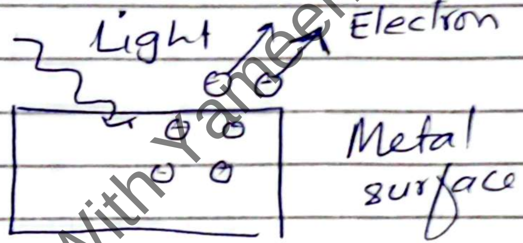
Quantum Physics

photo electric effect

Emission of electrons from metal surface when light of certain frequency is incident upon it.



Observations

① Concept of Threshold frequency (f_0)

If frequency of light (f) is smaller than threshold frequency (f_0) no emission of electrons took place even if you increase intensity of light.

Threshold frequency (f_0)

minimum frequency required to omit electrons from metal surface.

It is different for different metals.

(2) Instant emission

There was no delay between incidence of light and emission of electrons.

(3) Maximum Kinetic energy (E_{max}) of emitted electrons is only dependent on frequency

$f > f_0$ $E_{max} \uparrow$ if $f \uparrow$

E_{max} is independent of Intensity.

(4) If $f > f_o$ and intensity of light is increased then rate of emission of electrons will increase.
more electrons will emit per unit time. Electric current will increase.

These observations prove that light is not behaving as wave here it behaves as particle nature

light consists on small packets of energy known as photon

Photon: Discreate quanta (packet) of energy of electromagnetic radiation. $\boxed{\text{mass of photon} = 0}$

Energy of photon (E)

$$E = hf$$

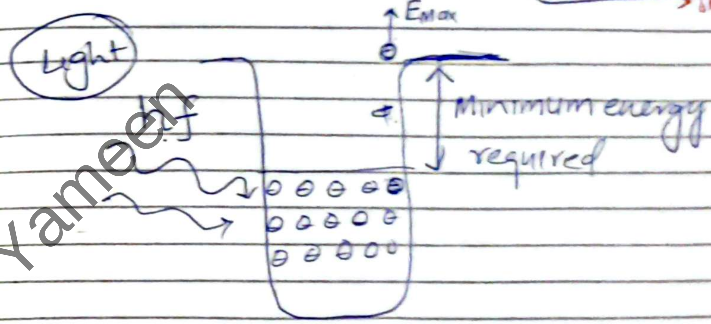
f: frequency of EM radiation

h = plank's constant

$h = 6.63 \times 10^{-34}$ Js

Momentum of photon: $\boxed{p = \frac{E}{c}}$

momentum — energy of photon — speed of light



Work function energy (Φ)

Minimum energy required to emit electrons from metal surf is called work function energy

$$\Phi = hf_o$$

Einstein equation

$$hf = \Phi + E_{max}$$

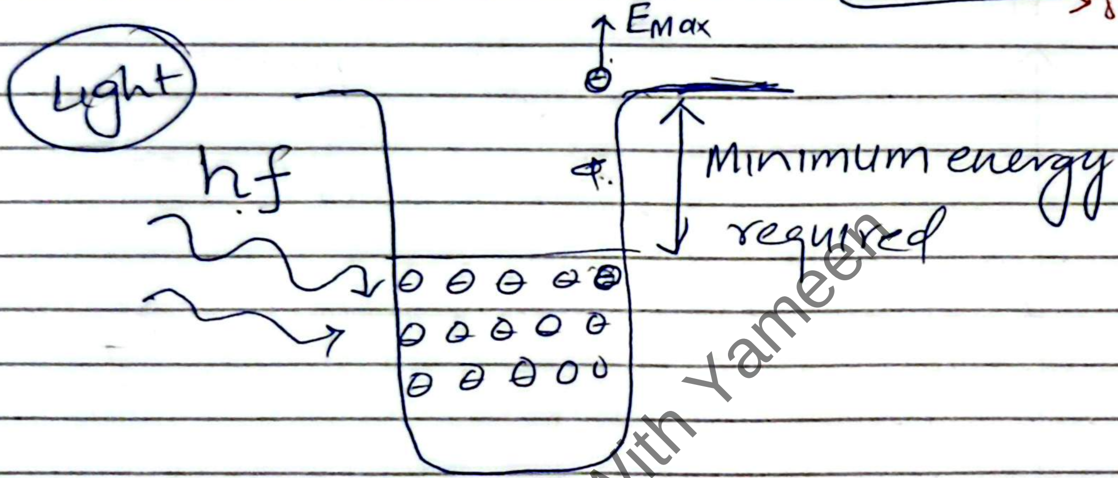
f: frequency of EM radiation

h = plank's constant

$h = 6.63 \times 10^{-34}$ Js

momentum

Momentum of photon: $\boxed{p = \frac{E}{c}}$ energy of photon. speed of light



Work function energy (ϕ)

