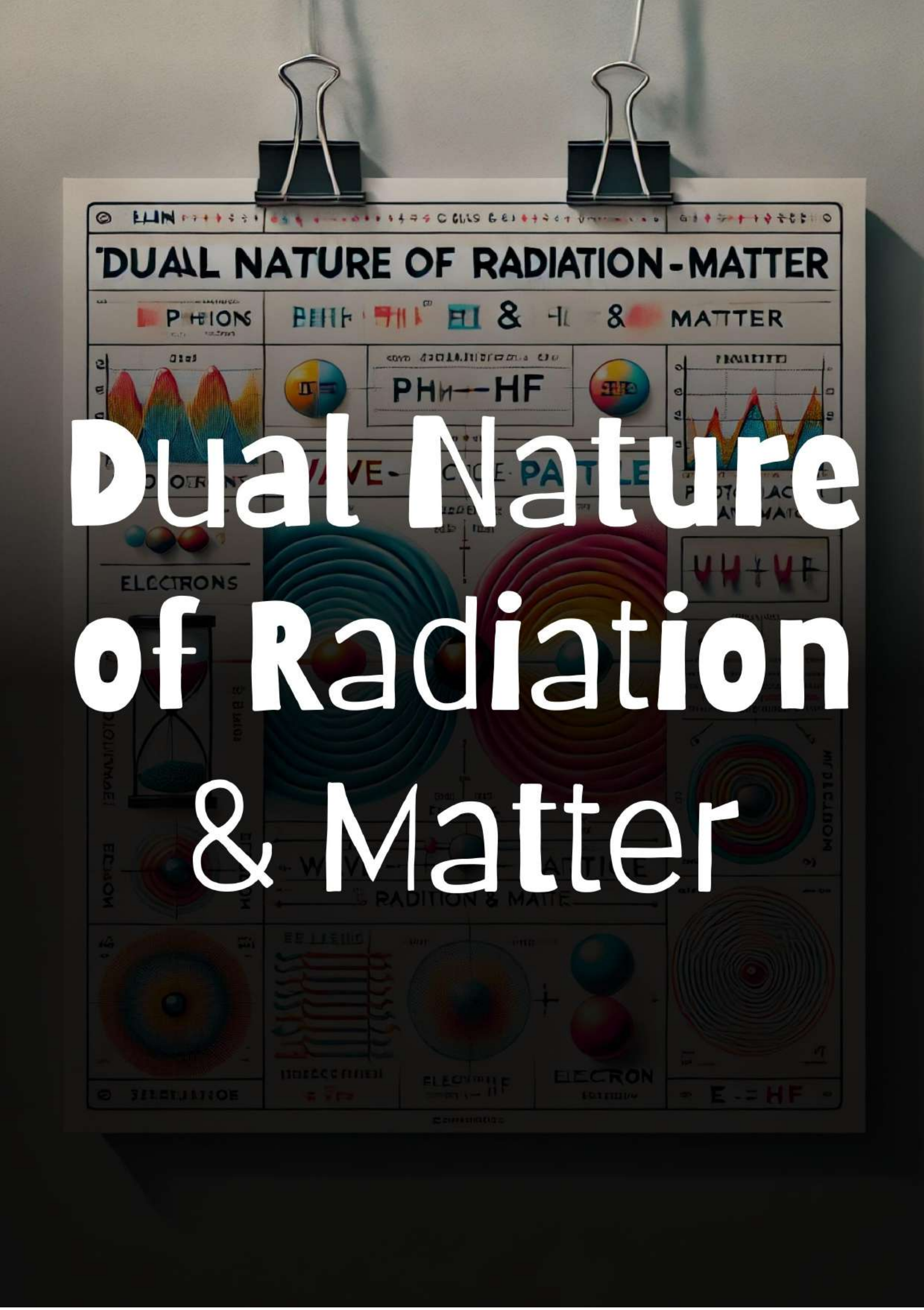
Dual Nature of Radiation & Matter



DUAL NATURE

Newton (1670)

- → Light is a particle (corpuscle)
- → reflection /refraction /ray optics.

Huygen (1690)

- → Light is a mechanical wave
- → Interference/ diffraction/ polarisation
- → Ether is a medium for light.

Maxwell (1865)

Light is a non mechanical wave
Does not require medium
Transverse wave in nature
EM wave , Energy is continuous

Max Planck (1901)

Light is a particle
Photon
Blacky body radiation
Photoelectric effect , compton effect
Energy is quantized.

De Broigle (1923) → Nobel prize.

Light have a dual nature

Davisson and Germer exp (1927)
$e^{\ominus}$ is a wave

G.P thomson
experimental verification
of $e^{\ominus}$ as a wave

Light is not a wave nor a particle it is a form of energy which sometimes behave as a wave or a particle.

Quantum theory
↓
Planck

Light

Light behave as a ray
$\lambda_{light} <<< l_{object}$

Light behave as wave
$\lambda_{light} \approx l_{object}$

Light behave as a particle (photon) when it interacts with $e^{\ominus}$, proton, neutron, α- particle.

When light behave as particle
↓
collection of small particle called photon.

Energy of each photon = hf
↓
planck constant = 6.626×10^{-34} $J s^{+1}$

$$E = hf$$

$$E = \frac{hc}{\lambda} \quad [\because f = \frac{c}{\lambda}]$$

$$E = \frac{2 \times 10^{-25} J}{\lambda (m)}$$

$$E = \frac{12400}{\lambda (\mathring{A})} eV = \frac{1240 \, eV}{\lambda (nm)}$$

Q What is the energy in Joule associated with a photon of wavelength, 4000 Å ?

⇒ $E = \frac{12\overset{4}{0}0\ eV}{\lambda(\AA)} = \frac{12400}{4000} = 3.1\ eV$

$E = \frac{2\times10^{-25}}{4000\times10^{-10}} = 5\times10^{-19}\ J$

Q Find frequency of 1 Mev photon?

Ans $E = hf$

$1MeV = hf$

$10^6 \times 1.6\times10^{-19} = 6.6\times10^{-34} f$

$f = \frac{16}{66}\times10^{21}\ s^{-1}$

Q Planck constant has the same dimension as

a) force × time
b) force × distance
c) force × speed
[✓ d)] force × distance × time

$E = hf$

$E \propto f$

$E\downarrow = f\downarrow$

$E\uparrow = f\uparrow$

Energy of light = nhf
↓
quantised

n = no. of photon

$$n\ (\text{no. of photon}) = \frac{E_{light}}{hf} = \frac{E_{light}\,\lambda}{hc}$$

Rest mass of Photon = 0

Speed of photon in vacuum = 3×10^8 m/s

Speed of photon in medium $\Rightarrow v = c/\mu$

Charge of photon ⇒ 0 (Neutral)

Photon can't be charged

It can't deviate in EM field

Photon has some moving mass
↓ ∴
it deviate in gravitational field.

Q The velocity of photons is proportional to:
(ν = frequency)

a) $1/\sqrt{\nu}$

~~b)~~ ν^0

c) ν^2

d) $\sqrt{\nu}$

$E = hf$
↓
for photon

Not for eletron

$E = hf$

↳ for photon

↳ not for electron

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

$E = pc$

p → momentum of photon

c → speed of light

E → Energy of photon

$M = \frac{E}{c^2}$

↓

moving mass of photon.

$E = mc^2$

$m = \frac{E}{c^2}$

$mc = \frac{E}{c}$

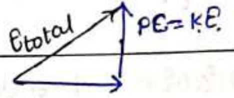
$pc = E$

For any relativistic particle (for electron/ photon/ Neutron)

$E = \sqrt{(m_0c^2)^2 + (pc)^2}$

↓

total energy



$E_0 = m_0c^2$

For photon

$m_0 = 0$

$\therefore E_{photon} = pc$

* X-ray cannot deviate in E.M field

$E = pc = hf$

↳ total energy of photon

K.E of photon.

} → true ∵ $m_0 = 0$

Q The momentum of the photon of wavelength 5000 Å will be

a) 1.3×10^{-27} kg m/s

b) 1.3×10^{-28} kg m/s

c) 4×10^{29} kg m/s

d) 4×10^{-18} kg m/s

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

Q A photon in motion has a mass.

a) $c/h\nu$

b) h/ν

c) $h\nu$

[✓ d)] $h\nu/c^2$

Ans $E = pc$

$h\nu = mc^2$

$m = \frac{h\nu}{c^2}$

Q A radiation of energy E and no. of photon n then find effective moving mass of photon?

Ans $E = npc$

$E = nmc^2$

$m = \frac{E}{nc^2}$

* ★ Total energy, total momentum are conserved in every $e^{\ominus}$ - photon interaction but no. of photon not conserved.

$$\underset{\text{photon}}{\gamma} + \gamma = \overset{\text{positron}}{e^+} + \overset{\text{electron}}{e^{\ominus}}$$ Pair production

$$e^+ + e^{\ominus} \rightarrow \gamma + \gamma$$ Pair anilation

Power of light / Radiation.

$$P = \frac{E}{t} = \frac{E_{radiation} / E_{light}}{t}$$

$$P = \frac{nhf}{t}$$

$$\boxed{\frac{n}{t} = \frac{P}{hf}} = \frac{P}{hc}\lambda \Rightarrow P\lambda \times 5 \times 10^{24}$$

$\downarrow$

no. of photon per second.

Q If Green light and red light have same power then which will have larger no. of photon.

Ans $(P)_G = (P)_{Red}$

$$\left(\frac{nhc}{\lambda}\right)_{Green} = \left(\frac{nhc}{\lambda}\right)_{Red}$$

$$n_{red} > n_{green}$$

Q If power of light 10kW and wavelength 300nm then find no. of photon per sec?

