CHAPTER 1: DUAL NATURE OF RADIATION AND MATTER

Test Your Concepts-I (Based on Photon Properties)

1. For completely absorbing surface,

$$P_{\text{rad}} = \frac{I}{C} = \frac{1.4 \times 10^3}{3 \times 10^8} = 4.7 \times 10^{-6}\ \text{Nm}^{-2}$$

2. $f = \frac{v_1}{2\pi r_1} = \frac{c}{\lambda}$

$$\Rightarrow \quad \lambda = \frac{2\pi c r_1}{v_1} = \frac{(2\pi)(3\times 10^8)(0.529\times 10^{-10})(10^{10})}{(2.2\times 10^6)}\ \text{Å}$$

$$\Rightarrow \quad \lambda = 453\ \text{Å}$$

3. For an electron, de-Broglie wavelength is given by,

$$\lambda = \sqrt{\frac{150}{V}} = \sqrt{\frac{150}{25}} = \sqrt{6}$$

$$\Rightarrow \quad \lambda \approx 2.5\ \text{Å}$$

4. Power of transmitter $= 10\ \text{kW} = 10^4\ \text{W}$

So, total energy emitted per second is 10^4 J

Energy of one photon,

$$E = h\nu = \frac{hc}{\lambda} = \frac{6.63\times 10^{-34}\times 3\times 10^8}{500}\ \text{J}$$

Number of photons emitted per second is

$$n = \frac{\text{Total energy emitted per second}}{\text{Energy of one photon}}$$

$$\Rightarrow \quad n = \frac{10^4 \times 500}{6.63\times 10^{-34}\times 3\times 10^8} = 2.51\times 10^{31}$$

5. Energy of one photon is

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

$$\Rightarrow \quad E = \frac{6.625\times 10^{-34}\times 3\times 10^8}{5600\times 10^{-10}} = 3.5\times 10^{-19}\ \text{J}$$

Since a 100 W bulb supplies 100 J of energy per second. So, energy released per second as visible photons is

$$E' = \frac{100\times 5}{100} = 5\ \text{J}$$

$\therefore$ Number of photons emitted per second as visible light is

$$\frac{E'}{E} = \frac{5}{3.5\times 10^{-19}} = 1.43\times 10^{19}$$

6. Energy of each photon is

$$E = h\nu = 6.62\times 10^{-34}\times 10^{12} = 6.62\times 10^{-22}\ \text{J}$$

Number of photons present in 6.62 J of radiation energy is calculated by using

$$E = N(h\nu)$$

$$\Rightarrow \quad N = \frac{E}{h\nu} = \frac{6.62}{6.62\times 10^{-22}} = 10^{22}$$

7. (a) Energy of each photon,

$$E = h\nu = 6.63\times 10^{-34}\times 6\times 10^{14} = 3.98\times 10^{-19}\ \text{J}$$

(b) If N is the number of photons emitted per second by the source, then

Power transmitted in the beam is

$$P = N\ \text{(energy of each photon)}$$

$$\Rightarrow \quad P = NE$$

$$\Rightarrow \quad N = \frac{P}{E} = \frac{2\times 10^{-3}\ \text{W}}{3.98\times 10^{-19}\ \text{J}}$$

$$\Rightarrow \quad N = 5\times 10^{15}\ \text{photons per second.}$$

8. The total energy of an electron with rest mass m_0 and momentum p is

$$E = \sqrt{m_0^2c^4 + p^2c^2}$$

where c is the speed of light in free space. Law of Conservation of Energy requires,

$$\begin{pmatrix}\text{Rest mass}\\\text{of electron}\end{pmatrix} + \begin{pmatrix}\text{Energy of}\\\text{photon}\end{pmatrix} = \begin{pmatrix}\text{Total energy of}\\\text{moving electron}\end{pmatrix}$$

$$\Rightarrow \quad m_0c^2 + h\nu = \sqrt{m_0^2c^4 + p^2c^2} \qquad \ldots(1)$$

Law of Conservation of Momentum requires.

$$\begin{pmatrix}\text{Initial}\\\text{momentum}\\\text{of electron}\end{pmatrix} + \begin{pmatrix}\text{Momentum}\\\text{of photon}\end{pmatrix} = \begin{pmatrix}\text{Final}\\\text{momentum}\\\text{of electron}\end{pmatrix}$$

$$\Rightarrow \quad 0 + \frac{h}{\lambda} = p$$

$$\Rightarrow \quad \frac{h\nu}{c} = p \qquad \left\{\because \lambda = \frac{c}{\nu}\right\}$$

$$\Rightarrow \quad h\nu = pc \qquad \ldots(2)$$

Squaring both sides of equation (1), we get

$$m_0^2c^4 + h^2\nu^2 + 2m_0c^2h\nu = m_0^2c^4 + p^2c^2$$

$\Rightarrow \quad 2\left(m_0c^2\right)(h\nu) = 0$ {using (2)}

This is impossible. In a frame, where the initial electron is moving with uniform velocity, the same conclusion must hold because if a process is forbidden in one inertial frame, it is also forbidden in another inertial frame.

9. KE of an electron is

$$E_K = 50 \text{ eV} = 1.6\times10^{-19}\times5\times10^{4} \text{ J} = 8\times10^{-15} \text{ J}$$

de-Broglie wavelength of electrons is

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

$$\Rightarrow \quad \lambda = \frac{6.63\times10^{-34}}{\sqrt{2\times9.11\times10^{-31}\times8\times10^{-15}}} \text{ m}$$

$$\Rightarrow \quad \lambda = \frac{6.63\times10^{-11}}{12.07} \text{ m} = 5.5\times10^{-12} \text{ m}$$

For yellow light, wavelength $\lambda = 5.9\times10^{-7}$ m

As resolving power is inversely proportional to wavelength, so the resolving power of an electron microscope is about 10^5 times greater than that of an optical microscope.

10. The kinetic energy of a particle of mass m can be expressed in terms of its momentum p as follows

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}\cdot\frac{(mv)^2}{m} = \frac{p^2}{2m}$$

As de-Broglie wavelength, $\lambda = \frac{h}{p}$

$$\Rightarrow \quad \frac{\lambda_e}{\lambda_P} = \frac{p_P}{p_e} = \sqrt{\frac{2m_P\cdot KE}{2m_e\cdot KE}} = \sqrt{\frac{m_P}{m_e}}$$

As $m_e < m_P$, therefore, $\lambda_e > \lambda_P$

Thus, the electron has greater de-Broglie wavelength.

11. Kinetic energy of electron is

$$E_e = \frac{1}{2}mv^2 = \frac{1}{2}\cdot\frac{(mv)^2}{m} = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2} \quad \left\{\because p = \frac{h}{\lambda}\right\}$$

Energy of a photon is totally kinetic and is given by

$$E_P = h\nu = \frac{hc}{\lambda}$$

$$\Rightarrow \quad \frac{E_P}{E_e} = \frac{hc}{\lambda}\cdot\frac{2m\lambda^2}{h^2} = \frac{2mc\lambda}{h}$$

$$\Rightarrow \quad \frac{E_P}{E_e} = \frac{m_P}{m_e}$$

Thus, the KE of a photon is greater than that of an electron of same wavelength.

12. The total relativistic energy of a particle is

$$E = \sqrt{m_0c^4 + p^2c^2}$$

As wavelength λ is same for both electron and proton,

Since, momentum, $p = \frac{h}{\lambda}$ is same for both particles and hence p^2c^2 is same for both.

But rest mass m_0 of a proton is greater than that of an electron, therefore, the energy of a proton is more than that of an electron of same wavelength.

13. Force on space vehicle is

$$F = \frac{P}{c} = \frac{100}{3\times10^8} = 3.33\times10^{-7} \text{ N}$$

Acceleration is $a = \frac{F}{m} = \frac{3.33\times10^{-7}}{50}$

$$\Rightarrow \quad a = 6.66\times10^{-9} \text{ ms}^{-2}$$

14. Momentum of photon having wavelength λ is

$$p = \frac{h}{\lambda} = \frac{6.626\times10^{-34}}{5200\times10^{-10}} \text{ kgms}^{-1}$$

Momentum of electron moving with a velocity v is

$$p_e = mv = 9.1\times10^{-31}v$$

Since the photon and the electron have same momentum

$$\Rightarrow \quad 9.1\times10^{-31}v = \frac{6.626\times10^{-34}}{5200\times10^{-10}}$$

$$\Rightarrow \quad v = 1400 \text{ ms}^{-1}$$

15. (a) The energy of each photon (in eV) is

$$E = \frac{hc}{\lambda} = \frac{\left(4.14\times10^{-15} \text{ eVs}\right)\times\left(3\times10^8 \text{ ms}^{-1}\right)}{496 \text{ nm}}$$

$$\Rightarrow \quad E = \frac{1240 \text{ eVnm}}{496 \text{ nm}} = 2.5 \text{ eV}$$

$$\Rightarrow \quad E = 4\times10^{-19} \text{ J}$$

In one second, 10 J of energy passes through any cross section of the beam. Thus, the number of photons crossing a cross section per second is

$$n = \frac{10}{4\times10^{-19}} = 2.5\times10^{19} \text{ photons/sec}$$

This is also the number of photons falling on the surface per second and being absorbed.

(b) The linear momentum of each photon is

$$p = \frac{h}{\lambda} = \frac{h\nu}{c}$$

The total change in momentum of all the photons falling on the surface is $\Delta p = N\left(\frac{h\nu}{c}\right) = (n\Delta t)\left(\frac{h\nu}{c}\right)$

As the photons are completely absorbed by the surface, this much momentum is transferred to the surface per second. The rate of change of the momentum of the surface, i.e., the force on it is

$$F = \frac{\Delta p}{\Delta t} = n\left(\frac{hv}{c}\right) = \frac{10}{3\times10^{8}}$$

$\Rightarrow \quad F = 3.33\times10^{-8}$ N

16. The energy of each photon $= \dfrac{200\ \text{Js}^{-1}}{4\times10^{20}\ \text{s}^{-1}} = 5\times10^{-19}$ J

Wavelength $= \lambda = \dfrac{hc}{E}$

$$\Rightarrow \quad \lambda = \frac{(6.63\times10^{-34}\ \text{Js})\times(3\times10^{8}\ \text{ms}^{-1})}{(5\times10^{-19}\ \text{J})}$$

$\Rightarrow \quad \lambda = 4.0\times10^{-7}$ m = 400 nm

17. The energy of each photon is

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

$$\Rightarrow \quad E = \frac{(6.63\times10^{-34}\ \text{Js})\times(3\times10^{8}\ \text{ms}^{-1})}{663\times10^{-9}\ \text{m}}$$

$\Rightarrow \quad E = 3.14\times10^{-19}$ J

The energy of the laser emitted per second is 5×10^{-3} J. Thus, the number of photons emitted per second is

$$n = \frac{P}{E}$$

$$\Rightarrow \quad n = \frac{5\times10^{-3}\ \text{J}}{3.14\times10^{-19}\ \text{J}} = 1.6\times10^{16}\ \text{photons/sec}$$

18. The linear momentum of the photon is

$$p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}\ \text{Js}}{122\times10^{-9}\ \text{m}} = 5.43\times10^{-27}\ \text{kgms}^{-1}$$

As the photon is absorbed and the atom stops, the total final momentum is zero.

From conservation of linear momentum, the initial momentum must be zero. The atom should move opposite to the direction of motion of the photon and they should have the same magnitudes of linear momentum.

$\Rightarrow \quad (1.67\times10^{-27}\ \text{kg})v = 5.43\times10^{-27}\ \text{kgms}^{-1}$

$$\Rightarrow \quad v = \frac{5.43\times10^{-27}}{1.67\times10^{-27}}\text{ms}^{-1} = 3.25\ \text{ms}^{-1}$$

Test Your Concepts-II (Based on Photoelectric Effect)

1. Since,

$$E = hv = (4.316\times10^{-15}\ \text{eV-sec})(1.5\times10^{15}\ \text{sec}^{-1})$$

$\Rightarrow \quad E \approx 6.5$ eV

$\Rightarrow \quad K_{max} = E - W = (6.5 - 3.7)$ eV = 2.8 eV

2. The energy of incident photon in eV is given by

$$E = \frac{12400}{2480}\ \text{eV} = 5\text{eV}$$

$\Rightarrow \quad E = (5)(1.6\times10^{-19})$ J $= 8\times10^{-19}$ J

The number of photons emitted per second by the source is

$$n = \frac{P_{\text{source}}}{E_{\text{each photon}}} = \frac{40}{8\times10^{-19}} = 5\times10^{19}\ \text{photons/s}$$

The number of photons incident on the metal surface per second per unit area is

$$\phi_N = \frac{n}{A} = \frac{n}{4\pi r^2} = \frac{5\times10^{19}}{4\times3.14\times(2)^2} = 0.995\times10^{18}$$

$\Rightarrow \quad \phi_N \approx 1\times10^{18}\ \text{s}^{-1}\text{m}^{-2}$

The kinetic energy of the fastest electron is given by

$$K_{max} = E - \phi_0$$

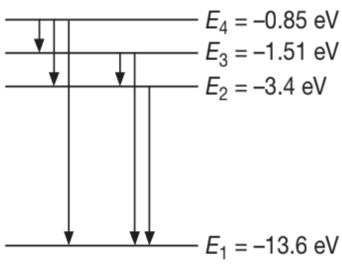
$\Rightarrow \quad K_{max} = 5$ eV $- 3.7$ eV $= 1.3$ eV

The threshold wavelength for the given metal surface for a work function of 3.7 eV is given by

$$\lambda_{th} = \frac{12400}{3.7}\ \text{Å} = 3351\ \text{Å}$$

3. $\dfrac{K_1}{K_2} = 5$

$$\Rightarrow \quad \frac{\Delta E_1 - W}{\Delta E_2 - W} = 5 \qquad \text{...(1)}$$



Here, $\Delta E_1 = E_4 - E_1 = 12.75\text{ eV}$ and

$\Delta E_2 = E_3 - E_1 = 12.09\text{ eV}$

Substituting in equation (1) and solving we get

$W = 11.93\text{ eV}$

4. $K_{max} = E - W$

$$\Rightarrow \quad 3\text{ eV} = \frac{12375}{\lambda} - \frac{12375}{5000}$$

$$\Rightarrow \quad \lambda = 2260\text{ Å}$$

5. Since, $E(\text{in eV}) = \dfrac{12375}{\lambda(\text{in Å})}$

$$\Rightarrow \quad E_1 = \frac{12375}{5000} = 2.475\text{ eV}$$

$$E_2 = \frac{12375}{6000} = 2.06\text{ eV} \text{ and}$$

$$E_3 = \frac{12375}{7000} = 1.77\text{ eV}$$

Since, W is 1.9 eV, photons of energy E_1 and E_2 can only emit photoelectrons. Charge emitted per second is

$$\frac{q}{t} = (1.6\times10^{-19})\left(\frac{1}{3}\right)\frac{(10^{-3})(10^{-4})}{\pi\times(10^{-3})^2\times2.475\times1.6\times10^{-19}} + (1.6\times10^{-19})\left(\frac{1}{3}\right)\frac{(10^{-3})(10^{-4})}{\pi\times(10^{-3})^2\times2.06\times1.6\times10^{-19}}$$

$$\Rightarrow \quad \frac{q}{t} = 9.28\times10^{-3}\text{ C} = 9.28\text{ mC}$$

6. $E_1 = \dfrac{12375}{4000} = 3.1\text{ eV}$

$$E_2 = \frac{12375}{4800} = 2.57\text{ eV}$$

$$E_3 = \frac{12375}{6000} = 2.06\text{ eV} \text{ and}$$

$$E_4 = \frac{12375}{7000} = 1.77\text{ eV}$$

Therefore, light of wavelengths 4000 Å, 4800 Å and 6000 Å can only emit photoelectrons.

So, number of photoelectrons emitted per second is

$$n = \frac{I_1A_1}{E_1} + \frac{I_2A_2}{E_2} + \frac{I_3A_3}{E_3}$$

$$\Rightarrow \quad n = IA\left(\frac{E_1E_2 + E_2E_3 + E_1E_3}{E_1E_2E_3}\right)$$

$$\Rightarrow \quad n = \frac{(1.5\times10^{-3})(10^{-4})}{1.6\times10^{-19}}\times\left[\frac{3.1\times2.57 + 2.57\times2.06 + 3.1\times2.06}{3.1\times2.57\times2.06}\right]$$

$$\Rightarrow \quad n = 1.12\times10^{12}$$

7. (a) $h\nu_0 = W = 3.75\times1.6\times10^{-19}\text{ J}$

$$\Rightarrow \quad \nu_0 = \frac{3.75\times1.6\times10^{-19}}{6.6\times10^{-34}} \approx 10^{15}\text{ Hz}$$

(b) $E = \dfrac{12375}{1980}\text{ eV} = 6.25\text{ eV}$

$$\Rightarrow \quad K_{max} = 2.5\text{ eV}$$

(c) $K_{max} = 2\text{ eV}$

8. $K_{max} = E - W = \dfrac{hc}{\lambda} - \dfrac{hc}{\lambda_0}$

$$0.18\times1.6\times10^{-19} = \frac{h(3\times10^8)}{5461\times10^{-10}} - \frac{h(3\times10^8)}{\lambda_0} \quad \ldots(1)$$

Further, $eV_0 = E - W = \dfrac{hc}{\lambda} - \dfrac{hc}{\lambda_0}$

$$\Rightarrow \quad 4.6\times1.6\times10^{-19} = \frac{h(3\times10^8)}{1849\times10^{-10}} - \frac{h(3\times10^8)}{\lambda_0} \quad \ldots(2)$$

Solving equations (1) and (2), for h and λ_0, we get

$h = 6.6\times10^{-34}\text{ Js}$

and $\lambda_0 = 5990.25\text{ Å}$

9. From Einstein's Photo-Electric Equation, we have

$$\frac{1}{2}mv_1^2 = \frac{hc}{\lambda_1} - W \quad \ldots(1)$$

$$\frac{1}{2}mv_2^2 = \frac{hc}{\lambda_2} - W \quad \ldots(2)$$

Dividing equation (1) with equation (2), and using the given fact that $v_1 = 2v_2$, we get

$$4 = \frac{\frac{hc}{\lambda_1} - W}{\frac{hc}{\lambda_2} - W}$$

$$\Rightarrow \quad 3W = 4\left(\frac{hc}{\lambda_2}\right) - \left(\frac{hc}{\lambda_1}\right) = \frac{4\times12375}{5400} - \frac{12375}{3500} = 5.63\text{ eV}$$

$$\Rightarrow \quad W = 1.9\text{ eV}$$

10. From Einstein's Photo-Electric Equation, we have

$$0.6 = \frac{12375}{4950} - W \quad \ldots(1)$$

$$1.1 = \frac{12375}{\lambda} - W \qquad \ldots(2)$$

Solving above two equations, we get

$$W = 1.9 \text{ eV} \text{ and } \lambda = 4125 \text{ Å}$$

No change is observed.

11. Since, $W = 2.3$ eV and $\lambda = 2800$ Å

$$E(\text{in eV}) = \frac{12375}{\lambda(\text{in Å})} = \frac{12375}{2800} = 4.4 \text{ eV}$$

(a) From Einstein's Photo-Electric Equation, we have

$$K_{max} = E - W$$

$$\Rightarrow K_{max} = (4.4 - 2.3) \text{ eV}$$

$$\Rightarrow K_{max} = 2.1 \text{ eV}$$

(b) Since, $K_{max} = eV_0$

$$\Rightarrow 2.1 \text{ eV} = eV_0$$

$$\Rightarrow V_0 = 2.1 \text{ V}$$

12. Energy of incident photon in eV is

$$E = \frac{12375}{1500} \text{ eV} = 8.25 \text{ eV}$$

According to Einstein's photo electric equation, we have

$$E = \phi_0 + K_{max}$$

$$\Rightarrow \phi_0 = E - K_{max}$$

$$\Rightarrow \phi_0 = (8.25 - 3) \text{ eV} = 5.25 \text{ eV}$$

Threshold wavelength for the metal surface corresponding to work function 5.25 eV is given by

$$\lambda_{th} = \frac{12375}{5.25} \text{ Å} = 2357 \text{ Å}$$

Stopping potential for the ejected photoelectrons is given by

$$V_S = \frac{K_{max}}{e} = \frac{3 \text{ eV}}{e} = 3 \text{ V}$$

13. (a) The work function of tungsten cathode is

$$\phi_0 = \frac{hc}{\lambda_{th}}$$

$$\Rightarrow \phi_0 = \frac{12375}{2300} \text{ eV} \approx 5.4 \text{ eV}$$

(b) The energy, in eV, of incident photons is

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

$$\Rightarrow E = \frac{12375}{1800} \text{ eV} = 6.9 \text{ eV}$$

The maximum kinetic energy of ejected electrons can be given as

$$K_{max} = E - \phi_0$$

$$\Rightarrow KE_{max} = (6.9 - 5.4) \text{ eV} = 1.5 \text{ eV}$$

14. The energy (in eV) of the incident photons is

$$E = \frac{12375}{2250} \text{ eV} = 5.5 \text{ eV}$$

Since. the stopping potential for ejected electrons is 1.5 V, so the maximum kinetic energy of ejected photoelectrons is

$$K_{max} = eV_s = 1.5 \text{ eV}$$

Applying Einstein's photo electric equation, we get

$$\Rightarrow \phi_0 = E - K_{max} = (5.5 - 1.5) \text{ eV} = 4 \text{ eV}$$

Energy (in eV) for photons of high intensity light of wavelength 6875 Å is

$$E' = \frac{12375}{6875} \text{ eV} = 1.8 \text{ eV} < \phi_0$$

Since, $E' < \phi_0$, so the photocell will not work even if irradiated by this high intensity light.

15. (a) Given that the threshold wavelength of a metal is $\lambda_{th} = 2750$ Å. So, work function (ϕ_0) of metal is

$$\phi_0 = \frac{hc}{\lambda_{th}}$$

$$\Rightarrow \phi_0 = \frac{12430}{2750} \text{ eV} = 4.5 \text{ eV}$$

(b) The energy (E) of incident photon of wavelength 1800 Å on metal in eV is

$$E = \frac{12430}{1800} \text{ eV} = 6.9 \text{ eV}$$

So, maximum kinetic energy (K_{max}) of the ejected electrons is

$$K_{max} = E - \phi_0$$

$$\Rightarrow K_{max} = (6.9 - 4.5) \text{ eV} = 2.4 \text{ eV}$$

(c) If the maximum speed of ejected electrons is v_{max}, then

$$\frac{1}{2} m v_{max}^2 = 2.4 \text{ eV}$$

$$\Rightarrow v_{max} = \sqrt{\frac{2 \times 2.4 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}} = 9.2 \times 10^5 \text{ ms}^{-1}$$

16. According to Einstein's photo-electric equation

$$K_{max} = \frac{1}{2}mv_{max}^2 = h\nu - \phi_0$$

$$\Rightarrow \quad K_{max} = 4.9 - 4.5 = 0.4 \text{ eV}$$

If p be the momentum of each ejected photo electron, then

$$p = \sqrt{2mK_{max}}$$

Also, we know that change in momentum of a body is equal to impulse. Hence the entire momentum of electron is gained when it is ejected out from the metal surface, so impulse (J) on the surface is given by

$$J = \Delta p = \sqrt{2mK_{max}}$$

Substituting the values, we get maximum impulse

$$J = \sqrt{2 \times 9.1 \times 10^{-31} \times 0.4 \times 1.6 \times 10^{-19}}$$

$$\Rightarrow \quad J = 3.45 \times 10^{-25} \text{ kgms}^{-1}$$

Single Correct Choice Type Questions

1. $E = nh\nu$

$$\Rightarrow \quad \frac{E}{t} = P = \left(\frac{n}{t}\right)h\nu$$

Hence, the correct answer is (C).

3. $$5\, eV_0 = \frac{hc}{\lambda} - W \qquad \ldots(1)$$

$$\Rightarrow \quad eV_0 = \frac{hc}{3\lambda} - W \qquad \ldots(2)$$

Solving equation (1) & (2), we get

$$\frac{hc}{\lambda} - W = \frac{5hc}{3\lambda} - 5W$$

$$\Rightarrow \quad 4W = \frac{2hc}{3\lambda}$$

$$\Rightarrow \quad W = \frac{hc}{6\lambda}$$

Hence, the correct answer is (A).

4. $$\lambda = \frac{h}{\sqrt{2meV}}$$

$$\lambda' = \frac{h}{\sqrt{2MeV}}$$

$$\Rightarrow \quad \lambda' = \lambda\sqrt{\frac{m}{M}}$$

Hence, the correct answer is (B).

8. $$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$$

$$\Rightarrow \quad \lambda = kE^{-\frac{1}{2}}$$

$$\Rightarrow \quad \log_e \lambda = \log k - \frac{1}{2}\log E$$

Hence, the correct answer is (A).

9. $E = mc^2$

$$\Rightarrow \quad E = m_0c^2\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$$

Since $\frac{v}{c} \ll 1$

$$\Rightarrow \quad E \simeq m_0c^2\left(1 + \frac{v^2}{2c^2}\right)$$

$$\Rightarrow \quad E \simeq m_0c^2 + \frac{1}{2}m_0v^2$$

Hence, the correct answer is (C).

10. Since both have same de Broglie wavelength, hence both must have equal value of momentum.

Since, $E = \frac{p^2}{2m}$

$$\Rightarrow \quad \frac{E_e}{E_p} = \frac{m_p}{m_e} = 1840 \simeq 2000 \qquad \left\{\text{nearest possible approximation to answer}\right\}$$

Hence, the correct answer is (C).

11. $E^2 = p^2c^2 + m_0^2c^4$

$$\Rightarrow \quad E^2 = p^2c^2 + E_0^2 \qquad \{\text{where } E_0 = m_0c^2\}$$

$$\Rightarrow \quad p = \frac{E}{c}\sqrt{1 - \left(\frac{E_0}{E}\right)^2} \simeq \frac{E}{c} \quad (\text{for } E \gg E_0)$$

$$\Rightarrow \quad \lambda = \frac{h}{p} \simeq \frac{hc}{E}$$

For a photon

$$E = h\nu = \frac{hc}{\lambda_\gamma}$$

$$\Rightarrow \quad \lambda_\gamma = \frac{hc}{E} \simeq \lambda$$

Hence, the correct answer is (A).

12. Energy of each lump before collision is

$$E = mc^2 = \frac{m_0c^2}{\sqrt{1 - \left(\frac{4}{5}\right)^2}} = \frac{5}{3}m_0c^2$$

The energy of composite lump after collision will be Mc^2.

By energy conservation principle we get

Total initial energy = Total final energy

$$\Rightarrow \frac{5}{3}m_0c^2 + \frac{5}{3}m_0c^2 = Mc^2$$

$$\Rightarrow M = \frac{10}{3}m_0$$

Hence, the correct answer is (A).

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

$$\Rightarrow r = \frac{2\times10^7}{1.76\times10^{11}\times2\times10^{-2}}$$

$$\Rightarrow r = 0.0055 \text{ m}$$

$$\Rightarrow D = 2r = 0.011 \text{ m}$$

$$\Rightarrow D = 1.1 \text{ cm}$$

Hence, the correct answer is (C).

14. $E_3 - E_2 = 13.6\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$

$$\Rightarrow \Delta E = \frac{13.6\times5}{36} = 1.89 \text{ eV}$$

Photoelectrons with K_{max} are moving on circular path, so

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

$$\Rightarrow mv = qBr$$

$$\Rightarrow p = qBr = 1.6\times10^{-19}\times\frac{1}{3200}\times10^{-3}$$

$$\Rightarrow p = \frac{1}{2}\times10^{-24} = 5\times10^{-25} \text{ kgms}^{-1}$$

Energy of photoelectron is $K_{max} = \frac{p^2}{2m}$

$$\Rightarrow K_{max} = \frac{25\times10^{-50}}{2\times9.1\times10^{-31}\times1.6\times10^{-19}} \text{ eV}$$

$$\Rightarrow K_{max} = 0.86 \text{ eV}$$

Now using Einstein equation, we get

$$h\nu = \phi + K_{max}$$

$$\Rightarrow 1.89 = 0.56 + \phi$$

$$\Rightarrow \phi = 1.03 \text{ eV}$$

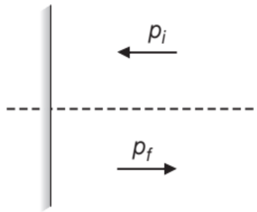
Hence, the correct answer is (A).

15. $F = \frac{I}{c}(\text{Effective Area})$

$$\Rightarrow F = \frac{I}{c}(\pi R^2) = \frac{\pi R^2 I}{c}$$

Hence, the correct answer is (A).

16.



Let $p = \frac{E}{c}$

$$\Rightarrow \Delta p = \frac{E}{c} - \left(-\frac{E}{c}\right) = \frac{2E}{c}$$

Hence, the correct answer is (B).

17. $\lambda = \frac{h}{\sqrt{2meV}}$

So, when V becomes 4 V, λ becomes $\frac{\lambda}{2}$

Hence, the correct answer is (C).

18. Energy of falling light

$$E = \frac{hc}{\lambda} = \frac{(4.14\times10^{-15})(3\times10^8)}{3\times10^{-7}}$$

$$\Rightarrow E = 4.14 \text{ eV}$$

So, electrons are emitted with a kinetic energy = 4.14 – 1 = 3.14 eV

$$\Rightarrow \frac{1}{2}mv^2 = 3.14\times1.6\times10^{-19}$$

$$\Rightarrow v = \sqrt{\frac{2\times3.14\times1.6\times10^{-19}}{9.1\times10^{-31}}}$$

$$\Rightarrow v = 1.2\times10^6 \text{ ms}^{-1}$$

Hence, the correct answer is (D).

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

$$\Rightarrow \lambda = \frac{h}{m\sqrt{\frac{2qV}{m}}} \qquad \left\{\because \frac{1}{2}mv^2 = \text{eV}\right\}$$

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

$$\Rightarrow \frac{\lambda_P}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_P q_P}} = 2\sqrt{2} \qquad \{\because m_\alpha = 4m_P, q_\alpha = 2q_P\}$$

Hence, the correct answer is (C).

20. $R \propto \frac{1}{\lambda}$ and $\lambda = \frac{h}{\sqrt{2mqV}} \propto \frac{1}{\sqrt{V}}$

$$\Rightarrow R \propto \sqrt{V}$$

$$\Rightarrow \frac{R_2}{R_1} = \sqrt{\frac{80 \text{ kV}}{20 \text{ kV}}} = 2$$

$\Rightarrow \quad R_2 = 2R_1 = 2R$

Hence, the correct answer is (B).

21. $A = \dfrac{N_1 A_1 + N_2 A_2}{N_1 + N_2}$

$\Rightarrow \quad 10.81 = \dfrac{N_1(10) + N_2(11)}{N_1 + N_2}$

Solving, we get

$$\frac{N_1}{N_2} = \frac{0.19}{0.81} = \frac{19}{81}$$

Hence, the correct answer is (A).

23. Since plate is in air, so gravitational force will act on this

$F_{\text{gravitational}} = mg$ {downward}

$\Rightarrow \quad F_{\text{gravitational}} = 10 \times 10^{-3} \times 10$

$\Rightarrow \quad F_{\text{gravitational}} = 10^{-1}$ N

for equilibrium force exerted by light beam should be equal to $F_{\text{gravitational}}$

$F_{\text{photon}} = F_{\text{gravitational}}$

If power of light beam be P, the photon force is

$F_{\text{photon}} = \dfrac{P}{c}$

$\Rightarrow \quad \dfrac{P}{c} = 10^{-1}$

$\Rightarrow \quad P = 3.0 \times 10^8 \times 10^{-1}$

$\Rightarrow \quad P = 3 \times 10^7$ W

Hence, the correct answer is (B).

24. For a photon $\lambda = \dfrac{h}{p} = \dfrac{hc}{E}$

For a particle of mass m moving with a velocity v de Broglie relationship is given by

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

Hence, the correct answer is (B).

25. $E = n\left(\dfrac{hc}{\lambda}\right)$

Also $\dfrac{1}{2}\varepsilon_0 E_0^2 = \dfrac{\text{Energy}}{\text{Volume}}$

$\Rightarrow \quad \text{Energy} = \left(\dfrac{1}{2}\varepsilon_0 E_0^2\right)(\text{Volume of cavity})$

$\Rightarrow \quad \text{Energy} = \left(\dfrac{1}{2}\varepsilon_0 E_0^2\right)(\text{Area}(c\Delta t))$

$\Rightarrow \quad n\dfrac{hc}{\lambda} = \dfrac{1}{2}\varepsilon_0 E_0^2 (Ac\Delta t)$

$\dfrac{n}{A\Delta t} = \dfrac{(\text{Number of photons striking the desk})}{(\text{Area})(\text{time})}$

$\Rightarrow \quad \dfrac{n}{A\Delta t} = N = \dfrac{\lambda}{2}\dfrac{\varepsilon_0 E_0^2}{h}$

Hence, the correct answer is (C).

27. $Kx_0 = \dfrac{I}{C}(\pi R^2)$

$\Rightarrow \quad x_0 = \dfrac{I}{KC}(\pi R^2)$

Hence, the correct answer is (B).

31. According to Einstein's Photoelectric Equation

$E_K = h\nu_0 - \phi$

$\Rightarrow \quad 0 = h\nu_0 - \phi$

$\Rightarrow \quad \phi = h\nu_0 = \dfrac{hc}{\lambda_0}$

$\Rightarrow \quad 4 \times 1.6 \times 10^{-19} = \dfrac{(6.626 \times 10^{-34})(3 \times 10^8)}{\lambda_0}$

$\Rightarrow \quad \lambda_0 \simeq 3100$ Å

Hence, the correct answer is (C).

35. Stopping potential of 1.36 V implies $E_K = 1.36$ eV.

Since $h\nu = \phi_0 + E_K$

$\Rightarrow \quad \dfrac{(4.14 \times 10^{-15})(3 \times 10^8)}{5000 \times 10^{-10}} = \phi_0 + 1.36$

$\Rightarrow \quad 2.46 = \phi_0 + 1.36$

$\Rightarrow \quad \phi_0 = 1.1$ eV

Hence, the correct answer is (C).

36. Stopping potential is independent of intensity and depends upon frequency.

Hence, the correct answer is (A).

37. Saturation current $\propto$ (Intensity)

$\Rightarrow$ Saturation current $= 4(0.4\ \mu A)$

$\Rightarrow$ Saturation current $= 1.6\ \mu A$

Hence, the correct answer is (C).

38. $\dfrac{1}{2}mv^2 = \dfrac{hc}{\lambda} - W$ ...(1)

$\dfrac{1}{2}mv'^2 = \dfrac{hc}{3\lambda/4} - W$ ...(2)

Dividing, $\left(\dfrac{v'}{v}\right)^2 = \dfrac{\dfrac{4hc}{3\lambda} - W}{\dfrac{hc}{\lambda} - W}$

$v' > v\sqrt{\frac{4}{3}}$

Hence, the correct answer is (D).

39. $\frac{1}{2}mv^2 = k_BT$

$v = \sqrt{\frac{2k_BT}{m}}$

$\Rightarrow \quad \lambda = \frac{h}{\sqrt{2mk_BT}}$

Hence, the correct answer is (B).

40. $\frac{1}{2}m_pv^2 = eV$

$\Rightarrow \quad v = \sqrt{\frac{2eV}{m_p}}$

Since, $\lambda = \frac{h}{m_pv}$

$\Rightarrow \quad \lambda = \frac{h}{\sqrt{2m_peV}}$

$\Rightarrow \quad \lambda = \frac{0.287}{\sqrt{V}}\text{Å}\left(\begin{array}{c}\text{is de-Broglie wavelength}\\\text{for a proton accelerated}\\\text{through a potential } V\end{array}\right)$

$\Rightarrow \quad \lambda = \frac{12.27}{\sqrt{V}}\text{Å}\left(\begin{array}{c}\text{is de-Broglie wavelength}\\\text{for an electron accelerated}\\\text{through a potential } V\end{array}\right)$

Hence, the correct answer is (B).

42. Number of photons per second entering human eye are

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

$\Rightarrow \quad n = \frac{10^{-10} \times 660 \times 10^{-9}}{6.63 \times 10^{-34} \times 3 \times 10^8} \times 10^{-4}$

$\Rightarrow \quad n = 3.31 \times 10^4$

Hence, the correct answer is (C).

