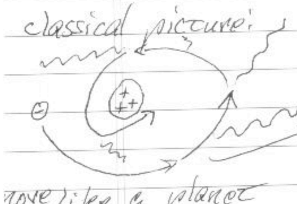
Quantum Mechanics

Electromagnetism presents a major problem for understanding the structure of matter

→ matter has + and − charges
-> negative can move around
→ not in atom center

classical picture:



acceleration of ⊖ by ⊕ charges

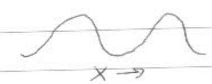
– But we know accelerating charges emit EM waves
→ i.e. they loose energy!
→ so spiral into ⊕ charge

Classical Physics cannot explain stable atoms!

Wave - Particle Duality

? { → light behaves like a wave: interference (Maxwell's Eqs)
→ light behaves like a particle: photoelectric Effect }

a wave extends thru space, has λ



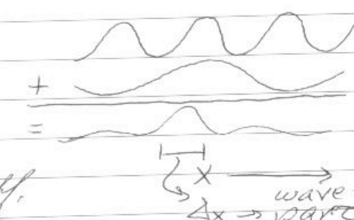
a particle is localized, has position x

↳ for light → $p = h/\lambda$ (Einstein)

Wave-particles (de Broglie)

→ if EM waves also particles (γ's), what about other particles?

consider electron:

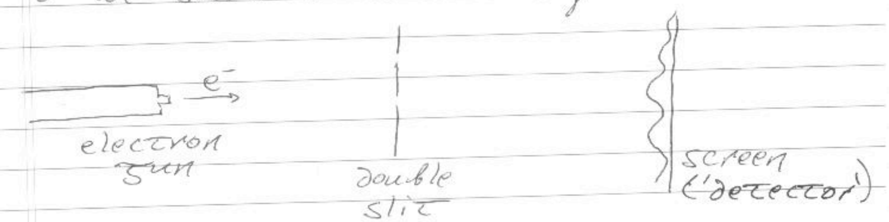


superposition (sum) of many diff. λ waves can produce localization: "wave packet"

→ wave-particle is localized
↓
means most probable location within Δx

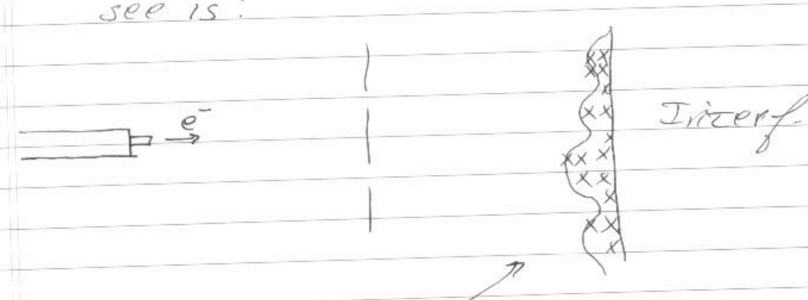
Double Slit for Electrons

If electrons inherently waves, we should see interference



→ an interference pattern is observed when $d \ll L$

I inject electrons individually, what see is:



pattern builds up one 'hit' at a time

→ single particle interferes with self: it's a wave!

Uncertainty

→ to produce a localized particle
  → Δx is small

  → need to sum more waves

→ multiple λ's associated with particle: ie. its λ is not well-defined (exact)

→ if more wave-like (Δx large)
  → momentum + λ well-defined

→ one λ

Since $p = h/\lambda$ → $\Delta\lambda$ related to Δp

So Δp + Δx inversely related
  → when localized, Δp large
  → when Δp known well, Δx large

$$\boxed{\Delta p \Delta x \geq \hbar/2}$$

Heisenberg Uncertainty Principle

cannot get Δp or Δx to zero

Not an Experimental Limitation

Implications

Classical physics is deterministic
- → can know $\vec{x}_i, \vec{p}_i$ perfectly
  - → if know initial $\vec{x}_i, \vec{p}_i$ perfectly
    - → fate of universe is completely determined

Quantum Mechanics
- → determinism is gone
  - → we can't know perfectly
    - → inherent randomness
      - e.g. radioactivity

→ chemistry, semiconductor physics
- → rely on uncertainty + wave-like properties of matter

FPGA's, CPU's, PROM's...