

PHOTO ELECTRIC EFFECT AND WAVE PARTICLE QUALITY CHAPTER 42

1. $\lambda_1 = 400 \text{ nm}$ to $\lambda_2 = 780 \text{ nm}$

$$E = h\nu = \frac{hc}{\lambda} \quad h = 6.63 \times 10^{-34} \text{ J-s}, c = 3 \times 10^8 \text{ m/s}, \lambda_1 = 400 \text{ nm}, \lambda_2 = 780 \text{ nm}$$

$$E_1 = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{400 \times 10^{-9}} = \frac{6.63 \times 3}{4} \times 10^{-19} = 5 \times 10^{-19} \text{ J}$$

$$E_2 = \frac{6.63 \times 3}{7.8} \times 10^{-19} = 2.55 \times 10^{-19} \text{ J}$$

So, the range is $5 \times 10^{-19} \text{ J}$ to $2.55 \times 10^{-19} \text{ J}$.

2. $\lambda = h/p$

$$\Rightarrow P = h/\lambda = \frac{6.63 \times 10^{-34}}{500 \times 10^{-9}} \text{ J-S} = 1.326 \times 10^{-27} = 1.33 \times 10^{-27} \text{ kg-m/s.}$$

3. $\lambda_1 = 500 \text{ nm} = 500 \times 10^{-9} \text{ m}$, $\lambda_2 = 700 \text{ nm} = 700 \times 10^{-9} \text{ m}$

$$E_1 - E_2 = \text{Energy absorbed by the atom in the process.} = hc [1/\lambda_1 - 1/\lambda_2]$$

$$\Rightarrow 6.63 \times 3 [1/5 - 1/7] \times 10^{-19} = 1.136 \times 10^{-19} \text{ J}$$

4. $P = 10 \text{ W}$ \therefore E in 1 sec = 10 J % used to convert into photon = 60%

\therefore Energy used = 6 J

$$\text{Energy used to take out 1 photon} = hc/\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{590 \times 10^{-9}} = \frac{6.633}{590} \times 10^{-17}$$

$$\text{No. of photons used} = \frac{6}{\frac{6.63 \times 3}{590} \times 10^{-17}} = \frac{6 \times 590}{6.63 \times 3} \times 10^{17} = 176.9 \times 10^{17} = 1.77 \times 10^{19}$$

5. a) Here intensity = $I = 1.4 \times 10^3 \text{ W/m}^2$ Intensity, $I = \frac{\text{power}}{\text{area}} = 1.4 \times 10^3 \text{ W/m}^2$

Let no. of photons/sec emitted = n

$$\therefore \text{Power} = \text{Energy emitted/sec} = nhc/\lambda = P$$

$$\text{No. of photons/m}^2 = nhc/\lambda = \text{intensity}$$

$$n = \frac{\text{intensity} \times \lambda}{hc} = \frac{1.9 \times 10^3 \times 5 \times 10^{-9}}{6.63 \times 10^{-34} \times 3 \times 10^8} = 3.5 \times 10^{21}$$

- b) Consider no. of two parts at a distance r and $r + dr$ from the source.

The time interval 'dt' in which the photon travel from one point to another = $dv/e = dt$.

$$\text{In this time the total no. of photons emitted} = N = n dt = \left(\frac{p\lambda}{hc} \right) \frac{dr}{C}$$

These points will be present between two spherical shells of radii ' r ' and $r+dr$. It is the distance of the 1st point from the sources. No. of photons per volume in the shell

$$(r + r + dr) = \frac{N}{2\pi r^2 dr} = \frac{P\lambda dr}{hc^2} = \frac{1}{4\pi r^2 ch} = \frac{p\lambda}{4\pi hc^2 r^2}$$

$$\text{In the case} = 1.5 \times 10^{11} \text{ m}, \lambda = 500 \text{ nm} = 500 \times 10^{-9} \text{ m}$$

$$\frac{P}{4\pi r^2} = 1.4 \times 10^3, \therefore \text{No. of photons/m}^3 = \frac{P}{4\pi r^2} \frac{\lambda}{hc^2}$$

$$= 1.4 \times 10^3 \times \frac{500 \times 10^{-9}}{6.63 \times 10^{-34} \times 3 \times 10^8} = 1.2 \times 10^{13}$$

- c) No. of photons = (No. of photons/sec/m²) \times Area

$$= (3.5 \times 10^{21}) \times 4\pi r^2$$

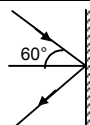
$$= 3.5 \times 10^{21} \times 4(3.14)(1.5 \times 10^{11})^2 = 9.9 \times 10^{44}$$

6. $\lambda = 663 \times 10^{-9} \text{ m}$, $\theta = 60^\circ$, $n = 1 \times 10^{19}$, $\lambda = h/p$

$$\Rightarrow P = p/\lambda = 10^{-27}$$

Force exerted on the wall = $n(mv \cos \theta - (-mv \cos \theta)) = 2n mv \cos \theta$.

$$= 2 \times 1 \times 10^{19} \times 10^{-27} \times \frac{1}{2} = 1 \times 10^{-8} \text{ N.}$$



7. Power = 10 W $P \rightarrow$ Momentum

$$\lambda = \frac{h}{p} \quad \text{or, } P = \frac{h}{\lambda} \quad \text{or, } \frac{P}{t} = \frac{h}{\lambda t}$$

$$E = \frac{hc}{\lambda} \quad \text{or, } \frac{E}{t} = \frac{hc}{\lambda t} = \text{Power (W)}$$

$$W = Pc/t \quad \text{or, } P/t = W/c = \text{force.}$$

or Force = $7/10$ (absorbed) + $2 \times 3/10$ (reflected)

$$= \frac{7}{10} \times \frac{W}{C} + 2 \times \frac{3}{10} \times \frac{W}{C} \Rightarrow \frac{7}{10} \times \frac{10}{3 \times 10^8} + 2 \times \frac{3}{10} \times \frac{10}{3 \times 10^8}$$

$$= 13/3 \times 10^{-8} = 4.33 \times 10^{-8} \text{ N.}$$

8. $m = 20 \text{ g}$

The weight of the mirror is balanced. Thus force exerted by the photons is equal to weight

$$P = \frac{h}{\lambda} \quad E = \frac{hc}{\lambda} = PC$$

$$\Rightarrow \frac{E}{t} = \frac{P}{t} C$$

$$\Rightarrow \text{Rate of change of momentum} = \text{Power}/C$$

30% of light passes through the lens.

Thus it exerts force. 70% is reflected.

$$\therefore \text{Force exerted} = 2(\text{rate of change of momentum})$$

$$= 2 \times \text{Power}/C$$

$$30\% \left(\frac{2 \times \text{Power}}{C} \right) = mg$$

$$\Rightarrow \text{Power} = \frac{20 \times 10^{-3} \times 10 \times 3 \times 10^8 \times 10}{2 \times 3} = 10 \text{ w} = 100 \text{ MW.}$$

9. Power = 100 W

Radius = 20 cm

60% is converted to light = 60 w

$$\text{Now, Force} = \frac{\text{power}}{\text{velocity}} = \frac{60}{3 \times 10^8} = 2 \times 10^{-7} \text{ N.}$$



$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{2 \times 10^{-7}}{4 \times 3.14 \times (0.2)^2} = \frac{1}{8 \times 3.14} \times 10^{-5}$$

$$= 0.039 \times 10^{-5} = 3.9 \times 10^{-7} = 4 \times 10^{-7} \text{ N/m}^2.$$