Minimum energy required to emit electrons from metal surface is called work function energy

$\phi = h f_0$

Einstein equation

$hf = \phi + E_{max}$

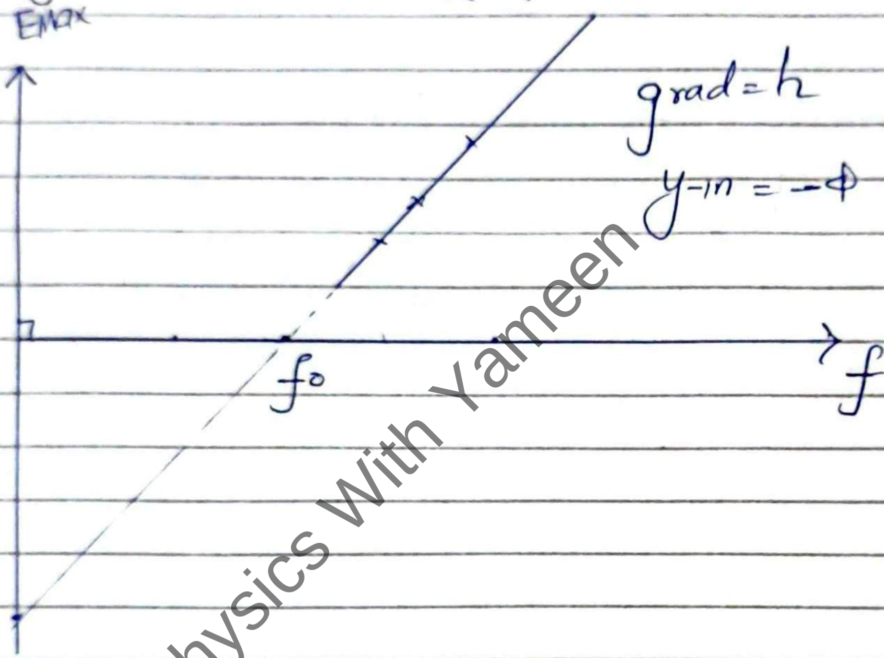
Energy of photon

maximum K.E

$$hf = \Phi + E_{Max}$$

E

$$E_{Max} = hf - \Phi$$
$$y = mx + c$$



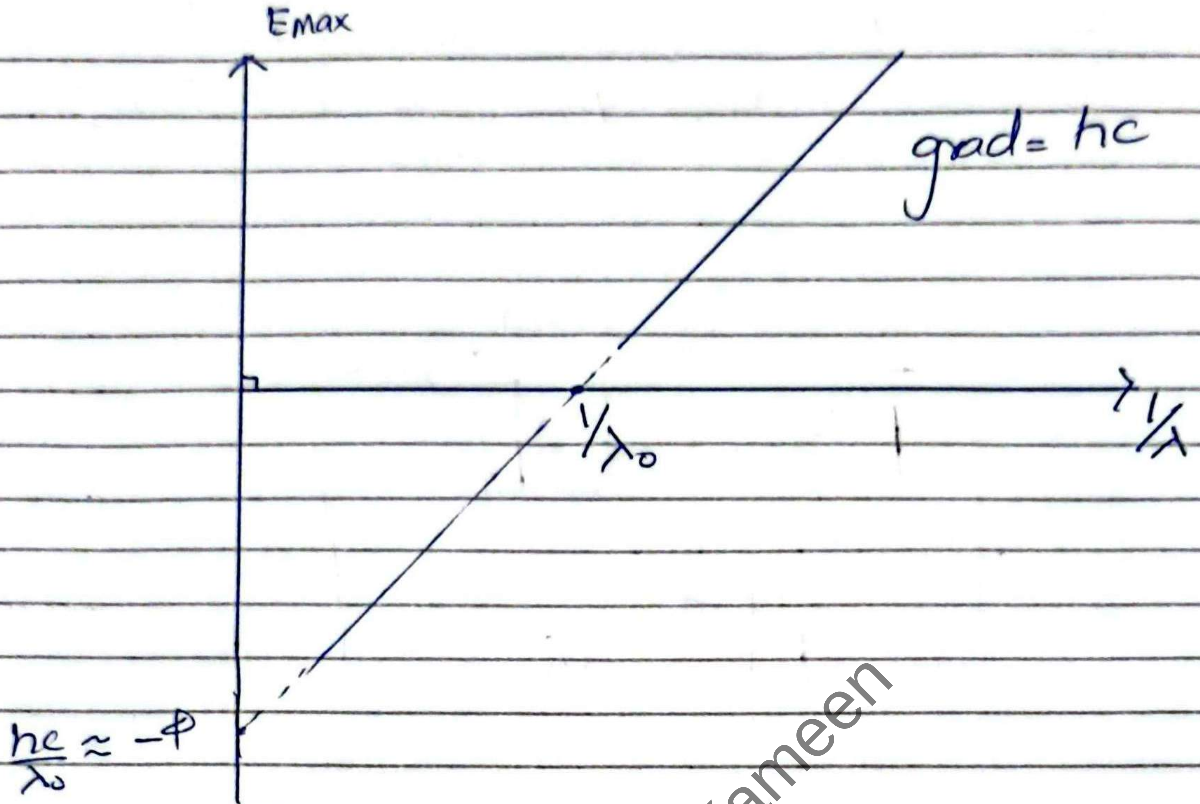
$$E_{Max} = hf - \Phi$$

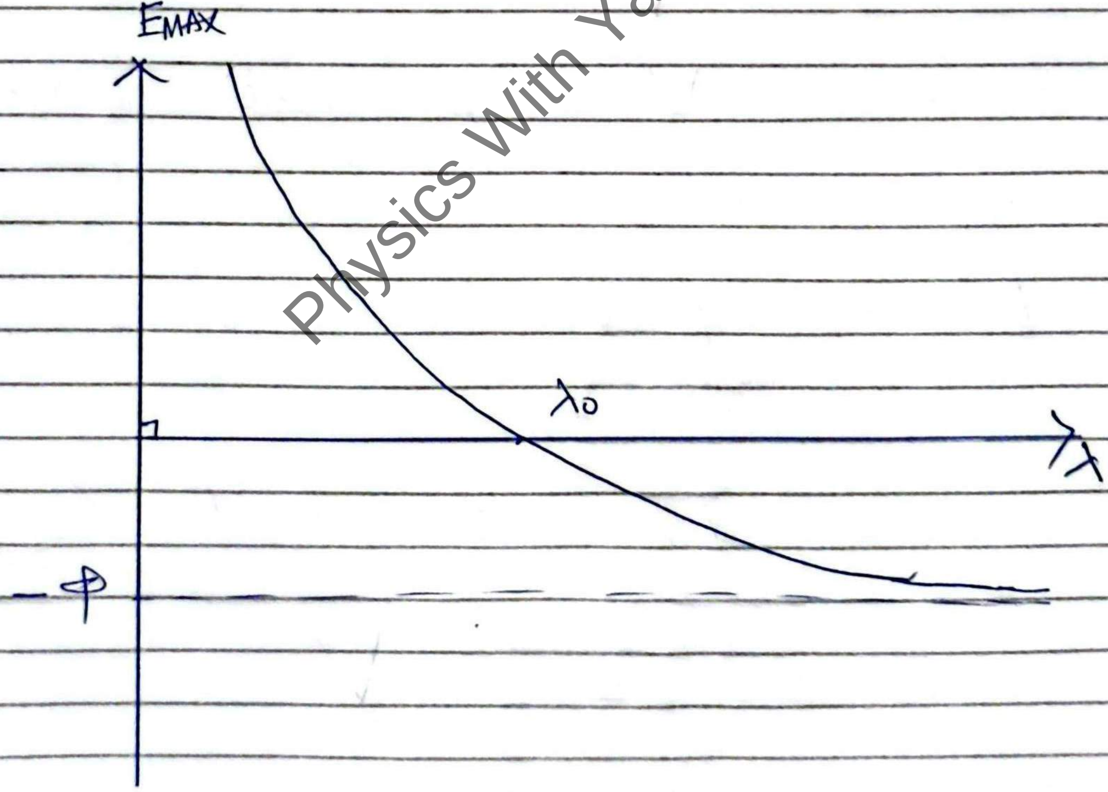
$$v = f\lambda \qquad c = f\lambda$$

$$f = \frac{c}{\lambda} \qquad \Phi = hf_0 = \frac{hc}{\lambda_0}$$

$$E_{Max} = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

$$E_{Max} = hc\left(\frac{1}{\lambda}\right) - \frac{hc}{\lambda_0}$$
$$y = mx + c$$



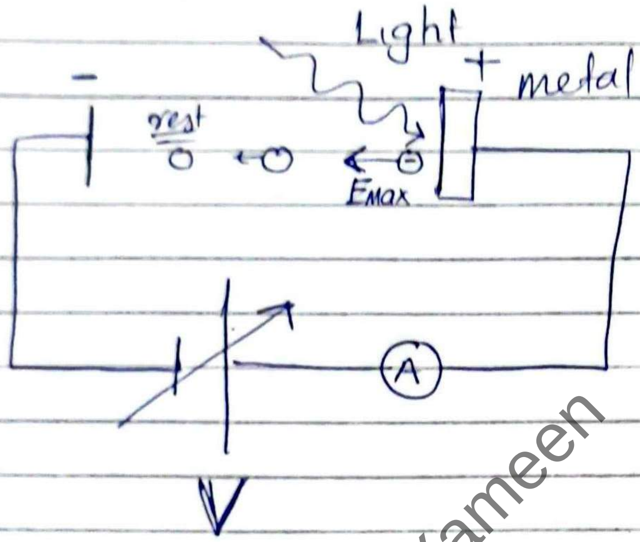


$\lambda \to \infty$

$E_{max} \to -\phi$

$V = \frac{\text{Work}}{\text{charge}}$

How to find maximum kinetic energy of electron?