Ans $$\frac{n}{t} = \frac{P}{h\nu} = \frac{P}{hc}\lambda = \frac{10 \times 10^3 \times 300 \times 10^{-9}}{2 \times 10^{-25}}$$

$$= 15 \times 10^{21}\ s^{-1}$$

Q A monochromatic source of light operating at 200W emits 4×10^{20} photons per second. Find the wavelength of the light

Ans $$\frac{P}{hf} = \frac{n}{t} = 4 \times 10^{20} = \frac{\overset{100}{\cancel{200}}}{\cancel{2} \times 10^{-21}} \times \lambda$$

$$\Rightarrow 4 \times 10^{-7} = \lambda$$

$\lambda = 0.4\,\mu m$ Ans

Q Let P and E denote the linear momentum and energy of a photon. If the wavelength is decreased

a) both P and E increase

b) P increases and E decreases

c) P decreases and E $\overset{\text{in}}{\text{de}}$creases

d) both P and E decreases

Ans $E = pc$

$E = ph\lambda$

$\uparrow P = \frac{h}{\lambda\downarrow}$

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

Intensity of Radiation :- Total energy per unit area per second

$$I = \frac{E}{At} = \frac{Power}{A}$$

$$IA = Power$$

$$I = \frac{nhf}{tA} = \frac{nhc}{t\lambda A}$$

Intensity depends on frequency but frequency does not depend on intensity.

$$\frac{n}{t} = \frac{IA}{hf} = \frac{IA\lambda}{hc}$$

$I \propto$ frequency

$I \propto$ no. of photon

For a given source

$I \propto$ no. of photon

↳ photon flux ⇒ counting of photon

Q The equation $E = pc$ is valid

a) for an electron as well as for a photon.
b) for an electron but not for a photon.
c) for a photon but not for an electron.
d) neither for an electron nor for a photon.

* If no information of source is given

↓

then frequency is constant.

Q If intensity becomes double then no. of photon will?

→ $I = \frac{nhf}{At}$

$I \propto n$ [no information about frequency]

$\therefore I =$ double

* Q If frequency and intensity both becomes double then no. of photon will be.

Ans $I = \frac{nhf}{At}$

$n =$ constant

$E \propto$ frequency

No. of photon $\propto (\text{frequency})^0$

↓

does not depend on frequency

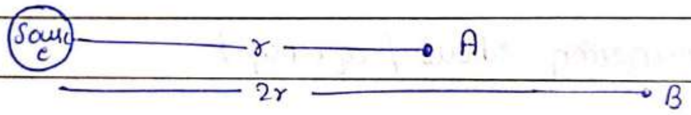
$I \propto$ no. of photon

$I \uparrow$ Energy of photon does not increase.

but we are sure no. of photon ↑

Q Find $\left(\frac{f_A}{f_B}\right)_{\text{Photon}}$ $\left(\frac{I_A}{I_B}\right)_{\text{light}}$

ratio of no. of photon per unit area ?



Ans $\left(\frac{f_A}{f_B}\right)_{\text{photon}} = 1$

$$\frac{I_A}{I_B} = \frac{\frac{n_1 \cancel{hf}}{A_1}}{\frac{n \cancel{hf}}{A_2}} = \frac{A_2}{A_1} = \frac{4\cancel{r^2}}{\cancel{r^2}} = 4:1$$

$$\frac{n_A}{A_B} = \frac{I_A}{I_B} = \frac{4}{1}$$

Radiation Pressure

Completely Reflecting surface

$\Delta P = 2P$

$F = \frac{2P}{t} = \frac{2h}{\lambda t}$

$(F)_{n photon} = \frac{2nh}{\lambda t} = \frac{2IA}{c}$

$I = \frac{nhc}{\lambda At}$

$\boxed{\text{Pressure} = \frac{F}{A} = \frac{2I}{c}}$

Completely Absorbing surface

$\Delta P = P$

$F = \frac{P}{t}$

$\boxed{P = \frac{2I}{c}}$

$\text{Pressure} = \frac{\text{Power}}{AC}$

$\boxed{\text{Force} = P \times A = \frac{\text{Power}}{c}}$

Q Radiation pressure in terms of absorption coefficient and reflection coefficient?

Ans ρ = reflection coefficient (कितना Reflection हुआ है।)

$\rho = 1 = 100\%$ reflection

$\rho = 0 = 0\%$ reflection

$P = \frac{I}{c}(\rho + 1)$ (Verify it by $\rho = 1, = 0$) $\frac{I}{c}(r+1)$

σ = absorption coefficient

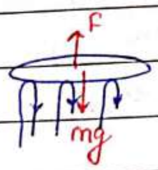
$\sigma = 1 = 100\%$ absorption

$\sigma = 0 = 0\%$ absorption

$P = \frac{I}{c}(2-\sigma)$ $\frac{P}{c}(2-a)$

Q A plate of mass 10g is in equilibrium in air due to light beam on plate then power of beam, if surface area of plate is A and complete reflecting.

Ans



$F = mg$

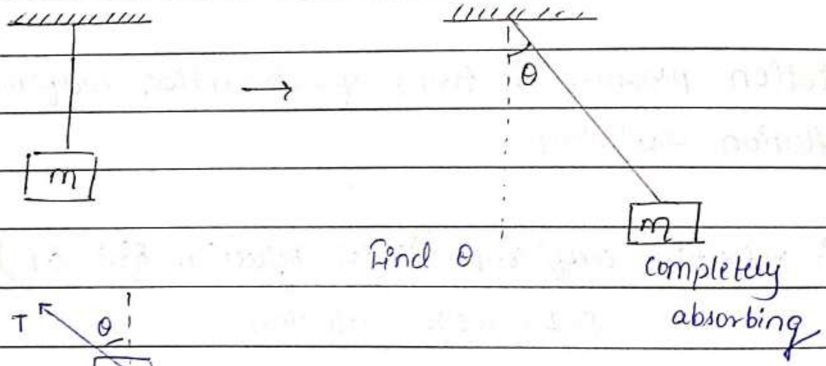
$\frac{2IA}{c} = mg$

$\frac{2\,Power}{c} = mg$

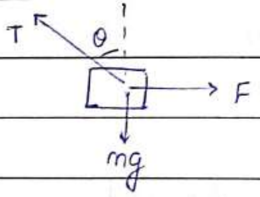
$Power = \frac{10\times10^{-3}\times10\times3\times10^{8}}{2}$

$= 1.5\times10^{7}$ Watt

Q



Ans F.B.D



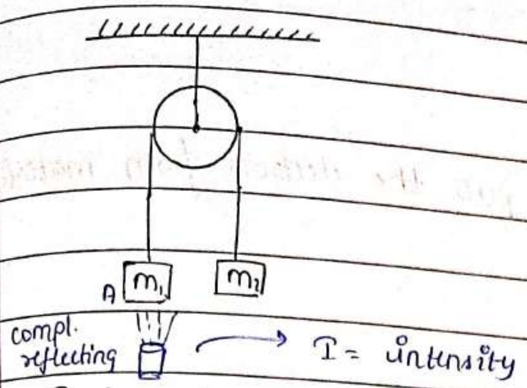
$T\cos\theta = mg$

$T\sin\theta = F$

$\tan\theta = \frac{F}{mg} = \frac{2P}{cmg}$

$\theta = \tan^{-1}\left(\frac{P}{cmg}\right)$

Q



Find acceleration of m_1 & m_2 $(m_2 > m_1)$

Ans $a = \frac{F_{net} \text{ unbalanced force}}{\text{net mass}}$

$$a = \frac{(m_2 - m_1)g + \frac{2IA}{c}}{m_1 + m_2}$$

Photoelectric effect

Discovered by Hertz and Leanard (1887 & 1892)

↓

can't be explained by wave theory

Photoelectric effect was explained by Einstein (in 1920)

Photoelectric effect is the emission of electron when electromagnetic radiation of suitable energy hits a material & emitted electron is photoelectron.

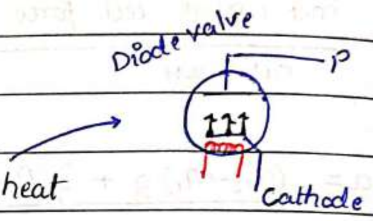
Photon (Light energy) ⟹ Electron (Electric energy)

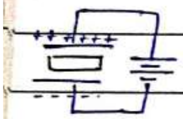
Work function (ϕ)

Minimum energy required to pull the electron from material is called work function.

ϕ unit → eV or (J)
↓
depends on nature of material (metal)

These energy can be given by





(i)	Thermionic emission	-------→	By heat
(ii)	Field emission	-------→	By electric field
(iii)	Secondary emission	-----→	By collision of $e^{\ominus}$
(iv)	Photoelectric effect	-------→	By light

Condition of Photoelectric effect

$\{E_{light} \geq \phi\}$ ← wrong
↓
because there is no one to one interaction b/w electron and light
↓
Einstein → one to one interaction b/w photon & electron.

$\boxed{\{E_{photon} \geq \phi\}}$ ✓
↓
$e^{\ominus}$ must eject ×
$e^{\ominus}$ may eject ✓

$E_p = 3eV$
$\phi = 1eV$
↓
$e^{\ominus}$ may eject

$\{E_{photon} \geq \phi\}$

- Hertz discovered the Photoelectron effect (PEE)
- Laws of PEE is given by "Lenard"
- Explanation of PEE is given by
- Einstein with the help of Planck's quantum theory.

