3/7/19

# Quantum Mechanics:

Saathi

Date __/__/__

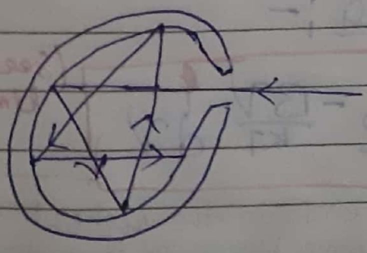
→ **Features of Classical Physics :-**

i) Classical physics is deterministic in nature.
ii) The various physical and their changes in classical physics can have any continuous value without any restriction.

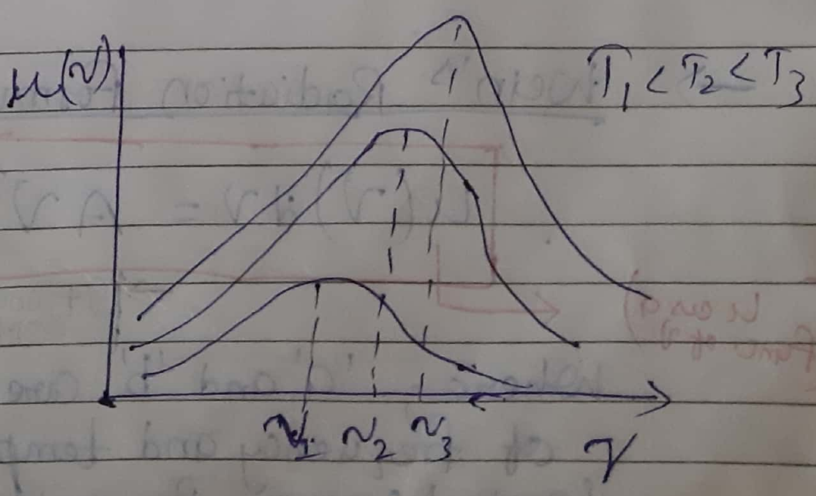
iii) Particles and waves in classical physics are regarded as distinct and separate entities without any ambiguity (doubt).

→ Evidences about the failure of classical physics accumulated from the study of energy distribution in the spectrum of black body radiation, Photo electric effect, Compton effect, atomic spectra and structure of atom.

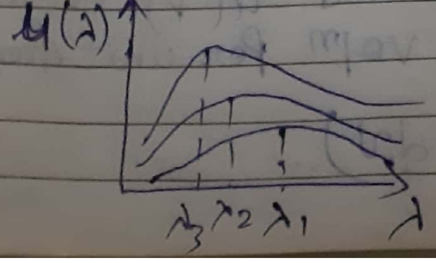
* **Black Body Radiation:**



Ferry's Black Body




Black body spectrum



3/7/19

ν

Date __/__/__

→ Stephen's Boltzman law:-

It states that the total radiant heat Power emitted from a surface is Proportional to the fourth power of its absolute temperature.

$$\boxed{E = e\sigma T^4}$$

→ Wein's displacement law:-

$$\boxed{\lambda_m T = \text{Const}}$$

Where $\lambda_m$ is the wavelength Corresponded to max^m energy density at a particular temp. and T is the absolute temp.

• Value of the const = $2.898 \times 10^{-3}$ mK

→ Wein's Radiation formula:-

$$\boxed{u(\nu)\,d\nu = A\nu^3 e^{-\frac{B\nu}{KT}}\,d\nu}$$

(See high freq limit for 'A' & 'B').

