PRAYAS

JEE 2025

Lecture - 02

Physics

Modern Physics (Debroglie wavelength, Matter Wave)

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Topics *to be covered*

1. Debroglie Wavelength

2. Matter wave

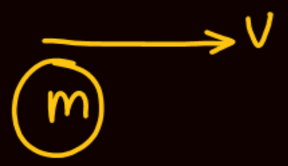
3.

4.

photon

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

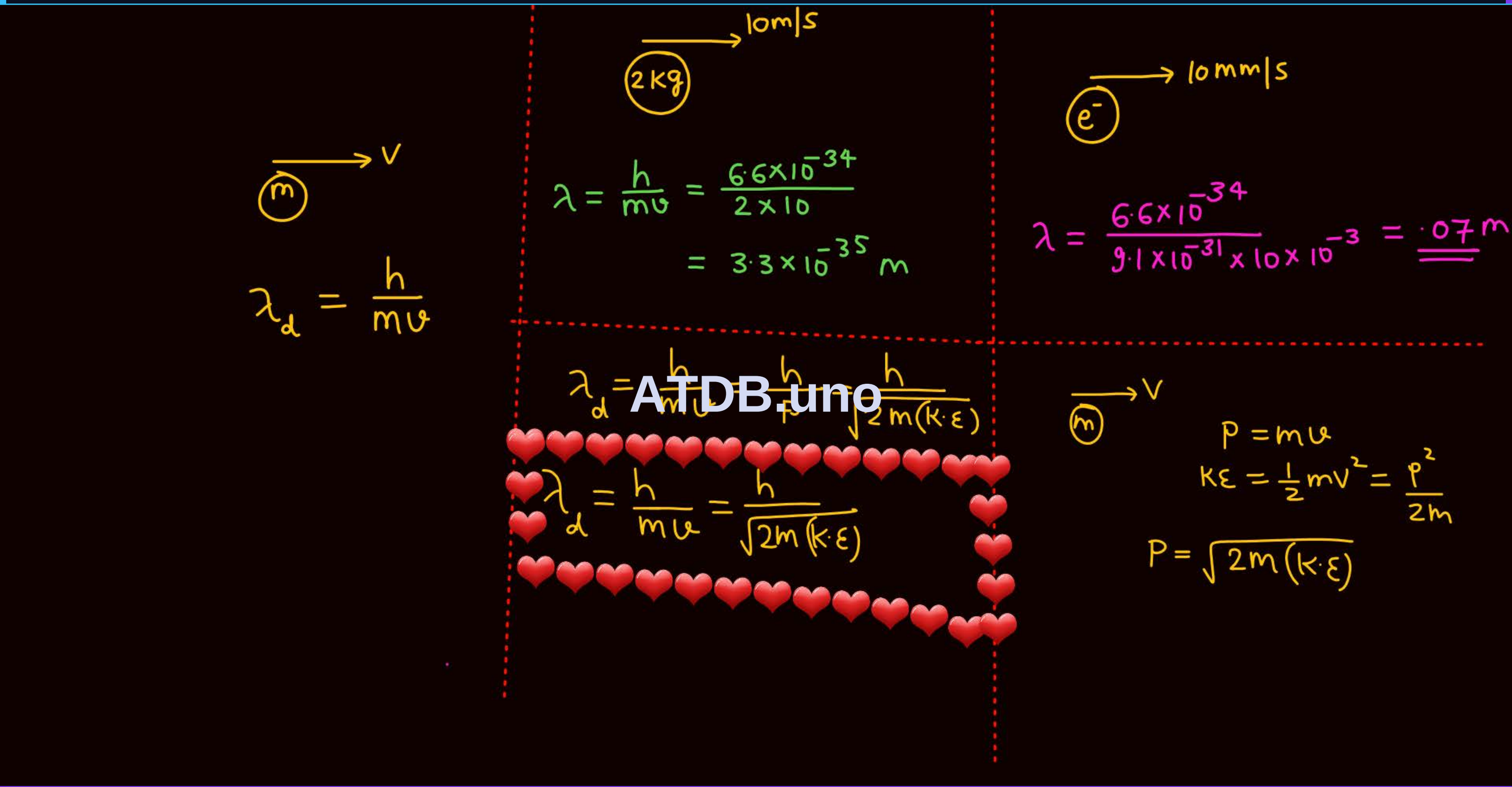
$$E = \frac{hc}{\lambda}$$



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

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

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



Matter Wave

* If a particle of mass m is moving with speed v then debroglie wavelength associated with this particle is given by