Increase V so that current becomes zero.

Fast moving electron losses all of its K.E

Loss of E_K = Gain in E_p (Electric p.e)

$$E_{K(max)} = eV$$

e = charge of electron

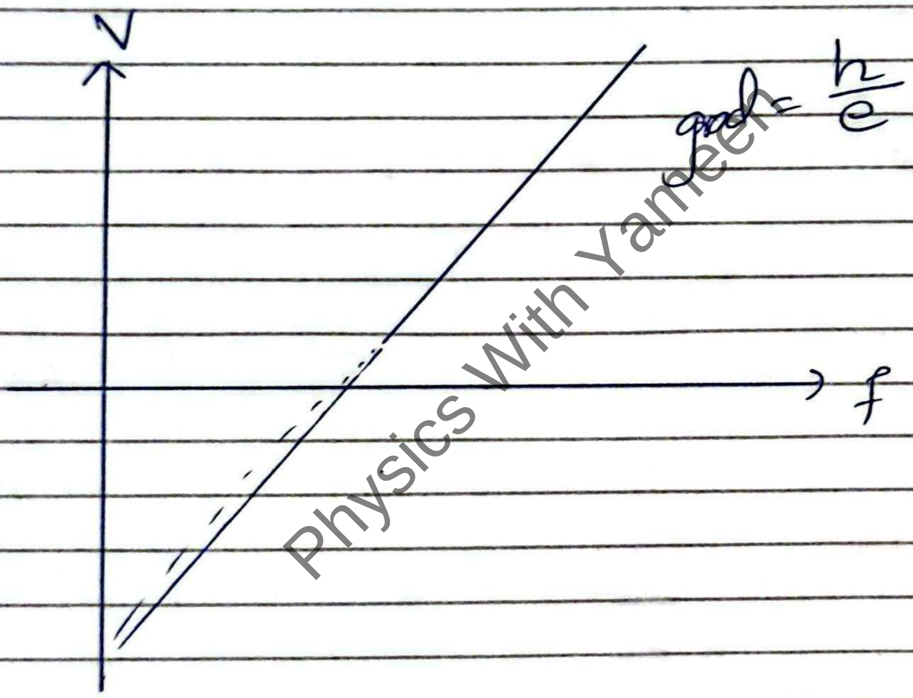
V = stopping potential

$$hf = \phi + \boxed{E_{max}}$$

$$hf = \phi + eV$$

$$eV = hf - \phi$$

$$V = \frac{h}{e}f - \frac{\phi}{e}$$



If I = constant and f is increased then what will be effect on rate of emission?

