LAKSHYA
JEE 2025

Physics | **Lecture – 3**

Modern Physics

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Todays Goal

- Matter wave
- photoelectric Effect (Introduction)

photon theory

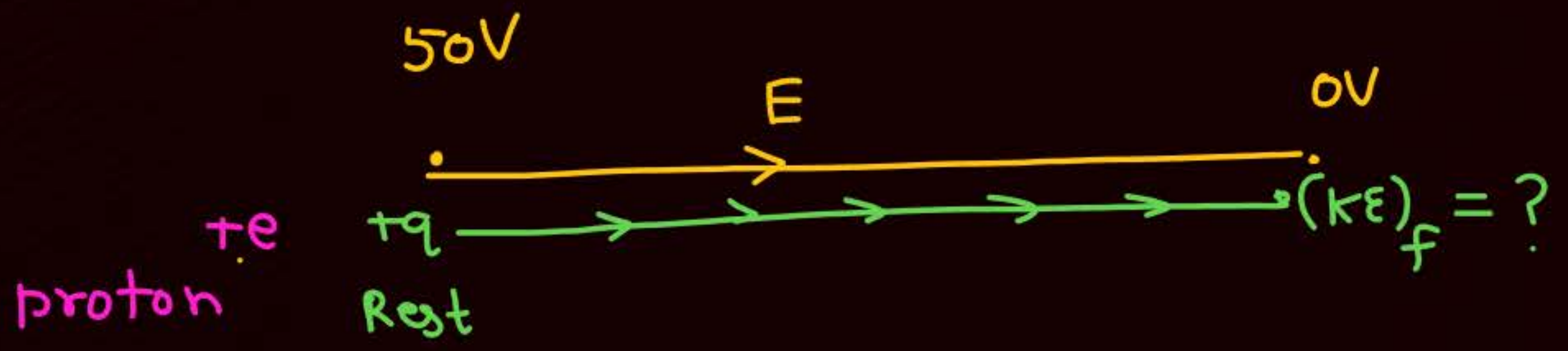
electron volt

$p = \frac{h}{\lambda}$ $\lambda = 310\ A^\circ$

$E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34} \times 3\times10^{8}}{310\times10^{-10}}\ J = (\quad)\ eV$

$\frac{1240}{\lambda_{(nm)}} = \frac{12400}{\lambda_{(A^\circ)}}$

$$e(50-0) = 50\ eV$$



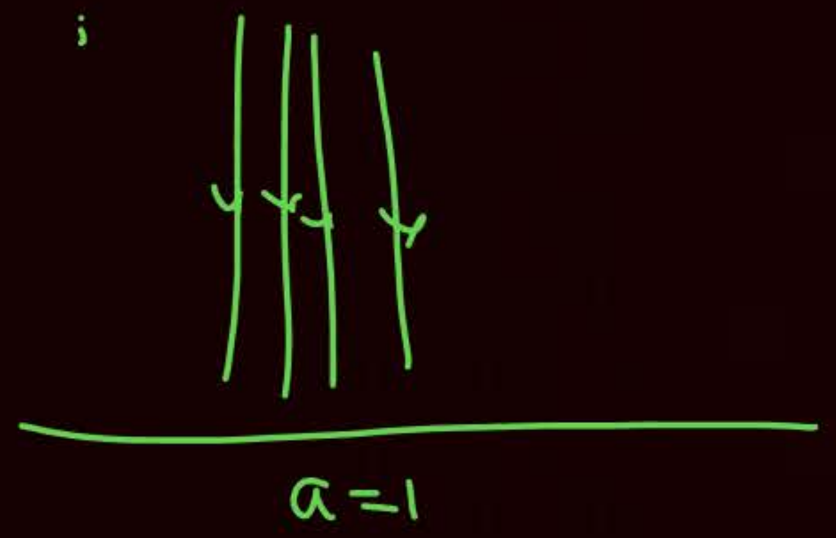
$$0 + q\,50 = K_f + 0$$

$$K_f = e \times 50 = 50\ eV$$

$$= 1.6 \times 10^{-19} \times 50$$

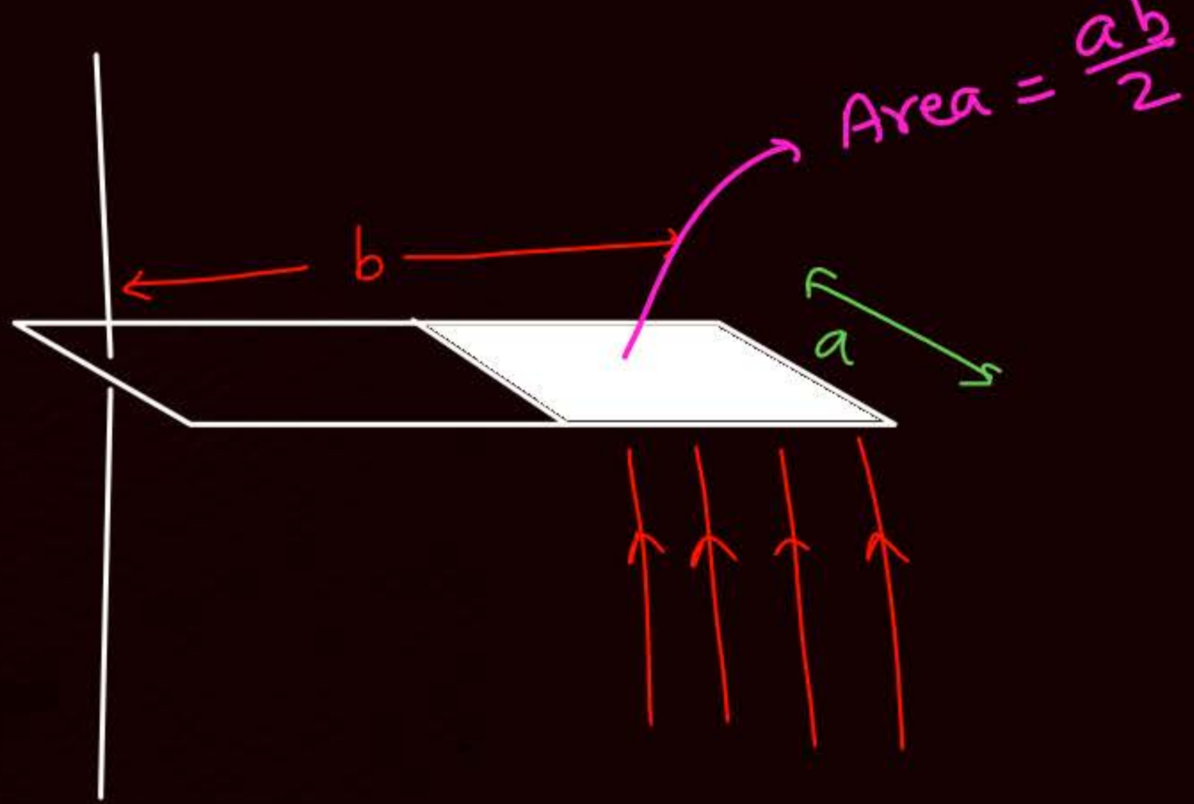
$$\lambda = \frac{h}{mv} = \frac{h}{p} = \frac{h}{\sqrt{2m(KE)}} = \frac{h}{\sqrt{2m(q\Delta V)}}$$