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

$$K.E = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$

$$P = \sqrt{2m(K.E.)}$$

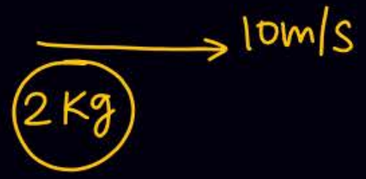
*

$$\lambda_d = \frac{h}{mv} = \frac{h}{p} = \frac{h}{\sqrt{2m(K.E)}}$$

* If light shows dual aspects (particle as well as wave), So matter (particle) should also have wave nature. (Debroglie)

Wave associated with moving particle is called Matter Wave.

Q

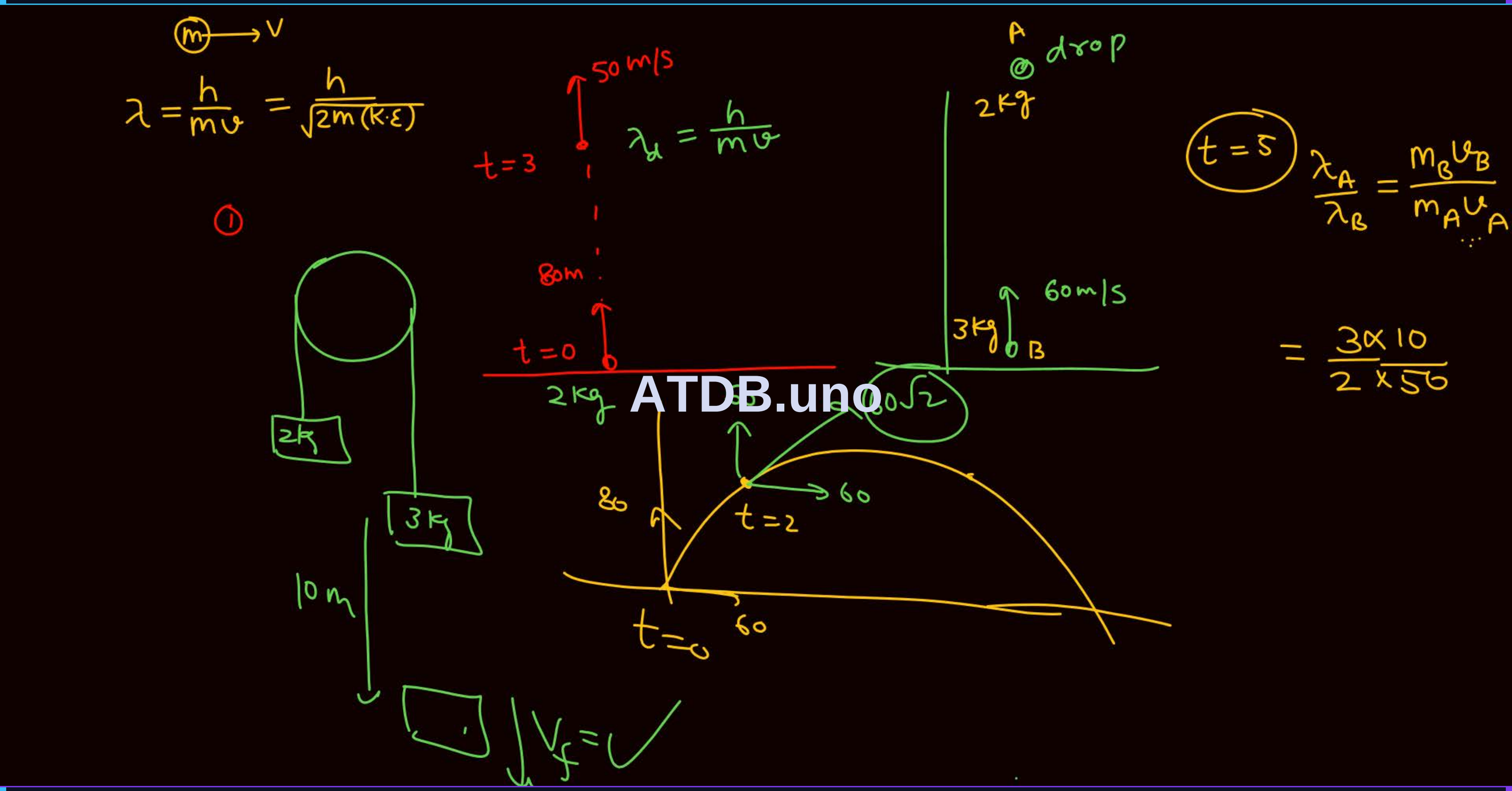


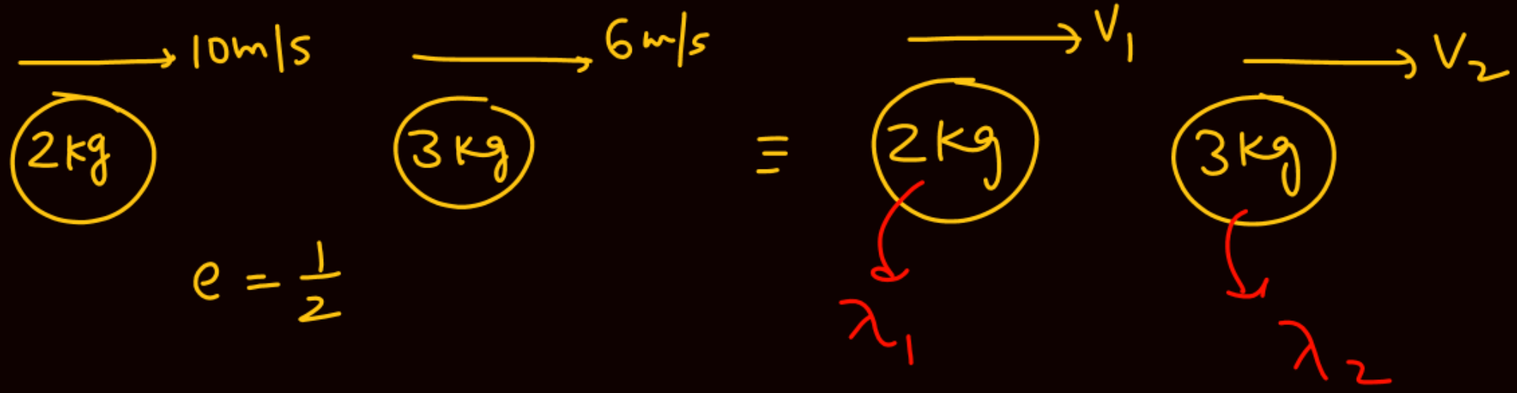
$$\lambda_d = \frac{h}{mv} = \frac{6.6 \times 10^{-34}}{2 \times 10} = 3.3 \times 10^{-35}\ m$$

Insignificant data

This debroglie hypothesis is more significant for subatomic particle e^-, α^+, proton, neutron - -

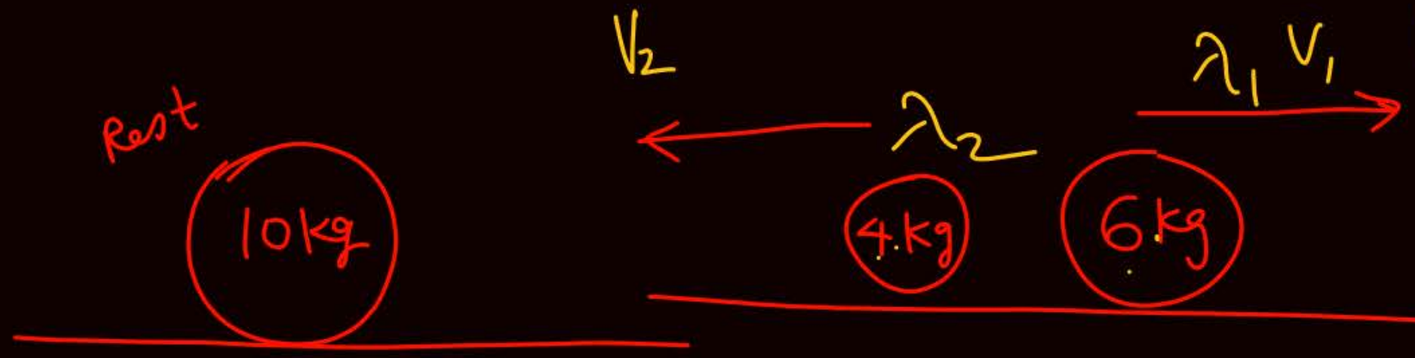
$$\lambda_d = \frac{h}{mv} = \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 10 \times 10^{-3}} \approx .074\ m$$





