The Atom Is Not a Solar System

Why the picture you were taught is quietly, beautifully wrong

You've drawn it a hundred times: a tiny nucleus with electrons whizzing round in neat rings. It's one of the most useful wrong pictures in all of science – and the truth is far stranger.

EXAM LINKS *AQA A-level Physics (7408): 3.2 Particles and radiation; 3.8 Nuclear physics. Extension: quantum behaviour of electrons and the stability of matter.*

Almost everyone leaves school with the same image of an atom in their head. A dense central nucleus, and electrons circling it in tidy orbits like planets round the Sun. It appears on posters, logos and hazard signs. It is simple, memorable and easy to draw. It is also, as a description of reality, wrong – and the ways in which it is wrong open the door to the whole of quantum physics.

This isn't a case of your teachers misleading you. The "planetary" picture (the **Bohr model**, from 1913) was a genuine step forward and it still explains a surprising amount. But physicists have known for a century that electrons do not really orbit at all.

Problem one: an orbiting electron should die

Here is the first crack, and it was obvious almost immediately. An electron is a charged particle. According to the classical physics of Maxwell – the same physics that makes radio work – any charged particle moving in a circle is accelerating, and an accelerating charge radiates energy as electromagnetic waves. An orbiting electron should therefore continuously bleed away energy and spiral into the nucleus in a tiny fraction of a second. Every atom in your body should have collapsed long before you finished reading this sentence.

They don't. Atoms are stubbornly, reliably stable. Classical physics simply cannot explain why – which told physicists that something entirely new was going on at this scale.

The real picture: clouds of probability

In the 1920s a new theory, **quantum mechanics**, replaced the orbits with something much harder to picture. An electron in an atom does not have a definite path or a definite position at all. Instead it exists as a spread-out **cloud of probability** – a fuzzy region around the nucleus where the electron is more or less likely to be found if you looked. These clouds are called **orbitals**, and they come in strange shapes: some are spheres, some are dumbbells, some look like clover leaves. Not one of them is a ring.

An electron isn't a little ball tracing a line, and it isn't smeared out like butter either. It is something genuinely new, for which everyday language has no good word. The probability cloud is the closest honest picture we have.

Atoms are almost entirely empty space

Whatever shape the cloud takes, one fact survives from the old model and is worth dwelling on: the atom is overwhelmingly empty. If you scaled a nucleus up to the size of a pea and placed it on the centre spot of a football stadium, the electron cloud would reach the back row of the seats, with essentially nothing in between. Well over 99.99% of an atom – and therefore of you, and of this page – is empty space.

Which raises a wonderful question. If atoms are almost all nothing, why does anything feel solid? Why don't you fall straight through your chair?

Why you don't fall through your chair

It is tempting to say "the atoms touch", but they never do. Two effects keep matter apart. The first is ordinary **electrostatic repulsion**: the electron clouds of your body and the chair are both negatively charged, and like charges repel. The second is a purely quantum rule called the **Pauli exclusion principle**, which forbids electrons from being crammed into the same state – a kind of resistance that has no classical explanation at all. Physicists still debate how the credit is shared between the two, but the headline is astonishing: "solidity" is not stuff meeting stuff. It is fields and quantum rules holding two clouds of mostly-empty space a whisker apart. You have never actually touched anything in your life.

Why the wrong picture still earns its place

So why are you still taught the planetary model? Because it is a superb *first approximation*. It gets the idea of energy levels roughly right, it explains why atoms emit specific colours of light, and it is the natural stepping stone to the real thing. Good physics education often works this way: you are given a model that is wrong in its details but right in its spirit, then later you are shown where it breaks and what replaces it. Terminal velocity, Newton's laws and the atom are all like this. Spotting the moment a trusted model cracks – and being excited rather than cheated by it – is one of the real pleasures of studying physics.

Terms explained

Bohr model The 1913 model of the atom with electrons in fixed circular orbits; useful but now known to be incorrect in its details.

Orbital A region around the nucleus describing where an electron is likely to be found; it replaces the idea of a fixed orbit.

Probability cloud A way of picturing an electron as a spread-out likelihood of being found in a region, rather than as a particle on a path.

Quantum mechanics The theory describing matter and energy at very small scales, where classical ideas of definite position and path break down.

Electrostatic repulsion The pushing-apart force between objects carrying the same type of electric charge.

Pauli exclusion principle A quantum rule stating that certain particles (including electrons) cannot occupy the same quantum state; a major reason matter is stable and solid.

Key points

- The planetary/Bohr model of the atom is a useful approximation, not a true picture.
- A classical orbiting electron should radiate energy and spiral into the nucleus – but atoms are stable, which classical physics cannot explain.
- In quantum mechanics, electrons occupy probability clouds (orbitals) of various shapes, not rings.
- Atoms are more than 99.99% empty space.
- Solidity comes from electrostatic repulsion and the Pauli exclusion principle – atoms never actually touch.

Think about …

- The Bohr model survives in schools despite being wrong. Suggest one thing it explains well and one thing it gets wrong.
- Explain, using the idea of an accelerating charge, why classical physics predicts atoms should collapse.
- If atoms are almost entirely empty space, how would you answer a younger student who asks why a table feels solid?
- Light can pass through glass but not through a thin sheet of metal, even though both are mostly empty space. What does this suggest about "emptiness" at the atomic scale?