THE QUANTUM CITY

EVERYDAY GUIDE TO QUANTUM SCIENCE

www.quantumcity.org.uk

WHAT IS QUANTUM SCIENCE?

Quantum science focuses on the behaviour of matter and energy at it's most fundamental level. Also known as quantum mechanics, this area of physics explores the often counterintuitive behaviour of atoms, subatomic particles and waves.

Understanding how the world behaves at this level is allowing scientists to make remarkable advances across a wide range of areas. Although it focuses on how the world behaves at the very smallest level, developments being made in this field will have a big impact on all our lives.

PROBABILITY

What is probability?

Probability is all about chance. Like rolling a dice or flipping a coin, some actions are based on chance. Quantum mechanics is a probabilistic theory: it shows us how many actions at the smallest level are based on chance and do not come with definite answers. This causes all kinds of interesting effects that can seem very strange to us because most things on 'human scale' don't behave like this.

ATOMS

What is an atom?

The atom is the basic building block for all matter in the universe. Atoms are extremely small and made up of a few even smaller particles. The basic particles that make up an atom are electrons, protons, and neutrons. Atoms fit together with other atoms to make up matter.

WAVE-PARTICLE DUALITY

What is wave-particle duality?

It is possible to describe an atom, an electron, or a photon as either a wave or a particle. In reality, they are both: a wave and a particle. They have wave and particle properties which manifest with different predominance depending on the experiment and the thing being experimented on.

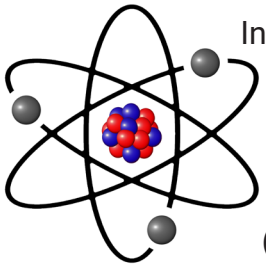
IS LIGHT A WAVE?

Is light a wave?

Scientists used to believe light was a wave, then we discovered it had the properties of a particle called a photon. Now we know that like all elementary quantum objects, it is both a wave and a particle!

QUANTUM STEPS

What are quantum steps?



In nature, properties like energy possessed by electrons cannot take any value, rather, there are discrete steps in values they can take.

Science can use these well understood steps to fix points precisely on measurement scales (e.g. for time).

ENTANGLEMENT

What is entanglement?

Entanglement is the property that gives correlations – stronger than any with which we are familiar in everyday life – between two or more quantum systems, even when these are separated by large distances. This can mean that if you observe the state of one system, you automatically know the state of the other.

SUPERPOSITION

What do we mean by superposition?

Superposition is the principle describing the ability of a quantum system to be in two or more states at the same time. A potentially helpful analogy is a musical note, which generally comprises many different fundamental tones or harmonics playing together at the same time.

THE UNCERTAINTY PRINCIPLE

What is the uncertainty principle?

Heisenberg's uncertainty principle states that, when working in the world of quantum mechanics, you cannot be completely certain of some paired features.

A common example is you can either know the exact speed or location of a particle but not both exactly, at the same time. The more you know about one the less you know about the other, and there will always be some uncertainty.

QUANTUM TUNNELING

What is quantum tunneling?

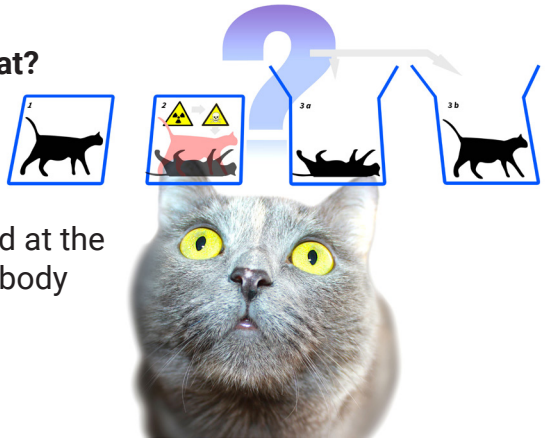
Quantum tunneling is a phenomenon where an atom or a subatomic particle can appear on the opposite side of a barrier that should be impossible for the particle to penetrate.

This happens when quantum objects "borrow" energy in order to bypass an obstacle such as a gap in an electrical circuit. It is possible, thanks to the uncertainty principle, and enables quantum particles to do things other particles can't.

SCHRÖDINGER'S CAT

What is Schrödinger's cat?

A hypothetical experiment in which a cat kept in a closed box can be alive and dead at the same time – as long as nobody lifts the lid to take a look.



DISTURBANCE

What is disturbance?

When we try to measure or interact with a quantum system to learn about what it is doing, we inevitably and irreversibly disturb it.

MANY WORLDS THEORY

What is the many worlds theory?

The Many-Worlds interpretation of quantum mechanics is that many universes exist in parallel at the same space and time as our own. It comes from the idea that each possible outcome of physical actions on the quantum scale creates a distinct universe. All possibilities become actualities — just in alternate realities!

TELEPORTATION

What is teleportation?

Quantum tricks allow a particle to be transported from one location to another without passing through the intervening space – or that's how it appears. The reality is that the process is more like scanning an image in one place to be printed somewhere else, where the information held by one particle is written onto a distant particle.

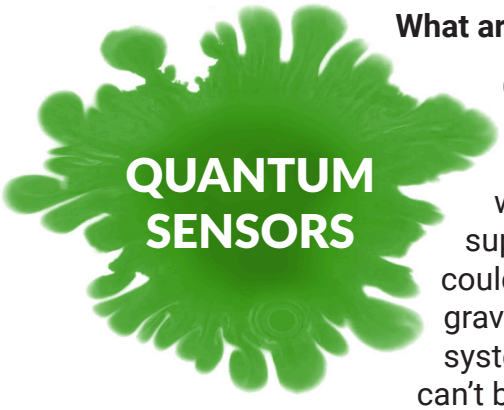
QUANTUM COMPUTING

What is a quantum computer?

Quantum computers harness the properties of quantum physics to perform calculations and store data.

In standard computing, information is represented by a series of 0s and 1s, known as bits, but ecause quantum particles can exist in many different states at once, a quantum bit - or qubit - is able to represent both 1 and 0 at the same time. This opens up the opportunity for extremely fast processing and the ability to tackle tasks that might take conventional computers hundreds of years to perform.

Find out more from the UK's Quantum Computing and Simulation Hub website here:
https://www.qcshub.org



What are quantum sensors?

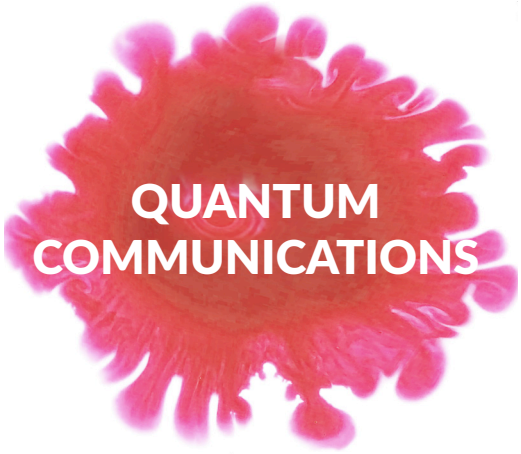
Quantum sensors have the potential to be cheaper, lighter, smaller, more sensitive and more energy-efficient than their existing, classical counterparts. These quantum devices will harness key principles of quantum mechanics such as superposition and entanglement to develop technology that could include lighter wearable brain scanning devices, quantum gravity sensors, atomic clocks for high precision use in radar systems, and navigation systems to be used in places that GPS can't be.

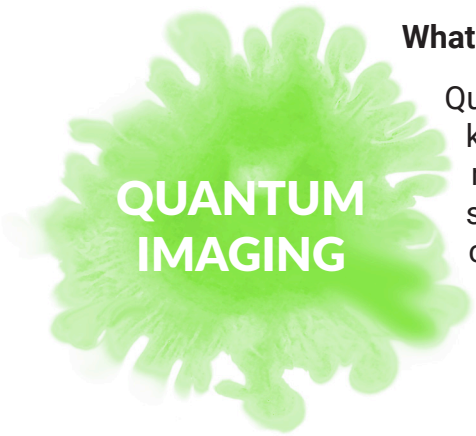
Find out more about the UK Quantum Technology Hub for Sensors and Timing at **https://www.quantumsensors.org/**

What are quantum communications?

Quantum communications will harness the fundamental properties of quantum physics, including superposition, uncertainty and entanglement, to provide guaranteed secure communications at all distances, future proofing cybersecurity for a quantum-enabled world.

Find out more about the Quantum Communication Hub here:**https://www.quantumcommshub.net/**





What is quantum imaging?

Quantum imaging devices with increased performance, thanks to key principles of quantum physics such as entanglement, will revolutionise imaging and have a huge impact upon industry and society as a whole. Quantum imaging technologies will include cameras that can see round corners, through smoke, fog and underwater, super sensitive gravity mapping and non-invasive medical devices.

Find out more from the UK Hub for Quantum Enhanced Imaging website at **https://www.quantic.ac.uk**

The UK National Quantum Technologies Programme

The UK National Quantum Technologies Programme is a ten-year, £1 billion public and private investment established by the UK Government, to ensure the successful translation of quantum technologies from laboratory to industry. The programme aims to create a coherent government, industry and academic quantum technology community that gives the UK a world-leading position in the emerging multi-billion-pound new quantum technology markets.

QUANTUM IN THE UK

More information on the UKNQTP can be found on the UK National Quantum Technologies Programme website at **https://uknqt.ukri.org**

QUANTUM VISIONS

Use your newfound knowledge of quantum science as inspiration to create art, photos, models or sculptures to enter in the Quantum Visions art competition from Quantum City:

www.quantumcity.org.uk/visions

We look forward to seeing your entries!

UKRI Engineering and Physical Sciences Research Council

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME