# Quantum Explainers 02

## QUANTUM STATES

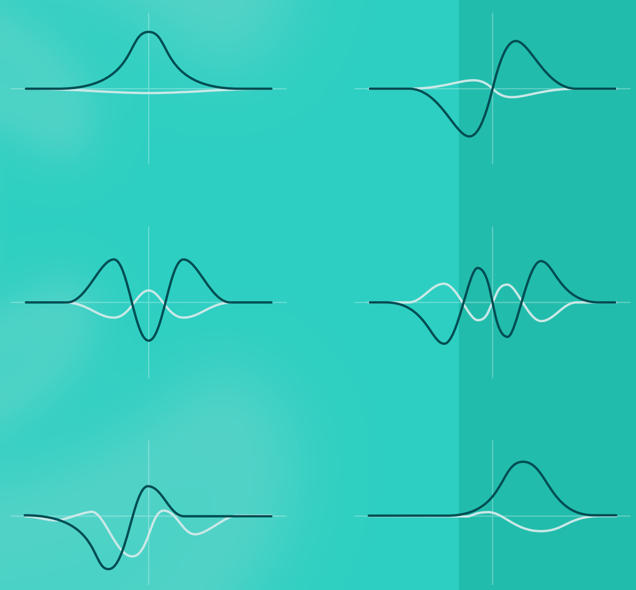
### WAVEFUNCTION

In quantum physics, everything can be thought of as a wave. We use maths to describe the shape and size of this wave, and this is called the **'wavefunction'**.

Even people!

The wavefunction tells us everything we need to know about a particle, like where it might be and how it might behave. The wavefunction of a particle describes its **'quantum state'**, which is a fancy way of saying what we'd expect the particle to look like when we measure it.

Waves can take on lots of different forms



### SPIN

In the quantum world, all things are made of particles. Even light is made up of particles called 'photons'.

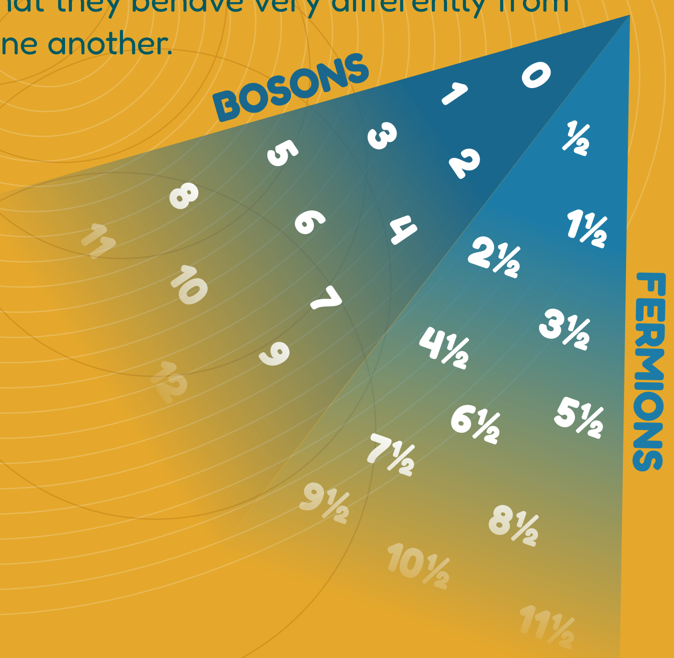
These particles have something that we call 'spin', a bit like the way a ball can spin around. It's not exactly the same, but our world doesn't have a good example of how it really is – that's how different the quantum world is to our own!

One difference between the world we're used to and the quantum world is that spin is 'quantised'.

This means that it can only have certain values – in this case, only full numbers and ½ numbers.

Particles with 'half integer' spin (e.g. ½ or 1½) are known as fermions. Particles with 'full integer' spin (e.g. 0, 1 or 2) are known as bosons. The spin of these two types of particle means that they behave very differently from one another.

An integer is just a word for any whole number, like 1, 37, 854 and all of the others.



# BOSE-EINSTEIN CONDENSATE

When you make some kinds of particles really, really cold, they all start to behave in exactly the same way, so that you can't tell them apart. This is called a 'Bose-Einstein Condensate' or BEC.

We mean really cold. Below -270°C! That's almost as cold as it's possible to make something.

Bose-Einstein condensation only happens for bosons – particles which have whole-number spin.

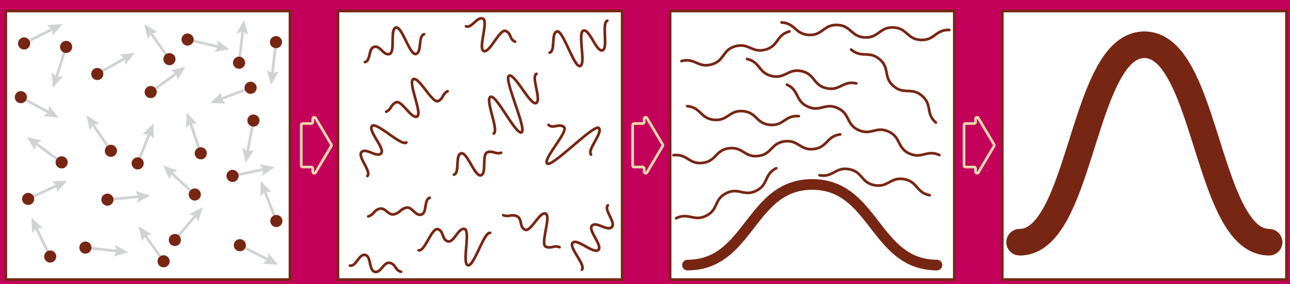
At these cold temperatures, the bosons have very little energy to move around, which makes their wavelengths get larger. When that wavelength grows to become similar to the distances between the particles, the bosons form a quantum state of a BEC, where all the bosons behave identically as one big, but spread-out particle.

BECs allow us to study the quantum world at much larger scales than we'd usually be able to see it - sometimes as large as millimetres!

BECs have helped make measurements more precise and may eventually make better sensors for things like navigating.

BECs might one day give us better navigation.

When the bosons' wavelengths overlap with one another, they behave as if they were just one particle!



High temperature | Low temperature | Slightly above absolute zero | Bose-Einstein condensate

# QUANTUM ENTANGLEMENT

Imagine having two lights that are linked so that there's always one that's on and one that's off. Turning one of them on or off means that the other must change at the same time. We can say that the two lights are 'entangled', because the state of one depends on the state of the other.

At the quantum level, the same thing can happen with particles, where the quantum state of one particle depends on the quantum state of others.

Even if the particles are moved very far away from each other, this link can still exist. In the future we hope to use this as a way to communicate.

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