PARISHRAM

2026

Lecture - 01

Dual Nature of Radiation and Matter

PHYSICS Lecture - 1

BY - RAKSHAK SIR

Topics *to be covered*

1. Photon Theory
2. Photo-electric Effect

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	Chapter–11: Dual Nature of Radiation and Matter	
Unit–VIII	**Atoms and Nuclei**	
	Chapter–12: Atoms	
	Chapter–13: Nuclei	

Unit VII: Dual Nature of Radiation and Matter

Chapter–11: Dual Nature of Radiation and Matter

Dual nature of radiation, Photoelectric effect, Hertz and Lenard's observations; Einstein's photoelectric equation-particle nature of light.

Experimental study of photoelectric effect

Matter waves-wave nature of particles, de-Broglie relation.

Introduction

Very small particles :- e^-, p^+, n^0 ....

Dual Nature of "Matter" and "Radiation" (Light)

Doglapan

Material (particle)

Energy (wave)

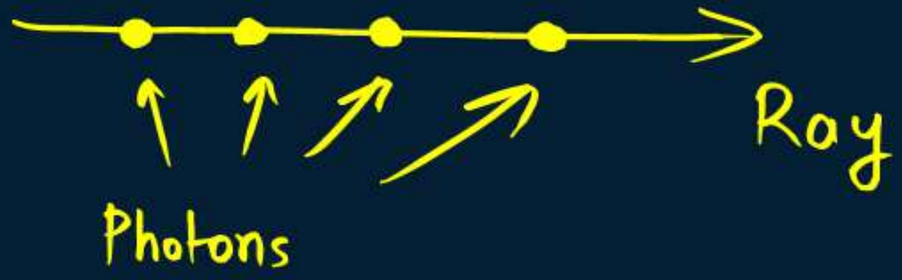
Max Planck's Photon Theory

Quanta ⇒ Energy packets

Quantum ⇒ Single Energy packet

$$\boxed{h = 6.6 \times 10^{-34} \text{ J-s}}$$

Planck's Constant



Energy ∝ frequency

$$\nu = \frac{1}{T}$$

sec

sec^{-1} or Hz

$$E \propto \nu$$

$$\boxed{E = h\nu}$$

Energy of Photon

planck's constant :-

Light as a photon : Properties

Wave

$\text{Speed} = \lambda \nu$

$c = \lambda \nu$

$\boxed{\nu = \frac{c}{\lambda}}$

1. The rest mass of photon is zero. $\boxed{m_{rest} = 0}$, $m_{Motion} \neq 0$
2. The momentum of photon is $\boxed{p = \frac{h}{\lambda}}$
3. The energy of photon is * $\boxed{E = h\nu}$ * $\boxed{E = h\frac{c}{\lambda}}$
4. Photons are $\underbrace{\text{electrically neutral}}$ and are not deflected by electric and magnetic fields.

$q_{net} = 0$

$F = qE$

$F = 0$

$F = qvB\sin\theta$

$F = 0$

plonck Saahab :- $E = h\nu$ ... (1)

Einstein Saahab :- $E = mc^2$ ... (2)

equate (1) & (2)

$$h\nu = mc^2$$

$$\frac{h\cancel{c}}{\lambda} = mc^{\cancel{2}}$$

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

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

$(p = mv)$

Types of emission

emit = Baahar Nikalna

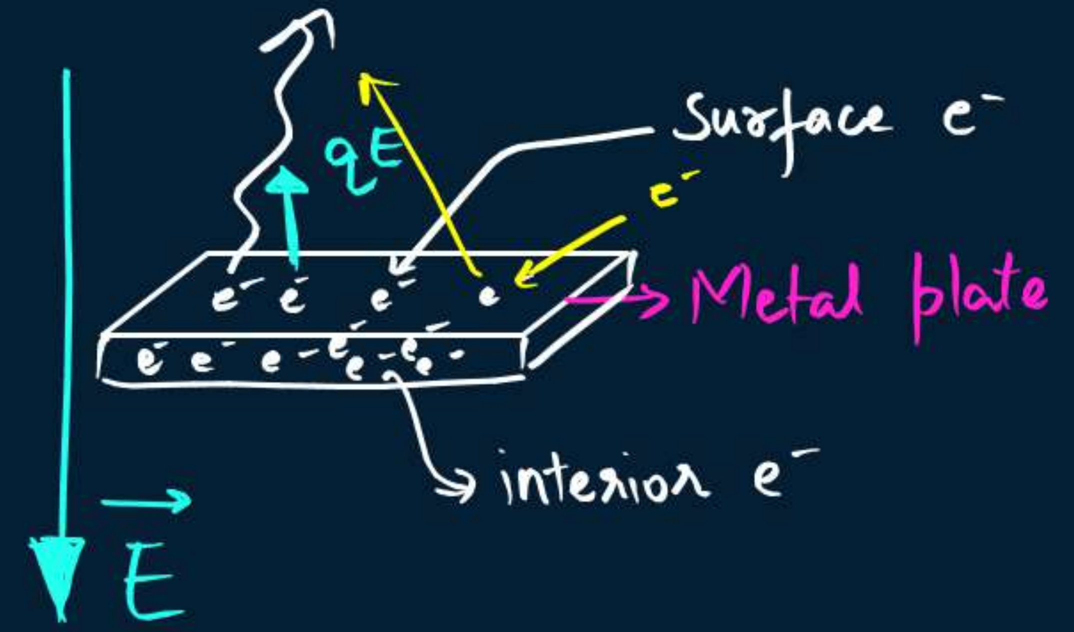
1. Thermo-ionic Emission: By providing sufficient heat (thermal energy)

↳ e^- : Thermoions

2. Field Emission: By applying a very strong Electric Field.

$F = qE$

$\boxed{F = eE}$



3. Secondary Emission: Electron is used to eject an electron.

(Kancha Emission)

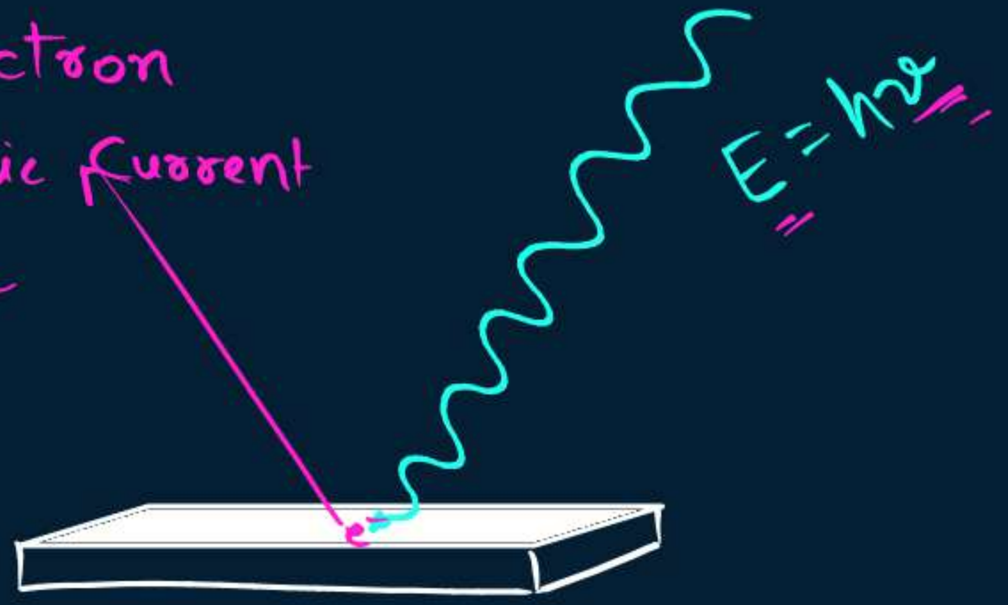
couldn't be explained by Wave Nature of Light

4. Photo-electric Emission: When a light radiation of sufficient energy strike on metal plate, the electrons are ejected. The ejected electrons are called photo-electrons and emission is called photo-electric emission.

electron : Photoelectron

Current : Photoelectric Current

Process : P.E. Effect



QUESTION

Which of the following are thermions? [CBSE AIPMT 1988]

A. Protons

B. Electrons

C. Photons

D. Positrons

Work Function

"W_0" → Joule

Minimum energy to eject the electron.

depends on Material of plate

incident Photon ki Energy $\geq$ Work function

→ Photo-electric effect

Threshold Frequency

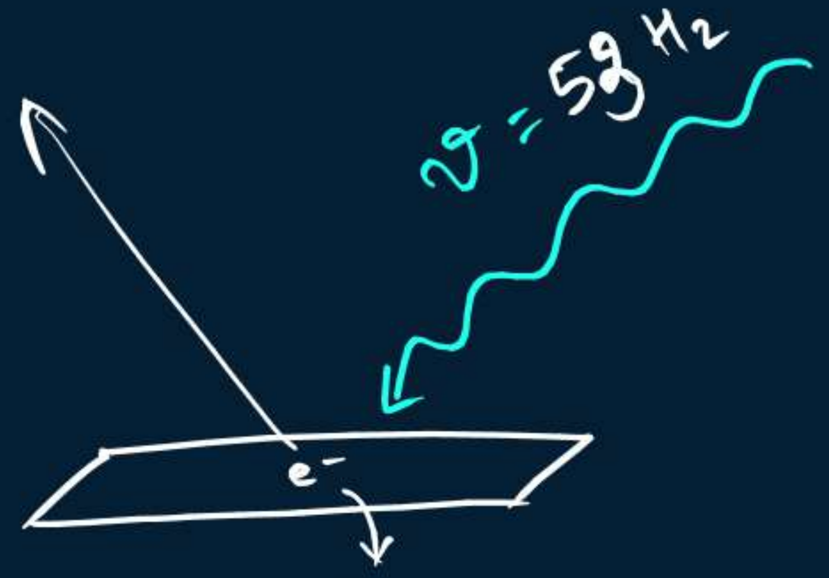
ν_0

Minimum frequency to eject the electron.

$$\boxed{W_0 = h\nu_0}$$

W_0 → Work function

ν_0 → Threshold frequency



$\nu_0 = 52\ Hz$

$$\boxed{\nu \geq \nu_0}$$

ν → incident frequency

ν_0 → Threshold frequency

Threshold Wavelength

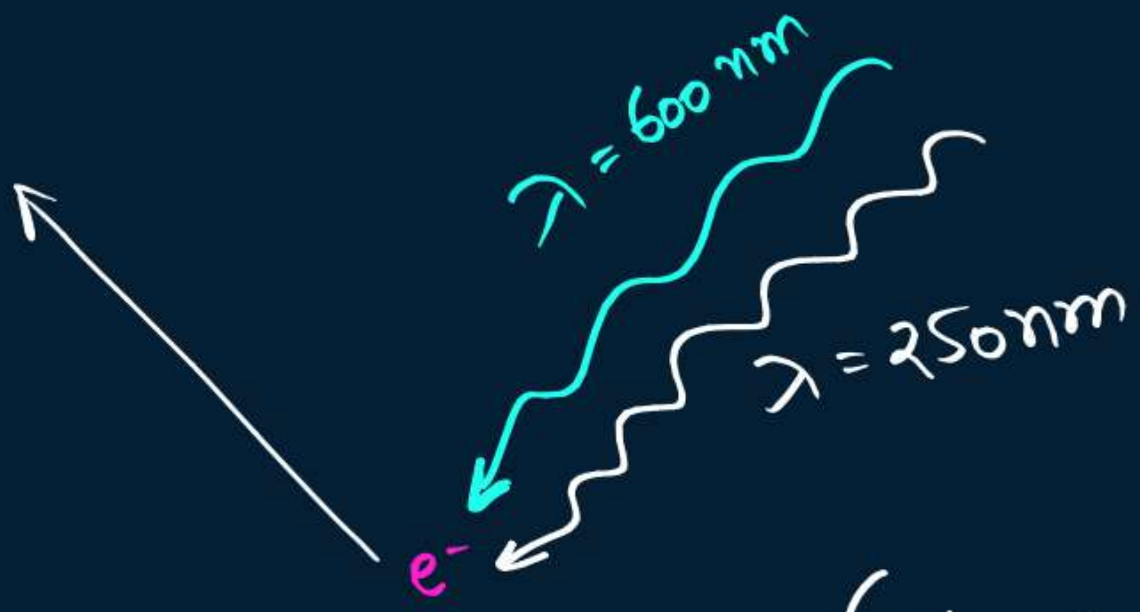
'λ_0'

$$E\downarrow = h\nu\downarrow$$

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

Maximum wavelength to eject the electron.

$$\boxed{\begin{aligned} W_0 &= h\nu_0 \\ W_0 &= \frac{hc}{\lambda_0} \end{aligned}}$$



$\lambda_0 = 300\ nm$ (No ejection)

Summary

$$\boxed{\begin{aligned} E_{inci} &\geq W_0 \\ \nu_{inci} &\geq \nu_0 \\ \lambda_{inci} &\leq \lambda_0 \end{aligned}}$$

$$E\uparrow \propto \nu\uparrow \propto \frac{1}{\lambda\downarrow}$$

RDx Calculations

energy of an e^- when accelerated by 1V. ← $1\ e.V. = 1.6 \times 10^{-19}\ J$

$1\ A^\circ = 10^{-10}\ m$

$E = h\nu$

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

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

$E = \frac{19.8 \times 10^{-26}}{\lambda}$

* $\boxed{E = \frac{20 \times 10^{-26}}{\lambda}}$

J ← E; 20×10^{-26} → J-m; λ → m

* $\boxed{E = \frac{12375}{\lambda} = \frac{12400}{\lambda}}$

e.v. (electron - Volt) ← E; 12400 → e.v. - A°; λ → A°

* $\boxed{E = \frac{1240}{\lambda}}$

e.v. ← E; 1240 → e.v. - nm; λ → nm

$1\ nm = 10^{-9}\ m$

QUESTION

The wavelength of a photon is 2000 Å. Find its energy.

$$\boxed{E = \frac{12400}{\lambda}}$$

$$E = \frac{\overset{62}{\cancel{124}\cancel{0}\cancel{0}}}{\underset{10}{\cancel{20}\cancel{0}\cancel{0}}} = 6.2$$

$$E = 6.2 \text{ e.V.}$$

QUESTION

H.W.

The wavelength of a photon is 496 nm. Find its energy.

QUESTION

H.W.

The work function of the photosensitive material is 2.0 eV. The longest wavelength of light that can cause photoelectric emission from the substance is (approximately):

A. 6200 nm

B. 966 nm

C. 62 nm

D. 620 nm

$W_0 = 2\,eV$

$\lambda_0 = ?$

$W_0 = \frac{hc}{\lambda_0}$

e.V. $\leftarrow E = \frac{1240}{\lambda}$ $\hookrightarrow$ nm

QUESTION

H.W.

The threshold frequency for photoelectric effect on sodium corresponds to a wavelength of 5000 Å. Its work function is [CBSE AIPMT 1988]

(A) 4×10^{-19} J

(B) 1 J

(C) 2×10^{-19} J

(D) 3×10^{-19} J

Intensity of a Light

Intensity is directly proportional to the number of photos emitted per second

$$\boxed{\text{Intensity} = \frac{(\text{Energy})}{\text{Area} \times (\text{time})}}$$

$$\text{Intensity} \propto \frac{\text{Number of Photons}}{\text{Second}}$$

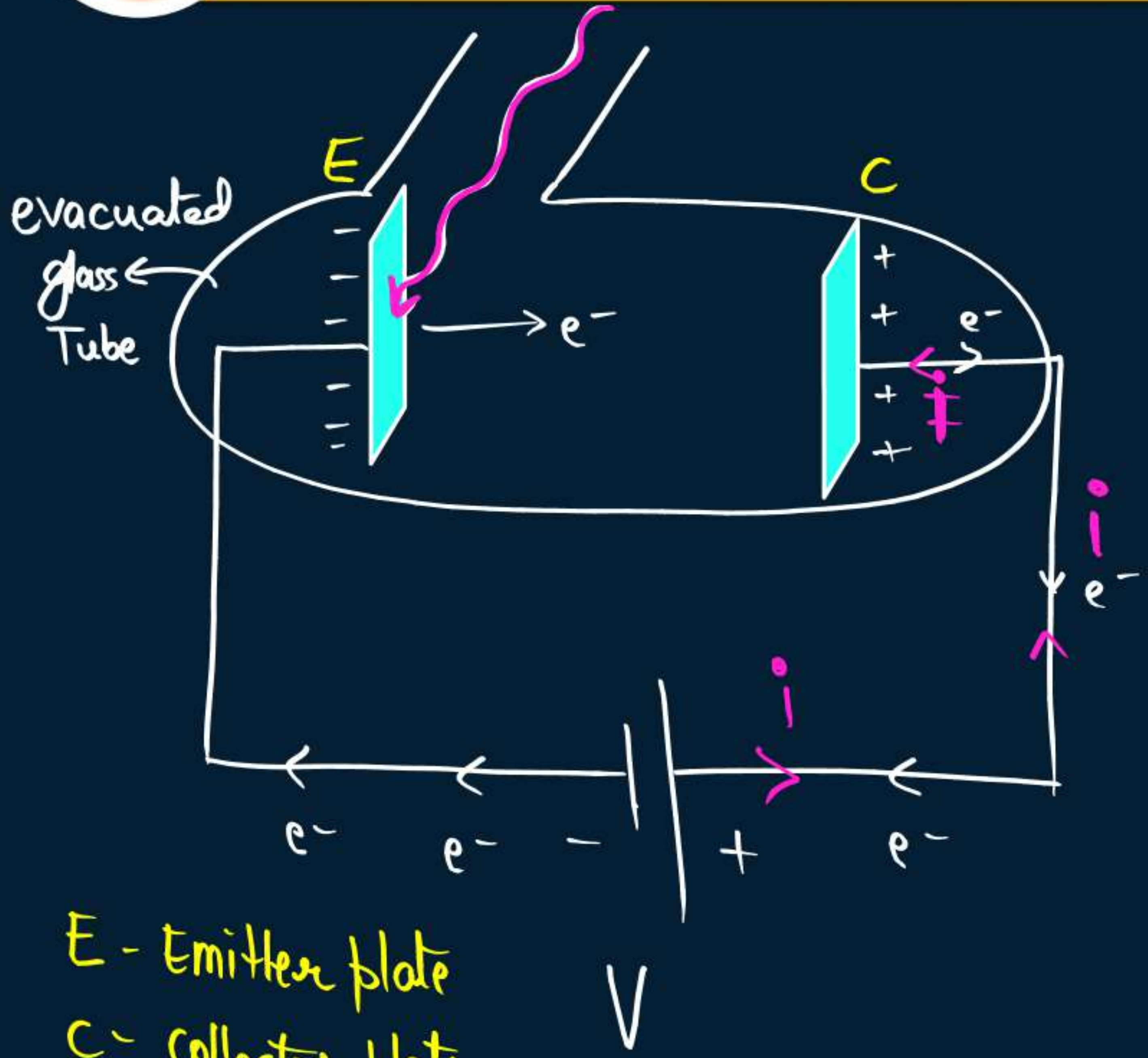
Chamak (Bright)

$$I = \frac{E}{A \times t}$$

$$I = \frac{\text{Power}}{\text{Area}} \quad \left(\frac{\text{Watt}}{m^2}\right)$$

