

E.F. Doreny / BSC Physics: Copenhagen Interpretation, measurement... Decoherence.

Note Title

That $|\Psi(x)|^2 = \text{prob density} \equiv \text{Born Interpretation}$
of Schrödinger Eqn
 $\hat{H}\Psi$.

what is Ψ ?
• don't know.

what is $\sqrt{\text{probability}}$
don't know that either.

So accepted interpretation is

$\Psi = \text{wavefunction}$, then don't know

but

$\Psi^* \Psi = \text{probability density}$,

1954 Nobel Prize

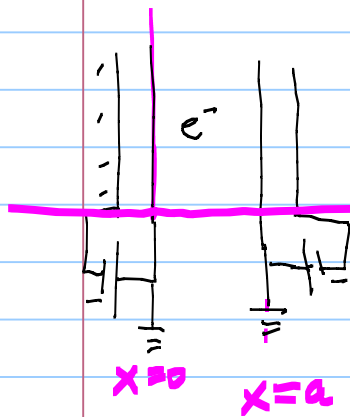
Oliver's Grand Dad,

See AJP article

73, (11) 999-1008

(2005)

So what do we do?



$$\hat{H}\Psi = i\hbar \frac{\partial \Psi}{\partial t}$$

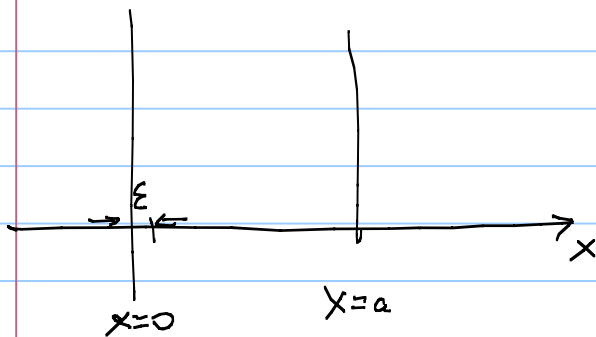
Solve

get

$$\Psi(x,t) = \begin{cases} \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi x}{a}\right) e^{-\frac{i\hbar k^2 t}{2ma^2}} & 0 \leq x \leq a \\ 0 & \text{otherwise} \end{cases}$$

Then ask what is the prob that upon measuring the result you

be that the e^- was within distance, ϵ , of the left hand wall?



So $|\Psi|^2 = \frac{\text{prob}}{\text{length}}$

$|\Psi(x)|^2 dx = \text{prob in bin size } dx$

So

$$P(0 \leq x \leq \epsilon) = \int_{x=0}^{\epsilon} \Psi^* \Psi dx$$

Now if $\epsilon \ll a$

Then $\sin(x) \approx 0 + x + \frac{-x^3}{6}$

So $\sin\left(\frac{2\pi\epsilon}{a}\right) \approx \frac{2\pi\epsilon}{a} - \left(\frac{2\pi\epsilon}{a}\right)^3 \frac{1}{6}$

So

$$\text{Prob} = \frac{\epsilon}{a} - \frac{1}{2\pi} \left(\frac{2\pi\epsilon}{a} - \left(\frac{2\pi\epsilon}{a}\right)^3 \frac{1}{6} \right) = \frac{\epsilon}{a} - \frac{\epsilon}{a} + (2\pi)^2 \left(\frac{\epsilon}{a}\right)^3 \frac{1}{24} = \frac{(2\pi)^2}{2} \left(\frac{\epsilon}{a}\right)^3$$

works perfectly!

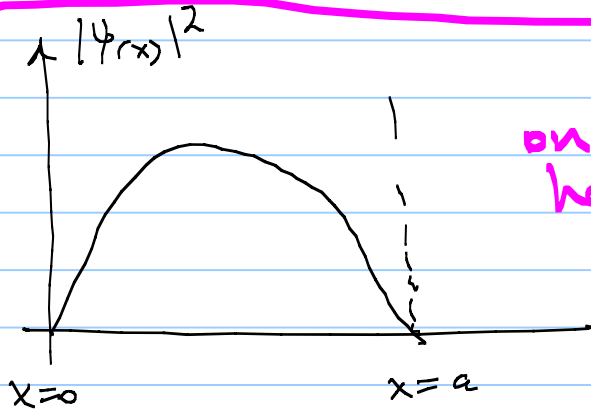
talk about pre-measurement

Schwever waits until

sect 8.8

on measurement theory here (pg 187)

I'll do a bit here



Quantum mechanics "says" before measurement, all you can say is that

This is the probability distribution function for where the particle is!

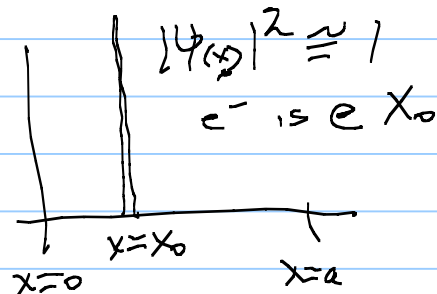
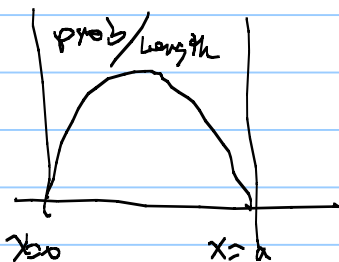
That's it, Q.M. says it is in superposition of this entire distribution function

Until the measurement!

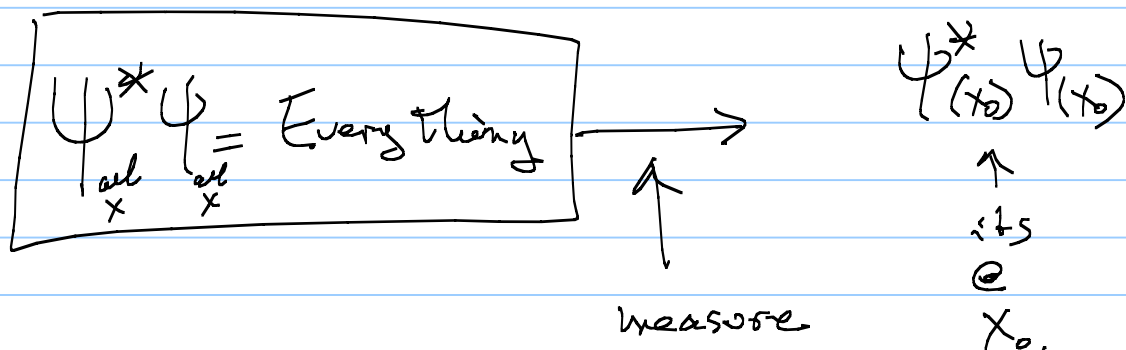
Once a measurement is made and it is where it is, it is said that the wavefunction instantly collapses into the state to which it was measured!

Before measurement

after measurement



This is called the collapse of the wavefunction!



Idea:

Spin = \uparrow or \downarrow

$$\Psi_{spin} = |\uparrow\rangle + |\downarrow\rangle \xrightarrow{\text{measure}} |\uparrow\rangle \text{ or } |\downarrow\rangle$$

Schrödinger's cat

$$|\text{dead}\rangle + |\text{alive}\rangle \xrightarrow{\text{measure}} |\text{dead}\rangle \text{ or } |\text{alive}\rangle$$

All called Copenhagen Interpretation of Quantum Mechanics!

See

problems?

w/ Copenhagen?
Hidden Variables \rightarrow Q.M. IS actually deterministic, and only our Ignorance makes it appear random!

* actually local hidden variables

See Scherrer pg 197 Sect 8.8 measurement theory

1) Spooky action, (AE 1935 EPR)

Local part means no faster than light signal

Today -- well that's the way it is

John Bell 1965 \Rightarrow Local hidden variable theories are incompatible w/ observed experimental results
Murray Aspect 1980

today 1990 Quantum Teleportation & Quantum Computer

Also: Many world's Interpretation of Q.M.
1957 Hugh Everett (Princeton student of Wheeler)
 \rightarrow to

Resolution?

Avoid? of wavefunction collapse (Copenhagen)

Decoherence!

what is they never really collapse?

$|\text{Universe}\rangle + |\text{dead}\rangle + |\text{alive}\rangle$

$|\text{dead}\rangle + |\text{alive}\rangle$

Cohance = Superposition state
 $|d\rangle + |a\rangle$ @ same time

cat

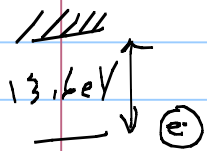
look + limit
 $|\text{alive}\rangle$

But as soon as "measurement" is made, it Decoheres

e's can keep coherent for a while ... seconds
cat = 10^{23} decoheres quickly $\sim 10^{-20}$ seconds

so quickly becomes $|\text{dead}\rangle$ or $|\text{alive}\rangle$

More on Coherence/Decoherence



Keep away from all interactions
stay away from $\vec{E} \cdot \vec{M} = \vec{H}' \leq 13.6 \text{ eV}$

$$\text{Then } \Psi_{e^-} = \frac{1}{\sqrt{2}} [|\uparrow\rangle + |\downarrow\rangle]$$

it is in Both states. = Coherent Superposition

* apply external \vec{B} field \Rightarrow measurement $\frac{1}{2}$

e^- becomes

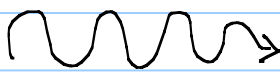
either $|\uparrow\rangle$ OR $|\downarrow\rangle$ w/ respect to the field.

* called

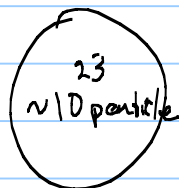
Space Quantization! BIG Surprise


(see Townsend for Great Story on this)

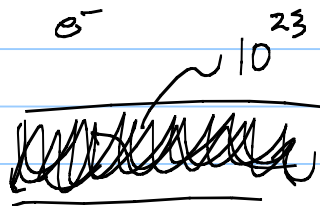
So

⊙ very much wave like 
very Quantum mechanical

Now take Tennis Ball



if each =  Then all together
 e^-



$\sim 10^{23}$ incoherent Ψ_{e^-}

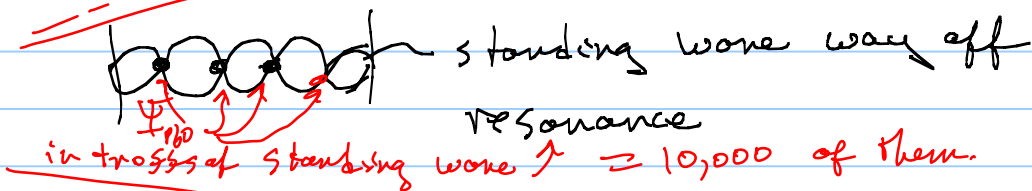
doesn't look wave like at all! looks

like decoherent particle.

Now resolve Schrödinger's (at w/ Decoherence...)

Dave DeMille \rightarrow Quantum PC

molecule (PbO) = $|\uparrow\rangle + |\downarrow\rangle$ = coherentent Ψ_{PbO}

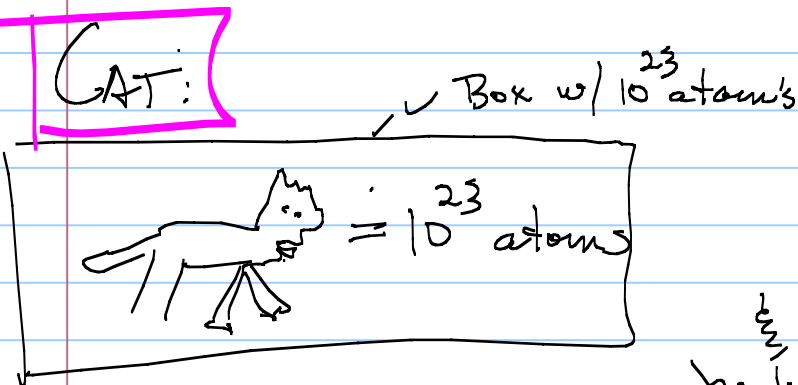


\rightarrow Varying E_{ext} he can apply to talk to each PbO individually

Dave can keep these PbO's $|\uparrow\rangle + |\downarrow\rangle$ (10K of them) for about 5 seconds.

"He can keep them coherent, i.e. from 'Decohering', for 5 seconds" because he TRIES not to measure them!

CAT:



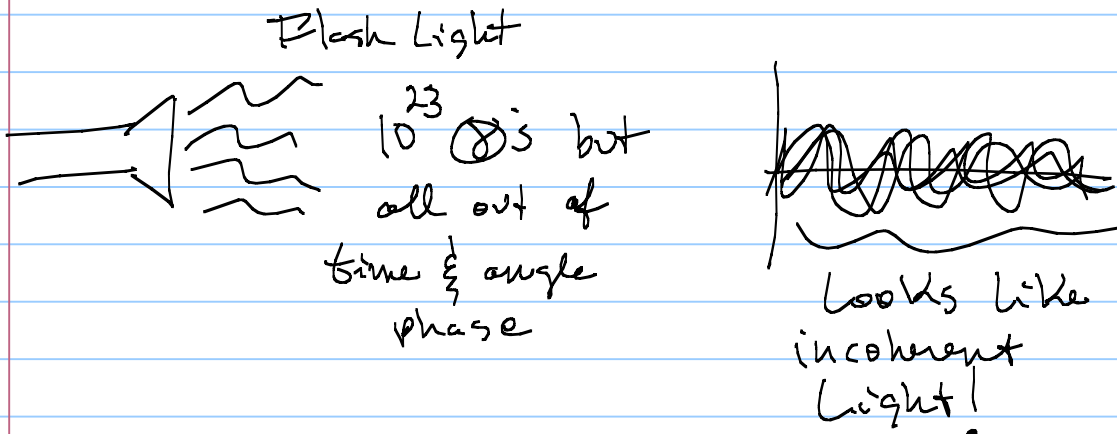
The E&M radiation from the box \rightarrow interactions between all particles

\Rightarrow Measurements so

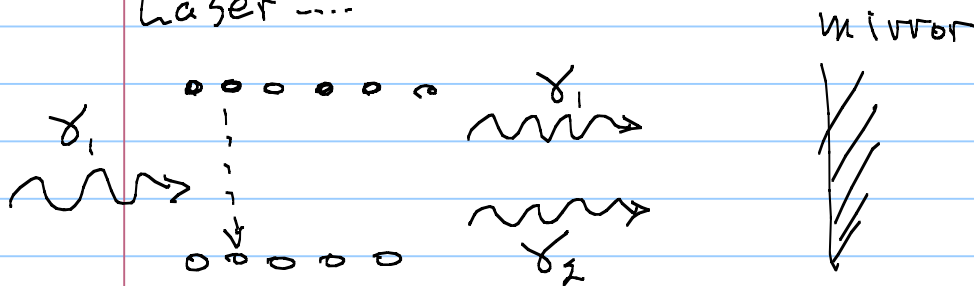
Quickly decohere the 10^{23} atoms into \downarrow collapsed observed state = Dead or alive \Rightarrow

Finally ... one more example of
Coherent Q.M. states

The laser!



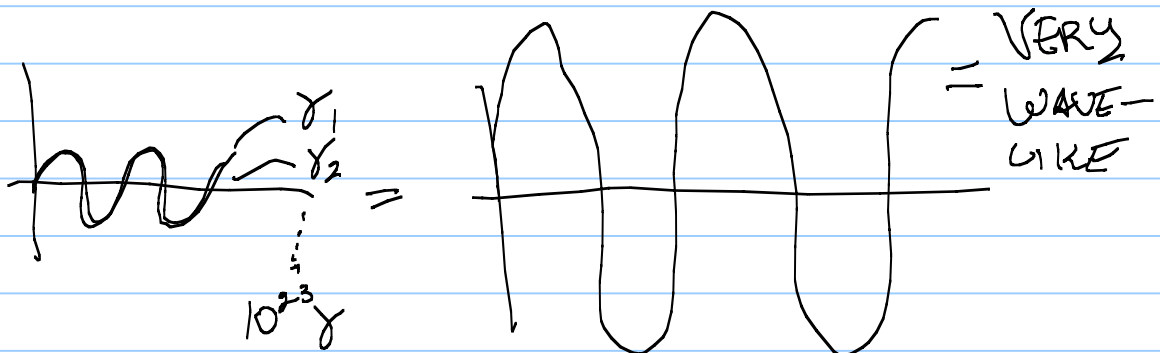
Laser ...



Stimulated emission

produces exact copy of δ \Rightarrow all starting
@ same time
& angle

after many trips back & forth between
mirror you get buildup of identical
COHERENT photons

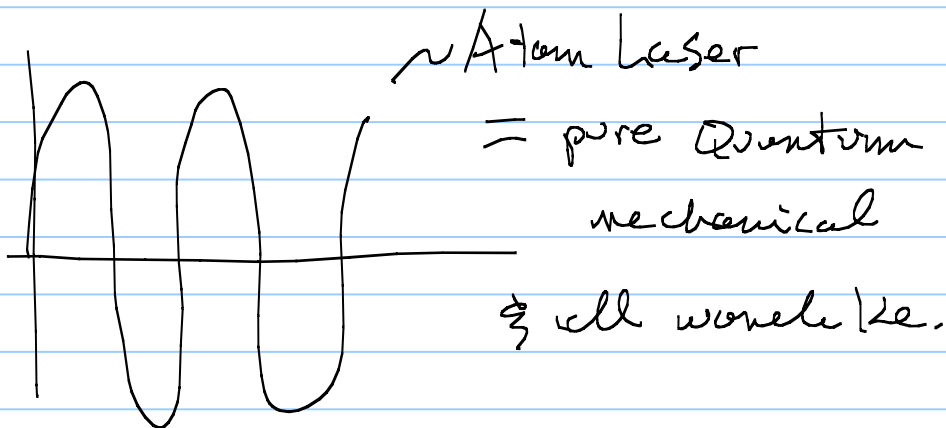
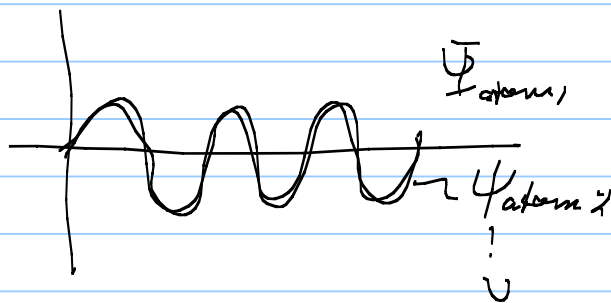


So laser = purely Q.M. coherent superposition of Ψ 's

BOO $\dots \Rightarrow$ Coherent superposition of atoms

$$\Psi_{\text{atom}} = \text{wave}$$

BEC = Atom laser



KEY is laser & BEC = Macroscopic SIZE

So great to study fundamental Q.M.