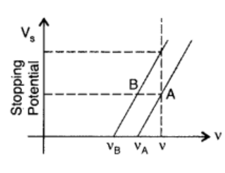
IMPORTANT QUESTIONS CLASS – 12 PHYSICS
CHAPTER – 11 DUAL NATURE OF RADIATION AND MATTER

Question 1.
Write three characteristic features in photoelectric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation. (Delhi 2016)
Answer:
(a) (i) The maximum kinetic energy of the emitted electron should be directly proportional to the intensity of incident radiations but it is not observed experimentally. Also maximum kinetic energy of the emitted electrons should not depend upon incident frequency according to wave theory, but it is not so.
(ii) According to wave theory, threshold frequency should not exist. Light of all frequencies should emit electrons provided intensity of light is sufficient for electrons to eject.
(iii) According to wave theory, photoelectric effect should not be instantaneous. Energy of wave cannot be transferred to a particular electron but will be distributed to all the electrons present in the illuminated portion. Hence, there has to be a time lag between incidence of radiation and emission of electrons.

Question 2.
Sketch the graph showing variation of stopping potential with frequency of incident radiations for two photosensitive materials A and B having threshold frequencies $v_A > v_B$.
(i) In which case is the stopping potential more and why?
(ii) Does the slope of the graph depend on the nature of the material used? Explain. (All India 2016)
Answer:

Graph :



(*i*) For material B, because from the graph for the same value of 'v', stopping potential is more for material 'B' $\left[V_0 = \frac{h}{e}(v - v_0)\right]$

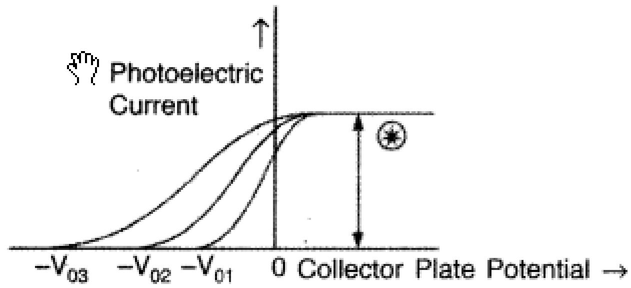
$\therefore$ V_0 is higher for lower value of v_0

(*ii*) No, it does not depend on the nature of material used.

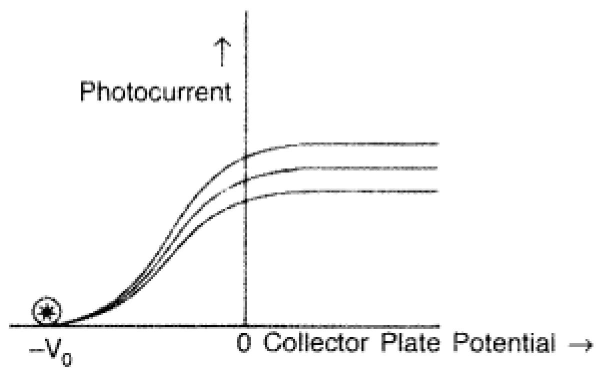
As slope is given by $\frac{h}{e}$ which is constant.

Question 3.
The graphs, drawn here, are for the phenomenon of photoelectric effect.

(i) Identify which of the two characteristics (intensity/frequency) of incident light, is being kept constant in each case.



Graph 1



Graph 2

(ii) **Name the quantity, corresponding to the, ⊛ mark, in each case.**

(iii) Justify the existence of a 'threshold frequency' for a given photosensitive surface. (Comptt. Delhi 2016)

Answer:

(i) (a) In graph 1 : intensity is being kept constant.
(b) In graph 2 : frequency is being kept constant.
(ii) (a) In graph 1 : Saturation current
(b) In graph 2 : Stopping potential.
(iii) For a given photo-sensitive surface electrons need a minimum energy to be emitted, this is called work function of the surface W.
∴ Photons energy hv should be greater/ equal to the work function.

$\therefore\ h\nu \geq W \qquad \text{or } \nu \geq \frac{W}{h}$

$\therefore$ Minimum frequency for photo emission

$$\nu_0 = \frac{W}{h}$$

which is justified to be called as threshold frequency.