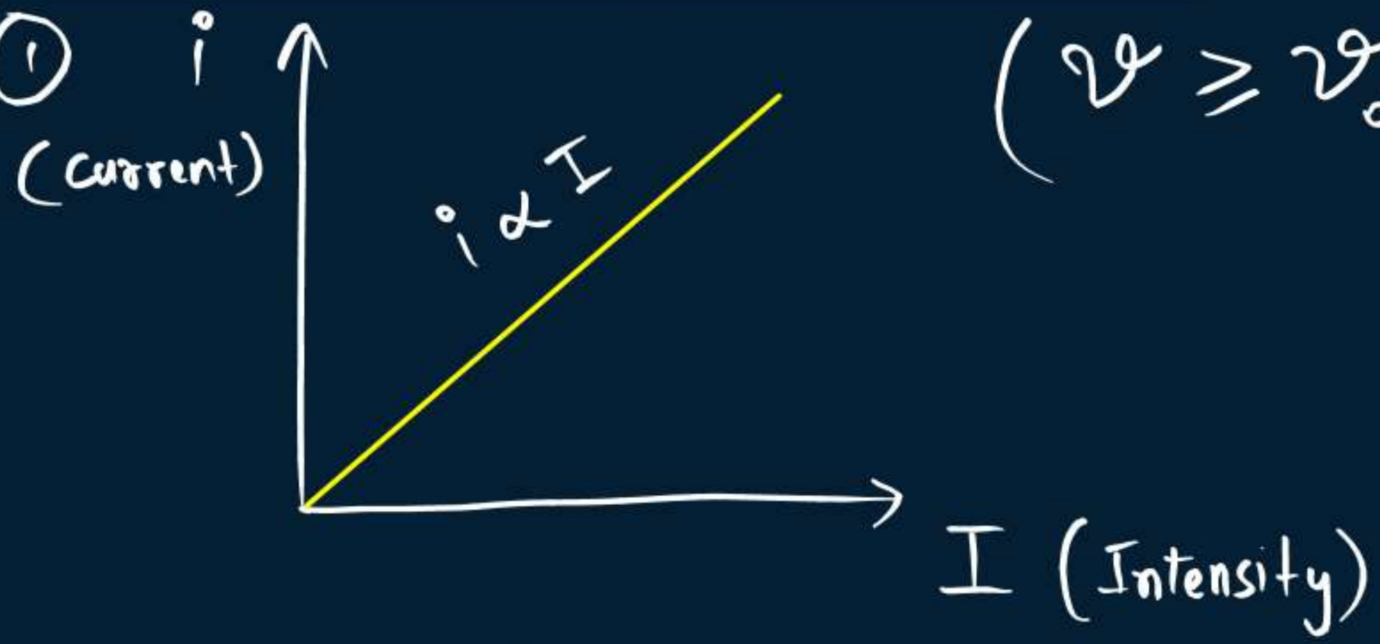
SI Unit : Watt m^{-2}

Hallwach's and Lenard's Observations



E - Emitter plate
C - Collector plate
V - Pot. Diff

①

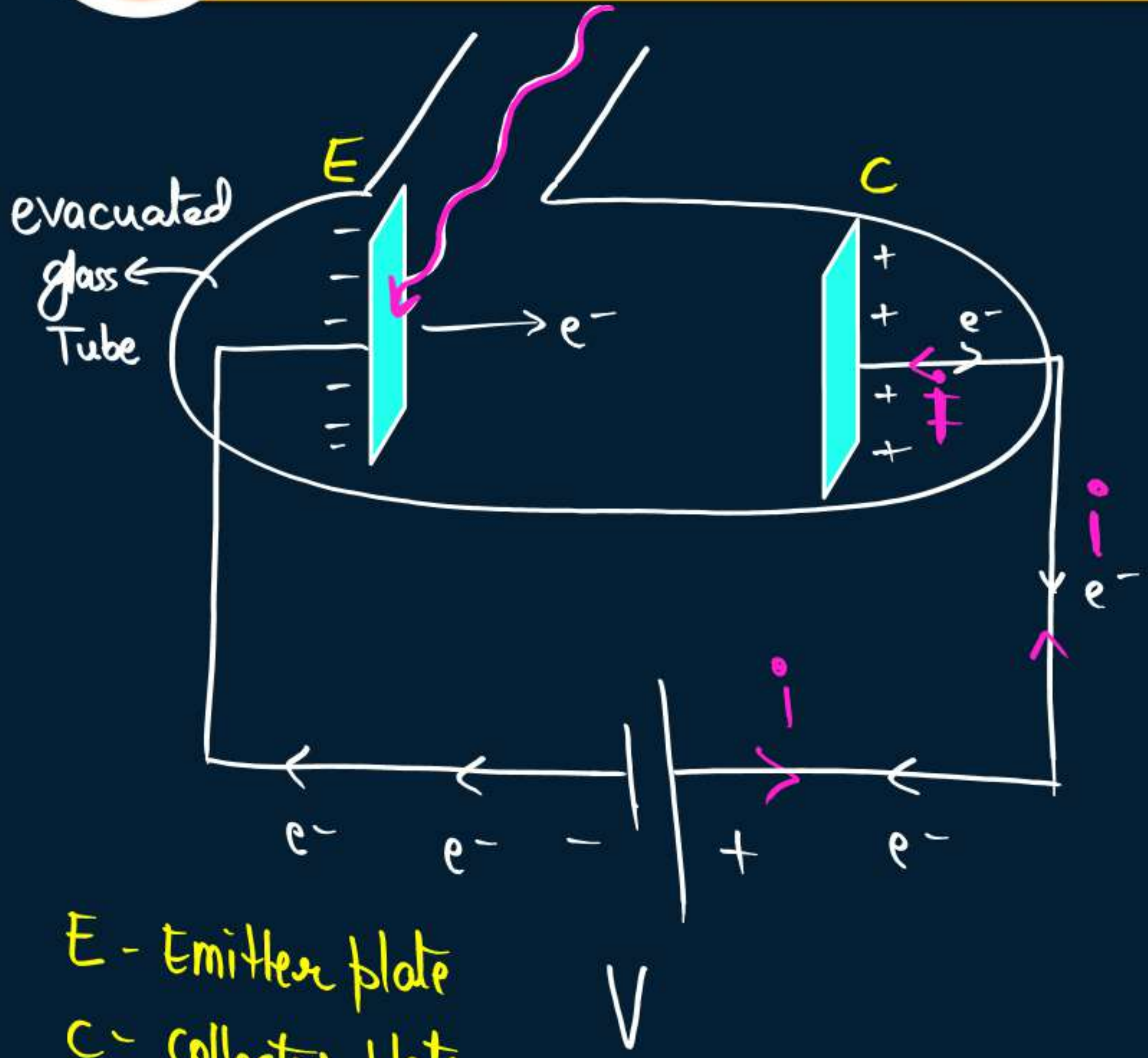


$(\nu \geq \nu_0)$

Intensity ↑ $\propto$ Current ↑

Number of Photons ↑ $\propto$ Number of ejected e^- ↑

Hallwach's and Lenard's Observations



E - Emitter plate
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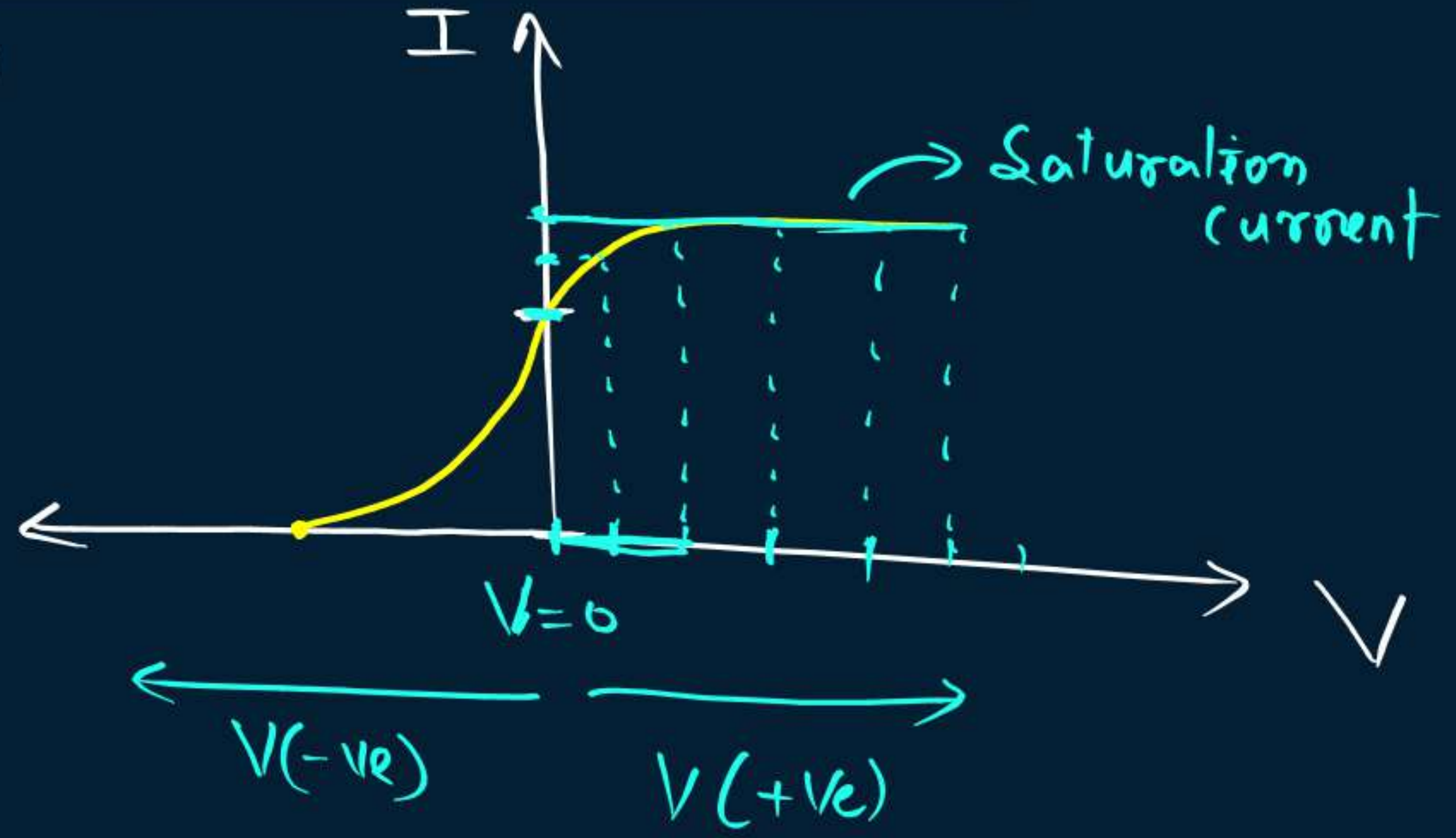


