How fast does electricity flow?

Well this question really needs some clarification, as the term electricity can be used in various ways.

Let's assume we are talking of electric current. Electric current is defined as the ordered movement of 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 x 10^{18} electrons.

Okay, 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

The 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.

The complicated answer

If a copper wire is connected into a series circuit with an aluminum wire of the same diameter, the charges in the copper will flow slower. This occurs because there is one movable charge per each atom in the metals, but copper is a denser material than aluminum.

To work out how fast an electric current is flowing in **any** conductor we do 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.

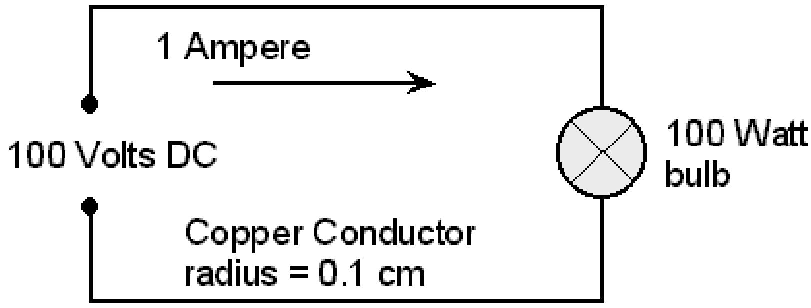

Fig. 1- How fast are the electrons?

We will use a light bulb of 100 watts. To simplify the maths a little we will say the bulb operates at 100 Volts. The current the bulb will draw will be 1 ampere for 100 watts; from P=ExI, 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 atoms per cubic centimeter for copper is Q = 8.5 x 10^{22} because there are that many atoms of copper in a cubic centimeter of copper and each copper atom has one free electron.

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

Figure 2 shows the working out for calculating the velocity of the electrons which is the same as the velocity of the electric current through the bulb. It works out at 84 millimetres per hour! Now, who said electricity was fast?

$$V = \frac{I}{Q \times e \times R^2 \times \Pi}$$

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

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

$V = 2.34 \times 10^{-3}$ cm/sec
= 0.00234 cm/sec
= 8.42 centimetres per hour
= 84 millimetres per hour

Fig. 2 - Calculating the speed of electricty

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 its 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 temperatures.

A final point. 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.

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.