Chapter-11: Dual Nature of Radiation and Matter

1. **For photoemission to take place, either of the following conditions must be satisfied:**
   $$\boldsymbol{E \geq W \ \ or \ \ f \geq f_0 \ \ \ or \ \ \lambda \leq \lambda_0}$$
2. **Effect of intensity of light on photoelectric current**
   Since the photoelectric current is directly proportional to the number of photoelectrons emitted per second which is also proportional to the intensity of incident radiation. Intensity ∝ photoelectric current ∝ number of photo electrons emitted per sec ∝ $\frac{1}{distance^2}$
3. **Maximum kinetic energy of emitted electrons is given as $\boldsymbol{K_{max} = eV_0 = \frac{1}{2}mv_{max}{}^2}$. Where m is the mass of photoelectron and V_{max} is the maximum velocity of photoelectrons. $\boldsymbol{V_0}$ is stopping potential or cut-off potential.**
4. **Einstein's photoelectric equation**
   When a photon of energy hf falls on a metal surface, the energy of the photon is absorbed by the electron and is used in the following two ways.
   (i)A part of energy is utilised to overcome the surface barrier and come out of the metal surface. This part of energy is called work function. W = hf_0
   (ii)The remaining part of energy is used in giving a velocity v to the emitted photoelectron. This is equal to maximum K. E. of the photoelectron. $K_{max} = \frac{1}{2} mv_{max}{}^2$.
   According to the law of conservation of energy, $hf = W + \frac{1}{2}mv_{max}{}^2 = W + K_{max}$
   So, **Einstein photoelectric equation** is, $K_{max} = hf - W$
5. **Relation between stopping potential and frequency**
   $K_{max} = h(f - f_0)$. If stopping potential is V_0 then $K_{max} = eV_0$
   Therefore, $eV_0 = h(f - f_0)$, (here $f = \frac{c}{\lambda}$ and $f_0 = \frac{c}{\lambda_0}$)
   Then, $V_0 = \frac{hf}{e} - \frac{hf_0}{e} = \frac{h}{e}(f - f_0)$
6. **De-Broglie wave equation**:
   Considering photons as an em wave of frequency f, its energy from Planck's quantum theory is given by $E = hf ----(1) where\ h\ is\ Planck's constant$
   Considering photon as a particle of mass m, the energy associated with it is given by Einstein's mass energy relationship as $E = mc^2 ----(2)$
   From equation (1) and (2), we get $hf = mc^2 \quad or, \frac{hc}{\lambda} = mc^2 \quad or, \lambda = \frac{h}{mc} = \frac{h}{p} ----(3)$
   Where p (=mc) is the momentum of the photon. The above equation (3) has been derived for a photon of radiation.
   According to de-Broglie hypothesis, it must be true for material particles like electrons, protons, neutrons etc. Hence a particle of mass m moving with velocity v must be associated with a matter wave of wavelength λ , given by $\lambda = \frac{h}{p} = \frac{h}{mv} ----(4)$
   This equation (4) is the de-Broglie wave equation for material particles.
   It explains the dual nature of matter as it connects the wave characteristic 'λ' with particle characteristic 'p'.

From de-Broglie's equation, we find that The wavelength of moving particle is inversely proportional to its momentum, that is, $\lambda \propto \frac{1}{p}$

7. De-Broglie wavelength of an electron

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2meV}} = \frac{12.27}{\sqrt{V}}$$

8. For any charge particle,

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

9. Similarly, de-Broglie wavelength for other charged particle can be given by

For proton, $\lambda = \frac{0.286}{\sqrt{V}}$ (in Å) , For deuteron, $\lambda = \frac{0.2o2}{\sqrt{V}}$ (in Å), For α-particle, $\lambda = \frac{0.101}{\sqrt{V}}$ (in Å)

For electrons, λ = $\frac{12.27}{\sqrt{V}}$ **(in Å)**