$$I = \frac{P}{A} \qquad I = \frac{Energy}{time} \times \frac{1}{A}$$

n: no of photons

$$I = \frac{E}{tA}$$

$$I = \frac{nhf}{tA}$$

$$I = \downarrow \frac{n}{t}\frac{hf\uparrow}{A}$$

$y = xt$

$y =$ constant

$t\uparrow$

$x\downarrow$

If I is constant

$f\uparrow$ then $\frac{n}{t}$ should decrease

So less no of photons will hit per unit time and hence less number of electrons will emit per unit time rate of emission will decrease.

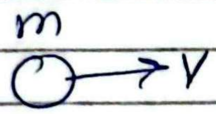
Wave par

Matter wave

Any particle that has a momentum behaves as wave..

Debroglie relation or wave length

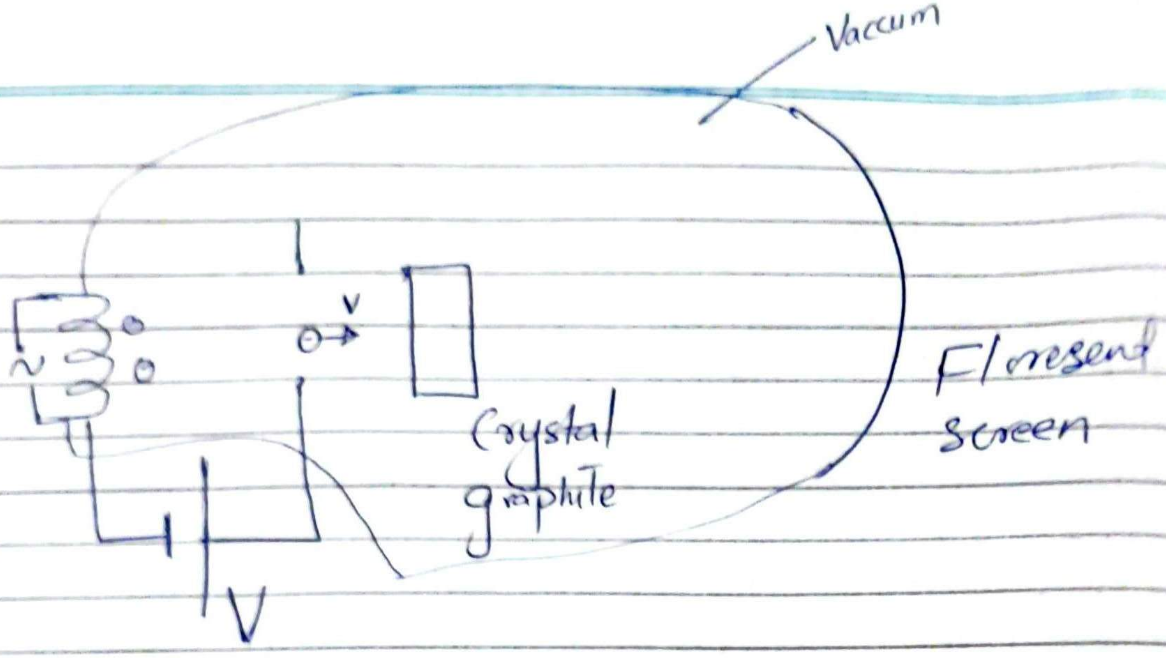
$$\lambda = \frac{h}{p}$$

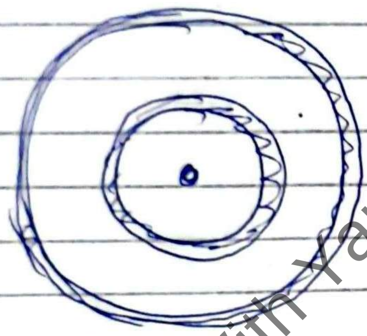


p= momentum

Debroglie wave

Wave associated with material particle that has momentum.





