

New

SURE SHOT QUESTIONS 2026

Chapter – 11 (Questions)

Dual Nature of Radiation and Matter

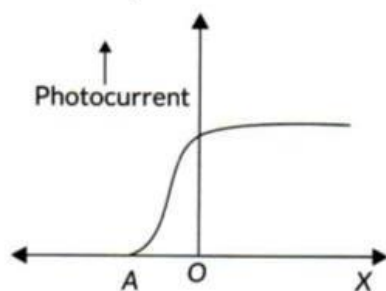
Questions

1. Plot a graph showing the variation of photoelectric current with intensity of light. The work function for the following metals is given.
Na : 2.75 eV and Mo : 4.175 eV.
Which of these will not give photoelectron

emission for a radiation of wavelength 3300 \AA from a laser beam? What happens if the source of laser beam is brought closer?

2. A beam of monochromatic radiation is incident on a photosensitive surface. Answer the following questions giving reasons.
- DO the emitted photoelectrons have the same kinetic energy?
 - Does the kinetic energy of the emitted electrons depend on the intensity of incident radiation?
 - On what factors does the number of emitted photoelectrons depend?

3. The following graph shows the variation of photocurrent for a photosensitive metal:

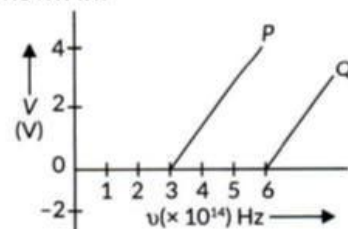


- Identify the variable X on the horizontal axis.
- What does the point A on the horizontal axis represent?
- Draw this graph for three different values of frequencies of incident radiation ν_1, ν_2 and ν_3 ($\nu_1 > \nu_2 > \nu_3$) for same intensity.
- Draw this graph for three different values of intensities of incident radiation I_1, I_2 and I_3 ($I_1 > I_2 > I_3$) having same frequency.

4. (a) Give an example each of a metal from which photoelectric emission takes place when irradiated by (i) UV light, (ii) visible light.
(b) The work function of a metal is 4.50 eV. Find the frequency of light to be used to eject electrons from the metal surface with a maximum kinetic energy of $6.06 \times 10^{-19} \text{ J}$.

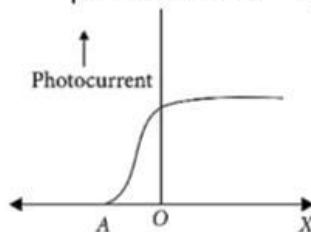
5. (i) State two important features of Einstein's photoelectric equation.
(i) Radiation of frequency 10^{15} Hz is incident on two photosensitive surfaces P and Q. There is no photoemission from surface P. Photoemission occurs from surface Q but photoelectrons have zero kinetic energy. Explain these observations and find the value of work function for surface Q.

6. In the study of a photoelectric effect the graph between the stopping potential V and frequency ν of the incident radiation on two different metals P and Q is shown in:



- Which one of the two metals has higher threshold frequency?
 - Determine the work function of the metal which has greater value.
 - Find the maximum kinetic energy of electron emitted by light of frequency $8 \times 10^{14} \text{ Hz}$ for this metal.
7. In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light?

