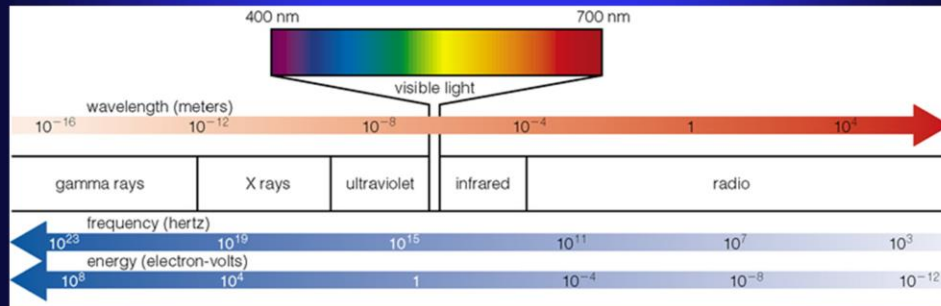




Quantum Mechanics

Light

“Color” refers to the Frequency or Wavelength of the light



Our eyes detect a rather small range of frequencies (wavelengths)

Visible meaning your eye can see it

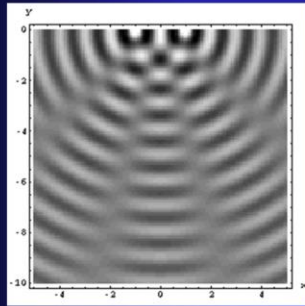
But it's ALL light

Radio waves are light with a looong wavelength.

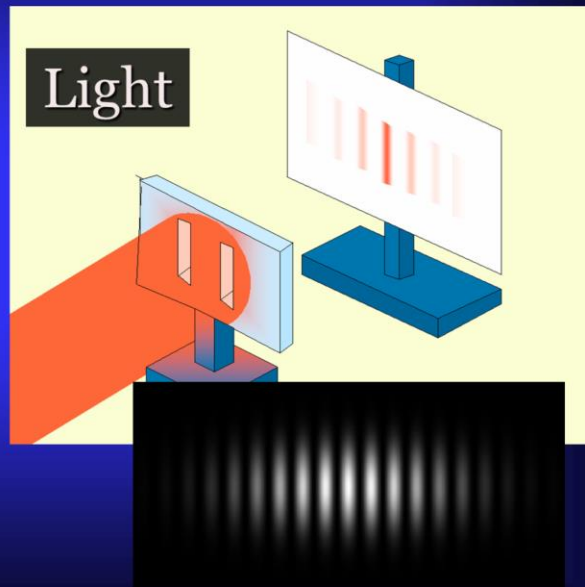
X-rays and Gamma rays are short wavelength light.

The characteristic of light that we call “color” is our eye’s response to the wavelength of the light.

Light is a Wave!



Ripple Tank



Light behaves like waves on the water.

When we force water waves through double slits, the waves interfere forming an interference pattern.

Shining light through a double slit results in an Interference Pattern also suggesting that light behaves like a wave.

No... It's a Particle

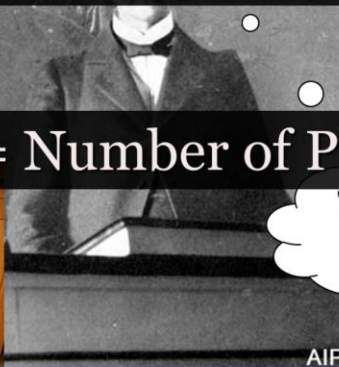
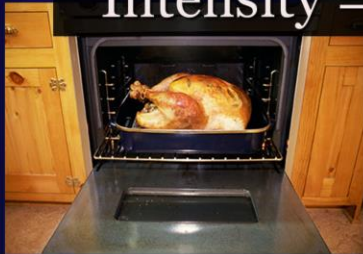
A Single Photon has a specific:
Wavelength or Frequency or Color

discrete jumps..

packets.