45. The net force on the plate is due to incidence of photons + due to emission of electrons. The number of photons incidents per second on the plate = number of electrons emitted per second

$\Rightarrow \quad n = \frac{IS}{h\nu}$

The momentum of photon is $\frac{h}{\lambda}$ and that of electron is $\sqrt{2m(h\nu - \phi)}$ where m is the mass of the electron. Hence the net force exerted on the metal plate is

$F = \frac{IS}{h\nu}\left(\frac{h}{\lambda} + \sqrt{2m(h\nu - \phi)}\right)$

Hence, the correct answer is (B).

51. $P = \frac{nhc}{\lambda t}$

$\Rightarrow \quad 1.7 \times 10^{-18} = \frac{n \times 6.6 \times 10^{-34} \times 3 \times 10^8}{6000 \times 10^{-10} \times 1}$

$\Rightarrow \quad n = 5.15 \approx 5$

Hence, the correct answer is (B).

52. $\frac{(e/m_P)}{(2e/4m_P)} = 2$

Hence, the correct answer is (D).

53. According to Plank's Quantisation Law.

$E = nh\nu = n\left(\frac{hc}{\lambda}\right)$

$\Rightarrow \quad \frac{E}{t} = \left(\frac{n}{t}\right)\left(\frac{hc}{\lambda}\right)$

$\Rightarrow \quad 10^{-7} = \left(\frac{n}{t}\right)\frac{(6.626 \times 10^{-34})(3 \times 10^8)}{5000 \times 10^{-10}}$

$\Rightarrow \quad \frac{n}{t} = 2.5 \times 10^{11}$

Hence, the correct answer is (B).

55. $\frac{hc}{\lambda} = \phi_0 + 2.5$

$\frac{hc}{(\lambda/2)} = \phi_0 + E'_K$

$E'_K - 2.5 = \frac{hc}{\lambda}$

$E'_K = 2 \cdot 5 + 4 \cdot 14$

$E'_K = 6.64 \text{ eV}$

So, stopping potential is $6.64 \text{ V} > 5 \text{ V}$

Hence, the correct answer is (D).

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

If E is kinetic energy of electron, then

$E = \frac{1}{2}mv^2$

$\Rightarrow \quad v = \sqrt{\frac{2E}{m}}$

$\Rightarrow \quad \lambda = \frac{h}{\sqrt{2mE}}$

Hence, the correct answer is (B).

57. Energy of falling photon < Threshold energy. So, no photoelectric effect takes place.
Hence, the correct answer is (C).

58. Since $\lambda = \frac{h}{p}$

For identical p's, λ are identical
Hence, the correct answer is (D).

59. $h\nu = E_K + \phi$

$\Rightarrow \quad h\nu - \phi = \frac{1}{2}mv^2$

$\Rightarrow \quad v = \sqrt{\frac{2(h\nu - \phi)}{m}}$

$\Rightarrow \quad v = \sqrt{\frac{2(hc - \lambda\phi)}{m\lambda}}$

Hence, the correct answer is (C).

61. Stopping potential is 4 V. So, maximum K.E. is 4 eV.
Hence, the correct answer is (B).

62. Photoelectric current $\propto$ Intensity

$\Rightarrow \quad i \propto I$

$\Rightarrow \quad i = kI$

Hence, the correct answer is (C).

63. $\frac{1}{2}mv^2 = eV$

$\Rightarrow \quad v = \sqrt{\frac{2\,eV}{m}}$

Hence, the correct answer is (B).

64. Since $\Delta E \Delta t \ge h$

$\Rightarrow \quad \Delta E(10^{-8}) = 6.6 \times 10^{-34}$

$\Rightarrow \quad \Delta E = 6.6 \times 10^{-26}$ J

Hence, the correct answer is (A).

66. $I = \frac{Nh\nu}{A\Delta t} = \frac{N\left(\frac{hc}{\lambda}\right)}{\frac{1\text{ mm}}{c} \times 1\text{ mm}^2}$

$\Rightarrow \quad N = \frac{100 \times 10^{-9} \times 2640 \times 10^{-10}}{(3 \times 10^8)^2 \times 6.63 \times 10^{-34}}$

$\Rightarrow \quad N \simeq 442$ photons mm^{-3}

Hence, the correct answer is (C).

67. $F = \frac{I}{c}(\text{Effective Area})$

$\Rightarrow \quad F = \frac{I}{c}(\pi R^2) = \frac{\pi R^2 I}{c}$

Hence, the correct answer is (A).

68. Initial de-Broglie wavelength is

$$\lambda_1 = \frac{h}{mv_0}$$

At time t, we have

$$\vec{v} = v_0\hat{j} + \left(\frac{qE}{m}\right)t\hat{i}$$

$\Rightarrow \quad |\vec{v}| = \sqrt{v_0^2 + \frac{q^2E^2t^2}{m^2}}$

$\Rightarrow \quad \lambda_2 = \frac{h}{m|\vec{v}|} = \frac{h}{\sqrt{m^2v_0^2 + q^2E^2t^2}}$

Since $\lambda_2 = \frac{\lambda_1}{2}$

$\Rightarrow \quad \sqrt{m^2v_0^2 + q^2E^2t^2} = 2mv_0$

$\Rightarrow \quad 3m^2v_0^2 = q^2E^2t^2$

$\Rightarrow \quad t = \frac{\sqrt{3}mv_0}{qE}$

Hence, the correct answer is (C).

69. Speed of first electron may increase or decrease, depending on the direction of electric field. However in the case of electron entering the magnetic field speed remains constant. Since, from de-Broglie relation

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

$\Rightarrow \quad \lambda_1 > \lambda_2$ OR $\lambda_2 > \lambda_1$

are both the possibilities.
Hence, the correct answer is (D).

70. $\frac{h}{\lambda} = m_e v$

$\Rightarrow \quad \lambda = 3.64$ nm

Hence, the correct answer is (C).

71. $K_1 = \frac{hc}{\lambda_1} - W \quad \ldots(1)$

$K_2 = \frac{hc}{\lambda_2} - W \quad \ldots(2)$

Since, $\lambda_1 = 2\lambda_2$, so (1) becomes

$$K_1 = \frac{hc}{2\lambda_2} - W = \frac{1}{2}\left(\frac{hc}{\lambda_2}\right) - W$$

$\Rightarrow \quad K_1 = \frac{1}{2}(K_2 + W) - W$

$\Rightarrow \quad K_1 = \frac{K_2}{2} - \frac{W}{2}$

$\Rightarrow \quad K_1 < \frac{K_2}{2}$

Hence, the correct answer is (C).

72. Total energy radiated per minute from sun is

$$E_{\text{radiated}} = \sigma\left(4\pi R_{se}^2\right)$$

Energy radiated annually is given by

$$E_{\text{total}} = 24\times 60\times 365\times E_{\text{radiated}}$$

$$\Rightarrow \quad \text{Annual loss of mass} = \Delta m = \frac{E_{\text{total}}}{c^2} = 1.38\times 10^{17}\ \text{kg}$$

Hence, the correct answer is (C).

73. Since $v = \alpha c$ $\{\text{where } \alpha \ll 1\}$

the electron is moving at non-relativistic speed.
By Law of Conservation of Momentum

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

$$\Rightarrow \quad \frac{hc}{\lambda}+\frac{hc}{\lambda'} = mcv = \frac{mv^2}{\alpha} \qquad \ldots(1)$$

By Law of Conservation of Energy

$$\frac{1}{2}mv^2 = \frac{hc}{\lambda}-\frac{hc}{\lambda'} \qquad \ldots(2)$$

Adding (1) & (2), we get

$$2\frac{hc}{\lambda} = \frac{1}{2}mv^2 + \frac{1}{\alpha}\left(mv^2\right)$$

$$\Rightarrow \quad \frac{hc}{\lambda} = E_\gamma = \frac{mv^2}{4}+\frac{mv^2}{2\alpha}$$

Since, $\alpha \ll 1$

$$\Rightarrow \quad \frac{1}{\alpha} \gg 1$$

$$\Rightarrow \quad \frac{mv^2}{4} \ll \frac{mv^2}{2\alpha}$$

$$\Rightarrow \quad E_\gamma \simeq \frac{1}{\alpha}\left(\frac{mv^2}{2}\right)$$

$$\Rightarrow \quad \frac{1}{2}mv^2 = \alpha E_\gamma$$

Hence, the correct answer is (A).

74. Photons are exchange particles for electromagnetic interactions.
Gravitons are exchange particles for gravitational interactions.
Mesons are exchange particles for nuclear interactions.
Whereas protons are not any sort of exchange particles.
Hence, the correct answer is (C).

75. The maximum K.E. of ejected photoelectron is

$$(KE)_{\max} = h\nu - \phi_0$$

If the frequency of photon is doubled, maximum kinetic energy of photon electron becomes

$$(\text{KE})'_{\max} = 2h\nu - \phi_0$$

$$\Rightarrow \quad \frac{(\text{KE})'_{\max}}{(\text{KE})_{\max}} = \frac{2\left(h\nu - \frac{\phi_0}{2}\right)}{h\nu - \phi_0} > 2$$

$$\text{Photo current} \propto \frac{\text{intensity of beam}}{h\nu}$$

If intensity and frequency both are doubled, the photo-current remains same.
Hence, the correct answer is (C).

76. Relativistic relative velocity of approach is given by

$$\vec{v}_r = \frac{\vec{v}_1 - \vec{v}_2}{\left(1-\frac{\vec{v}_1\cdot\vec{v}_2}{c^2}\right)}$$

$$\Rightarrow \quad v_r = \frac{c-(-c)}{1-\frac{(c)(-c)}{c^2}}$$

$$\Rightarrow \quad v_r = \frac{2c}{1+\frac{c^2}{c^2}}$$

$$\Rightarrow \quad v_r = c$$

Never expect the relative velocity to grow beyond the speed of light.
Hence, the correct answer is (B).

77. By Law of Conservation of Momentum, we have

$$0 = mv_1 + 2m(-v_2)$$

$$\Rightarrow \quad mv_1 = 2mv_2 \qquad \ldots(1)$$

Now, according to de-Broglie relation, we have

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

$$\Rightarrow \quad \frac{\lambda_1}{\lambda_2} = \frac{p_2}{p_1} = 1$$

Hence, the correct answer is (C).

78. The vector is perpendicular to initial velocity vector at $t = \frac{u}{g\sin\theta}$ and at this instant its speed is

$$v = u\cot\theta$$

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

$$\Rightarrow \quad \lambda = \frac{h}{mu\cot\theta}$$

$$\Rightarrow \quad \lambda = \left(\frac{h}{mu}\right)\tan\theta$$

Hence, the correct answer is (C).

79. $F_{ex} = \frac{P}{c} = \frac{IA}{c}$

where $I = 1.4 \times 10^3\ \text{Wm}^{-2}$

$\Rightarrow\ A = 4\pi r^2 = 4 \times 3.14 \times (2)^2\ \text{m}^2$

$\Rightarrow\ F_{ex} = 2.35 \times 10^{-4}\ \text{N}$

Hence, the correct answer is (A).

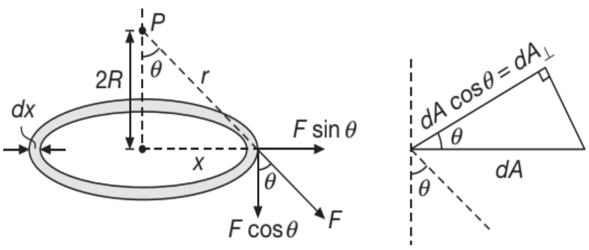
80. Number of photons striking per second are

$$n = \frac{IA}{h\nu}$$

where the area A is the area perpendicular to the direction of intensity or direction of energy flow.

Consider a ring of radius x and width dx on the disc.

Intensity I on the ring due to source is $I = \frac{P}{4\pi r^2}$



Since, $dA_\perp = dA\cos\theta$, where $dA = 2\pi x dx$

$\Rightarrow\ dA_\perp = (2\pi x dx)\cos\theta$

A photon will exert force F as shown. Only the $F\cos\theta$ component will remain whereas $F\sin\theta$ will cancel out as we integrate for the ring, where

$$F = \frac{nh}{\lambda}$$

Since only $F\cos\theta$ component of force remains, so

$$dF = \left(\frac{IdA_\perp}{h\nu}\right)\left(\frac{h}{\lambda}\cos\theta\right)$$

$$\Rightarrow\ \int_0^F dF = \int_0^R \left[\frac{P}{4\pi(4R^2 + x^2)}\right] \times \frac{(2\pi dx \cos\theta)}{\left(\frac{hc}{\lambda}\right)} \times \frac{h}{\lambda}\cos\theta$$

$$\left\{\because \text{As } r = \sqrt{4R^2 + x^2}\right\}$$

Solving we get $F = \frac{P}{20c}$

Hence, the correct answer is (D).

81. $\text{KE} = h\nu + \phi$ ...(1)

$2\text{KE} = h\nu' + \phi$ ...(2)

$\Rightarrow\ 2(h\nu + \phi) = h\nu' + \phi$

$\Rightarrow\ \nu' = 2\nu + \frac{\phi}{h}$

$\Rightarrow\ \nu' > 2\nu$

Hence, the correct answer is (C).

82. $\lambda = \frac{h}{mv}$ where,

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

As $v \to c$

$m \to \infty$

$\Rightarrow\ \lambda \to 0$

Hence, the correct answer is (C).

83. $E_K = h\nu - \phi_0$

$\Rightarrow\ (E_K)_1 = 1 - 0.5 = 0.5\ \text{eV}$

Similarly $(E_K)_2 = 2.5 - 0.5 = 2\ \text{eV}$

$\Rightarrow\ \frac{(E_K)_1}{(E_K)_2} = \frac{1}{4}$

$\Rightarrow\ \frac{v_1^2}{v_2^2} = \frac{1}{4}$

$\Rightarrow\ \frac{v_1}{v_2} = \frac{1}{2}$

Hence, the correct answer is (C).

84. Force $= \frac{2IA}{C}$

$\Rightarrow\ Fx = \left(\frac{1}{2}Kx^2\right) \times 3$

$\Rightarrow\ \left(\frac{2IA}{C}\right)x = \frac{3}{2}Kx^2$

$\Rightarrow\ x = \frac{4}{3}\left(\frac{IA}{KC}\right)$

Hence, the correct answer is (D).

85. $\text{K.E.} = E_K = h\nu - h\nu_0 = h\nu - \phi_0$

$\Rightarrow\ E_K = \frac{hc}{\lambda} - \phi_0$

$\Rightarrow\ E_K = \frac{(4.14 \times 10^{-15})(3 \times 10^8)}{2 \times 10^{-7}} - 5.01$

$\Rightarrow\ E_K = 6.21 - 5.01$

$\Rightarrow\ E_K = 1.2\ \text{eV}$

So, stopping potential required is 1.2 V

Hence, the correct answer is (A).

86. For two particles to have same de-Broglie wavelength

$$\sqrt{mqV} = \text{constant}$$

$$\Rightarrow m_P q_P V = m_\alpha q_\alpha V'$$

$$\Rightarrow V' = \frac{m_P}{m_\alpha}\frac{q_P}{q_\alpha} V$$

$$\Rightarrow V' = \frac{V}{8}$$

Hence, the correct answer is (D).

87. Under the given condition, energy of photon is made half the work function of the metal. Hence photo-emission shall stop altogether.
Hence, the correct answer is (A).

88. Energy of each photon,

$$E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{300\times10^{-9}}$$

$$E = 6.6\times10^{-19}\text{ J}$$

Power of source

$$P = IA = 1.0\times1.0\times10^{-4} = 10^{-4}\text{ watt}$$

So, number of photons per sec is

$$\frac{N}{t} = \frac{P}{E} = \frac{10^{-4}}{6.6\times10^{-19}}$$

Number of electrons emitted is

$$N' = \frac{1}{100}\times\frac{10^{-4}}{6.6\times10^{-19}}$$

$$\Rightarrow N' = 1.51\times10^{12}\text{ per second}$$

Hence, the correct answer is (C).

89. Transverse deflection is

$$y = \frac{1}{2}at^2 = \frac{1}{2}\left(\frac{qE}{m}\right)\left(\frac{x}{v}\right)^2 = \frac{\frac{1}{2}qEx^2}{mv^2}$$

$$\Rightarrow y = \frac{\frac{1}{2}qEx^2}{2\cdot\left(\frac{1}{2}mv^2\right)} = \frac{1}{4}\frac{qEx^2}{E_K}$$

For same electric field E, kinetic energy E_K and length x, $y \propto q$, q is smaller for proton, so y is smaller for proton. So proton's trajectory will be less curved than α-particle's trajectory.

Hence, the correct answer is (A).

91. $E_K = h\nu - h\nu_0$

$E_K \equiv y$, $\nu \equiv x$, $h\nu_0 = \text{constant}(k)$

$\Rightarrow y = hx - k$ (Equation of a straight line)

Hence, the correct answer is (D).

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

$$\Rightarrow \lambda = \frac{6.626\times10^{-34}}{(10^{-31})(10^{5})}$$

$$\Rightarrow \lambda = 6.63\times10^{-8}\text{ m}$$

Hence, the correct answer is (A).

95. $E_K = h\nu - h\nu_0$
is the equation of a straight line with slope h.
Hence, the correct answer is (D).

96. $E_K = h\nu - h\nu_0$

Hence, the correct answer is (A).

97. The time rate of change of momentum equals force.

$$\Rightarrow F = \frac{\Delta p}{\Delta t}$$

Force per unit area is pressure

$$\Rightarrow P = \frac{1}{A}\frac{\Delta p}{\Delta t}$$

But for a photon $E = pc$, where
p = momentum of photon
E = energy of photon

$$\Delta E = c\Delta p$$

$$\Rightarrow P = \frac{1}{Ac}\frac{\Delta E}{\Delta t} = \frac{1}{c}\left(\frac{\Delta E}{A\Delta t}\right) = \frac{1}{c}(I)$$

Because irradiance I is defined as energy per unit area per unit time.
Hence, the correct answer is (C).

98. $\lambda_e = \lambda_p$

$$\Rightarrow \frac{h}{mv} = \frac{hc}{E}$$

$$\Rightarrow \frac{p}{E} = \frac{1}{c}$$

Hence, the correct answer is (B).

99. Since, $K_{max} = h\nu - h\nu_0$

$$\Rightarrow K_{max} = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

$$\Rightarrow \frac{1}{\lambda_0} = \frac{1}{\lambda} - \frac{K_{max}}{hc}$$

This kinetic energy of ejected electron is converted to electrostatic potential energy, $\Delta U = eEd$, as electrons come to rest while moving in the direction of electric field. Therefore, $K_{max} = eEd$

and $\lambda_0 = \left(\frac{1}{\lambda} - \frac{eEd}{hc}\right)^{-1}$

Hence, the correct answer is (B).

100. $E = \frac{hc}{\lambda}$

Number of photons emitted is

$$\frac{Pt}{\left(\frac{hc}{\lambda}\right)} = n_0$$

$$\Rightarrow \quad n_0 = \frac{P\lambda t}{hc}$$

Since the radiation is spherically symmetric, so total number of photons entering the sensor is n_0 times the ratio of aperture area to the area of a sphere of radius ℓ.

$$\Rightarrow \quad N = n_0 \frac{\pi(2d)^2}{4\pi\ell^2} = \frac{P\lambda t}{hc}\frac{d^2}{\ell^2}$$

Hence, the correct answer is (A).

101. $\frac{hc}{\lambda} = \phi_0 + 3V_0$ ...(1)

$\frac{hc}{2\lambda} = \phi_0 + V_0$ ...(2)

Subtracting

$$2V_0 = \frac{hc}{2\lambda}$$

$$\Rightarrow \quad V_0 = \frac{hc}{4\lambda}$$

$$\Rightarrow \quad \phi_0 = \frac{hc}{4\lambda}$$

$$\Rightarrow \quad \frac{hc}{\lambda_0} = \frac{hc}{4\lambda}$$

$$\Rightarrow \quad \lambda_0 = 4\lambda$$

Hence, the correct answer is (C).

102. $p = \frac{hv}{c}$ (for a photon)

$$\Rightarrow \quad 3.3\times10^{-29} = \frac{6.6\times10^{-34}\,v}{3\times10^8}$$

$$\Rightarrow \quad v = 1.5\times10^{13} \text{ Hz}$$

Hence, the correct answer is (D).

103. Decreasing the λ of incident photon means energy of incident light is increased, so E_k increases and hence stopping potential increases.

Hence, the correct answer is (D).

104. $E_K = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$

$$E_K = \frac{4.14\times10^{-15}\times3\times10^8}{10^{-7}}\left(\frac{1}{5} - \frac{1}{6}\right)$$

$$\Rightarrow \quad E_K = 0.414 \text{ eV}$$

Wherever necessary we take $h = 6.626\times10^{-34}$ Js

$$\Rightarrow \quad h = 4.14\times10^{-15} \text{ eVs}$$

Hence, the correct answer is (B).

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

$$\Rightarrow \quad \frac{d\lambda}{dt} = \frac{h}{m}\frac{d}{dt}(v^{-1}) = \frac{h}{m}(-1)v^{-2}\frac{dv}{dt}$$

$$\Rightarrow \quad \frac{d\lambda}{dt} = -\frac{h}{mv^2}\cdot a$$

Also $v = u + at$

$\Rightarrow \quad v = at \qquad \{\because u = 0\}$

$$\Rightarrow \quad \frac{d\lambda}{dt} = -\frac{h}{ma^2t^2}\cdot a = -\frac{h}{mat^2}$$

Also $ma = eE$

$$\Rightarrow \quad \frac{d\lambda}{dt} = -\frac{h}{eEt^2}$$

Hence, the correct answer is (A).

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

Since electron is the lightest particle of these four. So λ_e is maximum.

Hence, the correct answer is (A).

107. We have

$\lambda_1 = 4100$ Å

$\lambda_2 = 4960$ Å

$\lambda_3 = 6200$ Å

$$\Rightarrow \quad E_1 = \frac{12400}{410} = 3 \text{ eV}$$

$$\Rightarrow \quad E_2 = \frac{12400}{4960} = 2.5 \text{ eV}$$

$$\Rightarrow \quad E_3 = \frac{12400}{6200} = 2 \text{ eV} < \phi_0$$

Hence only λ_1 and λ_2 can cause photoemission. Number of photons of wavelength λ_1 incident on the sodium surface in 1 sec is

$$n_1 = \frac{\frac{P}{3}}{E_1} = \frac{\frac{IA\cos\theta}{3}}{E_1} = \frac{\frac{144}{3}\times 10^{-4}\times\frac{1}{2}}{E_1} = \frac{2.4\times 10^{-3}}{E_1}$$

Similarly, $n_2 = \frac{P/3}{E_2} = \frac{2.4\times 10^{-3}}{E_2}$

So, total number of photoelectrons emitted in 1 sec is

$$n = n_1 + n_2$$

Photoelectric current is

$$I_P = (n_1 + n_2)e = 2.4\times 10^{-3}\left(\frac{1}{E_1} + \frac{1}{E_2}\right)e$$

$$\Rightarrow \quad I_P = 2.4\times 10^{-3}\left(\frac{1}{3} + \frac{1}{2.5}\right) A = \frac{44}{25}\text{ mA} = 1.76\text{ mA}$$

Hence, the correct answer is (A).

108. $I \propto \frac{1}{d^2}$

when d becomes $\frac{d}{4}$, I becomes $16I$

Hence, the correct answer is (D).

110. $hv = hv_0 + eV_0$

$$\Rightarrow \quad eV_0 = hv - hv_0$$

$$\Rightarrow \quad V_0 = \frac{h}{e}v - \frac{h}{e}v_0$$

which is again equation of a straight line with slope $\left(\frac{h}{e}\right)$.

Hence, the correct answer is (B).

112. 5% of 100 W is 5 Js^{-1}

$$\Rightarrow \quad 5 = \frac{n}{t}\left(\frac{hc}{\lambda}\right)$$

$$\Rightarrow \quad \frac{n}{t} = \frac{5\lambda}{hc}$$

$$\Rightarrow \quad \frac{n}{t} = \frac{5(5.6\times 10^{-7})}{6.626\times 10^{-34}\times 3\times 10^{8}}$$

$$\Rightarrow \quad \frac{n}{t} = 1.4\times 10^{19}$$

Hence, the correct answer is (A).

113. Since $\Delta x \Delta p \sim h$

$$\Rightarrow \quad (2\times 10^{-14})\Delta p = 6.6\times 10^{-34}$$

$$\Rightarrow \quad \Delta p = 3.3\times 10^{-20}\text{ kgms}^{-1}$$

Hence, the correct answer is (B).

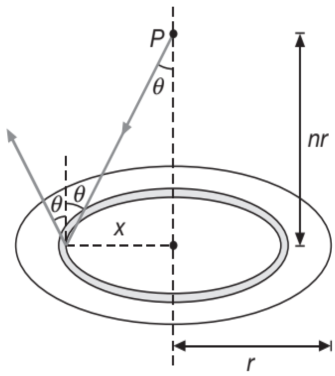
114. Consider a ring of radius x and width dx. Power incident on the ring

$$dP = \frac{P}{4\pi\left[(nr)^2 + x^2\right]}(2\pi x dx)\cos\theta$$

$$\Rightarrow \quad dP = \frac{(Pxdx)nr}{2\left[(nr)^2 + x^2\right]^{\frac{3}{2}}}$$

No. of photons falling (per unit time) on this area is

$$\frac{\lambda dP}{hc}$$



Momentum imparted due to one photon is

$$\Delta P = 2\left(\frac{h}{\lambda}\right)\cos\theta$$

So, force on the ring dF (in the downward direction) is

$$dF = \frac{\lambda dP}{hc}\left(\frac{2h}{\lambda}\cos\theta\right) = \frac{2dP\cos\theta}{c}$$

$$\Rightarrow \quad F = \int \frac{2Pxdxnr}{2\left[(nr)^2 + x^2\right]^{\frac{3}{2}}}\frac{\cos\theta}{c} = \frac{Pn^2r^2}{c}\int_0^r \frac{xdx}{(n^2r^2 + x^2)^2}$$

$$\Rightarrow \quad F = \frac{Pn^2r^2}{2c}\left[\frac{1}{n^2r^2(n^2+1)}\right] = \frac{P}{2c(n^2+1)}$$

Hence, the correct answer is (C).

115. $v_0 = 5\times 10^{14}$ Hz

Since, $c = v_0\lambda$

$$\Rightarrow \quad \lambda = \frac{3\times 10^{8}}{5\times 10^{14}}$$

$$\Rightarrow \quad \lambda = 6000\text{ Å}$$

Hence, the correct answer is (B).

116. Kinetic energy of recoil is

$$E_K = hv - hv'$$

$\Rightarrow \quad E_K = 12.375 - 9.375$

$\Rightarrow \quad E_K = 3 \text{ eV}$

Hence, the correct answer is (A).

117. $\lambda = \dfrac{h}{\sqrt{2meV}}$

Putting values of h, m, e, we get

$$\Rightarrow \quad \lambda = \sqrt{\frac{150}{V}} \text{ Å}$$

$$\Rightarrow \quad \lambda = \frac{12.27}{\sqrt{V}} \text{ Å}$$

Hence, the correct answer is (A).

118. $\dfrac{\lambda_e}{\lambda_P} = \sqrt{\dfrac{m_P q_P}{m_e q_e}} = \sqrt{\dfrac{m_P}{m_e}} \qquad \{\because q_e = q_P\}$

Hence, the correct answer is (D).

119. $\Delta x = \dfrac{2}{100} \text{ m}$

Since

$$\Delta x \Delta p = h$$

$$\Rightarrow \quad \Delta p = \frac{h}{\Delta x} = \frac{6.6 \times 10^{-34}}{(2/100)}$$

$$\Rightarrow \quad \Delta p = 3.3 \times 10^{-32} \text{ kgms}^{-1}$$

Hence, the correct answer is (A).

120. $\lambda = \dfrac{h}{\sqrt{2mE}}$

$\Rightarrow \quad mE = \text{constant}$

$m_e < m_P < m_\alpha$

$\Rightarrow \quad E_1 > E_3 > E_2$

Hence, the correct answer is (A).

121. Least detectable intensity for the eye is

$$I = (5 \times 10^4)\left(\frac{hc}{\lambda}\right)$$

$$\Rightarrow \quad I = (5 \times 10)\left(\frac{6.63 \times 10^{-34} \times 3 \times 10^8}{5 \times 10^{-7}}\right)$$

$$\Rightarrow \quad I = 1.99 \times 10^{-19} \text{ Wm}^{-2}$$

Thus, eye is more sensitive power detector.

Hence, the correct answer is (B).

122. $E = \dfrac{hc}{\lambda} - \phi \qquad \ldots(1)$

$2E = \dfrac{hc}{\lambda'} - \phi \qquad \ldots(2)$

$$\Rightarrow \quad 2E - E = hc\left[\frac{1}{\lambda'} - \frac{1}{\lambda}\right] = E$$

$$\Rightarrow \quad E + \frac{hc}{\lambda} = \frac{hc}{\lambda'}$$

$$\Rightarrow \quad \frac{E\lambda + hc}{\lambda} = \frac{hc}{\lambda'}$$

$$\Rightarrow \quad \lambda' = \left(\frac{hc\lambda}{E\lambda + hc}\right)$$

Hence, the correct answer is (B).

123. In order for scattering to occur, the wavelength of the waves must be of the same order of magnitude or smaller than the size of the object being observed. Hence the largest possible wavelength we can use in the present problem is $\lambda_{max} = 2.5$ Å. Hence minimum energy is

$$E_{min} = \frac{hc}{\lambda_{max}}$$

$$\Rightarrow \quad E_{min} = \frac{12.40 \times 10^3}{2.5 \text{ Å}} \text{eVÅ}$$

$$\Rightarrow \quad E_{min} = 4.96 \times 10^3 \text{ eV}$$

$$\Rightarrow \quad E_{min} = 5 \text{ keV}$$

Hence, the correct answer is (A).

124. $mc^2 = m_0 L$

$$(1)(3 \times 10^8)^2 = m_0 (80 \times 4200)$$

$$\Rightarrow \quad m_0 = 2.67 \times 10^{11} \text{ kg}$$

Hence, the correct answer is (A).

125. Density of star of mass M_0, radius R_0 is

$$\rho = \frac{M_0}{\frac{4}{3}\pi R_0^3}$$

On contracting the new mass becomes

$$M = \frac{4}{3}\pi R^3 \rho = M_0\left(\frac{R}{R_0}\right)^3$$

Loss in mass due to contraction $= -\Delta M$

$\Rightarrow \quad \text{Loss} = M_0 - M$

$\Rightarrow \quad \text{Energy radiated} = c^2 \Delta M$

Hence, the correct answer is (D).

126. $F = \dfrac{\Delta p}{\Delta t} = \dfrac{n}{\Delta t}\left[\dfrac{h}{\lambda} - \left(-\dfrac{h}{\lambda}\right)\right] = N\left(\dfrac{2h}{\lambda}\right)$

{∵ Photons rebound with the same initial value of momentum}

So, total number of photons striking the totally reflecting screen is

$$N = \frac{F}{\left(\frac{2h}{\lambda}\right)} = \frac{F\lambda}{2h}$$

$\Rightarrow \quad N = 5\times10^{26}$

Hence, the correct answer is (D).

127. $\sqrt{2mE} = \frac{h}{\lambda}$

$$\Rightarrow \quad E = \frac{h^2}{2m\lambda^2} = \frac{(6.6\times10^{-34})^2}{2\times20\times1.66\times10^{-27}\times(6.6\times10^{-10})^2}$$

$$\Rightarrow \quad E = \frac{10^{-48+27}}{40\times1.66} = \frac{1}{4\times1.66}\times10^{-22}\text{ J}$$

$\Rightarrow \quad E = 1.5\times10^{-23}$ J

Hence, the correct answer is (A).

128. $\frac{2nh}{\lambda} = 1$

$\Rightarrow \quad n = \frac{\lambda}{2h}$

Hence, the correct answer is (C).

129. Since, $\frac{hc}{\lambda} = \frac{1}{2}mv^2 + \phi$

$\Rightarrow \quad \phi = \frac{hc}{\lambda} - \frac{1}{2}mv^2$

$\Rightarrow \quad \phi = \frac{1240}{400} - 1.68 = 1.41$ eV

Hence, the correct answer is (B).

130. Both are independent of each other.

Hence, the correct answer is (A).

131. For a photon

$E = pc = h\nu$

$\Rightarrow \quad p = \frac{h\nu}{c}$

Hence, the correct answer is (B).

133. Potential of the sphere at any time is

$$V(t) = \frac{Q_0 + Qt}{4\pi\varepsilon_0 R} = V + \frac{\eta\lambda Pet}{4\pi\varepsilon_0 Rhc}$$

Here we have used, $Qt = \frac{P\lambda}{hc}\eta et$

Hence, the correct answer is (B).

135. $S_e = \frac{e}{m_e}$

$S_p = \frac{e}{m_p}$

$S_\alpha = \frac{2e}{4m_p} = \frac{e}{2m_p} = \frac{1}{2}s_p$

S_e is maximum, then comes S_p and then S_α

Hence, the correct answer is (A).

136. $I \propto \frac{1}{d^2}$

On doubling the distance the intensity becomes one fourth i.e. only one fourth of photons now strike the target in comparison to the previous number. Since photoelectric effect is a one photon-one electron phenomena, so only one-fourth photoelectrons are emitted out of the target hence reducing the current to one fourth the previous value.

Hence, the correct answer is (D).

137. The radiation pressure depend on the intensity of light used and not on its wavelength and frequency. Also, the radiation pressure depends on the nature of the surface on which light is falling. Hence (B).

Hence, the correct answer is (B).

138. Let threshold frequency be ν_0.

$\nu = 1.5\,\nu_0$

When the new frequency is halved

$\nu' = 0.75\nu_0 < \nu_0$

So, no photoelectric effect takes place.

Hence, the correct answer is (D).

139. $\frac{\lambda_P}{\lambda_\alpha} = \frac{m_\alpha v_\alpha}{m_P v_P}$

$\Rightarrow \quad \frac{1}{2} = 4\frac{v_\alpha}{v_P}$

$\Rightarrow \quad \frac{v_P}{v_\alpha} = 8$

Hence, the correct answer is (D).

140. $y = \frac{1}{2}at^2 = \frac{1}{2}\frac{eE}{m}\frac{l^2}{v^2}$

For same (nearly) circular path y is same

$\Rightarrow \quad \frac{E}{v^2} = \text{constant}$

CHAPTER 1

Here $E = x$

$$\Rightarrow \frac{x}{v^2} = \frac{x'}{(2v)^2}$$

$$\Rightarrow x' = 4x$$

Hence, the correct answer is (C).

142. Given that $\frac{h}{p} = \frac{hc}{E} = \frac{h}{mv}$

$$\Rightarrow E = mvc$$

$$\Rightarrow \frac{E_e}{E_p} = \frac{\frac{1}{2}mv^2}{mvc} = \frac{v}{2c}$$

Hence, the correct answer is (B).

143. $\lambda_{max} = 7500$ Å

So, $E = \frac{hc}{\lambda}$

$$\Rightarrow E = \frac{(4.14\times10^{-15}\text{ eVs})(3\times10^8\text{ ms}^{-1})}{7500\times10^{-10}\text{ m}}$$

$$\Rightarrow E = 1.6\text{ eV}$$

Hence, the correct answer is (B).

145. $eV_s = KE_{max} = h\nu - W$

$$V_s = \frac{hc}{e\lambda} - \frac{W}{e} \qquad \{\because W = \text{work function}\}$$

Hence, the correct answer is (B).

146. Change in momentum due to photon $= \frac{h}{\lambda}$

$F =$ rate of change of momentum

$$\Rightarrow F = n\frac{h}{\lambda} = ma$$

$$\Rightarrow a = \frac{nh}{\lambda m}$$

Hence, the correct answer is (B).

147. $E = nh\nu$

$$\Rightarrow \frac{E}{t} = \left(\frac{n}{t}\right)h\nu$$

$$\Rightarrow 10000 = \frac{n}{t}(6.6\times10^{-34})(880\times1000)$$

$$\Rightarrow \frac{n}{t} = 1.71\times10^{31}$$

Hence, the correct answer is (A).

148. Maximum microwave frequency $= 3\times10^{11}$ Hz

Since, $p = \frac{E}{c} = \frac{h\nu}{c}$

$$\Rightarrow p_{max} = \frac{(6.626\times10^{-34})(3\times10^{11})}{(3\times10^8)}$$

$$\Rightarrow p_{max} = 6.626\times10^{-31}\text{ kgms}^{-1}$$

Hence, the correct answer is (C).

149. $\lambda = \frac{h}{mv} = \frac{6.62\times10^{-34}}{9.1\times10^{-31}\times3\times10^7}$

$$\Rightarrow \lambda = 0.24\times10^{-10}\text{ m}$$

Hence, the correct answer is (C).

150. $(m - m_0)c^2 = 2m_0c^2$

$$\Rightarrow m = 3m_0$$

Hence, the correct answer is (C).

152. Stopping potential = 1 V

$$\Rightarrow E_K = 1\text{ eV}$$

$$\Rightarrow \frac{1}{2}mv^2 = 1.6\times10^{-19}\text{ J}$$

Hence, the correct answer is (C).

153. The energy of incident photons is given by

$$h\nu = eV_s + \phi_0 = 2 + 5 = 7\text{ eV}$$

(V_s is stopping potential and ϕ_0 is work function)

$$\Rightarrow \text{Saturation current} = 10^{-5}\text{ A} = \frac{\eta P}{h\nu}e = \frac{10^{-5}P}{7\times e}e$$

$$\Rightarrow P = 7\text{ W}$$

Hence, the correct answer is (C).

154. $E_1 = \frac{1240}{550} = 2.25$ eV

$E_2 = \frac{12400}{450} = 2.75$ eV

$E_3 = \frac{1240}{350} = 3.54$ eV

E_1 cannot emit photoelectrons from q and r plates.

E_2 cannot emit photoelectrons from r.

Further, work function of p is least and it can emit photoelectrons from all three wavelengths. Hence magnitude of its stopping potential and saturation current both will be maximum.

Hence, the correct answer is (A).

155. $E = \frac{1}{2} k_B T$

at $T = 300$ K

$\Rightarrow \quad E = \frac{1}{2}(1.38 \times 10^{-23})(300)$

$\Rightarrow \quad E = \frac{1}{2} \frac{(1.38 \times 10^{-23})(300)\text{eV}}{1.6 \times 10^{-19}}$

$\Rightarrow \quad E \simeq 0.01$ eV

Hence, the correct answer is (D).

156. $v = \sqrt{\frac{2qV}{m}}$

Hence, the correct answer is (D).

Multiple Correct Choice Type Questions

1. $\frac{hc}{\lambda} = \phi_0 + K_{\max}$

$\Rightarrow \quad \frac{hc}{4000} = (1.9 + 1)$ eV $= 2.9$ eV

$\Rightarrow \quad hc = (4000)(2.9) = 11600$ eVÅ

Now, for $\lambda = 500$ nm $= 5000$ Å, we have

$$\frac{11600}{5000} = 1.9 + K_{\max}$$

$\Rightarrow \quad 2.32 = 1.9 + K_{\max}$

$\Rightarrow \quad K_{\max} = 0.42$ eV

The longest wavelength which will eject photoelectrons is given by

$$\lambda_{\max} = \frac{hc}{\phi_0} = \frac{11600}{1.9} = 6105 \text{ Å}$$

$\Rightarrow \quad \lambda_{\max} \approx 6100$ Å

Hence, (A) and (C) are correct.

2. Since $P = \frac{I}{c} = 10^4$ Nm^{-2}

$\Rightarrow \quad P = \frac{F}{A} = \frac{1}{A}\frac{\Delta p}{\Delta t}$

$\Rightarrow \quad \Delta p = P A \Delta t = 10^{-5}$ kgms^{-1}

Hence, (B) and (D) are correct.

3. The total quantity of charge carried by one pulse of current is

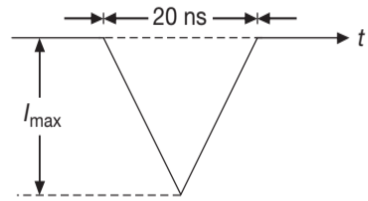
$$Q = \int I dt$$

which is the area of the triangle in figure. Thus

$$Q = \frac{1}{2}(20 \times 10^{-9})(80 \times 10^{-6}) = 8 \times 10^{-13} \text{ C}$$

and the number of electrons carried by one pulse is

$$n = \frac{Q}{e}$$



$\Rightarrow \quad n = \frac{8 \times 10^{-13}}{1.6 \times 10^{-19}} = 5 \times 10^6$

Then the number of photoelectrons emitted per light pulse is

$$n' = \frac{n}{10^6} = 5$$

and hence the number of photons in one light pulse is

$$N = \frac{n'}{0.1} = 50$$

Hence, (A), (B) and (C) are correct.

9. According to Heisenberg's Uncertainty Principle the product of

(a) uncertainty in position and uncertainty in momentum cannot be greater than $\frac{h}{4\pi}$.

(b) uncertainty in energy and uncertainty in time cannot be greater than $\frac{h}{4\pi}$.

(c) uncertainty in angular position and uncertainty in angular momentum cannot be greater than $\frac{h}{4\pi}$.

(d) uncertainty in generalised coordinate and generalised momentum cannot be greater than $\frac{h}{4\pi}$.

Hence, (A), (B), (C) and (D) are correct.

11. Wavelength of UV radiation is less than 5200 Å whereas wavelength for IR radiation is greater than 5200 Å. Hence photoelectric effect will be shown by UV radiation irrespective of its intensity.

Hence, (A) and (B) are correct.

14. For a photon

$$pc = h\nu$$

CHAPTER 1

$\Rightarrow \quad p = \dfrac{h\nu}{c}$

$\Rightarrow \quad p = 8.8 \times 10^{-28}\ \text{kgms}^{-2}$

$\Rightarrow \quad p = 1.65 \times 10^{-6}\ \text{MeV/c}$

Hence, (B) and (C) are correct.

16. (A) $f = \dfrac{c}{\lambda} = \dfrac{3 \times 10^8}{600 \times 10^{-9}} = 5 \times 10^{-14}$

(B) $N = \dfrac{p}{hf}$

(C) $KE_{max} = \dfrac{1240}{600} - 1.07 = 1$

(D) KE_{max} depends upon frequency of incident photons and not distance of source.

Hence, (A), (B) and (C) are correct.

17. Since, saturation current i is proportional to the number of photoelectrons ejected per second (n) from the metal surface. Further, we know that (n) is proportional to $\dfrac{I}{h\nu}$. So, when frequency and intensity (I) both are doubled, then saturation photocurrent remains almost the same.
Also, we know that

$$\frac{1}{2}mv^2 = eV_S = h(\nu - \nu_0)$$

When the frequency is doubled, then

$$h(2\nu - \nu_0) > h(\nu - \nu_0)$$

Hence, $\dfrac{1}{2}mv^2$ and eV_S become more than double.

Hence, (A) and (D) are correct.

19. $\lambda_{red} > \lambda_{violet}$

VIBGYOR pattern shows that VIBG all have λ less than that of yellow colour and hence can initiate photoelectric effect irrespective of intensity.
Hence, (B) and (D) are correct.

20. $K_{max} = 4 \times 10^{-19}\ \text{J} = \dfrac{4 \times 10^{-19}}{1.6 \times 10^{-19}} = 2.5\ \text{eV}$

$\Rightarrow$ Stopping potential $= 2.5\ \text{eV}$

Since, $K_{max} = hc\left(\dfrac{1}{\lambda} - \dfrac{1}{\lambda_0}\right)$

$\Rightarrow \quad 2.5 = \dfrac{1240}{300} - \dfrac{1240}{\lambda_0}$

$\Rightarrow \quad \lambda_0 = 759\ \text{nm}$

Hence, (A) and (B) are correct.

22. $K_{max} = 1.5\ \text{eV}$

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

$\Rightarrow \quad \lambda = 1\ \text{nm}$

E of incident photon $= \dfrac{1241}{496} \simeq 2.5\ \text{eV}$

$\Rightarrow \quad \phi = 2.5 - 1.5 = 1\ \text{eV}$

Since, $qvB = \dfrac{mv^2}{r}$

$\Rightarrow \quad B = \dfrac{mv}{qr} = \sqrt{\dfrac{2mK_{max}}{qr}}$

$\Rightarrow \quad B = \dfrac{\sqrt{2 \times 9.1 \times 10^{-31} \times e \times 1.5}}{e \times 1}$

$\Rightarrow \quad B = \sqrt{\dfrac{3 \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19}}}$

$\Rightarrow \quad B = 4.13 \times 10^{-6}\ \text{T} \cong 4\ \mu\text{T}$

X-rays are of order of $0.1\ \text{nm} \simeq 12.4\ \text{KeV}$

Hence, (A) and (C) are correct.

24. Energy of photon incident

$$h\nu = \frac{12400}{4000}\ \text{eV}$$

$\Rightarrow \quad h\nu = 3.1\ \text{eV}$

Since, $h\nu <$ work function of all metals
Hence no electron will come out

If $\lambda = 200\ \text{nm}$

then $h\nu = \dfrac{hc}{\lambda} = \dfrac{12400}{2000} = 6.2\ \text{eV}$

Since, $6.2\ \text{eV} >$ work function of all metals, hence photoelectron will be emitted.
Hence, (B) and (D) are correct.

25. More current means more number of photoelectrons, so better is the photosensitive material. Also, more stopping potential means less energy is used in work function.
Hence, (A) and (D) are correct.

26. Work function is the intercept on K-axis i.e. 2 eV
Hence, the correct answer is (C).

27. $2 = 4.14 \times 10^{-15} v$

$\Rightarrow \quad v = 4.8 \times 10^{14}$ Hz

Hence, the correct answer is (A).

29. Photoelectric effect and Compton effect are explained on particle nature of light i.e. light is considered to be made up of a stream of photons.
Hence, (A) and (B) are correct.

Reasoning Based Questions

6. $\lambda = \frac{h}{p}$, Same for both

Hence, the correct answer is (D).

8. Kinetic energy; $E = \frac{1}{2}mv^2 = qV$

$\Rightarrow \quad v \propto \sqrt{\frac{q}{m}}$ because V is constant

$\Rightarrow \quad v_p : v_d : v_\alpha = \sqrt{\frac{q_p}{m_p}} : \sqrt{\frac{q_d}{m_d}} : \sqrt{\frac{q_\alpha}{m_\alpha}}$

$\Rightarrow \quad v_p : v_d : v_\alpha = \sqrt{\frac{e}{m}} : \sqrt{\frac{e}{2m}} : \sqrt{\frac{2e}{4m}}$

$\Rightarrow \quad v_p : v_d : v_\alpha = 1 : \frac{1}{\sqrt{2}} : \frac{1}{\sqrt{2}} = \sqrt{2} : 1 : 1$

Hence, the correct answer is (D).

13. Energy of photoelectron emitted is different because after absorbing the photon electrons within metals collide with other atom before being ejected out of metal.
Hence, the correct answer is (A).

14. $\frac{\lambda_e}{\lambda_{ph}} = \sqrt{\frac{E}{2m_e c^2}} = \sqrt{\frac{10^6 eV}{1MeV}} = 1$

Hence, the correct answer is (A).

15. $m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$

$\Rightarrow \quad 2m_0 = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$

$\Rightarrow \quad v = \frac{\sqrt{3}}{2}c$

Hence, the correct answer is (A).

16. $K_{\max} = hv = \phi$

KE of emitted photoelectrons varies from zero to $K_{\max}$
Hence, the correct answer is (D).

17. $\lambda = \frac{12.27}{\sqrt{V}}$ Å

Hence, the correct answer is (D).

Linked Comprehension Type Questions

1. Since, $K_{\max} = \frac{hc}{\lambda} - \frac{hc}{\lambda_{th}}$

$\Rightarrow \quad \frac{1}{2}mv^2_{\max_1} = \frac{hc}{\lambda_1} - \frac{hc}{\lambda_{th}}$ ...(1)

$\frac{1}{2}mv^2_{\max_2} = \frac{hc}{\lambda_2} - \frac{hc}{\lambda_{th}}$ ...(2)

Dividing (2) by (1), we get

$$\left(\frac{v_{\max_2}}{v_{\max_1}}\right)^2 = \frac{\frac{hc}{\lambda_2} - \frac{hc}{\lambda_{th}}}{\frac{hc}{\lambda_1} - \frac{hc}{\lambda_{th}}}$$

$$\Rightarrow \quad (2)^2 = \frac{\frac{1}{1500} - \frac{1}{\lambda_{th}}}{\frac{1}{3000} - \frac{1}{\lambda_{th}}}$$

$$\Rightarrow \quad \frac{4}{3000} - \frac{4}{\lambda_{th}} = \frac{1}{1500} - \frac{1}{\lambda_{th}}$$

$$\Rightarrow \quad \frac{4}{3000} - \frac{1 \times 2}{1500 \times 2} = \frac{3}{\lambda_{th}}$$

$$\Rightarrow \quad \frac{2}{3000} = \frac{3}{\lambda_{th}}$$

$\Rightarrow \quad \lambda_{\text{th}} = 4500$ Å

Hence, the correct answer is (C).

2. $I_s \propto P\lambda$

$\Rightarrow \quad \frac{I_{s_2}}{I_{s_1}} = \frac{P_2\lambda_2}{P_1\lambda_1}$

$\Rightarrow \quad \frac{I_{s_2}}{20} = \frac{5 \times 1500}{1 \times 3000}$

$\Rightarrow \quad I_{s_2} = 50\ \mu$A

Hence, the correct answer is (A).

3. For CASE-1, we have

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

Since, $n_e = \frac{I_s}{e}$

Efficiency of photoelectron generation per incident photon is

$$\eta = \left(\frac{n_e}{n} \times 100\%\right) = \frac{I_s \times hc}{e \times P\lambda} \times 100$$

$$\Rightarrow \quad \eta = \frac{20 \times 10^{-6} \times 6.6 \times 10^{-34} \times 3 \times 10^{8} \times 100}{1.6 \times 10^{-19} \times 1 \times 10^{-3} \times 3000 \times 10^{-10}}$$

$$\Rightarrow \quad \eta = \left(\frac{20}{160}\right)\left(\frac{66}{10}\right) = \frac{66}{8} = 8.25\%$$

Hence, the correct answer is (B).

4. $$\frac{mv^2}{r} = qvB$$

$$\Rightarrow \quad \sqrt{2mE_K} = qBr$$

$$\Rightarrow \quad E_K = \frac{(qBr)^2}{2m}$$

$$\Rightarrow \quad E_K = 0.86 \text{ eV}$$

Hence, the correct answer is (C).

5. $$E_3 - E_2 = 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\Rightarrow \quad \Delta E = 1.89 \text{ eV}$$

Since, $\phi = E - K_{max}$

$$\Rightarrow \quad \phi = 1.89 - 0.86 = 1.03 \text{ eV}$$

Hence, the correct answer is (B).

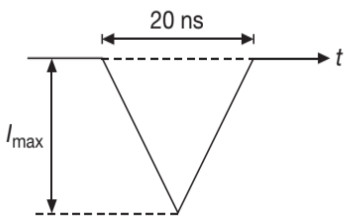
6. $$\lambda = \frac{hc}{\Delta E}$$

$$\Rightarrow \quad \lambda \simeq 6565 \text{ Å}$$

Hence, the correct answer is (A).

7. The total quantity of charge carried by one pulse of current is

$$Q = \int I dt$$



Since Q is the area under the current time graph, so the area of the triangle in Figure equals the charge flowing Q, given by

$$Q = \frac{1}{2} \times 20 \times 10^{-9} \times 80 \times 10^{-6} = 8 \times 10^{-13} \text{ C}$$

and the number of electrons carried by one pulse is

$$N = \frac{Q}{e} = \frac{8 \times 10^{-13}}{1.6 \times 10^{-19}} = 5 \times 10^{6}$$

The number of photoelectrons emitted per light pulse is

$$n' = \frac{N}{10^6} = 5$$

and hence the number of photons N' in one light pulse is

$$N' = \frac{N}{0.1} = 50$$

Hence, the correct answer is (C).

8. The probability that all the photons of a light pulse will go undetected is

$$\left(\frac{90}{100}\right)^N = (0.9)^{50} = 5.15 \times 10^{-3} = 0.52\%$$

N is the number of photons in one light pulse

Hence, the correct answer is (C).

9. In each pulse there is a finite probability for a certain number of photons not being detected. Thus, number of photons detected will vary from pulse to pulse. So, the maximum current I_{max} will fluctuate about a mean value. The greater the number of photons in a pulse, the smaller will be the fluctuation.

Hence, the correct answer is (A).

10. $$\lambda \propto \frac{1}{\sqrt{mq}}$$

Hence, the correct answer is (B).

11. $$\lambda_e = \frac{12.27}{\sqrt{V}} \text{ Å}$$

Hence, the correct answer is (A).

12. Since, $\lambda = \dfrac{h}{p}$

Further, $p_{electron} = p_{alpha}$

$\Rightarrow$ Wavelength will be same

Hence, the correct answer is (C).

13. Energy of photon, $E = \dfrac{hc}{\lambda}$

$$\Rightarrow \quad \frac{hc}{\lambda} = \frac{12400}{3100} = 4 \text{ eV}$$

For photo-electric effect, $E > \phi_0$

Since, 4 eV is greater than 2.5 eV and 3.5 eV, so electrons will be emitted from A and B.

Hence, the correct answer is (B).

14. The wavelength of light, which can emit electrons from D will also be able to emit electrons from A, B and C. So, for D

$$\lambda_0 = \frac{hc}{\phi_0} = \frac{12400}{5.5} = 2255 \text{ Å}$$

Hence, the correct answer is (D).

15. $\lambda = \dfrac{h}{mv} = \dfrac{6.63\times10^{-3}}{(66.3\times10^{-3})(5)}$

$\Rightarrow \quad \lambda = 0.02 \text{ m}$

Hence, the correct answer is (B).

16. Fringe width β is given by

$$\beta = \frac{\lambda D}{d} = \frac{12\times0.02}{0.6}$$

$\Rightarrow \quad \beta = 0.4 \text{ m}$

Hence, the correct answer is (D).

17. de-Broglie wavelength of electron is

$$\lambda = \frac{6.63\times10^{-3}}{9.1\times10^{-31}\times10^{7}}$$

$\Rightarrow \quad \lambda \approx 10^{21} \text{ m}$

Fringe width $\beta = \dfrac{\lambda D}{d} \approx \left(\dfrac{12}{0.6}\right)\times10^{21} \approx 10^{22} \text{ m}$

Fringe width is so large that it is not possible to observe it.
Hence, the correct answer is (D).

18. The intensity of electromagnetic radiation is

$$I = \frac{\text{Energy}}{A\times t} = \frac{10\times10^3}{10^{-3}\times10^{-4}\times10^{-9}}$$

$\Rightarrow \quad I = 10^{20} \text{ Wm}^{-2}$

Also, we know that for an electromagnetic wave, the intensity I is given by

$$I = \left(\frac{1}{2}\varepsilon_0 E^2\right)c = 10^{20}$$

where E is the rms value of the electric field.

$$\Rightarrow \quad E = \sqrt{\frac{2I}{\varepsilon_0 c}} = \sqrt{\frac{2\times10^{20}}{8.85\times10^{-12}\times3\times10^8}}$$

$\Rightarrow \quad E = 1.94\times10^{11} \text{ Vm}^{-1}$

Peak value of electric field is

$$E_0 = \sqrt{2}E = 2.75\times10^{11} \text{ Vm}^{-1}$$

Hence, the correct answer is (A).

19. Radiation pressure is

$$P_R = \frac{I}{c} = \frac{10^{20}}{3\times10^8} = 3.33\times10^{11} \text{ Nm}^{-2}$$

Hence, the correct answer is (A).

20. As all the absorbed energy is convert into the kinetic energy of thermal motion of hydrogen atoms, so we have

$$KE = \frac{3}{2}NK_BT$$

where N is the number of hydrogen atoms involved and K_B is the Boltzmann's constant.
Considering the hydrogen atoms as an ideal gas, we have,

$$PV = NK_BT$$

So, the pressure is given by

$$P = \frac{NK_BT}{V} = \frac{2}{3}\left(\frac{KE}{V}\right)$$

$$P = \frac{2}{3}(KE)\left(\frac{4}{3}\pi R^3\right)^{-1}$$

Since the radius R of the sphere is related to the area A of the focal spot, so we have

$$\pi R^2 = A$$

$$\Rightarrow \quad P = \frac{KE}{2\pi}\left(\frac{\pi}{A}\right)^{\frac{3}{2}}$$

Since $KE = 10^4$ J, $A = 10^{-7}$ m^2, we get

$$P = 2.8\times10^{14} \text{ pascal}$$

$\Rightarrow \quad P = 280\times10^{12}$ pascal

$\Rightarrow \quad P = 280$ Tera Pascal

Hence, the correct answer is (A).

21. $\lambda = \dfrac{h}{\sqrt{2mE}} = \sqrt{\dfrac{150}{1.5}} = 10 \text{ Å} = 100 \text{ nm}$

Hence, the correct answer is (B).

22. $qvB = \dfrac{mv^2}{r}$

$\Rightarrow \quad B = \dfrac{mv}{qr} = 4.1\times10^{-6} \text{ T}$

Hence, the correct answer is (A).

23. Photon energy $= \dfrac{hc}{\lambda} = \dfrac{12375}{4960} = 2.5 \text{ eV}$

Since, $V_s = 1.5$ V

So, work function is given by

$$\phi = 2.5 - 1.5 = 1 \text{ eV}$$

$$\Rightarrow \lambda_{min} = \frac{12375}{1} = 12375 \text{ Å} = 1237 \text{ nm}$$

$$\Rightarrow \lambda_{min} \cong 1250 \text{ nm}$$

Hence, the correct answer is (A).

24. $E = \dfrac{hc}{\lambda}$

$$\Rightarrow \lambda = \frac{hc}{E} = \frac{12400}{2.5} = 4960 \text{ Å}$$

$$\Rightarrow \lambda \approx 5000 \text{ Å}$$

Hence, the correct answer is (A).

25. Kinetic energy of the emitted photoelectron is given by applying Einstein's photoelectric equation, according to which

$$E = \phi_0 + K_{max}$$

$$\Rightarrow K_{max} = (2.5 - 2) \text{ eV} = 0.5 \text{ eV}$$

$$\Rightarrow K_{max} = 0.5 \text{ eV} = (0.5)(1.6 \times 10^{-19}) \text{ joule}$$

$$\Rightarrow K_{max} = 8 \times 10^{-20} \text{ J}$$

de-Broglie wavelength of photoelectron is given by

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mK_{max}}} = \frac{6.626 \times 10^{-34}}{\sqrt{2(9 \times 10^{-31})(8 \times 10^{-20})}}$$

$$\Rightarrow \lambda \approx 1.75 \text{ nm}$$

Hence, the correct answer is (B).

26. $p = \dfrac{I}{C} = \dfrac{3 \times 10^4}{3 \times 10^8} = 10^{-4} \text{ Pa}$

Hence, the correct answer is (B).

27. $\Delta p = PA\Delta t = 10^{-4} \times 10^{-4} \times 10 = 10^{-7} \text{ kgms}^{-1}$

Hence, the correct answer is (C).

28. $\dfrac{Nh}{\lambda} = \Delta p$

$$\Rightarrow N = \frac{10^{-7} \times 663 \times 10^{-9}}{6.63 \times 10^{-34}} = 10^{20}$$

Hence, the correct answer is (B).

29. Since, $K_{max} = h\nu - W$

If K_{max} and W both are in eV, but $h\nu$ is in joule, then we have

$$K_{max} = \frac{h\nu}{e} - W$$

So, for both the frequency values, we have

$$0.5 = \frac{h(8 \times 10^{14})}{e} - W \quad \ldots(1)$$

$$2 = \frac{h(12 \times 10^{14})}{e} - W \quad \ldots(2)$$

Subtracting equation (1) from (2), we get

$$1.5 = \frac{h(4 \times 10^{14})}{e}$$

$$\Rightarrow h = \frac{1.5 \times 1.6 \times 10^{-19}}{4 \times 10^{14}}$$

$$\Rightarrow h = 6 \times 10^{-34} \text{ Js}$$

Hence, the correct answer is (A).

30. From equation (1), we get

$$0.5 = \frac{(6 \times 10^{-34})(8 \times 10^{14})}{1.6 \times 10^{-19}} - W$$

$$\Rightarrow 0.5 = 3 - W$$

$$\Rightarrow W = 3 - 0.5 = 2.5 \text{ eV}$$

Hence, the correct answer is (C).

31. $\lambda = \dfrac{h}{\sqrt{2mK}} = \dfrac{12.27}{\sqrt{V}} \text{ Å}$

$$\Rightarrow \lambda = \frac{12.27}{\sqrt{0.5}} \text{ Å} = 12.27\sqrt{2} \text{ Å}$$

$$\Rightarrow \lambda = 17.35 \text{ Å}$$

Hence, the correct answer is (B).

Matrix Match/Column Match Type Questions

1. A → (p, r)
B → (p, r)
C → (q)
D → (s)

Consider two equations

$$eV_s = \frac{1}{2}mv_{max}^2 = h\nu - \phi_0 \quad \ldots(1)$$

Number of photoelectron ejected per second (n) is proportional to

$$n \propto \frac{I}{h\nu} \quad \ldots(2)$$

(A) As frequency is increased keeping intensity constant, stopping potential $|V_s|$ will increase, so kinetic energy $\frac{1}{2}m(V_{max}^2)$ also increases and saturation current will decrease.

(B) As frequency is increased and intensity is decreased, $|V_s|$ will increase $\frac{1}{2}m\left(v_{\max}^2\right)$ will increase and saturation current will decrease.

(C) If work function is increased photo emission may stop.

(D) If intensity is increased and frequency is constant, saturation current will increase.

6. A → (p)
B → (r)
C → (s)
D → (q)

de-Broglie wavelength of electron in X-Ray tube

$$\lambda = \frac{h}{\sqrt{2mKE}} = \frac{h}{\sqrt{2meV}}$$

$$\Rightarrow \quad \lambda = \frac{1.227\times10^{-9}}{\sqrt{V}} = \frac{12.27}{\sqrt{V}}\ \text{Å}$$

(A) Accelerating potential

$$V \simeq 10^4\ \text{eV in X-ray tube}$$

$$\lambda \simeq \frac{1.227}{10^2}\times10^{-9} = 1.227\times10^{-11}\ \text{m}$$

$$\lambda \simeq 0.1\ \text{Å}$$

(B) Wavelength associated with X-rays

$$\lambda = \frac{12.4\times10^{-7}}{10^4} \simeq 12.4\times10^{-11}\ \text{m}$$

$$\lambda = 1.2\times10^{-10}\ \text{m}$$

$$\lambda \simeq 1\ \text{Å}$$

(C) de-Broglie wavelength of most energetic photoelectron

$$\lambda = \frac{1.227\times10^{-9}}{\sqrt{V}} = 1.227\times10^{-9} = 12.2\times10^{-10}\ \text{m}$$

$$\lambda \simeq 10\ \text{Å}$$

(D) $E = \dfrac{hc}{\lambda}$

$$\Rightarrow \quad \lambda = \frac{hc}{E} = \frac{hc}{eV} = \frac{12.4\times10^{-7}\text{m}}{V}$$

$$V = 2.5\ \text{V}$$

$$E = \frac{12.4}{2.5}\times10^{-7} = 5000\ \text{Å}$$

Integer/Numerical Answer Type Questions

1. Since, $n = \dfrac{N}{t} = \dfrac{P}{E} = \dfrac{P\lambda}{hc}$

$$\Rightarrow \quad n = \frac{\left(1.7\times10^{-8}\right)\left(6000\times10^{-10}\right)}{\left(6.626\times10^{-34}\right)\left(3\times10^{8}\right)}$$

$$\Rightarrow \quad n = 5.1\times10^{10}\ \text{photons per sec}$$

$$\Rightarrow \quad n \approx 5\times10^{10}$$

$$\Rightarrow \quad \alpha = 5 \text{ and } \beta = 10$$

$$\Rightarrow \quad \frac{\beta}{\alpha} = 2$$

2. The target area is $S_1 = \pi\left(10^{-9}\right)^2 = \pi\times10^{-18}\ \text{m}^2$.

The area of a 5 metre sphere centred on the light source is, $S_2 = 4\pi(5)^2 = 100\ \pi\text{m}^2$.

Thus, if the light source radiates uniformly in all directions the rate P at which energy falls on the target is given by,

$$P = \left(10^{-3}\ \text{watt}\right)\left(\frac{S_1}{S_2}\right) = \left(10^{-3}\right)\left(\frac{\pi\times10^{-18}}{100\times\pi}\right)$$

$$\Rightarrow \quad P = 10^{-23}\ \text{Js}^{-1}$$

Assuming that all power is absorbed, the required time is,

$$t = \left(\frac{5\ \text{eV}}{10^{-23}\ \text{Js}^{-1}}\right)\left(\frac{1.6\times10^{-19}\ \text{J}}{1\ \text{eV}}\right) \approx 20\ \text{hr}$$

3. Rate of energy received from the sun

$$Q = 2\ \text{cal cm}^{-2}\ \text{min}^{-1} = 2\times4.2$$

$$\Rightarrow \quad Q = 8.4\ \text{J cm}^{-2}\ \text{min}^{-1}$$

Energy of a photon received from the sun is

$$E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{6600\times10^{-10}} = 3\times10^{-19}\ \text{J}$$

If n is the number of photons reaching the earth per cm^2 per minute, then their total energy will be $\left(3\times10^{-19}n\right)$ joule.

$$\Rightarrow \quad \left(3\times10^{-19}\right)n = 8.4$$

$$\Rightarrow \quad n = \frac{8.4}{3\times10^{-19}} = 28\times10^{18}\ \text{photons per minute per cm}^2$$

$$\Rightarrow \quad x = 28$$

4. Mass of an electron is

$$m = 9.11\times10^{-31}\text{ kg and } T = 27+273 = 300\text{ K}$$

$\therefore$ de-Broglie wavelength of electrons is

$$\lambda = \frac{h}{\sqrt{3mkT}}$$

$$\lambda = \frac{6.63\times10^{-34}}{\sqrt{3\times9.11\times10^{-31}\times1.38\times10^{-23}\times300}}\text{ m}$$

$$\Rightarrow \lambda = \frac{6.63\times10^{-8}}{\sqrt{3\times9.11\times1.38\times3}} = \frac{6.63\times10^{-8}}{10.64}$$

$$\Rightarrow \lambda = 6.2\times10^{-9}\text{ m}$$

Mean separation between two electrons in a metal is

$$r = 2\times10^{-10}\text{ m}$$

$$\Rightarrow \frac{\lambda}{r} = \frac{6.2\times10^{-9}}{2\times10^{-10}} = 31$$

5. The maximum kinetic energy of the emitted electron is

$$K_{max} = \frac{1}{2}mv_{max}^2 = \frac{hc}{\lambda} - W_0$$

$$\Rightarrow K_{max} = \frac{6.62\times10^{-34}\times3\times10^8}{180\times10^{-9}} - 2\times1.6\times10^{-19}$$

$$\Rightarrow K_{max} = 7.8\times10^{-19}\text{ J}$$

$$\Rightarrow v_{max} = \sqrt{\frac{K_{max}}{m}} = \sqrt{\frac{2\times7.8\times10^{-19}}{9.1\times10^{-31}}} = 1.3\times10^6\text{ ms}^{-1}$$

The magnetic field provides the centripetal force to the electron, so

$$Bev_{max} = \frac{mv_{max}^2}{r}$$

$$\Rightarrow r = \frac{mv_{max}}{Be} = \frac{9.1\times10^{-31}\times1.3\times10^6}{5\times10^{-5}\times1.6\times10^{-19}} = 0.148\text{ m}$$

$$\Rightarrow r = 148\text{ mm}$$

6. $F = \frac{IA_{effective}}{c} = \frac{I}{c}(\pi R^2)$

$$\Rightarrow F = \frac{(10^{-2})(3.14)\left(\frac{10}{100}\right)^2}{3\times10^8} = 1.046\times10^{-12}\text{ N}$$

$$\Rightarrow F \approx 1\times10^{-12}\text{ N} = 1\text{ pN}$$

7. The Einstein's photoelectric equation for the first case can be written as

$$\frac{hc}{\lambda} = W + K_1 \quad \ldots(1)$$

When illuminated with light of wavelength 2λ,

$$\frac{hc}{2\lambda} = W + K_2 \quad \ldots(2)$$

Subtracting (2) from (1), we get

$$\frac{hc}{\lambda} - \frac{hc}{2\lambda} = K_1 - K_2$$

$$\Rightarrow \lambda = \frac{hc}{2(K_1-K_2)} = \frac{(4\times10^{-15})(3\times10^8)}{2(30-10)}$$

$$\Rightarrow \lambda = 300\times10^{-10}\text{ m} = 300\text{ Å}$$

If λ_{max} is the maximum wavelength of the photons with which photoelectrons can be emitted, then

$$\frac{hc}{\lambda_{max}} = W_0 = \frac{hc}{\lambda} - K_1 = \frac{(4\times10^{-15})(3\times10^8)}{300\times10^{-10}} - 30\text{ eV}$$

$$\Rightarrow E = 40 - 30 = 10\text{ eV}$$

$$\Rightarrow \lambda_{max} = \frac{hc}{10\text{ eV}} = \frac{(4\times10^{-15})(3\times10^8)}{10}$$

$$\Rightarrow \lambda_{max} = 1200\times10^{-10}\text{ m}$$

$$\Rightarrow \lambda_{max} = 1200\text{ Å}$$

8. Since $K_{max} = h\nu - h\nu_0$

$$\Rightarrow \frac{1}{2}\text{m}(8\times10^6)^2 = h(5\nu_0 - \nu_0) \quad \ldots(1)$$

For the second case, we have

$$KE = \frac{1}{2}mv^2 = h(2\nu_0 - \nu_0) \quad \ldots(2)$$

$$\Rightarrow \frac{(8\times10^6)^2}{v^2} = 4$$

$$\Rightarrow v = 4\times10^6\text{ ms}^{-1}$$

9. Applying Einstein's photoelectric equation, we get

$$eV_0 = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) \quad \ldots(1)$$

$$\frac{eV_0}{6} = hc\left(\frac{1}{3\lambda} - \frac{1}{\lambda_0}\right) \quad \ldots(2)$$

$$\Rightarrow \frac{hc}{6}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = hc\left(\frac{1}{3\lambda} - \frac{1}{\lambda_0}\right)$$

$\Rightarrow \frac{1}{6\lambda} - \frac{1}{6\lambda_0} = \frac{1}{3\lambda} - \frac{1}{\lambda_0}$

$\Rightarrow \frac{1}{\lambda_0} - \frac{1}{6\lambda_0} = \frac{1}{3\lambda} - \frac{1}{6\lambda}$

$\Rightarrow \frac{5}{6\lambda_0} = \frac{1}{6\lambda}$

$\Rightarrow \lambda_0 = 5\lambda$

$\Rightarrow n = 5$

10. $F = (\text{Area})\frac{I}{c}$ here effective Area $= \pi R^2$

$\Rightarrow F = (\pi R^2)\frac{I}{c}$

$\Rightarrow F = \frac{22}{7} \times (21 \times 10^{-2})^2 \times \frac{1}{110} \times \frac{1}{3 \times 10^8}$

$\Rightarrow F = \frac{(22)(21 \times 10^{-2})(21 \times 10^{-2})}{7 \times 110 \times 3 \times 10^8}$

$\Rightarrow F = 42 \times 10^{-13}$ N

$\Rightarrow x = 42$

11. Since, $eV_1 = \frac{hc}{\lambda_1} - \phi$ and

$eV_2 = \frac{hc}{\lambda_2} - \phi$

Subtracting, we get

$e(V_2 - V_1) = hc\left(\frac{\lambda_1 - \lambda_2}{\lambda_1 \lambda_2}\right)$

$\Rightarrow V_2 - V_1 = \frac{hc}{e}\left(\frac{\lambda_1 - \lambda_2}{\lambda_1 \lambda_2}\right)$

$\Rightarrow V_2 - V_1 = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19}} \times \frac{100}{6 \times 10^{-5}}$

$\Rightarrow V_2 - V_1 = \frac{66}{32} \times 10^{-34+8+2+19+5}$

$\Rightarrow V_2 - V_1 = \frac{33}{16} \approx 2$ V

12. Since, $eV_s = hv - W$

$\Rightarrow 5 \text{ eV} = hv - 2 \text{ eV}$

$\Rightarrow hv = 7$ eV

So, total number of photons incident is

$n = \frac{P}{hv}$

Since, $\eta = 10^{-3}\%$

$\Rightarrow n_{\text{emitted}} = n \times \frac{10^{-3}}{100}$

$\Rightarrow i = \frac{q}{t} = \left(\frac{n_{\text{emitted}}}{t}\right)e$

where, from the graph

$i = 10 \times 10^{-6}$ A

$\Rightarrow 10 \times 10^{-6} = \frac{P}{hv} \times \frac{10^{-3}}{100} \times 1.6 \times 10^{-19}$

$\Rightarrow 10 \times 10^{-6} = \frac{P \times 10^{-3} \times 1.6 \times 10^{-19}}{7 \times 1.6 \times 10^{-19} \times 100}$

$\Rightarrow P = 7$ W

13. According to Einstein's Photo-Electric Equation, we have

$K_{\max} = eV_s = hv - W$

$\Rightarrow eV_s = 12 \text{ eV} - 4 \text{ eV}$

$\Rightarrow eV_s = 8$ eV

$\Rightarrow V_s = 8$ V

14. $F = \left[\frac{\left(\frac{P}{4\pi a^2}\right)(\pi R^2)}{hv}\right]\left[(0.7)\frac{2hv}{c} + (0.3)\frac{hv}{c}\right]$

$\Rightarrow F = \frac{P}{4}\left(\frac{R}{a}\right)^2\left(\frac{1.7}{c}\right) = \left(\frac{12}{4}\right)\left(\frac{3}{39}\right)^2\left(\frac{1.7}{3 \times 10^8}\right)$

$\Rightarrow F = \left(\frac{3}{169}\right)\left(\frac{1.7}{3 \times 10^8}\right) \approx 1 \times 10^{-10}$ N

$\Rightarrow x = 1$ and $y = 10$

$\Rightarrow \frac{y}{x} = 10$

15. Magnetic force experienced by a charged particle in a magnetic field is given by

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

CHAPTER 1

The de Broglie wavelength is given by

$$\lambda = \frac{h}{mv} = \frac{h}{qBr} \qquad \left\{\because r = \frac{mv}{qB}\right\}$$

$$\Rightarrow \frac{\lambda_p}{\lambda_\alpha} = \frac{q_\alpha r_\alpha}{q_p r_p}$$

Given, $\frac{r_\alpha}{r_p} = 1$ and $\frac{q_\alpha}{q_p} = 2$

$$\Rightarrow \frac{\lambda_p}{\lambda_\alpha} = 2$$

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1. 

$$p_1 = \frac{h}{\lambda_1}$$

$$p_2 = \frac{h}{\lambda_2}$$

$$\Rightarrow p_f = \sqrt{p_1^2 + p_2^2}$$

$$\Rightarrow \frac{h}{\lambda} = \sqrt{\frac{h^2}{\lambda_1^2} + \frac{h^2}{\lambda_2^2}}$$

$$\Rightarrow \frac{1}{\lambda^2} = \frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2}$$

Hence, the correct answer is (D).

2. $\lambda_A = \frac{h}{mV_A}$

Applying Conservation of Linear Momentum, we get

$$mV_A = \left(\frac{m}{2}\right)V - \left(\frac{m}{2}\right)\left(\frac{V}{2}\right) = \frac{mV}{4}$$

$$\Rightarrow \lambda_A = \frac{4h}{mV}$$

$$\Rightarrow V_A = \frac{V}{4}$$

$$\lambda_B = \frac{h}{\left(\frac{m}{2}\right)V} = \frac{2h}{mV} = \frac{\lambda_A}{2}$$

$$\lambda_C = \frac{h}{\left(\frac{m}{2}\right)\left(\frac{V}{2}\right)} = \frac{4h}{mV} = \lambda_A$$

Hence, the correct answer is (C).

3. $\lambda = 5 \times 10^{-7}$ m $= 5000$ Å

$$\Rightarrow E = \frac{12375}{5000} = 2.475 \text{ eV} \approx 2.48 \text{ eV}$$

Since, $K_{max} = E - \phi_0$

$$\Rightarrow K_{max} = 2.48 - 2 = 0.48 \text{ eV}$$

$$\Rightarrow V_s = 0.48 \text{ V}$$

Hence, the correct answer is (A).

4. Since $F_n = \frac{I}{c}(1 + r)$

$$\Rightarrow F_n = \frac{I}{c}(1 + 0.25) = \frac{(1.25)(50)}{3 \times 10^8} \approx 20 \times 10^{-8} \text{ N}$$

Hence, the correct answer is (A).

5. $p_1 = \frac{h}{\lambda_x}$ and $p_2 = \frac{h}{\lambda_y}$

Since particles are moving in opposite direction, so

$$p = p_1 - p_2 = h\left(\frac{1}{\lambda_x} - \frac{1}{\lambda_y}\right)$$

Also, the collision is perfectly inelastic, so

$$p_{\text{final}} = \Sigma p_{\text{initial}}$$

$$\Rightarrow \frac{h}{\lambda} = h\left(\frac{1}{\lambda_x} - \frac{1}{\lambda_y}\right)$$

$$\Rightarrow \frac{1}{\lambda} = \frac{|\lambda_y - \lambda_x|}{\lambda_x \lambda_y}$$

$$\Rightarrow \lambda = \frac{\lambda_x \lambda_y}{|\lambda_x - \lambda_y|}$$

Hence, the correct answer is (A).

6. Wavelength of incident wave $(\lambda) = 260$ nm

Cut off (threshold) wavelength $(\lambda_0) = 380$ nm

Since, $K_{max} = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$

$$\Rightarrow K_{max} = 1237\left(\frac{1}{260} - \frac{1}{380}\right)$$

$$\Rightarrow K_{max} = \frac{1237 \times 120}{380 \times 260} = 1.5 \text{ eV}$$

Hence, the correct answer is (D).

7. $E = \dfrac{hc}{\lambda}$

Let number of photons per second be n

$\Rightarrow\ n\left(\dfrac{hc}{\lambda}\right) = 2\text{ mW} = 2\times10^{-3}\text{ W}$

$\Rightarrow\ n = \dfrac{2\times\lambda}{hc} = \dfrac{(2\times10^{-3})(5000\times10^{-10})}{(6.6\times10^{-34})(3\times10^{8})}$

$\Rightarrow\ n = 5\times10^{15}$ photons/sec

Hence, the correct answer is (D).

8. $p = \dfrac{E}{c} = \dfrac{IAt}{c}$ $\qquad\left\{\because\ I = \dfrac{E}{At}\right\}$

$\Rightarrow\ p = \dfrac{(25\times25)\times40\times60}{3\times10^{8}} = 5\times10^{-3}\text{ Ns}$

Hence, the correct answer is (C).

9. $\phi_0 = \dfrac{hc}{\lambda} = h\nu_0$

$\Rightarrow\ \phi_0 = h(4\times10^{14}\text{ Hz}) = 1.654\text{ eV}$

$\Rightarrow\ \phi_0 \approx 1.66\text{ eV}$

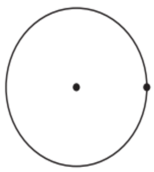
Hence, the correct answer is (D).

10. For $n = 3$

$2\pi r = n\lambda$

$\Rightarrow\ 2\pi r = 3\times\lambda$

$\Rightarrow\ \lambda = \dfrac{2\pi\times4.65}{3}\text{ Å} = 9.7\text{ Å}$



Hence, the correct answer is (C).

11. $\dfrac{1}{2}m(2v)^2 = \dfrac{hc}{350} - \phi_0$

and $\dfrac{1}{2}mv^2 = \dfrac{hc}{540} - \phi_0$

$\Rightarrow\ 4\left(\dfrac{hc}{540}\right) - \left(\dfrac{hc}{350}\right) = 3\phi_0$

$\Rightarrow\ 9.12 - 3.54 = 3\phi_0$

$\Rightarrow\ \phi_0 \approx 1.8\text{ eV}$

Hence, the correct answer is (A).

12. Maximum Angular Frequency is

$\omega_{\max} = 6.28\times10^{7}\times3\times10^{8}\text{ rads}^{-1}$

$\Rightarrow\ f_{\max} = 3\times10^{15}\text{ Hz}$

$E_{\max} = hf_{\max} = \dfrac{6.6\times10^{-34}\times3\times10^{15}}{1.6\times10^{-19}}\text{ eV}$

$= 12.375\text{ eV} = 12.38\text{ eV}$

$\Rightarrow\ KE_{\max} = 12.38 - 4.7 \simeq 7.7\text{ eV}$

Hence, the correct answer is (B).

13. Here $\lambda \simeq 7.5\times10^{-12}\text{ m}$

$\lambda = \dfrac{h}{mv} = \dfrac{h}{\sqrt{2mE_k}}$ $\qquad\{\because\ mv = \sqrt{2mE_k}\}$

$\Rightarrow\ E_k = \dfrac{h^2}{2m\lambda^2}$

$\Rightarrow\ E_k = \dfrac{(6.6\times10^{-34})^2\text{ eV}}{2\times9.1\times10^{-31}\times(7.5\times10^{-12})^2\times1.6\times10^{-19}}$

$\Rightarrow\ E_k = 25\text{ keV}$

Hence, the correct answer is (D).

14. $I = \left(\dfrac{Nhc}{\lambda}\right)\dfrac{1}{(\Delta t)(\Delta A)}$

$\Rightarrow\ \left(\dfrac{N}{\Delta t}\right) = \dfrac{16\times10^{-3}\times1\times10^{-4}\times\lambda}{hc}(\text{per sec})$

Since, $\dfrac{hc}{\lambda} = 10\text{ eV}$

So total incident photons per second

$\Rightarrow\ \dfrac{N}{\Delta t} = \dfrac{16\times10^{-7}}{10\text{ eV}} = 9.98\times10^{11}$

Number of emitted electrons per sec is $n = \dfrac{10}{100}\left(\dfrac{N}{\Delta t}\right)$

$\Rightarrow\ n = 9.98\times10^{10}$

$\Rightarrow\ n \approx 10^{11}$

Maximum kinetic energy $= 10\text{ eV} - 5\text{ eV} = 5\text{ eV}$

Hence, the correct answer is (B).

15. $\lambda_{\text{photon}} = \dfrac{3\times10^{8}}{6\times10^{14}} = 0.5\times10^{-6}\text{ m}$

Since, $\lambda_e = \dfrac{\lambda_{\text{photon}}}{10^3} = 0.5\times10^{-9}\text{ m}$

$\Rightarrow\ \dfrac{h}{mv} = 0.5\times10^{-9}$

$\Rightarrow\ v = \dfrac{6.63\times10^{-34}}{(9.1\times10^{-31})(0.5\times10^{-9})}$

$\Rightarrow\ v = 1.45\times10^{6}\text{ ms}^{-1}$

Hence, the correct answer is (B).

16. Since $h\nu = \phi_0 + eV_0$

$\Rightarrow\ \dfrac{hc}{\lambda_1} = \phi_0 + eV_1$

$\Rightarrow\ \dfrac{hc}{\lambda_2} = \phi_0 + eV_2$

$$\Rightarrow \quad 1240\left[\frac{1}{300}-\frac{1}{400}\right]=e\left(V_1-V_2\right)$$

$$\Rightarrow \quad \left(V_1-V_2\right)\approx 1.0\text{ V}$$

Hence, the correct answer is (A).

17. $\lambda=\frac{h}{p}=\frac{h}{\sqrt{2mqv}}$

$$\Rightarrow \quad \frac{\lambda_A}{\lambda_B}=\frac{\left(\frac{h}{2mq\times 50}\right)}{\left(\frac{h}{\sqrt{2\times 4m\times q\times 2500}}\right)}=\sqrt{200}=14.14$$

Hence, the correct answer is (B).

18. According to Einsteins Photoelectric Equation, we have

$$h\nu=\phi_0+e\left(\frac{V_0}{2}\right)$$

$$\Rightarrow \quad 2h\nu=2\phi_0+eV_0$$

Also, $\frac{h\nu}{2}=\phi+eV_0$

$$\Rightarrow \quad \frac{3h\nu}{2}=\phi$$

$$\Rightarrow \quad \nu_0=\frac{3\nu}{2}$$

Hence, the correct answer is (A).

19. Energy lost by electron is

$$\Delta E=5.6-0.7=4.9\text{ eV}$$

$$\Rightarrow \quad \frac{hc}{\lambda_{\min}}=4.9$$

$$\Rightarrow \quad \lambda_{\min}=\frac{12375}{4.9}\approx 2500\text{ Å}=250\text{ nm}$$

Hence, the correct answer is (C).

20. Momentum of two electrons are $\frac{h}{\lambda_1}\hat{i}$ and $\frac{h}{\lambda_2}\hat{j}$.

Velocity of centre of mass $\vec{V}_{\text{CM}}=\frac{h}{2m\lambda_1}\hat{i}+\frac{h}{2m\lambda_2}\hat{j}$

Velocity of first electron about centre of mass is

$$\vec{V}_{\text{CM}}=\frac{h}{2m\lambda_1}\hat{i}-\frac{h}{2m\lambda_2}\hat{j}$$

$$\Rightarrow \quad \lambda_{\text{CM}}=\frac{h}{\sqrt{\frac{h^2}{4\lambda_1^2}+\frac{h^2}{4\lambda_2^2}}}=\frac{2\lambda_1\lambda_2}{\sqrt{\lambda_1^2+\lambda_2^2}}$$

Hence, the correct answer is (A).

21. $\lambda_p=\frac{h}{p_p}=\frac{h}{m_p v_p}$ and $\lambda_\alpha=\frac{h}{m_\alpha v_\alpha}$

As, $\lambda_p=\lambda_\alpha$

$$\Rightarrow \quad \frac{h}{m_p v_p}=\frac{h}{m_\alpha v_\alpha}$$

$$\Rightarrow \quad \frac{v_p}{v_\alpha}=\frac{m_\alpha}{m_p}=\frac{4m_p}{m_p}=\frac{4}{1}$$

Hence, the correct answer is (D).

22. As de-Broglie wavelength is given by

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

$$\Rightarrow \quad \frac{\lambda_B}{\lambda_G}=\frac{p_G}{p_B}=\frac{mv_G}{mv_B}$$

Since, $v\propto\frac{Z}{n}$

$$\Rightarrow \quad \frac{\lambda_B}{\lambda_G}=\frac{n_B}{n_G}=\frac{3}{1}$$

$$\Rightarrow \quad \lambda_B=3\lambda_G$$

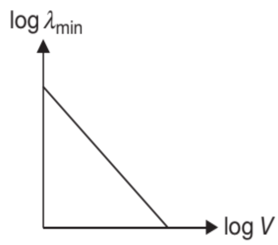
Hence, the correct answer is (B).

23. In X-ray tube

$$\lambda_{\min}=\frac{hc}{eV}$$

$$\Rightarrow \quad \log\left(\lambda_{\min}\right)=\log\left(\frac{hc}{e}\right)-\log V$$

Slope is negative and intercept on y-axis is positive



Hence, the correct answer is (A).

24. $v_1=\frac{(m_1-m_2)v}{m_1+m_2}+0$

Since, $m_1=m$ and $m_2=\frac{m}{2}$

$$\Rightarrow \quad v_1=\frac{v}{3}$$

$$\Rightarrow \quad p_1=m\left(\frac{v}{3}\right)$$

and $v_2 = \frac{2m_1 v}{m_1 + m_2} + 0$

$\Rightarrow \quad v_2 = \frac{4v}{3}$

$\Rightarrow \quad p_2 = \frac{m}{2}\left(\frac{4v}{3}\right) = \frac{2mv}{3}$

Since $\lambda = \frac{h}{p}$

$\Rightarrow \quad \frac{\lambda_A}{\lambda_B} = \frac{p_2}{p_1} = 2:1$

Hence, the correct answer is (B).

25. $E_1 = \frac{1}{2}mv^2 = hn - \phi$

If incident frequency is increased to $3n$

$$E_2 = \frac{1}{2}mv'^2 = h(3n) - \phi$$

$\Rightarrow \quad \frac{1}{2}mv'^2 = 3(hn - \phi) + 2\phi$

$\Rightarrow \quad \frac{1}{2}mv'^2 = 3 \times \left(\frac{1}{2}mv^2\right) + 2\phi$

$\Rightarrow \quad v'^2 = 3v^2 + \frac{4\phi}{m}$

$\Rightarrow \quad v' > v\sqrt{3}$

Hence, the correct answer is (A).

26. Here, $\lambda = 660 \text{ nm} = 660 \times 10^{-9} \text{ m}$

$t = 60 \text{ ms} = 60 \times 10^{-3} \text{ s}$, $P = 0.5 \text{ kW} = 500 \text{ W}$

$h = 6.62 \times 10^{-34} \text{ Js}$, $n = ?$

Since, $P = \frac{E}{t} = \frac{nhc}{\lambda t}$

$\Rightarrow \quad n = \frac{P\lambda t}{hc}$

$\Rightarrow \quad n = \frac{500 \times 660 \times 10^{-9} \times 60 \times 10^{-3}}{6.62 \times 10^{-34} \times 3 \times 10^8}$

$\Rightarrow \quad n \approx 10^{20}$

Hence, the correct answer is (D).

27. $\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi_0 \quad \ldots(1)$

$$\frac{1}{2}mv'^2 = \frac{4hc}{3\lambda} - \phi_0$$

$\Rightarrow \quad \frac{1}{2}mv'^2 = \frac{4hc}{3\lambda} - \frac{4\phi_0}{3} + \frac{\phi_0}{3}$

$\Rightarrow \quad \frac{1}{2}mv'^2 = \frac{4}{3}\left(\frac{hc}{\lambda} - \phi_0\right) + \frac{\phi_0}{3}$

$\Rightarrow \quad \frac{1}{2}mv'^2 = \frac{4}{3}\left(\frac{1}{2}mv^2\right) + \frac{\phi_0}{3}$

Since $\frac{\phi_0}{3} > 0$

$\Rightarrow \quad \frac{1}{2}mv'^2 > \frac{4}{3}\left(\frac{1}{2}mv^2\right)$

$\Rightarrow \quad v' > v\left(\frac{4}{3}\right)^{\frac{1}{2}}$

Hence, the correct answer is (B).

28. Let the threshold wavelength for sphere be λ_0. According to Einstein's Photoelectric Equation, we have

$$eV_s = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

So, $eV = \frac{hc}{\lambda_1} - \frac{hc}{\lambda_0} \quad \ldots(1)$

$3eV = \frac{hc}{\lambda_2} - \frac{hc}{\lambda_0} \quad \ldots(2)$

$eV' = \frac{hc}{\lambda_3} - \frac{hc}{\lambda_0} \quad \ldots(3)$

From equations (1) and (2), we get

$$\frac{2hc}{\lambda_0} = \frac{3hc}{\lambda_1} - \frac{hc}{\lambda_2}$$

$\Rightarrow \quad \frac{hc}{\lambda_0} = \frac{3hc}{2\lambda_1} - \frac{hc}{2\lambda_2}$

Substituting in equation (3), we get

$$eV' = \frac{hc}{\lambda_3} - \frac{3hc}{2\lambda_1} + \frac{hc}{2\lambda_2}$$

$\Rightarrow \quad V' = \frac{hc}{e}\left(\frac{1}{\lambda_3} - \frac{3}{2\lambda_1} + \frac{1}{2\lambda_2}\right)$

Hence, the correct answer is (D).

29. According to Einstein's Photoelectric Equation, maximum energy of photoelectrons

$$(KE)_{max} = hv - \phi_0$$

$\Rightarrow \quad (KE)_{max} = \frac{hc}{\lambda} - \phi_0$

For first case, $K = \frac{hc}{\lambda} - \phi_0 \quad \ldots(1)$

For second case, $3K = \frac{2hc}{\lambda} - \phi_0 \quad \ldots(2)$

From equations (1) and (2), we get

$$3\left(\frac{hc}{\lambda}-\phi_0\right)=\frac{2hc}{\lambda}-\phi_0$$

$$\Rightarrow \quad 2\phi_0=\frac{3hc}{\lambda}-\frac{2hc}{\lambda}=\frac{hc}{\lambda}$$

$$\Rightarrow \quad \phi_0=\frac{hc}{2\lambda}$$

Hence, the correct answer is (A).

30. Franck-Hertz Experiment-Discrete energy levels of atom. Photo-electric experiment – Particle nature of light Davisson-Germer Experiment – Wave nature of electron.
Hence, the correct answer is (A).

31. Momentum, $p=\sqrt{2mE}$ and $E=eV$

So, de-Broglie wavelength of the electron is given by,

$$\lambda=\frac{h}{p}=\frac{h}{\sqrt{2mE}}=\frac{h}{\sqrt{2meV}}$$

$$\Rightarrow \quad \lambda=\frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times1.6\times10^{-19}\times50}}$$

$$\Rightarrow \quad \lambda=1.7\times10^{-10}\text{ m}=1.7\text{ Å}$$

Hence, the correct answer is (C).

32. de-Broglie wavelength of electron, $\lambda=\frac{h}{mv}$

Also $mvr=\frac{nh}{2\pi}$

$$\Rightarrow \quad \lambda=\frac{2\pi r}{n}$$

Since $r\propto n^2$

$$\Rightarrow \quad \lambda\propto n$$

For $n=4$, $\lambda_4=4\lambda_1$ i.e., the de-Broglie wavelength is four times that of ground state.

Hence, the correct answer is (B).

33. When wavelength exceeds a certain wavelength, photoelectric effect ceases to exist.
Hence, the correct answer is (D).

34. Davisson-Germer experiment showed that electron beams can undergo diffraction when passed through atomic crystals. This shows the wave nature of electrons as waves can exhibit interference and diffraction.
Hence, the correct answer is (B).

35. The maximum kinetic energy of the electron

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

Here, ν_0 is threshold frequency.

The stopping potential is $eV_0=K_{max}=h\nu-h\nu_0$

Therefore, if ν is doubled K_{max} and V_0 is not doubled.

Hence, the correct answer is (D).

36. Here, power of a source, $P=4\text{ kW}=4\times10^3\text{ W}$

Number of photons emitted per second, $N=10^{20}$

Energy of photons, $E=h\nu=\frac{hc}{\lambda}$

$$\Rightarrow \quad E=\frac{P}{N}$$

$$\Rightarrow \quad \frac{hc}{\lambda}=\frac{P}{N}$$

$$\Rightarrow \quad \lambda=\frac{Nhc}{P}=\frac{10^{20}\times6.63\times10^{-34}\times3\times10^8}{4\times10^3}$$

$$\Rightarrow \quad \lambda=4.972\times10^{-9}\text{ m}=49.72\text{ Å}$$

This lies in the X-ray region.

Hence, the correct answer is (B).

37. According to Einstein's Photoelectric Equation

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

where, $\nu=$ frequency of incident light

$\phi_0=$ Work function of the metal

Since $K_{max}=eV_0$

$$V_0=\frac{h\nu}{e}-\frac{\phi_0}{e}$$

Since $\nu_{X\text{-rays}}>\nu_{\text{Ultraviolet}}$

Therefore, both K_{max} and V_0 increase when ultraviolet light is replaced by X-rays.

Statement-2 is False.
Hence, the correct answer is (A).

38. The wavelength of light illuminating the photoelectric surface is 400 nm.

$$\Rightarrow \quad h\nu=\frac{1240\text{ eVnm}}{400\text{ nm}}=3.1\text{ eV}$$

Maximum kinetic energy, K of the electrons is 1.68 eV

Since $h\nu=\phi_0+K$

$$\Rightarrow \quad \phi_0=h\nu-K$$

$$\Rightarrow \quad \phi_0=3.1-1.68\text{ eV}=1.42\text{ eV}$$

Hence, the correct answer is (B).

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Single Correct Choice Type Problems

1. According to photoelectric effect equation

$$KE_{\max} = \frac{hc}{\lambda} - \phi_0$$

$$\frac{p^2}{2m} = \frac{hc}{\lambda} - \phi_0 \qquad \left\{\because KE = \frac{p^2}{2m}\right\}$$

$$\frac{\left(\frac{h}{\lambda_d}\right)^2}{2m} = \frac{hc}{\lambda} - \phi_0 \qquad \left\{\because p = \frac{h}{\lambda}\right\}$$

Assuming small changes, differentiating both sides,

$$\frac{h^2}{2m}\left(-\frac{2d\lambda_d}{\lambda_d^3}\right) = -\frac{hc}{\lambda^2}d\lambda,\ \frac{d\lambda_d}{d\lambda} \propto \frac{\lambda_d^3}{\lambda^2}$$

Hence, the correct answer is (D).

2. Since, $eV = \frac{hc}{\lambda} - \phi$

$$\Rightarrow \quad e(V_1 - V_2) = \frac{hc}{\lambda_1} - \frac{hc}{\lambda_2} = \frac{hc(\lambda_2 - \lambda_1)}{\lambda_1\lambda_2}$$

$$\Rightarrow \quad h = \frac{e(V_1 - V_2)\lambda_1\lambda_2}{c(\lambda_2 - \lambda_1)}$$

$$\Rightarrow \quad h = \frac{1.6 \times 1 \times 0.3 \times 0.4 \times 10^{-12} \times 10^{-19}}{3 \times 10^8 \times 0.1 \times 10^{-6}} = 6.4 \times 10^{-34}$$

Hence, the correct answer is (B).

3. Energy corresponding to 248 nm wavelength is

$$E_1 = \frac{1240}{248}\ \text{eV} = 5\ \text{eV}$$

Energy corresponding to 310 nm wavelength is

$$E_2 = \frac{1240}{310}\ \text{eV} = 4\ \text{eV}$$

$$\frac{KE_1}{KE_2} = \frac{u_1^2}{u_2^2} = \frac{4}{1} = \frac{5\ \text{eV} - W}{4\ \text{eV} - W}$$

$$\Rightarrow \quad 16 - 4W = 5 - W$$

$$\Rightarrow \quad 11 = 3W$$

$$\Rightarrow \quad W = \frac{11}{3} = 3.67\ \text{eV} \cong 3.7\ \text{eV}$$

Hence, the correct answer is (A).

4. $E_1 = \frac{1240}{550} = 2.25\ \text{eV}$

$$E_2 = \frac{1240}{450} = 2.75\ \text{eV}$$

$$E_3 = \frac{1240}{350} = 3.54\ \text{eV}$$

E_1 cannot emit photoelectrons from q and r plates.

E_2 can not emit photoelectrons from r.

Further, work function of p is least and it can emit photoelectrons from all three wavelengths. Hence magnitude of its stopping potential and saturation current both will be maximum.

Hence, the correct answer is (A).

5. Momentum of striking electrons

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

So k Kinetic energy of striking electrons is

$$K = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$$

This is also, maximum energy of X-ray photons.

Therefore, $\frac{hc}{\lambda_0} = \frac{h^2}{2m\lambda^2}$

$$\Rightarrow \quad \lambda_0 = \frac{2m\lambda^2 c}{h}$$

Hence, the correct answer is (A).

6. As velocity (or momentum) of electron is increased, the wavelength $\left(\lambda = \frac{h}{p}\right)$ will decrease.

Hence, fringe width will decrease $(\beta \propto \lambda)$.

Hence, the correct answer is (C).

7. Saturation current is proportional to intensity while stopping potential increases with increase in frequency.

Hence, $f_a = f_b$ while $I_a < I_b$

Hence, the correct answer is (A).

8. $$\frac{\lambda_1}{\lambda_2} = \frac{\frac{h}{\sqrt{2mE}}}{\frac{hc}{E}}$$

$$\Rightarrow \quad \frac{\lambda_1}{\lambda_2} \propto E^{\frac{1}{2}}$$

Hence, the correct answer is (B).

9. By Law of Conservation of Momentum

$$\begin{pmatrix}\text{Momentum}\\ \text{before decay}\end{pmatrix} = \begin{pmatrix}\text{Momentum}\\ \text{after decay}\end{pmatrix}$$

$\Rightarrow \quad 0 = p_1 + p_2$

$\Rightarrow \quad p_1 = -p_2$

(–) sign indicates recoil

$\Rightarrow \quad |p_1| = |p_2|$

$$\frac{\lambda_1}{\lambda_2} = \frac{|p_2|}{|p_1|} = 1$$

Hence, the correct answer is (C).

10. $\lambda(\text{in Å}) = \dfrac{12400}{E(\text{in eV})}$

$\Rightarrow \quad \lambda = \dfrac{12400}{4} = 3100\ \text{Å} = 310\ \text{nm}$

Hence, the correct answer is (C).

11. Stopping Potential $V_s = \dfrac{K_{\max}}{e}$

$\Rightarrow \quad V_s = 4\ \text{V}$

Hence, the correct answer is (B).

Multiple Correct Choice Type Problems

1. Maximum KE of electron just after ejection is

$$K_i = \frac{hc}{\lambda_{ph}} - \phi$$

Maximum KE of electron on reaching anode is

$$K_f = \left(\frac{hc}{\lambda_{ph}} - \phi\right) + eV$$

For $V >> \dfrac{\phi}{e}$

$\Rightarrow \quad K_f \approx eV$

$\Rightarrow \quad \lambda_{\text{electron}} = \dfrac{h}{\sqrt{2m(eV)}} \propto \dfrac{1}{\sqrt{V}}$

So, (A) is correct

If ϕ and λ_{ph} increase, then K_f decreases

$\Rightarrow \quad \lambda_{\text{electron}}$ increases

So, (B) is incorrect

$$\lambda_{\text{electron}} = \frac{h}{\sqrt{2m(K_f)}} = \lambda_e$$

$\Rightarrow \quad \dfrac{d\lambda_e}{dt} \neq \dfrac{d\lambda_{ph}}{dt}$

λ_e is independent of d

Hence, the correct answer is (A).

2. $eV_0 = \dfrac{hc}{\lambda} - W$

$$V_0 = \left(\frac{hc}{e}\right)\left(\frac{1}{\lambda}\right) - \frac{W}{e}$$

V_0 versus $\dfrac{1}{\lambda}$ graph is in the form $y = mx - c$

Therefore option (C) is correct.

Clearly, V_0 versus λ graph is not a straight line but V_0 decreases with increase in λ and V_0 becomes zero when $\dfrac{hc}{\lambda} = W$.

i.e. $\lambda = \lambda_0$ (Threshold wavelength)

Hence, (A) and (C) are correct.

3. From the relation,

$$eV = \frac{hc}{\lambda} - \phi \text{ or } V = \left(\frac{hc}{e}\right)\left(\frac{1}{\lambda}\right) - \frac{\phi}{e}$$

This is equation of straight line.

Slope is $\tan\theta = \dfrac{hc}{e}$

$$\phi_1 : \phi_2 : \phi_3 = \frac{hc}{\lambda_{01}} : \frac{hc}{\lambda_{02}} : \frac{hc}{\lambda_{03}} = \frac{1}{\lambda_{01}} : \frac{1}{\lambda_{02}} : \frac{1}{\lambda_{03}} = 1:2:4$$

$\dfrac{1}{\lambda_{01}} = 0.001\ \text{nm}^{-1} \Rightarrow \lambda_{01} = 10000\ \text{Å}$

$\dfrac{1}{\lambda_{02}} = 0.002\ \text{nm}^{-1} \Rightarrow \lambda_{02} = 5000\ \text{Å}$

$\dfrac{1}{\lambda_{03}} = 0.004\ \text{nm}^{-1} \Rightarrow \lambda_{03} = 2500\ \text{Å}$

Violet colour has wavelength 4000 Å.

So violet colour can eject photoelectrons from Metal –1 and Metal –2.

Hence, (A) and (C) are correct.

4. $h\nu = K.E.(T) + \text{Work function}(W)$

$\Rightarrow \quad h\nu = T + W$

$\Rightarrow \quad 4.25\ eV = T_A + W_A$ (for Metal A)

$\Rightarrow \quad 4.70\ eV = T_B + W_B$ (for Metal B)

Since $T_B = (T_A - 1.5)\ eV$

Also $\lambda = \dfrac{h}{p}$

$\Rightarrow \quad \lambda = \dfrac{h}{\sqrt{2mT}} \qquad \left\{\because \dfrac{p^2}{2m} = T = K.E.\right\}$

$\Rightarrow \quad \dfrac{\lambda_A}{\lambda_B} = \sqrt{\dfrac{T_B}{T_A}}$

Since $\lambda_A = \frac{1}{2}\lambda_B$

$\Rightarrow \quad T_A = 4T_B$

$\Rightarrow \quad T_B = T_A - 1.50$ gives

$\Rightarrow \quad T_B = 4T_B - 1.5$

$\Rightarrow \quad T_B = 0.5 \text{ eV}$

$\Rightarrow \quad T_A = 2 \text{ eV}$

$\Rightarrow \quad W_A = 2.25 \text{ eV}$

$\Rightarrow \quad W_B = 4.20 \text{ eV}$

Hence, (A), (B) and (C) are correct.

5. Cut off voltage is independent of intensity and hence remains the same. Since distance becomes 3 times, so I becomes $\frac{I}{9}$. Hence photocurrent also decreases by this factor i.e. becomes $\frac{18}{9} = 2 \text{ mA}$

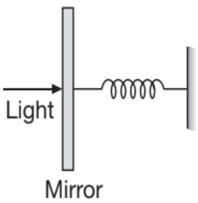
Hence, (B) and (D) are correct.

7. Infrared light has wavelength greater than 5200 Å and UV has $\lambda < 5200$ Å. So UV lamp will be able to get the photoelectrons emitted by a surface irrespective of intensity.

Hence, (C) and (D) are correct.

Integer/Numerical Answer Type Questions

1.



Momentum transferred to the mirror is

$$\Delta p = \frac{2Nh}{\lambda}$$

Given that $\Omega = \frac{10^{24} h}{4\pi m}$

So, the speed, acquired (V_0) by the mirror is given by applying conservation of linear momentum i.e.,

$$MV_0 = \frac{2Nh}{\lambda}$$

$$\Rightarrow \quad V_0 = \frac{2Nh}{\lambda M}$$

Since the system is also executing SHM, so

$$V_0 = A\Omega$$

where A is amplitude of SHM i.e. $A = 1\ \mu\text{m}$

$$\Rightarrow \quad \frac{2Nh}{\lambda M} = A\Omega$$

$$\Rightarrow \quad \frac{2Nh}{\lambda M} = A\left(\frac{10^{24} h}{4\pi M}\right)$$

$$\Rightarrow \quad N = \frac{10^{18} \times 8\pi \times 10^{-6}}{4\pi \times 2} = 1 \times 10^{12}$$

$$\Rightarrow \quad x = 1$$

2. $P = 200 \text{ Js}^{-1}$

No. of photons per second

$$(N) = \frac{200}{(6.25 \times 1.6 \times 10^{-19})} = 2 \times 10^{20}$$

$$\Delta p = \sqrt{2m(KE)} = \sqrt{2m(eV)}$$

$$\Delta p = \sqrt{2 \times 9 \times 10^{-31} \times 1.6 \times 10^{-19} \times 500} = 12 \times 10^{-24}$$

$$\Rightarrow \quad F = \Delta p \times N = 12 \times 10^{-24} \times 2 \times 10^{20} = 24 \times 10^{-4} \text{ N}$$

3. $V = \frac{hf}{e} - \frac{\phi}{e}$

Slope $= \frac{h}{e}$

It is same for both, so

Ratio $= 1$

4. $\frac{hc}{\lambda} - \phi = ev_0$

$$\Rightarrow \quad v_0 = \frac{ne}{4\pi\varepsilon_0 r}$$

$$\Rightarrow \quad \frac{1240}{200} \text{ eV} - 4.7 \text{ eV} = \left(\frac{xne}{4\pi\varepsilon_0 r}\right) \text{eV}$$

$$\Rightarrow \quad 6.2 - 4.7 = \frac{9 \times 19^9 \times n \times 1.6 \times 10^{-19}}{10^{-2}}$$

$$\Rightarrow \quad n = \frac{1.5 \times 10^{-2}}{9 \times 1.6 \times 10^{-10}} \approx 10^8$$

5. $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2qVm}}$

$$\Rightarrow \quad \lambda \propto \frac{1}{\sqrt{qm}}$$

$$\Rightarrow \quad \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{q_\alpha}{q_p} \cdot \frac{m_\alpha}{m_p}} = \sqrt{\frac{(2)(4)}{(1)(1)}} = 2.828$$

The nearest integer is 3.