

epiSTEMe Technician Notes

Electricity: electrical circuits

Introduction

The epiSTEMe Electricity: Electrical Circuits Module is designed to be taught over about nine lessons (including pre-test, post-test and student questionnaire). The lessons are broken down in 2, 3 or 4 parts, allowing teachers some flexibility over how quickly they progress through the material with different classes. Resources are therefore listed by lesson part, as in some cases, the teacher may not teach all the parts of the ‘same’ lesson in the same session.

Practical work

Many of the lessons include practical work done in groups, and it is often suggested in our teaching notes that this is reinforced by teacher demonstrations with a demonstration circuit and/or simulation software. It is assumed that in all student practical work the cells and lamps used in circuits will have the same ratings. This is important, as (a) students will draw inferences about how current and p.d. are behaving in some circuits by comparing the brightness of different lamps; (b) at this level most students will be confused by more complex phenomena such as the uneven dividing of potential across dissimilar lamps in a circuit branch. Due to the conceptual difficulty of the topic, it is important that students obtain and see clear outcomes that can be explained in terms of straightforward rules about current and p.d. in simple circuits, that can prepare them for more advanced work later in the school. For example, in upper secondary level students are often expected to calculate values of p.d., I, R etc in circuits, but research shows that students are only able to meaningfully relate such calculations to what is going on in circuits if such quantitative work builds on well established qualitative thinking about the physics.

It is important then that all the apparatus is tested by the school science technicians before lessons. So, for example, where one cell is used to power two lamps in series, the lamps should be chosen so that they clearly glow. If necessary instructions and diagrams may need to be customised to ensure practical work is effective if changes to apparatus are required.

Teachers are recommended to use demonstration circuits and/or simulation software (which presents ideal circuit outcomes) to reinforce student practical work and ensure the correct outcomes are observed. Demonstration circuits may simply be identical to the circuit built by students, but arranged so the whole class can see. However, where possible it may be sensible to provide the teacher with alternative kit that is easier to demonstrate to a full class, e.g. the large demonstration meters rather than the standard meters used by students, perhaps 12V lamps with a suitable supply etc.

LESSON 1

Lesson 1, Part 2: WHAT IS GOING ON IN THE CIRCUIT?

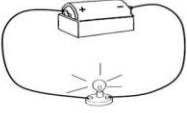
Teaching this lesson part will require:

- Demonstration circuit as shown in slide 2

Bulb light

This is a very simple electrical circuit.

EXPLAIN in as much detail as you can (thinking about both battery and bulb) why you think the bulb lights.



How would you change the circuit to make the bulb brighter? Explain why this would work.

If the circuit is left on, why will the battery go FLAT eventually?

Slide 2

Lesson 1, Part 3: THE ‘BIG CURCUIT’

Teaching this lesson part will require:

- The BIG CIRCUIT demonstration: the demonstration will require setting up a circuit that will run around the entire room. The lamp must light instantly. Of course lamps take a finite time to warm up enough to glow: so it is important that the set up uses a lamp/supply combination that appears to give a glow from the lamp *as soon as* the switch is closed.
- From the National Strategies document: ‘Explaining how electric circuits work’ (2008), pp.10-11. “The BIG circuit consists of a 12-volt power supply and a large bulb (12 volt/24watt) set up with insulated connecting wire running round the perimeter of the room. It is a good idea to tape the wire to the walls of the room and to mark it with ‘BIG CIRCUIT’ labels all the way around.”

LESSON 2

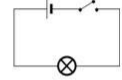
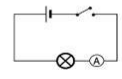
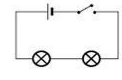
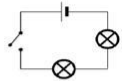
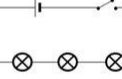
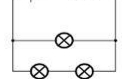
Lesson 2, Part 3: BREAKING THE CIRCUIT CODE

Teaching this lesson part will require:

- Six demonstration circuits that match those shown on the ‘Breaking the circuit code’ side (slide 20). The small-group activity will require setting up 6 circuits in the classroom *before* the groups start working.

Breaking the circuit code

Match the circuits set out around the room with the diagrams on the sheet.

