

Quantum Mechanics in Plain English

How to sit in 3 chairs at once,
and speed without getting a ticket.

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Quantum Mechanics

In the quantum world you can:

- Sit in 3 chairs at once

- Speed without getting a ticket

- Walk through walls

Can I create my own reality?

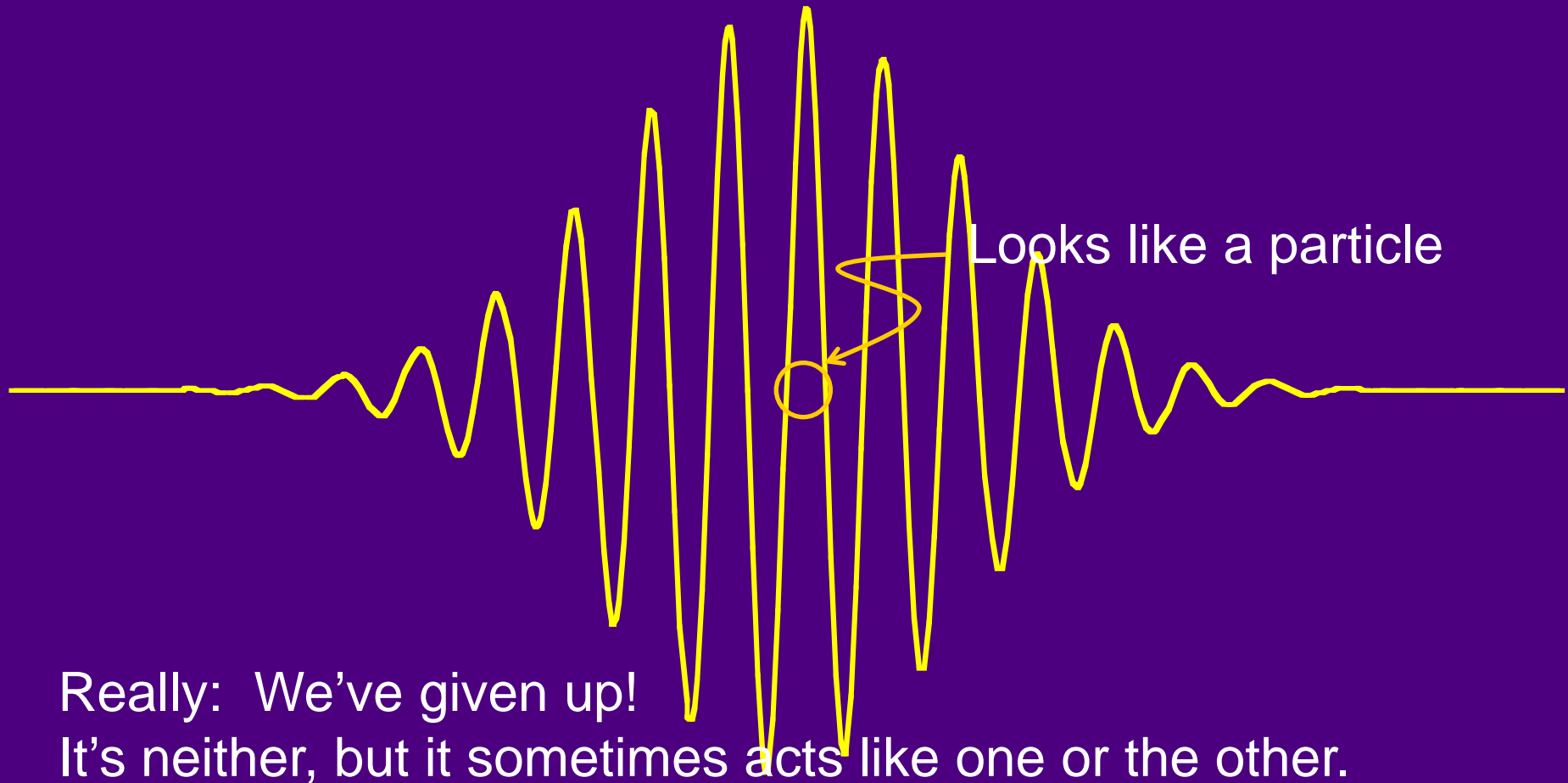
“God does not play dice!” (Einstein’s famous objection)