10. We know,

If a perfectly reflecting solid sphere of radius 'r' is kept in the path of a parallel beam of light of large aperture if intensity is I,

$$\text{Force} = \frac{\pi r^2 I}{C}$$

$$I = 0.5 \text{ W/m}^2, r = 1 \text{ cm}, C = 3 \times 10^8 \text{ m/s}$$

$$\text{Force} = \frac{\pi \times (1)^2 \times 0.5}{3 \times 10^8} = \frac{3.14 \times 0.5}{3 \times 10^8}$$

$$= 0.523 \times 10^{-8} = 5.2 \times 10^{-9} \text{ N.}$$

11. For a perfectly reflecting solid sphere of radius 'r' kept in the path of a parallel beam of light of large aperture with intensity 'I', force exerted = $\frac{\pi r^2 I}{C}$
12. If the i undergoes an elastic collision with a photon. Then applying energy conservation to this collision.
We get, $hC/\lambda + m_0 c^2 = mc^2$
and applying conservation of momentum $h/\lambda = mv$
Mass of e = $m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$
from above equation it can be easily shown that
 $V = C$ or $V = 0$
both of these results have no physical meaning hence it is not possible for a photon to be completely absorbed by a free electron.
13. $r = 1 \text{ m}$
Energy = $\frac{kq^2}{R} = \frac{kq^2}{1}$
Now, $\frac{kq^2}{1} = \frac{hc}{\lambda}$ or $\lambda = \frac{hc}{kq^2}$
For max ' λ ', ' q ' should be min,
For minimum ' e ' = $1.6 \times 10^{-19} \text{ C}$
Max $\lambda = \frac{hc}{kq^2} = 0.863 \times 10^3 = 863 \text{ m.}$
For next smaller wavelength = $\frac{6.63 \times 3 \times 10^{-34} \times 10^8}{9 \times 10^9 \times (1.6 \times 2)^2 \times 10^{-38}} = \frac{863}{4} = 215.74 \text{ m}$
14. $\lambda = 350 \text{ nm} = 350 \times 10^{-9} \text{ m}$
 $\phi = 1.9 \text{ eV}$
Max KE of electrons = $\frac{hC}{\lambda} - \phi = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{350 \times 10^{-9} \times 1.6 \times 10^{-19}} - 1.9$
 $= 1.65 \text{ eV} = 1.6 \text{ eV.}$
15. $W_0 = 2.5 \times 10^{-19} \text{ J}$
a) We know $W_0 = h\nu_0$
 $\nu_0 = \frac{W_0}{h} = \frac{2.5 \times 10^{-19}}{6.63 \times 10^{-34}} = 3.77 \times 10^{14} \text{ Hz} = 3.8 \times 10^{14} \text{ Hz}$
b) $eV_0 = h\nu - W_0$
or, $V_0 = \frac{h\nu - W_0}{e} = \frac{6.63 \times 10^{-34} \times 6 \times 10^{14} - 2.5 \times 10^{-19}}{1.6 \times 10^{-19}} = 0.91 \text{ V}$
16. $\phi = 4 \text{ eV} = 4 \times 1.6 \times 10^{-19} \text{ J}$
a) Threshold wavelength = λ
 $\phi = hc/\lambda$
 $\Rightarrow \lambda = \frac{hc}{\phi} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{4 \times 1.6 \times 10^{-19}} = \frac{6.63 \times 3}{6.4} \times \frac{10^{-27}}{10^{-9}} = 3.1 \times 10^{-7} \text{ m} = 310 \text{ nm.}$
b) Stopping potential is 2.5 V
 $E = \phi + eV$
 $\Rightarrow hc/\lambda = 4 \times 1.6 \times 10^{-19} + 1.6 \times 10^{-19} \times 2.5$
 $\Rightarrow \lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{\lambda \times 1.6 \times 10^{-19}} = 4 + 2.5$
 $\Rightarrow \frac{6.63 \times 3 \times 10^{-26}}{1.6 \times 10^{-19} \times 6.5} = 1.9125 \times 10^{-7} = 190 \text{ nm.}$

17. Energy of photoelectron

$$\Rightarrow \frac{1}{2} mv^2 = \frac{hc}{\lambda} - hv_0 = \frac{4.14 \times 10^{-15} \times 3 \times 10^8}{4 \times 10^{-7}} - 2.5 \text{ eV} = 0.605 \text{ eV}.$$

