Origin of Quantum Mechanics

Acc. to classical Mechanics,
The particle can behave like a particle & wave behave like a wave. Particle show single character (behaviour).
Particle is rep^n by E (energy) & mom. P.
Wave " " Max. wave eq^n.

$$E = E_0 e^{i(kx - \omega t)}$$

$$B = B_0 e^{i(kx - \omega t)}$$

To rep^n the wave we must know the amp. & propagation vector.

amp. E_0, B_0

$$K = \frac{2\pi}{\lambda}\hat{n}$$

Intensity energy incident per unit area per unit time.
Acc. to cla. mech. all the dynamical variables are de continous."
If we know x then

$$v = \frac{dx}{dt}, \quad a = \frac{d^2x}{dt^2}, \quad F = ma, \quad F = -\nabla V, \quad V = -\int F$$

$P = mv \Rightarrow K.E. = \frac{p^2}{2m}$, $E = K.E. + P.E.$

In classical mech. if we know position, we can calculate all the information

Particle & radiation behaved (shows) a single behavio

Classical mech can't explain some phenomena as photoelectric effect, compton effect, black body radiation. Energy exchange b/w radiation & matter take place continously.

C.M. fails

↓

Q.M.

Old Q.M. | New Q.M.

Acc to new Q. Theory, particle is rep^n by a wave.
" " old " , energy & ang. momentum both are quantised.

$$E = n\hbar\omega$$
$$L = n\hbar$$

Some phenomens explain by Old Q.M. not by C.M.:-

Particle Nature of radiation :-

(i) Photoelectric effect :- Here photon is a particle not a wave. Photon energy

$$E = n\hbar\nu$$

Radiation comprise of particle.

Principle :-

The emission of e^- by incident radiation is called Photo-electric effect.

⇒ Exp. Observations :- ① If we incident radiation of less freq. than threshold freq. then no emission of electron.
$\nu < \nu_0$ there is no emission of e^-

② $\nu > \nu_0$ there is always emission of e^-

③ There is no time difference bpw incident & emission.

Time diff. = 10^{-8} sec → neglesible

∴ i.e. e^- at once emitted.

④ The K.E. of emitted e^- depends only on freq. of incident radiation not on intensity.

These cond^{n}s should be satisfied.

If mag. field apply on e^- to accelerate it then force on it will be $\boxed{F = q(v \times B)}$

$W = F \cdot dl$ $\quad \left[v = \frac{dl}{dt}\right]$

Work done by mag. force is zero.

If $W = 0$ then we can't change the K.E. of e^- so by applying mag. field, e^- can not be emitted.

Mag. forces only change the dirⁿ, no change in speed.

Now applying Electric field, force on e^- is electrostatic force

$F = qE$

Work done is not zero, then K.E. can be change so e^- can be emitted.

Poor Intensity → less energy is supplied. Emiss of e^- is possible but in more time (acc. to classical

Strong Intensity → More energy is supplied. & this energy is used

$E = K.E._{max.} + W$

$F(E) = 1 \quad E \leq E_F$, all the energy levels r filled.

$= 0 \quad E > E_F$

Highest filled level is the fermi level.

Work fⁿ :- Mini energy required to move the highest occupied level to surface & remaining energy to supply the K.E.

In Photoelectric effect, the e^- with max. K.E. is emitted.

If energy is ≥ Work fⁿ r, e^- emits.

* ↓ e^-'s K.E. depends on intensity.

$K.E_{max} = E - \phi W \Rightarrow K.E_{max} = \frac{hc}{\lambda} - W$

$\lambda_0 = \frac{hc}{\phi W} \Rightarrow \nu_0 = \frac{c}{\lambda_0} = \frac{W}{h} \Rightarrow W = h\nu_0$

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so $\boxed{K.E_{max} = h(\nu - \nu_0)}$

If we include energy quantisation law & particle nature of e^- then we can explain P.E. effect.

In strong intensity, no. of photons inci. / unit area / unit are large

Poor → " " " small

Acc. to Q.M., E can be exp^n in terms of freq. ν

$E = h\nu$

$$\boxed{K.E_{max} = h(\nu - \nu_0)}$$

(1) If $\nu < \nu_0$, then $\nu - \nu_0 \rightarrow -ve$

so $K.E_{max} = -ve$

$K.E. = \frac{1}{2} m v^2$ (+ve) so K.E. is always +ve, but here K.E. is −ve. Not Possible i.e. no emission of e^-. So we have to supply more energy to move e^- upto the surface.

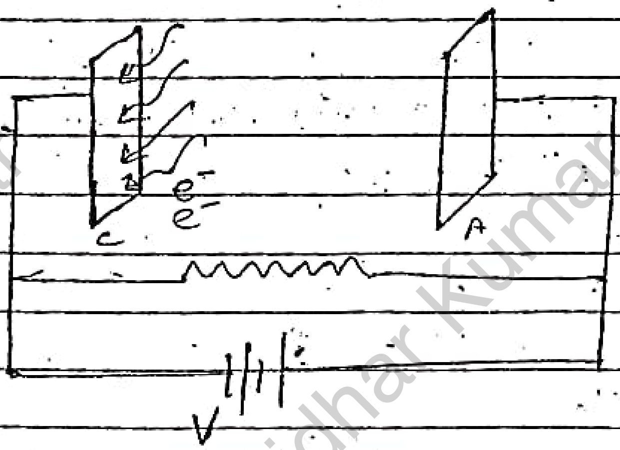
(2) If $\nu > \nu_0$:- $K.E_{max} = +ve$ then there is always emission of e^-. If this cond^n is satisfied then at once e^- emitted.

Stopping Pot^n :-

+ve pot^n w.r.t. to Ist elect. then e's accumulate

−ve then e^-s repel. e^- move from C →

P.E. ↑ by eV_0 = ↓ in K



By inc. +ve pot^n, there is no change in e^-s produced.