Dual Nature of Matter

$h = 6.624 \times 10^{-34}\,Js = 4.14 \times 10^{-15}\,eV/sec$, $1eV = 1.6 \times 10^{-19}\,J$

$$E = \frac{hc}{\lambda}(J) = h\nu = \frac{12{,}400}{\lambda(\text{in } \mathring{A})}\,eV$$

Properties of photons:

1. Energy radiated is in form of photons, speed of photon $= 3 \times 10^8\,m/s$
   E depends on ν. (st. line)
2. Photons are electrically neutral, neither deflected by electric or magnetic fields.
3. During propagation of photons, speed, λ of photons changes but ν = constant.
4. Rest mass of photon = zero.
   Mass of photon $(m) = \dfrac{h\nu}{c^2} = \dfrac{h}{\lambda c}$
5. Momentum
   $P = mc = \dfrac{h\nu}{c} = \dfrac{h}{\lambda}$

→ Intensity (I) $= \dfrac{\text{Energy}}{\text{Area} \times \text{time}} = \dfrac{\mathcal{E}}{At}\left(\dfrac{W}{m^2}\right)$, $I \propto \dfrac{1}{r^2}$

no of photons emitted $(n) = \dfrac{IA\lambda}{hc}$

absorbtion coefficient $(a) = \dfrac{\text{absorbed energy}}{\text{total energy}} \Rightarrow 0 < a < 1$

reflected coefficient $(r) = \dfrac{\text{reflected energy}}{\text{total energy}} \Rightarrow 0 < r < 1$

$\left.\right\}\, a + r = 1$

→ Radiation force; force acting on the surface of the body due to radiations in the form of photons is known as radiation force. Corresponding pressure is radiation pressure

Case 1: falls normally $\qquad a = 1, r = 0$

initial momentum (i.m) $= h/\lambda$ final momentum (f.m) $= 0$

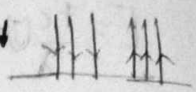
force acting on photons $= \dfrac{IA}{c}$ ↑↓

Radiation pressure $= \dfrac{I}{c}$

Case 2 : The amount of radiation falls on the surface completely reflected.

$a=0, r=1$ $\quad i \cdot m = h/\lambda \quad f \cdot m = h/\lambda \quad \Delta m = 2h/\lambda$

$n = \frac{IA\lambda}{hc}$, force on photons $= \frac{2IA}{c}$ $\uparrow\downarrow$



Radiation pressure $= \frac{2I}{c}$

Case 3 : partial absorption, partial reflection

$0 < a < 1, \quad 0 < r < 1$

$\Delta p = \frac{2h}{\lambda} \qquad F = \frac{IA}{c}[1+r] \qquad P = \frac{I}{c}[1+r]$

no. of photons incident $(N_i) = \frac{I(A\cos\theta)\lambda}{hc}$

If made θ with surface: " " absorbed $(N_a) = \frac{I(A\cos\theta)\lambda}{hc}(1-r)$

During absorption $F_{R\perp} = \frac{IA\cos^2\theta}{c}(1-r) \qquad F_{a\parallel} = \frac{IA(\cos\theta)\sin\theta\,(1-r)}{c}$

Total radiation $F_\perp = \frac{IA\cos^2\theta}{c}[1+r] \qquad F_\parallel = \frac{IA\cos\theta\sin\theta}{c}(1-r)$

Resultant force $F = \frac{IA\cos\theta}{c}\sqrt{1+r^2+2r\cos 2\theta}$ $\qquad F_{radi} = \frac{2P_{moment}\cos\theta}{c}$

Radiation pressure $P = \frac{I\cos^2\theta\,(1+r)}{c}$

Case 1 if θ made by radiation

$\Delta P = \frac{IA\cos^2\theta}{c}$ ⊥ar along surface $\Delta p = \frac{IA\cos\theta\sin\theta}{c}$

Radiation pressure $= \frac{I\cos^2\theta}{c}$

Case 2: if θ made by photon

$\Delta p = 0$ along surface $\qquad \Delta p = \frac{2h}{\lambda}\cos\theta$ ⊥ar