$$\text{We know } KE = \frac{P^2}{2m} \Rightarrow P^2 = 2m \times KE.$$

$$P^2 = 2 \times 9.1 \times 10^{-31} \times 0.605 \times 1.6 \times 10^{-19}$$

$$P = 4.197 \times 10^{-25} \text{ kg-m/s}$$

18. $\lambda = 400 \text{ nm} = 400 \times 10^{-9} \text{ m}$

$$V_0 = 1.1 \text{ V}$$

$$\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + eV_0$$

$$\Rightarrow \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{400 \times 10^{-9}} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{\lambda_0} + 1.6 \times 10^{-19} \times 1.1$$

$$\Rightarrow 4.97 = \frac{19.89 \times 10^{-26}}{\lambda_0} + 1.76$$

$$\Rightarrow \frac{19.89 \times 10^{-26}}{\lambda_0} = 4.97 - 1.76 = 3.21$$

$$\Rightarrow \lambda_0 = \frac{19.89 \times 10^{-26}}{3.21} = 6.196 \times 10^{-7} \text{ m} = 620 \text{ nm}.$$

19. a) When $\lambda = 350$, $V_s = 1.45$

$$\text{and when } \lambda = 400, V_s = 1$$

$$\therefore \frac{hc}{350} = W + 1.45 \quad \dots(1)$$

$$\text{and } \frac{hc}{400} = W + 1 \quad \dots(2)$$

Subtracting (2) from (1) and solving to get the value of h we get

$$h = 4.2 \times 10^{-15} \text{ eV-sec}$$

$$\text{b) Now work function } = w = \frac{hc}{\lambda} = \text{eV} - s$$

$$= \frac{1240}{350} - 1.45 = 2.15 \text{ eV}.$$

$$\text{c) } w = \frac{hc}{\lambda} = \lambda_{\text{threshold cathod}} = \frac{hc}{w}$$

$$= \frac{1240}{2.15} = 576.8 \text{ nm}.$$

20. The electric field becomes 0.12×10^{45} times per second.

$$\therefore \text{Frequency} = \frac{1.2 \times 10^{15}}{2} = 0.6 \times 10^{15}$$

$$h\nu = \phi_0 + KE$$

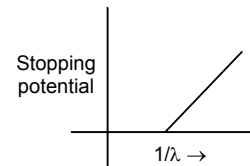
$$\Rightarrow h\nu - \phi_0 = KE$$

$$\Rightarrow KE = \frac{6.63 \times 10^{-34} \times 0.6 \times 10^{15}}{1.6 \times 10^{-19}} - 2$$

$$= 0.482 \text{ eV} = 0.48 \text{ eV}.$$

21. $E = E_0 \sin[(1.57 \times 10^7 \text{ m}^{-1})(x - ct)]$

$$W = 1.57 \times 10^7 \times C$$



$$\Rightarrow f = \frac{1.57 \times 10^7 \times 3 \times 10^8}{2\pi} \text{ Hz} \quad W_0 = 1.9 \text{ eV}$$

$$\text{Now } eV_0 = h\nu - W_0$$

$$= 4.14 \times 10^{-15} \times \frac{1.57 \times 3 \times 10^{15}}{2\pi} - 1.9 \text{ eV}$$

$$= 3.105 - 1.9 = 1.205 \text{ eV}$$

$$\text{So, } V_0 = \frac{1.205 \times 1.6 \times 10^{-19}}{1.6 \times 10^{-19}} = 1.205 \text{ V.}$$

$$22. E = 100 \sin[(3 \times 10^{15} \text{ s}^{-1})t] \sin [6 \times 10^{15} \text{ s}^{-1})t]$$

$$= 100 \times \frac{1}{2} [\cos[(9 \times 10^{15} \text{ s}^{-1})t] - \cos [3 \times 10^{15} \text{ s}^{-1})t]]$$

The ω are 9×10^{15} and 3×10^{15}

for largest K.E.