Homework

→ Notes ✓

→ revision ✓

AAKHRI SAAL HAI JAAN LAGA DE

PARISHRAM

2026

Lecture- 02

Dual Nature of Radiation and Matter

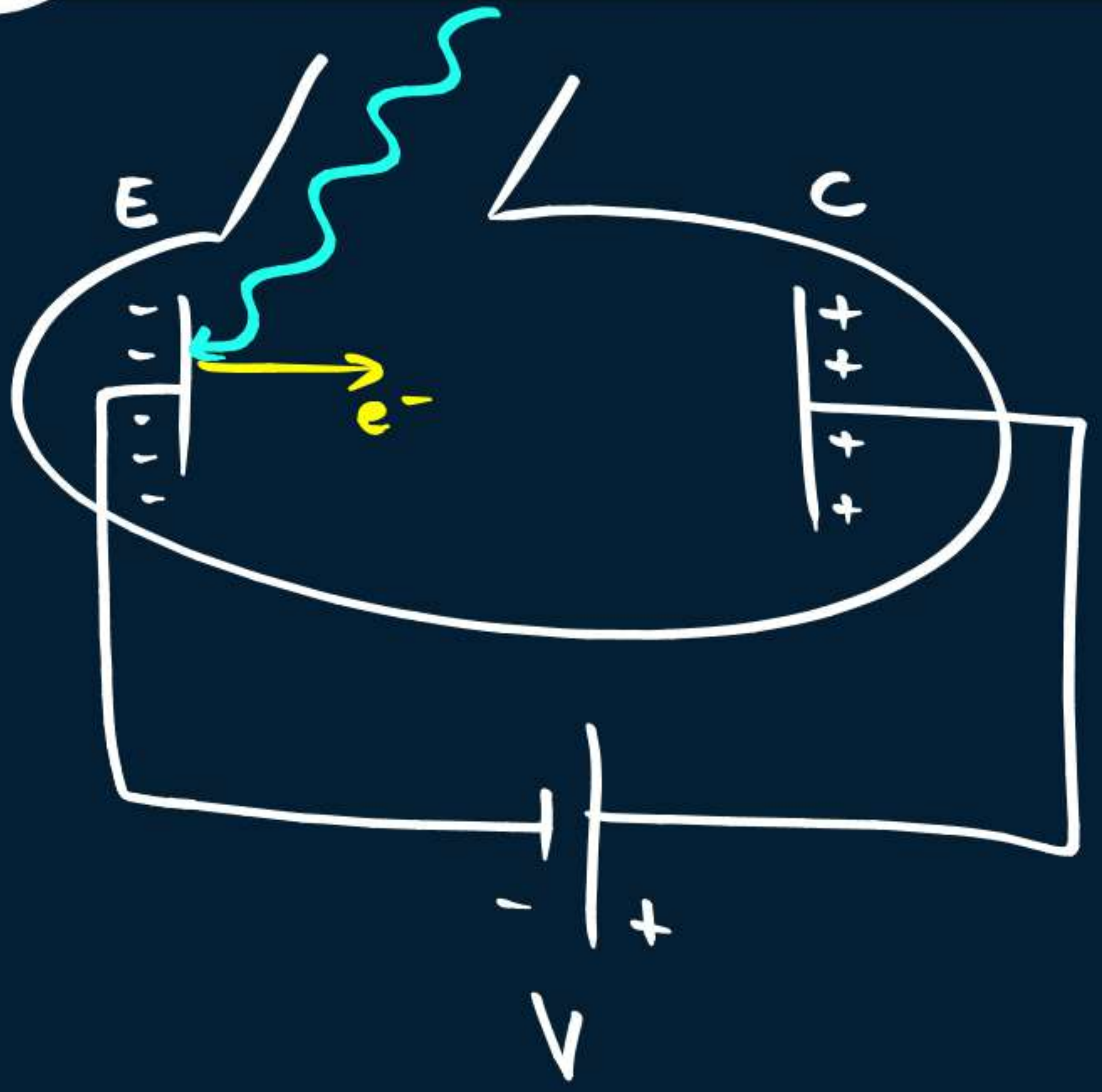
PHYSICS Lecture - 2

BY - RAKSHAK SIR

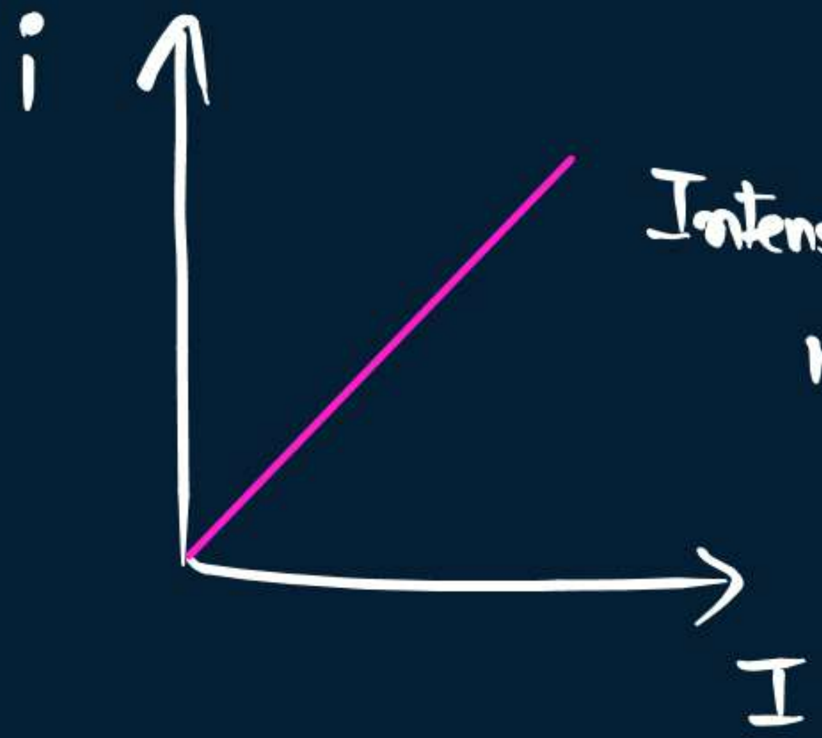
Topics *to be covered*

1 Einstein's Equation & Matter Waves

Hallwach's and Lenard's Observations



① i v/s I
(Current) (Intensity)

