Blue Print (As per PU Board)

Topic	1 mark questions	2 marks questions	3 marks questions	5 marks questions	Total Marks
Dual Nature of Radiation and Matter	2	–	1	1	10

One mark questions

1. **Define eV. What is the value of 1eV in joules?**
   Answer: The energy acquired by an electron when it is accelerated through a p.d of 1volt is called 1eV .
2. **Define 'Threshold frequency' and 'Threshold wavelength' of a photoelectric material.**
   Answer: The minimum frequency of the incident radiation, above which only, photoelectric effect takes place is called threshold frequency. It is characteristic of the particular photoelectric material.
   The maximum wavelength below which only photoelectric effect takes place is called threshold wavelength. It is characteristic of the particular photoelectric material.
3. **Define photoelectric work function. Why alkali metals are preferred for photoelectric emission?**
   Answer: The photoelectric work function of a metal is defined as the minimum energy that must be given to a metal in order that photoelectric effect takes place. Alkali metals are preferred for photoelectric effect since they have a low work function.
4. **Give a formula for the energy of a photon in terms of (i) frequency and (ii) wavelength**
   Answer: (i) $E = h\nu$ where $h =$ Planck's constant $c =$ speed of light in vacuum

   (ii) $E = \frac{hc}{\lambda}$ $\lambda =$ Wavelength of photon, $\nu =$ Frequency of photon

Two marks questions

5. **Calculate the energy** $(\text{in } e\text{V})$ **of**

   (a) A photon of frequency 4×10^{15} Hz

   (b) A photon of wavelength 800Å

   Answer:

   (a) $E = h\nu$

   $= 6.625\times10^{-34}\times4\times10^{15}$

   $= 26.500\times10^{-19} J$

   $= \frac{26.5\times10^{-19}}{1.6\times10^{-19}} = 16.56 e\text{V}$ (1 mark)

   (b) $E = \frac{hc}{\lambda}$

   $= \frac{6.625\times10^{-34}\times3\times10^{8}}{8\times10^{-8}}$

   $= 2.48\times10^{-18} J$

   $= 24.8\times10^{-19} J$

   $= \frac{24.8\times10^{-19}}{1.6\times10^{-19}}$

   $= 15.5 e\text{V}$

   (1 mark)

6. **Explain the variation of maximum kinetic energy of electrons liberated as a function of the frequency of incident radiation.**

Answer:
A graph of maximum kinetic energy of the emitted photoelectrons against frequency of incident radiation gives a straight line. Photoelectric effect starts only when the frequency of the incident radiation $\nu > \nu_o$. When ν is increased beyond ν_o, max K.E also increases. For different metals we get different straight

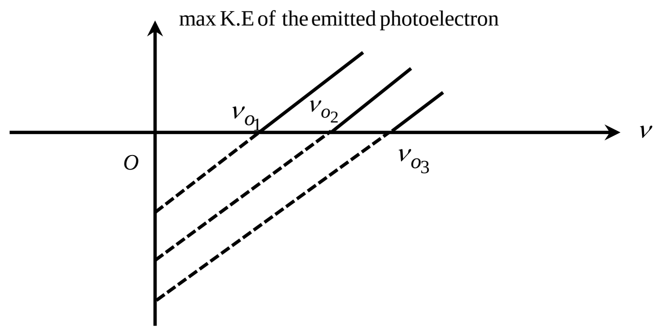


fig.
(1 mark)
lines which are parallel to each other. i.e they have a constant slope = h (Planck's constant).
y – Intercept gives the work function of the metal. (1 mark)

7. **Explain the variation of photoelectric current with the intensity of incident radiation.**
Answer: For frequencies of incident radiation beyond the threshold frequency photoelectric current is directly proportional to the intensity of incident radiation. (1 mark)

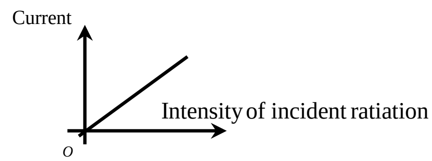


fig. (1 mark)

8. **Calculate the number of photons emitted by a $60\,\text{W}$ bulb in 1 second if the wavelength of photons emitted is $500\,\text{nm}$**
Answer: $60\,\text{W}$ bulb emits $60\,\text{J}$ of energy in 1s.

$$E = \frac{nhc}{\lambda}$$ (1 mark)

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

$$= \frac{60 \times 5 \times 10^{-7}}{6.625 \times 10^{-34} \times 3 \times 10^{8}}$$

$$= \frac{1}{6.625} \times \frac{10^{-7}}{10^{-26}}$$

$$= 0.151 \times 10^{19}$$

$$= 1.51 \times 10^{18}$$ (1 mark)

Three marks questions

9. **Using Einstein's photoelectric equation, explain the experimentally observed facts of photoelectric effect.**
Answer: According to Einstein's photoelectric equation

$$\frac{1}{2}mv^2 = h\left(\nu - \nu_o\right)$$

When $\nu < \nu_o$, $\frac{1}{2}mv^2$ is negative

$\left(\frac{1}{2}mv^2\right)$ i,e kinetic energy can never be negative.