8. (a) Write the important properties of photons which are used to establish Einstein's photoelectric equation.
(b) Use this equation to explain the concept of (i) Threshold frequency and (ii) stopping potential.
9. Obtain an expression for the ratio of the accelerating potentials required to accelerate a proton and an α -particle to have the same de-Broglie wavelength associated with them.
10. (a) An electron and a proton are accelerated through the same potential. Which one of the two has
(i) Greater value of de-Broglie wavelength associated with it, and
(ii) Lesser momentum?
Justify your answer in each case.
(iii) How is the momentum of a particle related with its de-Broglie wavelength? Show the variation on a graph.
11. Light of wavelength 500 nm is incident on caesium metal (work function 2.14 eV) and photoemission of electrons occurs. Calculate the (i) kinetic energy (in eV) of the fastest electrons and (ii) stopping potential for this situation. (Take $hc = 1240 \text{ eV}\cdot\text{nm}$)
12. A photosensitive surface of work function 2.1 eV is irradiated by radiation of wavelength 150 nm. Calculate (i) the threshold wavelength (ii) energy (in eV) of an incident photon, and (iii) maximum kinetic energy of emitted photoelectron.
13. (i) Monochromatic light of frequency $6.0 \times 10^{14} \text{ Hz}$ is produced by a laser. The power emitted is $2.0 \times 10^{-3} \text{ W}$. Estimate the number of photons emitted per second on an average by the source.
(ii) Draw a plot showing the variation of photoelectric current versus the intensity of incident radiation on a given photosensitive surface.
14. Draw a graph showing variation of photocurrent with the anode potential of a photocell.
15. (a) Define the terms, (i) threshold frequency and (ii) stopping potential in photoelectric effect.
(b) Plot a graph of photocurrent versus anode potential for a radiation of frequency ν and intensities I_1 and I_2 ($I_1 < I_2$)
16. What are matter waves? A proton and an alpha particle are accelerated through the same potential difference. Find the ratio of the de Broglie wavelength associated with the proton to that with the alpha particle.
17. (a) Calculate the energy and momentum of a photon in a monochromatic beam of wavelength 331.5 nm.
(b) How fast should a hydrogen atom travel in order to have the same momentum as that of the photon in part (a)?
18. An α -particle and a proton are accelerated through the same potential difference. Find the ratio of their de Broglie wavelengths.
19. State the main implications of observations obtained from various photoelectric experiments. Can these implications be explained by wave nature of light? Justify your answer.
20. Light of wavelength 2000 \AA falls on a metal surface of work function 4.2 eV.
(a) What is the kinetic energy (in eV) of the fastest electrons emitted from the surface?
(b) What will be the change in the energy of the emitted electrons if the intensity of light with same wavelength is doubled?
(c) If the same light falls on another surface of work function 6.5 eV, what will be the energy of emitted electrons?
21. (a) Explain de-Broglie argument to propose his hypothesis. Show that de-Broglie wavelength of photon equals electromagnetic radiation.
(b) If, deuterons and alpha particle are accelerated through same potential, find the ratio of the associated de-Broglie wavelengths of two.
The following 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 ν_1, ν_2 and ν_3 ($\nu_1 > \nu_2 > \nu_3$) 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.

22. Draw a plot showing the variation of photoelectric current with collector plate potential for two different frequencies, $\nu_1 > \nu_2$, of incident radiation having the same intensity. In which case will be stopping potential be higher? Justify your answer.

23. A proton and an electron have same kinetic energy. Which one has smaller de-Broglie wavelength and why?

24. Define the terms (i) 'Cut-off voltage' and (ii) 'threshold frequency' in relation to the phenomenon of photoelectric effect. Using Einstein's photoelectric equation show how the cut-off voltage and threshold frequency for a give photosensitive material can be determined with the help of a suitable plot/graph.

25. (a) Why photoelectric effect cannot be explained on the basis of wave nature of light? Give reasons.

(b) Write the basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based.

26. A deuteron and an alpha particle are accelerated with the same accelerating potential. Which one of the two has

- (1) greater value of de-Broglie wavelength, associated with it, and
- (2) less kinetic energy? Explain.

27. Plot a graph showing variation of de Broglie wavelength (λ) associated with a charged particle of a mass m , versus $1/\sqrt{V}$, where V is the potential

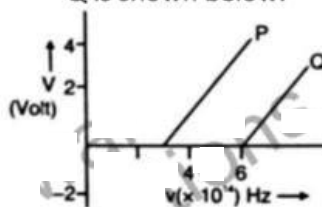
difference through which the particle is accelerated. How does this graph give us the information regarding the magnitude of the charge of the particle?

28. Write Einstein's photoelectric equation. Explain the terms (i) threshold frequency and (ii) stopping potential.

29. The work function (ω) of a metal X, equals 3×10^{-19} J. Calculate the number (N) of photons of light of wavelength 26.52 nm, whose total energy equals ω .

30. A monochromatic source emitting light of wavelength 600 nm has a power output of 66 W. Calculate the number of photons emitted by this source in 2 minutes.

31. In the study of photoelectric effect the graph between the stopping potential V and frequency of the incident radiation on two different metals P and Q is shown below:



- i. Which one of the two metals has higher threshold frequency?
- ii. Determine the work function of the metal. Which has the greater value?
- iii. Find the maximum kinetic energy of the electron emitted by the light of frequency 8×10^{14} Hz for this metal.

32. How did de-Broglie hypothesis lead to Bohr's quantum condition of atomic orbits?

New

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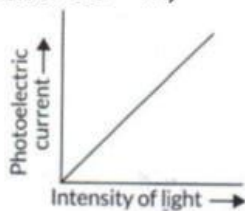
Chapter – 11 (Solutions)

Dual Nature of Radiation and Matter

Solutions

1. Ans. Variation of photoelectric current with intensity of light for a given frequency of incident radiation

Given that $\lambda = 3300 \times 10^{-10} \text{ m}$,



$$\phi_{Na} = 2.75 \text{ eV}, \phi_{Mo} = 4.175 \text{ eV}$$

Then energy of the laser beam is

$$E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3300 \times 10^{-10} \times 1.6 \times 10^{-19}} = 3.75 \text{ eV}$$

Since $E < \phi_{Mo}$ therefore there will be no emission of photoelectrons for molybdenum (Mo). Bringing the source nearer will cause to emit more photoelectrons as intensity on the plate will increase.

