

Unit Preparation Booklet

P1.4 Electric Circuits

Teacher name:

Science **Mastery**

Ark Curriculum+

Science Mastery

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Steps to Success

		What?	Why?	Who?	Page #
Preparing to teach	**1**	☐ Print this booklet or save a copy in a personal folder	To allow for engagement during planning and co-planning	*All teachers*	
	2	☐ Engage with the unit preparation checklist	To prepare for delivering the sequence of lessons	*All teachers*	4
	3	☐ Read the scope and sequence for the unit	To review the scope and sequence of the unit	*All teachers*	5-6
	4	☐ Complete the pre-unit quiz reflections task after administering to class	To plan how to remedy prior knowledge gaps	*New to teaching the unit only*	9
	6	☐ Complete the Mastery Quiz and exam-style questions activity	To learn/revisit the key assessment objectives of the unit	*New to teaching the unit only*	10-18
	7	☐ Complete the misconception activities	To develop a strong understanding of the most common misconceptions for the unit and how to address them	*New to teaching the unit only*	19-21
Delivering the unit	**8**	☐ Use the lesson by lesson objectives to monitor progression through the unit	To maintain a record of completion and to recognise what needs to be reviewed after each lesson	*Novice teachers only*	22-31
Utilise other features of the booklet	**9**	☐ Complete the advanced subject knowledge	To develop an understanding of where the unit can lead	*Non A-level specialists*	32
	10	☐ Engage in the keywords and new scientists for the unit	To identify the correct definitions for keywords throughout the unit	*Novice teachers only*	33-34

Unit preparation checklist

Resources can and should be tailored to meet your pupils' needs. We have aimed to do as much resourcing as possible so that teachers' time can be spent on co-planning and preparation; however, they are only ready for your pupils once you have decided how to make use of them.

Here is a suggested checklist:

Locate:

- ☐ **Find** the unit resources using MyMastery or SharePoint

Engage:

- ☐ Work through the preparation booklet. Complete the pre-unit quiz and mastery quiz yourself and reflect (all enclosed)
- ☐ Set your class the **pre-unit quiz** (in advance of the unit).
- ☐ Note which topics are **areas of weakness** for the class (space available in this booklet or on the planning pro-forma)
- ☐ **Decide** which topics you will re-visit 'in advance' and which to tackle during the unit (space available in this booklet or on the planning pro-forma)
- ☐ Identify where in the sequence of learning there are opportunities for embedding **guided reading**
- ☐ Use the **lesson planning guidance** to develop a grasp of the purpose of each lesson element

Adapt:

- ☐ Consider key timings for each lesson. Identify which lessons may need to be adapted to account for the length of your lessons or ability level of your class
- ☐ Identify what could be used as **homework** activities to support in-class learning in line with school policy
- ☐ Review the resources ahead of each lesson and ensure you are clear on the objectives of each lesson
- ☐ **Select** appropriate activities for each lesson from the selection within each lesson folder/on the slide deck
- ☐ **Administer** exit tickets and use outcomes of this to plan 'fix-it' tasks to tackle misunderstanding or misconception.
- ☐ Set the **mastery quiz** for your class. Use the information to plan a suitable re-teach lesson and further response, using the resources available.

Scope and Sequence

Scope

Pupils will learn about the fundamentals of electric circuits using different models, including comparing current and voltage in an electric to circuit to the flow of water through pipes in a heating system. They will also learn about the differences between series and parallel circuits, what makes a complete circuit and what is needed for current to flow.

Pupils will learn the definition of current as the rate of flow of charge and use the equation I = Q/t to describe current quantitatively. Pupils will investigate current in series and parallel circuits, learning how to correctly connect an ammeter to take readings of current and compare their findings to the accepted rules for current in series and parallel circuits.

Pupils will also investigate voltage in series and parallel circuits, learning how to correctly connect a voltmeter. They will learn about the rules for voltage in series and parallel circuits and investigate this through looking at the brightness of bulbs in different circuits.

Sequence

Electricity is a pathway by which energy is transferred, which means that pupils need to have first covered the different stores of energy and energy transfers in order to access this unit. From KS2 pupils should be able to explain the difference between conductors and insulators, which they will have also encountered in terms of thermal conductors and insulators in P1.3. They will also have looked at simple electrical circuits so this unit is placed here in order to develop their understanding of the key features of electrical circuits. This is important to cover at an early stage because there is a large amount of content in this big idea which is conceptually challenging because of its abstract nature, meaning that it is very useful to gradually introduce knowledge before building on it.

The same approach is taken within the unit, with pupils have a macroscopic introduction to the features of electrical circuits, using models to represent different features. Pupils will then look at the microscopic view in terms of the flow of current and the behaviour of current and voltage in series and parallel circuits, before developing their practical skills of measuring current and voltage in both types of circuit.

Pupils will be introduced to potential difference as voltage at this stage as they will not yet have a solid enough understanding of potential energy, so using voltage helps to simplify the concept. Pupils will also not be introduced to resistance at this stage, as this will be introduced in P2.3, where resistance is covered qualitatively before linking back to the relationships between current, voltage and resistance. In this unit pupils will be introduced to current as the flow of charge without reference to electrons, as the subatomic particles are covered later in C3.1.

Fundamental ideas from this unit will be built upon when pupils learn about Ohm's

Law and resistance and with more complex calculations for voltage and current in series and parallel circuits. They will also learn how electricity is generated from renewable and non-renewable resources and how it is used in domestic settings.

