current becomes zero is called stopping potential

At this stage, the maximum K.E. $\left(\frac{1}{2}mV_{max}^2\right)$ of photoelectron must be equal to the energy gained by an electron while passing through a potential difference V_0.

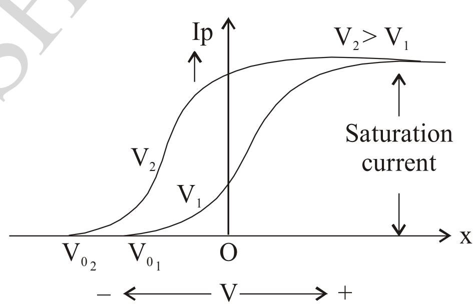
$$(K.E)_{max} = \frac{1}{2}mV_{max}^2 \propto V_0$$

$$\frac{1}{2}mV_{max}^2 = eV_0$$

Thus, the maximum K.E. of a photoelectron can be determined by knowing the value of the stopping potential,



Effect of Frequency :



The intensity of light const but the frequency of light is changed so that the saturation current is exaclty the same.

Now for a given frequency (V_1) of the incident light, positive potential of plate A decreased to zero. Now photoelectric current becomes zero. Let negative potential to plate A current becomes zero and value of negative potential be V_{0_1}.

The experiment repeated with incident light same intensity, but frequency $V_2 > V_1$ Now it is found that stopping potential is higher than V_{0_1}. let it be V_{0_2}.

Thus, the value of stopping potential depend upon frequency of incident light

$$V_0 \propto V (\text{For } V > V_0)$$

The value of saturation current does not depend upon frequency of the incident rediation.

b. Determine planck's constant from a certain metal surface by the light of frequency 2.2 × 10[15] Hz are fully retarded by a reverse potential of 6.6V and those emmited by light of frequency 4.6 × 10[15] Hz are stopped by a reverse potential of 16.5V.

Ans : **Given :** $V_1 = 2.2 \times 10^{15} H_z$

$$V_0 = 6.6V$$

$$V_2 = 4.6 \times 10^{15} H_z$$

$$V = 16.5V$$

$$(K.E.)_{max} = eV_0 = h(v - v_0)$$

By substituting values

$$6.6\ e = h(2.2 \times 10^{15} - v_0) \textbf{.....(i)}$$

$$16.5\ e = h(4.6 \times 10^{15} - v_0) \textbf{.....(ii)}$$

substracting equation (i) from (ii)

$$16.5\ e - 6.6\ e = h$$

$$(4.6 \times 10^{15} - 2.2 \times 10^{15})$$

$$9.9 \times 1.6 \times 10^{-19} = hx\ 2.4 \times 10^{15}$$

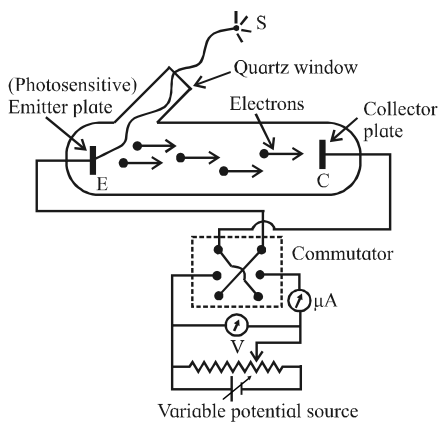
$$h = \frac{9.9 \times 1.6 \times 10^{-19}}{2.4 \times 10^{15}}$$

$$\boxed{\therefore h = 6.6 \times 10^{-34} \text{ J.S}}$$

OR

2) a. Draw schematic diagram of experimental set up for photoelectric effect. Describe the construction of photoelectric Hertz tube.

Ans : a)



Schematic of experimental set-up for photoelectric effect

A typical laboratory experimental set-up for the photoelectric effect (Fig.) consists of an evacuated glass tube with a quartz window containing a photosensitive metal plate - the emitter E and another metal plate - the collector C. The emitter and collector are connected to a voltage source whose voltage can be changed and to an ammeter to measure the current in the circuit. A potential difference of V, as measured by the voltmeter, is maintained between the emitter E (the cathode) and collector C (the anode), normally C being at a positive potential with respect to the emitter. This potential difference can be varied and C can even be at negative potential with respect to E. When the anode potential V is positive, it accelerates the electrons (hence called accelerating potential) while when the anode potential V is negative, it retards the flow of electrons (therefore known as retarding potential). A source S of monochromatic light (light corresponding to only one specific frequency) of sufficiently high frequency (short wavelength . $\leq 10^{-7}$ m) is used.

b. Find the maximum kinetic energy of electrons ejected from a certain material, if the materials workfunction is 2.7 eV and the frequency of the incident radiation is 3.2×10^{15} Hz.

Ans : Given data :

$\phi_0 = W_0 = 2.7 \text{ eV} = 2.7 \times 1.6 \times 10^{-19}$ J

$v = 3.2 \times 10^{15}$ Hz

Solution :

We know,

$$\frac{1}{2} m v_{max}^2 = h\nu - \phi_0$$

$$\therefore \text{K.E.}_{max} = h\nu - \phi_0$$

$$\therefore \text{K.E.}_{max} = 6.63 \times 10^{-31} \times 3.2 \times 10^{15} - 2.7 \times 1.6 \times 10^{-19}$$

$$= 21.21 \times 10^{-19} - 4.32 \times 10^{-19}$$

$$= (21.21 - 4.32) \times 10^{-19}$$

$= 16.89 \times 10^{-19}$ J

$\therefore \text{K.E.}_{max} = 16.89 \times 10^{-19}$ J

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