$$f_{\max} = \frac{W_{\max}}{2\pi} = \frac{9 \times 10^{15}}{2\pi}$$

$$E - \phi_0 = \text{K.E.}$$

$$\Rightarrow hf - \phi_0 = \text{K.E.}$$

$$\Rightarrow \frac{6.63 \times 10^{-34} \times 9 \times 10^{15}}{2\pi \times 1.6 \times 10^{-19}} - 2 = \text{KE}$$

$$\Rightarrow \text{KE} = 3.938 \text{ eV} = 3.93 \text{ eV.}$$

$$23. W_0 = h\nu - eV_0$$

$$= \frac{5 \times 10^{-3}}{8 \times 10^{15}} - 1.6 \times 10^{-19} \times 2 \quad (\text{Given } V_0 = 2\text{V, No. of photons} = 8 \times 10^{15}, \text{Power} = 5 \text{ mW})$$

$$= 6.25 \times 10^{-19} - 3.2 \times 10^{-19} = 3.05 \times 10^{-19} \text{ J}$$

$$= \frac{3.05 \times 10^{-19}}{1.6 \times 10^{-19}} = 1.906 \text{ eV.}$$

24. We have to take two cases :

$$\text{Case I ... } \nu_0 = 1.656$$

$$\nu = 5 \times 10^{14} \text{ Hz}$$

$$\text{Case II... } \nu_0 = 0$$

$$\nu = 1 \times 10^{14} \text{ Hz}$$

We know ;

$$\text{a) } eV_0 = h\nu - w_0$$

$$1.656\text{e} = h \times 5 \times 10^{14} - w_0 \quad \dots(1)$$

$$0 = 5h \times 10^{14} - 5w_0 \quad \dots(2)$$

$$1.656\text{e} = 4w_0$$

$$\Rightarrow w_0 = \frac{1.656}{4} \text{ eV} = 0.414 \text{ eV}$$

b) Putting value of w_0 in equation (2)

$$\Rightarrow 5w_0 = 5h \times 10^{14}$$

$$\Rightarrow 5 \times 0.414 = 5 \times h \times 10^{14}$$

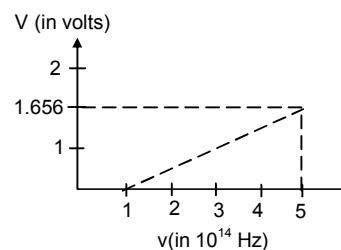
$$\Rightarrow h = 4.414 \times 10^{-15} \text{ eV-s}$$

$$25. w_0 = 0.6 \text{ eV}$$

For w_0 to be min ' λ ' becomes maximum.

$$w_0 = \frac{hc}{\lambda} \text{ or } \lambda = \frac{hc}{w_0} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{0.6 \times 1.6 \times 10^{-19}}$$

$$= 20.71 \times 10^{-7} \text{ m} = 2071 \text{ nm}$$



26. $\lambda = 400 \text{ nm}$, $P = 5 \text{ w}$

$$E \text{ of 1 photon} = \frac{hc}{\lambda} = \left(\frac{1242}{400} \right) \text{ eV}$$

$$\text{No. of electrons} = \frac{5}{\text{Energy of 1 photon}} = \frac{5 \times 400}{1.6 \times 10^{-19} \times 1242}$$

$$\text{No. of electrons} = 1 \text{ per } 10^6 \text{ photon.}$$

$$\text{No. of photoelectrons emitted} = \frac{5 \times 400}{1.6 \times 1242 \times 10^{-19} \times 10^6}$$

$$\text{Photo electric current} = \frac{5 \times 400}{1.6 \times 1242 \times 10^6 \times 10^{-19}} \times 1.6 \times 10^{-19} = 1.6 \times 10^{-6} \text{ A} = 1.6 \mu\text{A.}$$

27. $\lambda = 200 \text{ nm} = 2 \times 10^{-7} \text{ m}$

$$E \text{ of one photon} = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{2 \times 10^{-7}} = 9.945 \times 10^{-19}$$

$$\text{No. of photons} = \frac{1 \times 10^{-7}}{9.945 \times 10^{-19}} = 1 \times 10^{11} \text{ no.s}$$

$$\text{Hence, No. of photo electrons} = \frac{1 \times 10^{11}}{10^4} = 1 \times 10^7$$

Net amount of positive charge 'q' developed due to the outgoing electrons

$$= 1 \times 10^7 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-12} \text{ C.}$$