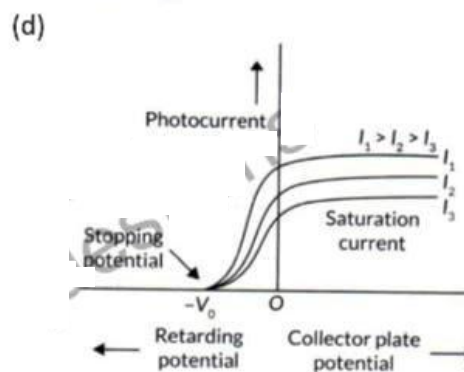
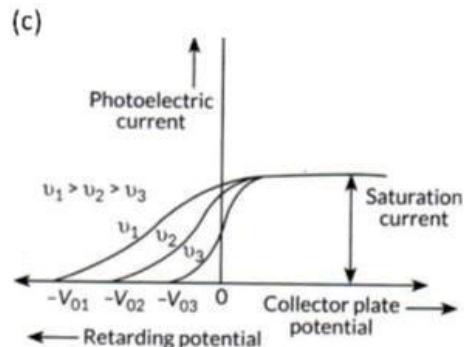
2. Ans. (a) Yes, all emitted photoelectrons have same kinetic energy as the kinetic energy of emitted photoelectrons depends upon frequency of the incident radiation for a given photosensitive surface,

(b) No, the kinetic energy of emitted electrons does not depend on the intensity of incident radiation. If the intensity is increased, number of photons will also increase but energy of each photon remains same as the frequency is also same. The maximum kinetic energy depends on frequency not on intensity,

(c) The number of emitted photoelectrons depends only on intensity of incident light. For a given frequency of incident radiation, its intensity depends on the number of photons.

3. Ans. (a) The variable X on the horizontal axis is collector plate potential.

(b) The point A on the horizontal axis represents stopping potential.



4. Ans. (a) (i) Zinc, cadmium
(ii) Lithium, sodium

(b) Work function of metal, $\phi = 4.50 \text{ eV}$

$$\text{Kinetic energy} = 6.06 \times 10^{-19} \text{ J}$$

$$= \frac{6.06 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV} = 3.78 \text{ eV}$$

$$\text{Now, } K.E. = h\nu - \phi$$

$$\Rightarrow h\nu = K.E. + \phi = 3.78 \text{ eV} + 4.50 \text{ eV} = 8.28 \text{ eV}$$

$$\nu = \frac{8.28 \text{ eV}}{h} = \frac{8.28 \text{ eV}}{4.135 \times 10^{-15} \text{ eVs}}$$

$$= 2.002 \times 10^{15} \text{ Hz}$$

5. Ans. (i) Two features of Einstein's photoelectric equation:

(a) Below threshold frequency ν_0 corresponding to W_0 , no emission of photoelectrons takes place.

(b) As the number of photons in light depend on its intensity, and one photon liberates one photoelectron. So number of emitted photoelectrons depends only on the intensity of incident light for a given frequency.

(ii) Below threshold frequency no emission takes place. As there is no photoemission from surface P i.e., the frequency of incident radiation is less than the threshold frequency for surface P.

From surface Q photoemission is possible i.e., the frequency of incident radiation is equal or greater than threshold frequency. As the kinetic energy of photo electrons is zero i.e., the energy of incident radiation is just sufficient to pull out the electron from the surface Q.

Work function for surface Q, $W_Q = h\nu$.

As $K.E. > 0$; $\nu = \nu_0 = 10^{15} \text{ Hz}$

$$W_Q = 6.6 \times 10^{-34} \times 10^{15} = 6.6 \times 10^{-19} \text{ J} = 4.125 \text{ eV}$$

6. Ans. (i) For P, threshold frequency

$$\nu_p = 3 \times 10^{14} \text{ Hz}$$

For Q, threshold frequency $\nu_Q = 6 \times 10^{14} \text{ Hz}$

So, metal Q has higher threshold frequency.