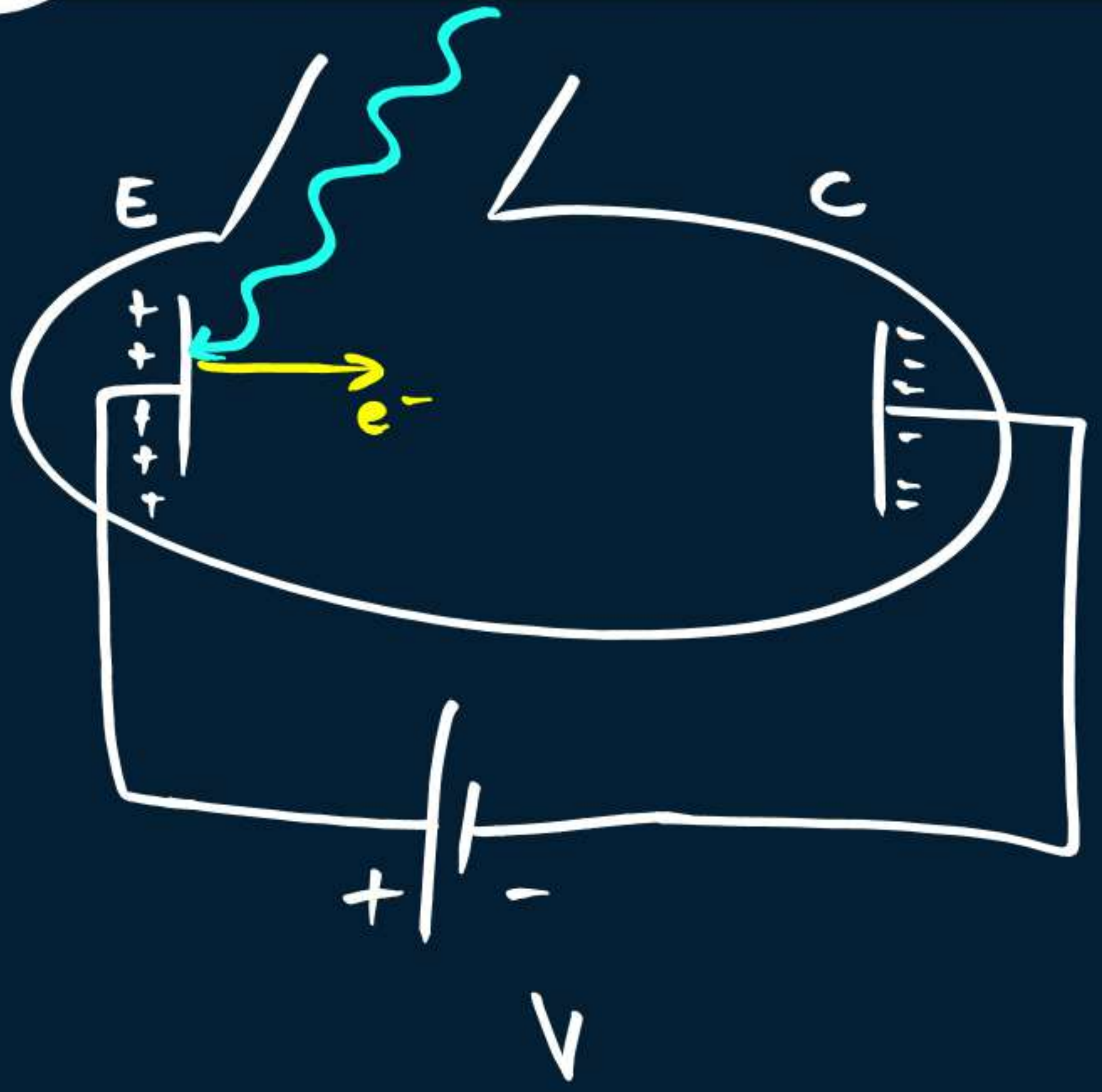


$I \propto i$

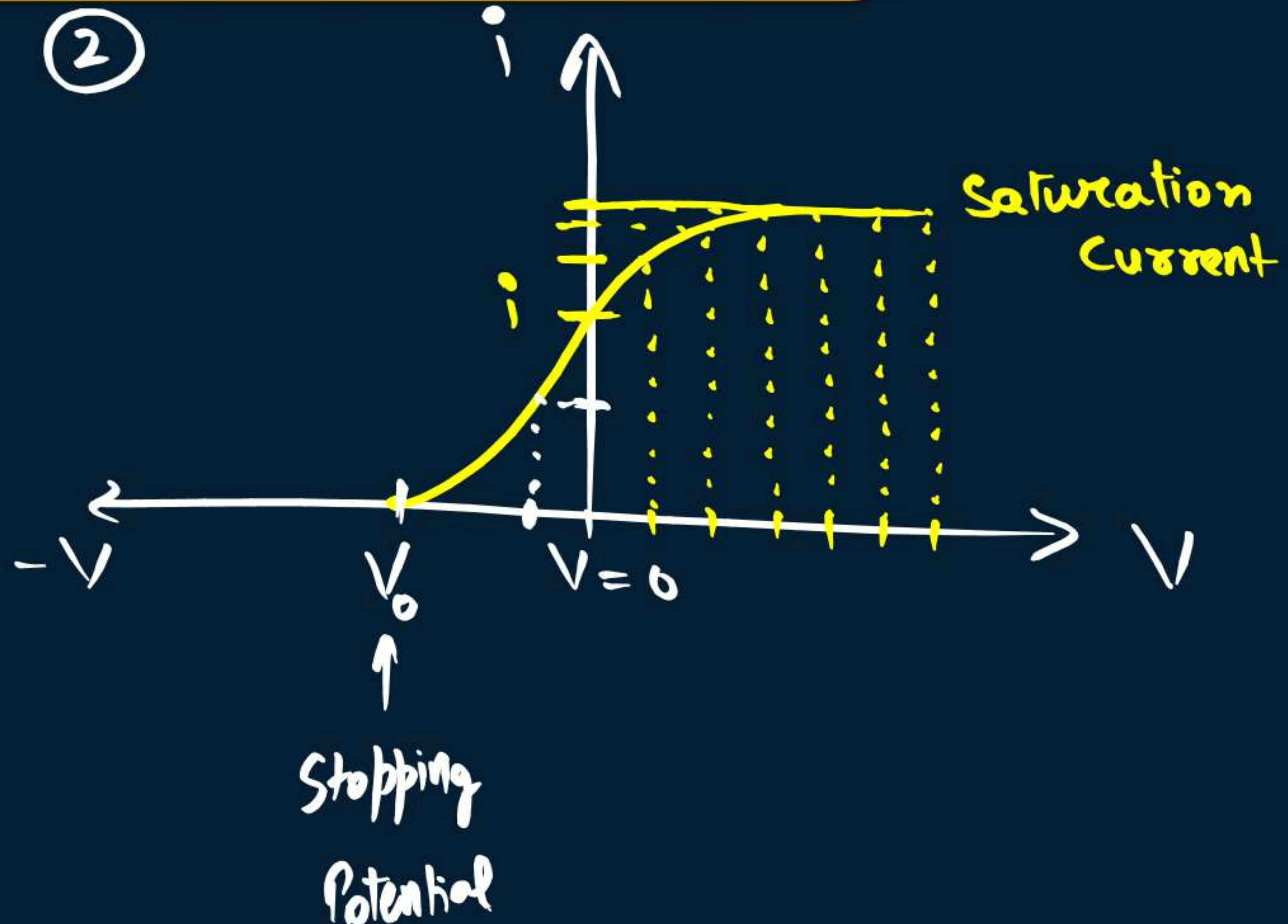
Intensity↑ $\propto$ Current↑

Number of Photons↑ $\propto$ No. of electrons free↑

Hallwach's and Lenard's Observations



②



Stopping Potential

V_0

$i = 0$

The minimum negative value of collector plate voltage, so that photocurrent stops or becomes zero is called stopping potential or cut-off voltage.

The electron with even maximum kinetic energy cannot reach the collector plate.

$$W = qV$$

$$K = qV$$

$$\boxed{K_{Max} = eV_0}$$

Kinetic energy

Stopping potential

QUESTION

Number of ejected photoelectron increases with increase [CBSE AIPMT 1993]

