Physics 100 - October 22, 2007

- Be sure to listen to accompanying Audio file for this lecture
- Let me know about technical difficulties
- Please e-mail me with questions
- I will assume you have covered this material (prob sets, recitations, future lectures)
- Presentation groups posted on web
  Meet + START thinking about it

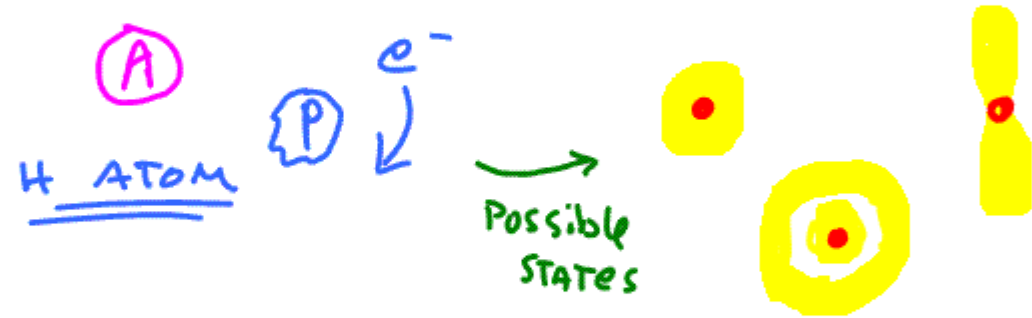
Last Time Quantum Uncertainty

Quantum Mechanics (Schrödinger's equation)
Allows you to determine Allowed energies and spatial configurations of a system ... called the STATE of System

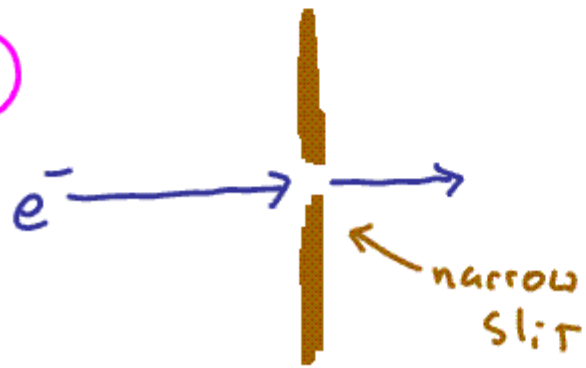
Examples

(A) H ATOM

(P) e^-



(B)