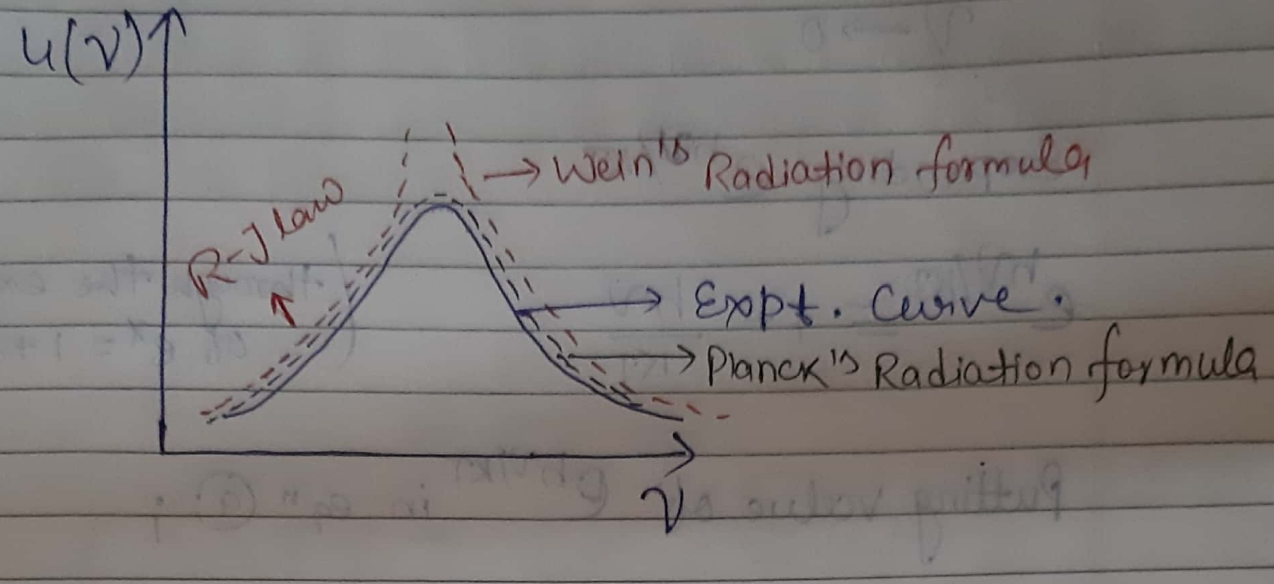
(u as a func. of ν)

→ It could explain the higher freq. side of expt. curve however at lower freq. it disagr.

Where, 'a' and 'b' are the constants independent of frequency and temp. and $u(\nu)$ is the spectral energy per unit vol^m per unit frequency in the range of $(\nu$ & $\nu + d\nu)$.

Page No.

Scanned with CamScanner




→ Rayleigh Jean's law (R-J law).

$$\boxed{u(\nu)\, d\nu = \frac{8\pi\nu^2}{c^3} KT\, d\nu}$$

The law could explain the lower frequency side of the expt. curve but fails to explain the higher freq. side.

→ Planck's Radiation formula :-

$$E_n = nh\nu \; ; \; n = 1, 2, 3, \dots$$

ees with expt. Curve

$$\boxed{u(\nu)\, d\nu = \frac{8\pi\nu^2}{c^3} \frac{h\nu}{e^{h\nu/KT} - 1} d\nu} \quad (a)$$

→ low freq. limit

$\nu \to 0$

Expanding $e^{h\nu/KT}$

$$e^{h\nu/KT} \simeq 1 + \frac{h\nu}{KT}$$ (through the expansion of $e^{x} = 1 + x + \cdots$)

Putting value of $e^{h\nu/KT}$ in eq$^n$ (a);

$$u(\nu)\,d\nu = \frac{8\pi\nu^2}{c^3} KT\,d\nu \longrightarrow \text{R-J law.}$$

→ high freq. limit :-

$\nu \to \infty$

$e^{h\nu/KT} \longrightarrow \infty$ $\qquad e^{h\nu/KT} \gg 1$

$$u(\nu)\,d\nu = \underbrace{\frac{8\pi h\nu^3}{c^3}}_{A} e^{-\overset{B}{h}\nu/KT}\,d\nu$$

⟶ Wein's Radiation formula.

A ↓ in Wein's Radiation formula.