(A) in intensity of light

(B) in wavelength of light

(C) in frequency of light

(D) Never

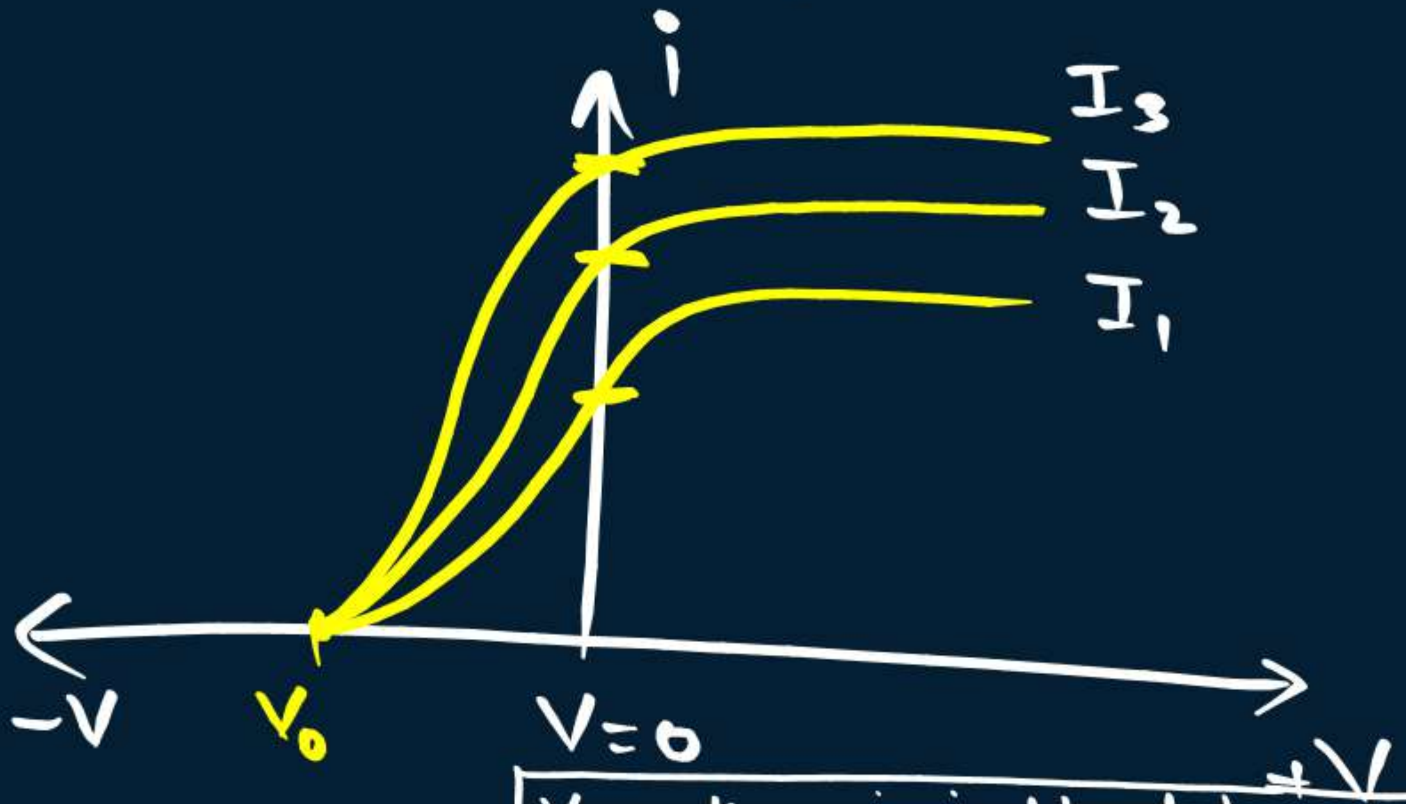
Intensity = Brightness

No. of Photon ↑

No. of e^- ↑

i ↑

③ Variation of 'I' in graph ②



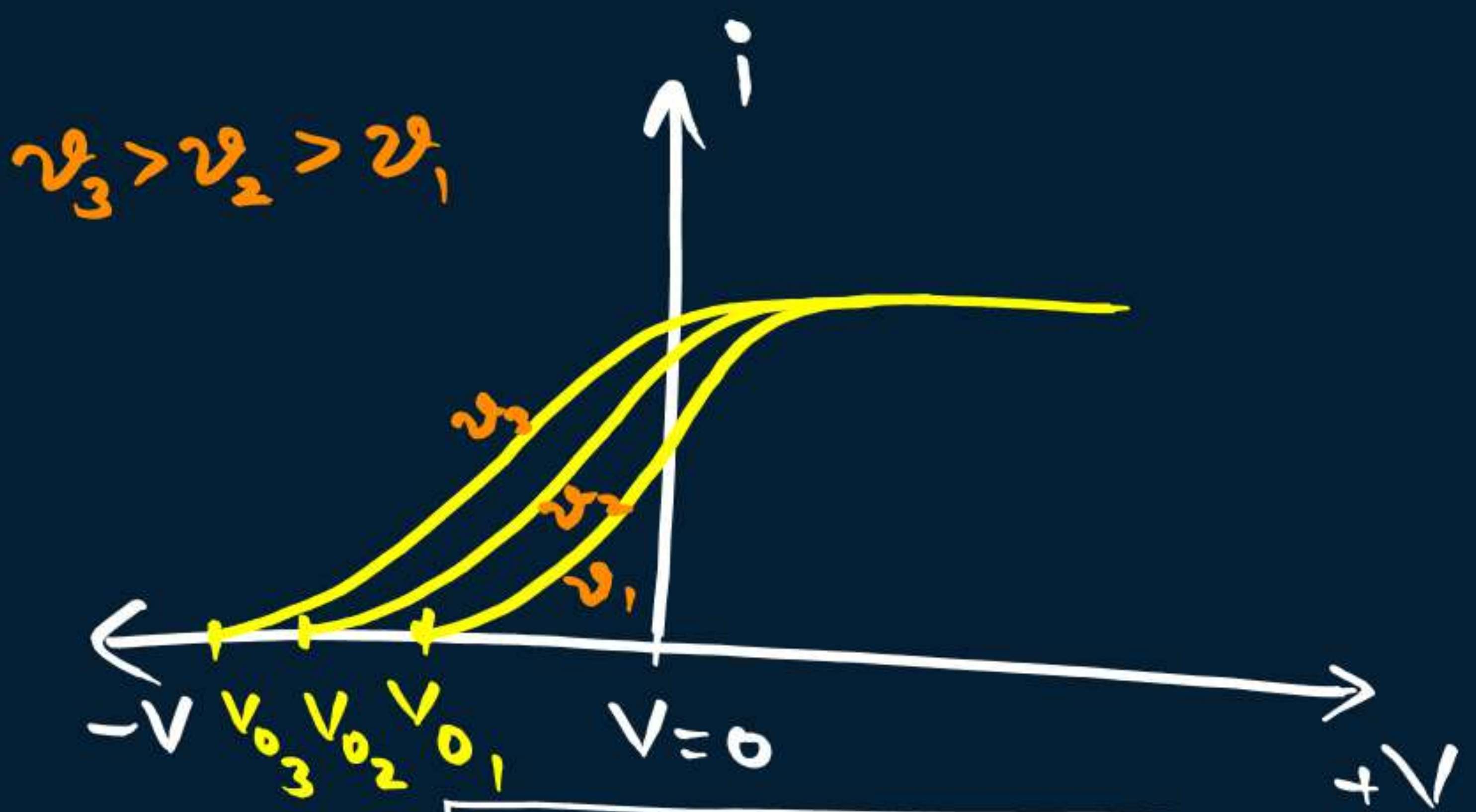
$\boxed{V_0 \text{ or } K_{max} \text{ is independent of } I}$

$\underbrace{K_{max} = eV_0}_{\text{fixed}}$

I↑
Photons↑
electrons↑
i↑

> Intensity Badhane se Number toh Bodega Par Stopping V_0 same, speed same, kinetic energy same

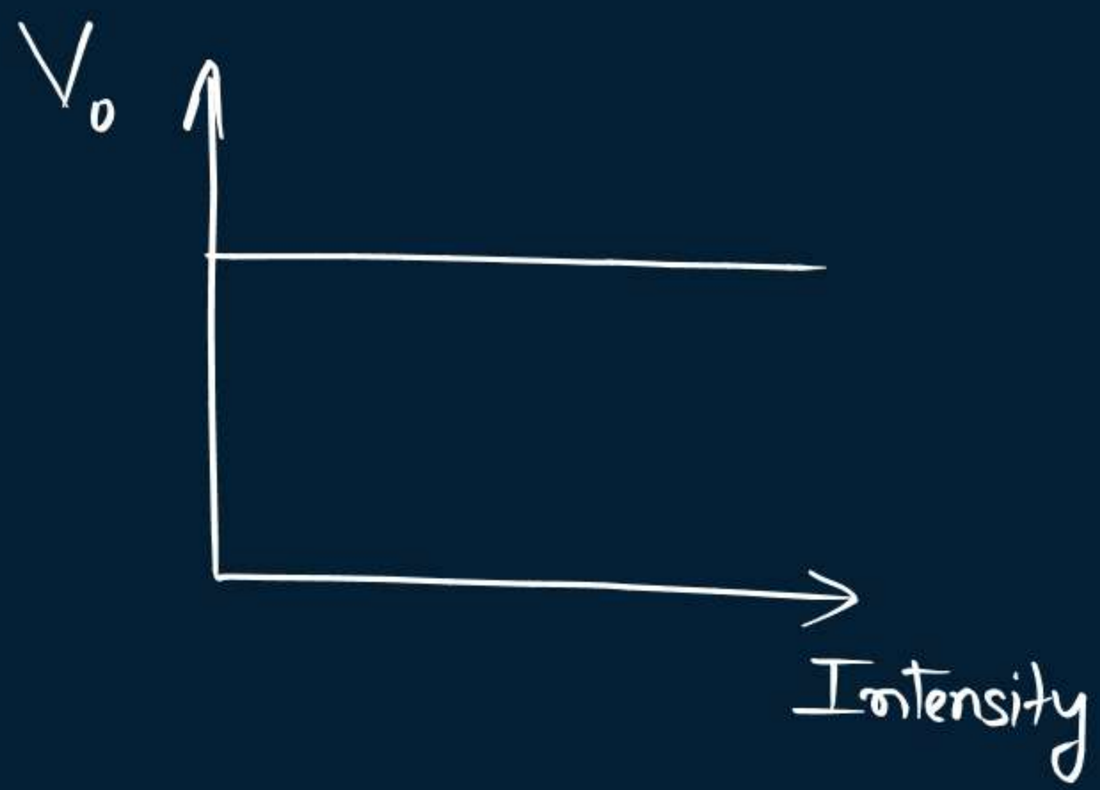
④ Variation of 'ν' in graph ②



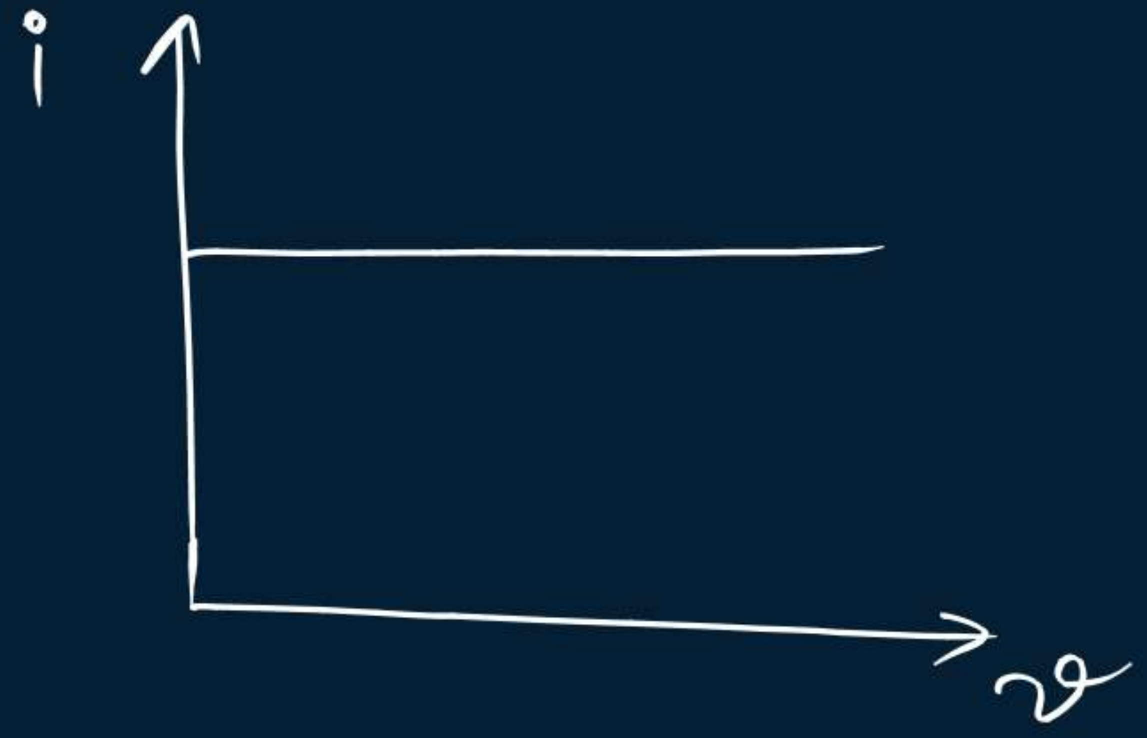
$\boxed{i \text{ is independent of } \nu}$