$hf \geq hf_0$

threshold frequency of metal

$\{f \geq f_0\}$

$\downarrow$

$f_{light} \downarrow$

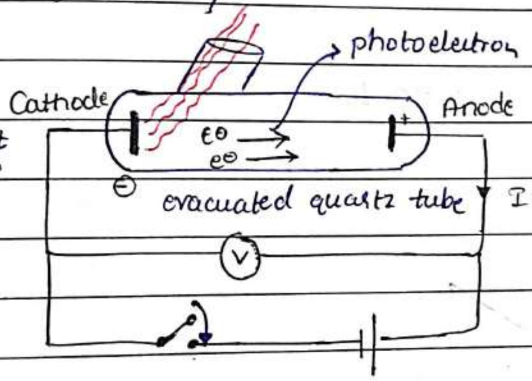
$$\frac{\cancel{hc}}{\lambda_{light}} \geq \frac{\cancel{hc}}{\lambda_0}$$

$\{\lambda_{light} \leq \lambda_0\}$

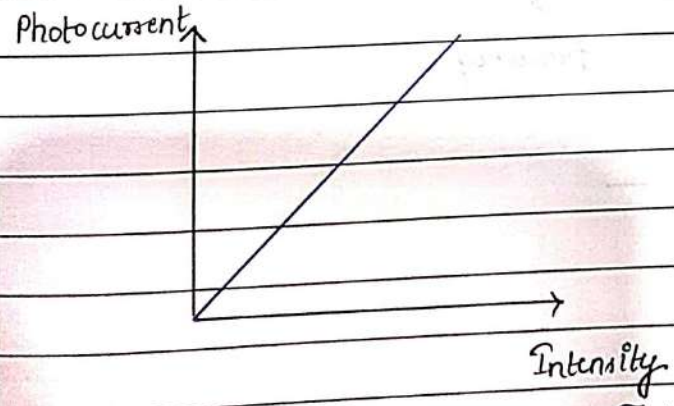
Hertz experiment

↓

Discovered first time



If we incident uv rays on anode then, photo $e^{\ominus}$ emits but no photo current will flow.



Photocurrent ∝ no. Intensity

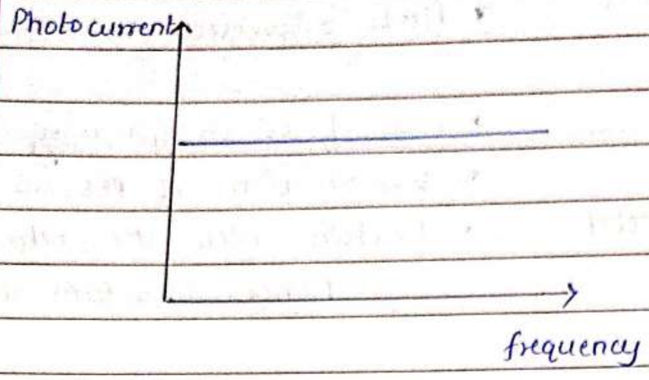
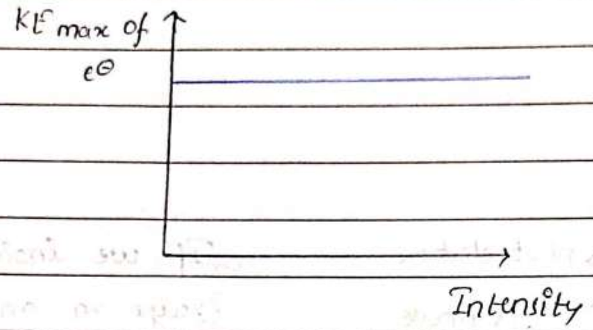
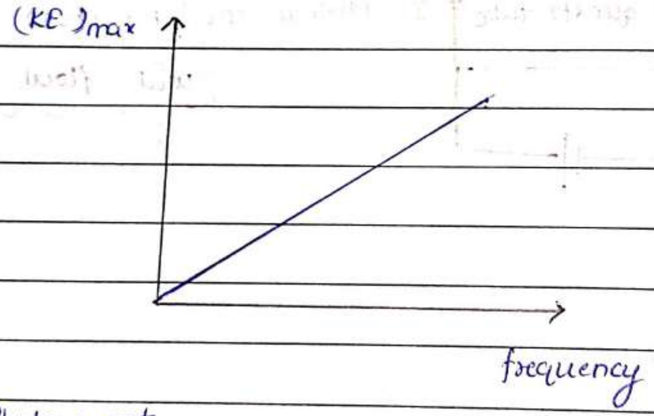
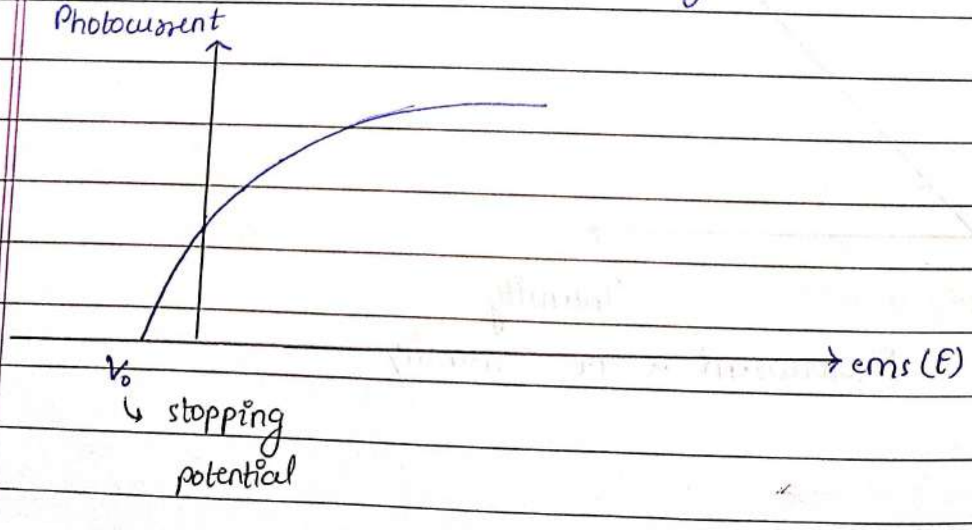
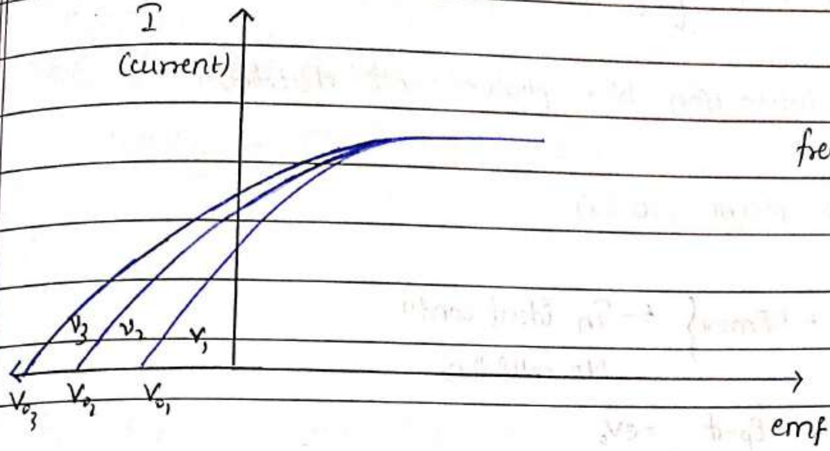


Photo current
frequency


KE max of e⊖
Intensity

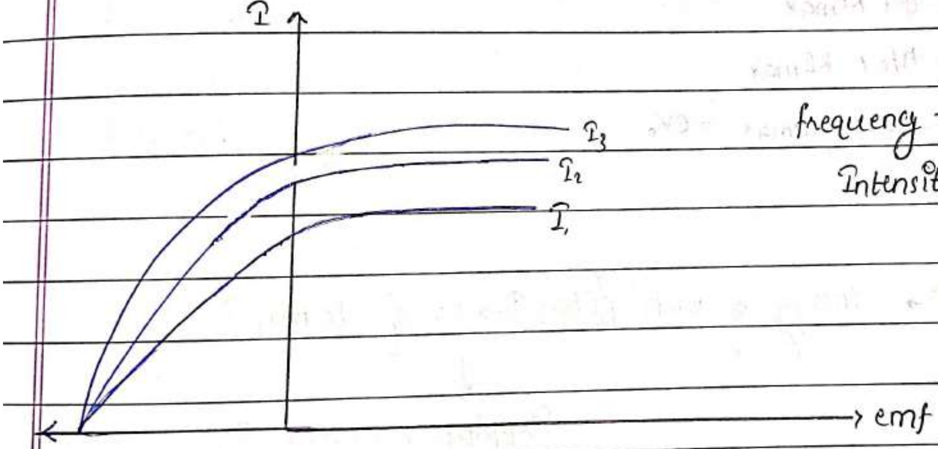

(KE)max
frequency


Photocurrent
V₀
↳ stopping potential
→ ems (E)



frequency → change
no. of photons = constⁿ
(Intensity)

$\nu_3 > \nu_2 > \nu_1$



frequency = constⁿ → stopping potential
Intensity changes

Einstein equation of photoelectric effect

one to one interaction b/w photon and electron

Instantaneous process ($10^{-9}s$)

$$\left\{E_p = \phi + KE_{max}\right\}$$ ← In ideal condⁿ
No collision

$KE_{max} = E_p - \phi \quad = eV_0$

$KE_{min} = 0$

$E_p = \phi + KE_{max}$

$hf = hf_0 + KE_{max}$

$\frac{hc}{\lambda} - \frac{hc}{\lambda_0} = KE_{max} = eV_0$

Frequency↑ → energy of each photon ↑→ KE. of electron ↑
↓
Stopping potential ↑

Intensity → no. of photon → no. of $e^{\ominus}$ → photocurrent $\left(I = \frac{ne}{t}\right)$

Laws of Photoelectric effect

PEE is an Instantaneous process

Efficiency of photoelectric $= \frac{\text{no. of electron}}{\text{no. of photon}} = 10^{-3}$ to 10^{-4}

Quantum efficiency

One to one interaction

one photon → one electron

$E_{photon} \geq \phi$ ($e^{\ominus}$ may eject)

K.E. of emitted electron $= E - \phi$

Stopping potential $eV_0 = KE_{max}$

Q The frequency and intensity of a light source are both doubled. Consider the following statements

(i) The saturation photocurrent remains also the same

(ii) The maximum kinetic energy of the photoelectrons is doubled.

a) Both A and B are true

[✓ b)] A is true but B is false

c) A is false but B is true

d) Both A and B are false

Ans Eg $E_p = 8eV$ $E_p' = 16eV$

$\phi = 3ev$ $\phi = 3ev$

$KE_{max} = 5eV$ $KE_{max} = 13eV$

Q The photoelectric work function.