ATDB.uno

$$i = V_d e n A$$



$$V_d = \frac{i}{enA}$$

$$d = \frac{h}{m_e V_d}$$

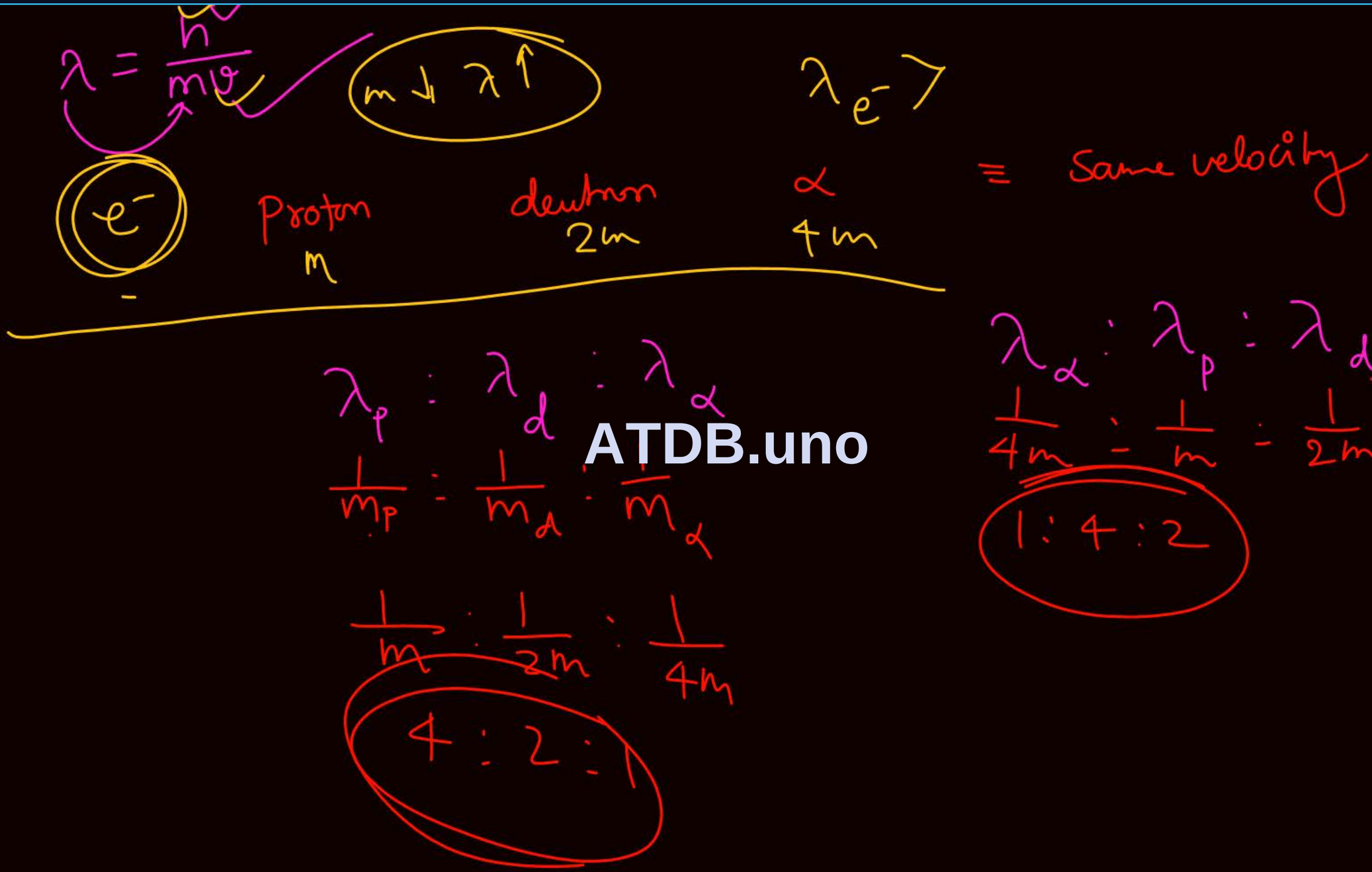
$$0 = 6V_1 - 4V_2$$

$$6V_1 = 4V_2$$

$$\frac{\lambda_1}{\lambda_2} = \frac{m_2 V_2}{m_1 V_1} = \frac{4V_2}{6V_1} = 1$$

$$\lambda_1 = \lambda_2$$

	mass	charge
proton	m	$+e$
deutron	$2m$	$+e$
α	$4m$	$+2e$



मेरामे Qus ①

Q If α particle, proton & deutron are moving with same velocity find ratio of debooglie w/l