8/7/19

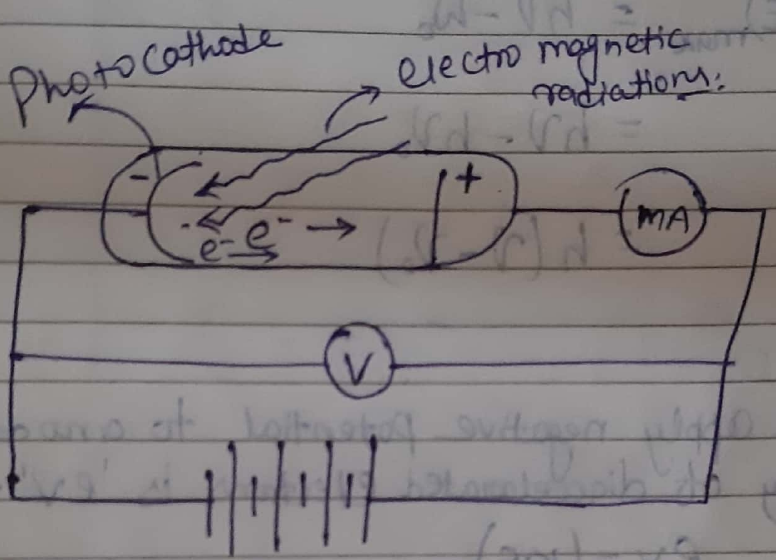
# Photo electric Effect :-

Date ___/___/___

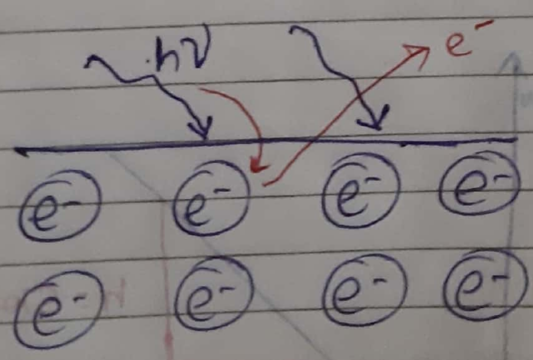
(Do from book)

i) what is Photoelectric effect?
ii) Photoelectrons.
iii) Expt. Setup & Observations of Photo electric effec
iv) why Classical Physics are failing to explain Photo-electric effect?

Ans
iii)




$E_{photon} = h\nu$ → $\nu$ → freq. of radiation.




Page No.

8/7/19

$$\boxed{h\nu = W_0 + (K.E)_{max}}$$

$$(K.E)_{max} = h\nu - W_0$$
$$= h\nu - h\nu_0$$
$$= h(\nu - \nu_0)$$

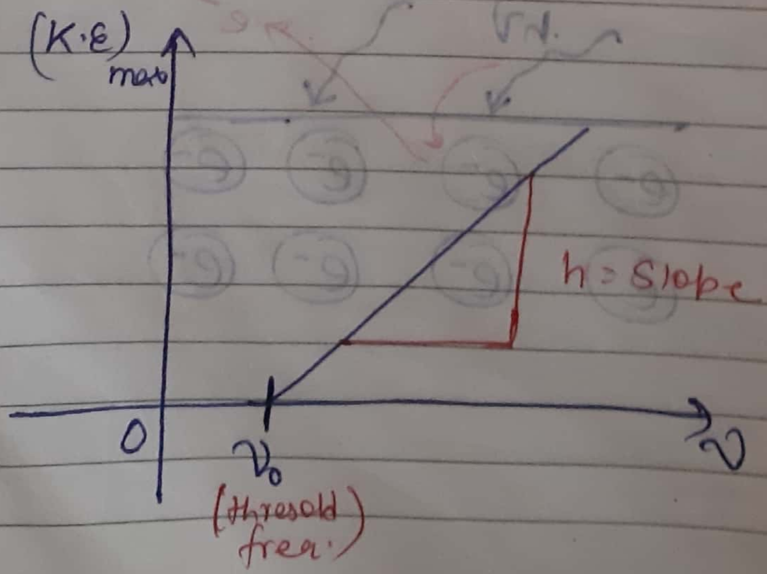
→ If we apply negative potential to anode the energy of diaccelarated electrons is 'eV'.

$$eV = (K.E)_{max}$$
$$= h(\nu - \nu_0) \Rightarrow \boxed{V = \frac{h}{e}(\nu - \nu_0)}$$

V → Stopping Potential.