A		Circuit No. <input type="checkbox"/>
B		Circuit No. <input type="checkbox"/>
C		Circuit No. <input type="checkbox"/>
D		Circuit No. <input type="checkbox"/>
E		Circuit No. <input type="checkbox"/>
F		Circuit No. <input type="checkbox"/>

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Slide 20

LESSON 3

Lesson 3, Part 1: BUILDING A SIMPLE SERIES CIRCUIT AND MEASURING CURRENT

Teaching this lesson part will require:

- Sufficient electrical kit for each student group to build the circuits (each group will need lamp, switch ammeter, cell and connecting leads) – see slides 23-26.
- Teacher demonstration circuit (e.g. using large demonstration meter if available) or suitable simulation software (see appendix)

Electric current in a simple circuit (1)

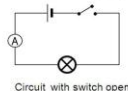
1) Build the circuit on the right, with the switch open.

2) What is the reading on the ammeter? _____ Amperes

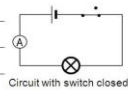
3) PREDICT what the reading will be if you close the switch (see on the right). Give reasons.

4) OBSERVE what happens when you close the switch. What is the reading on the ammeter? _____ Amperes

5) EXPLAIN why closing the switch has this effect.



Circuit with switch open

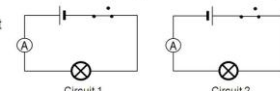


Circuit with switch closed

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Electric current in a simple circuit (2)

Circuit 1 and 2 look almost the same, except for that circuit 2 has the cell reversed in the circuit.



Circuit 1

Circuit 2

1) PREDICT what difference, if any, this would make to the circuit. Give reasons.

2) Build circuit 1 and circuit 2 and OBSERVE what happens in both. What is the reading on the ammeter?

Circuit 1: _____ Amperes

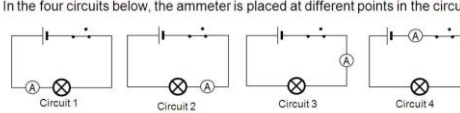
Circuit 2: _____ Amperes

3) EXPLAIN why changing the circuit in this way has this effect.

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Electric current in a simple circuit (3)

In the four circuits below, the ammeter is placed at different points in the circuit.



1) What do **you** think? Will the ammeter give the same or a different reading in the four circuits? Tick one box.

Same	Different
<input type="checkbox"/>	<input type="checkbox"/>

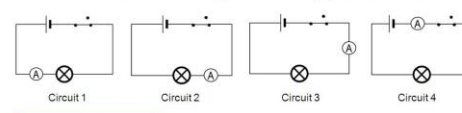
2) Now discuss in your **group** whether the ammeter will give the same or a different reading in the four circuits. Tick one box.

Same	Different
<input type="checkbox"/>	<input type="checkbox"/>

3) Try to reach an agreement and give reasons.

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Electric current in a simple circuit (3) continued



1) **PREDICT** the ammeter reading when the switch is closed.

Circuit 1: ___ Amperes Circuit 3: ___ Amperes
 Circuit 2: ___ Amperes Circuit 4: ___ Amperes

2) **BUILD** the circuit and **OBSERVE** the ammeter reading.

Circuit 1: ___ Amperes Circuit 3: ___ Amperes
 Circuit 2: ___ Amperes Circuit 4: ___ Amperes

3) **EXPLAIN** the measurements that you have obtained. Give reasons.

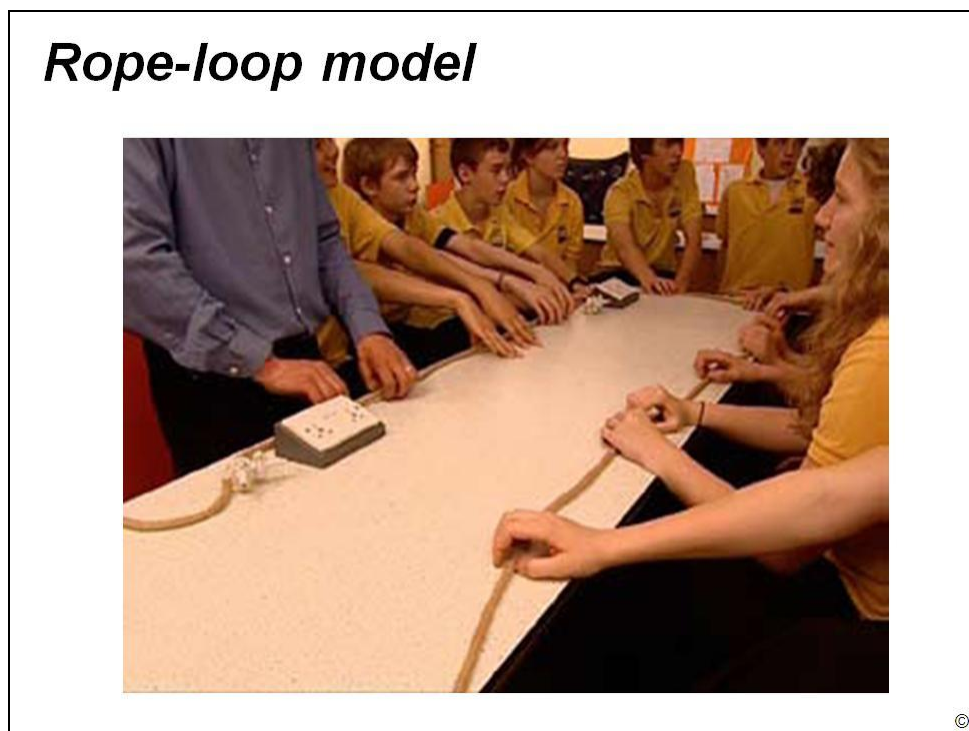
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Slides 23-26

Lesson 3, Part 2: MAKING SENSE OF CURRENT

Teaching this lesson part will require:

- Rope for rope loop model. “A long length of rope is needed, which can be passed in a BIG loop (prompting links to the BIG circuit) around all of the members of the class. Lightweight (4–6 mm diameter) rope used by climbers is ideal. If the rope is too heavy the frictional forces are too big and it is very difficult to get the rope moving across thirty pairs of fingers.” National Strategy: *Explaining how electric circuits work*, p.13.
- For more information on the rope-loop model, see National Strategy: *Explaining how electric circuits work*, p 12 and the video at <http://www.teachers.tv/video/18955>).



Slide 29

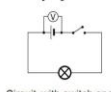
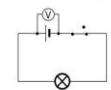
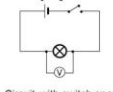
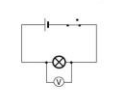
- Marbles for role-play activity. Sufficient marbles for the students to use them as quanta of energy to be moved round the room when simulating a circuit. (If marbles are not available, they can be substituted by a suitable alternative energy proxy – tokens that can be readily and visibly moved around the room to represent energy being transferred).

LESSON 4

Lesson 4, Part 1: BUILDING A SIMPLE SERIES CIRCUIT AND MEASURING P.D.

Teaching this lesson part will require:

- Sufficient circuit kit for each group of students to build circuits for ‘p.d./voltage in a simple circuit’ (each group will need cell, lamp, switch, voltmeter as well as connective leads) – see slides 33-34.
- Teacher demonstration circuit (e.g. using large demonstration voltmeter if available) or suitable simulation software.

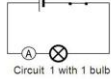
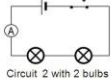
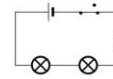
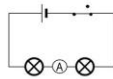
<p>p.d./voltage in a simple circuit (1)</p> <p>1) Build the circuit on the right, with the switch open.</p> <p>2) What is the reading on the voltmeter? _____ V</p> <p>3) PREDICT what the reading will be if you close the switch (see on the right). Give reasons.</p> <p>4) OBSERVE what happens when you close the switch. What is the reading on the voltmeter? _____ V</p> <p>5) EXPLAIN why closing the switch has this effect.</p> <div style="text-align: right;">  <small>Circuit with switch open</small> </div> <div style="text-align: right;">  <small>Circuit with switch closed</small> </div> <p style="text-align: right; font-size: small;">© epiSTEMe 2009/10</p>	<p>p.d./voltage in a simple circuit (2)</p> <p>1) Build the circuit on the right, with the switch open.</p> <p>2) What is the reading on the voltmeter? _____ V</p> <p>3) PREDICT what the reading will be if you close the switch (see on the right). Give reasons.</p> <p>4) OBSERVE what happens when you close the switch. What is the reading on the voltmeter? _____ V</p> <p>5) EXPLAIN why closing the switch has this effect.</p> <div style="text-align: right;">  <small>Circuit with switch open</small> </div> <div style="text-align: right;">  <small>Circuit with switch closed</small> </div> <p style="text-align: right; font-size: small;">© epiSTEMe 2009/10</p>
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Slides 33-34

Lesson 4, Part 2: BUILDING SERIES CIRCUITS WITH DIFFERENT NUMBERS OF LAMPS

Teaching this lesson part will require:

- Sufficient circuit kit for each group of students to build circuits for ‘p.d./voltage in a simple circuit’ (each group will need cell, 2 lamps, switch, ammeter, voltmeter as well as connective leads) – see slides 36-39.
- If the teacher decides to set the examples with three lamps in series as group work, then each student group will require 3 lamps (see slides 40-41).
- Teacher demonstration circuit (e.g. using large demonstration meters if available) or suitable simulation software.

<p>Electric current in a series circuit (1)</p> <p>1) Build circuit 1 on the right, with 1 bulb.</p> <p>2) What is the reading on the ammeter? Circuit 1: _____ Amperes</p> <p>3) PREDICT what the reading will be if you add another bulb (circuit 2 on the right). Give reasons.</p> <p>4) OBSERVE what happens when you add another bulb. What is the reading on the ammeter? Circuit 2: _____ Amperes</p> <p>5) EXPLAIN the reading. Include the words current, p.d. and energy in your explanation.</p> <div style="text-align: right;">  <small>Circuit 1 with 1 bulb</small> </div> <div style="text-align: right;">  <small>Circuit 2 with 2 bulbs</small> </div> <p style="text-align: right; font-size: small;">© epiSTEMe 2009/10</p>	<p>Electric current in a series circuit (2)</p> <p>In the two circuits below, the ammeter is placed at different points in the circuit.</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <small>Circuit 3</small> </div> <div style="text-align: center;">  <small>Circuit 4</small> </div> </div> <p>1) PREDICT the ammeter reading for circuit 3 and circuit 4.</p> <p>2) Move the ammeter to the points as shown in the diagrams and OBSERVE the ammeter reading.</p> <p>3) EXPLAIN the reading. Include the words current, p.d. and energy in your explanation.</p> <p>Circuit 3: _____ Amperes Circuit 4: _____ Amperes Circuit 3: _____ Amperes Circuit 4: _____ Amperes</p> <p style="text-align: right; font-size: small;">© epiSTEMe 2009/10</p>
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Slides 36-37

p.d./voltage in a series circuit (1)

1) Build circuit 1 on the right, with 1 bulb.

2) What is the reading on the voltmeter?
Circuit 1: _____ V

3) PREDICT what the reading will be if you add another bulb (circuit 2 on the right). Give reasons.

4) OBSERVE what happens when you add another bulb. What is the reading on the voltmeter?
Circuit 2: _____ V

5) EXPLAIN the reading. Include the words current, p.d. and energy in your explanation.

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p.d./voltage in a series circuit (2)

In the three circuits to the right, the voltmeter is placed at different points in the circuit.

1) PREDICT the voltmeter reading for circuit 3 and circuit 4.
Circuit 3: _____ V Circuit 4: _____ V

2) Move the voltmeter to the points as shown in the diagrams and OBSERVE the voltmeter reading.
Circuit 3: _____ V Circuit 5: _____ V
Circuit 4: _____ V

3) EXPLAIN the reading. Include the words current, p.d. and energy in your explanation.

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Slides 38-39

Electric current in a series circuit with three bulbs

1) Build circuit 1 on the right, with 3 bulbs.

2) What is the reading on the ammeter?
Circuit 1: _____ Amperes

3) PREDICT what the reading will be if you move the ammeter around the circuit as shown below.

4) Move the ammeter to the points as shown in the diagrams and OBSERVE the ammeter reading.

5) EXPLAIN the reading. Include the words current, p.d. and energy in your explanation.

Predicted _____ Amperes _____ Amperes _____ Amperes
Observed _____ Amperes _____ Amperes _____ Amperes

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p.d./voltage in a series circuit with three bulbs

1) Build circuit 1 on the right, with 3 bulbs.

2) What is the reading on the voltmeter?
Circuit 1: _____ V

3) PREDICT what the reading will be if you move the voltmeter around the circuit as shown below.

4) Move the voltmeter to the points as shown in the diagrams and OBSERVE the ammeter reading.

5) EXPLAIN the reading. Include the words current, p.d. and energy in your explanation.

Predicted _____ V _____ V _____ V
Observed _____ V _____ V _____ V

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Slides 40-41

LESSON 5

Lesson 5, Part 1: CIRCUITS WITH DIFFERENT NUMBERS OF CELLS

Resources

Teaching this lesson part will require:

- Demonstration kit for building circuits (2 cells, lamp, display meters, switch, connecting leads); optional use of simulation software – see slide 42.
- If using group practical work, enough electrical kit for each group to build circuits (each group needs 2 cells, lamp, ammeters, voltmeter, switch, connecting leads) – see slide 42.

Electric current and p.d./voltage in a series circuit with several cells

What is different between circuit 1 and circuit 2?
How will the current be affected?

What is different between circuit 3, 4, 5 and 6?
How will the p.d./voltage be affected?

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Slide 42

Lesson 5, Part 2: MODELLING SERIES CIRCUITS

Resources

- No practical apparatus is required for this lesson part, but the teacher *may* wish to demonstrate circuits or use simulation software to review previous practical work.

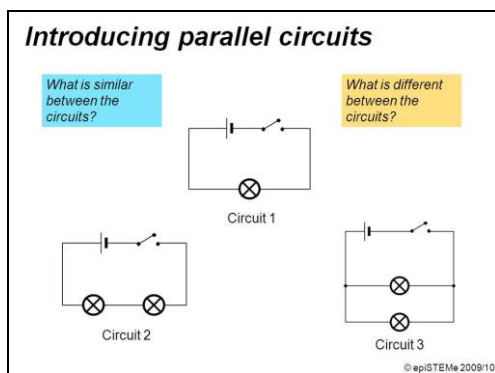
LESSON 6

Lesson 6, Part 1: INTRODUCING PARALLEL CIRCUITS

Resources

Teaching this lesson part will require:

- Three demonstration circuits, with a single lamp, two lamps in series, two lamps in parallel should be set up (with switches open) for the start of the class – see slide 54
- Preferably use 12V lamps and suitable supply, so that the effects are clear
- Sufficient Three demonstration circuits, with a single lamp, two lamps in series, two lamps in electrical kit for each group of students to construct circuits (each group needs cell, 2 lamps, 3 switches, ammeter and connecting leads) – see slides 54, 55
- Optional: simulation software



Slide 54

Electric current in a parallel circuit (1)

The circuit diagram shows a circuit with two lamps in parallel. There are three switches in the circuit.

1) **PREDICT** which switches would need to be closed so that

a) each lamp glows alone _____

b) both lamps glow together. _____

2) **Build** the circuit and **OBSERVE** what happens. _____

3) **EXPLAIN** your observations. Include the words 'parallel', 'current' and 'energy' in your explanation. _____

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Electric current in a parallel circuit (2)

1) **PREDICT** whether the ammeters would all give the same readings. If not, would you expect any pattern in the readings? Give reasons. _____

2) **Build** the circuit, move the ammeter around as shown and **OBSERVE** the readings. _____

3) **EXPLAIN** your observations. Include the words 'parallel', 'current' and 'junction' in your explanation. _____