(ii) Work function for Q <

$$W_Q = h\nu_Q = 6.6 \times 10^{-34} \times 6 \times 10^{14}$$

$$= 39.6 \times 10^{-20} \text{ J} = 2.47 \text{ eV}$$

(i) The maximum kinetic energy, of electron emitted by light of frequency $8 \times 10^{14} \text{ Hz}$ is,

$$\begin{aligned} \therefore K_{\text{max}} &= h(\nu - \nu_0) \\ &= 6.6 \times 10^{-34} (8 \times 10^{14} - 6 \times 10^{14}) \\ &= 13.2 \times 10^{-20} \text{ J} = 0.825 \text{ eV} \end{aligned}$$

7. Ans. For a given frequency, intensity of light in the photon picture is determined by

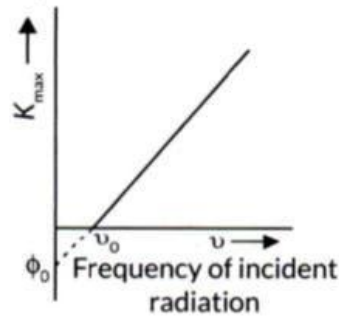
$$I = \frac{\text{Energy of photons}}{\text{area} \times \text{time}} = \frac{n \times h\nu}{A \times t}$$

Where n is the number of photons incident normally on crossing area A in time t.

8. Ans. (a) The main features of photons are as follows:

(i) In the interaction of photons with free electrons, the entire energy of photon is absorbed.

(ii) Energy of photon is directly proportional to frequency. Intensity of incident radiation depends on the number of photons falling per unit area per unit time for a given frequency.



(iii) In photon electron collision, the total energy and momentum remain constant.

Einstein's photoelectric equation is

$$K_{\text{max}} = h\nu - \phi_0$$

(b) Einstein's photoelectric equation : According to Einstein, when light is incident on metal surface, incident photons are absorbed completely by valence electrons of atoms of metal on its surface. Energy $h\nu$ of each photon is partially utilized by an electron to become free or to overcome its "work function" W_0 and rest of the absorbed energy provides the maximum kinetic energy to the photoelectron during the emission. i.e.,

$$h\nu = \frac{1}{2} m v_{\text{max}}^2 + W_0$$

The minimum value of the frequency of incident radiation below which the photoelectric emission stops i.e., kinetic energy of photoelectron is zero is called threshold frequency (ν_0).

$$\text{Threshold frequency, } \nu_0 = \frac{W}{h}$$

$$\frac{1}{2} m v_{\text{max}}^2 = K.E._{\text{max}} = h\nu - W_0$$

$$\text{or, } K.E._{\text{max}} = eV_0$$

When work done by collecting electrode potential on a photoelectron is equal to its maximum kinetic energy then the electrode potential is known as stopping potential.

$$\text{Stopping potential, } V_0 = \frac{K.E._{\text{max}}}{e}$$

9. Ans. De-Broglie wavelength of a particle of mass m and charge q accelerating through a potential V is given by

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}} \quad \dots\dots\dots(i)$$

Here,

$$m_p = m, q_p = e, m_e = 4m_p = 4m, q_e = 2q_p = 2e$$

From eqn. (i)

$$\therefore \frac{\lambda_p}{\lambda_e} = \sqrt{\frac{m_e q_e V_e}{m_p q_p V_p}}; 1 = \sqrt{\frac{4m \times 2e \times V_e}{m \times e \times V_p}}$$

$$(\because \lambda_p = \lambda_e)$$

$$\therefore \frac{V_p}{V_e} = \frac{8}{1}; V_p : V_e = 8:1$$

10. Ans. (a) (i) For same accelerating potential, a proton and an electron have same kinetic energy. The de-Broglie wavelength associated with same potential V is given by,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2m(qV)}}$$

$$\text{So, } \lambda = \frac{1}{\sqrt{m}}$$

As electron's mass is lesser than proton. Thus $\lambda_e > \lambda_p$

(ii) Momentum, $p = \sqrt{2mK}$ or $p \propto \sqrt{m}$

As electron's mass is lesser than proton. Thus momentum of electron is lesser than proton.

(b) De-Broglie wavelength of a particle

$$\lambda = \frac{h}{p} \text{ or } \lambda p = h = \text{constant}$$

It shows a rectangular hyperbola!

11. Ans. Given, incident wavelength, $\lambda_c = 500 \text{ nm}$
 $= 500 \times 10^{-9} \text{ m}$

Work function, $\phi = 2.14 \text{ eV}$

$$\text{Energy of incident photon} = \frac{hc}{\lambda_c} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{500 \times 10^{-9}}$$

$$E = 2.475 \text{ eV}$$

(i) By Einstein's equation,

$$\text{Kinetic energy of electron} = \text{Incident Energy} - \text{Work function}$$