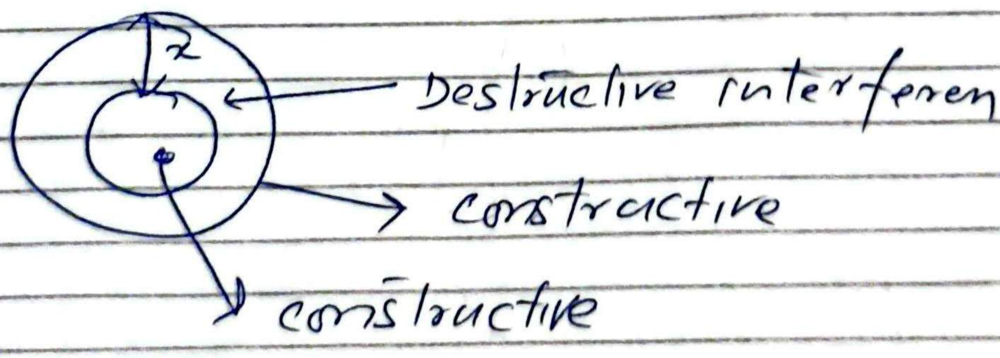
- Electrons are emitted from hot coil having current
- They are accelerated using uniform electric field of potential (V)
- these electrons are incident on graphite crystal

After passing through crystal these electrons are detected on flouresent screen

What is observed on the screen?

On screen we observe concentric circles of bright colours.

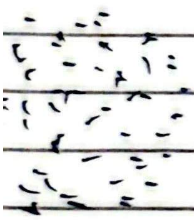
These show that electrons behave as wave



$\lambda \downarrow$ then radius of circles will decrease.

If electrons would have
behaved as particles
hat would you have seen on
screen?