Pupils will build on the key skills of this unit (building circuits and measuring values in series and parallel) with multiple components connected both in series and parallel.

A full set of knowledge objectives for this unit can be found as **Appendix 5.**

1	**2**	**3**	**4**
Prior Knowledge Review	Models of Electricity	Series and Parallel Circuits	Current
5	**6**	**7**	**8**
Circuit Components	Measuring Current	Measuring Voltage	Drawing Conclusions
9			
Feedback Lesson			

TASKS:

New teachers: Organise the lesson titles into those you feel most to least confident about *Experienced teachers:* Reflect on prior experience of teaching this unit. Which lessons have gone well? Which would you like to target for improvement this year?

Pre-unit quiz

TASK: Below is the pre-unit quiz available for your pupils. Complete yourself and set for your pupils ahead of starting the unit. There is space to record the key outcomes from marking the quiz for your class. **See Appendix 1 for the mark scheme.**

1. Which best describes what it means for a material to conduct electricity? [1]
   Tick (✓) **one** box.
   - (a) The material produces electricity ☐
   - (b) The material allows electricity to flow through it ☐
   - (c) The material stops electricity from flowing ☐

2. Which of these materials would conduct electricity? [1]
   Tick (✓) **one** box.
   - (a) Copper ☐
   - (b) Plastic ☐
   - (c) Wood ☐

3. Which of these terms means a substance that transfers heat easily? [1]
   Tick (✓) **one** box.
   - (a) An electrical conductor ☐
   - (b) A thermal conductor ☐
   - (c) An insulator ☐

4. Which of these **does not** contain a store of chemical energy? [1]
   Tick (✓) **one** box.
   - (a) A stretched elastic band ☐
   - (b) Food ☐
   - (c) A battery ☐

5. Which of these is a pathway by which energy is transferred? [1]
   Tick (✓) **one** box.
   - (a) Kinetic ☐
   - (b) Gravitational ☐
   - (c) Electrically ☐

6. Which best describes the function of a lightbulb? [1]
Tick (✓) **one** box.

(a) To emit heat ☐

(b) To emit light ☐

(c) To reflect light ☐

7. Which of these would **not** provide electricity to a circuit? [1]
Tick (✓) **one** box.

(a) A battery ☐

(b) A plug socket and plug ☐

(c) An appliance ☐

8. Which is the best definition of efficiency? [1]
Tick (✓) **one** box.

(a) A measure of how much useful energy is transferred ☐

(b) The total amount of energy transferred ☐

(c) How much energy is created ☐

9. Which of these statements about energy is correct? [1]
Tick (✓) **one** box.

(a) Energy is used up by appliances ☐

(b) Energy is made when things are burned ☐

(c) Energy can be transferred between stores ☐

10. If another battery is added to a circuit which contains a lightbulb, what would happen to the lightbulb? [1]
Tick (✓) **one** box.

(a) There would be no change ☐

(b) The lightbulb would get brighter ☐

(c) The lightbulb would get dimmer ☐

Total = ___ /10

Pre-unit quiz reflections

To be completed once you have reviewed your pupils' response to the pre-unit quiz.

What topics are your pupils confident with?
What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout the unit?

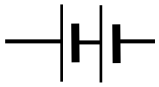
Other notes

Mastery Quiz

TASK: Below is the mastery quiz available for your pupils to sit at the end of the unit. Complete yourself and consider the key misconceptions this quiz aims to address. See **Appendix 2** for the mark scheme.

Section A

1. Choose which component the symbol below represents. [1]



Tick (✓) **one** box.

A. Cell ☐

B. Wire ☐

C. Battery ☐

2. Choose the unit that current is measured in. [1]

Tick (✓) **one** box.

A. Volts ☐

B. Ammeter ☐

C. Amps ☐

3. In a series circuit containing 1 bulb, the voltage of the battery was increased from 1.5 V to 3.0 V.

The brightness of the bulb …[1]

Tick (✓) **one** box.

A. doesn't change. ☐

B. increases. ☐

C. decreases. ☐

4. In parallel circuits, there…[1]

Tick (✓) **one** box.

A. is **more than one** path that current can flow. ☐

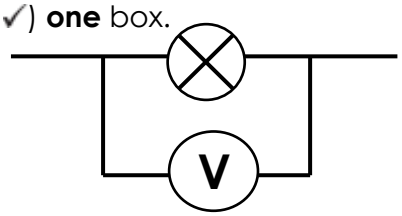
B. is **only one** path that current can flow. ☐

C. are **always two** paths that current can flow. ☐

5. Choose which shows the correct way to measure voltage across a bulb. [1]

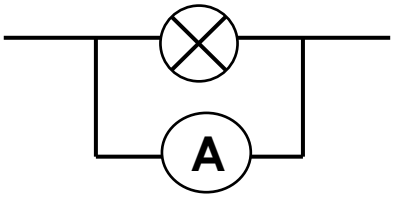
Tick (✓) **one** box.

A.



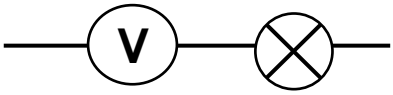
☐

B.



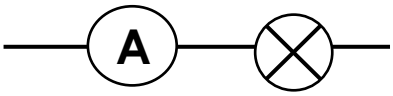
☐

C.



☐

D.



☐

6. Choose the best definition of voltage. [1]

Tick (✓) **one** box.