Quantum Mechanics is about really small things



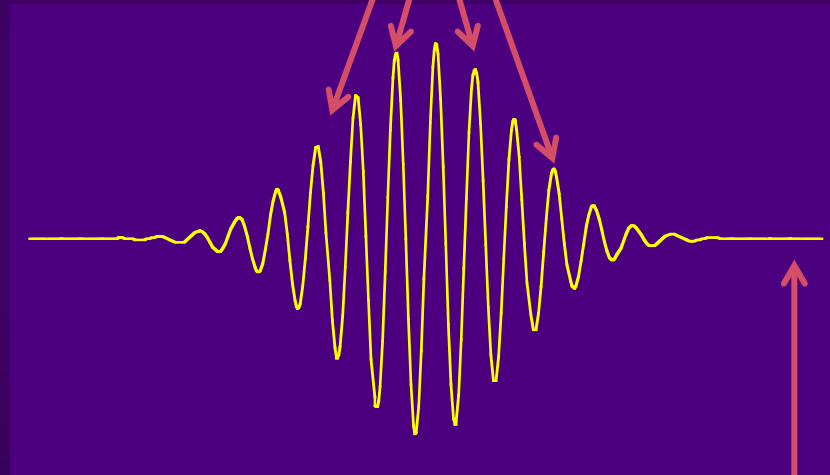
Atoms, protons, electrons...

Particles are Waves?



The Wave Tells All

The particle is somewhere in here



But not here

Shape of the wave: Energy, Velocity, etc.

Quantum means quantized

Answers come in whole numbers

Example: Coke cans in your refrigerator are quantized.



Waves can be quantized too -- like a violin string or jumprope

Measurements Part I: How to Sit in Three Chairs at Once

What's in a state?

State = whatever the particle is doing.

“In the tree” state



What's in a state?

State = whatever the particle is doing.

“In the tree” state

Wave wiggles in the tree



What's in a state?

State = whatever the particle is doing.

“On the couch” state

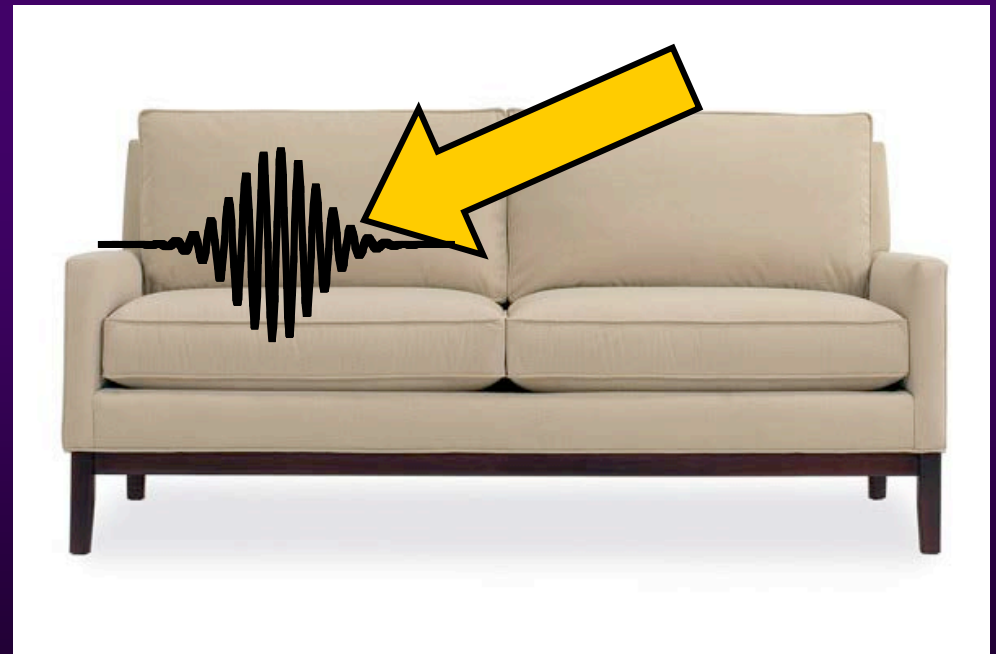


What's in a state?

State = whatever the particle is doing.

“On the couch” state

Wave wiggles on the couch



Measurements

Ask the particle questions

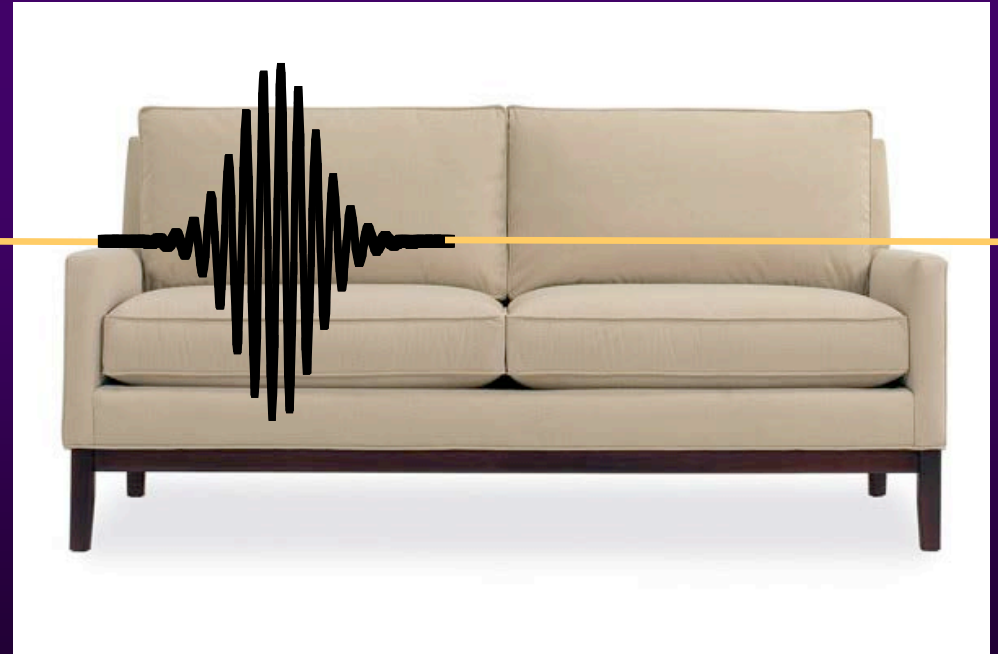
Where are you?



Waves can be in two places at once

There's still only one particle!

30% "In the tree" state and 70% "On the couch" state
(No more movie theater dilemmas!)



Measurements Part II: Observers Disturb What They Measure



Quantum Weirdness

Wave can do *anything*.

But only certain answers are allowed when we ask questions.

Like a bad government form (what's your ethnicity?)

Or like a spinning coin...



Official Quantum Measurement Form 101

Ask the particle: Where are you?
(Choose only one)

- On the couch
- In the tree
- On the ceiling
- Behind the door
-
-
-

Only certain
answers are
allowed!

Answers
must correspond
to “pure states”
according to
the question asked.

Measurements

Ask the particle questions

Where are you?



That was easy -- the wave was in a pure state.

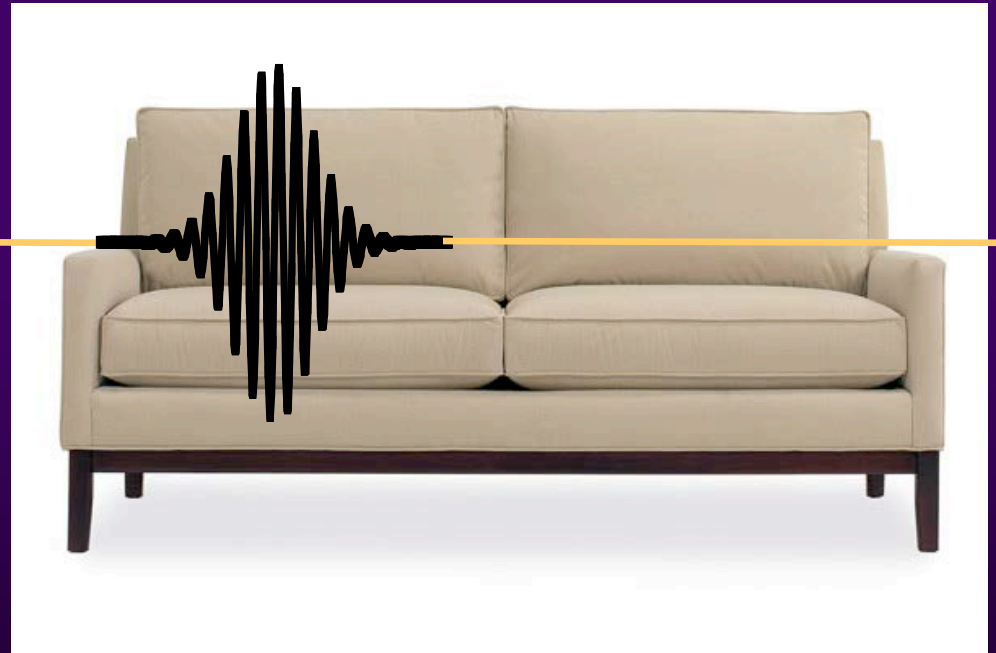
Where are you?

On the couch

In the tree

On the ceiling

Quantum Mechanics
forces the particle into
an *allowed state* so it can give
an *allowed answer*.



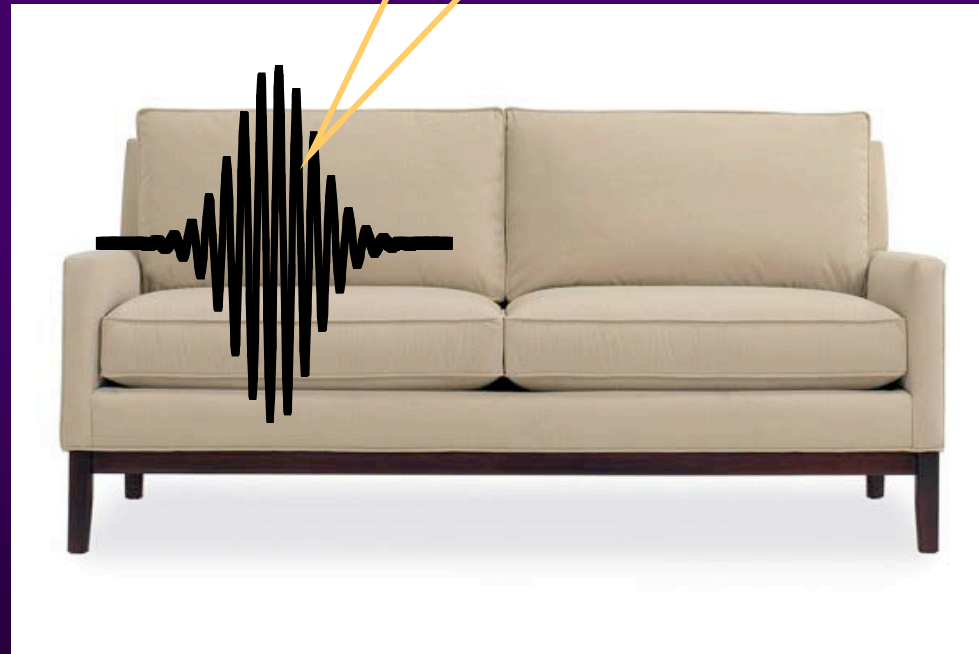
30% “In the tree” state and 70% “On the couch” state

Where are you?

On the couch

In the tree

On the ceiling



100% "On the couch" state



What happened?



Asking the question (taking a measurement)
forced the particle into an allowed state of that measurement.

Sudden, uncontrollable change.
The prior state only sets the probabilities.

The wavefunction is the real truth, and tells all.
Too bad we can't measure it directly!
We're stuck measuring position, energy, velocity...

What happened?

Spinning Coin



Question: Heads or Tails?

- No heads or tails while spinning
- Measurement forced a “pure” answer
- 50/50 chance

Particle



Question: Where are you?

- Two places before we asked
- Measurement forced a “pure” answer
- 30/70 chance

Observer Determines Reality?

In a very limited sense, yes.

By measuring, we choose the *allowed set of answers*

We never choose the *actual answer*



We only get to choose the dice...

Is it really a dice roll?



The particle doesn't even know which answer it will give until asked!

Experimentally confirmed by Bell's Inequality:
There are no "hidden variables" predetermining the outcome.

"God does not play dice" -- Einstein (wrong!)

Is The Whole World Random?



No. Casinos still make money.

Throw the dice enough times, and we know the outcome.

Quantum Police and the Uncertainty Principle

How to speed without getting a ticket



“I know you’re speeding!
Now, where are you?”

Quantum Police

Heisenberg's Uncertainty Principle

The more we know about
a particle's position
the less we know about
its momentum

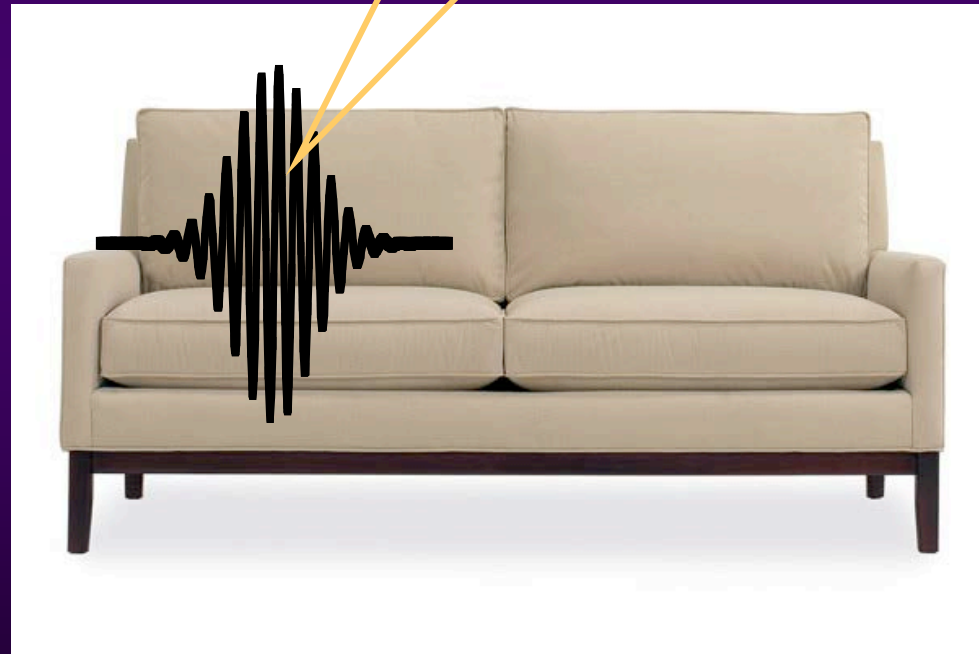
(Momentum? Think speed.)

Where are you?

On the couch

In the tree

On the ceiling

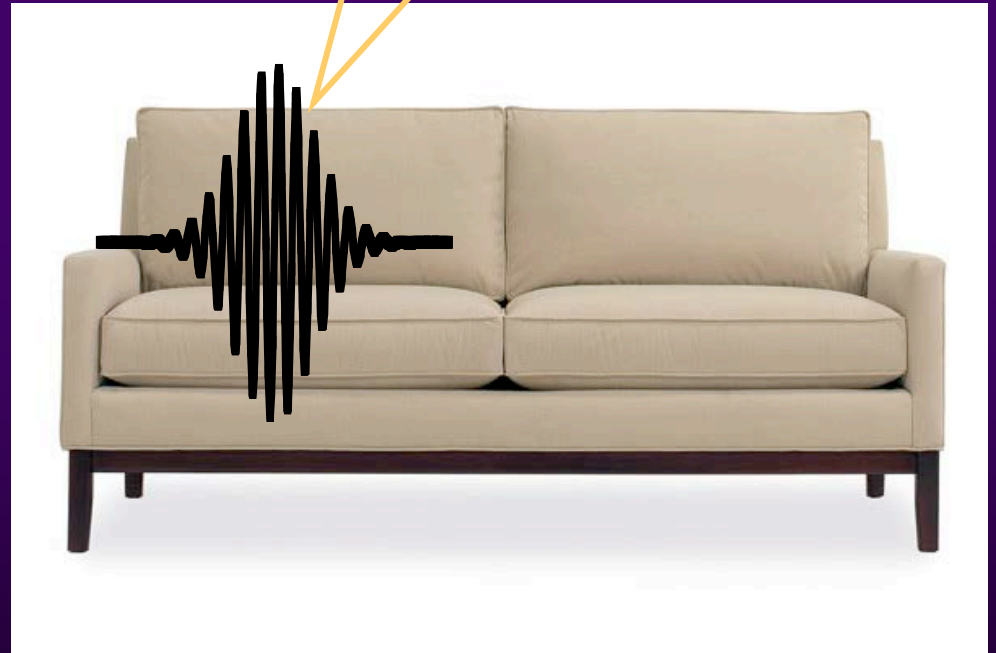


100% "On the couch" state

How fast are you going?

- Really fast
- Really slow
- Medium speed

There's no telling what speed I'll answer!



