Chapter 2 (Particle Nature of Light)
Solution of PYQ [IIT-JAM]

$A_1 \rightarrow$ Photo Electric Effect

Ans. 1: (c)

Solution: $K_{\max} = \hbar\omega - W$

For given wave maximum kinetic energy is for highest ω so $\omega = 12.56\times10^{15}\ \sec^{-1}$

$$\hbar\omega = \frac{6.6\times10^{-34} J s\times 12.56\times10^{15} s^{-1}}{2\pi} = \frac{82.8\times10^{-19} J}{6.28\times1.6\times10^{-19}} eV = 8.24 eV$$

$K_{\max} = \hbar\omega - W \Rightarrow 8.24eV - 2eV = 6.24eV$

Ans. 2: (d)

Solution: $E = a\left(\cos\omega_0 t + \sin\omega t \sin\omega_0 t\right)$

$$E = a\cos\omega_0 t + \frac{a}{2}\cos\left(\omega+\omega_0\right)t + \frac{a}{2}\cos\left(\omega-\omega_0\right)t$$

This electric field consists of three frequencies i.e., $\omega-\omega_0$, ω_0, $\omega+\omega_0$

So maximum kinetic energy will be corresponding to highest frequency $\left(\omega+\omega_0\right) = 6\times10^{15}\ \sec$

$KE_{\max} = h\nu_{\max} - W$ where $\nu_{\max} = \dfrac{\omega+\omega_0}{2\pi} = \dfrac{6\times10^{15}}{2\pi}$

$$= \frac{6.6\times10^{-34}\times6\times10^{15}}{1.6\times10^{19}\times2\pi} eV - 2eV = 3.95 - 2 = 1.95eV = 1.95\times1.6\times10^{-19} J = 3.12\times10^{-19} J$$

$KE_{\max} = eV_s \Rightarrow V_s = 1.95V$

Ans. 3: (a)

Solution: Since, $K.E = eV = \hbar\omega - W \Rightarrow V = \dfrac{hc}{e\lambda} - \dfrac{W}{e}$

Now, $\lambda = 320\times10^{-9} m$, $W = 2.1\ eV$

$$\Rightarrow V = \frac{6.6\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times320\times10^{-9}} - 2.1$$

$V = 3.867 - 2.1 \approx 3.9 - 2.1 = 1.8\ V$. Thus, option (a) is correct.

Ans. 4: 4

Solution: For tungsten $eV_s = h\nu - W_t \Rightarrow h\nu = eV_s + W_t = 1.8 + 4.5 = 6.3$

For sodium $eV_s = h\nu - W_s = 6.3 - 2.3 = 4eV$

Ans. 5: (b)

Solution: Stopping potential is not defined at power of light source

$B_1 \rightarrow$ Compton Effect

Ans. 6: (d)

Solution: $\Delta\lambda = \lambda_c(1-\cos\theta)$

When photon scattered in backward direction then $\theta = \pi$. So, $\Delta\lambda = 2\lambda_c$

Functional shift is $\dfrac{\Delta\lambda}{\lambda} = \dfrac{2\lambda_C}{\lambda}$

Ans. 7: 25

Solution: $\lambda = 0.24\,nm,\ \lambda_C = 0.00243$ and $\theta = 60^0$

$$\because \lambda' - \lambda = \lambda_C(1-\cos\theta) \Rightarrow \lambda' = \lambda + \lambda_C(1-\cos\theta)$$

$$\Rightarrow \lambda' = 0.24 + 0.00243\left(1-\frac{1}{2}\right) = 0.24 + 0.00243\times\frac{1}{2} = 0.24 + 0.00121 = 0.2412nm$$

Kinetic Energy of scattered electron

$$K.E. = \frac{hc}{\lambda} - \frac{hc}{\lambda'} = 6.6\times10^{-34}\times3\times10^{8}\left(\frac{1}{0.24} - \frac{1}{0.2412}\right)\times\frac{1}{10^{-9}}\,Joules$$

$$\Rightarrow K.E. = \frac{19.8\times10^{-26}}{10^{-9}}(4.17-4.15) = \frac{19.8\times10^{-26}}{10^{-9}}\times0.02 = 396\times10^{-20}\ Joules$$

$$\Rightarrow K.E. = \frac{396\times10^{-20}}{1.6\times10^{-19}}\ eV = 24.75\ eV$$

Ans. 8: 0.77

Solution: $\because\ \lambda' - \lambda = \dfrac{h}{mc}(1-\cos\theta) \Rightarrow \lambda' - \lambda = \dfrac{h}{mc} \qquad \because \theta = \dfrac{\pi}{2}$

$$\Rightarrow \frac{\lambda'}{hc} - \frac{\lambda}{hc} = \frac{1}{mc^2} \Rightarrow \frac{1}{E'} - \frac{1}{E} = \frac{1}{mc^2} \Rightarrow \frac{1}{E'} = \frac{1}{E} + \frac{1}{mc^2} \Rightarrow \frac{1}{20keV} + \frac{1}{.5MeV}$$

$$\Rightarrow E' = 19.23keV$$

Recoil velocity of electron $E - E' = 0.77keV$

Ans. 9: (a),(c)

Solution: $\lambda' - \lambda = \dfrac{h}{mc}(1-\cos\phi) \Rightarrow \dfrac{c}{\nu'} - \dfrac{c}{\nu} = \dfrac{h}{mc}(1-\cos\phi)$

$$\Rightarrow \frac{2c}{\nu} - \frac{c}{\nu} = \frac{h}{mc}(1-\cos\phi) \Rightarrow \frac{c}{\nu} = \frac{h}{mc}(1-\cos\phi) \Rightarrow \cos\phi = \left(1 - \frac{mc^2}{h\nu}\right)$$

From the conservation of momentum in y direction

$$\frac{h\nu'}{c}\sin\phi = p\sin\theta \Rightarrow \frac{p}{\frac{h\nu'}{c}} = \frac{\sin\phi}{\sin\theta}$$

Ans. 10: 1.02

Solution: From conservation of energy

$$E_e = m_e c^2 + K_e = \left(m_n - m_p\right)c^2 = \left(1.675 - 1.673\right)\times 10^{-27}\left(3\times 10^8\right)^2 = 1.8\times 10^{-13}\,Joules$$

$$E_e^2 = \left(pc\right)^2 + m_e^2 c^4 \approx \left(pc\right)^2 \quad \Rightarrow p = \frac{E_e}{c} = 0.6\times 10^{-22}\,kg.m/\sec \qquad \left[\because pc >> m_e c^2\right]$$

$$\lambda = \frac{h}{p} = \frac{6.6\times 10^{-34}}{0.6\times 10^{-22}} = 1.1\times 10^{-12}\,m = 1.1\,pm$$

Ans. 11: (c)

Solution: $\Delta\lambda = \dfrac{h}{m_e c}\left(1-\cos\theta\right) \Rightarrow \cos\theta = 1 - \dfrac{\Delta\lambda . m_e c}{h}$

$$= 1 - \frac{3.25\times 10^{-13}\times 9.109\times 10^{-31}\times 3\times 10^8}{6.6\times 10^{-34}} = 0.866 = \frac{\sqrt{3}}{2}$$

$$\theta = 30^0$$

Ans. 12: 0.548

Solution: $\Delta\lambda = \dfrac{h}{mc}\left(1-\cos\phi\right)$

$$\lambda_2 - \lambda_1 = \frac{h}{mc}\times 2$$

$$\lambda_2 = 0.024\times 2 + 0.500 = 0.048 + 0.500 = 0.548\,\overset{0}{\mathrm{A}}$$