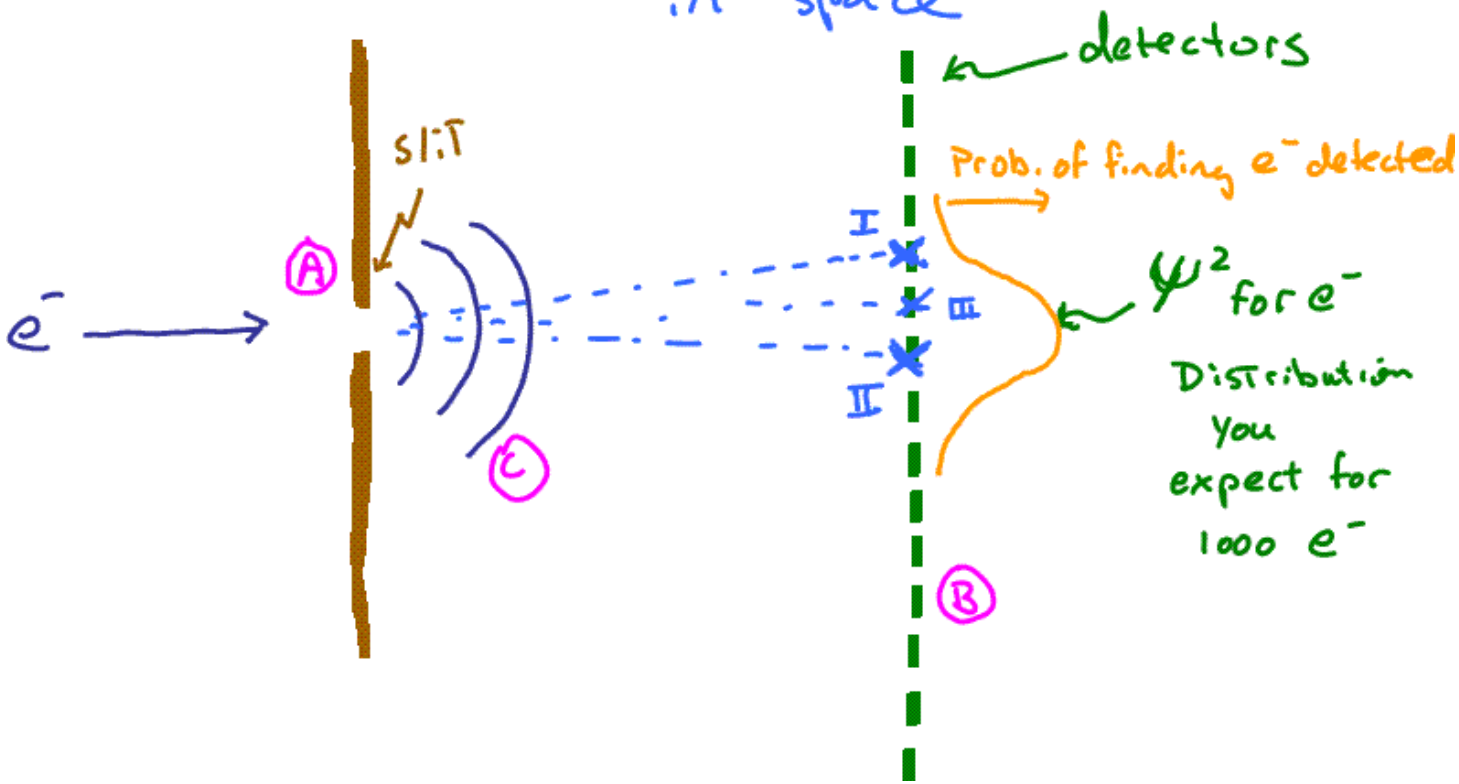
Q.M. determines

$\psi(x)$

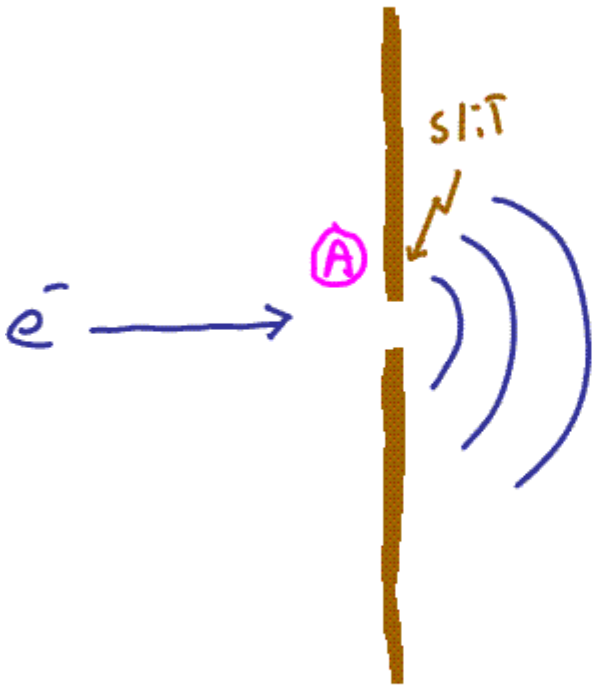
"wave function" of particle

$\psi_{(x)}$ NOT well defined ... not sure how to interpret

$\psi^2_{(x)}$ is well defined ... ψ^2 of particle at certain point in space is Probability of finding Particle at that point in space



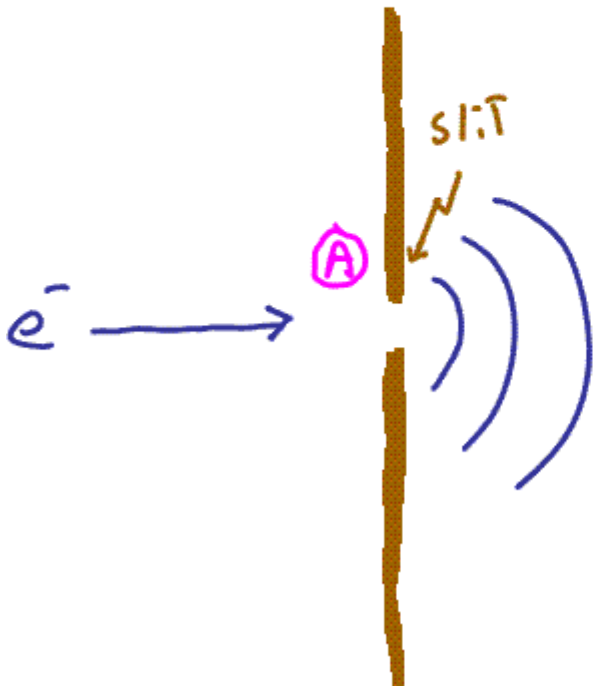
Consider Single e^-

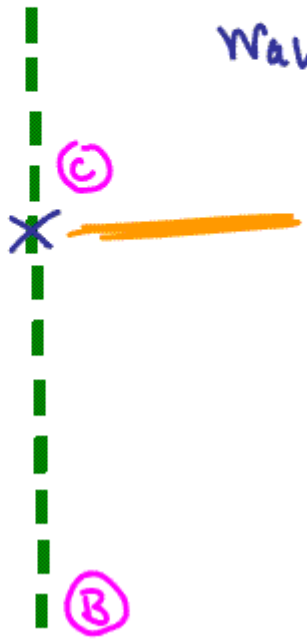


e^- could be Anywhere according to QM

Probab. of where it Might go is all you have

Single e^-

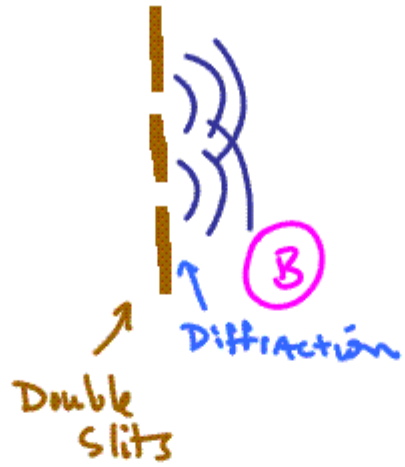




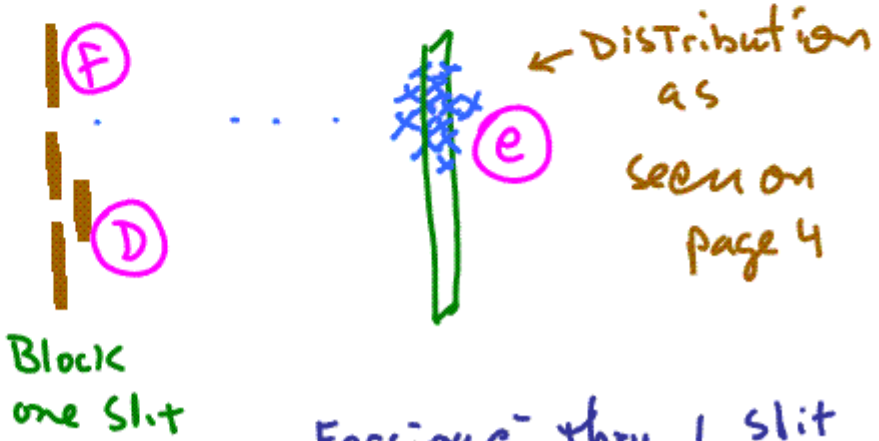
once e^- observed

Wavefunction collapses

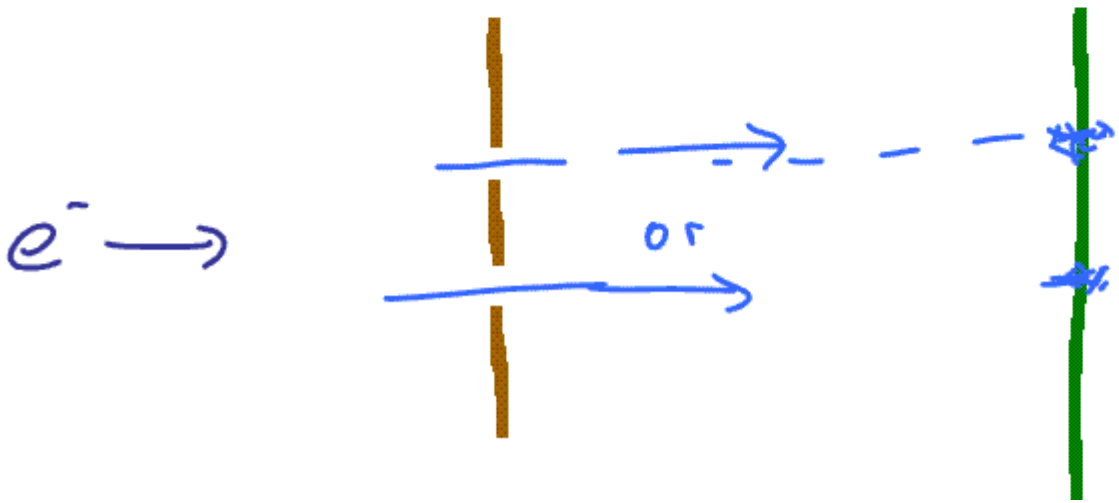
we know where it is.

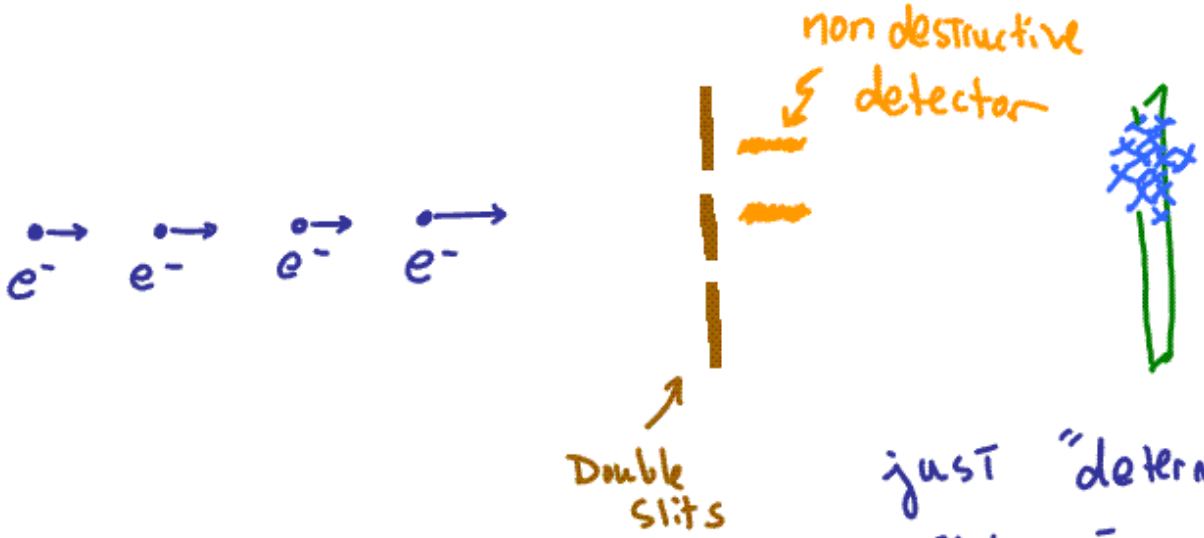


Happens because $\Psi(x)$ interferes w/ itself just like a water wave.

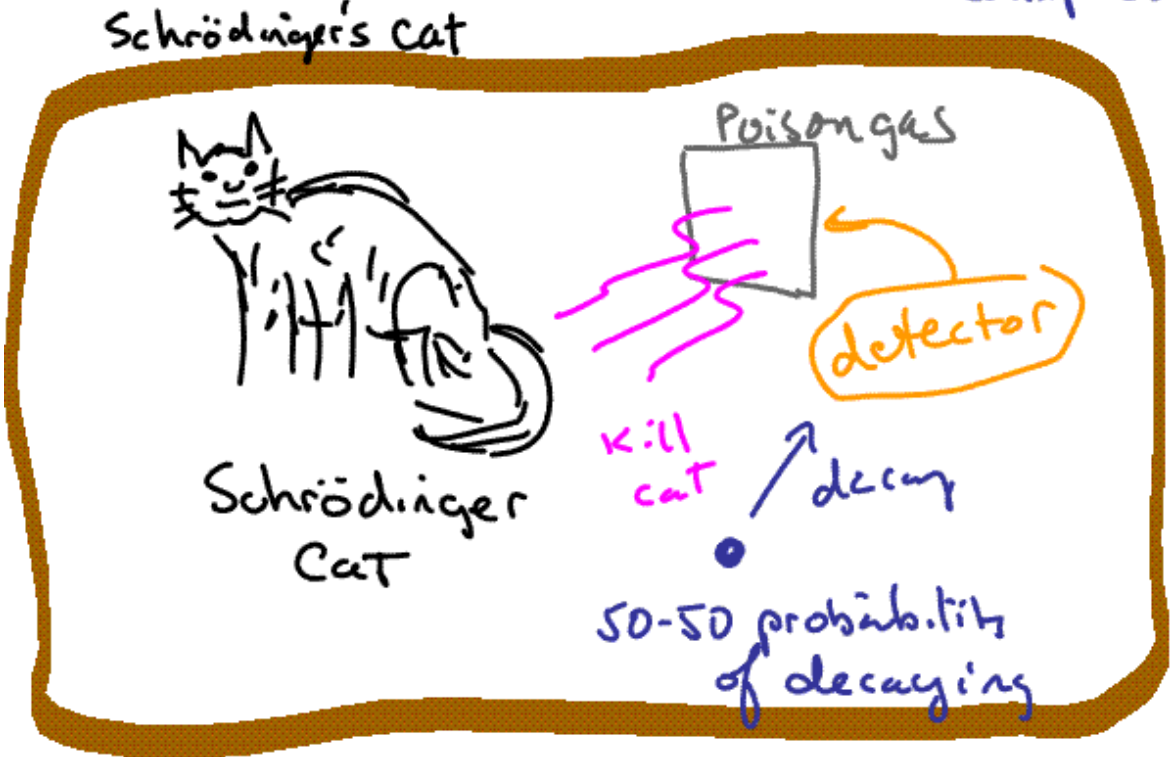


classically expect to see, e^- like marble





just "determining" which slit e^- passed thru collapses the wavefunction



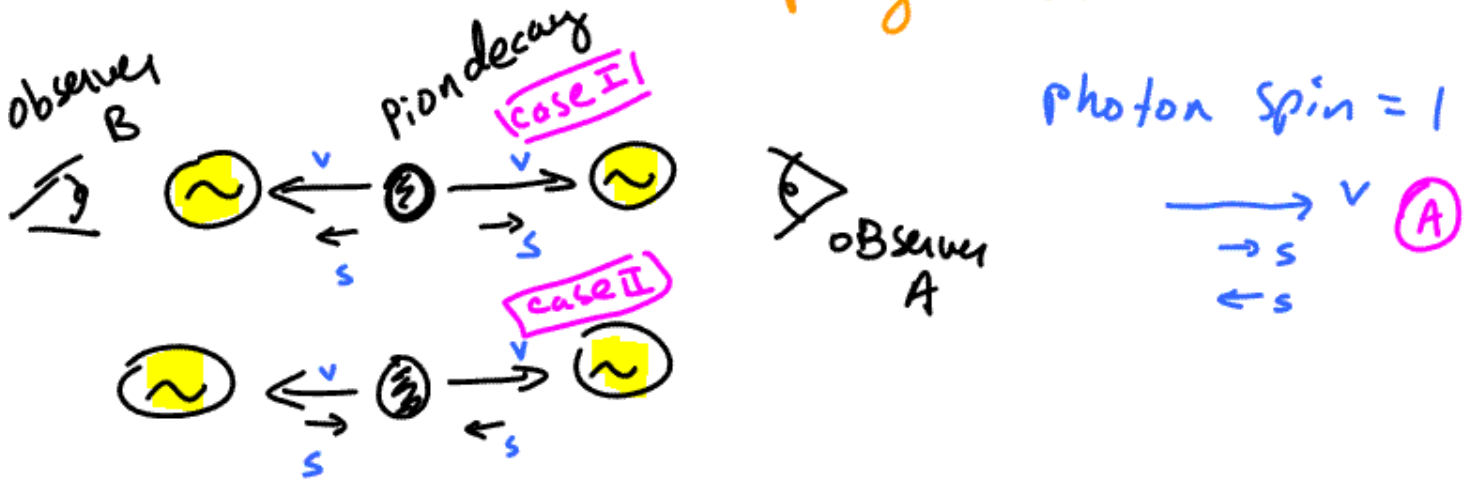
To QM cat is in STATE that is

$\frac{1}{2}$ dead + $\frac{1}{2}$ alive

very STRANGE

EPR Paradox — Einstein, Podolski, Rosen 1935

"Spooky Action at a distance"



Two photons are produced at once — They are correlated.
If one has spin one way the other has spin the other way.
They are in an "entangled quantum STATE"

When observer A observes the spin of photon — The wavefunction collapses and the spin of the photon observer B will observe is determined.

