Electricity and Magnetism: Teaching and Learning Issues 04

Contents

This is the 'Teaching and Learning Issues' that explains the particular challenges. To develop your expertise in the episode, work with the 'Physics Narrative' and the 'Teaching Approaches'. Navigate to any part of the topic using the Topic Menu, or use the tabs below to stay within this episode. .

Some challenges to be met

- Challenge 1: What do voltages measure?
- Challenge 2: Seeing the differences between current and voltage measurements
- Challenge 3: Sharing the battery voltage
- Challenge 4: Sharing the voltage between unequal resistances
- Challenge 5: Each bulb gets the full battery voltage

These challenges reflect research carried out into alternative conceptions.

Challenge 1: What do voltages measure?

Thinking about the learning

Thinking about voltage either in terms of size of push or in terms of energy shifted per unit of charge (see Physics Narrative) is likely to make intuitive good sense to pupils at this stage in the teaching. Batteries of greater voltage provide a bigger push, which leads to more energy shifted per unit charge.

Thinking about the teaching

Why are voltage measurements important? What kind of information do they provide? What do voltage measurements tell us that is different from measurements of current?

These are important questions to be addressed in teaching. The short answer to all of them is that voltage measurements provide an “energy picture” of the electric circuit. Whilst current measurements tell us about the flow of charge (coulomb/second), voltage measurements provide information about energy shifted by those charges (joule/coulomb) in different parts of the circuit.

Challenge 1: What do voltages measure?

Different treatments of the voltage/energy story

It is possible to introduce the idea of voltage at different levels of difficulty that can be used with pupils of different age and ability.

Voltage: A measure of energy

At the simplest level, the battery voltage is taken as a measure of how much energy the battery can provide for the circuit. The voltage across a bulb or some other circuit resistance is taken as a measure of the amount of energy transferred in that component.

Here the voltmeter may be referred to as an “energy meter”, measuring how much energy is shifted in different parts of the circuit.

Voltage: Joule per coulomb

At a more advanced level, the battery voltage is taken as a measure of the number of joules of energy provided for each coulomb of charge. The voltage across a bulb or some other circuit resistance is taken as a measure of the number of joules of energy transferred by each coulomb of charge in that component.

The concept of voltage as energy shifted per unit charge can easily be linked to the supermarket picture teaching analogy:

Challenge 1: What do voltages measure?

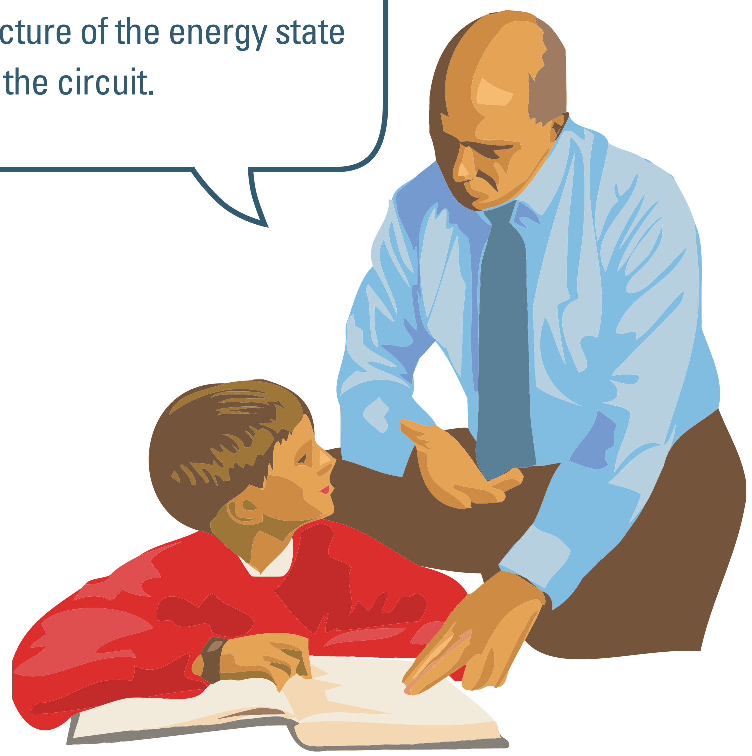
Voltage: Energy hill diagram

The energy hill diagram (see Physics Narrative) provides an "as if" picture. Pupils may find these diagrams helpful.

In using an energy hill diagram you should be aware that it is another teaching picture. In this picture the charges are picture being lifted up an electrical hill, just lke a gravitational hill, and there they rest. They don't, of course, as soon as you cut the wire you can see how this picture breaks down. The shifting of energy in circuits depends on the flow, not on lifting things "up", leaving them there, and then dropping them later on. (As you can do with pumping water up a mountain, leaving it in a reservoir, and then letting it fall back down later any time you like - this truly is a gravitational store of energy).

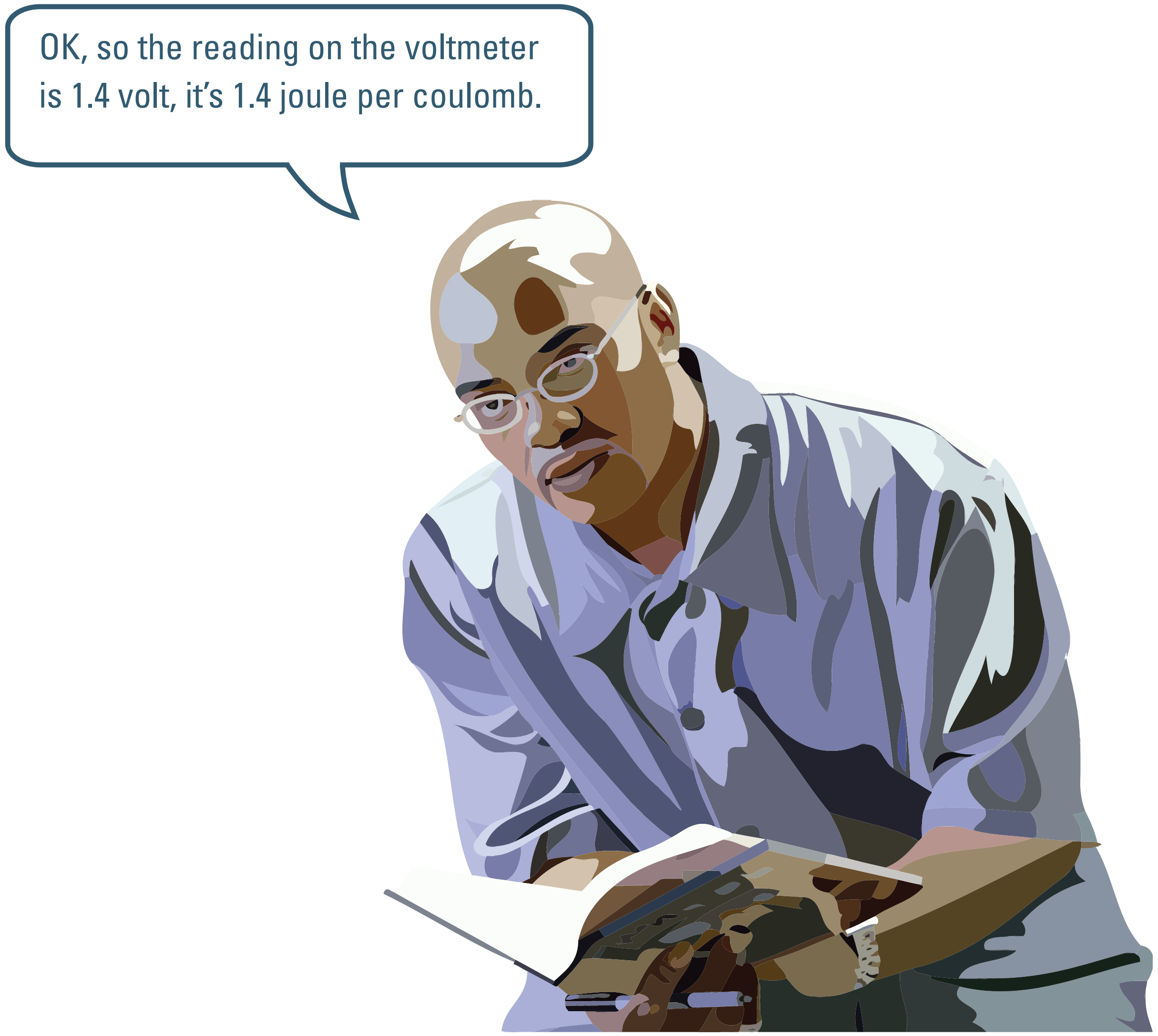
The hill model is a psuedo-static picture of a dynamic process: but may be helpful to some in guiding calculations about where the energy ends up. You have to think of the level of charges (in joule/coulomb) as represented in such a way that the battery shifts the charges to a higher energy level. When the charges fall to a lower energy level in any resistance the energy corresponding to the difference in levels is dissipated. The picture that is painted here is one of the charges behaving as if they are masses being lifted up and then allowed to fall in a gravitational field. This is not what happens in a circuit: the charges in one wire, linking the cell to the lamp, are not "more uphill" than the charges in the other linking wire.