A. The rate of flow of charge around the circuit. ☐

B. The amount of energy shifted from the moving charges to the component. ☐

C. The amount of cells or batteries that are in the circuit. ☐

7. Some students make a model of a circuit by holding a loop of rope in a circle.

The teacher pushes the rope along so it moves at a steady speed, whilst 4 students hold the rope loosely in their hands.

(a) What does the speed of the moving rope represent? [1]

Tick (✓) **one** box.

A. Voltage ☐

B. Energy ☐

C. Current ☐

(b) Choose a limitation of this model. [1]

Tick (✓) **one** box.

A. It does not model a battery ☐

B. Components cannot be represented ☐

C. It only models a series circuit and not a parallel circuit ☐

8. The voltage across a battery is…[1]

Tick (✓) **one** box.

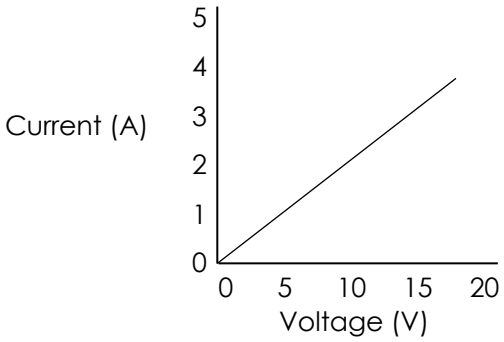
A. split between two bulbs in a series circuit. ☐

B. the same as the voltage across each bulb in a series circuit. ☐

C. is split between two bulbs each in a branch of a parallel circuit. ☐

9. A student measured how increasing the voltage affected the current in a series circuit.

The graph below shows the results.



Choose the best conclusion for this investigation. [1]

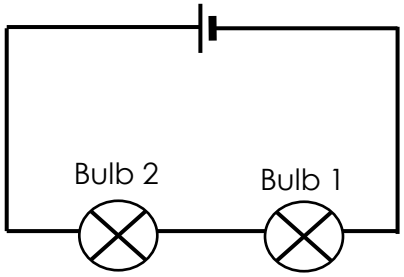
Tick (✓) **one** box.

A. At 10 V the current is 2 A ☐

B. When the current is high the voltage is low ☐

C. As the voltage increases, the current increases ☐

10. Bulb 1 breaks in the circuit shown below.



Now bulb 2 does not light. Assume bulb 2 hasn't broken.

Choose the best explanation for this. [1]

Tick (✓) **one** box.

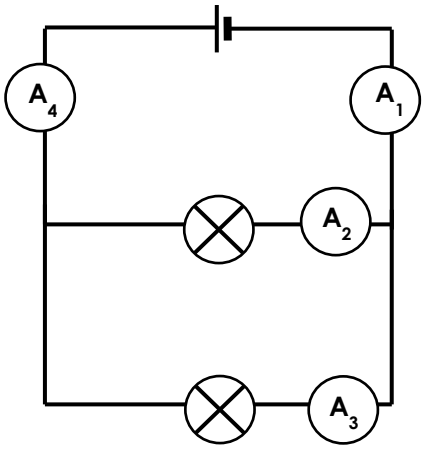
A. Bulb 1 has used up all the current in the circuit ☐

B. The circuit is now incomplete so current cannot flow ☐

C. Bulb 2 must need more energy to light up ☐

11. The bulbs in the circuit below are identical.

The ammeters in the circuit showed the following readings:
A_1 = 2 A
A_2 = 1 A



Choose what the readings would be at A_3 and A_4. [1]

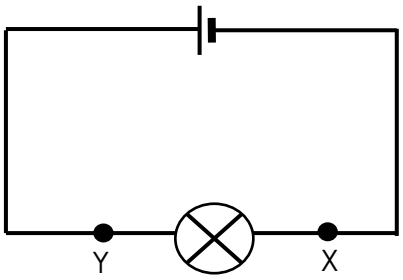
Tick (✓) **one** box.

A. A_3 = 2 A A_4 = 2 A ☐

B. A_3 = 1 A A_4 = 1 A ☐

C. A_3 = 1 A A_4 = 2 A ☐

12. Choose the best description of current at points X and Y on the circuit below. [1]



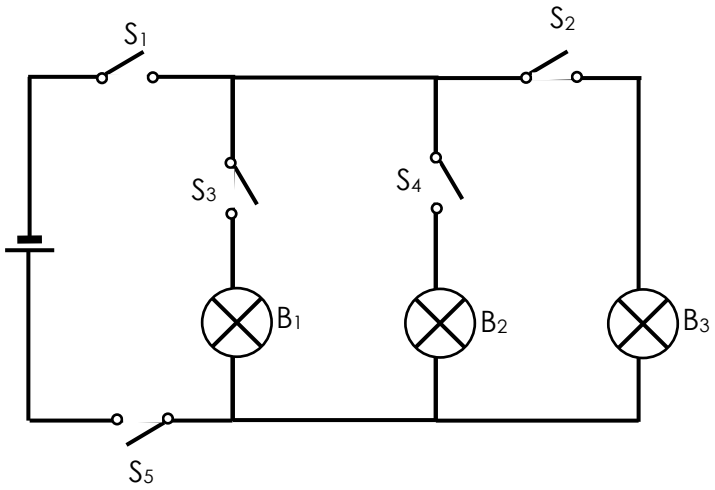
Tick (✓) **one** box.

A. The electric current at X is bigger than at Y ☐

B. The electric current is the same at X and Y ☐

C. The electric current at X is bigger than at Y ☐

13. Choose which bulbs would be on if only switches 1, 2 and 3 were closed in the circuit below. [1]



Tick (✓) **one** box.