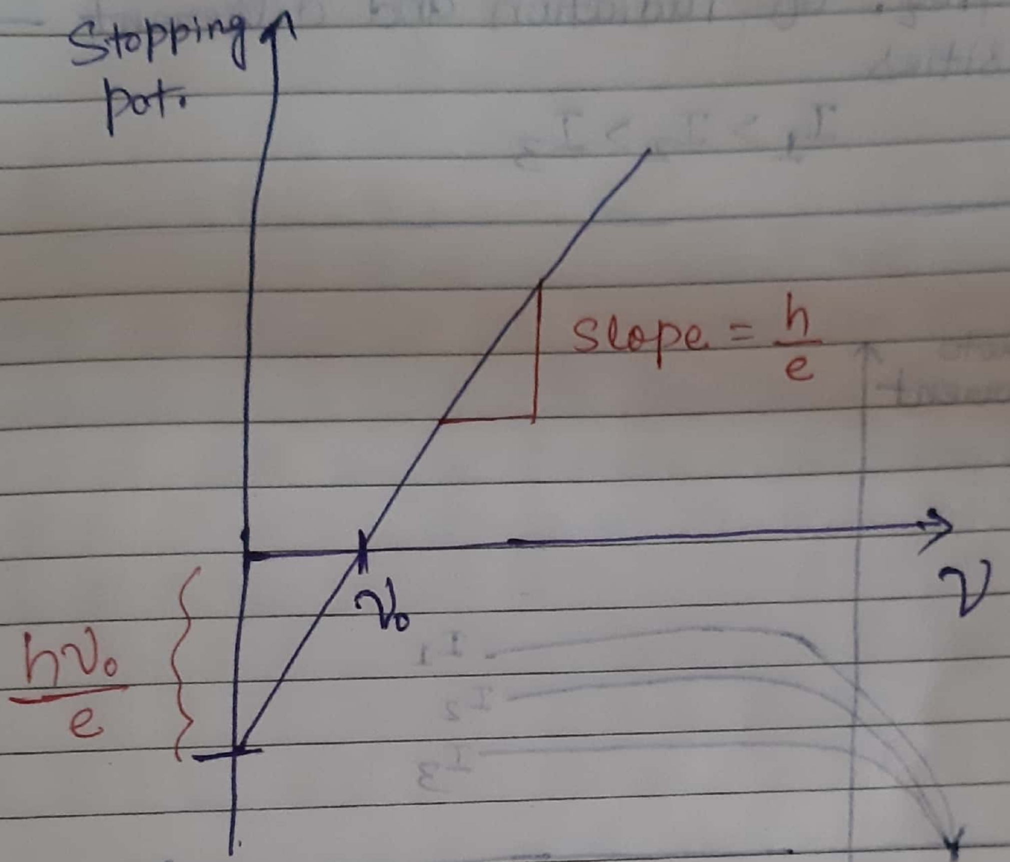
~~Make a plot of $(K.E)_{max}$~~

* Graph of $(K.E)_{max}$ vs freq. $(\nu)$

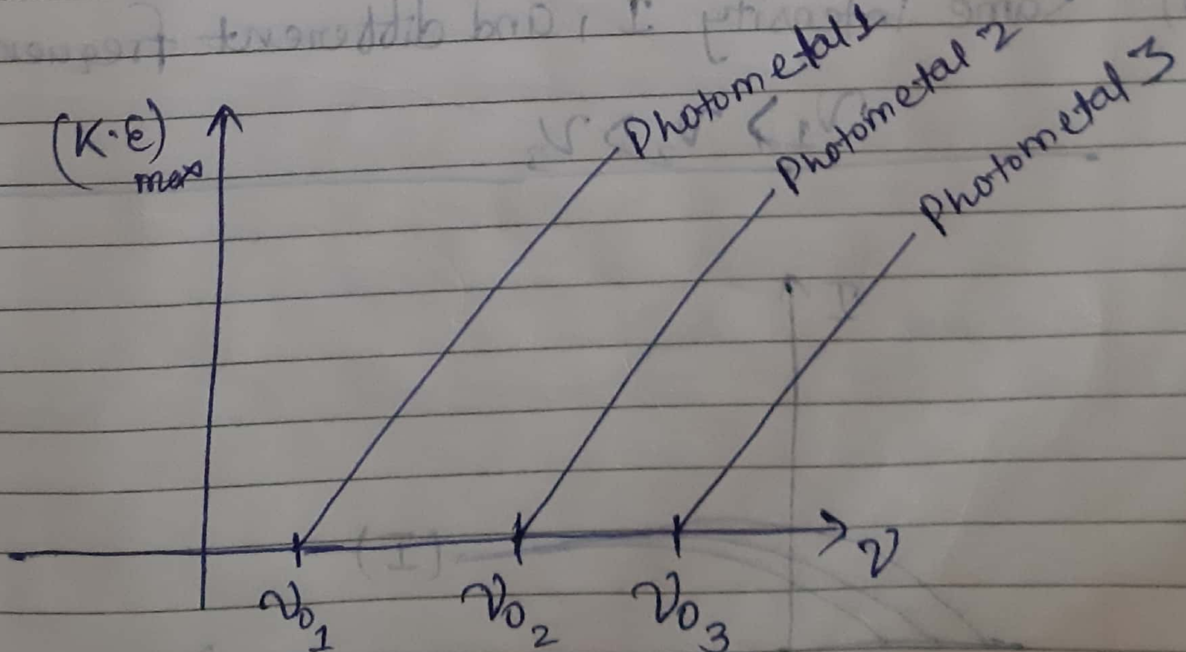


Date ___/___/___

## * Stopping potential vs frequency:-




## * $(K.E)_{max}$ vs $\nu$ for