But collapse INSTANTaneous and observers A + B far apart
Does this mean information conveys faster than speed of light?

Sdns to paradox

- Copenhagen interpretation of QM
  - ↳ $\psi_{(x)}$ Not real actually
    - Things become real only when observation made
    - So why be bothered ?

- Many Worlds interpretation of QM
  - Universe Splits into two → one where spins one way
  - Universe Splits into two → one where spins other way

Effect is Real

Len Mandel (1928 - 2001) University of Rochester
Physicist

observed "entangled" photons

QUANTUM cryptography

Heisenberg's Uncertainty principle

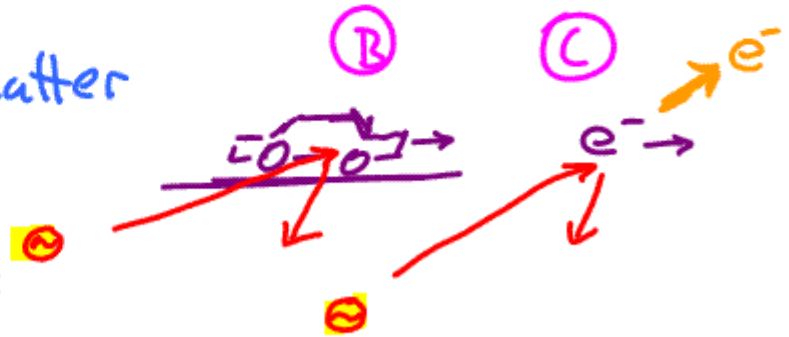
(A) $\Delta x \, \Delta p > \frac{h}{2\pi} \sim 10^{-34}$ Planck's constant

Δx: uncertainty in position

Δp: uncertainty in momentum (mv)

CANNOT know both the position and momentum with arbitrarily good precision

Size Really DOES matter



Say goodbye to the deterministic Universe

A different form of Heis. unc. princ.

$$\Delta E \, \Delta t > \frac{h}{2\pi}$$

ΔE: unc. in energy

Δt: time over which it exists

CAN Break Conservation of energy — so long as you do it over a short enough time.

Tremendous implications

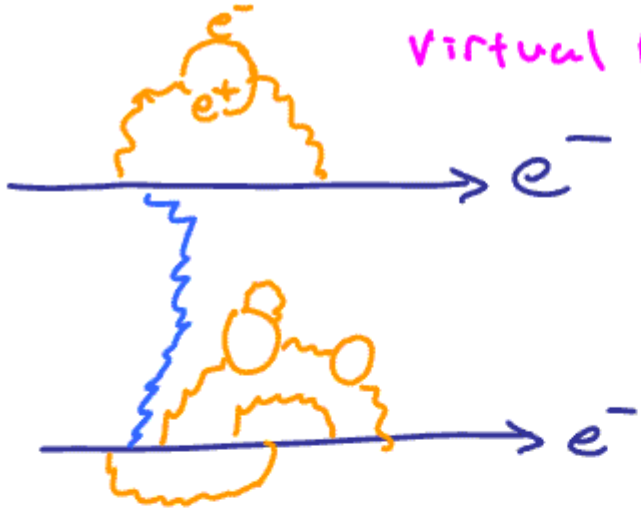
It's a Harry Potter universe

e⁻ not a marble

Superposition of possible quantum states

Virtual particles

Virtual particles



$$F \sim \frac{q_1 q_2}{r^2}$$

Quantum Field theory – views the essence of forces to be the exchange of virtual particles

These only exist as quantum fluctuation as allowed by Heisenberg's Unc. Princ

$$\Delta E \Delta t > \frac{h}{2\pi}$$

We'll discuss this much more in future classes