Now potential developed at the centre as well as at the surface due to these charger

$$= \frac{Kq}{r} = \frac{9 \times 10^9 \times 1.6 \times 10^{-12}}{4.8 \times 10^{-2}} = 3 \times 10^{-1} \text{ V} = 0.3 \text{ V.}$$

28. $\phi_0 = 2.39 \text{ eV}$

$$\lambda_1 = 400 \text{ nm}, \lambda_2 = 600 \text{ nm}$$

for B to the minimum energy should be maximum

$\therefore \lambda$ should be minimum.

$$E = \frac{hc}{\lambda} - \phi_0 = 3.105 - 2.39 = 0.715 \text{ eV.}$$

The presence of magnetic field will bend the beam there will be no current if the electron does not reach the other plates.

$$r = \frac{mv}{qB}$$

$$\Rightarrow r = \frac{\sqrt{2mE}}{qB}$$

$$\Rightarrow 0.1 = \frac{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 0.715}}{1.6 \times 10^{-19} \times B}$$

$$\Rightarrow B = 2.85 \times 10^{-5} \text{ T}$$

29. Given : fringe width,

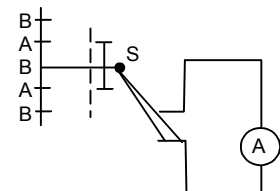
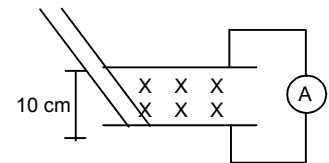
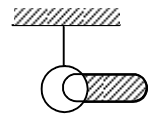
$$y = 1.0 \text{ mm} \times 2 = 2.0 \text{ mm}, D = 0.24 \text{ mm}, W_0 = 2.2 \text{ eV}, D = 1.2 \text{ m}$$

$$y = \frac{\lambda D}{d}$$

$$\text{or, } \lambda = \frac{yd}{D} = \frac{2 \times 10^{-3} \times 0.24 \times 10^{-3}}{1.2} = 4 \times 10^{-7} \text{ m}$$

$$E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} \times 3 \times 10^8}{4 \times 10^{-7}} = 3.105 \text{ eV}$$

$$\text{Stopping potential } eV_0 = 3.105 - 2.2 = 0.905 \text{ V}$$



30. $\phi = 4.5 \text{ eV}$, $\lambda = 200 \text{ nm}$

$$\text{Stopping potential or energy} = E - \phi = \frac{WC}{\lambda} - \phi$$

Minimum 1.7 V is necessary to stop the electron

The minimum K.E. = 2eV

[Since the electric potential of 2 V is reqd. to accelerate the electron to reach the plates]
the maximum K.E. = (2+1, 7)ev = 3.7 ev.

31. Given

$$\sigma = 1 \times 10^{-9} \text{ cm}^{-2}, W_0 (C_s) = 1.9 \text{ eV}, d = 20 \text{ cm} = 0.20 \text{ m}, \lambda = 400 \text{ nm}$$

we know \rightarrow Electric potential due to a charged plate = $V = E \times d$

Where $E \rightarrow$ electric field due to the charged plate = σ/E_0

$d \rightarrow$ Separation between the plates.

$$V = \frac{\sigma}{E_0} \times d = \frac{1 \times 10^{-9} \times 20}{8.85 \times 10^{-12} \times 100} = 22.598 \text{ V} = 22.6$$

$$V_0 e = h\nu - w_0 = \frac{hc}{\lambda} - w_0 = \frac{4.14 \times 10^{-15} \times 3 \times 10^8}{4 \times 10^{-7}} - 1.9$$

$$= 3.105 - 1.9 = 1.205 \text{ ev}$$

or, $V_0 = 1.205 \text{ V}$

As V_0 is much less than 'V'

Hence the minimum energy required to reach the charged plate must be = 22.6 eV

For maximum KE, the V must be an accelerating one.