[✓ a)] is different for different materials

b) is same for all metals

c) Depends upon frequency of the incident light

d) Depends upon intensity of the incident light.

Q If the frequency of the light incident on a metallic plate be doubled, how will the maximum kinetic energy of the photoelectrons change ?

[✓ a)] It becomes be more than double
b) It becomes less than double
c) It becomes exactly double
d) It does not change

Q If frequency of light in a photoelectric experiment is doubled, the stopping potential will.

a) be doubled
b) be halved
[✓ c)] become more than doubled
d) become less than double

Q When photons of energy 3.8 eV falls on metallic surface of work function 2.8 eV the kinetic energy of emitted electrons are.

a) 1eV
b) 6.6 eV
[✓ c)] 0 to 1 eV
d) 2.8 eV

Q For a certain metal ν is five times the ν_0 and the maximum velocity of coming out photo electrons is 8×10^6. If $\nu = 2\nu_0$ the maximum velocity of photo electrons will be ?

a) 4×10^6 m/s

b) 6×10^6 m/s

c) 8×10^6 m/s

d) 1×10^6 m/s

Ans

$$\frac{4\cancel{h}\nu_0 = \frac{1}{\cancel{2}}mv_1^2}{\cancel{h}\nu_0 = \frac{1}{\cancel{2}}\cancel{m}v_2^2}$$

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

$$v_2 = \frac{v_1}{2} = 4\times10^6 \text{ m/s}$$

Q Wave nature of light cannot explain photoelectric effect because in photoelectric effect, it is seen that.

a) For the frequency of light below a certain value the photoelectric effect does not take place, irrespective of intensity.

b) Maximum kinetic energy of ejected electrons is independent of intensity of radiation.

c) There is no time lag between the incidence of radiation and emission of electrons.

d) All of these.

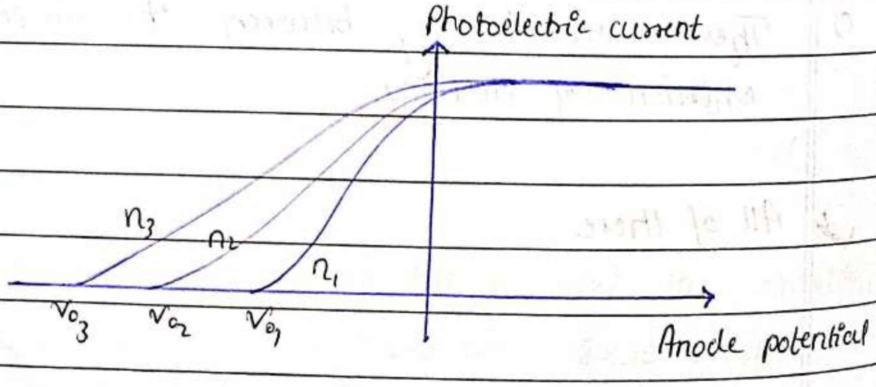
Q When the intensity of a light source is increased

[✓ a)] the no. of photons emitted by the source in unit time increase
b) the total energy of the photons emitted per unit time increases
c) more energetic photons are emitted.
d) faster photons are emitted.

Q A monochromatic point source of light is placed at a distance d from a metal surface. Photo electrons are ejected at a rate n per second and with maximum kinetic energy E. If the source is brought nearer to distance d/2, the rate and maximum kinetic energy per photoelectron becomes nearly.

a) 2n and 2E
b) 4n and 4E
[✓ c)] 4n and E
d) n and 4E

Q In the photoelectric effect, the curve between photoelectric current and the anode potential v (for different frequencies) is shown in figure, then.



a) $v_1 > v_2 > v_3$

[✓ b)] $v_1 < v_2 < v_3$

c) $v_1 = v_2 = v_3$

d) $v_1 > v_2 > v_3$

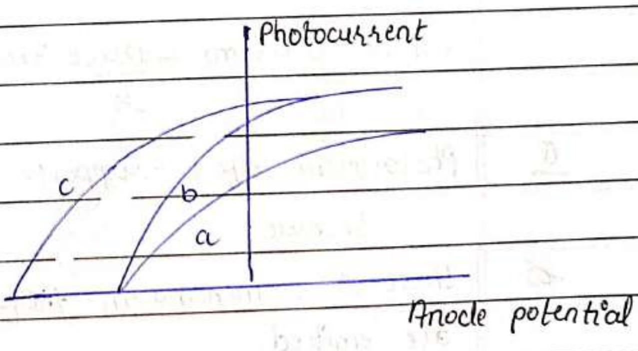
Q The figure shows a plot of photocurrent versus anode potential for a photosensitive surface for three different radiations. Which one of the following is a correct statement?

a) Curves (b) and (c) represent incident radiations of same frequency having same intensity

b) Curves (a) and (b) represent incident radiations of different frequencies and different intensities.

[✓ c)] Curves (a) and (b) represent incident radiations of same frequency but of different intensities.

d) Curves (b) and (c) represent incident radiations of different frequencies and different intensities.



Q Light of frequency 15 times the threshold frequency is incident on photosensitive material. If the frequency is halved and intensity is doubled, the photocurrent becomes.

a) Quadrupled
b) Doubled
c) Halved
[✓ d)] Zero

Ans $f_1 = \frac{3}{2} f_0$

$f_1' = \frac{3}{4} f_0$ = No ejection of $e^{\ominus}$

Q The work ~~woo~~ function of a substance is 4eV. The longest wavelength of light that can cause the emission of photoelectrons from this substance is approximately.

a) 540 nm
b) 400 nm
c) 310 nm
d) 220 nm

Ans $\lambda_{light} = \lambda_0$

$$\lambda_0 = \frac{hc}{\phi}$$

$\lambda_0 (nm) = \frac{12400}{4}$ 310 = 310 nm. Ans

Q Photoelectric effect supports quantum nature of light because.

[✓ a)] there is a minimaum frequency below which no photoelectrons are emitted.
[✓ (b)] the maximum kinetic energy of photoelectrons depend only on the frequency of light and not on its intensity.

[✓ c)] even when the metal surface is faintly illuminated the photoelectrons leave the surface immediately.

d) electric charge of the photoelectrons is quantized.

GRAPH BETWEEN STOPPING POTENTIAL AND FREQUENCY OF LIGHT

$E_p = \phi + KE_{max}$

$hf = \phi + eV_0$

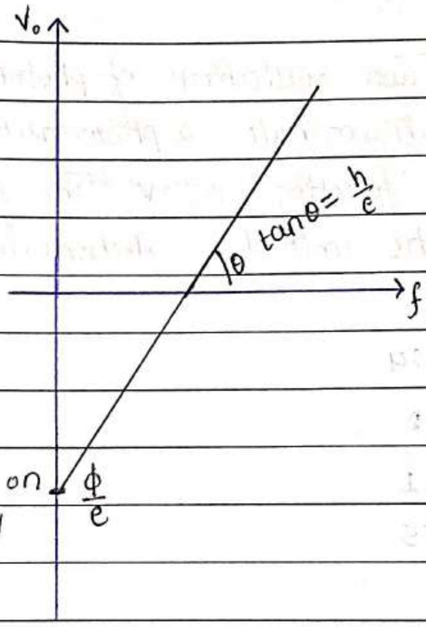
$eV_0 = \frac{hf}{e} - \frac{\phi}{e}$

$Y = mx + c$

$c = -\frac{\phi}{e}$

$m = \frac{h}{e}$ = slope

↳ does not depend on light and metal



Q In photoelectric effect, the slope of stopping potential versus frequency of incident light for a given surface will be.

