Explanations

1. (c) The photoelectric current in a photocell is related to the distance of source of light as

$$I \propto \frac{1}{r^2}$$

$$\therefore \quad \frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$$

Here, $r_1 = d, r_2 = \frac{d}{2}$ and $I_1 = I$

$$\therefore \quad \frac{I}{I_2} = \frac{\left(\frac{d}{2}\right)^2}{(d)^2} = \frac{1}{4}$$

or $\quad I_2 = 4I$

2. (b) From Einstein's photoelectric equation, maximum kinetic energy of emitted electrons,

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

where, h is Planck's constant,
ν is frequency of incident radiation
and ν_0 is threshold frequency of metal surface.
For metal A,

$$K_{(\max)A} = h\left(\nu - \frac{\nu}{2}\right)$$

or $\quad K_{(\max)A} = \frac{h\nu}{2} \quad \ldots \text{(i)}$

Similarly, for metal B,

$$K_{(\max)B} = h\left(\nu - \frac{\nu}{3}\right)$$

or $\quad K_{(\max)B} = \frac{2h\nu}{3} \quad \ldots \text{(ii)}$

So, from Eqs. (i) and (ii), the ratio of the maximum kinetic energy of electrons emitted from A to that from B is given as,

$$\frac{K_{(\max)A}}{K_{(\max)B}} = \frac{\frac{h\nu}{2}}{\frac{2h\nu}{3}}$$

$$= \frac{1}{2} \times \frac{3}{2} = \frac{3}{4}$$

or $\quad K_{(\max)A} : K_{(\max)B} = 3:4$

3. (b) The de-Broglie wavelength associated with a particle is given by

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

Given, $K_p = 4\,\text{eV}$ and $K_\alpha = 1\,\text{eV}$

$$\therefore \quad \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha K_\alpha}{m_p K_p}} = \sqrt{\frac{4}{1} \times \frac{1}{4}} \qquad \left[\because \frac{m_\alpha}{m_p} = 4\right]$$

$$= 1$$

or $\quad \lambda_p : \lambda_\alpha = 1:1$

4. (b) de-Broglie wavelength associated with a moving charged particle is given as $\lambda = \frac{h}{p}$.

where, h is Planck's constant and p is the linear momentum.

$$\Rightarrow \quad p\lambda = h$$

This equation is in the form of $yx = c$, which is the equation of a rectangular hyperbola. Hence, the graph given in option (b) is correct.

5. (c) Given, work function, $\phi = 4$ eV

Longest wavelength of light $= \lambda_m$

$$\therefore \quad \frac{hc}{\lambda_m} = \phi$$

$$\therefore \lambda_m = \frac{hc}{\phi} = \frac{(6.63 \times 10^{-34} \times 3 \times 10^8)}{4.0 \times 1.6 \times 10^{-19}} = 310\,\text{nm}$$

6. (b) We know that, work function $= \frac{hc}{\lambda}$

$$\frac{\phi_{\text{Na}}}{\phi_{\text{Cu}}} = \frac{hc/\lambda_{\text{Na}}}{hc/\lambda_{\text{Cu}}} = \frac{hc}{\lambda_{\text{Na}}} \times \frac{\lambda_{\text{Cu}}}{hc} = \frac{\lambda_{\text{Cu}}}{\lambda_{\text{Na}}} = \frac{2.3}{4.5} = \frac{1}{2}$$

$$\therefore \quad \lambda_{\text{Na}} : \lambda_{\text{Cu}} = 2:1$$

7. (b) Given, $E = 3\,\text{eV} = 3 \times 1.6 \times 10^{-19}$ J

We know that, $E = \frac{hc}{\lambda}$

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

$$= \frac{19.8 \times 10^{-26}}{4.8 \times 10^{-19}} = 4.125 \times 10^{-7}$$

$$= 412.5 \times 10^{-9}$$

$$= 412.5\,\text{nm}$$

8. (c) de-Broglie wavelength of an electron is given by

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2meV}} = \frac{12.27}{\sqrt{V}}\,\text{Å}$$

where, h = Planck's constant, m = mass of electron, e = electronic charge and V = potential difference with which electron is accelerated.

$$\lambda = \frac{12.27}{\sqrt{10000}} = \frac{12.27}{100} = 0.1227\,\text{Å}$$

9. (a) We know that, $\lambda = \frac{h}{p}$

Here, $\left|\frac{\Delta\lambda}{\lambda}\right| = \left|\frac{\Delta p}{p}\right|$

$\Rightarrow \quad \frac{0.5}{100} = \frac{p}{p_i}$

$\Rightarrow \quad p_i = 200p$

10. (b) $KE = \frac{1}{2}mv^2$ (same for all particles) know,

de-Broglie wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m(KE)}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$$

Here, mass of α-particle is highest, hence it has lowest wavelength.

