Physics 100 - March 4, 2009

- Please listen to accompanying audio file as you go thru the slides

- Preliminary class presentation topic list Posted ... look it over ... have a couple of days to petition for new topics when you return from Sp. Break. Decide which topics most interest you.

- Have a great Spring Break

Last Time Quantum Uncertainty

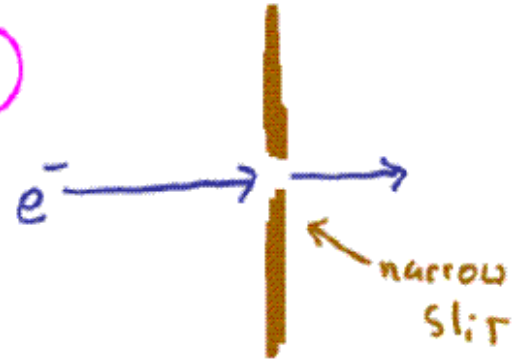
Quantum Mechanics (Schrödinger's equation)
Allows you to determine allowed energies and spatial configurations of a system ... called the STATE of system

Examples

A

H ATOM

B



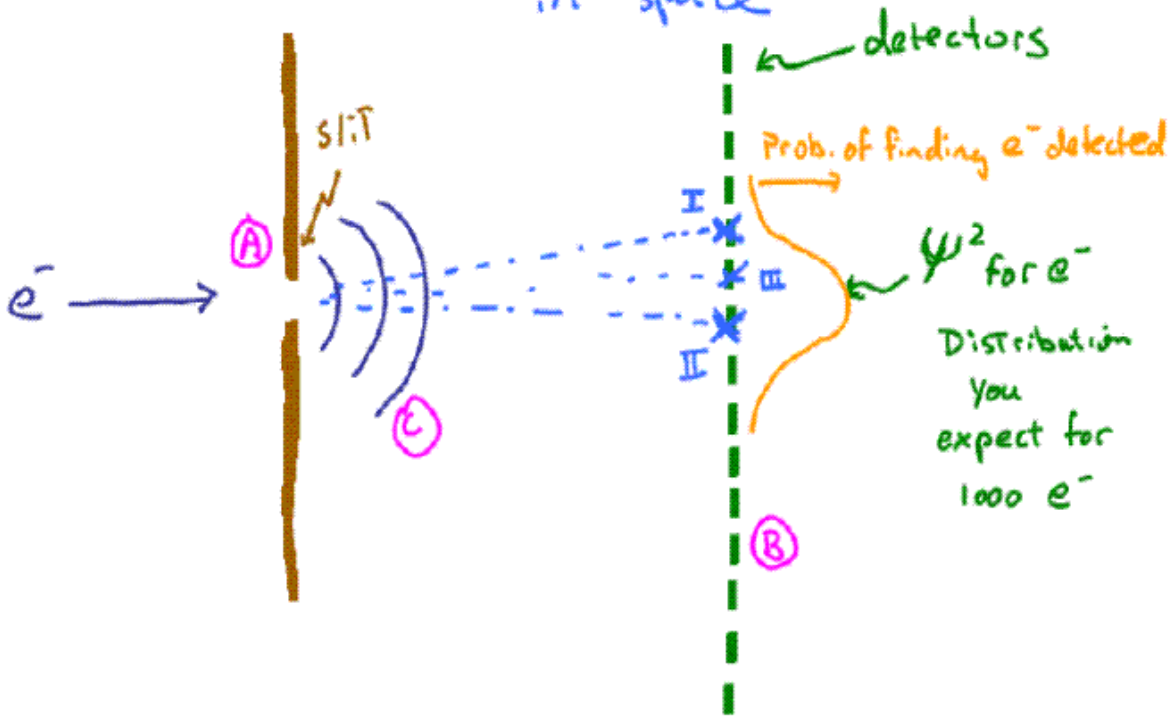
Q.M. determines

$\psi(x)$

"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



Max Born German (1882 - 1970)

3a

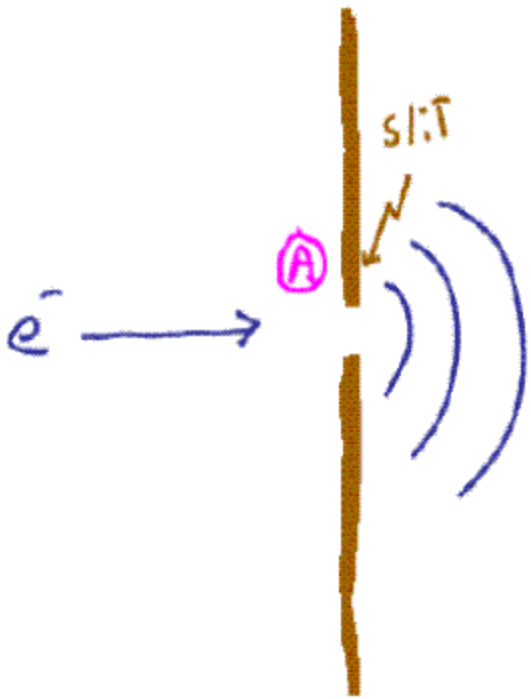
1954 Nobel Prize in physics

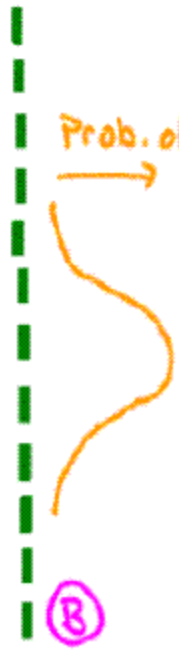
"For his fundamental research in quantum mechanics, especially for his statistical interpretation of the wavefunction"

$\psi(x)$ wave function

$\psi^2(x)$ ~ probability of finding particle in region of space

Consider Single e^-

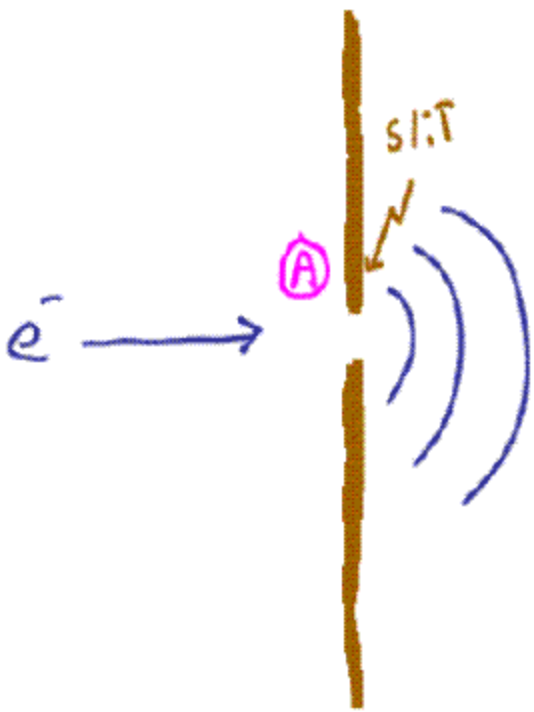


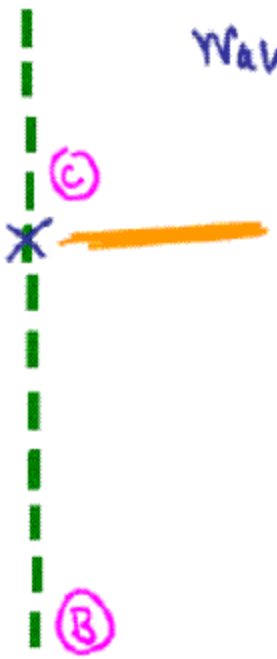


e^- could be Anywhere according to QM

Probab. of where it Might go is all you have

Single e^-

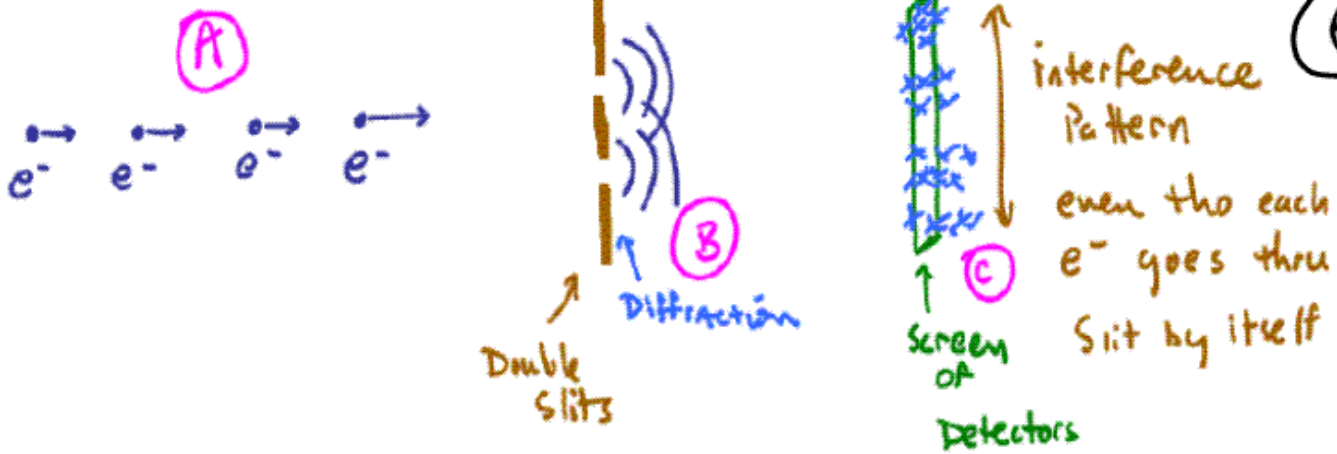




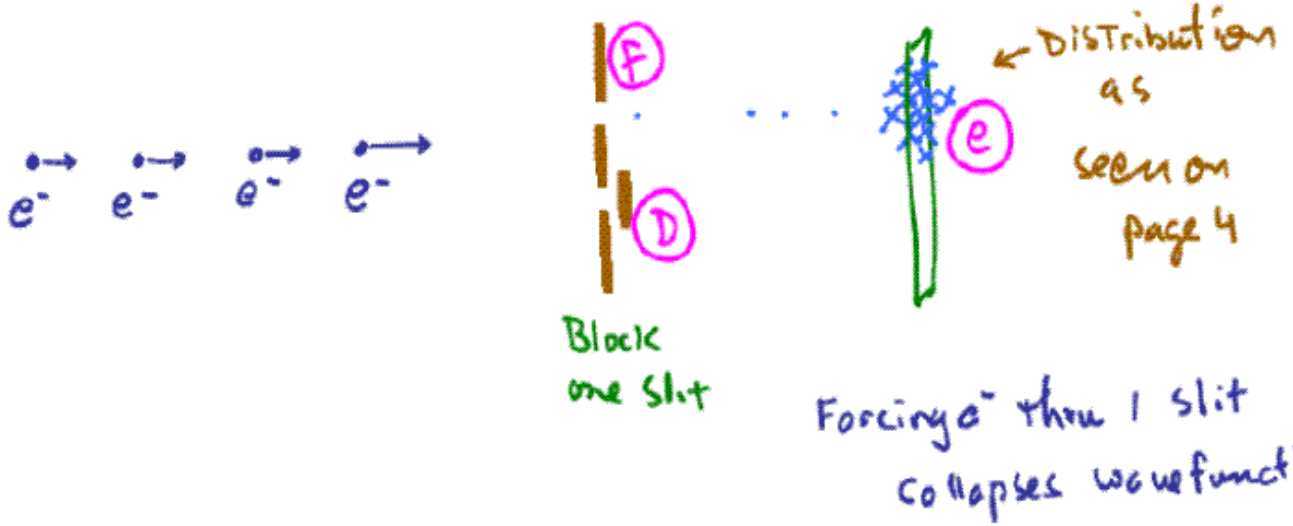
once e^- observed

Wavefunction collapses

we know where it is.



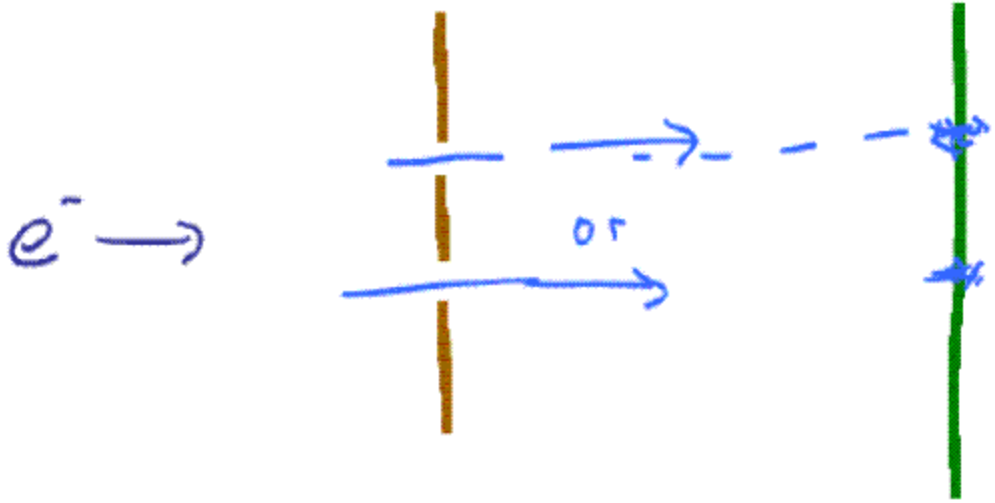
Happens because $\psi(x)$ interferes w/ itself just like a water wave.

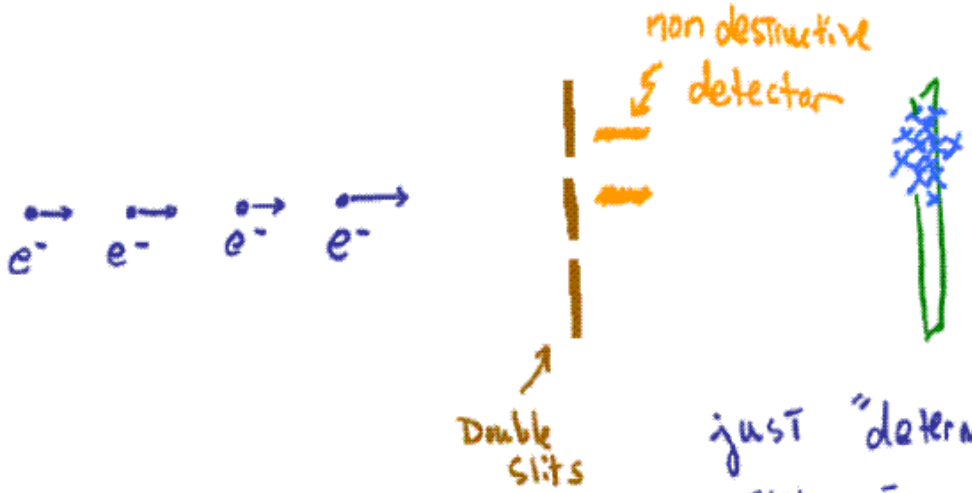


Forcing e⁻ thru 1 slit collapses wavefunction

6A

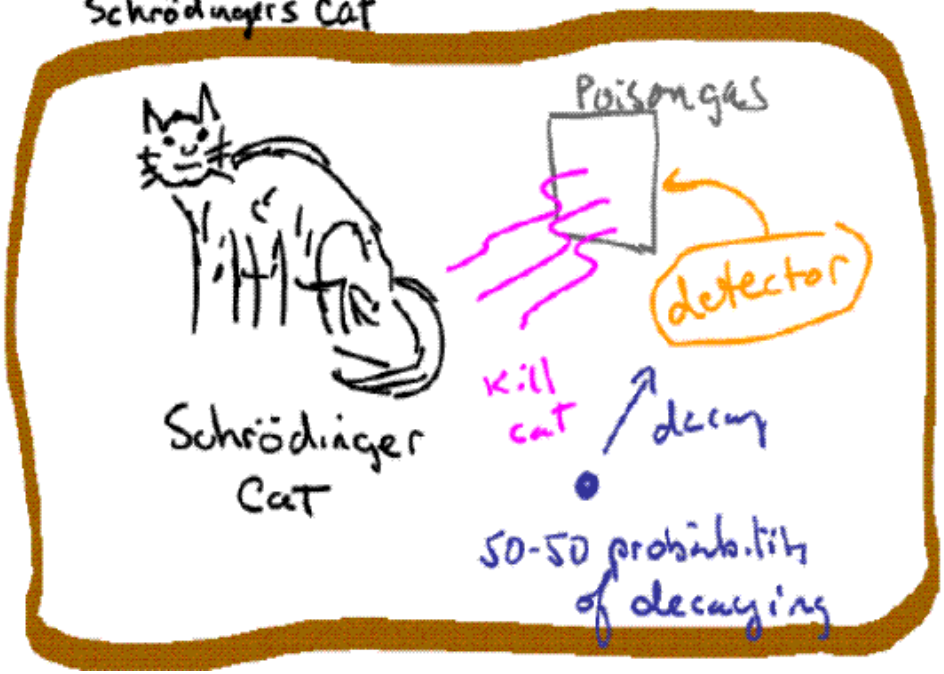
classically expect to see, e^- like marble





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

Schrödinger's cat

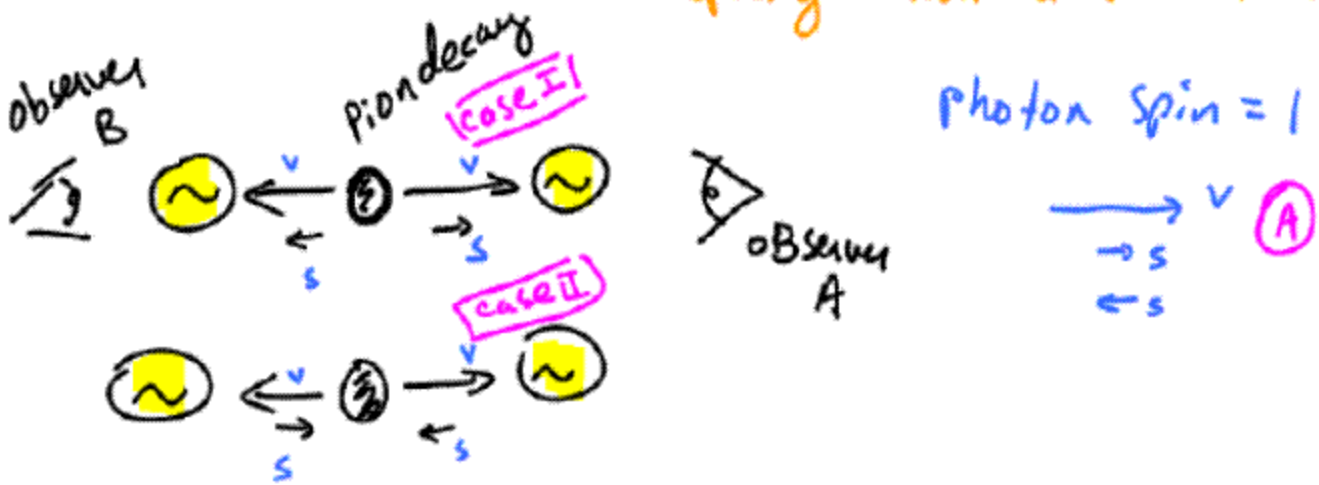


To QM cat is in state that is $\frac{1}{2}$ dead + $\frac{1}{2}$ alive

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?

Solns 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
    - 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

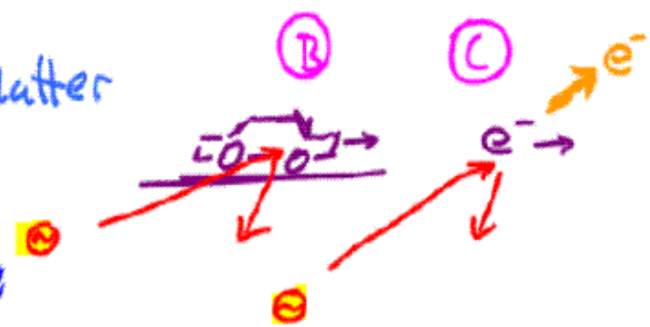
(A) $\Delta x \, \Delta p > \frac{h}{2\pi}$ ~ $\sim 10^{-34}$ Planck's constant

uncertainty in position

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.

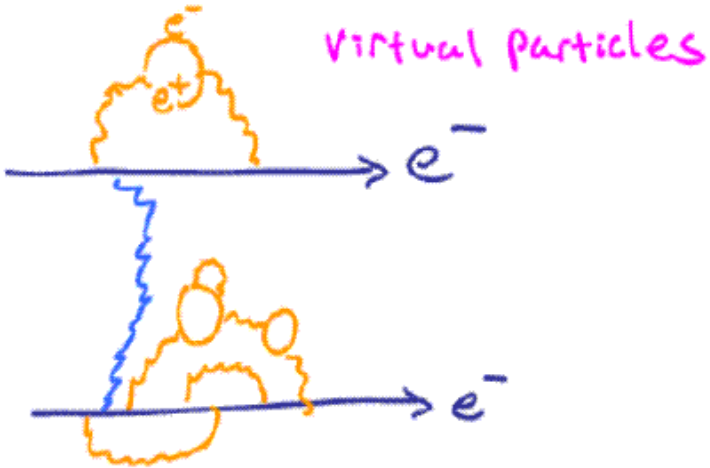
Tremendous implications

It's a Harry Potter universe

e⁻ not a marble

Superposition of possible quantum states

Virtual Particles



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

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