Modelling Electric Circuits

At some point during the early teaching of electric circuits, students will want to know what an electric current is. Indeed students may already have their own ideas about what it is and how it behaves. There has been much research into the ideas students bring to their lessons, and the misunderstandings they develop during the teaching/learning process.

Electric current is known only by its heating, magnetic or chemical effects. Beyond this there are only models which explain such effects and make possible reliable predictions.

Misconceptions common among students

- •the ‘clashing currents model’ in which electric current is thought to leave both ends of the cell and meet at a component, for example a lamp, and make it operate;
- •the ‘single lead model’ in which students see the need for only one connecting wire leading from the cell to the lamp (this is often exacerbated if all the connections are not clearly visible on the circuit itself);
- •the ‘current is used up around the circuit model’ in which the current is thought to leave one terminal of the cell and is used up in the components; nothing returns to the other terminal. In fact, why have a return wire?

Teachers' models

There are many models which teachers use to describe electric circuits. Different ones are useful in different situations. Three of these are listed here:

- •the water circuit in which the flow of water is likened to the electric current;
- •a grid of wide and narrow streets, complete with car parks and one way systems, on which cars pass at speeds determined by the density of traffic;
- •the pupil circuit in which sweets are given up by the ‘cell pupil’ (energy) and ‘pupil charges’ transfer them to ‘component pupils’.

When discussing the water circuit as a model for an electric circuit, you could say to students:

‘*There is something the same all the way round the circuit, the same reading with a simple ammeter, or the same brightness of a series of lamps. One of the lamps could even be placed in series between the two cells and will be just as bright as the others.*

‘That is why scientists say, “There is a current; there is something running round the circuit which stays the same all along, just like a current of water in a river.” If a river is carrying 1,000 litres per minute past one place, it must be carrying 1,000 litres a minute past any other place farther down the river unless there is some side stream or a mysterious hole in the ground. Some scientists like to think of this electric current story as rather like water being pumped round a closed ring of piping.’

Bring out the analogy between:

- •the pump and the cell,
- •the tubing and connecting wires,
- •the wide and narrow tubes and resistances,
- •the flow meter and an ammeter, and
- •the pressure gauge and a voltmeter.

Once students have used other components then the model can be extended in imagination to the idea of one-way valves representing diodes, and reservoirs representing capacitors. Stress that the flow of water is the same all round the circuit, unless of course you have a leak!

Once the model has been described then discussion can return to the electric circuit.

'*Is there really something that moves round through the copper wires and through the lamp and makes the lamp light or pulls the magnet? As far as you or I can tell, this electric circuit behaviour is rather like the behaviour of a current of water flowing that makes the same thing happen all the way round. We do not know, yet, whether anything is really flowing and certainly not what it is. If it flows it might be some kind of juice flowing this way round the circuit (positive juice) or it might be some opposite juice (negative juice) running the other way round the circuit. Or it might be both of those each running its own way.'*

'Instead of some smooth juice flowing like water in a pipe the current might be a movement of little particles, moving along like a line of rabbits in a burrow or an army on a road. Again this might be a row of positive bits travelling this way or negative bits travelling that way or both kinds each travelling its own way.'

'Which of all these things do you think is right? Nothing travelling at all, or a juice travelling one way or another, or little bits of electricity travelling one way or another?'

Whatever the answers at this stage students need to wait for further evidence. Nowadays scientists know that there are things which move when an 'electric current' happens, in some cases several kinds of things. In fact, contrary to wishful hopes, nothing in elementary physics teaching, even cathode ray tubes, requires a view that electric charges come in small particles. Continuous (negative) juice would do just as well. Only when students meet Millikan's experiment do they require particles of electric charge to explain the data.

'*For the moment stick to the standard agreement, used by all electrical engineers, which is the idea of bits of positive electricity coming out of the red knob of the cell and going round the circuit in one direction to the negative end of the cell. That was settled long before anyone knew about electrons and is used to put arrows on the electric circuit drawings. Later on you will be able to decide for yourselves what is really going on and you might find it even more complicated than you think.'*