[✓ a)] he^{-1}
b) eh
c) e
d) h

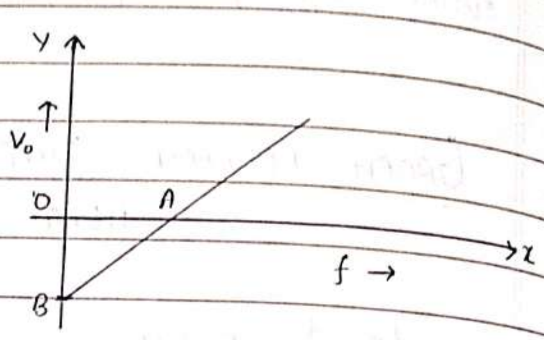
Q In an experiment on photoelectric effect the frequency f of the incident light is plotted against the stopping potential V_0. The work function of the photoelectric current is given by (e is electronic charge)

a) OB × e in eV

b) OB in volt

c) OA in eV

d) The slope of line AB



Q Two radiations of photons energies 1eV and 2.5 eV successively illuminate a photosensitive metallic surface of work function 0.5 eV. The ratio of the maximum speeds of the emitted electrons is.

a) 1:4

b) 1:2

c) 1:1

d) 1:5

Ans

$$\frac{1eV = 0.5 + KE_{max_1}}{2.5 = 0.5 + KE_{max_2}}$$

$$\Rightarrow \frac{0.5}{2} = \frac{v_1^2}{v_2^2}$$

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

Q In photoelectric emission process from a metal of work function 1.8 eV, the kinetic energy of most energetic electrons is 0.5 eV. The corresponding stopping potential is.

a) 2.3 V
b) 1.8 V
c) 1.3 V
[✓ d)] 0.5 V

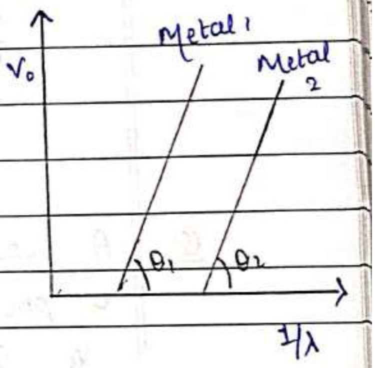
ANS $KE_{max} = eV_0$

$0.5\cancel{e}V = \cancel{e}V_0$

$V_0 = 0.5\ V$

Q V (stopping potential) is plotted against 1/λ where λ is wavelength of incident radiations, for two metals.

a) Metal 1 may be gold and metal 2 may be cesium
b) $\theta_1 > \theta_2$ if metal 1 is gold and metal 2 is cesium
c) $\theta_1 > \theta_2$ if " " " cesium and " " gold
[✓ d)] $\theta_1 = \theta_2$, for any two metals.



Q The cathode of a photocell is changed such that the work function changes from ω_1 to ω_2 ($\omega_2 > \omega_1$). If the saturation currents before and after the change are I_1 and I_2 and all other conditions are unchanged, then (assuming $h\nu > \omega_2$).

[✓ a)] $I_1 = I_2$
b) $I_1 < I_2$
c) $I_1 > I_2$
d) $I_1 < I_2 > 2I_2$

ANS light remains same

Intensity = same
frequency = same
no. of photon = same

Q A source S_1 is producing 10^{15} photons per second of wavelength 5000 Å. Another source S_2 is producing 1.02×10^{15} photons per second of wavelength 5100 Å. Then (power of S_2)/(power of S_1) is equal to.

a) 0.98

[✓ b)] 1.00

c) 1.02

d) 1.04

Ans $P = IA = \frac{nhc}{t\lambda}$ $\quad \frac{n}{t} = \eta$

$$\frac{P_2}{P_1} = \frac{n_2}{n_1}\frac{\lambda_1}{\lambda_2} = \frac{\overset{0.02}{\cancel{1.02}} \times \cancel{10^{15}}}{\cancel{10^{15}}} \times \frac{50\cancel{00}}{51\cancel{00}}$$

$\Rightarrow$ 1.00 Ans

Q A source of light is placed at a distance of 50 cm from a photo cell and the stopping potential is found to be V_0. If the distance between the light is and source and photo cell is made 25 cm, the new stopping potential will be.

a) $V_0/2$

[✓ b)] V_0

c) $4V_0$

d) $2V_0$

Ans V_0

Energy is same at both places.

Q when a metallic surface is illuminated with radiation of wavelength λ, the stopping potential is V. If the same surface is illuminated with radiation of wavelength 2λ the stopping potential is V/4. The threshold wavelength for the metallic surface is.

a) $\frac{5}{2}\lambda$

b) 3λ ✓

c) 2λ

d) 4λ

An

$$\frac{\cancel{V} = \frac{h\cancel{c}}{\cancel{e}}\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)}{\frac{\cancel{V}}{4} = \frac{h\cancel{c}}{\cancel{e}}\left(\frac{1}{2\lambda}-\frac{1}{\lambda_0}\right)}$$

$$2\cancel{4} = \frac{\lambda_0-\lambda}{\cancel{\lambda}\lambda_0}\frac{(2\cancel{\lambda}\cancel{\lambda_0})}{\lambda_0-2\lambda}$$

$$2\lambda_0-4\lambda=\lambda_0-\lambda$$

$$\lambda_0=3\lambda$$

Q A photoelectric surface is illuminated successively by monochromatic light of wavelength λ and λ/2. If the maximum kinetic energy of the emitted photoelectrons in the second case is 3 times that in the first case, the work function of the surface of the material is.

a) $\frac{2hc}{\lambda}$ (c) ✓ $\frac{hc}{2\lambda}$

b) $\frac{hc}{3\lambda}$ (d) $\frac{hc}{\lambda}$

Ans $\frac{hc}{\lambda} - \phi = KE$

$\frac{2hc}{\lambda} - \phi = 3KE$

Q When the energy of the incident radiation is increased by 20%, the kinetic energy of the photoelectrons emitted from a metal surface increased from 0.5eV to 0.8eV. The work function of the metal is

a) 0.65eV

[✓ b)] 1.0 eV

c) 1.3 eV

d) 1.5 eV

Ans

$\Delta E = \Delta KE$

$0.2E = 0.3eV$

$E = 1.5 eV$

$1.5 = \phi + KE_i$

$\phi = 1 eV$ Ans

Q Photons with 5eV are incident on a cathode C in a photoelectric cell. The maximum energy of emitted photoelectrons is 2eV. When photons of energy 6eV are incident on C, no photoelectrons will reach the anode A, if the stopping potential of A relative to C is

a) +3V

b) +4V

[✓ c)] -3V

d) -4V

Ans $\phi = 3eV$

$eV_0 = 6eV - 3eV$

~~$V_0 = 3V$~~ $V_C - V_A = 3V$

~~$V_A - V_C = 3V$~~ $0 - V_A = 3V$

~~$V_A = 3V$~~ $V_A = -3V$ Ans

Q For photoelectric emission from certain metal the cutoff frequency is ν. If radiation of frequency 2ν impinges on the metal plate, the maximum possible velocity of the emitted electron will be.

[✓ a)] $\sqrt{\frac{2h\nu}{m}}$ (b) $\sqrt{\frac{h\nu}{m}}$

c) $\sqrt{\frac{h\nu}{2m}}$ (d) $\sqrt{\frac{h\nu}{m}}$

Ans $2h\nu = h\nu + \frac{1}{2}mv^2$

Q The photoelectric work function for a metal surface is 4.125 eV. The cut off wavelength for this surface is.

[✓ a)] 3000 Å
b) 20625 Å
c) 4125 Å
d) 6000 Å

Ans $\phi = \frac{hc}{\lambda}$

$\lambda_{(Å)} = 2\ 16\ 120\ \frac{12400}{4.125} = \approx 3000\ Å$

Q ★ In a photo emissive cell, with exciting wavelength λ, the fastest electron has speed v. If the exciting wavelength is changed to $3\lambda/4$, the speed of the fastest emitted electron will be.

a) less than $v(4/3)^{1/2}$

b) $v(4/3)^{1/2}$

c) $v(3/4)^{1/2}$

d) ✓ greater than $v(4/3)^{1/2}$

ANS $E = \phi + \frac{1}{2}mv^2 \quad \left[E = \frac{hc}{\lambda}\right]$ $\qquad E' = \phi + \frac{1}{2}mv'^2 \quad \left[E' = \frac{4E}{3}\right]$

$$\sqrt{\frac{2E}{m} - \frac{\phi \times 2}{m}} = v \qquad \sqrt{\frac{2E'}{m} - \frac{2\phi}{m}} = v'$$

$$v' = \sqrt{\frac{\frac{2 \times 4E}{3}}{m} - \frac{2\phi}{m}} \cancel{= v'}$$

$$v' = (4/3)^{1/2} \sqrt{\frac{2E}{m} - \frac{2\phi}{m(4/3)^{1/2}}}$$

$$\therefore \; v' > v(4/3)^{1/2} \qquad \left[\sqrt{\frac{2E}{m} - \frac{2\phi}{m(4/3)^{1/2}}} > v\right]$$

Q A metal surface is illuminated by light of two different wavelengths 248 nm and 310 nm. The maximum speeds of the photoelectrons corresponding to these wavelengths are u_1 and u_2 respectively. If the ratio of $u_1 : u_2 = 2:1$ and $hc = 1240$ eV nm, the work function of the metal is nearly?

a) 3.7eV

b) 3.2eV

c) 2.8eV

d) 2.5eV

ANS $\frac{hc}{\lambda_1} - \phi = \frac{1}{\cancel{2}}\cancel{m}v_1^2$

$\frac{hc}{\lambda_2} - \phi = \frac{1}{\cancel{2}}\cancel{m}v_1^2$

⇒ $5\,\frac{\cancel{1240}\,eV}{\cancel{248}} - \phi = v_1^2$

$4\,\frac{\cancel{1240}\,eV}{\cancel{310}} - \phi = v_2^2$

⇒ $\frac{5-\phi}{4-\phi} = \frac{1}{\cancel{4}}4$

~~$20-4\phi = 4-\phi$~~ $5-\phi = 16-4\phi$

~~$16 = 3\phi$~~ $3\phi = 11$

$\phi = 3.7\,eV$

Matter wave

not mechanical or non mechanical wave

not longitudinal and transverse wave.

nor EM wave

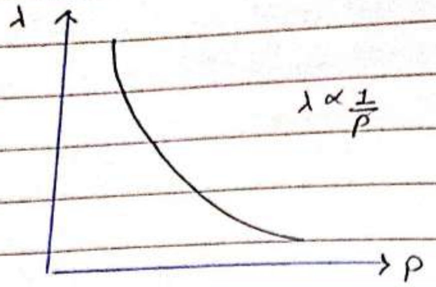
$m_0 \xrightarrow{} v$

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

$0 \leq v \leq \infty$

Scalar

depends on frame of refrence



$$\frac{\Delta\lambda}{\lambda} = -\frac{\Delta P}{P}$$ → for small change.

A For classical particle (large & slow moving)

car, man, ball

$m_0 \to v$

$P = mv$

$KE = \frac{P^2}{2m}$

$P = \sqrt{2mKE}$

$$\boxed{\lambda = \frac{h}{P} = \frac{h}{mv} = \frac{h}{\sqrt{2mKE}}}$$

True / False

(A) If two particles having same momentum must have same wavelength.

True

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

(B) If two particle have same wavelength momentum must have same momentum

False

∵ momentum is a vector quantity.

Ⓑ For relativistic particle (small & fast moving)

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

$$\lambda = \frac{h}{mv} = \frac{h\sqrt{1-\frac{v^2}{c^2}}}{v m_0}$$

↓

if object is of rest mass m_0
moving with speed $v = \frac{c}{2}$
then find debroglie wavelength.

$$\lambda = \frac{h\sqrt{1-\frac{c^2}{4c^2}}}{m_0 \frac{c}{2}} = \frac{\sqrt{3}h}{\sqrt{4}m_0 \frac{c}{2}} = \frac{\sqrt{3}h}{m_0 c} \quad \underline{Ans}$$

Ⓒ If charge q is accelerated through potential diff V then its debroglie wavelength.

$$\lambda = \frac{h}{\sqrt{2mKE}} = \frac{h}{\sqrt{2mq\Delta V}} = \frac{h}{\sqrt{2mq\Delta V}}$$

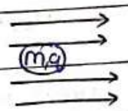
for $e^{\ominus}$
$\lambda = \frac{12.27 \mathring{A}}{\sqrt{V}}$

for proton
$\frac{0.286 \mathring{A}}{\sqrt{V}}$

For Deutron
$\frac{0.202 \mathring{A}}{\sqrt{V}}$

For alpha
$\lambda = \frac{0.101 \mathring{A}}{\sqrt{V}}$

Ⓓ When charge is placed in electric field (E)



$F = qE$

$a = \frac{qE}{m}$ $\quad v = \frac{qE}{m}t$

$$\lambda_t = \frac{h}{\cancel{m}\frac{qE}{\cancel{m}}t} = \frac{h}{qEt}$$

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

Ⓔ If charge q and mass m is moving in the circular path then in magnetic field B then its debroglie wavelength will be.

$$\Rightarrow \frac{mv^{\cancel{2}}}{R} = q\cancel{v}B$$

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

$$\left\{ \lambda = \frac{h}{mv} = \frac{h}{qBR} \right\}$$

Ⓕ If gaseous molecule is at temp 'T' then its debroglie wavelength.

(KE) per degree of freedom $= \frac{1}{2}K_bT$

Monoatomic gas $KE = \frac{3}{2}K_bT$ $\lambda = \frac{h}{\sqrt{2m\,KE}} = \frac{h}{\sqrt{3mK_bT}}$

d.o.f = 3

diatomic gas = $KE = \frac{5}{2}K_bT \Rightarrow \lambda = \frac{h}{\sqrt{2m\,KE}} = \frac{h}{\sqrt{5mK_bT}}$

d.o.f = 5

Ⓖ Debroglie wavelength of e° which is moving in nth orbit of hydrogen like atom.

$$\Rightarrow KE = \frac{13.6}{n^2}$$

$$\lambda = \frac{h}{\sqrt{2m\,KE}} = \frac{hn}{\sqrt{27.2\,m_e}}$$

Velocity of e° in nth orbit

$$V = \frac{V_0 Z}{n}$$

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

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

$$\lambda_\alpha = \frac{0.101}{\sqrt{V}}$$

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

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

$$\lambda = \frac{h}{\sqrt{2m\,KE}}$$

$$\lambda = \frac{nh}{\sqrt{272}\,m_e}$$

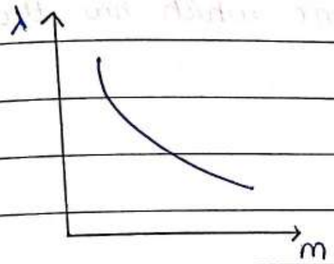
$$\lambda = \frac{h\sqrt{1-\frac{v^2}{c^2}}}{m_0 v}$$

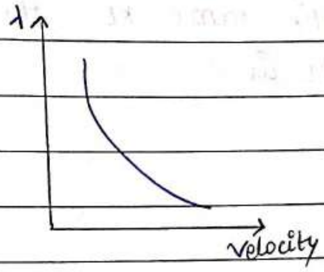
$$\lambda = \frac{h}{\sqrt{3m\,k_b T}}$$

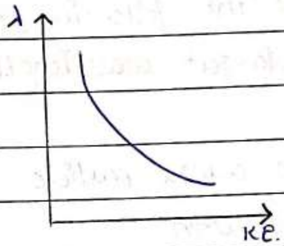
$$\lambda = \frac{h}{qBR}$$

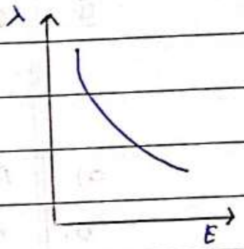
$$\lambda = \frac{h}{qEt}$$

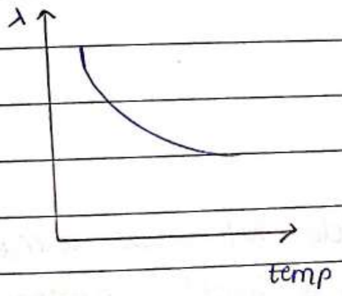
$$\lambda = \frac{h}{\sqrt{2mq\Delta V}}$$

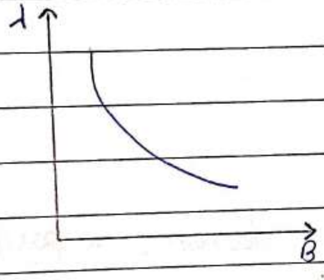


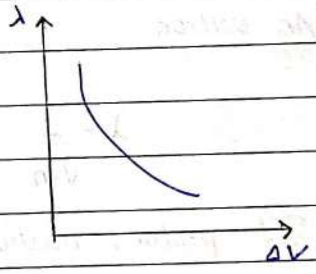


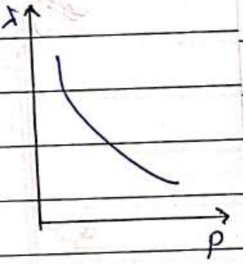












★ Q If the velocity of e⁰ is doubled, its de Broglie frequency will

a) be halved
b) Remain same
[✓ c)] Be doubled
d) Become four times

Ans de broglie's frequency $= \frac{1}{\lambda}$

Q Find the ratio of velocities of proton and α-particle if the de Broglie wavelengths of both the particles is same.

Ans

$$\frac{\cancel{\lambda_p}}{\cancel{\lambda_\alpha}} = \frac{m_\alpha v_\alpha}{m_p v_p}$$

$$m_p v_p = m_\alpha v_\alpha$$

$$\frac{m_\alpha}{m_p} = \frac{v_p}{v_\alpha} = \frac{4\cancel{m_p}}{\cancel{m_p}} = 4 \quad \underline{\text{Ans}}$$

Q Of the following having the same K.E., the one which has the largest wavelength is

a) An alpha particle
b) A neutron
c) A proton
d) An electron

$$\lambda \propto \frac{1}{\sqrt{m}}$$

Q If proton, neutron, deutron, α particle all have same momentum then find ration of de broglie wavelength

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

$\lambda_1 : \lambda_2 : \lambda_3 : \lambda_4 = 1:1:1:1$

Q " " " same velocity
" " "

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

$\lambda_1 : \lambda_2 : \lambda_3 : \lambda_4 = \frac{1}{\cancel{m}_p} : \frac{1}{\cancel{m}_p} : \frac{1}{2\cancel{m}_p} : \frac{1}{4\cancel{m}_p}$

$= 4 : 4 : 2 : 1$

Q " " " " same KE ... " "
"

Ans $\lambda_1 : \lambda_2 : \lambda_3 : \lambda_4 = \frac{1}{\sqrt{m_p}} : \frac{1}{\sqrt{m_p}} : \frac{1}{\sqrt{2m_p}} : \frac{1}{2\sqrt{m_p}} = 1 : 1 : \frac{1}{\sqrt{2}} : \frac{1}{2}$

$2 : 2 : \sqrt{2} : 1$

Q " Proton, deutron, α particle all are accelerated to same potential then find ratio of de broglie wavelength.

Ans $\lambda = \frac{h}{\sqrt{2mq\Delta V}}$

$\lambda_1 : \lambda_2 : \lambda_3 = \frac{1}{\sqrt{m_p q}} : \frac{1}{\sqrt{2m_p q}} : \frac{1}{\sqrt{4m_p 2q}} = 1 : \frac{1}{\sqrt{2}} : \frac{1}{2\sqrt{2}}$

$= 2\sqrt{2} : 2 : 1$

Q Find the de Broglie wavelength of revolving electron for the Bohr's first orbit of circumference $2\pi r$.

⇒ de-broglie → there is n-wave in n^{th} orbit of atom

⇒ 1^{st} orbit = 1 wave

$\lambda = 2\pi r$

Q The de Broglie wavelength of a particle accelerated with 150 volt potential is 10^{-10} m. Find the wavelength of the particle if it is accelerated by 600 volt potential difference.

Ans $\lambda \propto \frac{1}{V}$

$\lambda' = \frac{10^{-810}}{2}$

Q The de Broglie wavelength of a neutron at 27°c is λ. What will be its wavelength at 927°c ?

a) $\frac{\lambda}{2}$

b) $\frac{\lambda}{3}$

c) $\frac{\lambda}{6}$

d) $\lambda/9$

Ans $\lambda \propto \frac{1}{\sqrt{T}}$

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

Q An electron of mass m when accelerated through a potential difference (V) has de broglie wavelength λ. The de broglie wavelength associated with a proton of mass M accelerated through the same potential difference will be

a) $\lambda \frac{m}{M}$

b) $\lambda \frac{M}{m}$

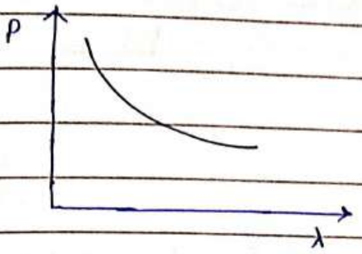
c) $\lambda \sqrt{\frac{M}{m}}$

d) $\lambda \sqrt{\frac{m}{M}}$

Ans $\lambda = \frac{h}{\sqrt{2mq\Delta V}}$

$\lambda \sqrt{m} = \text{constn}$

Q Variation of momentum of particle (p) with associated de Broglie wavelength (λ) is shown correctly by.



Q A photon and a proton have equal energy E. Ratio of
* wavelengths $\frac{\lambda_{photon}}{\lambda_{proton}}$ is proportional to.

a) E

b) $\sqrt{E}$

[✓ c)] $1/\sqrt{E}$

d) E°

Ans $E = \frac{hc}{\lambda}$ [for photon]

$$\frac{\lambda_{photon} = \frac{hc}{E} \quad \propto \frac{1}{\sqrt{E}}}{\lambda_{proton} \propto \frac{1}{\sqrt{E}}}$$

Q A object of mass M at rest break into two part of ratio 2:3. then ratio of their de-broglie wavelength.

Ans momentum conserved

$P_1 = -P_2$

magnitude same

$\therefore \frac{\lambda_1}{\lambda_2} = 1:1$

Page No.

Shivalal

9/ Q De broglie wavelength associated with an electron revolving in the n^{th} state of hydrogen atom is directly proportional to.

[✓ a)] n

b) 1/n

c) n^2

d) $1/n^2$

Ans $\lambda = \frac{nh}{\sqrt{2m 13.6 Z^2}}$

Q A proton is accelerated through 225V. Its de broglie wavelength is.

a) 0.1 nm

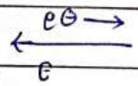
b) 0.2 nm

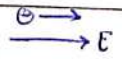
c) 0.3 nm

d) 0.4 nm

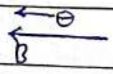
Ans $\lambda = \frac{0.286 \text{ Å}}{\sqrt{225}} = \frac{\overset{0.019}{\cancel{0.286}} \text{ Å}}{\cancel{15}} = 0.0019 \text{ nm}$ Ans

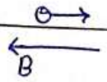
Q Figure shows four situations in which an electron is moving in electric / magnetic field. In which case the de Broglie wavelength of $e^{\ominus}$ is increasing.

a) 

[✓ (b)] 

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

c) 

(d) 

Q Electrons used in the electron microscope are accelerated by voltage of 25 kV. If the voltage is increased to 100 kV then the de Broglie wavelength associated with the electrons would

⇒ $\lambda \propto \frac{1}{\sqrt{V}}$

$\lambda \rightarrow$ decrease by 2 times

Q For same energy find the ratio of λ photon and λ electron.

[✓ (A)] $c\sqrt{\frac{2m}{E}}$

(B) $\frac{1}{c}\sqrt{\frac{2m}{E}}$

c) $\frac{1}{c^2}\sqrt{\frac{2m}{E}}$

d) $\frac{1}{c}\sqrt{\frac{2m}{E^2}}$

Ans $\frac{\lambda_{photon}}{\lambda_{electron}} = \frac{\frac{hc}{E}}{\frac{hc}{\sqrt{2mKE}}} = c\sqrt{\frac{2m}{E}}$

Q The de broglie wavelength associated with a proton increases by 25%. If its momentum is decreased by P_0. The initial momentum was

a) $4P_0$

b) $\frac{P_0}{4}$

[✓ c)] $5P_0$

d) $\frac{P_0}{5}$

Ans $\lambda_{new} = \frac{5}{4}\lambda_i$

$$\lambda = \frac{h}{\cancel{mv}\,P}$$

$$P v_{new} = \frac{4}{5} P v_i = 0.8\, P v_i$$

$$\Delta P v = 0.2\, P v_i = P_0$$

$$P = 5P_0 \quad \underline{\text{Ans}}$$

Q An electron is accelerated from rest through a potential difference of V volt. If the de Broglie wavelength of the electron is 1.227×10^{-2} nm, the potential difference is.

a) 10V
b) 10^2V
c) 10^3V
d) 10^4 V

Ans $$\lambda = \frac{12.27\,\text{Å}}{\sqrt{V}}$$

$$\cancel{1.227} \times 10^{-2}\,\cancel{nm} = \frac{\cancel{1.227}\,\cancel{nm}}{\sqrt{V}}$$

$$V = 10^4 \quad \underline{\text{Ans}}$$

Q De broglie wavelength of a neutron (same as monoatomic gas) in thermal equilibrium with heavy water at a temperature T (kelvin) and mass m is.

~~(A)~~ $\frac{h}{\sqrt{3mKT}}$ (b) $\frac{2h}{\sqrt{3mKT}}$ (c) $\frac{2h}{\sqrt{2mKT}}$ (d) $\frac{h}{\sqrt{mKT}}$

Q If the momentum of an electron is changed by P, then the de broglie wavelength associated with it changes by 0.5 %. The initial momentum of electron will be.

[✓ (A) 200 P]
(B) 400P
(C) P/200
(D) P/400

Ans $\frac{\Delta\lambda}{\lambda} = \frac{-\Delta P}{P}$

$\frac{\Delta\lambda}{\lambda} = \frac{0.5}{100}$

$\Delta P = P$

$\therefore \frac{P}{P_i} = \frac{0.5}{100}$

$P_i = 200P$. Ans

Q An α particle moves in a circular path of radius 0.83 cm in the presence of a magnetic field of 0.25 wb/m². The de broglie wavelength associated with the particle will be.

a) 1 Å
b) 0.1 Å
c) 10 Å
[✓ d) 0.01 Å]

Ans $\lambda = \frac{h}{qBR} = \frac{h \times 100}{2e \times 0.25 \times 0.83} = \frac{\overset{8}{6.62} \times 10^{-34} \times \cancel{4} \times 10^{2}}{\cancel{2} \times \underset{0.2}{\cancel{1.6}} \times 10^{-19} \times 1 \times \cancel{0.83}}$ 0.1

$= 10^{-12}$ m

$= 0.01$ Å Ans

Q The wavelength λ_e of an electron and λ_p of a photon of same energy E are related by

a) $\lambda_p \propto \sqrt{\lambda_e}$ (b) $\lambda_p \propto \frac{1}{\sqrt{\lambda_e}}$

[✓ c)] $\lambda_p \propto \lambda_e^2$ (d) $\lambda_p \propto \lambda_e$

Ans ~~$\lambda_p = \lambda \frac{hc}{E}$~~

~~$\lambda_e = \frac{h}{\sqrt{2m_e E}}$~~

~~$\frac{\lambda_p}{\lambda_e} = c\sqrt{\frac{2m_e}{E}}$~~

~~$\lambda_p \propto \lambda_e$~~

$\lambda_p = \frac{hc}{E}$ —①

$(\lambda_e)^2 = \left(\frac{h}{\sqrt{2m_e E}}\right)^2 \Rightarrow \lambda_e^2 = \frac{h^2}{2m_e E}$ —②

Now ① / ②

$\Rightarrow \frac{\lambda_p}{\lambda_e^2} = \frac{2cm_e}{h}$

$\lambda_p \propto \lambda_e^2$

Q A charge q_0 mass m_0 is projected along the y axis at $t=0$ from origin with a velocity v_0. If a uniform electric field ~~v_0~~ E_0 also exits along the x axis, then time at which de Broglie wavelength of the particle becomes half of the initial value is.

a) $\frac{m_0 v_0}{q_0 E}$

b) $\sqrt{2}\frac{m_0 v_0}{q_0 E_0}$

[✓ c)] $\sqrt{3}\frac{m_0 v_0}{q_0 E_0}$

d) $\frac{3m_0 v_0}{q_0 E_0}$

Ans $$\frac{\lambda}{\lambda/2} = \frac{\cancel{m}\sqrt{V_0^2 + \frac{q^2E_0^2}{m_0^2}t^2}}{\cancel{m_0}V_0}$$

$$4 = \frac{V_0^2 + \frac{q^2E_0^2}{m_0^2}t^2}{V_0^2}$$

$$4V_0^2 = V_0^2 + \frac{q^2E_0^2}{m_0^2}t^2$$

$$t = \sqrt{3}\,\frac{m_0V_0}{qE_0}$$ Ans

Q Ⓐ $\longrightarrow V_1$ Ⓑ $\rightarrow V_2$ After perfect inelastic collision find debroglie wavelength of combined mass system

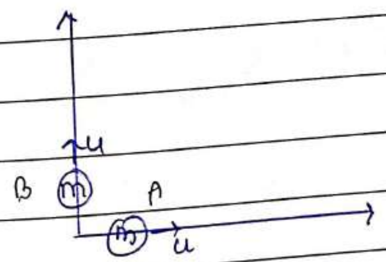
Ans $$P_1 + P_2 = P$$

$$\frac{\cancel{h}}{\lambda_1} + \frac{\cancel{h}}{\lambda_2} = \frac{\cancel{h}}{\lambda}$$

$$\lambda = \frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$$

Q Two identical particle move with same speed along x & y axis then find de broglie wavelength of A wrt C.O.M.