Teacher: OK, so the battery is rated at 3 volt. What does that mean?
Pupil: 3 joule for every coulomb
Teacher: That's right. Excellent! So the charges around here (pointing to the hill diagram) are all at a level of 3 joule per coulomb. As they pass through the bulb the stored energy is transferred and the charges fall to what?
Pupil: 0 joule
Teacher: That's right 0 joule per coulomb. And then the battery raises the charges up again to 3 joule per coulomb. This diagram provides us with a picture of the energy state of the charges in different parts of the circuit.



Volt and joule per coulomb

As these new ideas about voltage are first introduced, it is helpful if sometimes you refer to “volt” and sometimes “joule per coulomb”. By using the terms interchangeably in this way, the underlying meaning of voltage is continually made explicit:



Challenge 2: Seeing the differences between current and voltage measurements

Thinking about the learning

Introducing the idea of voltage and voltage measurement with a voltmeter can create confusions for pupils who tend to mix them up with existing ideas about electric current. The fact that ammeters and voltmeters look just the same can add to this confusion.

Thinking about the teaching

It is a good idea to explicitly refer to the "two stories" which can be drawn upon in thinking and talking about electric circuits. These two stories are:

- the charge/electric current story
- the energy/voltage story

Referring to the two sets of ideas in this way can help pupils to see the difference between them.

Two useful phrases

Insist at all times on describing:

- current IN
- voltage ACROSS

It just does not make sense to talk about the "current across the bulb" or the "voltage in the bulb". If pupils get these the wrong way around, the chances are that they do not understand the underlying ideas.