e^-, p^+, d, α

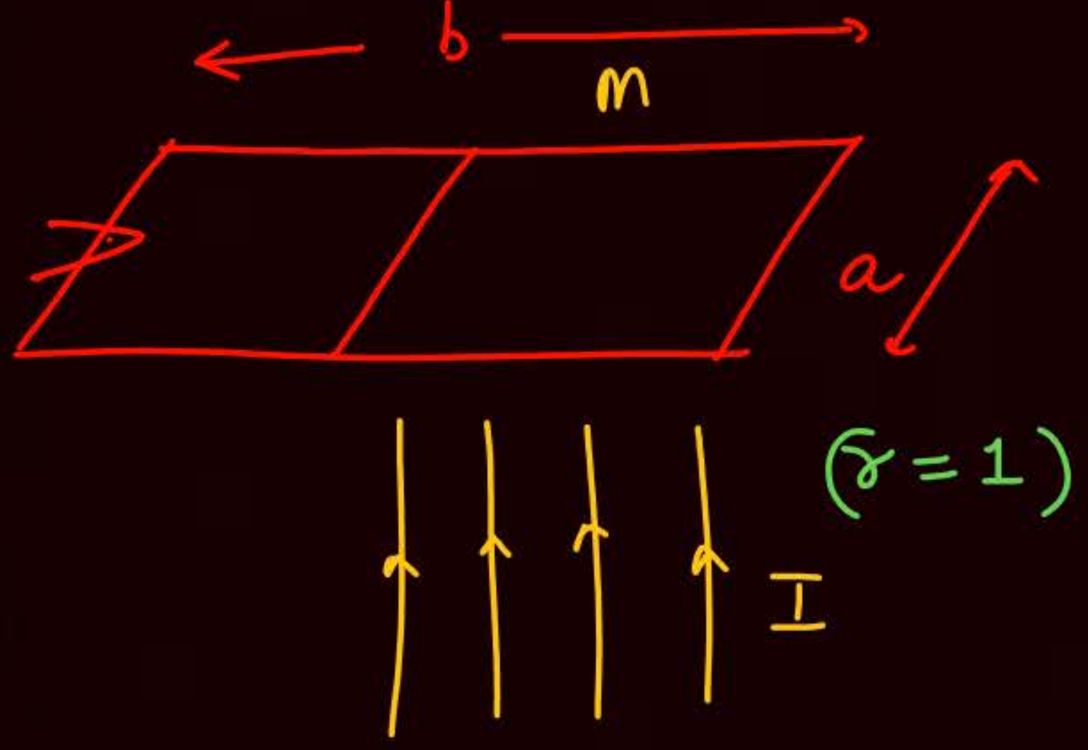


$$P = \frac{I\cos^2\theta}{c}(1+r)$$

Q



Equilibrium



$$mg\frac{b}{2} = \frac{2I}{c}\left(\frac{b}{2}\cdot a\right)\left(\frac{3b}{4}\right)$$

PM If charge is accelerated by pot. diff 'V' from rest

RM

for $e^- \Rightarrow \lambda = \sqrt{\frac{150}{V}}$ Å

$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2m(K.E)}} = \frac{h}{\sqrt{2m\, q\, \Delta V}}$

or $\frac{h}{\sqrt{2mqV}}$

for $p^+ \Rightarrow \lambda = \sqrt{\frac{.081}{V}}$ Å

for deutron $\Rightarrow \lambda = \sqrt{\frac{.04}{V}}$

for 'α' particle $\Rightarrow \lambda = \sqrt{\frac{0.0102}{V}}$

proton ⟶ (m, e)

α particle ⟶ $(4m, 2e)$

deutron ⟶ $(2m, e)$

mass of deutron = 2 mass of proton

$$m_d = 2 m_p$$

Q

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

$$P_i = P_f$$

$$0 = 6V_1 - 4V_2$$

$$6V_1 = 4V_2 \quad \text{— (1)}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{m_2V_2}{m_1V_1} = \frac{4V_2}{6V_1} \quad \text{— (2)}$$

Direct

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

P → दोनों का same

from — (1) & (2)

$$\frac{\lambda}{\lambda_2} = 1, \quad \boxed{\lambda_1 = \lambda_2}$$

10. A particle A of mass m and initial velocity v collides with a particle B of mass $m/2$ which is at rest. The collision is head on, and elastic. The ratio of the de-Broglie wavelengths λ_A to λ_B after the collision is

(1) $\frac{\lambda_A}{\lambda_B} = \frac{2}{3}$

(2) $\frac{\lambda_A}{\lambda_B} = \frac{1}{2}$

(3) $\frac{\lambda_A}{\lambda_B} = \frac{1}{3}$

(4) $\frac{\lambda_A}{\lambda_B} = 2$

(JEE Main 2017)

$m \xrightarrow{v}$, $\frac{m}{2}$ (Rest), $e = 1$ $\equiv$ $m \xrightarrow{v_1}$, $\frac{m}{2} \xrightarrow{v_2}$