100% "On the couch" state

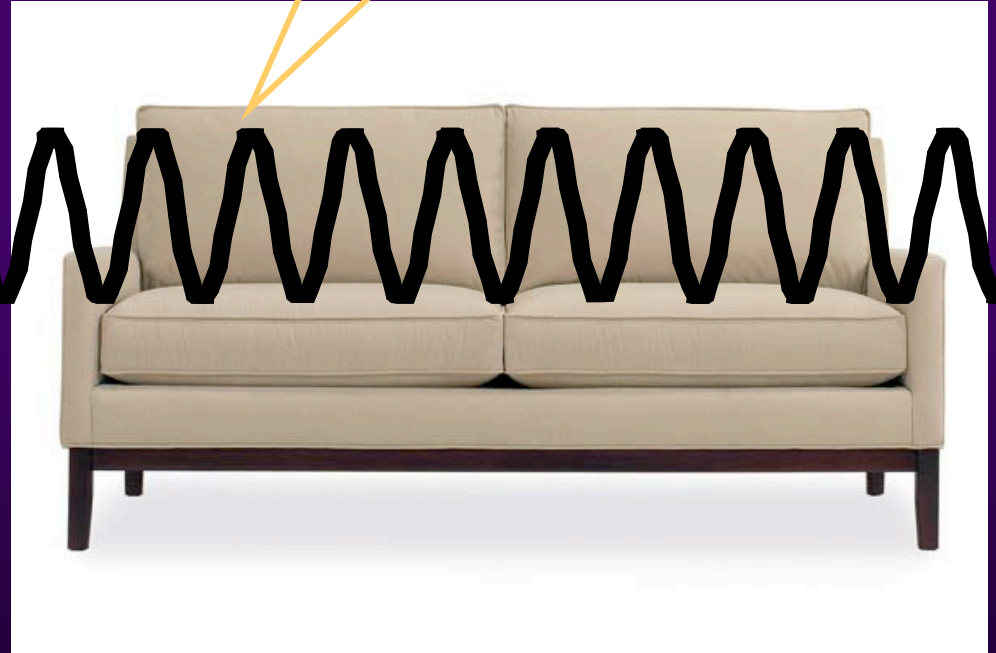
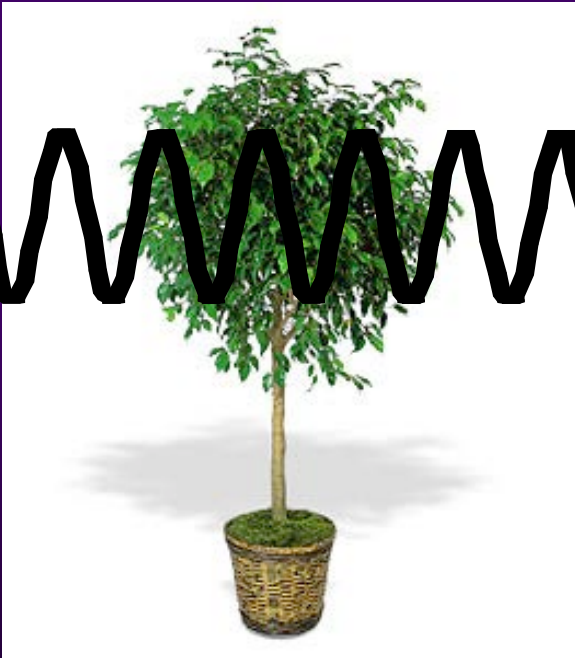
How fast are you going?

Really fast

Really slow

Medium speed

You had to ask!



100% "On the couch" state

All Waves Have Uncertainty

Momentum (speed) related to wavelength
(wavelength = repeat distance of the wave)

To be really sure of the repeat distance,
need to see the wave wiggle many times.



Really sure of the repeat distance, but
the particle is smeared out everywhere

All Waves Have Uncertainty

Momentum (speed) related to wavelength
(wavelength = repeat distance of the wave)

To be really sure of the position, need fewer wiggles.



Now the wavelength (and therefore momentum) is less certain.

No speeding tickets



Quantum Police

Sure, the officer knows your speed.

But he can't find you to write the ticket.

Quantum Myths

Quantum Myth #1

Quantum Mechanics means I can control/create reality

Quantum Truth:

Humans have even less control over outcomes in quantum mechanics than we do in classical mechanics.

We can force particles into new states,
but the outcome is uncontrollably random.

Quantum Myth #2

It takes a conscious observer to change the state

Quantum Truth:

Observers do not have to be conscious.
Any (inanimate) measurement device will do.

Quantum Myth #3

Quantum mechanics has uncaused events,
so maybe the universe itself is uncaused.

Quantum Truth:

Although we cannot predict *when* a
radioactive decay will occur,
we can predict *that* it will occur,
and we know *why* it occurs.

“If you think you understand quantum mechanics,
you don’t understand quantum mechanics.”
-- Richard Feynman