$$= (2.475 - 2.14) \text{ eV} = 0.335 \text{ eV}$$

(ii) Kinetic energy, $K_{\max} = eV_0$, where V_0 is the stopping potential

$$V_0 = 0.335 \text{ V}$$

12. Ans. Given that, $\phi = 2.1 \text{ eV}$ and $\lambda = 150 \text{ nm}$.

(i) The threshold wavelength is, $\phi = \frac{hc}{\lambda_0}$

$$\lambda_0 = \frac{hc}{\phi} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2.1 \times 1.6 \times 10^{-19}}$$

$$\lambda_0 = 5.892 \times 10^{-7} \text{ m}$$

$$\lambda_0 = 589.2 \text{ nm}$$

(ii) Energy of an incident photon, $E = h\nu$

$$\text{or } E = \frac{hc}{\lambda}$$

$$\therefore E = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{150 \times 10^{-9}} \text{ J}$$

$$E = 0.132 \times 10^{-17} \text{ J} \quad (\because 1 \text{ eV} = 1.6 \times 10^{-19} \text{ J})$$

$$E = 0.0825 \times 10^2 \text{ eV}$$

$$E = 8.25 \text{ eV}$$

(iii) Maximum kinetic energy of emitted photoelectrons

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

$$= 6.6 \times 10^{-34} \left(\frac{c}{\lambda} - \frac{c}{\lambda_0} \right)$$

$$= 6.6 \times 10^{-34} (2 \times 10^{15} - 0.51 \times 10^{15})$$

$$= 6.6 \times 10^{-34} \times 1.49 \times 10^{15}$$

$$= 9.834 \times 10^{-19} \text{ J}$$

$$= 6.146 \text{ eV} \quad (\because 1 \text{ eV} = 1.6 \times 10^{-19} \text{ J})$$

13. Ans. (i) Given, $\nu = 6.0 \times 10^{14} \text{ Hz}$

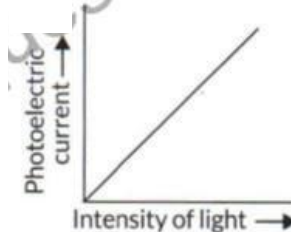
$$P = 2.0 \times 10^{-3} \text{ W}$$

Let n is the number of photons emitted by the source per second.

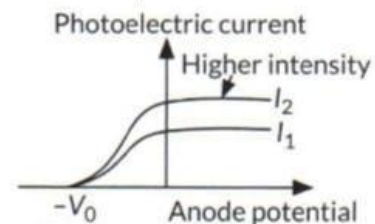
$$n = \frac{P}{E} = \frac{P}{h\nu} = \frac{2 \times 10^{-3}}{6.63 \times 10^{-34} \times 6.0 \times 10^{14}}$$

$$= 0.0502 \times 10^{17} = 5 \times 10^{15} \text{ photons per second.}$$

(ii)



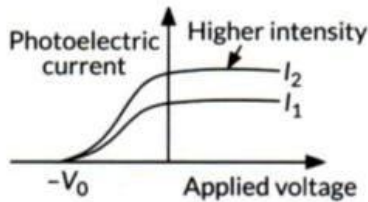
14. Ans. For a given frequency, Photoelectric current varies with anode potential is as shown in graph.



15. Ans. (a) (i) Threshold Frequency: The minimum frequency of incident light which is just capable of ejecting electrons from a metal is called the threshold frequency. It is denoted by ν_0 .

(ii) Stopping Potential: The minimum retarding potential applied to anode of a photoelectric tube which is just capable of stopping photoelectric current is called the stopping potential. It is denoted by V_0 (or V_s).

(b)



16. Ans. According to Louis de-Broglie, wave is associated with every moving particle. These are called matter waves.

∴ de-Broglie wavelength of a charged particle accelerated through a potential difference V is

$$\text{given by, } \lambda = \frac{h}{\sqrt{2mqV}}$$

∴ For proton and α particle charges are q and $2q$ respectively,

$$\therefore \lambda_p = \frac{h}{\sqrt{2m_p qV}} \dots\dots\dots(i)$$

$$\lambda_\alpha = \frac{h}{\sqrt{4m_\alpha qV}} \dots\dots\dots(ii)$$

From eqn. (i) and (ii)

$$\therefore \frac{\lambda_p}{\lambda_\alpha} = \left(\frac{4m_\alpha}{2m_p}\right)^{1/2} = 2\sqrt{2} \quad (\text{As } m_\alpha = 4m_p)$$

17. Ans. (a) Wavelength, $\lambda = 331.5 \text{ nm}$

$$\text{Energy, } E = \frac{hc}{\lambda} = \frac{1240 \text{ nm-eV}}{331.5 \text{ nm}} = 3.74 \text{ eV}$$

Momentum,

$$p = \frac{E}{c} = \frac{3.74 \times 1.6 \times 10^{-19}}{3 \times 10^8} = 2 \times 10^{-27} \text{ kg ms}^{-1}$$