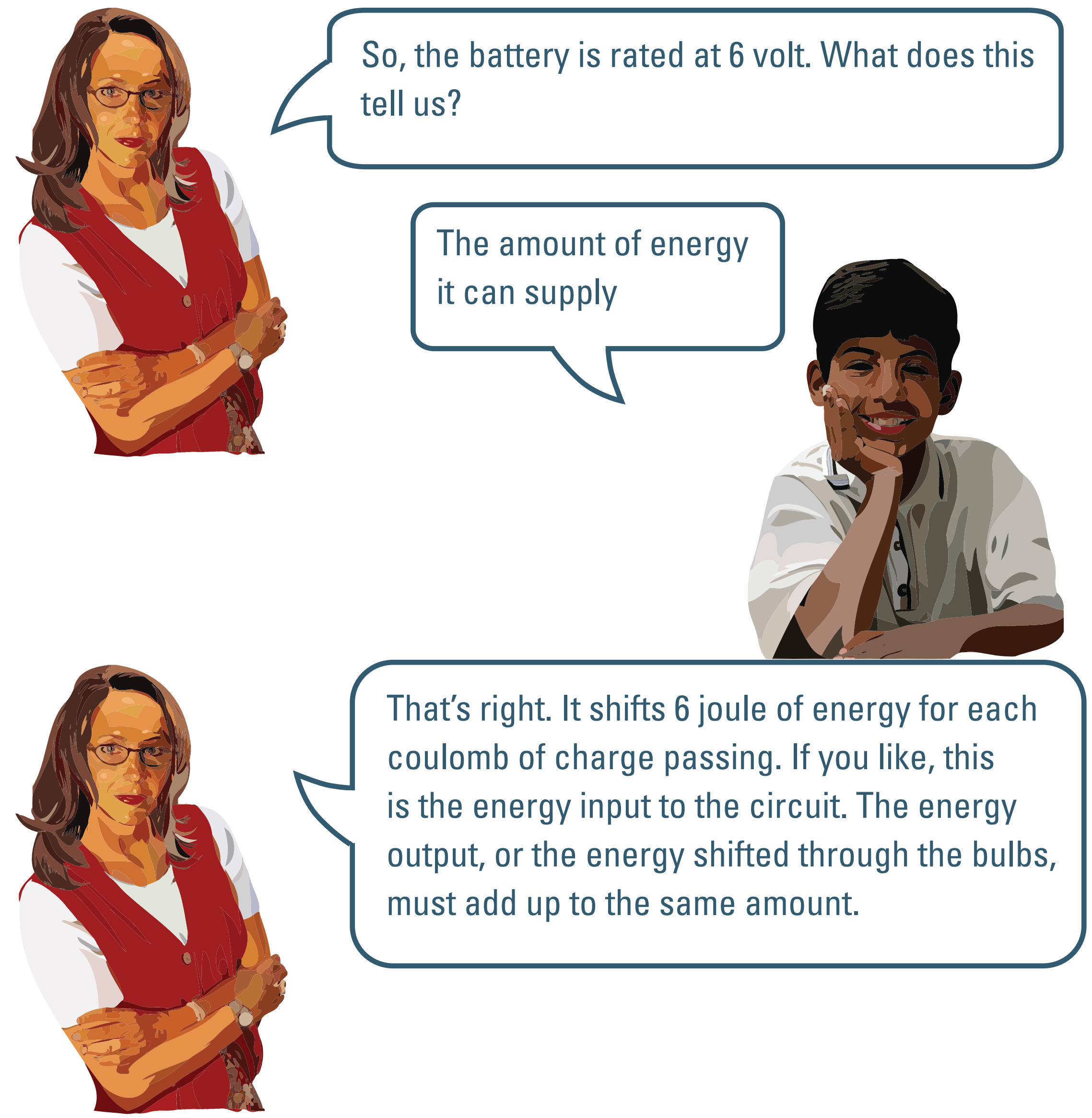
Challenge 3: Sharing the battery voltage

Thinking about the learning

Pupils will be familiar with the idea that when a second bulb is added in series to a circuit the two bulbs become equally dim. In episode 3, the point was made that each charge shifts equal amounts of energy in the two bulbs (the energy is shared equally). We now have a way of quantifying this by stating that the voltage supplied by the battery is shared between the two bulbs. Hopefully pupils will see this as being a logical development of ideas.

Thinking about the teaching

Having introduced voltage as a measure of energy in the circuit and emphasised the point that energy must be conserved:

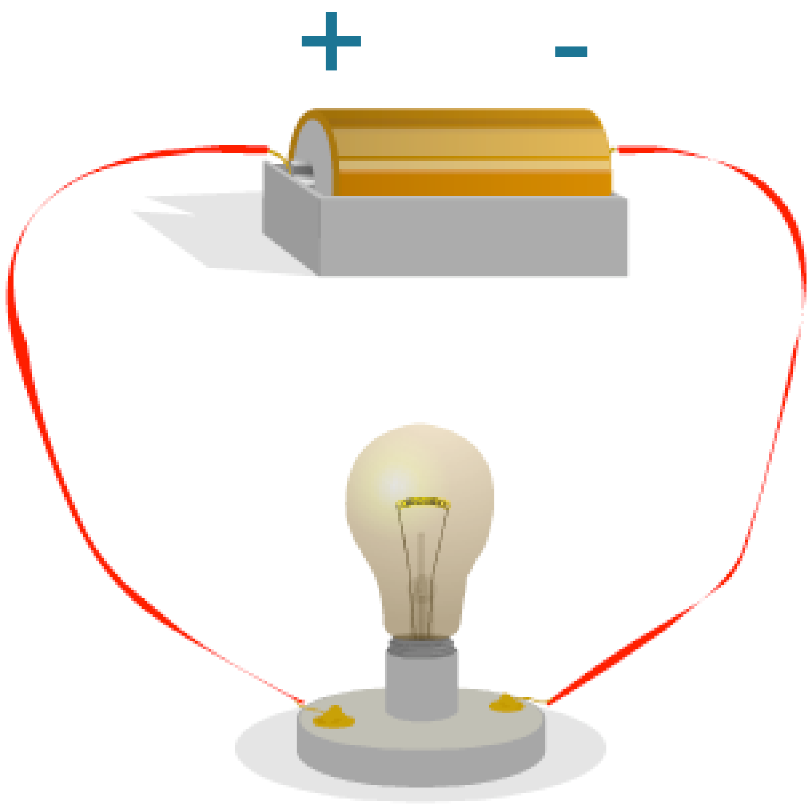


Now it should not be too big a step to establish that the battery voltage is shared between two bulbs in series.

Challenge 3: Sharing the battery voltage

Start with predictions and measurements

The simplest approach is for pupils to make their own predictions and measurements of voltage values, starting with simple battery/bulb circuits and moving on to circuits with extra bulbs in series. This is presented in further detail in the teaching approaches section.



Challenge 3: Sharing the battery voltage

An energy hill diagram provides a helpful visual summary of what happens in the series circuit:

OK, so the battery supplies 3 volt or 3 joule of energy for each coulomb of charge. How many joules of energy are dropped per coulomb of charge passing in the first bulb?

1.5 joule

Yes that's right! The energy drop for each coulomb of charge is from 3 to 1.5 joule, so the voltage across the first bulb is 1.5 volt. What about the second bulb?

Same, 1.5 volt

Exactly! 1.5 joule of energy are transferred per coulomb of charge passing.

Challenge 4: Sharing the voltage between unequal resistances

Thinking about the learning

The idea to get over here is that if two resistors are connected in series to a battery, the greater share of the battery voltage is dropped across the bigger resistance. A full understanding of the circuit involves recognising that:

- The battery voltage is divided between the resistors.
- The sum of the voltage drops across the two resistors must equal the battery voltage.
- More volts are dropped across the bigger resistance.
- The current is the same through both resistances.

Thinking about the teaching

This is an interesting situation, which might be set as a practical extension exercise for some pupils. However it is probably too involved for many pupils to wrestle with it at this stage.

Challenge 5: Each bulb gets the full battery voltage

Thinking about the learning

Pupils will be familiar with the idea that when a second bulb is added in parallel to a circuit, the two bulbs become equally, normally bright. In episode 3, the point was made that adding a bulb in parallel sets up a second current loop in which charges are set in motion and that the full energy available to each charge is transferred in one or other of the bulbs.

We now have a way of formalising this idea by stating that the full battery voltage is dropped across each of the two bulbs.

Thinking about the teaching

The energy hill diagram provides a helpful visual summary of what happens in the parallel circuit.

The key point here is that pupils are able to visualise the "double flow" of charge through the battery, which then divides equally with half passing through one bulb and half through the other. In this way each coulomb of charge, passing through either bulb, transfers a full 3 joule of energy.

OK, so the battery supplies 3 volt or 3 joule of energy for each coulomb of charge. How many joule of energy are dropped in the first bulb?

3 joule?

Exactly! 3 joule of energy are shifted for each coulomb of charge passing.

Yes that's right! Each bulb gets the full 3 joule of energy. The energy drop for each coulomb of charge is from 3 to 0 joule, so the voltage across the first bulb is 3 volt. What about the second bulb?

It's the same! 3 volt.