Electrons Move Slower Than a Snail

Why the lights come on instantly even though the electrons barely move

Flick a switch and the light comes on at once, so it feels obvious that electrons must race through the wire at nearly the speed of light. They don't. In a typical wire they drift slower than a snail – and the explanation is wonderful.

EXAM LINKS *AQA A-level Physics (7408): 3.5 Electricity – current, charge carriers, drift velocity (I = nAvq); the distinction between charge flow and energy transfer.*

It seems like the safest assumption in the world. You press a switch and the bulb lights instantly, even if it's at the far end of a long wire. So the electrons must be hurtling along at enormous speed – near light speed, surely – to get there so fast. It's the picture almost everyone carries in their head. And it's wrong by an almost comical margin.

The astonishing slowness of electrons

In a typical copper wire carrying a household current, the electrons that make up the current drift along at **less than a millimetre per second**. That's not a typo. Their average forward speed – called the **drift velocity** – is so slow that a single electron would take something like **half an hour to travel one metre** down the wire. A snail would beat it comfortably. If the light only came on once electrons had travelled from the switch to the bulb, you would be waiting a very long time in the dark.

You can see why from the equation you'll meet at A-level, $\boldsymbol{I = nAvq}$. The current I is large not because the electrons are fast (the drift speed v is tiny) but because the number of charge carriers n is staggering – a cubic metre of copper holds around 10^{29} free electrons. A vast, slow-moving crowd delivers a big current without any individual moving quickly.

So why is the light instant?

If the electrons crawl, why does the bulb light the instant you flip the switch? Because the *signal* is not the same thing as the *electrons*. The wire is already packed full of free electrons everywhere – including right next to the bulb – before you touch the switch. When you close the circuit, an **electric field** sweeps through the wire at close to the speed of light, and every electron along the whole length starts drifting almost at once, like water starting to move all along a hose the instant you open the tap. The electron at the bulb doesn't wait for the one from the switch to arrive – it was already there, and it gets the "go" signal immediately.

Three speeds hiding in one wire

The confusion clears up once you realise a wire actually contains *three* different speeds. First, the **drift velocity** – the slow net crawl of the electrons that is the current – a fraction of a millimetre per second. Second, the **signal speed** – how fast the electric field, and so the "switch-on", travels – a large fraction of the speed of light. Third, and most surprising, the **random thermal speed**: even with no current at all, the free electrons are already whizzing around in all directions at around a million metres per second, like a frantic swarm of bees. Switching on the current just adds a barely-perceptible forward drift to that furious random motion. "How fast do electrons move?" has no single answer – it depends which of the three you mean.

Why this matters

This isn't a curiosity to file away – it fixes a mental model that would otherwise quietly mislead you all through electricity. Understanding that current is a slow drift of a huge number of carriers, while energy and signal travel almost instantly through the field, is exactly what you need to make sense of circuits, of why wires heat up, and of how power reaches your home the moment it's generated. It also captures something you'll see again and again in physics: the thing that moves and the thing that carries the message are often not the same thing at all.

Terms explained

Drift velocity The slow average forward speed of charge carriers (electrons) that constitutes an electric current; often well under a millimetre per second.

Charge carrier A particle that carries electric charge through a material; in a metal wire these are free electrons.

I = nAvq The equation for current: n is the number of carriers per cubic metre, A the cross-sectional area, v the drift velocity and q the charge on each carrier.

Electric field The influence that sweeps through a circuit at near light speed when it is switched on, setting all the electrons drifting almost at once.

Thermal motion The rapid, random movement of electrons (around 10^6 m s^{-1}) that happens even when no current flows and averages to zero.

Key points

- In a typical wire, electrons drift at less than a millimetre per second – slower than a snail.
- Current is large because the number of charge carriers is enormous, not because they move fast (I = nAvq).
- The bulb lights instantly because the electric field sweeps through the already-full wire at near light speed.
- The electrons at the bulb were already there; they don't travel from the switch.
- A wire hides three speeds: slow drift, near-light-speed signal, and fast random thermal motion.

Think about …

- Explain how a wire can carry a large current even though each electron moves extremely slowly.
- When you flip a switch, the distant bulb lights almost instantly. Explain why, given that the electrons crawl.
- Using I = nAvq, explain what happens to the drift velocity if the same current flows through a thinner wire.
- Distinguish clearly between the drift velocity of electrons and the speed at which the "switch-on" signal travels.