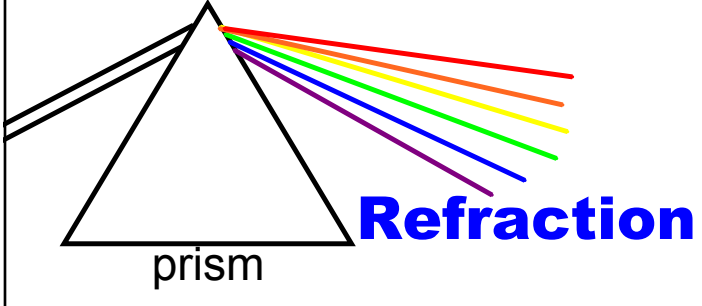
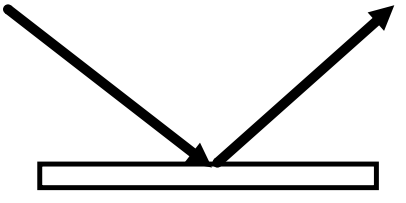
Is light a particle or a wave?

Isaac Newton

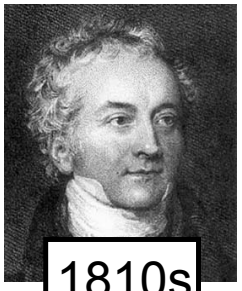
Christiaan Huygens



Refraction



Reflection



1810s

Thomas Young

Light bends around corners. (Diffraction)

(it's a wave?)

1810s

Etienne -Louis Malus

Light can be polarized

(it's a wave.)

1820s

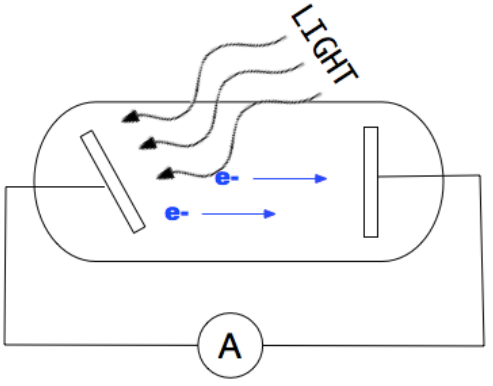
Augustin -Jean Fresnel

Explained refraction, diffraction and polarization in terms of light's wave nature.

(ok, it's definitely a wave)

BUT...

The Photoelectric Experiment



Light dislodges electrons.

But below a certain minimum frequency of light, no electrons are dislodged, no matter how bright the light is.

Einstein (1905)

It is as if the light is really a bunch of little separate packets of energy that can't combine. "Photons."

Higher frequency means each photon has more energy and each can dislodge an electron.

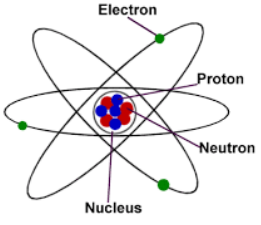
Brighter light just means more photons, but if each one isn't enough to do the job, then no electrons are dislodged.

So light is a particle again???

First Try: Atomic Model

1910s

Niels Bohr



When atoms emit or absorb light, their electrons will change orbits.

But it seems like only certain orbits are allowed.

That means they'll only absorb or emit light in packets of energy that correspond to the allowed orbits.

"Quantum of Energy"

Wave-Particle Duality

Light has properties of both, depending on the experiment you do.

First inkling that maybe things in the world of the small don't behave like things on our level.

1920s

Louis de Broglie

If waves like light can act like particles...

Could particles like electrons act like waves??

Maybe electrons aren't in orbits at all.

Maybe they're like waves around the nucleus and only certain frequencies are allowed.

1920s

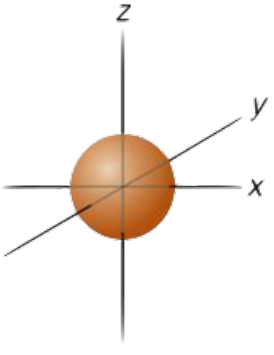
Werner Heisenberg

Matrix Mechanics

A mathematical model of the atom.

Predicts the probability of finding the electron around the nucleus.

But it only predicts probabilities.



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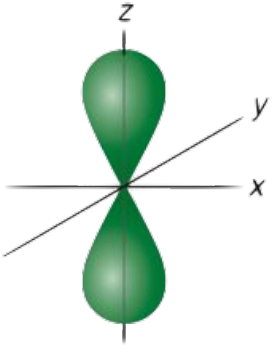

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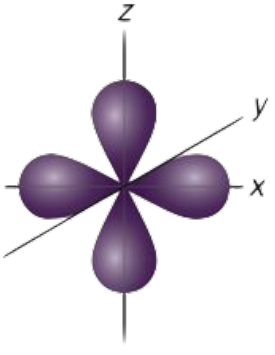

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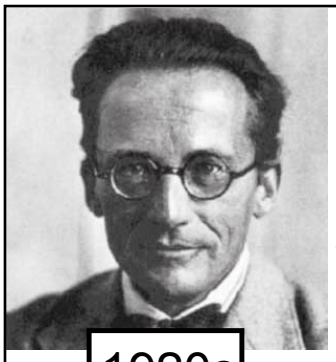
Orbitals, not orbits



1920s

Erwin Schrödinger

Wave Mechanics

The electron is a wave around the nucleus.

The catch: the wave function includes imaginary numbers.

Note: Schrödinger's wave mechanics and Heisenberg's matrix mechanics are equivalent.

1920s

Werner Heisenberg

Interacting with an electron changes it's energy & position, so you can't know both at the same time.

The Heisenberg Uncertainty Principle

Position & energy of an electron can't both be known accurately at the same time.

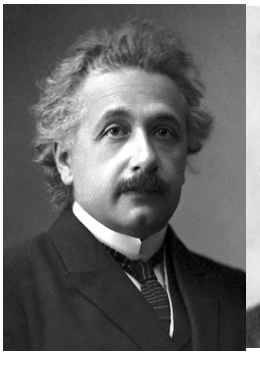
So maybe the electron is just a cloud of potentiality until you measure it.


Bohr & Heisenberg

What goes on at the atomic level can't be visualized. It's all just probabilities.

Einstein & Schrödinger

"God does not play dice with the universe."




Relativity

Gravity, fields, space

The realm of
the very large

Quantum Mechanics

Particles, waves, probability

The realm of
the very small

All attempts to combine them into one theory get stuck. They are just too different.

So either one is right

and the other wrong

or

There's a larger theory

that they both fall under.

The only way to know would be to get data from somewhere where they both apply.

But where??

The Singularity of a Black Hole.