(b) For hydrogen atom, momentum,

$$p = 2 \times 10^{-27} \text{ kg ms}^{-1}$$

$$\text{Speed, } v = \frac{p}{m} = \frac{2 \times 10^{-27}}{1.6 \times 10^{-27}} = 1.24 \text{ ms}^{-1}$$

18. Ans. De-Broglie wavelength of a charged particle accelerated through a potential difference V is given by,

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

∴ For proton and α particle charges are q and $2q$ respectively,

$$\therefore \lambda_p = \frac{h}{\sqrt{2m_p qV}} \dots\dots\dots(i)$$

$$\lambda_\alpha = \frac{h}{\sqrt{4m_\alpha qV}} \dots\dots\dots(ii)$$

From eqn (i) and (ii)

$$\therefore \frac{\lambda_\alpha}{\lambda_p} = \left(\frac{2m_p}{4m_\alpha}\right)^{1/2} = \frac{1}{2\sqrt{2}}$$

19. Ans. Main implications:

- (i) Kinetic energy of emitted electrons depends upon frequency, but not on intensity of radiation.
- (ii) There exist a frequency of radiation below which no photoemission takes place, how high intensity of radiation may be known as threshold frequency.

Explanation of wave nature of radiation fails to explain photoelectric effect.

According to wave theory, when light falls on a metal surface, energy is continuously distributed over the surface. All electrons may be ejected only when it acquires energy more than the work function. So, if we use low intensity source, it should take hours for photoelectric emission, but photoelectric effect is almost a spontaneous process.

20. Ans. Given, $\lambda = 2000 \text{ \AA} = 2000 \times 10^{-10} \text{ m}$

$$W_0 = 4.2 \text{ eV}$$

$$h = 6.63 \times 10^{-34} \text{ J s}$$

$$\frac{hc}{\lambda} = W_0 + K.E. \text{ or } K.E. = \frac{hc}{\lambda} - W_0$$

$$= \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{(2000 \times 10^{-10})} \times \frac{1}{1.6 \times 10^{-19}} \text{ eV} - 4.2 \text{ eV}$$

$$= (6.2 - 4.2) \text{ eV} = 2.0 \text{ eV}$$

(b) The energy of the emitted electrons does not depend upon intensity of incident light, hence the energy remains unchanged.

For this surface, electrons will not be emitted as the energy of incident light (6.2 eV) is less than the work function (6.5 eV) of the surface.

21. Ans. (a) De-broglie reasoned out that nature was symmetrical and two basic physical entities – mass and radiation must be symmetrical. If radiation shows dual aspect than matter should do so.

$$\text{De-broglie equation, } \lambda = \frac{h}{p}$$

$$\text{For photon, } p = \frac{h\nu}{c}$$

Therefore, $\frac{h}{p} = \frac{c}{\nu} = \lambda$, wavelength of electromagnetic radiation.

$$(b) \text{ As } \lambda = \frac{h}{\sqrt{2mK}}$$

So, alpha particle will be having shortest De-Broglie wavelength compared to deuterons.

$$\frac{\lambda_d}{\lambda_\alpha} = \frac{\sqrt{m_\alpha q_\alpha V}}{\sqrt{m_d q_d V}} = \sqrt{\frac{2m_\alpha \times 2q_d}{m_d q_d}} \quad (m_\alpha = 2m_d, q_\alpha = 2q_d)$$

$$\frac{\lambda_d}{\lambda_\alpha} = \frac{2}{1} \Rightarrow \lambda_d : \lambda_\alpha = 2 : 1$$

22. Soln. $\lambda_{pr} = \frac{h}{m_p v}$ de-Broglie wavelength of proton

$$\lambda_{ph} = \frac{hc}{E}, \quad (\because E_{ph} = \frac{hc}{\lambda})$$

(de - Broglie wavelength of photon)

$$KE_{proton} = \frac{1}{2} m_p v^2$$

$$\Rightarrow \lambda_{pr} = \lambda_{ph}$$

Hence,
$$\frac{hc}{E} = \frac{h}{m_p v}$$

$$v = \frac{h}{m_p} \cdot \frac{E}{hc} = \frac{E}{m_p c}$$

$$K.E. = \frac{1}{2} \cdot \frac{E}{m_p c} \cdot \frac{E}{m_p c} m_p$$

$$= \frac{1}{2} \cdot \frac{E \cdot E}{m_p c \cdot c}$$

$$= \frac{1}{2} \cdot \frac{E}{m_p} \cdot \frac{hc}{\lambda c}$$

$$K.E. = \frac{1}{2} \frac{E}{m_p} \cdot \frac{h}{c\lambda}$$

$$K.E. \left(\frac{2m_p c \lambda}{h} \right) = E$$

$$K.E. \left(\frac{2mc\lambda}{h} \right) = E$$

23. Soln. de Broglie postulated that the material particles may exhibit wave aspect. Accordingly a moving material particle behaves as wave and the wavelength associated with material particle is

$$\lambda = \frac{h}{mv}$$

Where h = Planck's constant

m = mass of the object

v = velocity of the object

24. Soln. In terms of kinetic energy, wavelength is given by

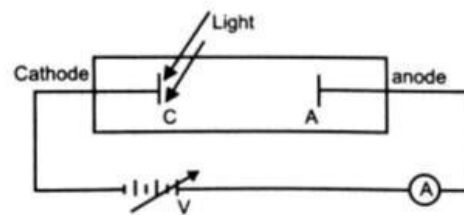
$$\lambda = \frac{h}{\sqrt{2mE_k}}$$

$$\Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$$

So wavelength is inversely proportional to \sqrt{m} , i.e., more the mass, less the wavelength and vice-versa.

So, for same kinetic energy, as a proton has a larger mass than an electron, thus a proton has smaller de-Broglie wavelength than a electron.

25. Soln. When light of suitable frequency is incident on a metal surface, electrons are ejected from the metal. This phenomenon is called the photoelectric effect.



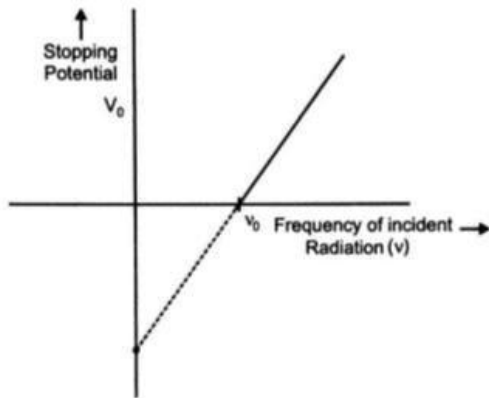
(i) The cathode is illuminated with light of some fixed frequency ν and fixed intensity I_1 . A small photoelectric current is observed due to few electrons that reach anode just because they have sufficiently large velocity of emission. If we make the potential of the anode negative with respect to cathode then the electrons emitted by cathode are repelled. Some electrons even go back to the cathode so that the current decreases. At a certain value of this negative potential, the current is completely stopped. The least value of this anode potential which just stops the photocurrent is called cut off potential or stopping potential.

(ii) For a given material, there is a certain minimum frequency that if the incident radiation has a frequency below this threshold, no photoelectric emission will take place, howsoever intense the radiation may be falling. This minimum frequency is called threshold frequency.

According to Einstein's photoelectric equation, maximum K.E. is given as

$$K.E._{\text{max}} = \frac{hc}{\lambda} - \phi = h\nu - \phi$$

Where λ is wavelength of light and ν is corresponding frequency and ϕ is work function. We expose a material to lights of various frequencies and thus photoelectric current is observed and cut off potential needed to reduce this current to zero is noted. A graph is plotted and that is straight line.



According to Einstein's photoelectric equation

$$K.E._{\max} = \frac{hc}{\lambda} - \phi = h\nu - \phi$$

$$K.E._{\max} = eV_0$$

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

$$V_0 = \left(\frac{h}{e}\right)\nu - \frac{\phi}{e} \dots\dots(i)$$

We can read the value of threshold frequency from graph.

From equation (i), we can find the value of stopping potential (V_0).

26. Soln. (a) Wave nature of radiation cannot explain the following:

1. The immediate ejection of photoelectrons.
2. The presence of threshold frequency for a metal surface.
3. The fact that kinetic energy of the emitted electrons is independent of the intensity of light and depends upon its frequency.

Thus, the photoelectric effect cannot be explained on the basis of wave nature of light.

(b) Photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based on particle nature of light.

Its basic features are:

1. In interaction with matter, radiation behaves as if it is made up of particles called photons.
2. Each photon has energy ($E=h\nu$). Momentum $\left(p = \frac{h\nu}{c}\right)$, where c is the speed of light.
3. All photons of light of a particle frequency ν , or wavelength λ , have the same energy $\left(E = h\nu = \frac{hc}{\lambda}\right)$ and momentum $\left(p = \frac{h\nu}{c}\right)$
4. By increasing the intensity of light of given wavelength, there is only an increase in the number of photons emitted per second crossing a given area, with each

photon having the same energy. Thus, photon energy is independent of intensity of radiation.

5. Photons are electrically neutral and are not deflected by electric and magnetic fields.
6. In a photon - particle collision (such as photon electron collision), the total energy and total momentum are conserved. However, number of photons may not be observed.

27. Ans. dependent on its mass and charge for same accelerating potential, such that

$$\lambda \propto \frac{1}{\sqrt{(\text{Mass})(\text{Charge})}}$$

Mass and charge of a deuteron are $2m_p$ and e respectively and mass and charge of an alpha particle are $4m_p$ and $2e$ respectively.

Where,

m_p = the mass of a proton.

And e = the charge of an electron.

$$\frac{\lambda_D}{\lambda_\alpha} = \frac{\sqrt{m_\alpha q_\alpha}}{\sqrt{m_D q_D}} = \frac{\sqrt{(4m_p)(2e)}}{\sqrt{(2m_p)(e)}} = \frac{2}{1}$$

Thus, de-Broglie wavelength related with deuteron is twice of the de-Broglie wavelength of alpha particle.

$$(2) \quad K.E. \propto q$$

(for same accelerating potential)

Charge of a deuteron is less as compared to an alpha particle. So, deuteron will have less kinetic energy.

28. Soln.

Since,
$$\lambda = \frac{h}{\sqrt{2meV}}$$

i.e.,
$$\lambda \propto \frac{1}{\sqrt{e}}$$

Therefore, more the wavelength lesser is the charge.

29. Soln. (i) Einstein's photoelectric equation, K.E. of photoelectron = Incident energy of photons - Work function

Or
$$K.E. = h\nu - \phi_0$$

Or
$$K.E. = h\nu - h\nu_0$$

Where, ν_0 is called threshold frequency.

Threshold Frequency: For a given metal, there exists a certain minimum frequency of the incident radiation below which no emission of photoelectrons takes place. This frequency is called threshold frequency. It is denoted by ν_0 .

(ii) **Stopping Potential:** It is that minimum negative potential given to anode in a photocells for which the photoelectric current becomes zero. It is denoted by V_0 . It is independent of the intensity of the incident light.

30. Soln. The work function of a metal is the minimum energy by it to eject an electron. It is given for metal $X = 3 \times 10^{-19} \text{ J}$

Energy of a photon of wavelength $26.52 \text{ nm} = h\nu$

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

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{26.52 \times 10^{-9}}$$

$$= 0.746 \times 10^{-17} \text{ J}$$

If number of photons = n ; for total energy $3 \times 10^{-19} \text{ J}$.
Then,

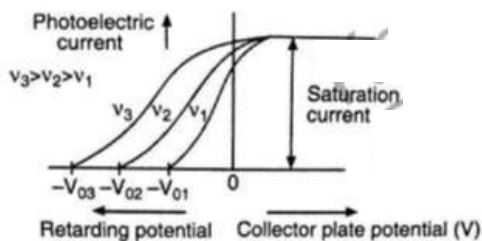
$$n \times 0.746 \times 10^{-17} = 3 \times 10^{-19}$$

Hence,

$$n = \frac{3 \times 10^{-19}}{0.746 \times 10^{-17}}$$

$$= 4.021 \times 10^{-2}$$

31. Soln. (i)



(ii) According to Einstein's photoelectric equation

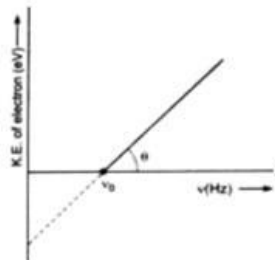
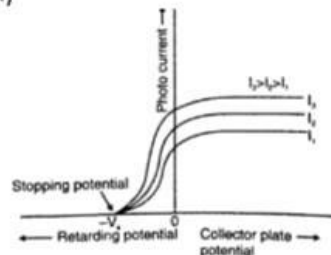
$$K_{\max} = h\nu - \phi_0$$

If V_0 is stopping potential then

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

Thus, for different values of frequency (ν) there will be different values of cut off potential V_0 .

(iii)



32. Soln. (i) de Broglie wavelength

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$$

For same V , $\lambda \propto \frac{1}{\sqrt{mq}}$

$$\therefore \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}} = \sqrt{\frac{4m_p \cdot 2e}{m_p \cdot e}}$$

$$= \sqrt{8} = 2\sqrt{2}$$

Clearly, $\lambda_p > \lambda_\alpha$.

Hence, proton has a greater de-Broglie wavelength.

(ii) Kinetic energy, $K = qV$

For same V , $K \propto q$

$$\frac{K_p}{K_\alpha} = \frac{q_p}{q_\alpha} = \frac{e}{2e} = \frac{1}{2}$$

Clearly, $K_p < K_\alpha$.

Hence, proton has less kinetic energy.