Question 4.
Point out two distinct features observed experimentally in photoelectric effect which' cannot be explained on the basis of wave theory of light. State how the 'photon picture' of light provides an explanation of these features. (Comptt. All India 2016)
Answer:
(a) (i) The maximum kinetic energy of the emitted electron should be directly proportional to the intensity of incident radiations but it is not observed experimentally. Also maximum kinetic energy of the emitted electrons should not depend upon incident frequency according to wave theory, but it is not so.
(ii) According to wave theory, threshold frequency should not exist. Light of all frequencies should emit electrons provided intensity of light is sufficient for electrons to eject.
(iii) According to wave theory, photoelectric effect should not be instantaneous. Energy of wave cannot be transferred to a particular electron but will be distributed to all the electrons present in the illuminated portion. Hence, there has to be a time lag between incidence of radiation and emission of electrons.
(b) Basic features of photon picture of electromagnetic radiation :
(i) Radiation behaves as if it is made of particles like photons. Each photon has energy E = hv and momentum p = h/λ.
(ii) Intensity of radiation can be understood in terms of number of photons falling per second on the surface. Photon energy depends only on frequency and is independent of intensity.
(iii) Photoelectric effect can be understood as the result of one to one collision between an electron and a photon.
(iv) When a photon of frequency
(v) is incident on a metal surface, a part of its energy is used in overcoming the work function and other part is used in imparting kinetic energy, so KE = $h(v - v_0)$.

Question 5.
(i) How does one explain the emission of electrons from a photosensitive surface with the help of Einstein's photoelectric equation?
(ii) The work function of the following metals is given : Na = 2.75 eV, K = 2.3 eV, Mo = 4.17 eV and Ni 5.15 eV. Which of these metals will not cause photoelectric emission for radiation of wavelength 3300 A from a laser source placed 1 m away from these metals? What happens if the laser source is brought nearer and placed 50 cm away? (Delhi 2017)

Answer:

(*i*) Einstein's Photoelectric equation is

$$hv = \varphi_0 + K_{max}$$

When a photon of energy 'hv' is incident on the metal, some part of this energy is utilized as work function to eject the electron and remaining energy appears as the kinetic energy of the emitted electron.

(*ii*) $$E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34}) \times (3 \times 10^{8})}{(3.3 \times 10^{-7}) \times (1.6 \times 10^{-19})} \text{ ev}$$

$$= 3.77 \text{ eV}$$

Because the work function of Mo and Ni is more than the energy of the incident photons; so photoelectric emission will not take place from these two metals Mo and Ni. When the laser source is brought nearer and placed 50 cm away, the kinetic energy of photo-electrons will not change, only photoelectric current will change.

Question 6.
In the study of a photoelectric effect the graph between the stopping potential V and frequency v of the incident radiation on two different metals P and Q is shown here:
(i) Which one of the two metals has higher threshold frequency?
(ii) Determine the work function of the metal which has greater value.
(iii) Find the maximum kinetic energy of electron emitted by light of frequency 8×10^{14} Hz for this metal.

Answer:

(*i*) '*Q*' has **higher** threshold frequency.

(*ii*) $$\phi_0 = hv_0 = (6.6 \times 10^{-34}) \times \frac{6 \times 10^{14}}{1.6 \times 10^{-19}} \text{eV}$$

$$= \mathbf{2.5 \text{ eV}}$$

(*iii*) $$K_{max} = h(v - v_0)$$

$$= (6.6 \times 10^{-34}) \left[\frac{(8 \times 10^{14} - 6 \times 10^{14})}{1.6 \times 10^{-19}}\right] \text{eV}$$

$$= (6.6 \times 10^{-34}) \frac{(2 \times 10^{14})}{1.6 \times 10^{-19}} = \mathbf{0.83 \text{ eV}}$$

Question 7.
Explain giving reasons for the following:
(a) Photoelectric current in a photocell increases with the increase in the intensity of the incident radiation.
(b) The stopping potential (V_0) varies linearly with the frequency (v) of the incident radiation for a given photosensitive surface with the slope remaining

the same for different surfaces.
(c) Maximum kinetic energy of the photoelectrons is independent of the intensity of incident radiation.
Answer:
(a) The collision of a photon can cause emission of a photoelectron (above the threshold frequency). As the intensity increases, number of photons increases. Hence, the current increases.

(b) We have, $eV_s = h(v - v_0)$

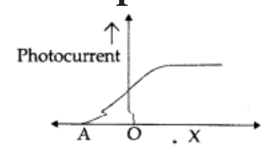
$\therefore \quad V_s = \frac{h}{e}(v) + \left(-\frac{hv_0}{e}\right)$

$\therefore$ Graph of V_s with v is a straight line and slope $\left(\frac{h}{e}\right)$ is a constant.