Ans



$$V_{com} = \frac{mv\hat{i} + mv\hat{j}}{2m} = \cancel{\frac{\sqrt{}v}{\sqrt{2}}}$$

$$\lambda = \frac{h}{m_A(V_A \text{ wrt com})}$$

$$V_A \text{ wrt com} = v\left(1 - \frac{1}{\sqrt{2}}\right)$$

$$\therefore \lambda = \frac{h}{m\left(v - \frac{v}{\sqrt{2}}\right)}$$ Ans

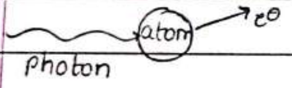
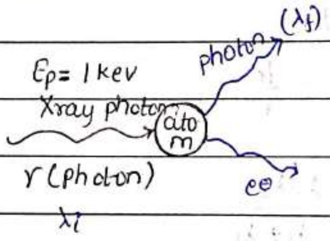
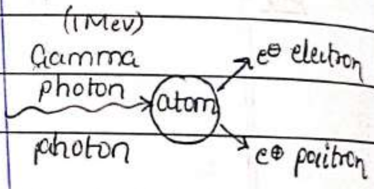
$V_{com} = \frac{v}{2}\hat{i} + \frac{v}{2}\hat{j}$

$V_{A\ wrt\ com} = v\hat{i} - \frac{v}{2}\hat{i} - \frac{v}{2}\hat{j}$

$= \frac{v}{2}\hat{i} - \frac{v}{2}\hat{j}$

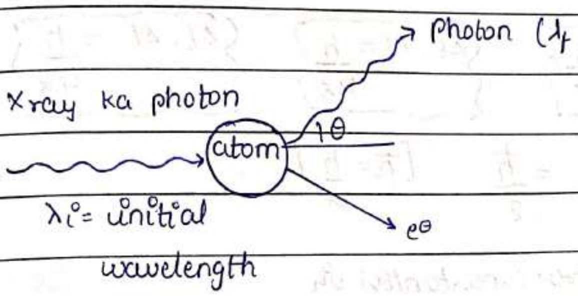
magnitude $= \frac{\sqrt{2}v}{2} = \frac{v}{\sqrt{2}}$

$\lambda = \frac{h}{mv} = \frac{\sqrt{2}h}{mv}$ Ans

Photoelectric effect	Compton effect	Pair production
ejection of $e^{\ominus}$ due to photon ($E_p \geq \phi$)	Scattering of photon Partial photoelectric effect	$e^{\ominus}, p^{+}$ eject hote hai
		
$E_p \sim 1eV$ $E_p \sim 1eV$		
	$\boxed{\lambda_f > \lambda_i}$	
	$\boxed{\Delta\lambda = \lambda_f - \lambda_i}$ = Compton shift	

Compton effect

The redution in the energy (hence increase in wavelength) of high energy (x-ray or low gamma ray) photons when they are scattered by free electrons, or loosely bound electrons which thereby gain energy.



$$\Delta\lambda = \lambda_f - \lambda_i = \frac{h}{m_e c}(1-\cos\theta)$$

If $\theta = 0°$ (without any deviation]

$\Delta\lambda = 0$

If $\theta = 90°$

$$\Delta\lambda = \frac{h}{m_e c} = 0.24 \text{nm}$$

If $\theta = 180°$

$$\Delta\lambda = \frac{h}{m_e c}(1-\cos 180°)$$

$$\Delta\lambda = \frac{2h}{m_e c} \quad \underline{\text{Ans}} \quad = 0.48 \text{ nm}$$

Heisenberg Uncertainity Principle

For any relativistic particle momentum and displacement cannot be measure accurately simultaneously

$$\boxed{\Delta x \cdot \Delta p \geq \frac{h}{4\pi}} \quad \boxed{\Delta \theta \cdot \Delta L = \frac{h}{4\pi}} \quad \boxed{\Delta E \cdot \Delta t = \frac{h}{4\pi}}$$

$$\Delta x \cdot \Delta p = \frac{h}{4\pi} = \frac{\hbar}{2} \qquad \left[\hbar = \frac{h}{2\pi}\right]$$

Δx → error in measurement of position of object

Δp → error (uncertanity) in the measurement of momentum

Q Why $e^{\ominus}$ cannot reside inside nucleus?

Ans If $e^{\ominus}$ resides inside nucleus

$$\Delta x = 10^{-15} m$$

$$\Delta x \cdot \Delta p = \frac{h}{4\pi}$$

$$\Delta v = \frac{h}{4\pi \Delta x \, m_e}$$

$$\Delta v >>> c$$

↳ which is not possible.

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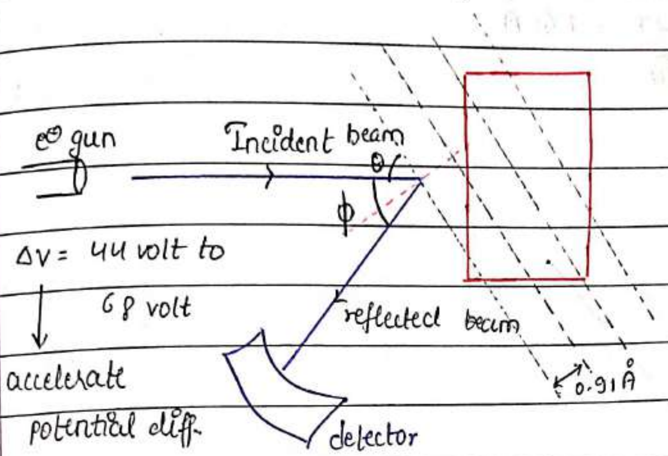
Davisson - Germer experiment → Experimentally verify that $e^{\ominus}$ shows wave nature

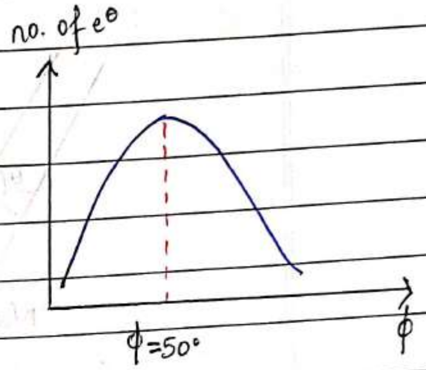
↓

$e^{\ominus}$ is a wave

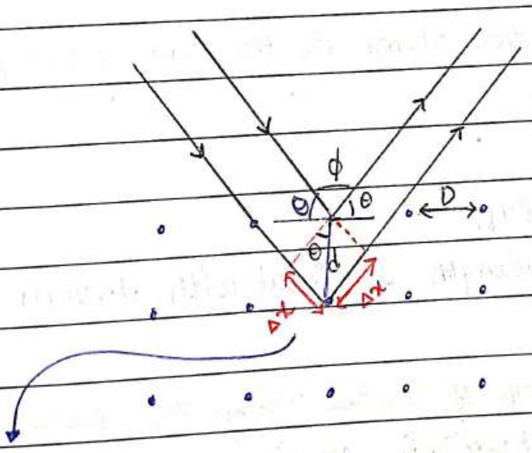
Interference & Diffraction of $e^{\ominus}$



ΔV = 44 volt to 68 volt
↓
accelerate potential diff.



↓
ΔV = 54 volt



$2\theta + \phi = 180°$

$2\theta = 130°$

$\theta = 65°$

$\Delta x = d\sin\theta$

Path difference $= 2\Delta x$

$= 2d\sin\theta$

↑

angle b/w $e^{\ominus}$ beam and surface

For constructive interference

$(2d\sin\theta = n\lambda)$ Bragg's law

$n = 1$

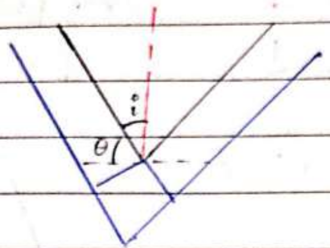
$\theta = 65°$

$d = 0.91$ Å

$\lambda = 1.67 \mathring{A}$

Now According to De broglie

$$\lambda = \frac{12.27\mathring{A}}{\sqrt{V}} = \frac{12.27}{\sqrt{54}} = 1.65\mathring{A}$$



Now Braggs law = $2d\cos i = n\lambda$

d ⇒ Distance between the consecutive crystal plane or interplanar distance

D ⇒ Distance between two atoms in the same lattice plane

n ⇒ order of diffraction

θ ⇒ Glancing angle

ϕ ⇒ Angle of diffraction.

λ ⇒ De-broglie wavelength associated with electrons.

Electron gun :- Electrongs of desired energy are produced in it by the process of thermionic emision

Nickel crystal :- diffracts the electron beam obtained from electron gun.

Detector :- It detects the electron beam diffracted by the nickel crystal

Conclusion and result :- Curve between the intensity (I) of diffraced electrons and diffracting angle.