niform distribution of
right dots



pression of wave length

Electrons gain K.E and lose P.E

$E_K = qV$

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

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

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

$E_K = \frac{1}{2}\frac{m^2v^2}{m}$

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

$$P^2 = 2mqV$$

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

Wave length

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

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

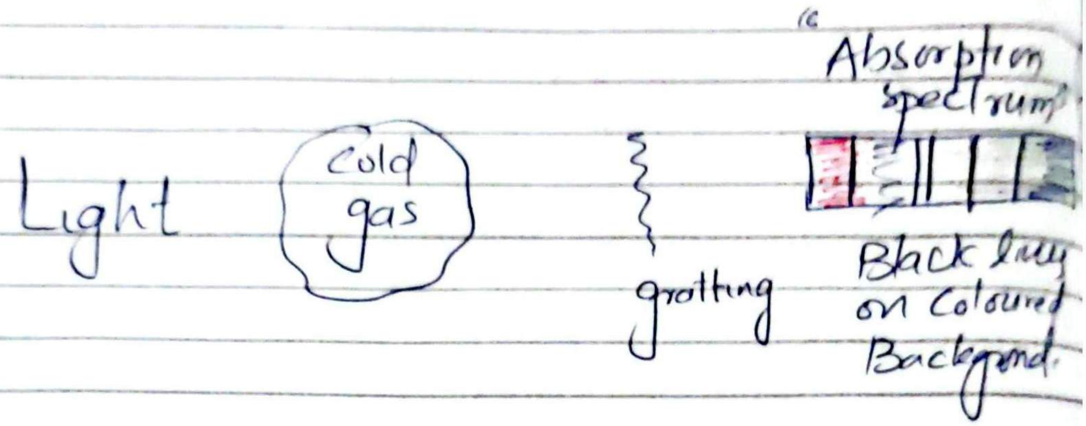
If $V\uparrow$ $\lambda\downarrow$

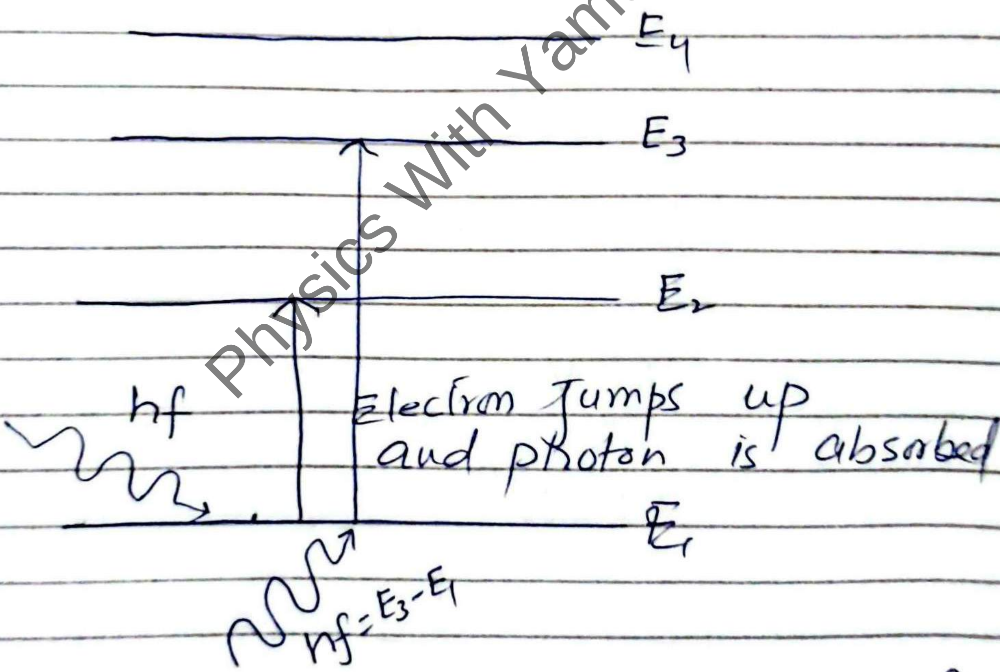
If $V = 100\,V$

$\lambda = 1.23 \times 10^{-10}\,m$

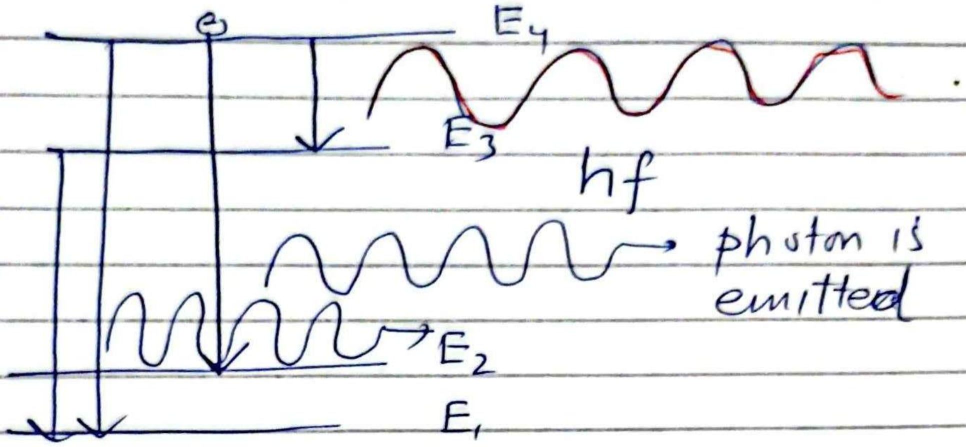
the spacing b/w atoms in crystal are also in this range so electron wave will diffract and interfer so they form constructive and distructive interference pattern

Energy levels





If energy of photon is equal to energy diff of any two levels then photon will be absorbed



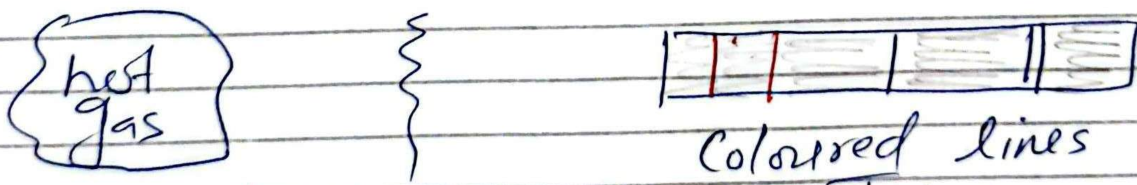
$$\frac{hf}{} = E_4 - E_2$$

$$\frac{hc}{\lambda} = E_4 - E_2$$

$$\lambda = \frac{hc}{E_4 - E_2}$$

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

Emission Spectrum



Coloured lines with black backgro

When electrons jump from higher energy level to lower level They release energy in the form of photon. They emit photon.