Intensity = Number of Photons

That's just
weird...



AIP

A turkey in an oven heats up by absorbing infra-red light from the oven walls. The temperature does not increase continuously, it goes up in little jumps.

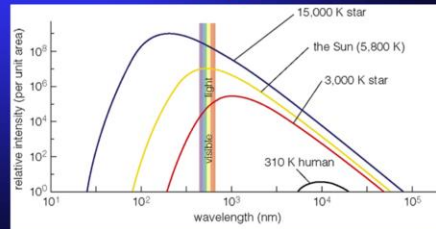
Sometimes, light behaves like a particle... it appears to come in little packets called "Photons"

Our interpretation of this phenomenon is that light is "granular," meaning that it comes in discrete packets called photons.

Black Body Radiation

What if... now this is going to sound crazy... but suppose the energy must be exchanged in discrete packets?

And each packet has Energy
 $E = hc/\lambda$



If you make a hollow oven out of iron, poke a hole in it, and take the spectra of the escaping light, that spectrum will be a black body curve.

Energy is being exchanged between the walls of the oven and electro-magnetic waves.

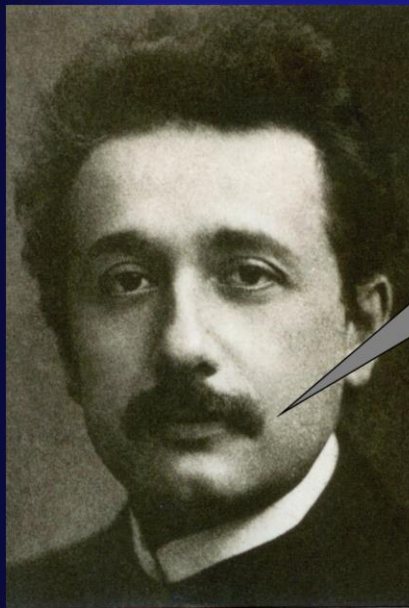
The classical view holds that any amount of energy can be transferred. It is a continuum.

The classical view fails to explain the black body spectrum.

If the energy exchange is restricted to discrete packets (photons), the black body curve arises naturally.

Photon energy is $h \cdot \nu$. We've seen this before, in the section about light.

The Photoelectric Effect



**Well of course!
Each packet of
energy is a photon
of light!**

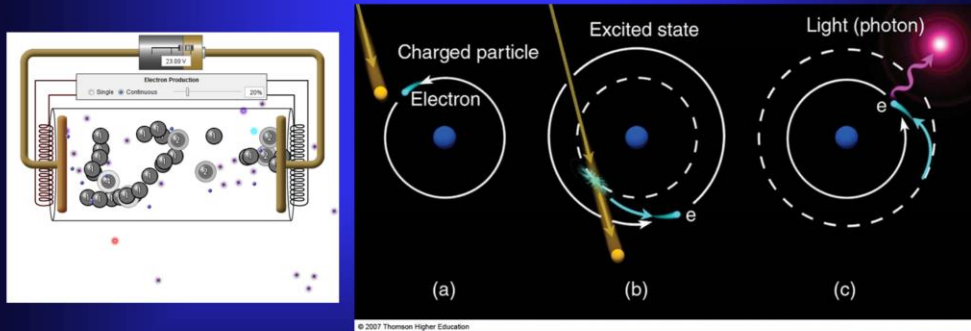


Another major piece of work by Einstein.

We talked about the photoelectric effect in our section on light.

Atomic Structure

Excited atoms *Selectively* emit photons



Classical View

Electrons in an atom can gain or lose energy (like the potential energy in a planetary orbit)

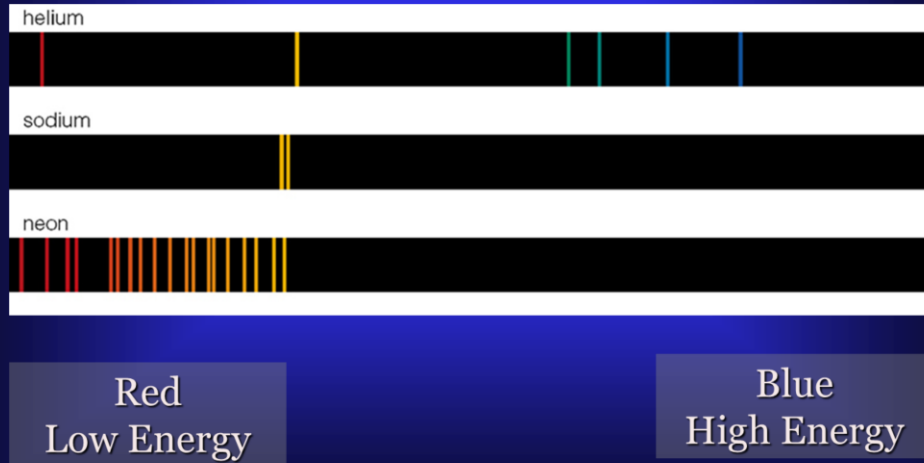
When they undergo a collision, the bound electron gains energy and bounces up. It doesn't LIKE being up, so it drops back down, losing energy and emitting a photon.

But, they can ONLY occupy discrete orbits, there are no in between.

Every element has its own unique set of orbital levels, and thus A fingerprint in light.

Emission Lines

Every substance has its own spectral fingerprint



So... if we excite some atoms, we'll see the fingerprint as emission lines.
A line is a very narrow emission feature of a very specific color

Hydrogen Emission

Ah! That's so cool!

So what if the angular momentum of electron orbitals are integer multiples of h !



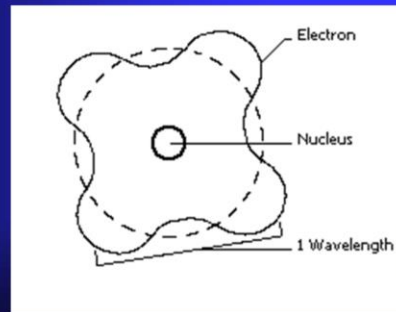
Aha! What if orbiting electrons are only allowed discrete energy levels too? And then, they release their energy as one of these new photon thingies with just the right amount of energy.

Then the hydrogen emission lines arise naturally. Exciting! We're really on to something here.

Particles can be Wavelike

Oooh! Oooh!

**If light can be particle
like...
Can electrons be
wavelike?**



If light can be a particle then....

Electrons can be waves. What's the wavelength of an electron wave?

Then electron orbits have to be, 1 wavelength, 2 wavelengths, 3 wavelengths, 4 wavelengths, ect...

That explains why Bohr's model worked.

What's the wavelength of a fastball? Very tiny, around 1×10^{-34} meters. Less than the size of the nucleus of an atom. We don't notice the wave nature of baseballs.

Schrödinger's Equation

Ahem. Yes well...

**I believe this is the
CORRECT
formulation**

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{8\pi^2 m}{h^2} (E - V) \psi = 0$$

Second derivative with respect to X
Shrodinger Wave Function
Position
Energy
Potential Energy



Don't memorize this...

We understand waves... So we can work out exactly how particle waves must work.

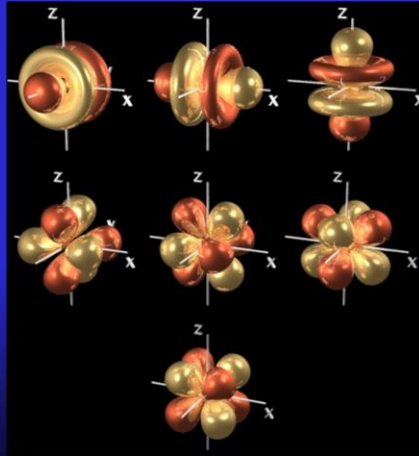
Don't memorize this.

Really... Nobody besides physicists and physics students need to know this.

Astronomers forget this equation as soon as the Quantum Mechanics course is over.

A Whole New Atom

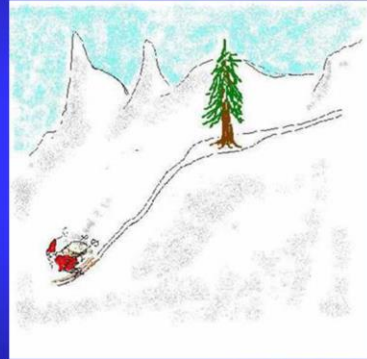
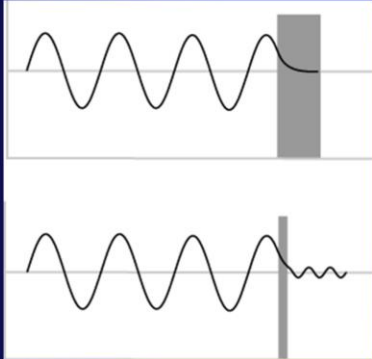
Since electrons are waves... what are electron orbits REALLY?



The solutions to the wave equation are interpreted as *probability distributions*. The waves represent the probability of finding the electron at a particular point in space around the nucleus.

Tunneling

Another consequence of particle/wave duality.



A particle can tunnel through an impenetrable barrier

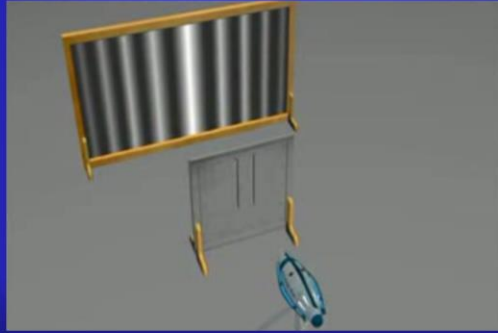
There is a small but non-zero probability that particles can appear on the other side of a classically impenetrable barrier

The probability of this happening is directly proportional to the wavelength of the particle.

There is an extremely small chance that you will tunnel through your seat and appear suddenly in the basement.

The Double Slit

Spooky intelligent particles



The Uncertainty Principal



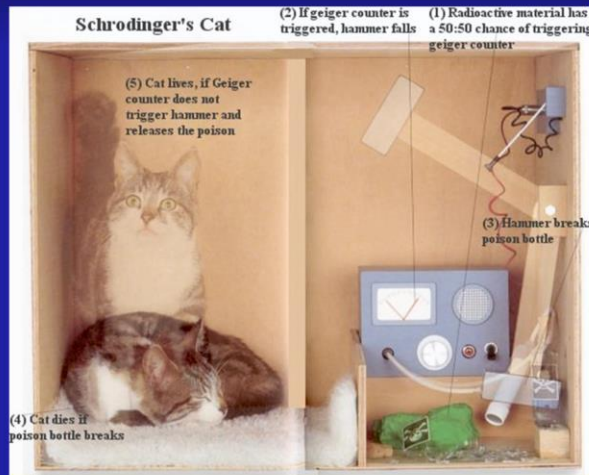
We cannot simultaneously know the **position** and **velocity** of a particle

Heisenberg went further... He said that the actual position of the particle is CHOSEN when and ONLY when it is observed.

Somehow, nature depends on the observer to decide what state it's in.

If a tree falls in the forest and nobody is there to hear it... It waits in an in between state until it is observed.

Schrödinger's Cat



The cat does not *choose* a state (alive or dead) until it is observed

A live cat is placed in a box.

Some random event is set up to break a poison bottle which will kill the cat.

Once the box is closed, the cat is neither alive or dead.

It chooses a state once it's observed.

Preposterous! says Einstein. God does NOT play dice with the universe.