A. All bulbs on ☐

B. All bulbs off ☐

C. Only bulbs 1 and 3 on ☐

14. A very long series circuit that contained a battery and a bulb was set up around a whole classroom.

When the wires are connected… [1]

Tick (✓) **one** box.

A. the bulb lights instantly because there are already charges in the wires that all move at the same time. ☐

B. it takes time for the charges to travel from the battery, around the long wires to the bulb. ☐

C. the bulb lights quickly because the charges travel around the wires to the bulb very quickly. ☐

15

Section B

1. Define current.

_____

_____

2. Complete this circuit diagram below.

The circuit must:
- be parallel and contain two branches
- contain 2 motors (one in each branch)
- contain 1 buzzer
- be drawn using a pencil and ruler



3. A student wanted to investigate whether having 1, 2 or 3 bulbs in a series circuit affected the current.

(a) State the dependent variable in this investigation.

_____

(b) Describe a method the student could use.

_____
_____
_____
_____
_____
_____

(c) The results of this investigation are shown below.

Number of bulbs	Current (A)
1	4
2	3
3	1

Write a conclusion for this investigation.

_____
_____
_____
_____
_____
_____

Mastery quiz reflections

Which aspects of genetics are likely to be the most challenging to teach?	
What are your pupils likely to find most challenging and why?	
Challenging.....	Because....
E.g. The number of new keywords	*They are abstract words that aren't used in other areas of science*
How can you pre-empt some of the key misconceptions the mastery quiz aims to identify?	
Misconception	**How to avoid**

Exam-style questions

TASK: Using exampro (or the software used by your exam board), look through the typical exam-style questions for this topic. These sorts of questions are posed throughout the unit and pupils should be prepared to answer similar questions in the end-of-year assessments.

Suggested questions to guide this process:

How is knowledge from this unit typically assessed? What are the most common questions?
Which question types are the most challenging?
What general trends can you spot in the typical errors pupils make (from examiner reports/notes)?
How could you help prepare your students for answering these types of questions?

Common mistakes, errors and misconceptions

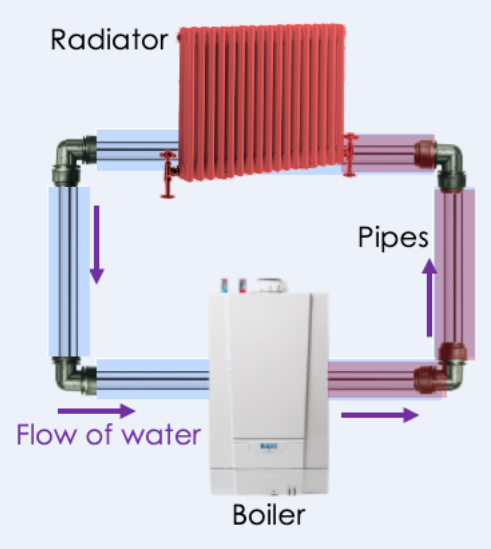
How would you tackle the following common mistakes, errors and misconceptions by pupils?

TASK: Consider why each of the following typically seen statements is a mistake/misconception. What possible approaches can you plan to pre-empt and respond to this? Which lessons do these correlate to?

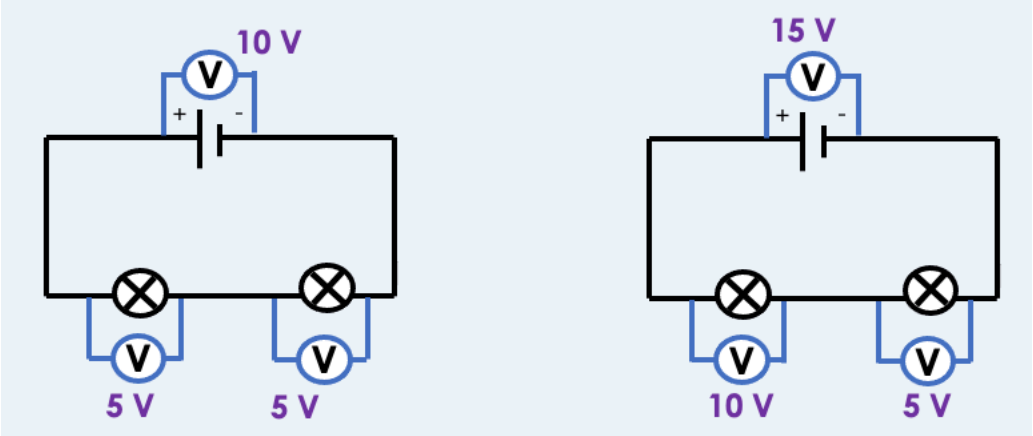
CHALLENGE: Cover the middle column and explain yourself why each is a mistake.

Mistake	**Reason why it's a mistake**	**Possible approaches to pre-empt and respond?**
Current and voltage are the same	Current is the rate of flow of charge. Voltage is how much energy is shifted from the power supply to the moving charges or from the charges to a component.	
Current is the same at all points in a parallel circuit	Current is the same at all points in a series circuit. Current splits at junctions in a parallel circuit because there are different paths for the current to take.	
Current is used up in a circuit	Current is the rate of flow of charge so cannot be used up.	
Voltage is the same across each component in a series circuit	Voltage is only the same across each component in a series circuit if the components are the same (they have the same resistance). If the components are not the same, the voltage across them will not be the same, but will sum to equal the total voltage of the power supply.	
Voltage is split at the branches of a parallel circuit	Current is split at the branches of a parallel circuit. Voltage is the same across each branch of a parallel circuit (but not each component if there are multiple components on a branch). This is because the work done per unit charge, or the energy shifted by the moving charges to the component is still the same.	
Voltage is shared evenly between the components in a series circuit.	Voltage is only shared evenly if the components are identical.	

Planning for the misconceptions

Misconception: Current and voltage are the same
Often students use the words electricity, energy, current and voltage interchangeably to all mean 'electricity'.
Supporting pupil understanding
Current is the rate of flow of charge. Voltage is the work done per unit charge (so how much energy each charge transfers). At this level, students will use the definition 'how much energy the charges transfer to the components or the battery transfers to the charges. Using the water heater model is a useful way to get students to understand the difference. In this model, the rate at which water flows around the circuit represents the current. The thermal energy that is transferred from the water to the radiator represents the voltage. Once students have a reference, it can then be useful to identify the representations in different models: E.g. the rope model *In the rope model, what represents the current?* ***How quickly the rope is moving*** *What represents the voltage?* ***How hot our hands get – this represents the thermal energy being transferred from the rope (the charges) to the components (our hands).*** 
Taking it further
It is important that students understand the difference between current and voltage before they simply rote learn the rules for current and voltage in series and parallel circuits.

Misconception: Current is used up in a circuit
Current is the rate of flow of charge. It cannot be used up. If there is a break in the circuit, current cannot flow but this is not the same as being used up. Students will not learn about resistance until Y8 and will learn that even as resistance increases and current decreases, this is the current decreasing rather than being used up.
Supporting pupil understanding
Using a model such as the rope model can be useful so that students understand that current is a rate rather than a thing that can be used up.

Misconception: Voltage is always shared evenly between the components in a series circuit.
Voltage is shared between the components in a series circuit because energy is transferred to the components when the charges pass through them. The voltage is only shared evenly when the components are the same.
Supporting pupil understanding
Many of the examples used use identical bulbs for simplicity so it is worth explicitly using some examples where the components are not identical. The key for students to understand is that the voltages across each bulb can be summed to equal the total voltage supplied by the power source. When using examples where the components are identical, it is still worth explicity 
Taking it further
You may want to give students more challenging examples, where they have to determine missing voltages from series and parallel circuits.

Unit objectives: knowledge, skills and concepts

As you teach the lessons, track here the objectives you meet.

TKT = to know that TBAT = to be able to

Critical: it is critical that all pupils become proficient; future learning will be very challenging for them if they do not and it is likely they will not come across this content again. These are priority objectives for reteaching, revision, and intervention. Before moving on, discuss a strategy with your HOD if some pupils are not making progress with these objectives.
Core: it is important for all pupils to learn this, and it will be essential for success at GCSE. However, it will not impede them in other units if they are not (yet) proficient in it as they are likely to revisit it again in subsequent units.
Stretch: pupils should have the opportunity to be work on this aspect of science. This content is crucial for pupils to achieve the highest GCSE grades and to succeed at A-level.
Key skill: pupils should have the opportunity to develop this key skill as part of this unit.

Intended outcome for separate sciences pupils are denoted in blue and italised.

Lesson 1: Prior knowledge review

Intended outcome	Example questions
*This lesson is a review of content from previously studied units relating to this big idea	
TBAT identify the circuit symbols for a battery, bulb and switch	Identify the circuit symbol for a battery Identify the circuit symbol for a bulb Identify the circuit symbol for a switch
TBAT state whether or not a bulb will light in a circuit	Is this a complete circuit? Will current flow if there is a break in the circuit? Will the bulb light when the switch is open?
TBAT Describe electricity as a pathway by which energy can be transferred	Describe the pathways by which energy can be transferred State the stores of energy
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 2: Models of Electricity

Intended outcome	Example questions
TKT current is the flow of charge around a circuit	Define current Describe what represents current in the water heater model Describe what represents current in the rope model
TBAT compare features of an electrical circuit with a model	Describe what represents voltage in the water heater model Describe what represents a battery in the water heater model Describe what represents a bulb in the water heater model
TBAT describe the effect of increasing current and voltage in a circuit	Describe what happens to the current in the water heater model if more water is flowing Describe what happens to the current in a circuit if charges are flowing more quickly Describe what happens to the voltage in the water heater model if the temperature of the boiler is increased Describe what happens to the voltage in a circuit if charges transfer more energy
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 3: Series and Parallel Circuits

Intended outcome	Example questions
TBAT identify series and parallel circuits	Identify whether the circuit is series or parallel Explain why this circuit is series/parallel
TBAT describe how the brightness of bulbs changes as they are connected in series and in parallel	Describe the effect of adding another bulb in series on the brightness of the bulb Describe the effect of adding another bulb in parallel on the brightness of the bulb
TBAT predict the effect of broken components in series and parallel circuits	Predict which of the bulbs will light in a given circuit Explain why lights in a home are connected in parallel
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 4: Current

Intended outcome	Example questions
TBAT define current as the rate of flow of charge	Define current State the units for current State the equation that links current, charge and time Calculate the current using the equation
TBAT explain that voltage is the energy transferred between two points in a circuit	Define voltage Describe the effect that increasing the voltage has on the current
TBAT describe the effects of adding components on current and voltage	Describe the effect of adding another bulb in series on the current Describe the effect of adding another cell in series on the current Describe the effect of adding another cell in series on the voltage
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 5: Circuit Components

