

## Using physical models: teaching electricity to Class X



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through School-based  
Support in India  
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### **Video resources**

*Some of the activities in this unit are accompanied by the following icon: . This indicates that you will find it helpful to view the TESS-India video resources for the specified pedagogic theme.*

*The TESS-India video resources illustrate key pedagogic techniques in a range of classroom contexts in India. We hope they will inspire you to experiment with similar practices. They are intended to complement and enhance your experience of working through the text-based units, but are not integral to them should you be unable to access them.*

*TESS-India video resources may be viewed online or downloaded from the TESS-India website, <http://www.tess-india.edu.in/>. Alternatively, you may have access to these videos on a CD or memory card.*

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All India - English

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## What this unit is about

Science is often described as a ‘hard’ subject. By the time students in secondary school approach public examinations, success in science depends on the ability to handle abstract concepts and models as well as being numerate, literate and able to recall a body of factual knowledge. Teachers help students to improve their understanding by providing structured experiences that help students to develop increasingly sophisticated mental models. These models will allow students to assimilate information and concepts effectively, so that they can not only recall them but also apply them appropriately.

One way of helping your students to develop sophisticated mental models is to use physical models. Physical models provide a way of helping students to develop their understanding of a topic by manipulating objects that are representations of things or concepts. They ‘move stuff around’, which can result in a much deeper understanding than reading the textbook or looking at two-dimensional pictures. With physical models, students can explore behaviour, patterns and connections, and make predictions. They must also learn to evaluate the strengths and limitations of different models.

In this unit the focus will be on using physical models to help develop students’ understanding of electricity. What you learn about physical models will also be applicable to other topics. You can learn more about helping students to develop mental models in another TESS-India unit.

## What you can learn in this unit

- Types of models and analogies, and the characteristics of good models.
- Some strengths and limitations of physical models used in teaching electricity.
- Some ways of using physical models to help your students gain a better understanding of electricity.

## Why this approach is important

Many students find electricity a difficult or challenging topic. One reason for this is that learning about electricity involves the use of abstract concepts and refers to things that are not directly observable with the naked eye, such as charge and electrons.

Physical models and analogies can help learning by ‘concretising’ abstract concepts through:

- helping students to visualise an object or process that they cannot easily see directly (for example, because of the object’s size, or because the timescale of the process is too long or too short)
- simplifying a complex situation
- allowing students to manipulate objects to make the ideas more memorable or to explore relationships between the parts of a system
- allowing students to manipulate the model to explore some aspect of how the object it represents supposedly works.

Teaching electricity with physical models allows students to test out ideas, make predictions and develop effective mental models.

Models and analogies each have their own strengths and limitations. A model that works in one context may be inappropriate in another. The ‘right’ model helps, but the ‘wrong’ model can hinder learning. Evaluating physical models of electrical circuits involves thinking about the characteristics of a good model. This relates to the nature of scientific enquiry as a whole, not just to electricity.

# 1 What do students find difficult about electricity?

Apart from the abstract nature of the concepts involved, it is possible that students have developed misunderstandings about electricity from everyday experience. For example, younger students see a piece of electrical equipment connected to the electricity supply by a single cable and plug, but have to learn that there must be a complete circuit inside this for the device to work.

Research has shown that some misunderstandings of electrical circuits are common even among older students. These misunderstandings include the examples in Table 1.

**Table 1** *Misunderstandings of electrical circuits.*

Student idea	Accepted science idea
The battery provides current or charge	The battery provides the potential difference needed to move charge round the circuit
The current is 'used up' by the components in a circuit	The current is the same throughout a series circuit. The best way to challenge these misunderstandings is to provide evidence to the contrary by showing that ammeter readings are the same on either side of a lamp, but some students may still hold on to this idea

Some students may also find it difficult to distinguish between voltage and current, or between current and energy.

For some students, it is also difficult to relate neat, deceptively simple circuit diagrams to the array of wires and components that make up some of the circuits that they will work with. There is a lot to take in when looking at the construction of many circuits. Your students may find it difficult to pick out the important detail unless you explain the circuit, asking them to tell you what is connected where, whether it is connected in series or in parallel, and so on.

## Case Study 1: Difficulties faced when learning about electricity

*At a recent training session, Miss Joshi learnt about some of the things that many students find difficult or confusing when learning about electricity.*

In the training session we discussed some examples of the problems that many students have in learning about electricity and where we might encounter some of these in lessons.

We started with ideas about what a battery does, but it soon led into other areas of confusion. I hadn't really thought about it before, but as we talked, I realised that I had seen this problem in some of my students that I had taught. They thought the battery was providing the charge, and needed to keep doing this because the charge was 'used up' as it went through components in the circuit. If they didn't believe that the charge was there already and the battery provided the potential difference to make the charge move, then how could closing a switch make everything come on instantly? The idea of charge drifting along at millimetres a second doesn't make sense unless the charge is already there ...

As we talked about where some of the difficulties might occur in the Class X electricity lessons, I realised that having some of these misunderstanding and difficulties could cause problems again and again. I would need to take account of the possible difficulties when planning my lessons.



## Pause for thought

- What have your students found especially difficult about the electricity topic?
- Have you noticed any of the misunderstandings described above when teaching electricity?

### Activity 1: Planning how to teach students about electricity

This activity will help you to plan for teaching about electricity by considering what kinds of difficulties your students may encounter in particular lessons.

Look at each section of Chapter 12 in the Class X textbook and identify the key points and sources of difficulty in each section. Use Table 2 to record your ideas. (You will look at some possible strategies for countering these difficulties in a later activity.)

When you have finished, compare your notes to Resource 1, which includes some possible comments.

*Table 2 Planning how to teach students about electricity.*

Section	Activity	Key teaching points/what do I want students to learn from activity and related text?	Sources of difficulty?
12.1	–	Current (measured in amperes) is the flow of charge (measured in coulombs) per second Current measured by an ammeter. Conventional current flow is from + to – Current and electron drift through a conductor. Current is instantaneous but drift speed is about $1\text{mm s}^{-1}$	Charge is not something that is visible.  Reconciling slow drift of electrons with instantaneous current.
12.2	–		
12.3	–		
12.4	12.1		
	12.2		
	12.3		
12.5	12.4		
12.6.1	12.5		
12.6.2	12.6		
12.7			
12.7.1			
12.8			

## 2 Using models to support learning about electricity

Teachers use a range of models and analogies to help students to develop their knowledge and understanding of science concepts.

Models and analogies relate unfamiliar concepts and experiences to familiar, everyday ones. For example, an analogy often used to explain electric circuits is: 'electric current in a conductor is like water flowing in a river or a pipe'.

Physical models use tangible, real objects to represent parts of an object or system (Figure 1). Students manipulate real objects to describe and explore concepts, processes and relationships. For example, you might model the effect of changing potential difference across an electrical circuit by tilting a track with marbles on it: the marbles don't roll if the track is flat, but will roll from high to low if it is tilted. (The marbles are the current and the tilt is the potential difference.) If there is no potential difference, then no current will flow round the circuit. But if you increase the potential difference, the current will increase.



**Figure 1** A group of students designing their own physical models.  
The pencil case with a zip represents a variable resistor.

Physical models can include computer simulations, as well as the use of students themselves as part of the model. For example, students might take part in a role play activity where one person is the battery and pulls a loop of rope around; as it is supported by the group; the moving rope represents moving charge in the circuit. There are many computer simulations available on the internet. You could encourage your students to go to an internet cafe and find some.

A key point about using any model with your students is that it should be an *interactive* process. You should not simply tell your students what the model is: you should ask questions such as 'What does this feature of the model represent?' or 'What represents resistance in this model?', and encourage your students to explain their ideas. They will learn more if they have to identify the connections rather than simply being told.

Your students should also work in groups and discuss their ideas with each other. Using the model and talking about it should help your students to develop their understanding, and when you listen to your students' comments and discussions it will help you to have a better understanding of where they have difficulties.

## Case Study 2: Role play model for electric circuits

*Mr Patel attended a training session at the local DIET and experienced the use of a role play model for electric circuits. (You can find descriptions of both these models in Resource 2.)*

Last week I attended a training session about teaching electricity. I was surprised at first when the trainer told us that we were going to try out a model for electricity called 'the rope model'. I had not met this model before and was even more surprised when I found out that it was a role play activity! I went back to school and tried it with Class X.

There were 50 students in Class X so I divided them into two groups of 12 and two groups of 13. Each group had a circle of washing line. I told them to hold it loosely in their hands. One person pulled it round.

Then I quietly spoke to one person in each group and asked them to hold the rope a bit more tightly. It became harder for the person pulling the rope to make it move, and the person holding the rope tightly found that their hands got warm.

I wrote some questions on the blackboard:

- What does the person pulling the rope represent in this model?
- What does the moving rope represent?
- What happens when someone holds the rope more tightly? What does this represent?
- How does this model represent electricity flowing in a circuit?
- What is helpful about this model?

I asked my students to work in groups of four to answer the questions. Whilst they were working, I walked around and listened to the conversations.

After ten minutes, I asked representatives from some of the groups to explain their answers.

Finally, I asked them to get back into their groups of 12 and we did the exercise again. This time, while they were moving the rope, I went through the answers to the questions to highlight the key features of the model.

The good thing about this model is that all the rope starts moving at the same time. All the charge in a circuit starts moving at the same time, too. This was the point so many students had found difficult to understand when I taught Class X electricity last year. I realised that it was because they were still thinking about charge coming out of the battery and whizzing round the circuit instead of being there all the time and just starting to move when a potential difference was applied.

When someone gripped the rope more tightly, this was the equivalent to adding a resistor. Students could see that the rope was still in the circuit, so the charge wasn't leaving the circuit, as some of them had thought. Instead some of the energy was leaving through the resistor, because the student acting as the resistor's hands got hotter.

The whole exercise only took about 20 minutes but I am sure it has helped my students to understand electric circuits better.



## Pause for thought

- What analogies have you used to teach about electricity? Which ones have worked well?
- Have you used any physical models to teach about electricity? What were they?

For more information on role play activities, see Resource 2.



## Video: Storytelling, songs, role play and drama

<http://tinyurl.com/video-ssrpd>

### Activity 2: Utilising models

This activity will help you to plan your teaching for electricity by considering how models are used already and where additional models might be helpful.

You will need the table you completed for Activity 1. Add another column to the right of the table, as shown in Table 3.

Look through the chapter again and identify what models and analogies are used in the text.

Add any other models or analogies that you think might be helpful.

The first row is filled in as an example. You can find out more about the rope model and also about another model called the 'sweets and cups' model in Resource 3.

When you have completed the table, compare your notes with those in Resource 4.

**Table 3** Considering what models and analogies can help with textbook learning.

Section	Activity	Key teaching points/What do I want students to learn from activity and related text?	Sources of difficulty?	What models or analogies <i>are</i> being used or <i>might</i> help here?
12.1	–	Current (measured in amperes) is the flow of charge (measured in coulombs) per second Current measured by an ammeter. Conventional current flow is from + to – Current and electron drift through a conductor. Current is instantaneous but drift speed is about $1\text{mm s}^{-1}$	Charge not something that is visible Confusion over electron flow direction and conventional current Reconciling slow drift of electrons with instantaneous current	<b>Being used:</b> Electric current as a flow. Circuit is a continuous closed path – any break stops the flow <b>Might also help:</b> Rope model.
12.2	–			–
12.3	–			–
12.4	12.1			
	12.2			
	12.3			
12.5	12.4		–	
12.6.1	12.5		–	–
12.6.2	12.6			
12.7	–			
12.7.1	–			–
12.8	–			

### 3 Strengths and limitations of models and analogies

There are some general strengths and limitations to the use of models and analogies, but every model and analogy has its own strengths and limitations.

Simple models may work well in a limited range of situations and a model that is appropriate for one context may be rejected as inadequate in another. Sometimes, there are two or more models you could use in a particular context, each offering a slightly different approach.

Choice of model or analogy is important. If your students are not familiar with an object or situation, you should not use it as part of a model or an analogy, as it could make them more confused.

It is also important to be aware of possible additional misunderstandings created by the models you use. Sometimes, students can be distracted by what you as a teacher regards as irrelevant details, or can misapply some of the details when they recall the model.

For example, you might use a ‘roller coaster’ model of electric circuits to model the need for electrical potential. This shows the idea that the cars need to be dragged up to a high point before they will start to roll on their own, and the idea that all the charge just moves round the circuit with the idea that all the cars

just go round the track and nobody gets out during the ride. This should be a suitable model, but it is possible that instead of learning what you intended, your students might fixate on 'the first hill of a roller coaster is always the highest' and decide that somehow there is less energy available as you go further round a circuit.

You will only know that misunderstandings have crept in with your model if you ask your students about the model and listen carefully to check their understanding. You can also pick up some issues by asking your students to draw diagrams or add information and comments to diagrams that you have provided. You can find out more about probing your students' understanding in the unit *Probing understanding: work and energy*, and in the key resource 'Assessing progress and performance' (<http://tinyurl.com/kr-assessingprogress>).

### Activity 3: Comparing two role play models of an electric circuit

This activity is to give you experience of using and evaluating physical models with your class. You will need Resource 2 for this activity.

You could introduce and use either of these models at various times during a teaching sequence, but asking students to compare and evaluate models can be particularly useful at the end of a topic, as it can help students to review their understanding.

Before the lesson, identify what groups your students will work in and how you are going to introduce the activity without telling them too much about the two models.

You will need to provide an instruction sheet or a poster, including the questions you want your students to think about, for each model. Each group of students needs to try out both models. Some groups will start with the rope model and other groups, with the 'sweets' model. Then you will need to stop everyone so they can swap resources with a group using the other model.

Circulate around the groups as they work. Encourage them to share their ideas with each other. Be prepared for things to get noisier than usual, especially if your students are trying to make themselves heard in large working circles.

When everyone has tried both models, discuss the questions with the whole class.

Ask your students to discuss in their groups what are the strengths and limitations of each model. Discuss these ideas as a whole class.

## 4 Summary

In this unit, you have learned about some of the things that make electricity a difficult topic and how you can use models to support your teaching.

Case Study 2 and Activity 3 examined the use of one technique, role play, in the context of teaching about electric circuits. There are, however, several different ways of using models and in Activity 2 you identified several topics where a model could help students' understanding.

There is sometimes a feeling that by Class X, students should be developing mental models, rather than physical models. However, physical models are very helpful in supporting the process of developing understanding and even university students can benefit from using physical models, for example, in chemistry, building models of molecules to understand different forms of isomerism.

For your next teaching topic, identify where students are most likely to have conceptual difficulties and where the use of models is likely to be helpful. Consider what models and analogies would be most suitable.

Discuss your plans for the activities with your colleagues:

- What types of model or analogy do you plan to use?
- What are the strengths of the model and what are the possible limitations?
- How will you implement these activities with your group?
- What particular features will you draw attention to?

Draw up a teaching plan for including at least one model-based activity in the teaching sequence.

## Resources

### Resource 1: Sources of difficulty in the electricity topic

This resource is used in Activity 1.

*Table R1.1 What might your students find difficult in the electricity topic?*

Section	Activity	Key teaching points/What do I want students to learn from activity and related text?	Sources of difficulty? Possible misunderstandings?
12.1	–	Current (measured in amperes) is the flow of charge (measured in coulombs) per second. Current measured by an ammeter. Conventional current flow is from + to –  Current and electron drift through a conductor. Current is instantaneous but drift speed is about $1\text{mm s}^{-1}$	Charge not something that is visible  Confusion over electron flow direction and conventional current  Reconciling slow drift of electrons with instantaneous current
12.2	–	Potential difference across a conductor makes charge move through it  Potential difference = work done per unit charge  1 volt = 1 joule per coulomb measured using a voltmeter	Idea that a battery provides current rather than voltage
12.3	–	Conventional symbols for commonly used components	–

Section	Activity	Key teaching points/What do I want students to learn from activity and related text?	Sources of difficulty? Possible misunderstandings?
12.4	12.1	Voltage and current relationship for a conductor. Ohm's Law derived from graph of V vs I for different numbers of cells	Residual confusion between voltage and current Relating circuit diagram to real circuit construction Voltmeter and ammeter connections
	12.2	Changing the component affects the current. Concept of resistance: increasing resistance gives lower current	Possible 'current is used up by components' misunderstanding Mental model of electrons moving through a conductor used in text discussion
	12.3	Factors affecting resistance of a conductor The greater the resistivity or length of wire, the greater the resistance The greater the cross-sectional area, the lower the resistance	Measuring current and inferring resistance – not measuring resistance directly. To derive cross-sectional area rule, need to remind students that doubling the diameter quadruples the area Remembering relationship
12.5	12.4	For resistors in series: current the same anywhere in a series circuit; current depends on the total value of the resistance	Relating circuit to circuit diagram – 'current used up' misunderstanding
12.6.1	12.5	For resistors in series, total potential difference is sum of potential differences across each resistor. As $V = IR$ , combined resistance of resistors in series = sum of individual resistances	Relating circuit to circuit diagram
12.6.2	12.6	For three resistors in parallel, pd across each resistor is the same as the pd across the combination Current through undivided part of circuit = sum of currents through each resistor	Relating circuit to circuit diagram Measurements could be confusing to follow Derivation of total resistance that follows activity could be challenging; idea of reduced total resistance is at first counter-intuitive

Section	Activity	Key teaching points/What do I want students to learn from activity and related text?	Sources of difficulty? Possible misunderstandings?
12.7	–	Some energy is dissipated as heat when a current flows through a conductor Power $P = VI$ Energy $H = VIt$ Energy $H = I^2 R$	
12.7.1	–	Practical applications of heating effect: heaters, toasters, etc., filament lamps, fuses	Will all students be familiar with all of these examples?
12.8	–	Electric power $P = V/I$ $P = V/R$ $P = I^2 R$ Power is measured in watts Commercial unit of energy = kilowatt hour (kWh) = $3.6 \times 10^6$ joules. Charge is not used up by electrical equipment. We pay for energy used, not charge	Confusion between energy and charge

## Resource 2: Role play

Role play is when students have a role to play and, during a small scenario, they speak and act in that role, adopting the behaviours and motives of the character they are playing. No script is provided but it is important that students are given enough information by the teacher to be able to assume the role. The students enacting the roles should also be encouraged to express their thoughts and feelings spontaneously.

Role play has a number of advantages, because it:

- explores real-life situations to develop understandings of other people's feelings
- promotes development of decision making skills
- actively engages students in learning and enables all students to make a contribution
- promotes a higher level of thinking.

Role play can help younger students develop confidence to speak in different social situations, for example, pretending to shop in a store, provide tourists with directions to a local monument or purchase a ticket. You can set up simple scenes with a few props and signs, such as 'Café', 'Doctor's Surgery' or 'Garage'. Ask your students, 'Who works here?', 'What do they say?' and 'What do we ask them?', and encourage them to interact in role these areas, observing their language use.

Role play can develop older students' life skills. For example, in class, you may be exploring how to resolve conflict. Rather than use an actual incident from your school or your community, you can describe a similar but detached scenario that exposes the same issues. Assign students to roles or ask them to choose one for themselves. You may give them planning time or just ask them to role play immediately. The role play can be performed to the class, or students could work in small groups so that no group is being watched. Note that the purpose of this activity is the experience of role playing and what it exposes; you are not looking for polished performances or Bollywood actor awards.

It is also possible to use role play in science and maths. Students can model the behaviours of atoms, taking on characteristics of particles in their interactions with each other or changing their behaviours to show the impact of heat or light. In maths, students can role play angles and shapes to discover their qualities and combinations.

## Resource 3: Two models for teaching about electric circuits

This resource is referred to in Case Study 2 and is used in Activity 2.

Each of the two models takes five minutes or so to work through once a group has all the resources and the instructions.

**Note:** For both these models, allow students to follow the instructions without telling them what all the features and actions represent. Use the questions to direct their attention and encourage them to work out the answers for themselves.

The answers and comments follow the instructions for each model.

### Sweets and cups

#### *What you need*

A packet of wrapped sweets, two boxes and some paper cups. Put half the wrapped sweets in one box and half in the other.

This model works well if you have, say, 20 sweets and ten people in the circle, plus an observer and someone to read the questions. If you use a bigger group and more sweets, it will take too long before all the sweets are going round the circle.

#### *What to do*

Before you start, choose one person from the group to read out the instructions and the questions.

- Start with everyone except one in a circle. The one outside the circle is an observer.
- One person has a box with half of the wrapped sweets in it. They pass one sweet every second to the person on their right, who immediately passes each sweet to the person on their right, and so on. (It may help to have someone outside the circle keep time for this by tapping the table once a second.)
- One person in the circle has a cup. When a sweet arrives, they hold it in the cup for a second before they pass it on. Soon, all the sweets in the box are moving steadily around the circle. The observer stands behind the person on the left of the person with the box, and claps every time the person they are standing behind passes a sweet back to the person with the box. Allow the sweets to go round several times, so that everyone settles into the rhythm before you make any changes.
- Now give a cup to a second person. What happens to the rate that sweets pass round the circuit (i.e. how often the observer claps) now?

- Now give someone else in the group a box, and the other half of the sweets. They also pass one sweet a second, so now there are two people passing sweets to the rest of the circle, so there are two sweets a second being passed). This increases the rate that sweets pass round the circle, and the observer claps twice as fast.

### *Questions*

- What does the person giving out sweets represent?
- What do the sweets represent?
- What do the cups represent?
- What does adding a second person with sweets represent and what is the effect?

### *Answers and comments*

- The person giving out the sweets is like a battery pushing the charge round the circuit. (This model may suggest, incorrectly, that the battery supplies charge. The battery only makes the charge move.)
- The sweets are the charge. You can see that the same number of sweets move. The rate at which sweets are moving around is the current. The faster the observer claps, the bigger the current in the circuit. The observer is like an ammeter, counting the rate of flow of charge.
- The cups slow down the flow of sweets. They are acting like resistors or lamps. (This is where energy leaves a real circuit, but it is harder to see this connection in this model.)
- The second person with sweets is like another battery. Adding another battery increases the current: sweets are moving past the observer more frequently now. The problem with adding someone with more sweets is that it looks as though adding the battery added more charge, when the charge moving around should be the same. It is just the speed it moves at that increases.

### *Strengths*

This model is good for showing that the charge moving around the circuit stays the same. No sweets leave the group, and adding resistors reduces the current.

### *Limitations*

The model suggests that batteries are a source of charge and that it takes a while for all the charge to be in motion round the circuit. The model does identify clearly where energy transfer occurs.

## **Rope model**

### *What you need*

A (large) loop of lightweight rope, ideally with a pattern or marks on it every metre, so you can see how fast it is moving round. The longer the rope, the more people you can have in the group doing the role play.

### *What to do*

Before you start, choose one person from the group to read out the instructions and the questions.

- Everyone in the group stands in a circle, so that the rope loop is not pulled too tightly, but does not sag anywhere either.
- One person pulls the rope around steadily, i.e. with a steady amount of pull.
- Everyone else should grip the rope very lightly as it moves round.

- One person should grip more tightly than the others and notice what happens. Note that they should not grip too tightly – this is not a tug of war game! The person pulling is meant to give a constant amount of pull, and should not start pulling harder and harder.

### *Questions*

- What does the person pulling the rope represent in this model?
- What does the moving rope represent?
- When someone grips the rope more tightly, what does this represent?

### *Answers and comments*

- The person pulling the rope is the battery. When the person pulls the rope, this supplies energy to the circuit.
- The moving rope is the charge moving round the circuit.
- When someone grips the rope more tightly, they feel their hands getting warmer, and the rope gets harder to pull. The extra grip is increased resistance. The person's hands being warmed is like energy being transferred out of the circuit. The person gripping the rope is like a bulb or a resistor.

### *Strengths*

This model shows that all the charge is moving around the circuit at the same time, and it makes a link between resistance and energy transfer.

### *Limitations*

If the person pulling the rope starts to pull harder when someone grips the rope more tightly, it could suggest that the battery works harder to keep the current the same when the resistance increases.

## **Resource 4: Using models and analogies to teach electricity**

This resource is used in Activity 2. Table R3.1 identifies models and analogies being used and provides some suggestions for other models that might be helpful.

Table R4.1 Using models and analogies to teach electricity.

Section	Activity	Key teaching points/what do I want students to learn from activity and related text?	Sources of difficulty?	What models or analogies are being used or might help here?
12.1	–	<p>Current (measured in amperes) is the flow of charge (measured in coulombs) per second</p> <p>Current measured by an ammeter. Conventional current flow is from + to –</p> <p>Current and electron drift through a conductor.</p> <p>Current is instantaneous but drift speed is about <math>1 \text{ mm s}^{-1}</math></p>	<p>Charge not something that is visible</p> <p>Confusion over electron flow direction and conventional current</p> <p>Reconciling slow drift of electrons with instantaneous current</p>	<p><b>Being used:</b> Electric current as a flow. Circuit is a continuous closed path – any break stops the flow</p> <p><b>Might also help:</b> Rope model</p>
12.2	–	<p>Potential difference across a conductor makes charge move through it</p> <p>Potential difference = work done per unit charge.</p> <p>1 volt = 1 joule per coulomb, measured using a voltmeter</p>	<p>Idea that a battery provides current rather than voltage</p>	<p><b>Being used:</b> Gravitational potential difference needed for water to flow downhill. Electrical potential difference needed for flow of charge</p> <p><b>Might also help:</b> Rope model</p>
12.3	–	<p>Conventional symbols for commonly used components.</p>		–

Section	Activity	Key teaching points/what do I want students to learn from activity and related text?	Sources of difficulty?	What models or analogies are being used or might help here?
12.4	12.1	Voltage and current relationship for a conductor. <b>Ohm's Law</b> derived from graph of V vs I for different numbers of cells	Residual confusion between voltage and current  Relating circuit diagram to real circuit construction  Voltmeter and ammeter connections	<b>Being used:</b> Circuit diagram as representation of circuit (used throughout activities)
	12.2	Changing the component affects the current. Concept of resistance: increasing resistance gives lower current	Possible 'current is used up by components' misunderstanding  Mental model of electrons moving through a conductor used in text discussion	<b>Might help:</b> Rope model, sweet model
	12.3	Factors affecting resistance of a conductor  The greater the resistivity or length of wire, the greater the resistance  The greater the cross-sectional area, the lower the resistance	Measuring current and inferring resistance – not measuring resistance directly  To derive cross-sectional area rule, need to remind students that doubling the diameter quadruples the area  Remembering relationship	<b>Might help:</b> (Something that could be acted out?) Carrying stacks of parcels in a crowded corridor. Things get knocked off the stacks by collisions  More gets knocked off the longer the corridor (length), and the narrower the corridor, the higher the frequency of collisions

Section	Activity	Key teaching points/what do I want students to learn from activity and related text?	Sources of difficulty?	What models or analogies are being used or might help here?
12.5	12.4	For resistors in series: current the same anywhere in a series circuit. Current depends on the total value of the resistance	Relating circuit to circuit diagram 'current used up' misunderstanding	<b>Might help:</b> Sweet model
12.6.1	12.5	For resistors in series: total potential difference is sum of potential differences across each resistor  As $V = IR$ , the combined resistance of resistors in series = sum of individual resistances	Relating circuit to circuit diagram	–
12.6.2	12.6	For three resistors in parallel: pd across each resistor is the same as the pd across the combination  Current though undivided part of circuit = sum of currents through each resistor	Relating circuit to circuit diagram  Measurements could be confusing to follow  Derivation of total resistance that follows activity could be challenging; idea of reduced total resistance is at first counter-intuitive	<b>Might help:</b> A slope model for pd. Allow three ball-bearings to roll simultaneously down from the lip of a wide plastic funnel (held over a bowl). Each has its own route but the drop distance is the same each time.  <b>Might help:</b> Current model of group splitting up to go along three routes then rejoining again. Reduced resistance effect like using three delivery vans at the same time rather than one

Section	Activity	Key teaching points/what do I want students to learn from activity and related text?	Sources of difficulty?	What models or analogies are being used or might help here?
12.7	-	Some energy is dissipated as heat when a current flows through a conductor Power $P = VI$ Energy $H = VIt$ Energy $H = I^2 R$		<b>Might help:</b> Rope model
12.7.1	-	Practical applications of heating effect: heaters, toasters, etc., filament lamps, fuses	Will all students be familiar with all of these examples?	-
12.8		Electric power: $P = VI$ $P = V/R$ $P = I^2 R$ Power is measured in watts Commercial unit of energy = kilowatt hour (kW h) = $3.6 \times 10^6$ joules. Charge is not used up by electrical equipment. We pay for energy used, not charge	Confusion between energy and charge	

## Additional resources

- Information on practical activities in physics for 11–19-year-olds:  
<http://www.nuffieldfoundation.org/practical-physics> (accessed 19 May 2014)

## References/bibliography

Boohan, R. (2002) 'Learning from models, learning about models', in Amos, S. and Boohan, R. (eds) *Aspects of Teaching Secondary Science*. London, UK: RoutledgeFalmer.

Driver, R., Squires, A., Rushworth, P. and Wood-Robinson, V. (1994) *Making Sense of Secondary Science*. London, UK: Routledge.

National Strategies (2008) *Science Teaching Unit: Explaining How Electric Circuits Work*. London, UK: Department for Children, Schools and Families. Available from: <http://webarchive.nationalarchives.gov.uk/20110202093118/http://nationalstrategies.standards.dcsf.gov.uk/node/286751> (accessed 21 May 2014).

Strawson, R. (2011) 'Electricity and magnetism' in Sang, D. (ed.) *Teaching Secondary Physics*. London, UK: John Murray.

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