How fast does electricity travel?

Well this question really needs some clarification, as the term electricity can be used in various ways and to means different things. Here we are talking about electric current.

Electric current is defined as the ordered movement of charge. The charge that moves in electricity could be ionic charges in a liquid or a gas (right). However most of us usually think of electrons as the charge carrier in electricity. So we will refine the question further by saying “How fast is an electric current comprising of moving electrons?”.

The unit of current is the Ampere. One ampere of current flows when one Coulomb passes a given point in a circuit in one second. The Coulomb is the unit of charge as is equivalent to 6.25×10^{18} electrons.

Okay, let’s make the question really clear, when we close a switch in a circuit say to turn a light bulb on, how fast do electrons actually flow in the circuit?

The simple answer is that electrons inside the wires move *very slowly*, almost as slowly as the minute hand on a clock! The exact velocity of the electrons will depend on how much current is flowing and the type of conductor that it flows in.

Suppose a length of copper wire is connected into a series circuit with a length of aluminium wire of the same diameter. The charges in the copper will be flow slower than those in the aluminium. Why?

Both copper and aluminium have one moveable charge carrier (electron) for electricity. However *copper is denser* than aluminium. Therefore copper has more free charge carriers in its cross sectional area than aluminium.

Alright but really how fast?

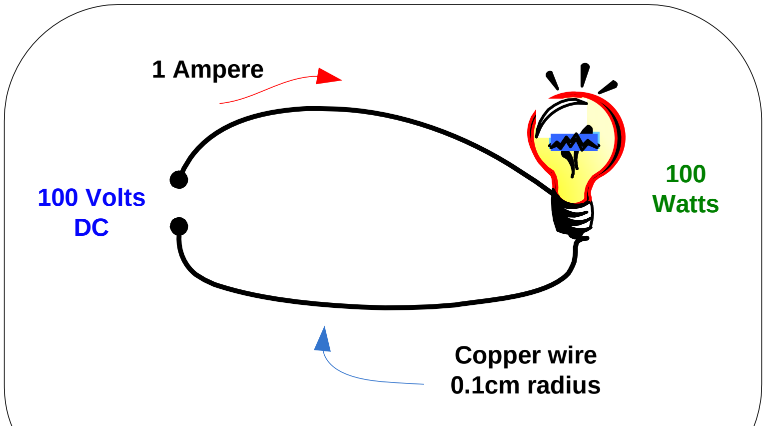

Figure 1

To work out a close approximation of how fast an electric current is flowing in any conductor we need to know the *charge carrier density* on the material carrying the current. In other words the number of free electrons per cubic measure.

Since nothing visibly moves when electrons flow, we cannot measure their speed by eye. Instead we need to do it by making some assumptions and do a calculation. Let's say we have an electric current through a light bulb as shown in figure 1.

We will use a light bulb of 100 watts. To simplify the maths a little we will say the bulb operates at 100 Volts DC. The current the bulb will draw will be 1 ampere for 100 watts; from P=E x I, therefore I=P ÷ E.

We will use copper conductor with a diameter (D) of 0.2 cm or a radius (R) of 0.1 cm.

Copper has one mobile (free) electron per atom. The number of mobile electrons (one per atom) per cubic centimetre for copper is $Q = 8.5 \times 10^{22}$

The charge 'e' of a single electron = 1.6×10^{-19} coulombs

{ A coulomb is then equal to exactly $6.241\,509\,629\,152\,65 \times 10^{18}$ elementary charges. Therefore the charge of a single electron is then $1/6.241\,509\,629\,152\,65 \times 10^{18} = 1.602 \times 10^{-19}$ Coulombs – *rounded to 3 places*.}

The Mathematics

$$V = \frac{1}{Q\,e\,R^2\,\pi}$$

V = velocity of charges (cm/sec)
I = current in amperes
Q = number of mobile charge carriers per cc
e = charge of a single electron in Coulombs
R = radius of conductor
π = numeric constant approx. 3.14159

$$V = \frac{1}{8.5 \text{x} 10^{22} \text{ x} 1.6 \text{x} 10^{-19} \text{ x} 0.1^2 \text{ x} 3.14159}$$

$$V = 2.34\ x\ 10^{-3}\ \text{cm/sec}$$

$$V = 0.00234\ cm/sec$$

$$V = 8.42\ \ cm/hour$$

$$V = 2.02\ Metres/day$$

As you can see from the calculations the velocity of the electrons (whose movement is electric current) is *really* slow. It works out at 84 millimetres per hour! Now who said electricity was fast?

This calculation is for DC. For AC the velocity of the electrons would be the same however the electrons would move back and forth and not actually go anywhere. This means that the electrons in your household wiring are probably the same ones that were there when you house was built many years ago. Maybe it's time to connect a battery for a few days and flush them out!

Note: the above value for Q assumes that each copper atom donates a single movable (free) electron. Such is the case at normal room temperatures.

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Electrons in metals do not hold still. They wiggle around constantly even when there is zero electric current. However, this movement is not really a current flow, it is more like a vibration, or like a high-speed wandering movement.

Relativity

It is really absurd to argue that electrons travel at or anywhere near light velocity. To fully understand this requires some understanding of the Theory of Relativity. Basically, one part of this theory explains that as anything with mass (an electron has mass) is accelerated towards light velocity its mass increases (energy is converted to mass) and this mass approaches infinite mass as its velocity approaches the speed of light. To accelerate electrons or anything else to anywhere near light velocity would require huge amounts of energy, approaching infinity as we approach light speed.

So why does electricity seem to travel so fast?

The action of electricity over distance using wires is fast because the electrons are already in the wire waiting to move and move through the entire circuit at once. Much like a pipe totally filled up with marbles. When an extra marble is placed in one end and marble *almost* instantaneously drops out the other no matter how long the pipe.

The effect of electric current at a distance is almost instantaneous (it cannot be instant) due to the domino effect of the electron charge carriers already filling the entire length of the conductive circuit.

Actually there is a little delay between real dominoes but imagine them touching each other shoulder to shoulder and you will get the picture.

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