diff. Photometals:-

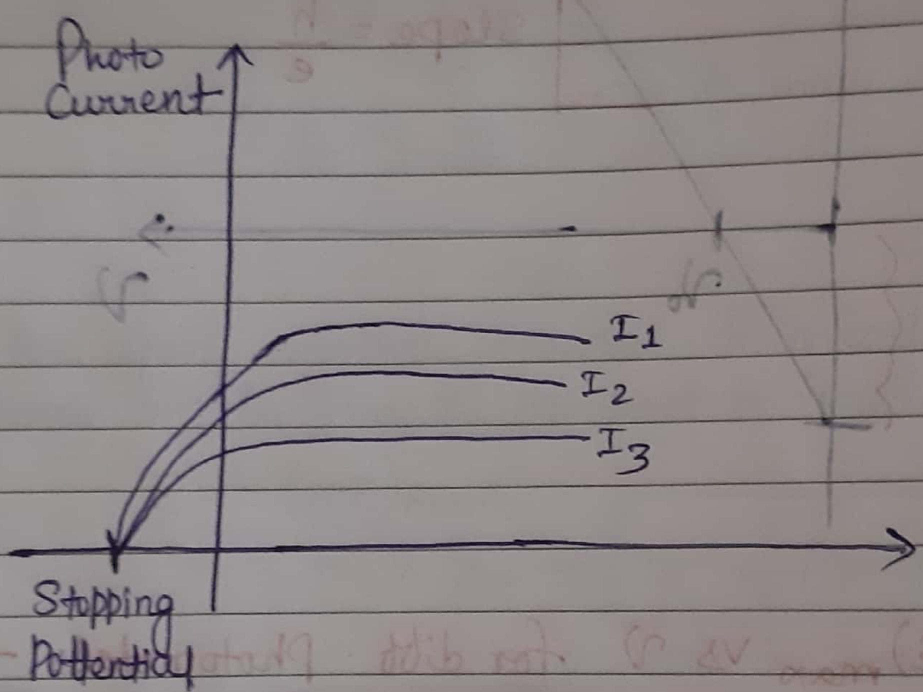



→ in case of diff. Photometals only thresold freq will be diff.

* ## Photocurrent vs applied voltage ($V$)

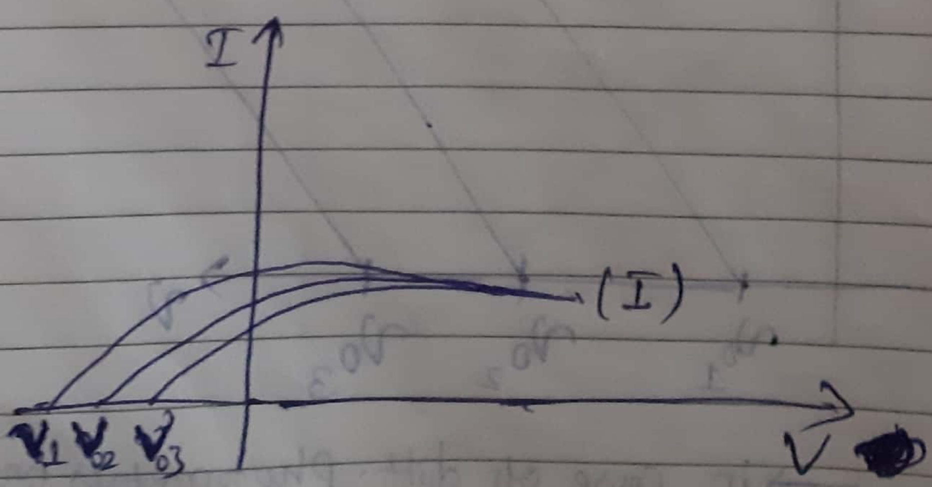
(a) Same freq. of radiation and different intensities