Hence no photoelectric effect takes place when the frequency of the incident radiation is less than the threshold frequency. (1 mark)

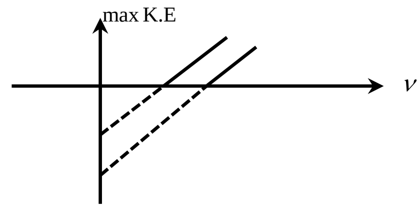
When $\nu = \nu_o$, $\frac{1}{2}mv^2 = 0$

The liberated photoelectrons will have no kinetic energy when the frequency of the incident radiation is equal to the threshold frequency. The electrons are liberated, but they cannot move.

When $\nu > \nu_o, \quad \frac{1}{2}mv^2 > 0$

The liberated photoelectrons will have no kinetic energy when the frequency of the incident radiation is greater than the threshold frequency. As the frequency of the incident radiation is increased beyond the threshold frequency, the K.E of the photoelectrons increases.

$\frac{1}{2}mv^2 = h\nu - h\nu_o$ (1 mark)



If we draw a graph of $\frac{1}{2}mv^2$ against ν, we get a straight line. The slope of this give $h =$ Planck's constant. The $y-$intercept gives the work function.

According to Planck's quantum theory, the intensity of radiation is directly proportional to the number of photons. So when the intensity is increased, the number of photons increases. So there will be more number of collisions. Hence the number of photoelectrons increases. So photoelectric current increases. (1 mark)

10. Derive an expression for deBroglie wavelength.

Answer: Consider a photon having wavelength λ

$E = \frac{hc}{\lambda}$ …(1)

According to Einstein's mass – energy equivalence relation,

$E = mc^2$ …(2) (1 mark)

From (1) and (2)

$\frac{hc}{\lambda} = mc^2$

$\therefore \lambda = \frac{h}{mc}$ (1 mark)

$mc =$ momentum of the photon $= p$

$\therefore \lambda = \frac{h}{p}$ …(3)

If this formula is applied in the case of matter waves, we have to replace $'p'$ by the momentum of a material particle moving with velocity v.

Then $p = mv$

$\therefore \lambda = \frac{h}{mv}$ (1 mark)

11. Show that the deBroglie wavelength of an electron subjected to an electric field of voltage V is given by $\lambda = \frac{12.27}{\sqrt{V}}$ Å

Answer: $\lambda = \frac{h}{\sqrt{2mqV}}$ (1 mark)

Put $m =$ mass of the electron $= 9.1\times10^{-31} kg$

$q =$ charge of the electron $= 1.6\times10^{-19} C$

$\therefore \lambda = \frac{6.625\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times1.6\times10^{-19}\times V}}$ (1 mark)

$$=\frac{6.625\times10^{-34}}{\sqrt{29.12\times10^{-50}V}}$$

$$=\frac{6.625}{5.396}\times\frac{10^{-9}}{\sqrt{V}}m$$

$$=\frac{1.227}{\sqrt{V}}\times10^{-9}m$$

$$=\frac{1.227}{\sqrt{V}}nm \quad \text{or} \quad \frac{12.27}{\sqrt{V}}\text{Å}$$ (1 mark)

12. The work function of caesium metal is $2.14\,\text{eV}$. When light of frequency 6×10^{4} Hz is incident on the metal surface, photo emission of electrons occurs. Find

(a) Energy of the incident photon

(b) Maximum kinetic energy of photoelectrons

Given Planck's constant $= h = 6.63\times10^{-34}\,Js$

$1\text{eV}=1.6\times10^{-19}J$

Answer:

(a) $E = h\nu$ (1 mark)

$= 6.625\times10^{-34}\times6\times10^{14}$

$= 39.750\times10^{-20}J$

$= 3.975\times10^{-19}J$

$$=\frac{3.975\times10^{-19}}{1.6\times10^{-19}} = 2.484\,\text{eV}$$ (1 mark)

(b) $E = W + \frac{1}{2}mv^2$

$\frac{1}{2}mv^2 = E - W \quad = 2.484 - 2.14 \quad = 0.344\,\text{eV}$ (1 mark)