$\lambda_\alpha : \lambda_p : \lambda_d$

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

	mass	Charge
Proton ⇛	m	+e
deutron ⇛	2m	+e
α ⇛	4m	+2e

① $\lambda_\alpha : \lambda_p : \lambda_d \Rightarrow \frac{1}{4m} : \frac{1}{m} : \frac{1}{2m}$

$\Rightarrow 1 : 4 : 2$

रनारा

② $\lambda_\alpha : \lambda_d : \lambda_p \Rightarrow \frac{1}{4m} : \frac{1}{2m} : \frac{1}{m} \Rightarrow 1 : 2 : 4$

SKC

* अगर मैं Kissi chaye q को Rest से ΔV pot-diff से accelerate करवाऊं तो उसकी Final K.E. $q\Delta V$ होगी

$$(K\varepsilon)_f = q\,\Delta V$$

$\Delta V \longrightarrow$ pot. Diff.

Q If e^-, proton, deutron, α particle are accelerated from rest by potential diff ΔV. Find find λ_d of them

Sol^n $(KE)_f = q\Delta V$

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

for e^- $\Rightarrow$ $\lambda_{e^-} = \sqrt{\frac{(6.6\times10^{-34})^2}{2\times9.1\times10^{-31}\times1.6\times10^{-19}\times\Delta V}} = \sqrt{\frac{150}{\Delta V}}$ A°

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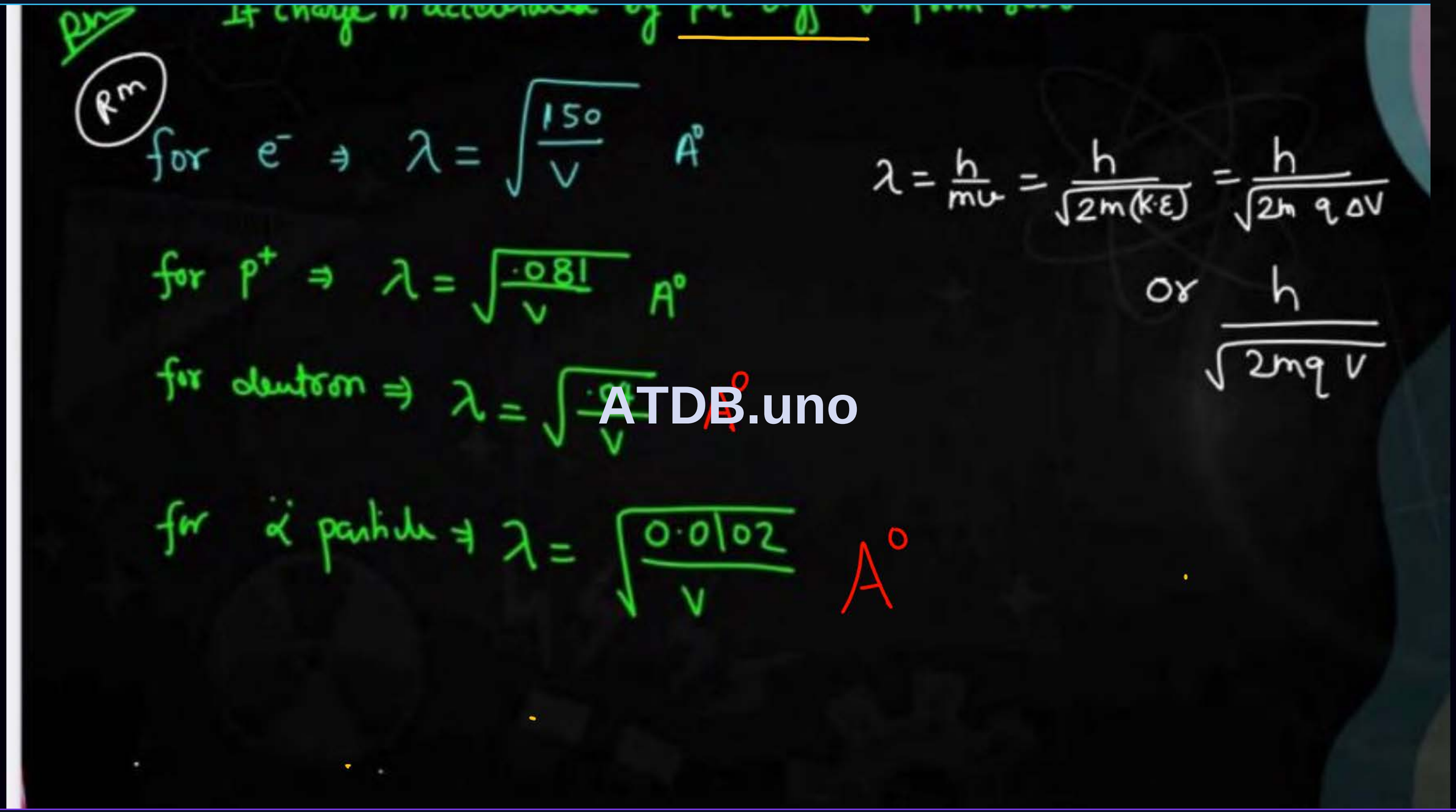