ν↑
$E\uparrow = h\nu\uparrow$
KE of e^-↑
V_0↑

> frequency Badhane se speed Bodhti hai, toh V_0 Badhana hoga.
>
> Number of e^- same, i same



V_0
Intensity



i
ν

QUESTION

$\nu \uparrow \; E \uparrow \; KE_{max} \uparrow \; V_0 \uparrow$

Assertion: On increasing the frequency of incident light on the metal surface, K.E. of ejected particle decreases. F

Reason: Energy of photon **α** Frequency of light T

$E \propto \nu$

A Both A and R are true, R is correct explanation of A

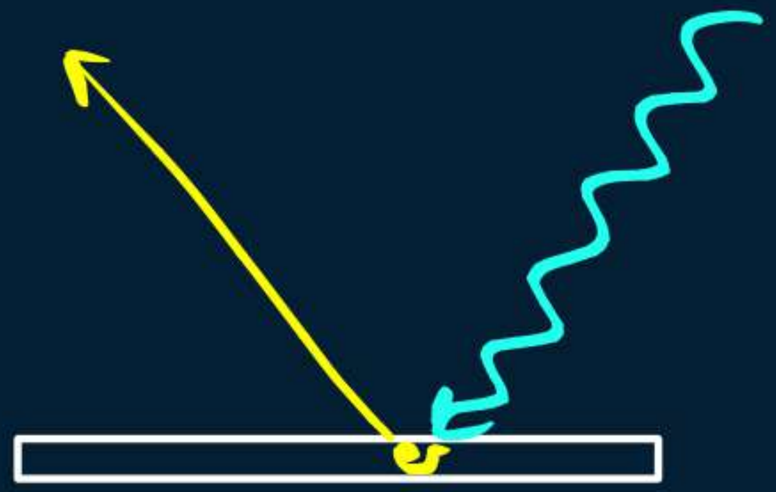
B Both A and R are true, R is not a correct explanation of A

C A is true, R is false

D A is false, R is true.

Einstein Photo-electric Equation

Conservation of Energy



$$\boxed{E_{\substack{\text{incident}\\\text{Photon}}} = W_0 + K_{Max}}$$

$$h\nu = h\nu_0 + \frac{1}{2}mv_{max}^2$$

$$\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + \frac{1}{2}mv_{max}^2$$

$$h\nu = h\nu_0 + \frac{1}{2}mv_{Max}^2$$

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

$$h(\nu - \nu_0) = \frac{1}{2}mv_{Max}^2$$

$$\frac{2h(\nu - \nu_0)}{m} = v_{Max}^2$$

$$\boxed{V_{Max} = \sqrt{\frac{2h(\nu - \nu_0)}{m}}}$$

Max Velocity of e^-

RDx Points to be noted

1. The photoelectric emission is an instantaneous process without any apparent time lag($\sim 10^{-9}$) s or less).

2. It is one-on-one collision. One photon collides with one electron only.

3. In a photon-electron collision, the total energy and total momentum are conserved.

4. The number of photons may not be conserved in a collision.

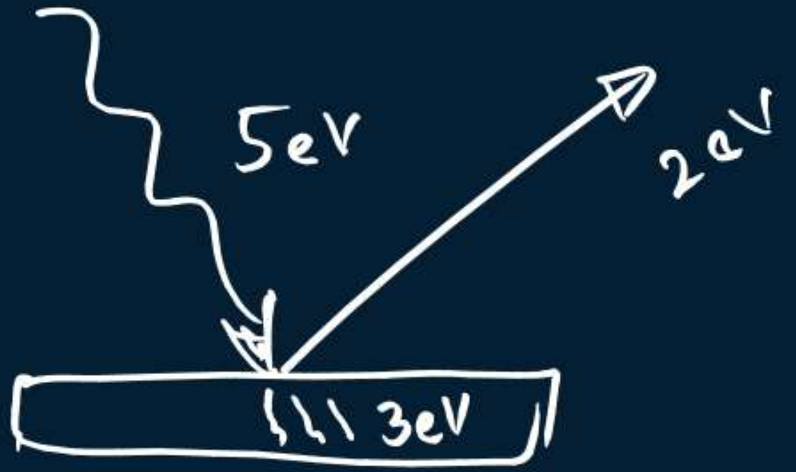
5. Intensity of light is directly proportional to the number of photons per sec.

6. In a photon-particle collision (such as photon-electron collision), the total energy and total momentum are conserved. However, the number of photons may not be conserved in a collision. The photon may be absorbed or a new photon may be created.

QUESTION

When photon of energy 5 eV falls on metallic surface of work function 3 eV then the kinetic energy of emitted electrons are

$$E_{in} = W_0 + K_{max}$$



A 2 eV

B 4.6 eV

C 0 to 2 eV

D 3 eV

(7) Graph

$$E_{inci} = W_0 + K_{max}$$

$$K_{max} = E_{inci} - W_0$$

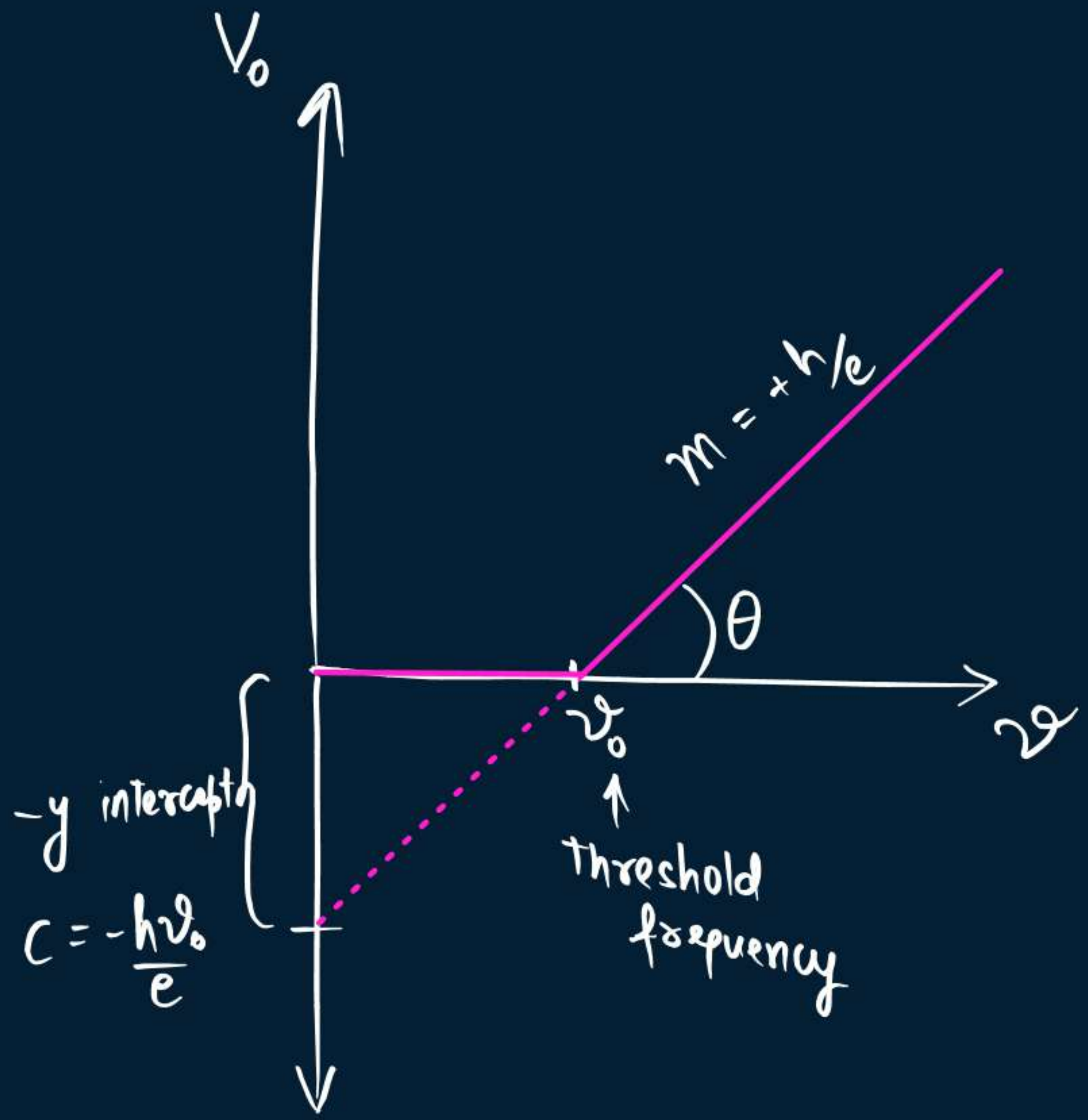
$$eV_0 = h\nu - h\nu_0$$

$$\underset{y}{V_0} = \underset{m}{\left(\frac{h}{e}\right)}\underset{x}{\nu} \underset{c}{\left(-\frac{h}{e}\nu_0\right)}$$

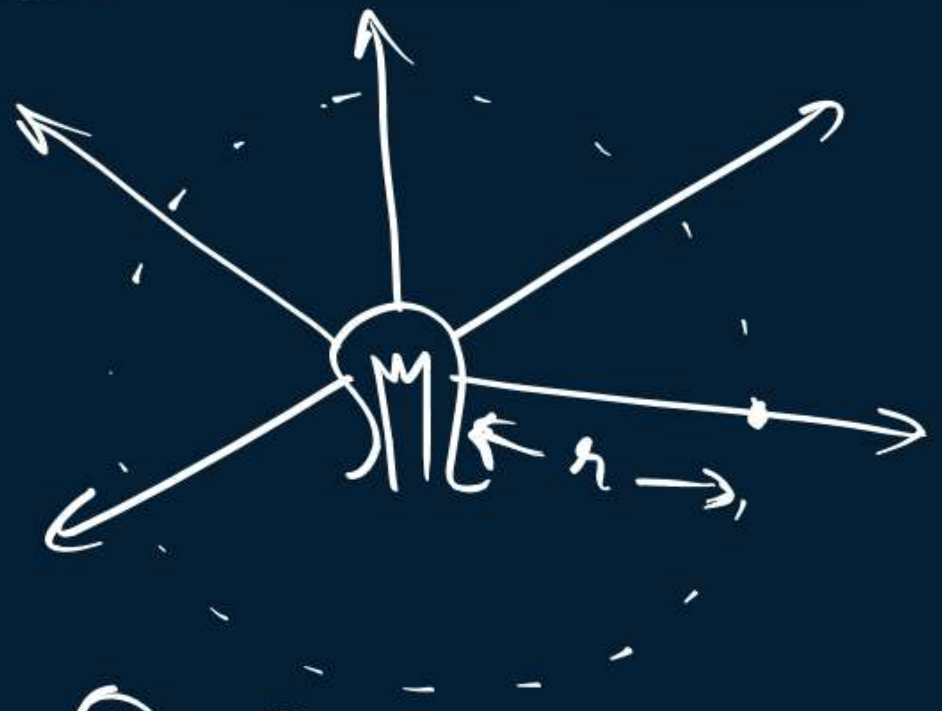
$$y = mx + c$$

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

$c \Rightarrow$ y-intercept $= -\frac{h\nu_0}{e}$



Intensity of a Point Source

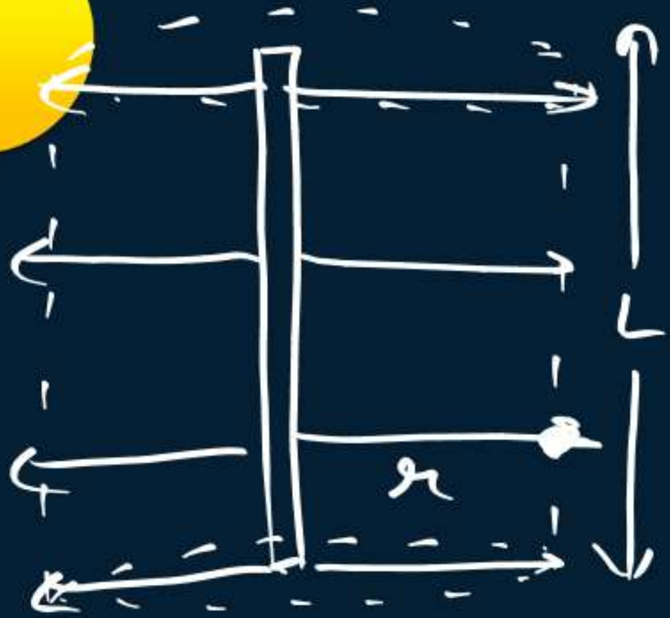


① Point source (Bulb)

$$I = \frac{\text{Power}}{\text{Area}} \rightarrow \left(\frac{W}{m^2}\right)$$

$$I = \frac{P}{4\pi r^2}$$

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



② Linear source (Tubelight)

$$I = \frac{P}{A}$$

$$I = \frac{P}{2\pi r L}$$

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

③ Infinite source (Sun)

I is independent of r

QUESTION

H.W.

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

$p = ?$

$\lambda = 5000 A^\circ = 5000 \times 10^{-10} m$

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

Number of Photons Emitted per sec

$\dfrac{N}{t}$ → Number of photons / → time

Energy of one photon :- $E = h\nu$

Energy of N-photons :- $E = Nh\nu$

$E = \dfrac{Nhc}{\lambda}$

No. of photons

$\boxed{N = \dfrac{E\lambda}{hc}}$

$\boxed{N = 5\times10^{24}\, E\lambda}$

RDx

$\dfrac{N}{t} = \dfrac{(E)\lambda}{(t)hc}$

No. of Photons per second

$\boxed{\dfrac{N}{t} = \dfrac{P\lambda}{hc}}$

$\boxed{\dfrac{N}{t} = 5\times10^{24}\, P\lambda}$

RDx

QUESTION

VIBGYOR

$\longrightarrow \lambda\uparrow$

$E \rightarrow$ same

If CSK's yellow light and MI's blue light having same energy, then which team's jersey will emit more number of photons?

A MI

B CSK

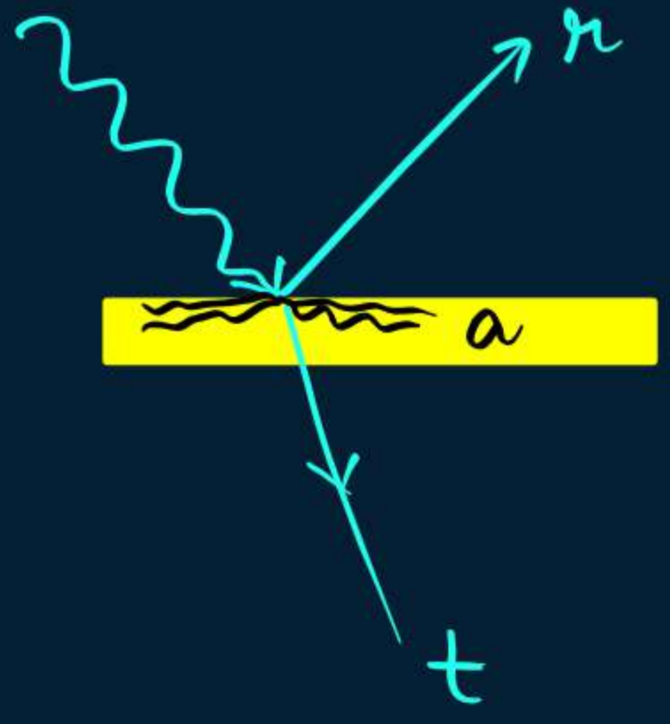
C ~~RCB~~

D ~~DC~~

$$N = \underbrace{5\times10^{24}}_{\text{Same}} \underset{\downarrow}{E} \lambda$$

$$\boxed{N \uparrow \propto \lambda \uparrow}$$

Radiation Pressure



t = transmittivity

a = absorptivity

r = reflectivity

$$\boxed{r + t + a = 1}$$

'opaque'

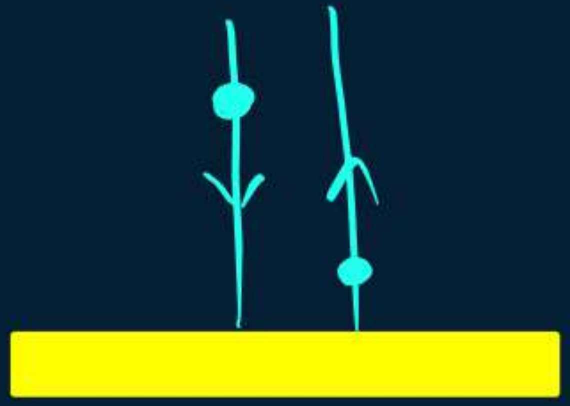
$t = 0$

$$\boxed{r + a = 1}$$

① perfectly reflective $(r = 1)$

② perfectly absorptive $(a = 1)$

(I) Perfectly reflective



$p_i = -\frac{h}{\lambda}$ $p_f = +\frac{h}{\lambda}$

$$F = \frac{\Delta p}{t} = \frac{p_f - p_i}{t} = \frac{\frac{h}{\lambda} - \left(-\frac{h}{\lambda}\right)}{t} = \frac{\frac{h}{\lambda} + \frac{h}{\lambda}}{t} = \frac{2h}{t\lambda}$$

$$F = \frac{2}{t}\left[\frac{h}{\lambda}\right]$$

$$F = \frac{2E}{tc} \quad \left\{E = \frac{hc}{\lambda}\right\}$$

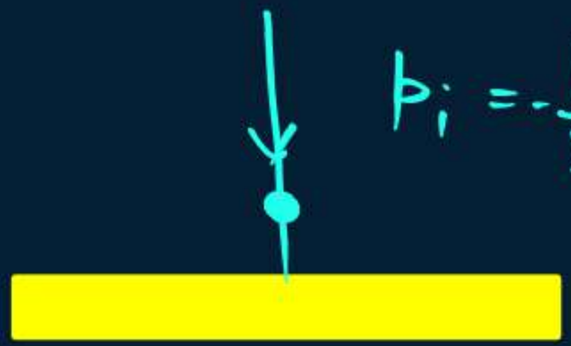
$$\boxed{F = \frac{2P}{c}} \quad \left\{P = \frac{E}{t}\right\}$$

$$P' = \frac{F}{A} = \frac{2P}{Ac} \quad \left(I = \frac{P}{A}\right)$$

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

$\left(\begin{array}{l} P' \to \text{Pressure} \\ P \to \text{Power} \end{array}\right)$

(II) Perfectly absorptive



$p_i = -\frac{h}{\lambda}$, $p_f = 0$

$$\Delta p = p_f - p_i = 0 - \left(-\frac{h}{\lambda}\right)$$

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

$$F = \frac{\Delta p}{t} = \frac{h}{t\lambda} = \frac{E}{tc}$$

$$\boxed{F = \frac{P}{c}}$$

$$P' = \frac{F}{A} = \frac{P}{cA}$$

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

Wave Nature of Matter

Louis de-Broglie

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

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

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

de-Broglie Wavelength

1kg → 1m/s

$$\lambda = \frac{h}{1 \times 1}$$

$$\lambda = h = 6.6 \times 10^{-34} m$$

→ impossible to measure by any instrument

So wave Nature of massive particles cannot be observed.

$$\boxed{\lambda = \frac{12.27}{\sqrt{V}}}$$

V → Voltage

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

$$K = \frac{p^2}{2m}$$

$$2mK = p^2$$

$$\sqrt{2mK} = p$$

Homework

Notes ✓

NCERT Ques ✓

Revision ✓