$mv + 0 = mv_1 + \frac{m}{2}v_2$

$2v = 2v_1 + v_2$ ——— (1)

$v = v_2 - v_1$ ——— (2)

1. A pulse of light of duration 100 ns is absorbed completely by a small object initially at rest. Power of the pulse is 30 mW and the speed of light is 3×10^8 m/s. The final momentum of the object is

(1) 0.3×10^{-17} kg ms^{-1}
(2) 1.0×10^{-17} kg ms^{-1}
(3) 0.2×10^{-17} kg ms^{-1}
(4) 9.0×10^{-17} kg ms^{-1}

(JEE Advanced 2013)

1. An α-particle and a proton are accelerated from rest by a potential difference of 100 V. After this, their de Broglie wavelengths are λ_α and λ_p, respectively. The ratio λ_p/λ_α, to the nearest integer, is

(IIT-JEE 2010)

A free particle with initial kinetic energy E and de–broglie wavelength λ enters a region in which it has potential energy U. What is the particle's new de–Broglie wavelength?

एक मुक्त कण प्रारम्भिक गतिज ऊर्जा E तथा डी–ब्रोग्ली तरंगदैर्ध्य λ के साथ एक ऐसे क्षेत्र में प्रवेश करता है जहां इसकी स्थितिज ऊर्जा U है। कण की नई डी–ब्रोग्ली तरंगदैर्ध्य क्या होगी ?

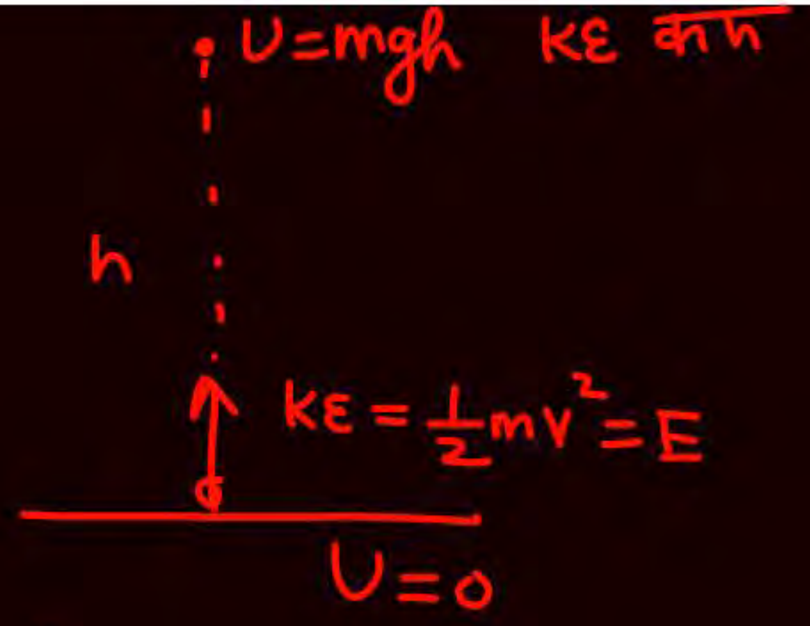
(A) $\lambda(1-U/E)^{-1/2}$ (B) $\lambda(1-U/E)$ (C) $\lambda(1-E/U)^{-1}$ (D) $\lambda(1+U/E)^{1/2}$

Ans. (A)

$(KE)_f = E - U$

$$\lambda_i = \frac{h}{\sqrt{2m(K.E)_i}} = \frac{h}{\sqrt{2m.E}}$$

$$\lambda_f = \frac{h}{\sqrt{2m(KE)_f}} = \frac{h}{\sqrt{2m(E-u)}}$$



$0 + \frac{1}{2}mv^2 = mgh + K_f$

17. A particle of mass 4m at rest decays into two particles of masses m and 3m having non-zero velocities. The ratio of the de-Broglie wavelengths of the particles 1 and 2 is

विरामावस्था में स्थित एक 4m द्रव्यमान का एक कण m तथा 3m द्रव्यमान तथा अशून्य वेग वाले दो कणों में क्षयित होता है। इन कणों 1 तथा 2 की डी-ब्रोग्ली तरंगदैर्ध्य का अनुपात होगा

(A) $\frac{1}{2}$ (B) $\frac{1}{4}$ (C) 2 (D) 1

Ans. (D)

16. **Statement-1 :** If an electron has the same wavelength as a photon, they have the same energy.

Statement-2 : by debroglie hypothesis, $p = h/\lambda$ for both the electron and the photon.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

कथन-1 : यदि किसी इलेक्ट्रॉन तथा फोटोन की तरंगदैर्ध्य समान हो तो उनकी ऊर्जा समान होती है।

कथन-2: दे ब्राग्ली परिकल्पना के अनुसार इलेक्ट्रॉन तथा फोटॉन के लिए $p = h/\lambda$ होता है।

(A) कथन–1 सत्य है, कथन–2 असत्य है।

(B) कथन–1 सत्य है, कथन–2 सत्य है; कथन–2 कथन–1 की सही व्याख्या करता है।

(C) कथन–1 सत्य है, कथन–2 सत्य है; कथन–2 कथन–1 की सही व्याख्या नहीं करता है

(D) कथन–1 असत्य है, कथन–2 सत्य है।

Ans. (D)

Bohr's theory is unable to explain the following facts :

- The spectral lines of hydrogen atom are not single lines but each one is a collection of several closely spaced lines.
- The structure of multielectron atoms is not explained.
- No explanation for using the principles of quantization of angular momentum.
- No explanation for Zeeman effect. If a substance which gives a line emission spectrum is placed in a magnetic field, the lines of the spectrum get splitted up into a number of closely spaced lines. This phenomenon is known as Zeeman effect.

3. A photocell is illuminated by a small bright source placed 1 m away. When the same source of light is place $\frac{1}{2}$ m away, the number of electrons emitted by photocathode would- **[AIEEE - 2005]**

(A) decrease by a factor of 4

(B*) increase by a factor of 4

(C) decrease by a factor of 2

(D) increase by a factor of 2

किसी फोटोसेल को 1 m दूर रखे किसी छोटे चमकीले स्रोत द्वारा प्रदीप्त किया जाता है। जब इसी प्रकाश स्रोत को $\frac{1}{2}$ m दूरी पर रखते हैं, तो फोटोकैथोड़ द्वारा उत्सर्जित इलेक्ट्रोनों की संख्या-

(A) 4 के गुणक द्वारा घट जाएगी

(B) 4 के गुणक द्वारा बढ़ जाएगी

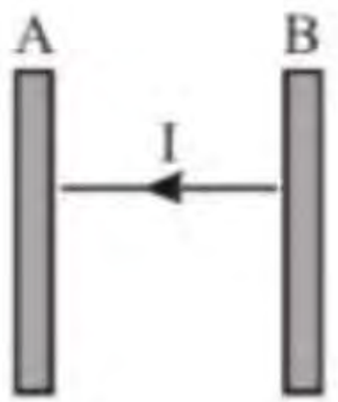
(C) 2 के गुणक द्वारा घट जाएगी

(D) 2 के गुणक द्वारा बढ़ जाएगी

Ans. (B)

15. A parallel beam of light of intensity I is incident normally on a plane surface A which absorbs 50% of the incident light. The reflected light falls on B which is perfect reflector, the light reflected by B is again partly reflected and partly absorbed and this process continues. For all absorption by A, asborption coefficient is 0.5. The pressure experienced by A due to light is :-

तीव्रता I वाला एक समान्तर प्रकाश पुंज एक ऐसी समतल सतह A पर लम्बवत् आपतित होता है जो आपतित प्रकाश का 50% अवशोषित कर लेती है। परावर्तित प्रकाश एक पूर्णतया परावर्तक B पर आपतित होता है। B द्वारा परावर्तित प्रकाश पुनः आंशिक परावर्तित तथा आंशिक अवशोषित होता है तथा यह प्रक्रम लगातार चलता रहता है। A द्वारा किये गये सम्पूर्ण अवशोषण के लिये अवशोषण गुणांक 0.5 है। प्रकाश के कारण A पर लगने वाला दाब होगा:-



(A) $\frac{1.5\,I}{c}$ (B) $\frac{I}{c}$ (C) $\frac{3I}{2c}$ (D) $\frac{3I}{c}$

Ans. (D)

घर पर

Q ① For what K.E. of a neutron will the associated de-broglie wavelength is 1.4 A°

$m_n = 1.66 \times 10^{-27}$ kg

[redacted]

② Find the debroglie w/l of neutron in thermal equilibrium of matter, having avrg kinetic Energy of $\frac{3}{2}KT$ at 300K.

given $K = 1.38 \times 10^{-23}$ J/Kg

$m_n = 1.66 \times 10^{-27}$ kg

घर पर

Q ① For what K.E. of a neutron will the associated de-broglie wavelength is 1.4 A°

$m_n = 1.66\times10^{-27}$ kg

$$\lambda = \frac{h}{\sqrt{2m(K.E)}} \qquad KE = \frac{h^2}{2m\lambda^2} = \frac{(6.6\times10^{-34})^2}{2\times1.66\times10^{-27}\times(1.4\times10^{-10})^2} = \checkmark$$

② Find the debroglie w/l of neutron in thermal equilibrium of matter, having avrg kinetic energy of $\frac{3}{2}KT$ at 300K. given $K = 1.38\times10^{-23}$ J/Kg

$m_n = 1.66\times10^{-27}$ kg

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

$$KE = \frac{3}{2}KT = \frac{3}{2}\times1.38\times10^{-23}\times300$$

$$\lambda = \frac{h}{\sqrt{2m(KE)}} = \frac{h}{\sqrt{2m \frac{3KT}{2}}} = \frac{h}{\sqrt{m3KT}}$$

Debroglie wavelength of a gas molecule

At temp T, K.E. of a gas molecule $= \frac{3}{2}KT$

K → Boltzman Const

$$\lambda_{\text{gas molecule}} = \frac{h}{\sqrt{3mKT}}$$

$$\lambda = \frac{h}{\sqrt{2m(KE)}} = \frac{h}{\sqrt{2m \cdot \frac{3KT}{2}}}$$

$\lambda = 620\,nm \Rightarrow E = \frac{1240}{\lambda} = \frac{1240}{620} = 2\,eV$

Pm If charge is accelerated by pot. diff 'V' from rest

(Rm)

for $e^- \Rightarrow \lambda = \sqrt{\frac{150}{V}}$ Å

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2m(K.E)}} = \frac{h}{\sqrt{2m\, q\, \Delta V}}$$

or $\frac{h}{\sqrt{2mqV}}$

for $p^+ \Rightarrow \lambda = \sqrt{\frac{.081}{V}}$ Å

for deutron $\Rightarrow \lambda = \sqrt{\frac{.04}{V}}$ Å

for 'α' particle $\Rightarrow \lambda = \sqrt{\frac{0.0102}{V}}$ Å

Q.

A particle moving with kinetic energy E has de Broglie wavelength λ. If energy ΔE is added to its energy, the wavelength become $\lambda/2$. Value of ΔE, is:

(JEE Main-2020)

(A) $2E$

(B) E

(C) $3E$ ✓

(D) $4E$

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

λ → half; E → 4 times

$$E \xrightarrow{+3E} 4E$$

Ans : (C)

Q. An electron of mass m and magnitude of charge $|e|$ initially at rest gets accelerated by a constant electric field E. The rate of change of de-Broglie wavelength of this electron at time t ignoring relativistic effects is:

(JEE Main-2020)

(A) $\frac{-h}{|e|Et^2}$

(B) $\frac{|e|Et}{h}$

(C) $\frac{h}{|e|Et^2}$

(D) $-\frac{h}{|e|Et}$

$v = 0 + \frac{eE}{m}t$

$\frac{d\lambda}{dt} = ?$

$\lambda = \frac{hm}{m \cdot eEt} = \frac{h}{eEt}$

Ans : (A)

Q.

Particle A of mass $m_A = m/2$ moving along the x-axis with velocity v_0 collides elastically with another particle B at rest having mass $m_B = m/3$. If both particles move along the x-axis after the collision, the change $\Delta\lambda$ in de-Broglie wavelength of particle A, in terms of its de-Broglie wavelength (λ_0) before collision is:

(JEE Main-2020)

A $\Delta\lambda = 4\lambda_0$

B $\Delta\lambda = \frac{5}{2}\lambda_0$

C $\Delta\lambda = 2\lambda_0$

D $\Delta\lambda = \frac{3}{2}\lambda_0$

Ans : (A)

Q. An electron (mass m) with initial velocity $\vec{v} = v_0\hat{i} + v_0\hat{j}$ is in an electric field $\vec{E} = -E_0\hat{k}$. If λ_0 is initial de-Broglie wavelength of electron, its de-Broglie wave length at time t is given by: **(JEE Main-2020)**

(A) $\dfrac{\lambda_0\sqrt{2}}{\sqrt{1+\dfrac{e^2E^2t^2}{m^2v_0^2}}}$

(B) $\dfrac{\lambda_0}{\sqrt{2+\dfrac{\sqrt{e^2E^2t^2}}{m^2 2+v_0^2}}}$

(C) $\dfrac{\lambda_0}{\sqrt{1+\dfrac{e^2E^2t^2}{2m^2v_0^2}}}$

(D) $\dfrac{\lambda_0}{\sqrt{1+\dfrac{\sqrt{e^2E_0^2t^2}}{m^2v_0^2}}}$

$\lambda_0 = \dfrac{h}{mv_0\sqrt{2}}$

At time t

$\vec{v} = v_0\hat{i} + v_0\hat{j} + \left(\dfrac{eE}{m}t\right)\hat{k}$

$\lambda_f = \dfrac{h}{mv_f} = \dfrac{h}{m\sqrt{v_0^2+v_0^2+\left(\dfrac{qEt}{m}\right)^2}}$

$\lambda_f = \dfrac{h}{m\sqrt{2v_0^2+\left(\dfrac{qEt}{m}\right)^2}}$

$= \dfrac{h}{mv_0\sqrt{2}\left[\sqrt{1+\dfrac{q^2E^2t^2}{m^2 2v_0^2}}\right]}$

$= \dfrac{\lambda_0}{\sqrt{1+(\quad)}}$

Ans : (C)

18. A parallel beam of light of intensity I is incident normally on a plane surface A which absorbs 50% of the incident light. The reflected light falls on B which is perfect reflector, the light reflected by B is again partly reflected and partly absorbed and this process continues. For all absorption by A, asborption coefficient is 0.5. The pressure experienced by A due to light is :-

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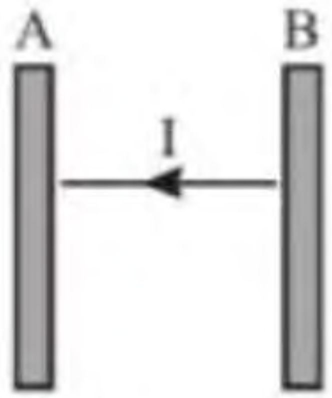


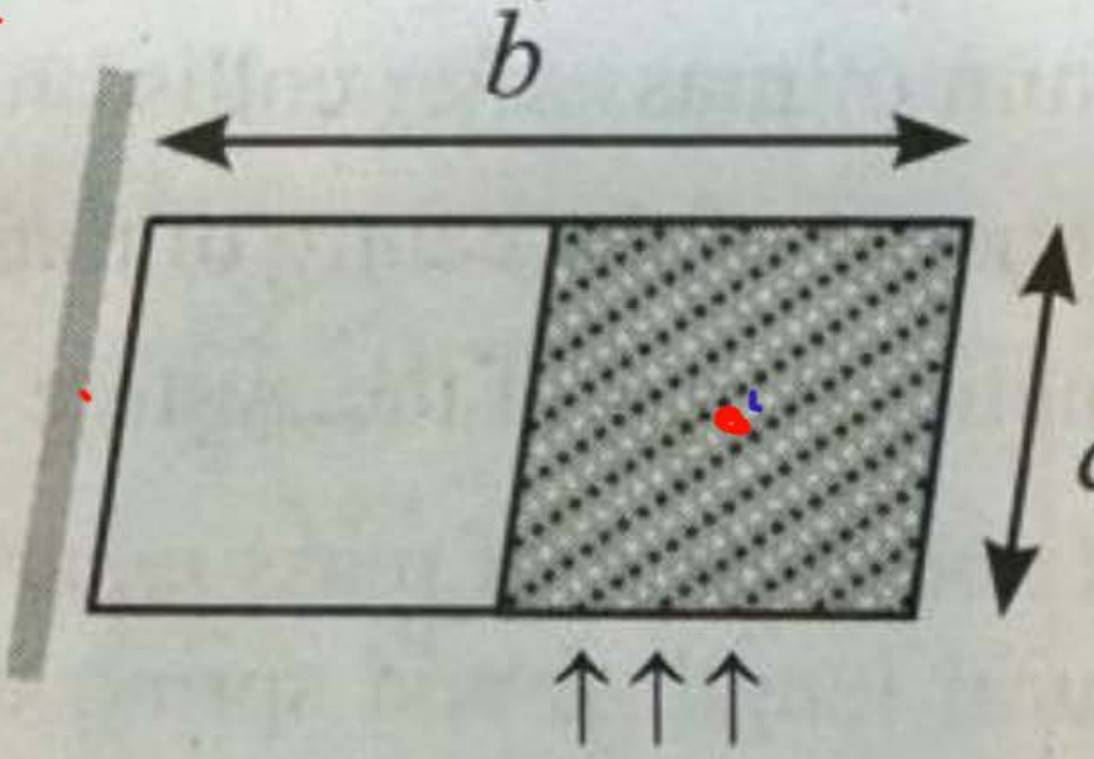
(A) $\frac{1.5\,I}{c}$ (B) $\frac{I}{c}$ (C) $\frac{3I}{2c}$ (D) $\frac{3I}{c}$

Ans. (D)

39. There is a rectangular plate of mass M kg of dimensions $(a \times b)$. The plate is held in horizontal position by striking n small balls uniformly each of mass m per unit area per unit time. These are striking in the shaded half region of the plate. The balls are colliding elastically with velocity v. What is v? **(IIT-JEE 2006)**

एक Ball का $\Delta P = 2mv$

$mg\frac{b}{2} = \left(2mv.n\frac{ab}{2}\right)\frac{3b}{4}$



$\left(2mv.n\frac{ab}{2}\right)\frac{3b}{4}$

It is given $n = 100$, $M = 3$ kg, $m = 0.01$ kg
$b = 2$ m; $a = 1$ m; $g = 10$ m/s^2

Photoelectric Effect

- when light of sufficient energy, or sufficient small wavelength is incident on a metal surface, e^- are ejected from metal surface. This phenomenon is called photoelectric Effect.

-

Work function (ϕ) → It is the min amount of energy required by material for photoelectric effect. It is property of material & commonly its have value between .5eV to 5eV.

Threshold Energy → It is the min Energy that photon must have to cause photoelectric effect.

ϕ = Work function = Threshold Energy

* ϕ = work function $= h\nu_0 = \frac{hc}{\lambda_0}$

$\nu_0 \longrightarrow$ Threshold frequency

$\lambda_0 \longrightarrow$ Threshold wavelength.

* $E = \phi + (KE)_{max}$

$(KE)_{max} \longrightarrow$ max possible K.E. of e^-

$E \rightarrow$ Energy of one photon

$\phi \rightarrow$ work function

* $0 \leq (KE) \leq (KE)_{max}$

$(KE) \rightarrow$ Kinetic Energy of photo electron

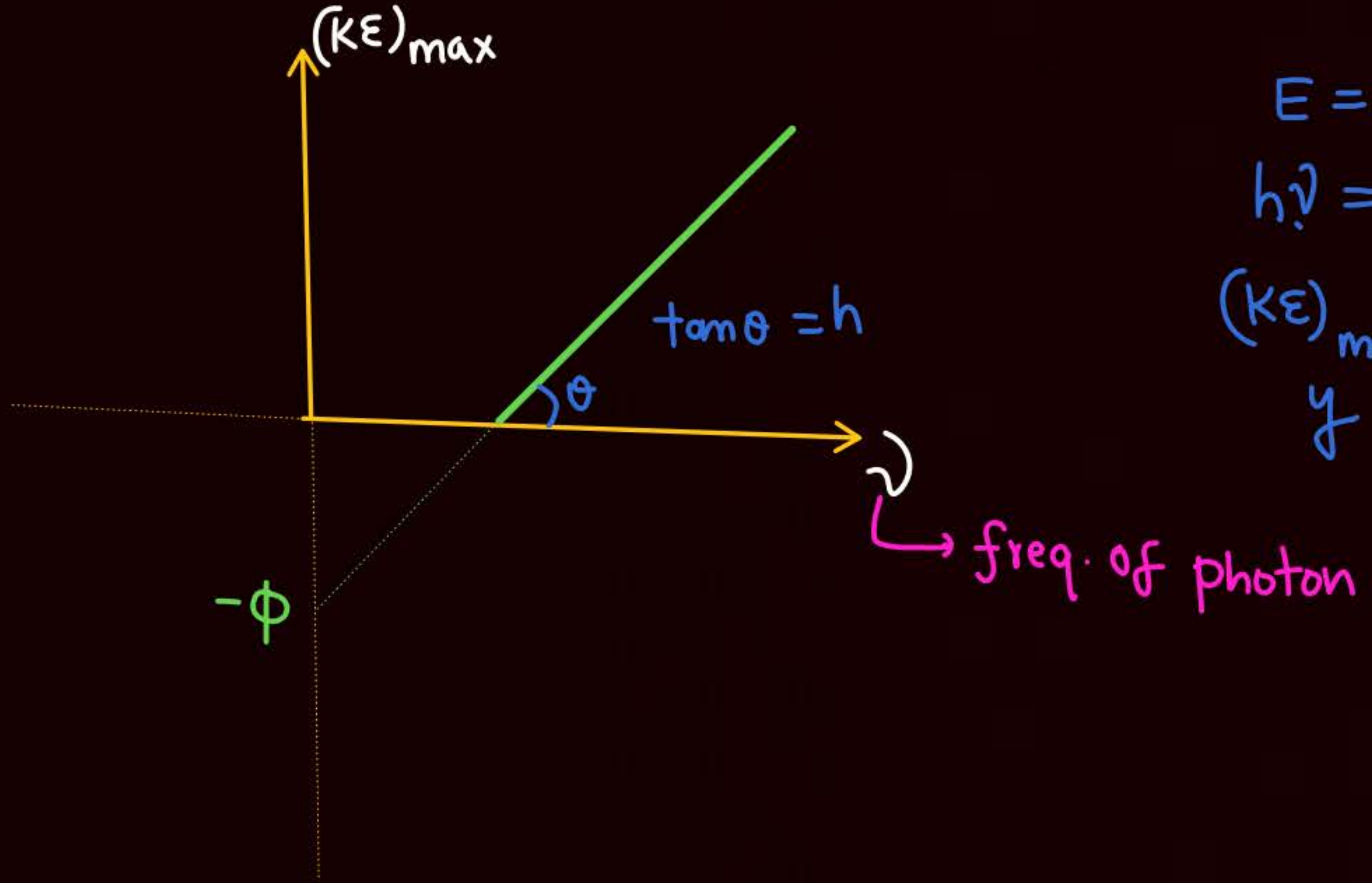
- Electron Emitted from phoelectric Effect is called photoelectron.

Draw Graph between $(KE)_{max}$ Vs ν

$$E = \phi + (KE)_{max}$$

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

$$\phi = h\nu_0 = \frac{hc}{\lambda_0}$$



$$E = \phi + (KE)_{max}$$

$$h\nu = \phi + (KE)_{max}$$

$$(KE)_{max} = h\nu - \phi$$

$$y = mx - c$$

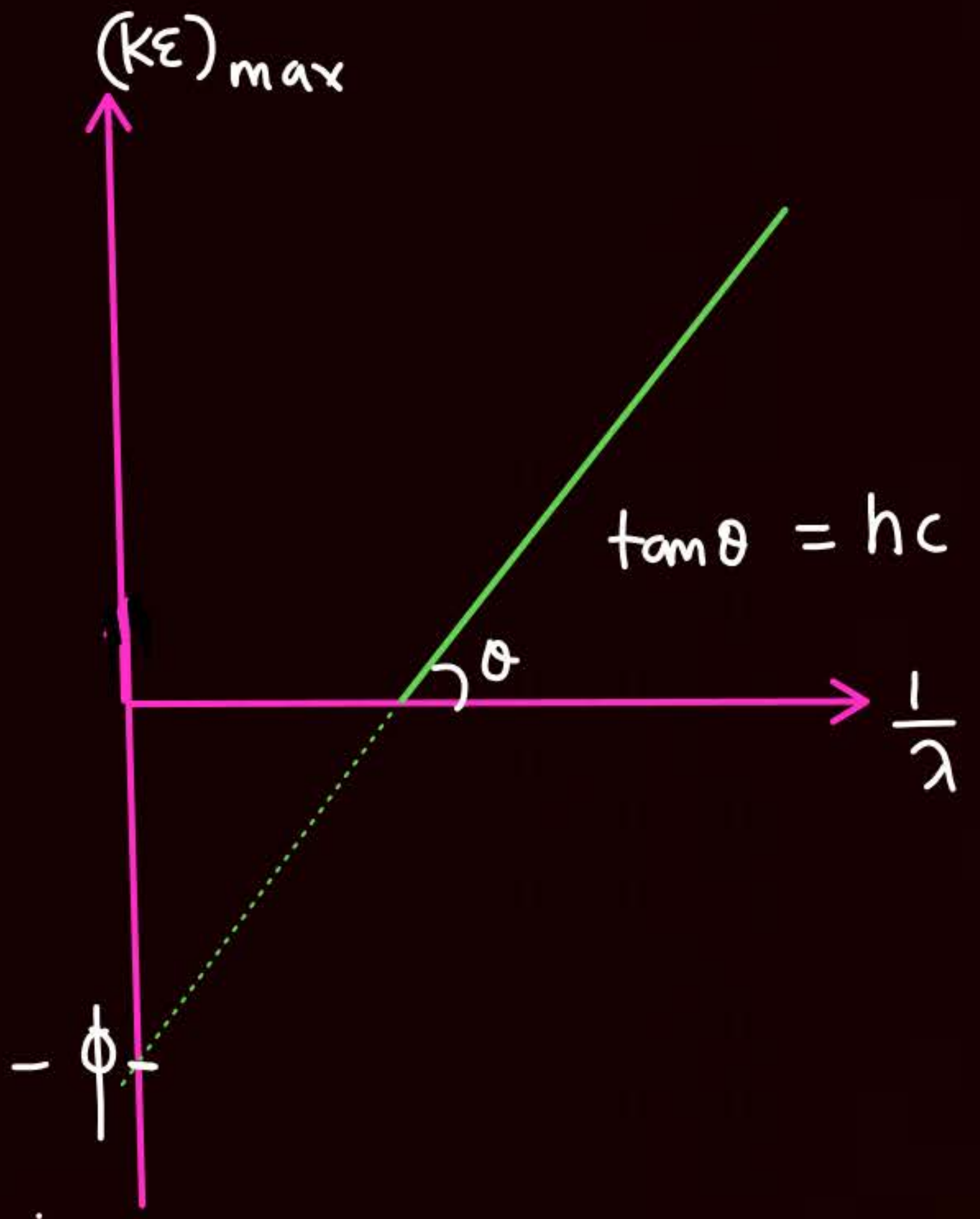
* Draw the graph b/w $(KE)_{max}$ Vs $\frac{1}{\lambda}$

$$E = \phi + KE_{max}$$

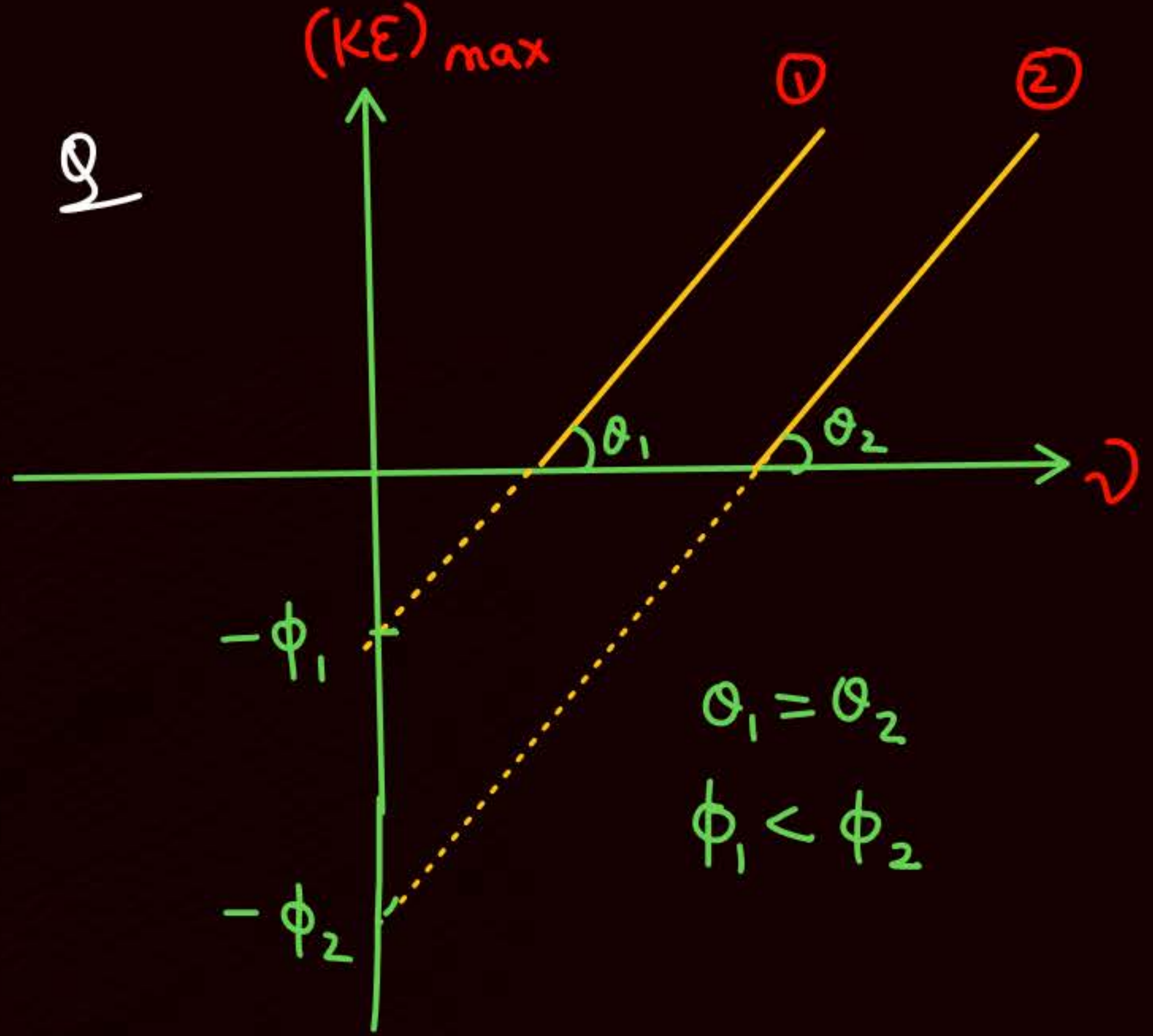
$$\frac{hc}{\lambda} = \phi + (KE)_{max}$$

$$(KE)_{max} = \frac{hc}{\lambda} - \phi$$

$$y = mx - c$$



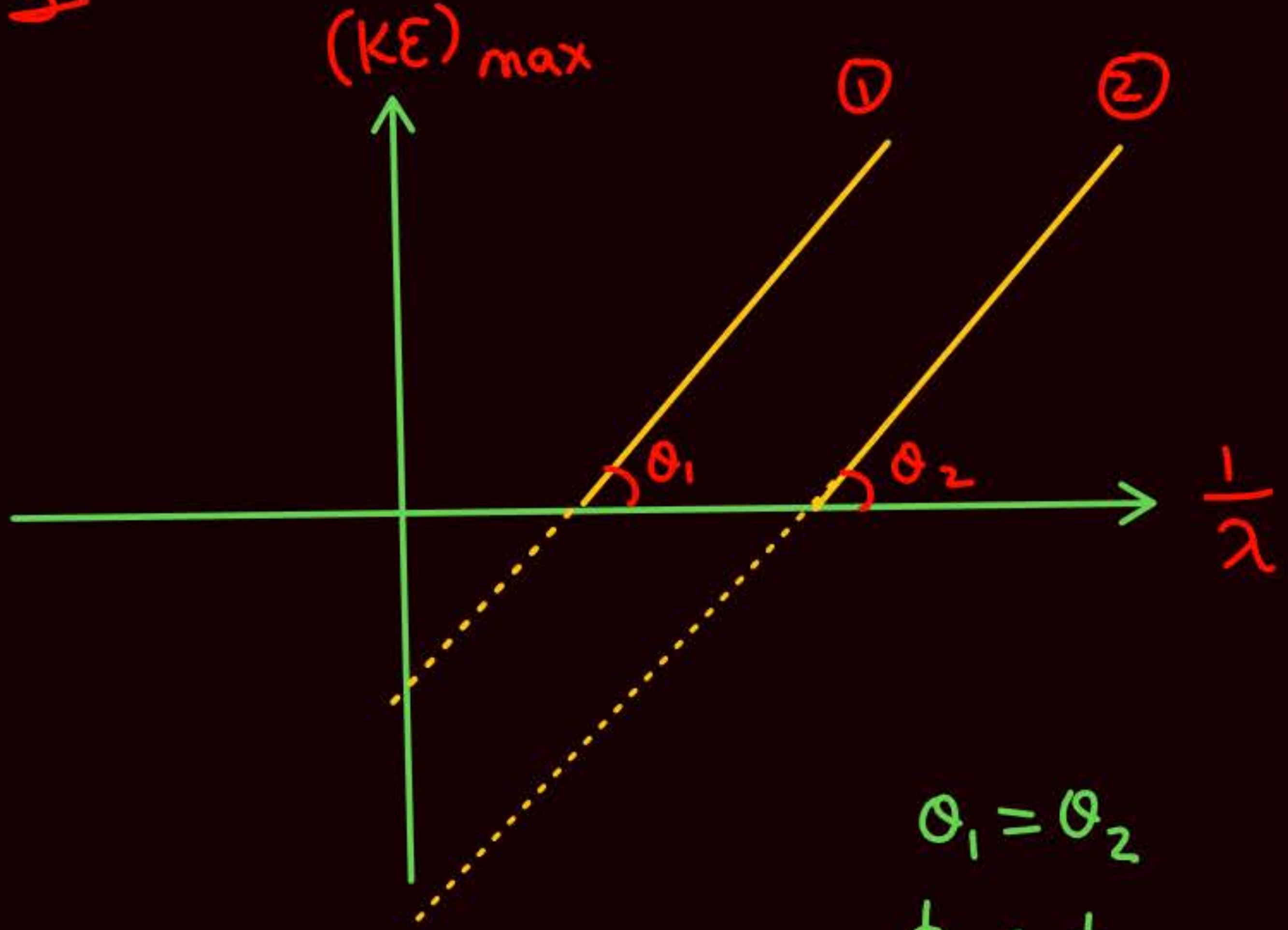
Q



$\theta_1 = \theta_2$

$\phi_1 < \phi_2$

Q



$\theta_1 = \theta_2$

$\phi_1 < \phi_2$

- photoelectron efficiency $= \dfrac{\text{No. of photoelectron emitted per unit time}}{\text{No. of photon incident per unit time}}$

Home Work

- Module ⇒ Prarambh ⇒ 1, 2, 3, 24, 25, 26, 27–33

  Prabal ⇒ 2–8, 18,

THANK YOU