11. (c) de-Broglie wavelength, $\lambda_e = \frac{h}{\sqrt{2m_e E}}$

and $\quad \lambda_p = \frac{h}{\sqrt{2m_p E}} \Rightarrow \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}}$

12. (a) The electromagnetic theory of light failed to explain photoelectric effect. It cannot be explained by assuming wave nature of radiation. If wave nature of radiation is assumed, then it will take quite a long time (about one year) for electron to come out of the metal surface.

13. (a) There is a very small time lag between the instants, the photon of light falls on the metal surface and instantly a photoelectron is emitted from the metal surface.

14. (b) Stopping potential is dependent on frequency, but independent of the intensity. So, increasing the distance, affects the intensity as

$$\text{Intensity} \propto \frac{1}{\text{Distance}^2}$$

So, the stopping potential will not change. But name of saturation current depends on the intensity of incident radiation, so more the distance, the intensity will decrease. Hence, the saturation current will also decrease.

15. (a) According to the Einstein's picture of photoelectric effect, intensity of the radiation is proportional to the number of energy quanta per unit area per unit time. Thus, greater the number of the energy quanta available, greater is the number of electrons the absorbing the energy quanta and therefore greater is the number of electrons coming out of the metal.

Hence, for $\nu > \nu_0$, photoelectric current is proportional to intensity.

16. (b) Work function is the minimum energy required to eject the photoelectron from photosensitive metal.

Hence for metal to have high photosensitivity, the work-function should be small.

Mathematically, work function is given as $h\nu_0$, where ν_0 is the threshold frequency.

17. (a) Light when interacted with matter behaves as, if it is made up of quanta or packet of energy, each packet of energy $h\nu$. Einstein later arrived at a important result that, the light quantum can also be associated with momentum $\left(\frac{h\nu}{c}\right)$.

Thus, a definite value of energy as well as momentum is a strong sign that the light quantum can be associated with a particle. This particle was later named photon.

18. (a) A person approaching a doorway may intrupt a light beam which is incident on photocell.

This interuption will leads to abrupt change in the amount of photocurrent. Thus, this change in photocurrent helps to start a motor which is fitted in the doorway which opens the door.

19. (d) de-Broglie wavelength, $\lambda = \frac{h}{\sqrt{2mK}}$, where K is kinetic energy.

For same kinetic energy, $\lambda \propto \frac{1}{\sqrt{m}}$ ... (i)

As α-particle is heaviest amongst the given particles. From relation (i), λ is smallest for α-particle.

20. (i) (b) de-Broglie wavelength λ of moving particle with velocity v is given as

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

where, m = mass of particle

and h = Planck's constant.

Hence, λ does not depend on the amount of charge q of the particle.

(ii) (c) de-Broglie wavelength λ and kinetic energy K of particle are related as

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

$$\Rightarrow \quad \lambda \propto \frac{1}{\sqrt{K}}$$

$$\Rightarrow \quad \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{K_1}{K_2}} = \sqrt{\frac{K}{K/9}} = 3$$

$$\Rightarrow \quad \lambda_2 = 3\lambda_1 = 3\lambda \qquad (\because \lambda_1 = \lambda)$$

(iii) (b) de-Broglie wavelength λ of moving particle is given as

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

$$\lambda = \frac{h}{p} \qquad (\because \text{momentum}, p = mv)$$

$$\therefore \qquad \lambda \propto \frac{1}{p}$$

Graph will be a rectangular hyperbola.

Hence, correct variation of particle momentum p and the associated de-Broglie wavelength λ is shown in option (b).

(iv) (b) Accelerating potential difference,

$$V = 100 \text{ V}$$

de-Broglie wavelength, $\lambda = \frac{1.227}{\sqrt{V}}$ nm

$$= \frac{1.227}{\sqrt{100}} = 0.123 \text{ nm}$$

The de-Broglie wavelength 0.123 nm lies in the range of wavelength of X-rays.

(v) (d) de-Broglie wavelength λ of charge particle of charge q accelerating through a potential difference V is given as

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

$$\Rightarrow \qquad \lambda \propto \frac{1}{\sqrt{mq}}$$

$$\therefore \qquad \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}}$$

$$= \sqrt{\frac{4m_p \cdot 2q_p}{m_p \cdot q_p}} \qquad \left(\begin{array}{l} \because m_\alpha = 4m_p \\ q_\alpha = 2q_p \end{array}\right)$$

$$\Rightarrow \qquad \frac{\lambda_p}{\lambda_\alpha} = \sqrt{8}$$

$$\Rightarrow \lambda_p : \lambda_\alpha = \sqrt{8} : 1$$