Circuit 1: _____ Amperes

Circuit 2: _____ Amperes

Circuit 3: _____ Amperes

Circuit 4: _____ Amperes

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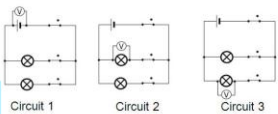
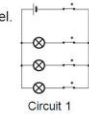
Slides 55-56

Lesson 6, Part 2: POTENTIAL DIFFERENCE AND PARALLEL CIRCUITS

Resources

Teaching this lesson part will require:

- Sufficient electrical kit for each student group to build circuits (each student group needs cell, 2 lamps, 3 switches, voltmeter, ammeter and connecting leads; each student group undertaking the extension activity with need an additional lamp and switch) – see slides 59-60
- Optional demonstration circuit and/or simulation software

<p>p.d./voltage in a parallel circuit</p> <p>The voltmeter is reading p.d. across different components in each circuit.</p>  <p>1) PREDICT whether the voltmeters would all give the same readings. If not, would you expect any pattern in the readings? Give reasons.</p> <p>2) Build the circuit move the voltmeter around as shown and OBSERVE the readings.</p> <p>3) EXPLAIN your observations. Include the words 'parallel', 'p.d.' and 'energy' in your explanation.</p> <p>Circuit 1: ____ V Circuit 2: ____ V Circuit 3: ____ V</p> <p><small>© epiSTEMe 2009/10</small></p>	<p>Electric current and p.d./voltage in a parallel circuit</p> <p>This circuit diagram shows a cell powering three lamps in parallel.</p>  <p>1) How will current vary around the circuit?</p> <p>2) How will current flowing from the cell compare with current through each lamp?</p> <p>3) How will the p.d. across each component in the circuit compare?</p> <p>4) How you could test your predictions?</p> <p><small>© epiSTEMe 2009/10</small></p>
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Slides 59-60

LESSON 7

Lesson 7, Part 1: MODELLING PARALLEL CIRCUITS

Resources

Teaching this lesson part will require:

- rope for rope loop model of circuits (see note above, lesson 3, part 2)
- marbles (or other tokens) for role play (see note above, lesson 3, part 2)
- optional: the teacher may wish to use a demonstration circuit or simulation software to reiterate points for earlier lessons

Lesson 7, Part 2: CHALLENGING CIRCUITS [EXTENSION]

Resources

If this lesson part is to be taught, it will require:

- Sufficient electrical kit for each student group to build circuits (each group will need 2 cells, switch, 6 lamps and sufficient connecting leads) – see slide 72
- Optional use of a demonstration circuit (as per student circuit) or simulation software

Practicing parallel circuits

1) DESCRIBE the arrangement of components in each circuit (using the words 'series' and 'parallel').

2) PREDICT how the current passing through different parts of the circuit will compare when the switch is closed. Draw ammeters into the circuit diagram to show each of the positions you would place ammeters.

3) PREDICT how the p.d. measured across different components will compare when the switch is closed. Draw voltmeters into the circuit diagram to show each of the positions you would place voltmeters.

4) BUILD the circuit and CHECK your predictions. Record your readings next to the ammeters and voltmeters in the diagram.

5) Explain your findings. Use the words 'current', 'series', 'parallel', 'p.d.', 'energy', 'junction'.

Circuit 1 Circuit 2 Circuit 3 Circuit 4
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Slide 72

LESSON 8

Lesson 8, Part 1: EVALUATING MODELS OF CIRCUITS

Resources

This lesson part does not require any equipment, unless the teacher wishes to reinforce earlier work (with demonstration circuits/simulation software, the rope loop and/or marbles for role play).

Lesson 8, Part 2: COMPARING CIRCUITS

Resources

This lesson part does not require any equipment.

LESSON 9

Lesson 9, Part 1: CIRCUIT DOMINOES

Resources

Teaching this lesson part will require:

- Sets of dominos copied from provided master sheets

There are three versions of the domino task (to allow differentiation between classes, or between groups within mixed ability classes):

- 1) only closed circuits, and no measuring instruments (simplest *);
- 2) open and closed circuits mixed, but no measuring instruments (more difficult **);
- 3) only closed circuits, but with or without meters (most difficult ***).

The class teacher will decide which version(s) to use for a particular class.