No. of photons $N = \frac{I(A\cos\theta)\lambda}{hc}$ " $\qquad$ Total $\Delta P_{\parallel \& \perp ar} = \frac{2IA\cos^2\theta}{c}$

Radiation pressure $= \frac{2I\cos^2\theta}{c}$

Photoelectric effect:

- → Min energy required to eject e^-s from metal is work function.
- → Min. frequency of photon required to eject e^-s from metal is threshold frequency
- → Max. wavelength of photons required to eject e^- is threshold wavelength

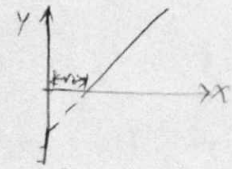
Work function $(W) = h\nu_0 = \frac{hc}{\lambda_0}$ (J) $\Rightarrow W = \frac{12400}{\lambda(\mathring{A})}$ eV

if $\nu < \nu_0$, $E < W$, $\lambda > \lambda_0$ no emission of photoelectron.

if $\nu \geq \nu_0$, $E \geq W$, $\lambda \leq \lambda_0$ e^- ejected from metal.

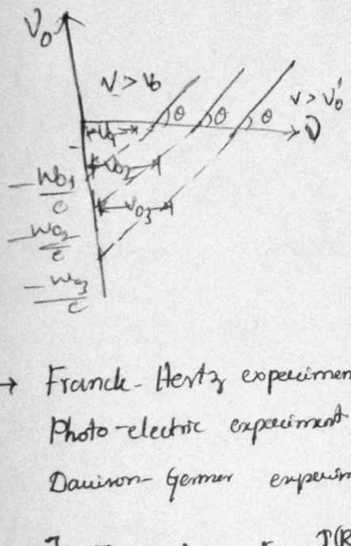
→ $E = W + KE$ $\quad n = \frac{I A \lambda}{hc} \propto$ photo $e^- \propto$ photo current

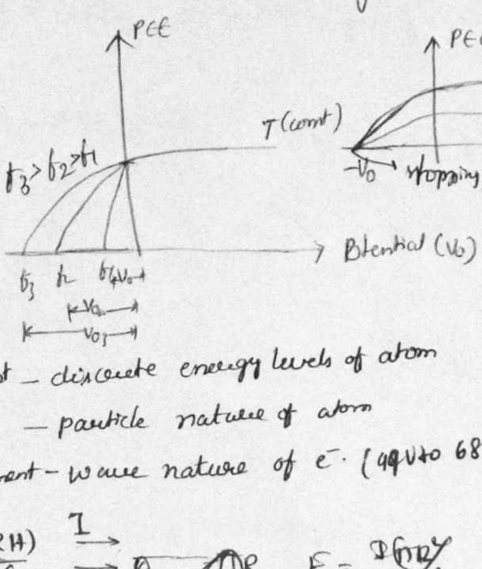
$E = \frac{hc}{\lambda} = h\nu$

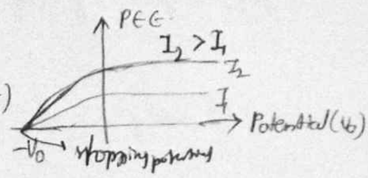


$KE_{max} = eV$ (V = stopping potential)

$$KE = h\nu - W_0 \Rightarrow eV_0 = h\nu_0 - W_0 \Rightarrow V_0 = \frac{h}{e}\nu_0 - W$$
$$y = mx + c$$



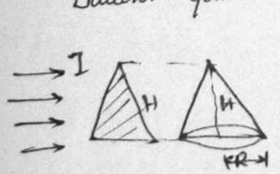




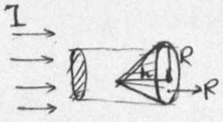
→ Franck-Hertz experiment – discrete energy levels of atom

Photo-electric experiment – particle nature of atom

Davison-Germer experiment – wave nature of e^-. (44V to 68V) at 54V max. I
$\theta = 50°$



$F = \frac{I(RH)}{c}$,



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

Recoil velocity $\boxed{V_R = h/m\lambda}$