(c) Since maximum kinetic energy for different surfaces is given by $(K.E.)_{max} = h(v - v_0)$,

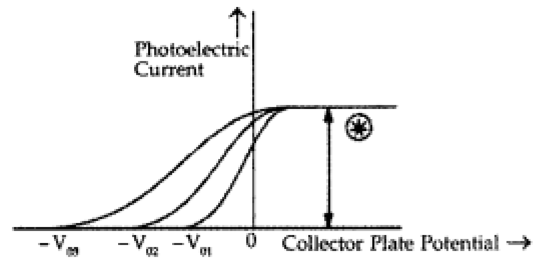
hence, it depends on the frequency and not on the intensity of the incident radiation.

Question 8.
The given graph shows the variation of photocurrent for a photosensitive metal:

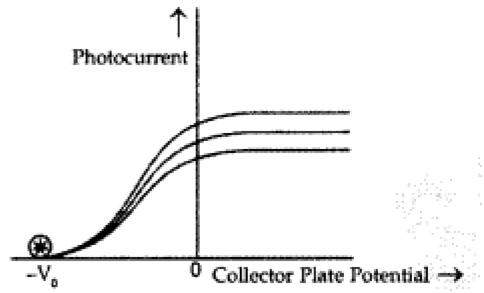


(a) Identify the variable X on the horizontal axis.
(b) What does the point A on the horizontal axis represent?
(c) Draw this graph for three different values of frequencies of incident radiation v_1 v_2 and v_3 ($v_1 > v_2 > v_3$) for same intensity.
(d) Draw this graph for three different values of intensities of incident radiation I_1 I_2 and I_3 ($I_1 > I_2 > I_3$) having same frequency.
Answer:
(a) 'X' is a collector plate potential.
(b) 'A' represents the stopping potential.
(c) Graph for different frequencies :

Question 9.
Draw a graph showing the variation of de Broglie wavelength of a particle of charge q and mass m with the accelerating potential. Proton and deuteron have the same de Broglie wavelengths. Explain which has more kinetic energy.
Answer:

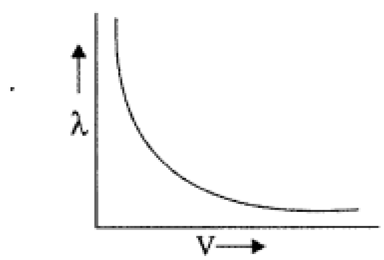


(*d*) Graph for different intensites :



We have, $\lambda = \frac{h}{\sqrt{2mqV}} = \frac{h}{\sqrt{2mK}}$ ($\because$ K = qV = K.E.)

$\because$ Mass of deuteron is more than that of proton,



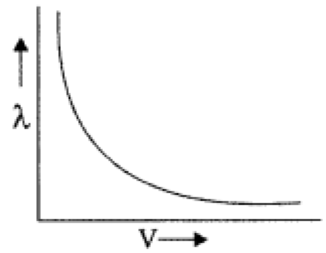
i.e., $m_d > m_p$

$\therefore$ For same λ, we must have $K_p > K_d$ *i.e.*, **the proton has more kinetic energy.**

Question 10.
(a) Draw the graph showing the variation of de Broglie wavelength of a particle of charge q and mass m with the accelerating potential.
(b) An electron and proton have the same de Broglie wavelengths. Explain, which of the two has more kinetic energy.
Answer:
(a) For Graph :

We have, $\lambda = \frac{h}{\sqrt{2mqV}} = \frac{h}{\sqrt{2mK}}$ ($\because$ K = qV = K.E.)

$\because$ Mass of deuteron is more than that of proton,



i.e., $m_d > m_p$

$\therefore$ For same λ, we must have $K_p > K_d$ *i.e.*, **the proton has more kinetic energy.**

(*b*) de Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

$$\left[\because E = \frac{1}{2}mv^2 \text{ or } mv = \sqrt{2mE}\right.$$

Given : $\lambda_e = \lambda_p$, $q_p = q_e$

$$\frac{h}{\sqrt{2m_eE_e}} = \frac{h}{\sqrt{2m_pEp}}$$

$$m_eE_e = m_pE_p$$

$$\frac{E_e}{E_p} = \frac{m_p}{m_e} \text{ or } E \propto \frac{1}{m}$$