Hence max KE = $V_0 + V = 1.205 + 22.6 = 23.8005 \text{ ev}$

32. Here electric field of metal plate = $E = P/E_0$

$$= \frac{1 \times 10^{-19}}{8.85 \times 10^{-12}} = 113 \text{ v/m}$$

accl. $de = \phi = qE / m$

$$= \frac{1.6 \times 10^{-19} \times 113}{9.1 \times 10^{-31}} = 19.87 \times 10^{12}$$

$$t = \frac{\sqrt{2y}}{a} = \frac{\sqrt{2 \times 20 \times 10^{-2}}}{19.87 \times 10^{12}} = 1.41 \times 10^{-7} \text{ sec}$$

$$\text{K.E.} = \frac{hc}{\lambda} - w = 1.2 \text{ eV}$$

$$= 1.2 \times 1.6 \times 10^{-19} \text{ J [because in previous problem i.e. in problem 31 : KE = 1.2 ev]}$$

$$\therefore V = \frac{\sqrt{2KE}}{m} = \frac{\sqrt{2 \times 1.2 \times 1.6 \times 10^{-19}}}{4.1 \times 10^{-31}} = 0.665 \times 10^{-6}$$

$$\therefore \text{Horizontal displacement} = V_t \times t$$

$$= 0.655 \times 10^{-6} \times 1.4 \times 10^{-7} = 0.092 \text{ m} = 9.2 \text{ cm.}$$

33. When $\lambda = 250 \text{ nm}$

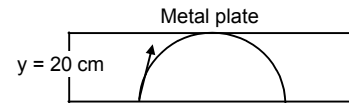
$$\text{Energy of photon} = \frac{hc}{\lambda} = \frac{1240}{250} = 4.96 \text{ ev}$$

$$\therefore \text{K.E.} = \frac{hc}{\lambda} - w = 4.96 - 1.9 \text{ ev} = 3.06 \text{ ev.}$$

Velocity to be non positive for each photo electron

The minimum value of velocity of plate should be = velocity of photo electron

$$\therefore \text{Velocity of photo electron} = \sqrt{2KE/m}$$



$$= \sqrt{\frac{3.06}{9.1 \times 10^{-31}}} = \sqrt{\frac{3.06 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}} = 1.04 \times 10^6 \text{ m/sec.}$$

34. Work function = ϕ , distance = d

The particle will move in a circle

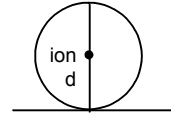
When the stopping potential is equal to the potential due to the singly charged ion at that point.

$$eV_0 = \frac{hc}{\lambda} - \phi$$

$$\Rightarrow V_0 = \left(\frac{hc}{\lambda} - \phi \right) \frac{1}{e} \Rightarrow \frac{ke}{2d} = \left(\frac{hc}{\lambda} - \phi \right) \frac{1}{e}$$

$$\Rightarrow \frac{Ke^2}{2d} = \frac{hc}{\lambda} - \phi \Rightarrow \frac{hc}{\lambda} = \frac{Ke^2}{2d} + \phi = \frac{Ke^2 + 2d\phi}{2d}$$

$$\Rightarrow \lambda = \frac{hc \cdot 2d}{Ke^2 + 2d\phi} = \frac{2hcd}{\frac{1}{4\pi\epsilon_0 e^2} + 2d\phi} = \frac{8\pi\epsilon_0 hcd}{e^2 + 8\pi\epsilon_0 d\phi}$$



35. a) When $\lambda = 400 \text{ nm}$

$$\text{Energy of photon} = \frac{hc}{\lambda} = \frac{1240}{400} = 3.1 \text{ eV}$$

This energy given to electron

But for the first collision energy lost = $3.1 \text{ eV} \times 10\% = 0.31 \text{ eV}$

for second collision energy lost = $3.1 \text{ eV} \times 10\% = 0.31 \text{ eV}$

Total energy lost the two collision = $0.31 + 0.31 = 0.62 \text{ eV}$

K.E. of photon electron when it comes out of metal

= $hc/\lambda - \text{work function} - \text{Energy lost due to collision}$

= $3.1 \text{ eV} - 2.2 - 0.62 = 0.31 \text{ eV}$

- b) For the 3rd collision the energy lost = 0.31 eV

Which just equate the KE lost in the 3rd collision electron. It just comes out of the metal

Hence in the fourth collision electron becomes unable to come out of the metal

Hence maximum number of collision = 4.