$I_1 > I_2 > I_3$




(b) Same intensity $I$, and different frequencies

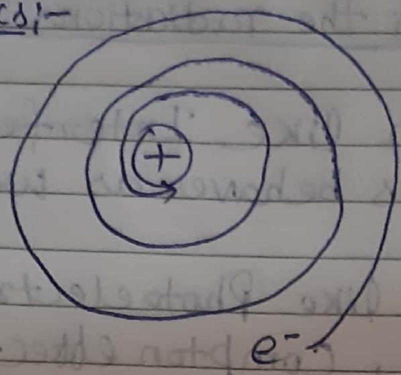
$\nu_1 > \nu_2 > \nu_3$



9/7/19

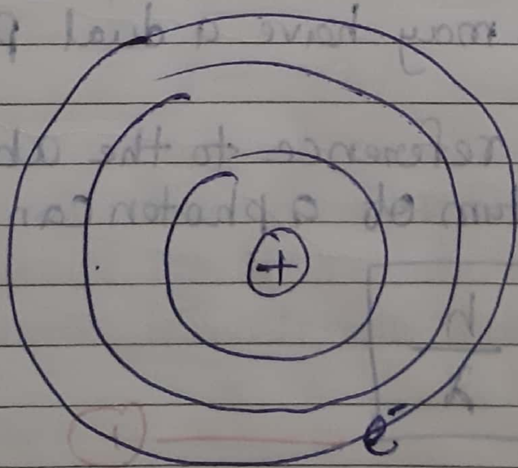
# * Structure of Atom:-

→ Classical Physics:-




A/c to classical physics an $e^-$ moves around the nucleus (which is positively charged) in a orbit, whose energy is decreasing so, once the $e^-$ will fall into nucleus and the structure will collapse.

→ Quantum physics:-



Date __/__/__

## * Dual nature of the radiations :-

i) In Phenomenon like Interferance, diffractions etc. radiations behaves as wave

ii) In experiments like Photoelectric effect, Black-Body radiations, Compton effect etc., the radiations are behaving as Particles.

So, this explains the dual Wave-Particle nature of the radiations.

#

## * De-Broglie Hypothesis :-

In 1923 louis de-Broglie Postulated that since Photons have both wave and Particle - Characteristics Perhaps all forms of matter have both the Characteristics. A/c him electrons Just like Photons may have a dual particle wave nature.

With reference to the above explanation, the momentum of a photon can be expressed as

$$\boxed{p = \frac{h}{\lambda}} \quad (1)$$

=)

derivation;

For Photons

$$E = h\nu = h\frac{c}{\lambda} \Rightarrow \frac{E}{c} = \frac{h}{\lambda} \Rightarrow \boxed{P = \frac{h}{\lambda}}$$ from (a)

A/C to the special theory of relativity,

$$\boxed{E = [P^2c^2 + m_0^2c^4]^{1/2}}$$

P = momentum
C = Speed of light
$m_0$ = Rest mass

for Photon,

$$m_0 = 0 \Rightarrow \boxed{E = PC} \text{ — (a)}$$

From this equation we observe that Photon wavelength can be specified by its momentum

$$\boxed{\lambda = \frac{h}{P}} \text{ — (2)}$$

In Analogy to this de-Broglie suggested that material particles of momentum 'p' can have a characteristic wavelength given by the same expression,

$$\boxed{\lambda = \frac{h}{P}} \text{ — (3)}$$

Wave Property (λ)　　Material Property (P)

So, $\boxed{\lambda = \frac{h}{mv}}$ — (4)

$v \rightarrow$ Velocity of the Particle.

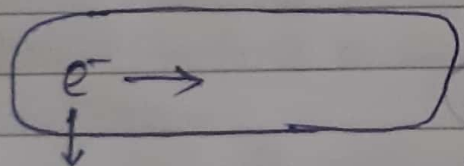
$m \rightarrow$ mass of the Particle

& $\boxed{m = \frac{m_0}{\sqrt{1-v^2/c^2}}}$ $m_0 \rightarrow$ Rest mass.

→ Case: 1

i) Consider the Case of an electron of rest mass 'm', Charge 'e' and accelarated through a potential of 'V' volts from rest to velocity 'v', find — de-Broglie wavelength.

Sol$^n$




(m,e)

V volts

$0 \rightarrow v$

$\frac{1}{2} mv^2 = eV$

$\Rightarrow \quad mv = \sqrt{m2eV}$

Page No.

9/7/19

Date ___/___/___

de-Broglie wavelength $\lambda = \frac{h}{mv}$

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

$$\lambda = \frac{h}{\sqrt{2meV}} = \frac{12.26}{\sqrt{V}} A^{\circ}$$

ii) A Particle accelarated through a K.E '$E_K$'

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

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

$$P = \sqrt{2mE_K}$$

iii) A Particle accelarated through thermal energy.

$$E_K = \frac{3}{2} KT$$

$$\lambda = \frac{h}{\sqrt{3mKT}}$$

iv) A Particle moving with relativistic vel.

Sol^n in this case mass will be changing as,

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

Now,

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

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

Scanned with CamScanner