Q If an electron is accelerated from rest by potential diff 50Volt

$\lambda_d = ?$

Soln

$$\lambda = \sqrt{\frac{150}{V}} = \sqrt{\frac{150}{50}} = \sqrt{3}\ A^0$$

Q If an electron is accelerated by potential diff 50 volt

$\lambda_d = ?$

Soln

$$\lambda_d = \sqrt{\frac{150}{V}} = \sqrt{\frac{150}{50}} = \sqrt{3}\ A^\circ$$

50 eV

Q If (KE) of electron is 50 eVolt. If this electron is accelerated by pot. diff of 30 Volt. find $\lambda_d = ?$

Soln

$$\lambda_1 = \sqrt{\frac{150}{\Delta V_{eff}}} = \sqrt{\frac{150}{80}}\ A^\circ$$

$$\lambda_2 = \sqrt{\frac{150}{\Delta V_{eff}}} = \sqrt{\frac{150}{20}}\ A^\circ$$

$\Delta U = q\,\Delta V = e\,80 = 80\ \text{eVolt}$

$$\lambda = \sqrt{\frac{150}{80}}$$

e, p^+, d, α ≡ are acc. from rest with same pot diff.

$$\lambda_{e^-} \propto \lambda_{p^+} \lambda_d \lambda_\alpha$$

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

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

वेरार्म Qus (2)

JEE 25

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

Q If proton, deutron, alpha particle are accelerated by same potential diff ΔV from rest

find $\lambda_p : \lambda_d : \lambda_\alpha$

वेरार्म Qus (2)

JEE 25

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

Q If proton, deutron, alpha particle are accelerated by same potential diff ΔV from rest

find $\lambda_p : \lambda_d : \lambda_\alpha$

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

$$\lambda_p : \lambda_d : \lambda_\alpha \equiv \frac{1}{\sqrt{me}} : \frac{1}{\sqrt{2me}} : \frac{1}{\sqrt{4m\,2e}}$$

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

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

Q ① For what K.E. of a neutron will the associated de-broglie wavelength is $1.4\ A^0$

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

$$\lambda = \frac{h}{\sqrt{2m(K.E)}} \qquad KE = \frac{h^2}{\lambda^2\, 2m}$$

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

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

Q ① For what K.E. of a neutron will the associated de-broglie wavelength is $1.4\ A^0$

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

Sol^n $\lambda = \dfrac{h}{\sqrt{2m(K.E)}} \Rightarrow K\varepsilon = \dfrac{h^2}{\lambda^2 . 2m} = \dfrac{(6.6\times10^{-34})^2}{(1.4\times10^{-10})^2 \times 2 \times 1.66\times10^{-27}} = 6.735 \times 10^{-21}$ J

② Find the debroglie w/l of neutron in thermal equilibrium of matter, having avrg kinetic Energy of $\frac{3}{2}KT$ at 300 K. given $K = 1.38 \times 10^{-23}$ J/Kg

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

$E = \frac{3}{2} \times 1.38 \times 10^{-23} \times 300 = 6.2 \times 10^{-21}$ J

$\lambda = \dfrac{h}{\sqrt{2mE}} = \checkmark = \underline{1.46 \times 10^{-10}\ m}$

Debroglie wavelength of a gas molecule

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

k → Boltzman Const

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

$$\lambda = \frac{h}{\sqrt{2m(K\varepsilon)}} = \frac{h}{\sqrt{2m \cdot \frac{3kT}{2}}}$$

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 $4E$

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 $-\frac{h}{|e|Et}$

Ans : (A)

Q.

A particle is moving 5 times as fast as an electron. The ratio of the de-Broglie wavelength of the particle to that of the electron is 1.878×10^{-4}. The mass of the particle is close to:

(JEE Main-2020)

A 4.8×10^{-27} kg

B 1.2×10^{-28} kg

C 9.1×10^{-31} kg

D 9.7×10^{-28} kg

Ans : (D)

Q.

An electron (mass m) with initial velocity $\vec{v} = v_0\hat{\imath} + v_0\hat{\jmath}$ 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 $\dfrac{\lambda_0}{\sqrt{1+\dfrac{\sqrt{e^2E_0^2t^2}}{m^2v_0^2}}}$

Ans : (C)

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, a doubly ionized helium ion (He^{++}) and a proton are having the same kinetic energy. The relation between their respective de-Broglie wavelengths λ_e, $\lambda_{He^{++}}$ and λ_p is:

(JEE Main-2020)

A $\lambda_e < \lambda_p < \lambda_{He^{++}}$

B $\lambda_p < \lambda_{He^{++}} = \lambda_p$

C $\lambda_e > \lambda_{He^{++}} > \lambda_p$

D $\lambda_e > \lambda_p > \lambda_{He^{++}}$

Ans : (D)

Q.

Given below are two statements:

Statement-I: Two photons having equal linear momenta have equal wavelengths.

Statement-II: If the wavelength of photon is decreased, then the momentum and energy of a photon will also decrease.

In the light of the above statements, choose the correct answer from the options given below.

(JEE Main-2021)

A. Both Statement I and Statement II are true

B. Statement I is false but Statement II is true

C. Both Statement I and Statement II are false

D. Statement I is true but Statement II is false

Ans : (D)

Q.

The de Broglie wavelength of a proton and α-particle are equal. The ratio of their velocities is:

(JEE Main-2021)

A 4 : 3

B 4 : 1

C 4 : 2

D 1 : 4

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

Ans : (B)

Q.

An α particle and a proton are accelerated from rest by a potential difference of 200 V. After this, their de Broglie wavelengths are λ_α and λ_p respectively. The ratio λ_p/λ_α is:

(JEE Main-2021)

A 3.8

B 8

C 7.8

D 2.8

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

Ans : (D)

Q.

An electron of mass m_e and a proton of mass $m_p = 1836\, m_e$ are moving with the same speed. The ratio of their de Broglie wavelength $\frac{\lambda_{electron}}{\lambda_{proton}}$ will be:

(JEE Main-2021)

A 1839

B 1

C 918

D 1/1836

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

$\frac{\lambda_1}{\lambda_2} = \frac{m_2 v_2}{m_1 v_1}$

$\frac{\lambda_e}{\lambda_p} = \frac{m_p}{m_e} = 1836$

Ans : (A)

Q.

The de-Broglie wavelength associated with an electron and a proton were calculated by accelerating them through same potential of 100 V. What should nearly be the ratio of their wavelengths? ($m_p = 1.00727\ u$, $m_e = 0.00055u$)

(JEE Main-2021)

A $1860 : 1$

B $(1860)^2 : 1$

C $41.4 : 1$

D $43 : 1$

Ans : (D)

Q.

A particle is travelling 4 times as fast as an wavelength of a particle to that of electron is 2 : 1, the mass of the particle is :-electron. Assuming the ratio of de-Broglie

(JEE Main-2021)

A. 1/16 times the mass of e^-

B. 8 times the mass of e^-

C. 16 times the mass of e^-

D. 1/8 times the mass of e^-

Ans : (D)

Q.

A proton and an α-particle, having kinetic energies K_P and K_α, respectively, enter into a magnetic field at right angles. The ratio of the radii of trajectory of proton to that of α-particle is 2 : 1. The ratio of $K_P : K\alpha$ is : **(JEE Main-2021)**

A 1 : 8

B 8 : 1

C 1 : 4

D 4 : 1

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

Ans : (D)

Q.

An electron of mass m_e and a proton of mass m_p are accelerated through the same potential difference. The ratio of the de-Broglie wavelength associated with the electron to that with the proton is :-

(JEE Main-2021)

A $\frac{m_p}{m_e}$

B 1

C $\sqrt{\frac{m_p}{m_e}}$

D $\frac{m_e}{m_p}$

Ans : (C)

Q.

What should be the order of arrangement of de-Broglie wavelength of electron (λ_e), an a-particle (λ_α) and proton (λ_p) given that all have the same kinetic energy?

(JEE Main-2021)

A $\lambda_e = \lambda_p = \lambda_\alpha$

B $\lambda_e < \lambda_p < \lambda_\alpha$

C $\lambda_e > \lambda_p > \lambda_\alpha$

D $\lambda_e = \lambda_p > \lambda_\alpha$

Ans : (C)

Q.

An electron (of mass m) and a photon have the same energy E in the range of a few eV. The ratio of the de-Broglie wavelength associated with the electron and the wavelength of the photon is (c = speed of light in vacuum) **(JEE Main-2020)**

A $\left(\frac{E}{2m}\right)^{1/2}$

B $\frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$

C $c(2mE)^{1/2}$

D $\frac{1}{c}\left(\frac{2E}{m}\right)^{1/2}$

Ans : (B)

Q.

A particle of mass $4M$ at rest disintegrates into two particles of mass M and $3M$ respectively having non zero velocities. The ratio of de- Broglie wavelength of particle of mass M to that of mass $3M$ will be:

(JEE Main-2021)

A $1:3$

B $3:1$

C $1:\sqrt{3}$

D $1:1$

Ans : (D)

Q.

A particle of mass 9.1×10^{-31} kg travels in a medium with a speed of 10^6 m/s and a photon of a radiation of linear momentum 10^{-27} kg m/s travels in vacuum. The wavelength of photon is _____ times the wavelength of the particle.

(JEE Main-2021)

Ans : (910)

Q.

A moving proton and electron have the same de-Broglie wavelength. If K and P denote the K.E. and momentum respectively. Then choose the correct option:

(JEE Main-2021)

A $K_p < Ke$ and $P_p = P_e$

B $K_p = K_e$ and $P_p = P_e$

C $K_p < K_e$ and $P_p < P_e$

D $K_p > K_e$ and $P_p = P_e$

Ans : (A)

Q.

The ratio of de-Broglie wavelengths of proton and deuteron accelerated by potential V_P and V_d is $1 : \sqrt{2}$. Then the ratio of V_P to V_d will be **(JEE Main-2022)**

A $1 : 1$

B $\sqrt{2} : 1$

C $2 : 1$

D $4 : 1$

Ans : (D)

Q.

An α particle and a proton are accelerated from rest through the same potential difference. The ratio of linear momenta acquired by above two particles will be :

(JEE Main-2022)

A $\sqrt{2}:1$

B $2\sqrt{2}:1$

C $4\sqrt{2}:1$

D $8:1$

Ans : (B)

Q.

A proton, a neutron, an electron and an α-particle have same energy. If λ_p, λ_n, λ_e and λ_α are the de-Broglie's wavelength of proton, neutron, electron and α particle respectively, then choose the correct relation from the following:

(JEE Main-2022)

A $\lambda_p = \lambda_n > \lambda_e > \lambda_\alpha$

B $\lambda_\alpha < \lambda_n < \lambda_p < \lambda_e$

C $\lambda_e < \lambda_p = \lambda_n > \lambda_\alpha$

D $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

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

Ans : (B)

Q.

An α particle and a carbon 12 atom has same kinetic energy K. the ratio of their de-Broglie wavelength $(\lambda_a : \lambda_{C12})$ is :

(JEE Main-2022)

A $1 : \sqrt{3}$

B $\sqrt{3} : 1$

C $3 : 1$

D $2 : \sqrt{3}$

Ans : (B)

Q.

The de-Broglie wavelength for an electron and a photon are λ_e and λ_p respectively. For the same kinetic energy of electron and photon. Which of the following presents the correct relation between the de-Broglie wavelength of two?

(JEE Main-2022)

A $\lambda_p \propto \lambda_e^2$

B $\lambda_p \propto \lambda_e$

C $\lambda_p \propto \sqrt{\lambda_e}$

D $\lambda_p \propto \sqrt{\frac{1}{\lambda_e}}$

Ans : (A)

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)

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)

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)

18. 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)

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)

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)

Home work

- Try ques attached in the ppt