Intended outcome	Example questions
TBAT recall the symbols of the following components: cell, battery, bulb, motor, switch, buzzer, ammeter, voltmeter	Draw the circuit symbols for each of these components
TBAT describe the function of circuit components	Describe the function of each of these circuit components
TBAT draw accurate circuit diagrams	Draw a circuit diagram to show how these components would be connected
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 6: Measuring Current

Intended outcome	Example questions
TBAT describe how to measure current in a circuit	Describe how to measure current in a circuit Draw a circuit to show how you could measure the current Name the component used to measure current and describe how it should be connected
TBAT state that current is the same at all points in a series circuit	State the rule for current in series circuits Identify what the current would be given the current at another point in the circuit.
TBAT state that current splits at branches in parallel circuits	State the rule for current in parallel circuits Calculate what the current would be given the current at other points in the circuit.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 7: Measuring Voltage

Intended outcome	Example questions
TBAT describe how to measure voltage across a component	Describe how to measure voltage across a component Draw a circuit to show how you could measure the voltage across a bulb Name the component used to measure voltage and describe how it should be connected
TBAT state that voltage is shared between components in a series circuit	State the rule for voltage in series circuits Identify what the voltage would be given voltages across different components
TBAT state that voltage is equal across each branch of a parallel circuit	State the rule for voltage in parallel circuits Calculate what the voltage would be given the voltage at other points in the circuit
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 8: Drawing Conclusions

Intended outcome	Example questions
TBAT draw a suitable conclusion from a circuit diagram	Use the values given to draw a conclusion about current/voltage in series/parallel circuits
TBAT identify a suitable method to measure current and voltage in a circuit	Which method would allow you to measure the current and voltage in a circuit?
TBAT explain why the method is suitable	Explain why a method is suitable Explain how to connect an ammeter Explain how to connect a voltmeter
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Mastery Quiz re-teach planning

To be completed once you have reviewed your pupils' response to the mastery quiz.

What topics are your pupils confident with?
What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout another unit? When will that be taught?

Other notes

Lesson 9: Feedback lesson

Intended outcome	Example questions
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Advanced subject knowledge

Where does this learning lead?

At GCSE level, pupils are expected to use current and voltage in more complicated series and parallel circuits. They will look at resistance in P2.3 and at A-Level will have to calculate effective resistance of combinations in series and parallel. Students will also learn to relate electrical circuits with domestic electricity, as well as comfortably work with the following equations:

$P=IV$	$V=IR$	$E = VQ$
$P= I^2R$	$E = Pt$	$Q = It$

Have a look at the questions below and think about what this means for this unit.

How does learning from this unit develop at KS4?
What content from this unit is fundamental to student understanding at KS4?
How could you check that students have grasped these fundamentals?

Vocabulary and literacy

Tier 3 vocabulary and phrases in this unit that pupils are likely to already know:

Word	Definition	Example in context
Electrical Conductor	A material that has a low resistance and allows current to flow through it easily.	Metals are electrical conductors.
Electrical Insulator	A material that has a high resistance and does not allow current to flow through it easily.	Rubber is an electrical insulator.
Switch	A component that can be open or closed to control whether or not current can flow.	When a switch is open, the circuit is incomplete.

Tier 3 vocabulary that will need to be explicitly taught in context:

Word	Definition	Example in context
Ammeter	A component used to measure current in electrical circuits, connected in series.	Ammeters measure current in Amps.
Amperes (Amps)	The unit of measurement for current.	The current in the circuit was 2 Amps.
Battery	Two or more cells connected together.	A battery is a power source in an electrical circuit.
Cell	A single energy source that can be used to power an electrical circuit, two or more of which can be connected	A cell is a power source in an electrical circuit.
Charge	Particles that transfer energy in an electrical circuit.	The SI unit for charge is the Coulomb.
Component	Any device in an electrical circuit.	Components in a circuit can be connected in series or parallel.
Current	The rate of flow of charge.	The current in a circuit is measured using an ammeter.
Energy	The ability or capacity to do work (such as move an object through a distance).	Energy cannot be created or destroyed but can be shifted between stores.
Junction	A point in a parallel circuit where the current can split.	The different branches in a parallel circuit split at a junction.
Parallel circuit	A circuit in which there is more than one branch through which current can flow.	Current splits at branches in a parallel circuit.
Power	The rate of energy transfer.	An appliance with a higher power

		rating transfers more energy per second.
Series circuit	A circuit in which there is only one branch through which current can flow.	Current is the same at all points in a series circuit.
Voltage	The amount of energy shifted from the power source to the moving charges or from the charges to the component.	Adding another cell can increase the voltage in a circuit.
Voltmeter	A component used to measure voltage in electrical circuits, connected in parallel.	Voltmeters measure voltage in Volts.
Volts	The unit of measurement for voltage.	The voltage across the bulb was 5 Volts (V).

Appendices

Appendix 1: Mark scheme for pre-unit quiz

Qu	Answer	Marks	Supporting information for fix-it tasks
1	B	1	Answering A or C show that pupils are not secure on what it means to conduct electricity. *Task: Explain the difference between an electrical conductor and an electrical insulator.*
2	A	1	Answering B or C shows that pupils are not secure on conductors and insulators. *Task: State what kind of materials conduct electricity and give an example.*
3	B	1	Answering A shows that pupils have the general idea of conducting meaning allowing something to pass through but not the difference between thermal and electrical. Answering C shows that pupils have misunderstood conductors and insulators. *Task: Explain the difference between an electrical conductor and a thermal conductor.*
4	A	1	Answering B or C shows that pupils are not clear on the different stores of energy and common examples of each. *Task: State the five different stores of energy and give an example of each.*
5	C	1	Answering A or B shows that pupils do not recall the difference between energy stores and energy transfers. *Task: State the four pathways by which energy can be transferred.*
6	B	1	Answering A shows that pupils have understood that lightbulbs emit heat but not that this is a wasteful energy transfer rather than the function. Answering C shows that pupils have not understood the difference between luminous and non-luminous objects from KS2. *Task: Name a component that could be used to*

			turn on and off a lightbulb in a circuit.
7	C	1	Answering A or B shows that pupils are not secure on the function of a battery or power supply in a circuit. *Task: Describe where most of our household electricity comes from.*
8	A	1	Answering B shows that pupils have forgotten that some energy is usually wasted in an energy transfer. Answering C shows that pupils do not understand that energy cannot be created or destroyed, only transferred. *Task: Describe how to calculate efficiency of an energy transfer.*
9	C	1	Answering A or B shows that pupils have a misconception around energy being created or destroyed. *Task: Explain what conservation of energy means.*
10	B	1	Answering A or C shows that pupils are not secure on the KS2 learning of adding batteries to a circuit and the effect on brightness. *Task: Explain what it meant by the word 'dimmer'.*

Appendix 2: Mark scheme for mastery quiz

Section A

Qu	Answer	Marks	Supporting information for fix-it tasks
1	C	1	Answering A suggests a common error of confusing a single cell with multiple cells, which is a battery. To *fix it, recap circuit symbols and then ask students to draw out, and explain the difference between, a cell and a battery.* Answering B suggests a lack of knowledge about circuit symbols. *To fix it, ask students to describe how wires are represented in circuit diagrams.*
2	C	1	Answering A suggests a confusion about the units of current and voltage. Answering B suggests a gap in knowledge about units vs. equipment used to measure current. *To fix both issues, ask students to complete a table about current and voltage that includes: definition, how to measure (i.e. ammeter/voltmeter), units.*
3	B	1	Answering A suggests a misconception that increasing the voltage of the battery does **not** increase the current and therefore increase the brightness of the bulb. *To fix it,* Answering C suggests a misconception that increasing the voltage of the battery **decreases** the current and decreases the brightness of the bulb. *To fix both of these, either do a live demo or use this brilliant Phet animation to demonstrate and ensure you include exposition to explain that increasing voltage increases the current, so that more energy is transferred to the bulb so it looks brighter.*
4	A	1	Answering B suggests a confusion with series circuits. *To fix it, show students several circuit diagrams and ask them to label which are series and which are parallel circuits, then ask them to explain why.* Answering C suggests a misconception that parallel circuits are always just two branches, as many diagrams show. *To fix it, recap the definition of a parallel circuit and ask students to draw a parallel circuit with 4 possible paths for current to flow.*
5	A	1	Answering B suggests some understanding that voltage is measured in parallel but shows a gap in knowledge about what is used to measure voltage. *To fix it, ask students to complete a table about current and voltage that includes: definition, how to measure (i.e. ammeter/voltmeter), units.* Answering C suggests that there is a misconception about how to connect a voltmeter, since in the diagram shown, it is incorrectly connected in series, rather than in parallel. *To fix it, ask students to copy out a circuit diagram and add in voltmeters to measure voltage across two bulbs.* Answering D suggests that there is a gap in knowledge about how to measure voltage, since an ammeter is shown. *To fix it, ask students to complete a table about current and voltage*

			that includes: definition, how to measure (i.e. ammeter/voltmeter), units.
6	B	1	Answering A shows a confusion with the definition of current. *To fix this, use this Phet animation to show that current is the flow of charge (electrons) around a complete circuit, then use the animation to measure voltage before and after a bulb to show that it is the difference in energy transferred from the charge (electrons) to the bulb.* Answering C suggests some understanding that a cell/battery provides a voltage, but it is not the definition of voltage. *To fix this, ask students to define current and voltage, perhaps using the rope model as an analogy to support.*
7a	C	1	Answering A or B suggests a confusion with the definitions of these key terms and there are many misconceptions that arise from assuming these mean the same. *To fix it, discuss the rope model again or demo it in the classroom and follow up with questions about what each part represents (ie. Moving rope = current, teacher pushing the rope = battery/cell, rope itself = charge (electrons) in the wire)*
7b	C	1	Answering A suggests a gap in knowledge that the teacher pushing the rope around is representing the battery. *To fix it, ask students to explain how the teacher holding the rope represents a battery.* Answering B suggests a gap in knowledge that the students holding the rope and feeling the heat produced from friction are a model for components. *To fix it, ask students to complete a table to describe what each part of the model represents. Include: the rope itself, the teacher pushing the rope and the students gently holding the rope.*
8	A	1	Answering B or C shows a confusion about how voltage acts in series and parallel circuits. *To fix it, ask students to write out rules using their notes and/or knowledge organiser about how current and p.d. acts in series and parallel circuits, then give many practice questions to apply this.*
9	C	1	Answering A suggests the misconception that a conclusion is simply stating data points from the results. *To fix it, ask students to state the trend the graph shows, referencing data points and then add a sentence to explain why the result happened.* Answering B suggests a gap in knowledge both about how to interpret line graphs and also that current prevents voltage. *To fix it, ask students to describe what happens to current in s circuit when the voltage is increased.*
10	B	1	Answering A shows the misconception that components 'use up' current; re-teach that current is a flow of charge that flows through components in the circuit and never gets 'used up'; this can be easily demonstrated (in the lab or virtually using this Phet animation) by measuring current at different places in the series circuit and seeing that it is the same everywhere. Answering C suggests that students have a gap in knowledge about complete vs. incomplete circuits; to resolve this, demonstrated (in the lab or virtually using this Phet animation)

			that once the circuit is incomplete as the result of a disconnected wire, a switch or a broken component, current does not flow.
11	C	1	Answering A suggests a confusion about current splitting at the branch point. Answering B suggests a misconception about current after the branches have re-joined. *To fix both of these issues reteach that current is the same everywhere in a series circuit but it splits between branches in a parallel circuit, then give many example circuits with missing ammeter readings to practice applying this.*
12	B	1	Answering A or C suggests the common misconception that some or all of the current it 'used up' by the bulb. *To fix it, recap that current is the same everywhere is a series circuit and then give students practice questions to apply this.*
13	B	1	Answering A or C suggests a misconception that if there is a switch open one side of the cell, then bulbs in the circuit will light. *To fix it, model how to answer this question by drawing switches 1, 2 and 3 as closed and then follow each branch around to show that there is an incomplete circuit every time because switch 5 is open.*
14	A	1	Answering B or suggests the common misconception that charge must travel from the battery to the component. *To fix it, recap using the rope model, that there are already charges in the rope/wire that all move at the same time.*

Section B

Qu	Model answer	Supporting information ***Suggestions for fix-it tasks***
1	Current is the rate of flow of charge.	A common error could be difficulty in recalling key terms because many key words from this unit are mistakenly used interchangeably (e.g. current, charge, electricity, voltage). *To fix it, recap the definitions of current and voltage and then ask students to explain how voltage affects current.*
2	*See diagram in PPT for feedback lesson*	An error here is to not use straight lines at right angles. *To fix it, give success criteria to students to peer assess each other's circuit diagrams and give a www to action.* Another common error is to draw lines through connected components e.g. through the motor. *To fix it, model how to draw a line for a wire by leaving a gap to draw the circle for the motor*

		symbol.
3a	Current	Students may still be struggling to identify variables from an experimental context. *to fix it, remind students of the definitions of the IV and DV and explain why current is the DV here. Then ask students to state the IV and CVs of this investigation.*
3b	**Exceptional model response** 1. Build a series circuit using a cell, wires, a bulb and an ammeter connected in series 2. Record the reading of current from the ammeter 3. Disconnect a wire from the same circuit and add in another bulb 4. Record the reading of current from the ammeter 5. Repeat steps 3-4 **Minimally acceptable response** Make a circuit with different numbers of bulbs and measure the current.	The common issue with writing methods is to not refer to specific pieces of equipment. *To fix it, ask students to write an equipment list for this investigation and then try again to write the method.*
3c	**Exceptional model response** Adding more bulbs to a series circuit causes the current to decrease. When there was 1 bulb the current was 4 A whereas when 3 bulbs were added, the current decreased to 1 A. This happened because the more components there are in a series circuit, the current is slowed down. **Minimally acceptable response** Current goes down when more bulbs are added.	A common error when writing a conclusion is to simply state the trend in the data without including some explanation. *To fix it, ask students to write a conclusion for the data in Q9 of Section A, ensuring they describe the trend, state some data and include an explanation of why the results happened.*

Appendix 3: Core knowledge statements

Electric Circuits

- *Models can be used to describe how a circuit works but no model is perfect because they are not the same as the live phenomenon*
- *In a series circuit there is only one path for the current to take*
- *In a parallel circuit there are multiple paths (or branches)*
- *If a component in a series circuit breaks, the circuit is now incomplete*
- *If a component in a parallel circuit breaks there may still be another path for the current to flow, depending on the location of the circuit break*
- *The following are common circuit components: cell, battery, bulb/lamp, motor, switch, buzzer, ammeter, voltmeter*
- *A battery is a group of cells working together*

Current

- *Current is the rate of flow of charge*
- *Current is measured in Amperes/Amps (A) using an Ammeter*
- *Ammeters are placed in series*
- *Current transfers energy*
- *Current can be calculated with the following equation:* $Current\ (A) = \frac{Charge\ (C)}{Time\ (s)}$
- *Charge is measured in Coulombs (C)*
- *For current to flow there needs to be a complete circuit and a power supply or battery to push the charges around the circuit*
- *Current is the same everywhere in a series circuit*
- *Current splits at the junctions in a parallel circuit*

Voltage

- *Voltage is measured in Volts (V) using a Voltmeter*
- *Voltmeters are placed in parallel*
- *Voltage is the amount of energy shifted from the power source to the moving charge, or from the charge to the circuit component in V*
- *Adding voltage increases the current and increases the brightness of bulbs*
- *Brightness of a bulb is decreased with more bulbs (components) added*
- *A battery with a higher voltage is able to give the charges a larger push around the circuit*
- *A battery that is bigger in size is able to store more charge so lasts longer*
- *Voltage is shared between components in series circuits*
- *Voltage is the same in branches of a parallel circuit*

Disciplinary Knowledge

3. Use models to represent data, events, processes, behaviours and other scientific phenomena

15. a. Select the best procedure from given options
b. Explain why a given practical procedure is well designed for its specified purpose.
c. Apply understanding of apparatus and techniques to suggest a procedure for a specified purpose.

51. Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements

Practical Skills

50. Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements