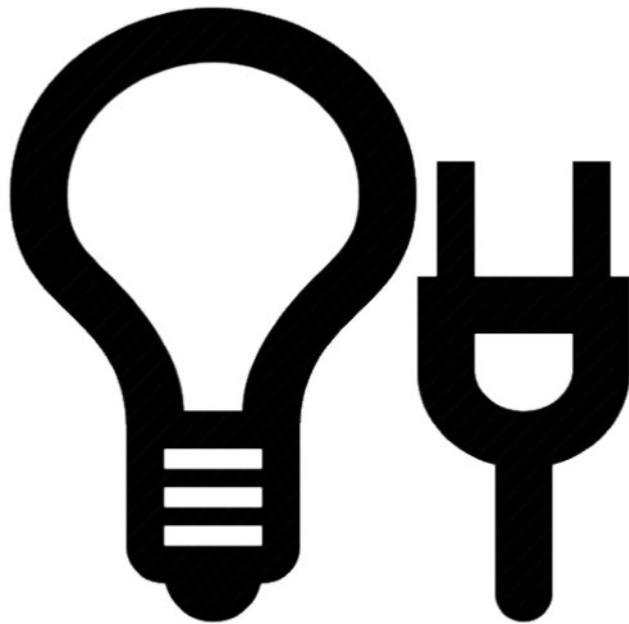


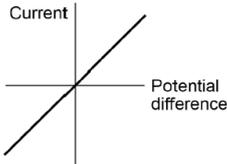
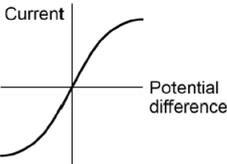
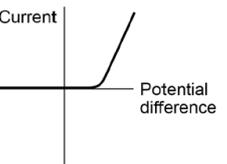
Year 9 Physics Workbook



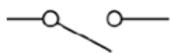
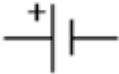
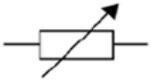
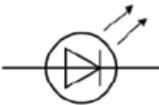
**The Polesworth
School
Electricity**

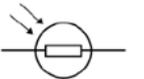
Name	Symbol	Factor	To convert to standard units:
Tera	T	10^{12}	× by
Giga	G	10^9	× by
Mega	M	10^6	× by 1,000,000
kilo	k	10^3	× by 1,000
centi	c	10^{-2}	÷ by 100
milli	m	10^{-3}	÷ by 1,000
micro	μ	10^{-6}	÷ by 1,000,000
nano	n	10^{-9}	÷ by 1,000,000,000

By the end of this booklet you should know the answers to all the common questions below

	Question	Answer
1	What are the positive things that move in a circuit?	Charges
2	What is current?	The rate of flow of charge
3	What is needed for current to flow in a circuit?	A potential difference (provided by a battery or mains supply)
4	What is potential difference?	A push on the charges in a circuit
5	What formula relates charge, current and time?	$Q = It$
6	What is the property of components that causes them to oppose a current flowing through them?	Resistance
7	What formula relates potential difference, resistance and current?	$V = IR$
8	Sketch the V-I graph for an ohmic conductor (resistor)	
9	Sketch the V-I graph for a filament bulb	
10	Sketch the V-I graph for a diode	
11	What does a diode do?	Only allows current to flow in one direction
12	What does an LDR do?	Resistance decreases as light level increases
13	What does a thermistor do?	Resistance decreases as temperature increases

14	Draw a circuit for determining the V-I characteristics of a component.	
15	What is the rule for current in series?	Is the same
16	What is the rule for current in parallel?	Splits up
17	What is the rule for potential difference in series?	Splits up
18	What is the rule for potential difference in parallel?	Is the same
19	What is the rule for resistance in series?	Adds up
20	What is the rule for resistance in parallel?	Is less than the lowest resistor
21	What is the difference between direct p.d. and alternating p.d.?	Direct p.d. is always positive or always negative; alternating pd switches between positive and negative.
22	Describe the characteristics of UK mains electricity	Alternating current with a frequency of 50Hz and a p.d. of 230V.
23	Describe the structure of a three-core cable	Live wire – brown – carries the alternating current from the supply Neutral wire – blue – completes the circuit Earth wire – yellow and green – safety wire – stops the appliance becoming live
24	Explain why the live wire is dangerous even if the circuit is not switched on	The live wire is at a high p.d. (230V) relative to Earth If the live wire is connected to Earth then a large current will flow through that object.
25	What formula relates power, current and potential difference?	$P = VI$
26	What formula relates power, current and resistance?	$P = I^2R$

27	What formula relates energy, power and time?	$E = Pt$
28	What formula relates energy, charge and potential difference?	$E = QV$
29	What is the National Grid?	A system of cables and transformers linking power stations to consumers
30	What do step-up transformers do?	Increase the p.d. ready for transport through cables across long distances
31	What do step-down transformers do?	Decrease the p.d. for use by consumers
32	Why is the National Grid an efficient way of transferring energy?	Because electricity is transported at a high p.d. and therefore low current, the energy lost due to heating is minimised.
	What is this component? 	Switch (open)
	What is this component? 	Switch (closed)
	What is this component? 	Cell
	What is this component? 	Battery
	What is this component? 	Diode
	What is this component? 	Resistor
	What is this component? 	Variable resistor
	What is this component? 	Light emitting diode (LED)

	What is this component? 	Filament lamp
	What is this component? 	Fuse
	What is this component? 	Voltmeter
	What is this component? 	Ammeter
	What is this component? 	Thermistor
	What is this component? 	Light dependent resistor (LDR)

Electric circuits

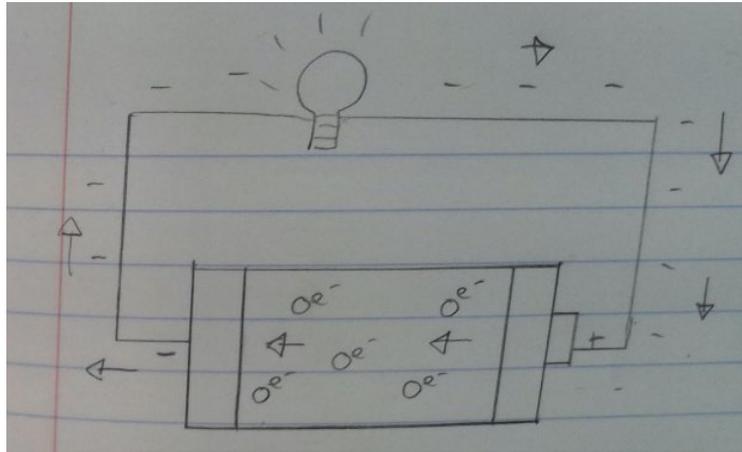
Electronic technology has been one of the most significant advancements of the human race. In an electric circuit, a power supply such as a cell or battery, supplies energy. This energy is transferred electrically to the components in the circuit. All components have work done on them by electrical current when it flows through them. Components then transfer this energy to the surroundings through either heating or light. Some components behave differently depending on the conditions around them; others are sensitive to the direction of the potential difference.

What happens in a battery?

A battery works like a reverse electrolysis cell. You put in two different metals and an electrolyte and you get electricity.

At each end of the battery is a different chemical species – e.g. zinc (negative end) and manganese oxide (positive end). Between them is an electrolyte. When the battery is connected, the chemicals react in a redox reaction. Electrons are pushed to the negative end of the battery and then around the circuit and back to the positive end of the battery.

When all the reactants have been used up, the battery is “dead”.



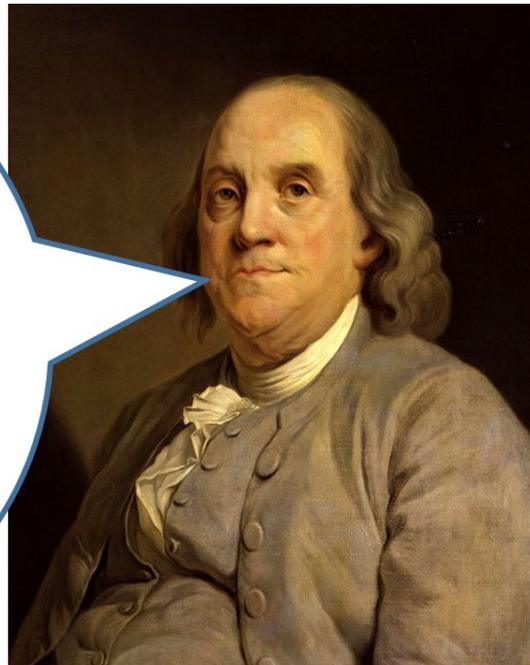
Conventional current vs true current

Hi everyone! My name is Benjamin Franklin and I began investigating electricity in the 1740s – over a hundred years before electrons were discovered.

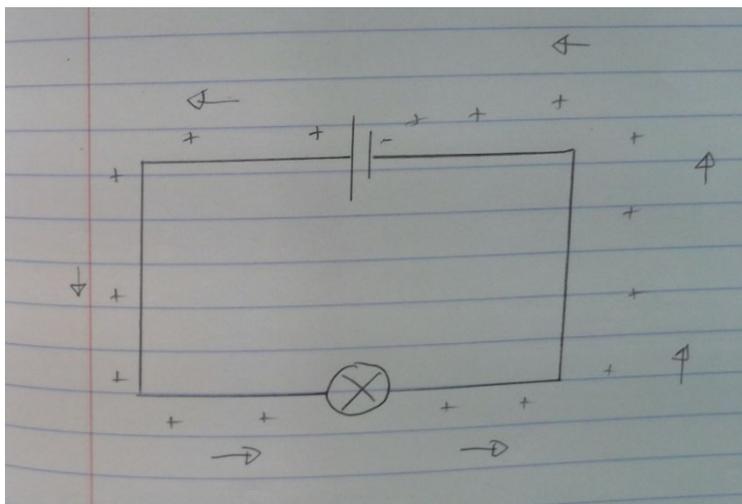
I came up with the idea of electric current – of charges being pushed around a circuit by a potential difference.

Unfortunately I got it a bit wrong because I thought that positive charges were pushed from positive to negative.

By the time electrons were discovered, scientists were so used to using my system (“conventional current”) they decided to stick with it even though actual current is the opposite!



What does a battery do in terms of conventional current?



A battery provides a force on charges, because of the chemicals in it.

This force is given the name "potential difference". This is because there is a difference between the potential (electrostatic) energy a charged particle would store at one end compared to the other.

If the battery is connected in a complete circuit, then this force does work on the charges in

the circuit and causes them to move around.

Although this really happens involving electrons, we use the model of conventional current: positive charges experience a force away from the positive terminal and towards the negative terminal.

Where do the charges in a circuit come from?

The charges in a circuit are already there in the wires and the components before the battery is connected.

All the battery does is provide the force to push the charges round.

All charges in the circuit start and stop moving at the same time.

The charges are not made in the battery/come out of the battery first and then flow round the circuit.

1. How does a battery work?
2. Draw a diagram to show how a battery works in a circuit.
3. What does a battery do to electrons?
4. Why do batteries get used up?
5. What electrical concept did Benjamin Franklin come up with?
6. Why was Benjamin Franklin wrong?
7. Why do we still use the idea of conventional current even though we know it's wrong?
8. How does conventional current compare to true current?
9. What happens in conventional current?
10. In terms of conventional current, what does a battery do in a circuit?
11. Where do the charges that move in a circuit come from?

What happens in a circuit?

Consider a simple circuit which is not connected. There are charges in the wires and the lamp, but they are not moving as there is no force to start them moving.

When we connect the circuit to each side of a battery, we create a potential difference between one part and the other. The positive side is at a high potential and the negative side is at a low potential. This causes a force on the charges in the circuit.

Charges experiencing a potential difference behave like balls on a tray which has a height difference between one side and the other. Just as the balls on the tray would roll from the high height to the low height, the charges move from the place of high potential to the place of low potential. In the battery, the redox reaction inside the battery does work on the charges to put them up to a high potential again.

Scientists are interested in charge as a quantity. We can measure the amount of charge that is moved around a circuit. We measure charge using the unit coulombs: C.

For example, an AA battery will move 1000C of charge through a circuit before it runs out.

One coulomb is 6.2×10^{18} "not-electrons".

1. What happens when a circuit is connected to a potential difference from a battery?
2. Draw a diagram showing charges in a circuit before and after it is connected to a potential difference from a battery.
3. Describe the balls-on-a-tray model for explaining why a potential difference causes charges to move in a circuit.
4. What is charge measured in?
5. How many "not-electrons" in 1C of charge?
6. What does the battery provide that causes charges to move around the circuit?
7. Why do scientists often say the battery pushes charges around the circuit?

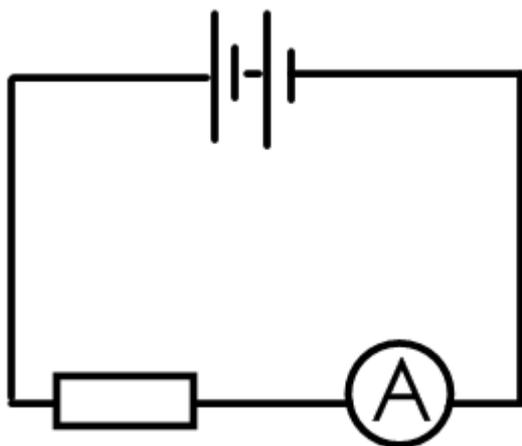
Current

We have already seen that current is the flow of charges around a circuit, caused by the potential difference exerted by the battery or other power supply. This is the definition you need to learn:

Current is the rate of flow of charge

This is to do with the speed the charges flow at but also to do with the width of the wire: a thicker wire has more spaces for charges to be flowing and so will have a higher current at the same speed of charge flow.

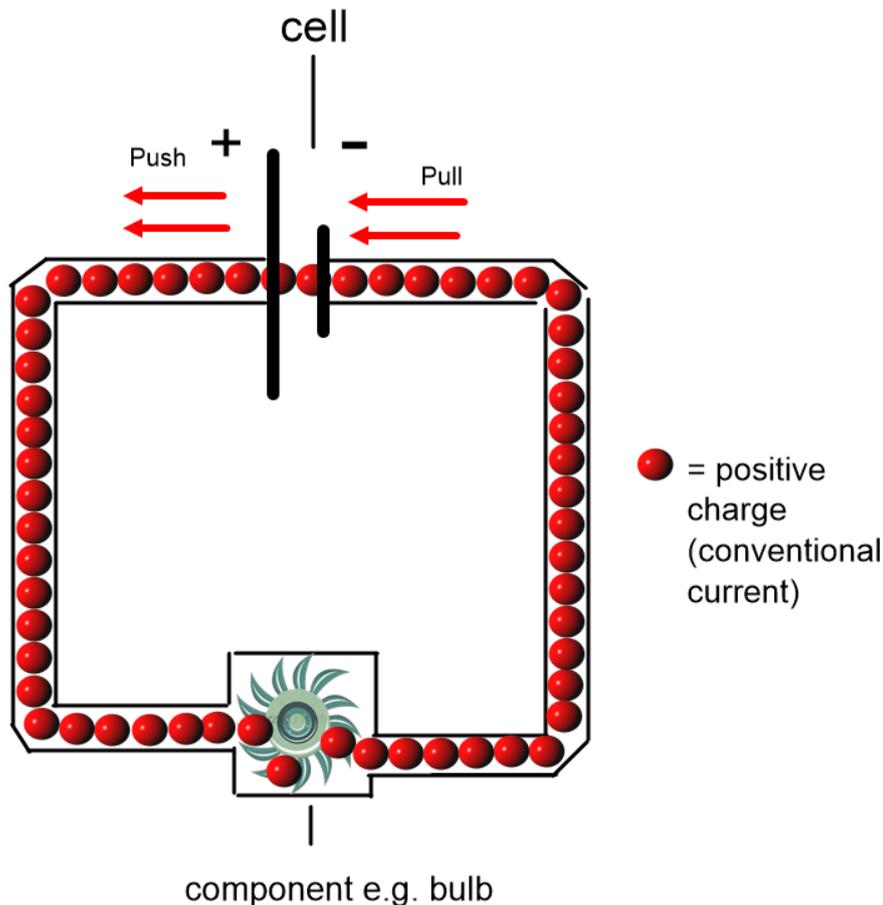
Current is measured in A (amps) and the symbol is I. We measure current using an ammeter, connected in series:



Ammeters measure the number of charges that flow through in one second. It is important for ammeters to have almost zero resistance so that they do not reduce the current by being in series.

What happens in a circuit?

Circuits work by moving **charge** around. Charge is a property of matter. It can be positive, negative, or neutral. Electrons have negative charge. In circuits, charges are pushed around by the potential difference.



When a potential difference is applied to a circuit, there is a difference in electrical potential between one side and another. This means that positive charges in the circuit are repelled from the positive side and attracted to the negative side. The charges move or “flow”. They might flow more quickly or slowly depending on factors like the size of the potential difference or how easy it is for them to get through the wire and components. This rate of flow of charge is called current.

When the charges flow through a component, they do work on it. This causes energy to be transferred by the component, for example a bulb emits light.

Because current was discovered before it was known that the charge on the electron is negative, circuits are described using conventional current. Conventional current is positive and flows from positive to negative: the opposite of electron flow.

Quantity	Symbol	Unit	Meaning
Charge	Q	Coulombs (C)	The amount of charge
Current	I	Amps (A)	The rate of flow of charge
Time	T	Seconds (s)	Time for charge to pass a point

There are about 6.25×10^{18} electrons in 1 Coulomb

Charge, current and time are linked by the equation:

$$Q = I t$$

Charge = current x time

Questions

1. Define "charge" and give its unit and symbol
2. Define "current" and give its unit and symbol
3. What equation relates current and charge?
4. If charges move more quickly, what happens to the amount of current?
5. The total amount of charge in a circuit remains constant. Explain why.
6. How do we measure current?
7. A circuit has a current of 0.2A. Find the charge transferred if the circuit is switched on for 45s.
8. A circuit has a current of 3.1A. Calculate the charge transferred if the circuit is switched on for 104s.
9. A circuit has a current of 400A. Find the charge transferred if the circuit is switched on for 0.3s.
10. A circuit is switched on for 180s. If the current is 5A, find the charge that flows through the circuit.
11. A circuit is switched on for 78s. If the current is 8.9A, calculate the charge transferred.
12. A circuit transfers 45C of charge in 38 seconds. Calculate the current in the circuit.
13. When a circuit is switched on for 1010 seconds, 5690C of charge flows. Find the current in the circuit.

14. A teacher switches on a circuit for 18 seconds and transfers 46C of charge.
Find the current in the circuit.
15. Calculate the current in a circuit that delivers 490C of charge in two minutes.
16. Find the current of a circuit that takes 52 seconds to deliver 520C of charge.
17. How long must a circuit of 4A be left on to transfer a charge of 12C?
18. Find the time taken for 800C of charge to flow in a circuit of current 2.5A.
19. When a circuit is switched on, its current is 0.4A. Find the time taken for 48C of charge to flow.
20. The current through a bulb is 1.7A. How long does the bulb need to be switched on for 85C of charge to flow through it?
21. A circuit of current 12.5A is switched on to charge a mobile phone. If the phone needs 150C of charge, how long does it need to be plugged in?

Potential difference and resistance

Potential difference

We have already seen that a battery provides a potential difference in a circuit. Potential difference is also known as voltage and it has the symbol V and the units V (volts).

Potential difference is a push on all the charges in a circuit. It is always a comparison between two places on a circuit. Because of this we must always say "the potential difference across" or "between" and never "at" or "in". We measure potential difference using a voltmeter, and we must always use two leads to join the voltmeter across two points:

Draw circuit diagrams to show how you would measure the potential difference across the component/s labelled A in each of these circuits:

Cells and batteries

If you cut open a battery you would see that inside it is made of several cells:



Two or more cells in series make a battery. The total potential difference provided by the battery is the sum of all the cells in the battery (provided they are all oriented the same way)

Resistance

When charges are pushed through components, particles inside the components get in their way. This obstruction is called resistance. The symbol for resistance is R and the unit is Ω (ohms).

Resistance splits up the potential difference in a loop of a circuit. As you follow a circuit round from the positive terminal of the battery, components with resistors are like steps in the potential difference. We will return to this phenomenon later in the unit.

The higher the resistance, the harder it is for the potential difference to push the charges through the component.

Resistance is not measured directly but is calculated by measuring the potential difference across, and the current through, a component, and then using the equation $V=IR$. In this section, we will be considering components called resistors. Resistors are simple components that have their resistance set at a certain amount: you can get 100Ω resistors, 2000Ω resistors, etc. Remember, though, that all components have resistance. We will study other components later in the unit.

A circuit to investigate resistance

Often we will want to investigate the resistance of a component. This may be to identify it or to answer a question about resistance. The circuit used is this:

The variable resistor is a resistor whose resistance can be increased or decreased by moving a slider or a dial. This allows us to easily change the p.d. we are testing and to get a set of results for a range of potential difference across the component we are investigating.

V = IR

The current in a circuit is affected by the potential difference and the resistance. The higher the potential difference, the higher the current: current and potential difference are directly proportional. Conversely, the higher the resistance, the lower the current: current and resistance are inversely proportionate.

So we can say that current = potential difference / resistance

$$I = V/R$$

More commonly known as $V = IR$

Current is measured using an ammeter. An ammeter must always be connected in the loop of the circuit where current is being measured, because it is a measure of something flowing through a point. If you connect an ammeter directly before or directly after a component, with no changes in the loops of the circuit, then it will tell you the current flowing through that component.

Questions

1. What is the symbol for potential difference?
2. What are the units for potential difference?
3. What does potential difference do?
4. What is the name of the piece of equipment used to measure potential difference?
5. Why must potential difference always be measured across two points?
6. Copy and complete this circuit diagram to show how you would measure the potential difference across component X:
7. What is resistance?
8. What is the symbol for resistance?
9. What are the units for resistance?
10. Resistance is not measured directly. How is it found?
11. Copy and complete the circuit to show how you would find the resistance of component X:
12. What formula links potential difference, current and resistance?

13. Plot a graph for the following results:

Potential difference (V)	Current (A)
0	0
1	0.18
2.5	0.44
3.2	0.56
4	0.70

14. Describe the relationship shown in your graph.

15. Plot a graph for the following results:

Resistance (Ω)	Current (A)
1	0.4
3	0.14
4	0.11
6	0.08
9	0.05

16. Describe the relationship shown in your graph.

17. Find the potential difference that will push 2.4A of current through a 90Ω resistor.

18. What is the potential difference needed to create 14A of current through a 12Ω resistor?

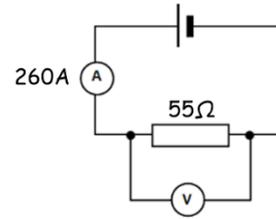
19. Find the resistance of a component which allows 25A of current to flow when 100V of potential difference is put across it.

20. What is the resistance of a resistor with 680V of potential difference across it if 46A of current are flowing?

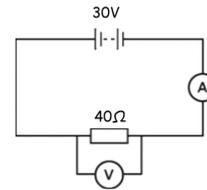
21. A battery gives a potential difference of 12V. Find the current through a resistor of 30Ω connected directly to the battery.

22. Calculate the current flowing when a 45Ω resistor has 20V of potential difference across it.

23. Copy the diagram and find the potential difference across the resistor:

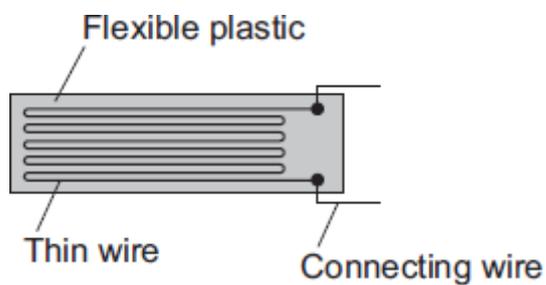


24. Copy the diagram and find the current through the resistor:



25. The diagram shows a strain gauge, which is an electrical device used to monitor a changing force.

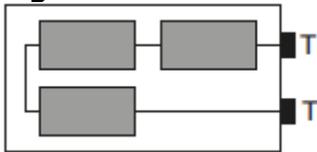
Applying a force to the gauge causes it to stretch.
This makes the electrical resistance of the wire change.



Using the correct symbols, **add** to the diagram to show how a battery, an ammeter and a voltmeter can be used to find the resistance of the strain gauge drawn above.

26. **Figure 1** shows the inside of a battery pack designed to hold three identical 1.5 V cells.

Figure 1



Which **one** of the arrangements shown in **Figure 2** would give a 4.5 V output across the battery pack terminals T?

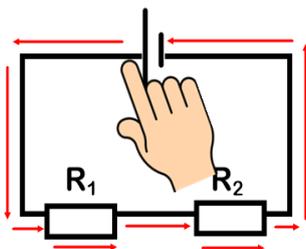
Figure 2



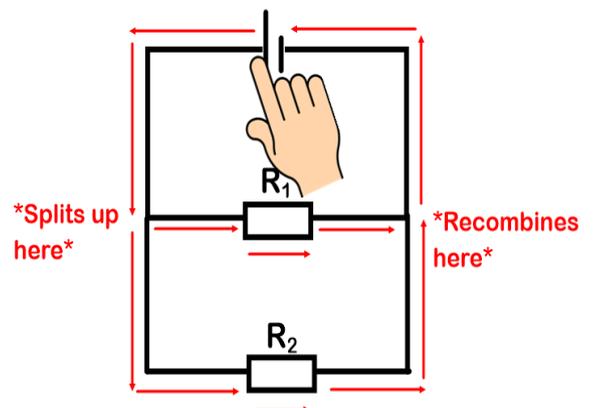
Electrical quantities in series and parallel

When we use two or more components in a circuit, the effect is different depending on if the components are all on the same loop of the circuit or if they are on different loops. We call these different arrangements series and parallel respectively.

To find out what is happening in a circuit, follow the path of the circuit round, starting at the power supply (battery).



If you have to go through one component and then the next, they are in series.

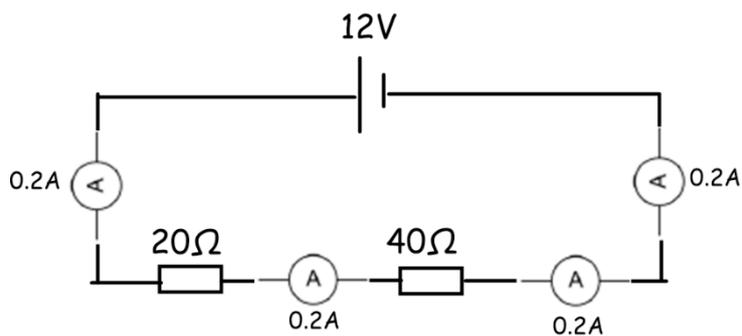


If the circuit splits up into two "loops", the components are in parallel.

Current in Series

When we connect components in series, it means that a unit of charge has to flow first through one and then through the other.

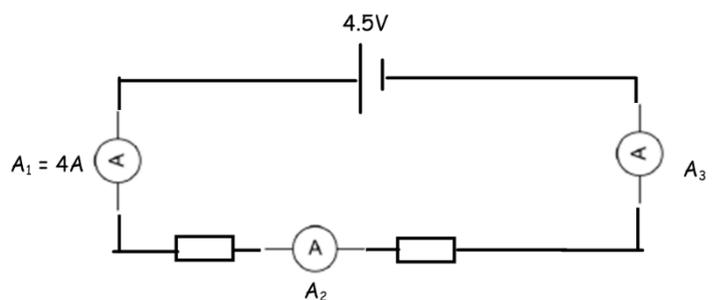
Current is the same in all positions in series:



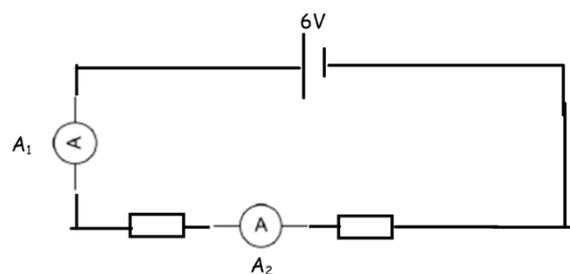
Questions:

1. Explain what it means for components to be "in series".
2. Define current
3. Give the unit of current
4. How do we measure current?
5. Copy the circuit diagram above and state the rule for current in series.

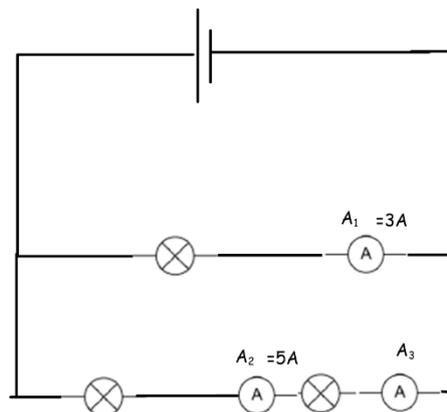
6. Find A_2 and A_3 :



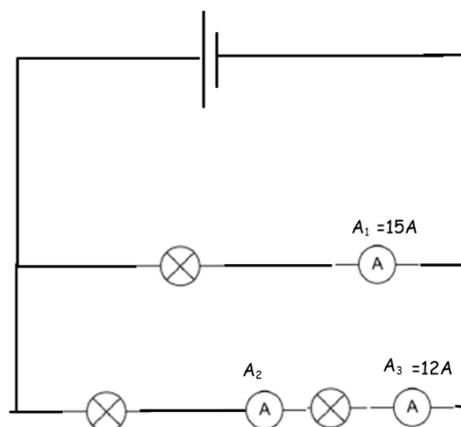
7. If $A_2 = 0.6A$, what is A_1 ?



8. What is A_3 in this circuit? How do you know?



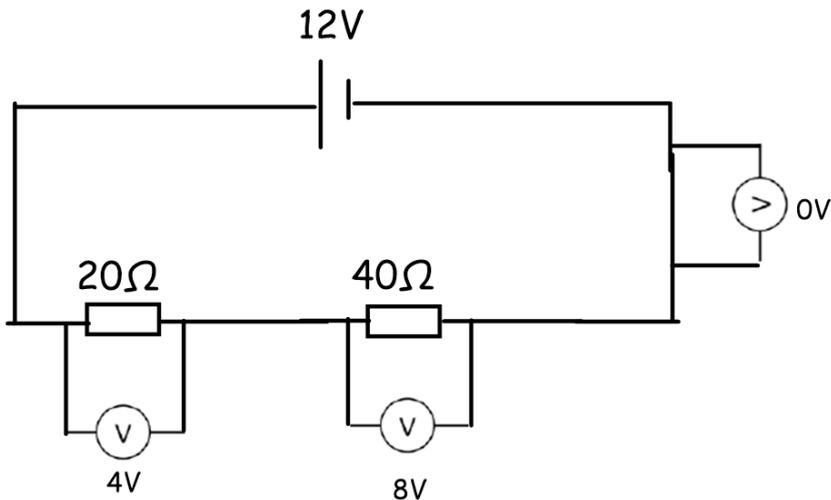
9. What is A_2 in this circuit? How do you know?



Potential Difference in Series

1. Total potential difference is shared across the components:

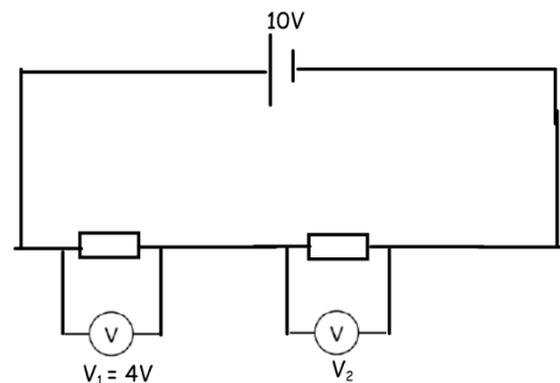
The total potential difference from the cell in this circuit is 12V. This is split up across the components. $4V + 8V = 12V$. The potential difference is split across the components because each component has a resistance through which the



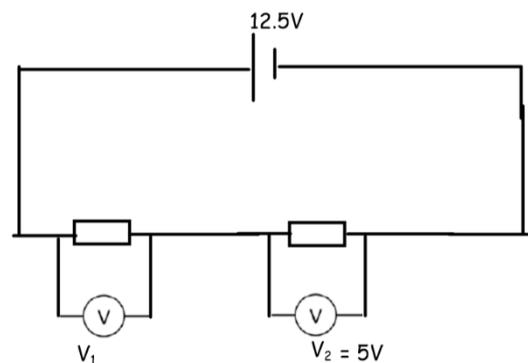
charge needs to be pushed. The higher the resistance, the higher the push needed, so the higher the p.d. There is no potential difference across a wire as it has (virtually) 0 resistance.

Questions

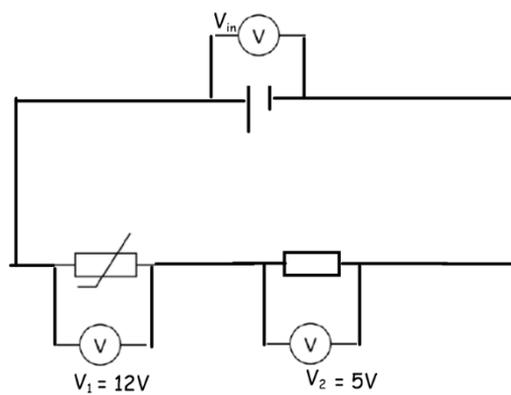
1. Define potential difference
2. What is the unit for potential difference?
3. How do we measure potential difference?
4. What is V_2 ? How do you know?



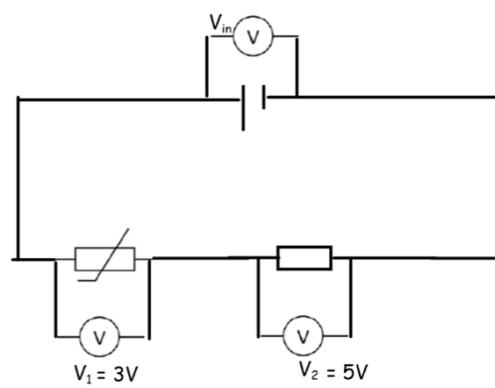
5. What will the reading on V_1 be? How do you know?



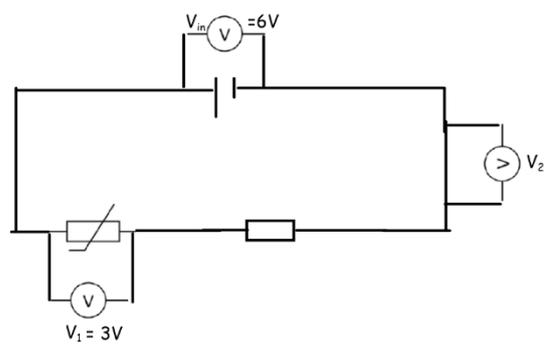
6. Find V_{in} :



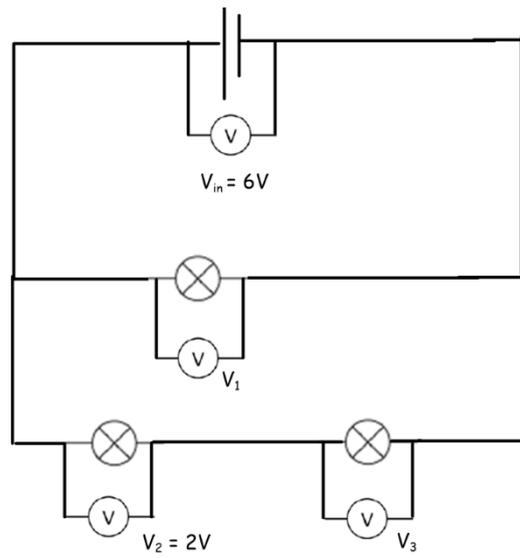
7. What is the potential difference across the cell?



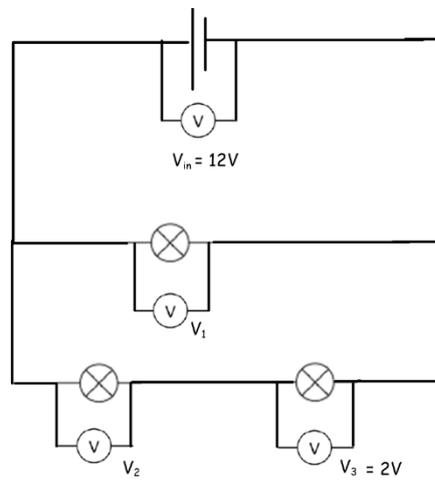
8. What is V_2 ?



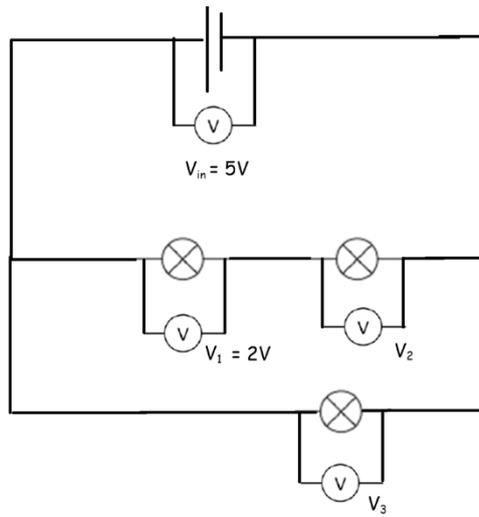
9. Find V_3 .



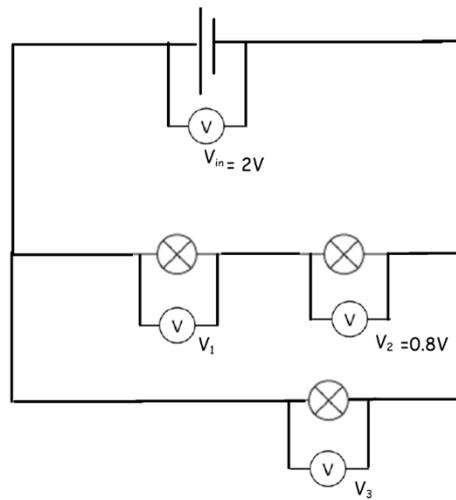
10. Find V_2 .



11. Find V_2 :

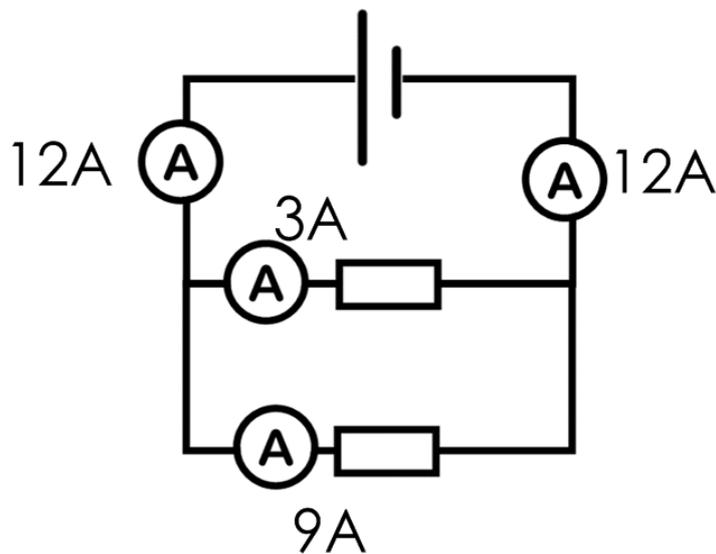


12. Find V_1 :



Current in parallel

In parallel, the current in the branch directly next to the power supply must be split between each of the loops. The current in each loop then recombines as you follow the circuit back round to the other side of the power supply.

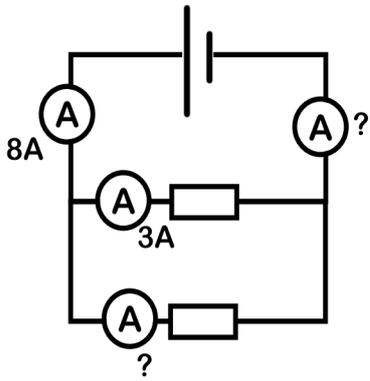


You can think of current as a team of joggers that leave the starting point following the same route, then branch off into different routes, before joining again on the same road and returning to the starting point.

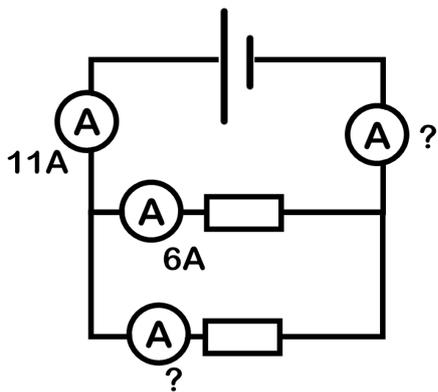
Questions

1. What does it mean for components to be in parallel?
2. Copy the diagram and state the rule for current in parallel.
3. Describe the joggers analogy for current in a circuit with components in parallel

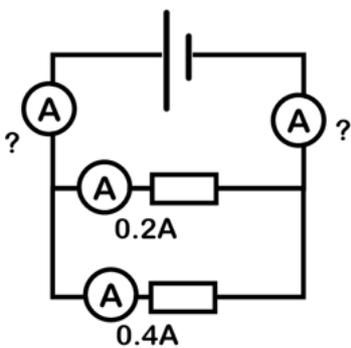
4. What are the missing readings? How do you know?



5. What are the missing readings? How do you know?

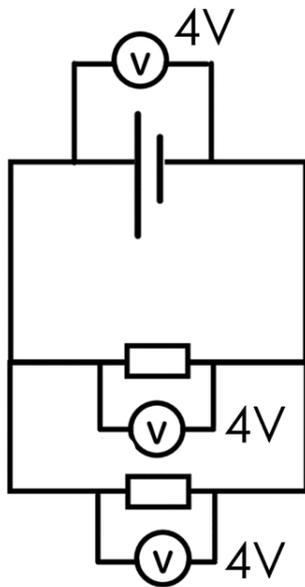


6. What are the missing readings? How do you know?



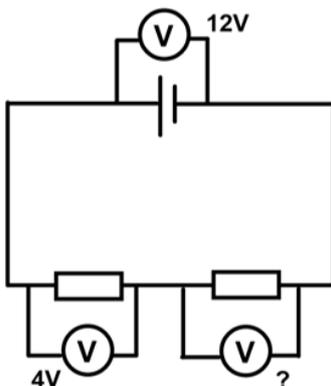
Potential difference in parallel

When we add another loop in parallel, we are connecting each side to the same potential difference as the previous loop. So potential difference is the same across all parallel loops.

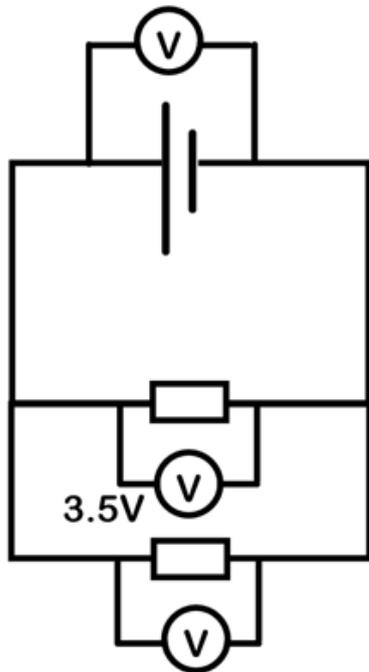


Questions

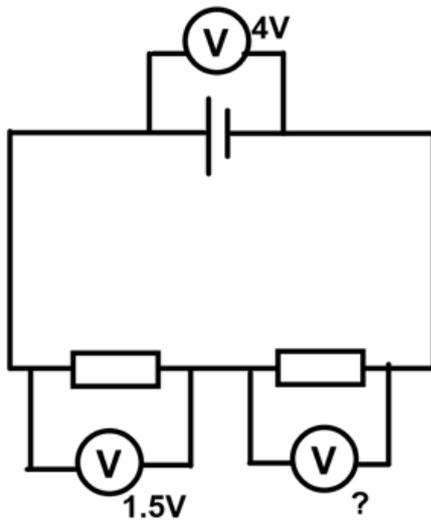
1. Copy the diagram for potential difference in parallel and state the rule for potential difference in parallel.
2. Explain why potential difference across parallel loops is the same.
3. What are the missing values? How do you know?



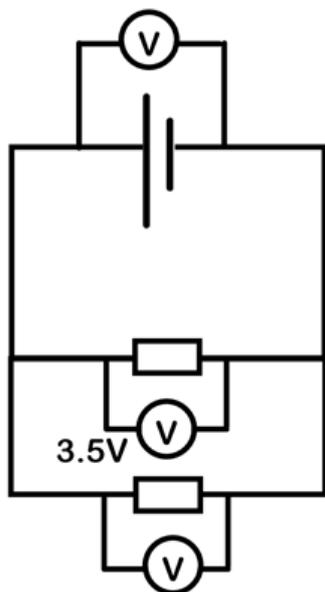
4. What are the missing values? How do you know?



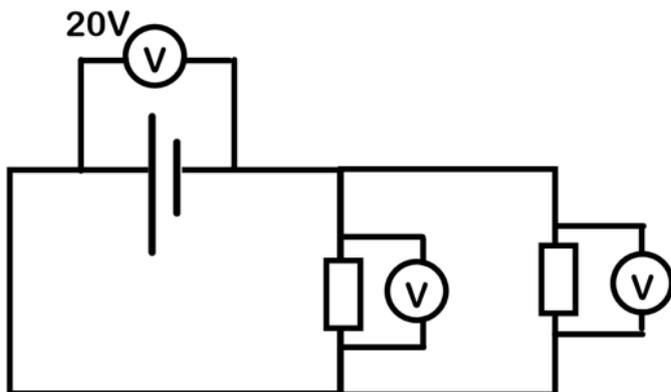
5. What are the missing values? How do you know?



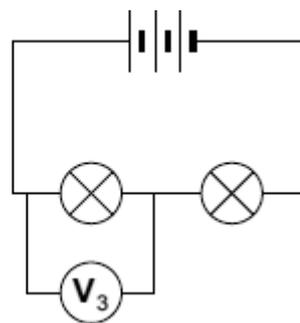
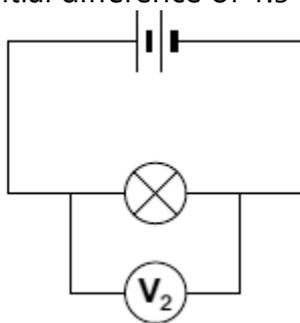
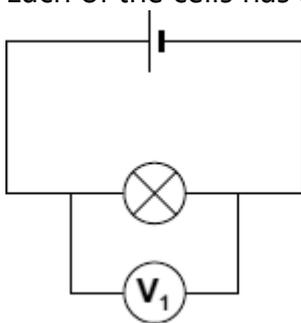
6. What are the missing values? How do you know?



7. What are the missing values? How do you know?

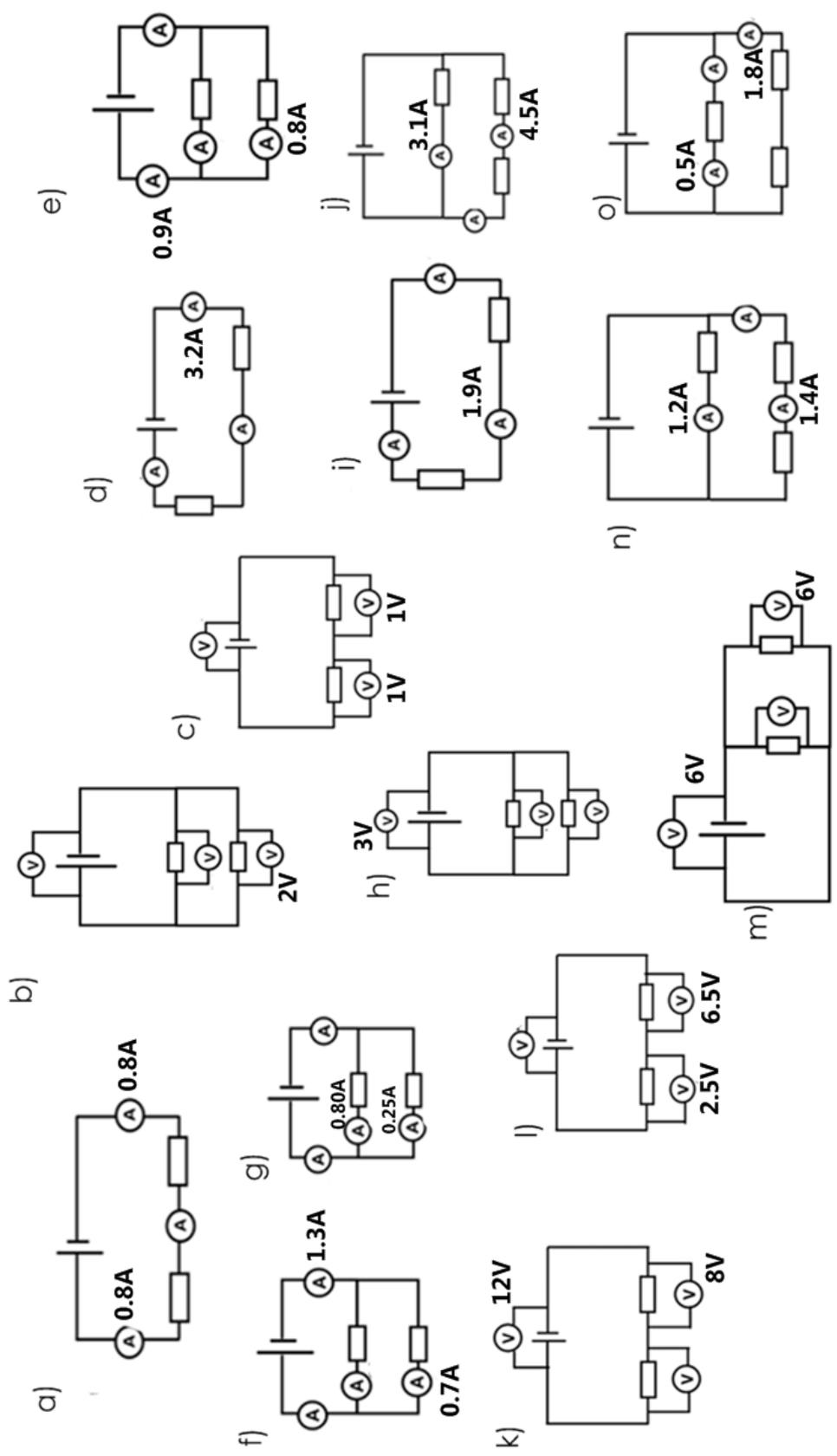


8. The lamps in the circuits drawn below are all identical.
Each of the cells has a potential difference of 1.5 volts.



- (i) What is the potential difference across the 3 cells that are joined in series?
- (ii) What will be the reading on the voltmeter labelled V_3 ?
- (iii) Which voltmeter, V_1 , V_2 or V_3 , will give the highest reading?

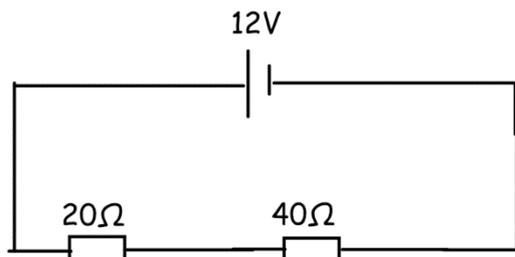
Mixed practice:



Resistance in series

The total resistance is the sum of the resistance of all the components.

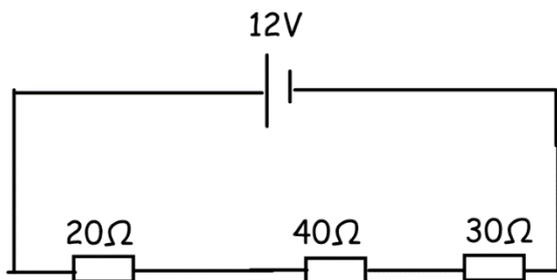
$$R_{\text{total}} = R_1 + R_2$$



$$R_{\text{Total}} = 60\Omega$$

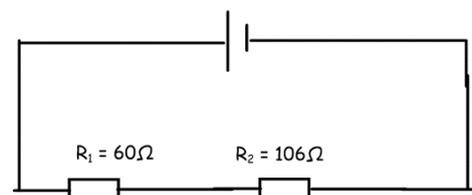
The resistance adds up in series because the current has to overcome more obstacles.

If we add another resistor in series, the total resistance in the circuit goes up:

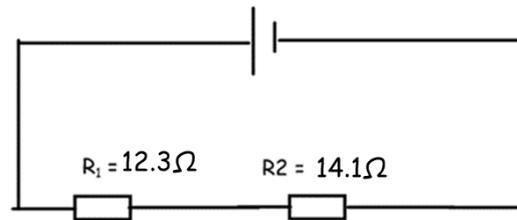


$$R_{\text{Total}} = 90\Omega$$

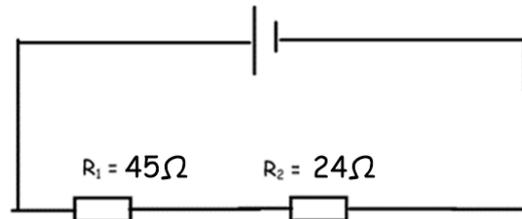
1. Copy the diagram above and state the rule for resistance in series.
2. Why does resistance in series add up?
3. What is R_{Total} here? How do you know?



4. What is R_{Total} ? How do you know?



5. What is R_{Total} ? How do you know?

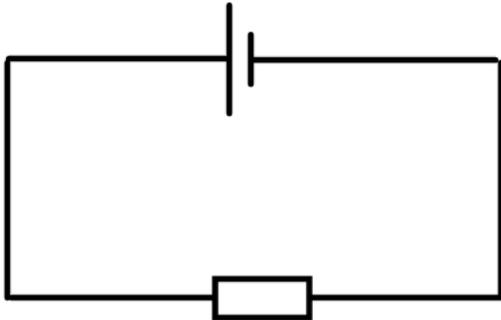


6. Earlier in this unit you studied a circuit for determining the resistance of a circuit by experiment.
- Draw the circuit/s you would use to answer the following question:
"How does adding resistors in series affect the total resistance of a circuit?"
 - Describe how you would use this circuit to answer the question, including the results table and any formulas you would use.
 - Describe the main causes of error and how you would minimise these.

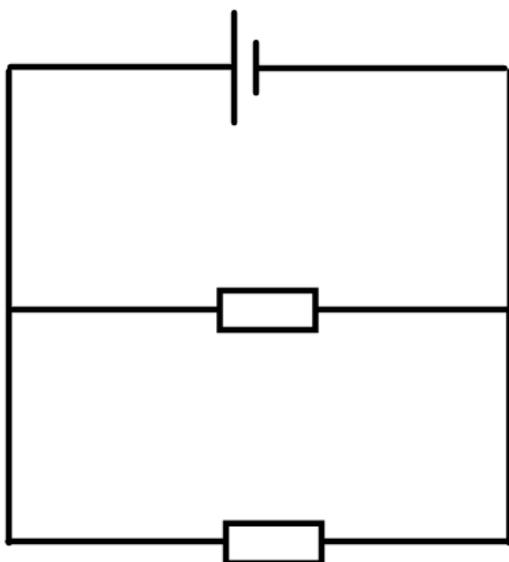
Resistance in parallel

When we add components to a circle, we might expect the total resistance to increase, because there are more things resisting. However in fact the opposite is the case: the total resistance goes down and is less than the lowest resistance loop.

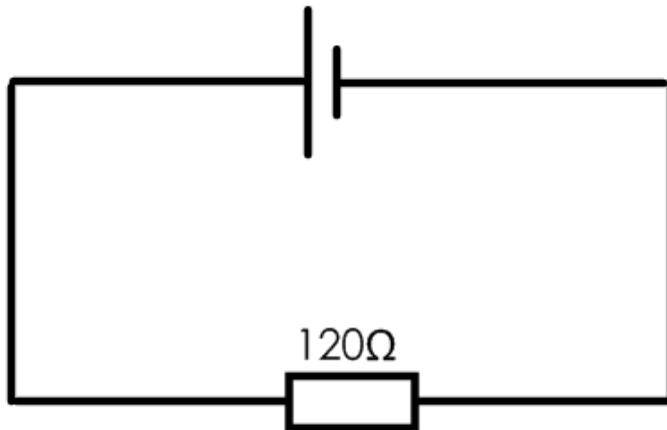
When we think about it this makes sense: think back to the joggers analogy. Imagine the joggers reach a built up area where the only route through is one narrow alley: this is like a circuit with just one loop:



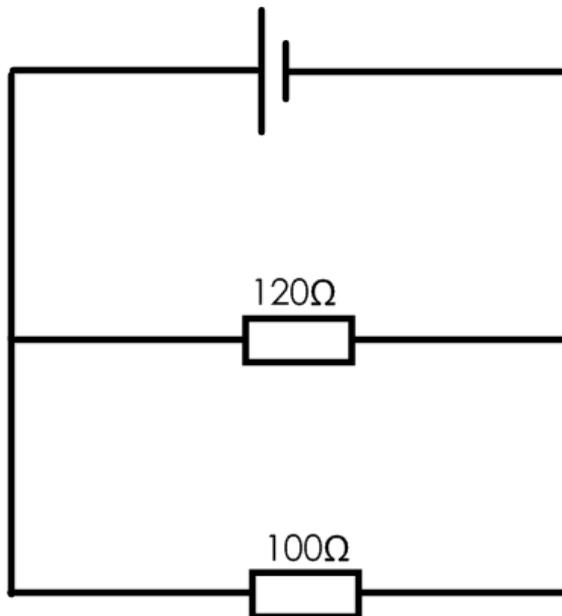
Now imagine adding a second alley: what happens to the rate of flow of joggers? It increases because there is another route for them. In other word, it is less difficult for them to pass through: the resistance has decreased. Adding another alley is like adding another loop onto our circuit.



Now let us see what this looks like with values:



$$R_{\text{Total}} = 120\Omega$$



$$R_{\text{Total}} = \text{less than } 100$$
$$= 54.5\Omega$$

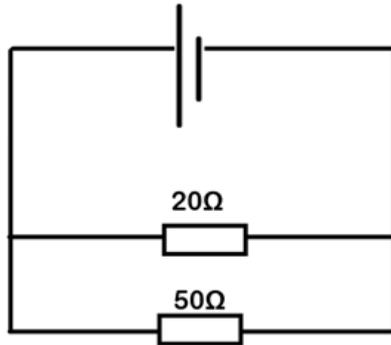
You would never have to calculate the value for R_{total} for loops in parallel as it uses a formula that is not required until A level. The formula is:

$$1/R_{\text{Total}} = 1/R_1 + 1/R_2 \dots$$

But you do not need to learn or use this! It is included here as an extra to appease curiosity.

Questions

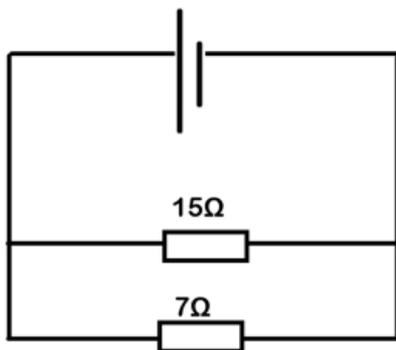
7. Copy the diagrams with values above and state the rule for resistance in parallel.
8. Describe the joggers analogy for understanding the rule for resistance in parallel.
- 9.



Total resistance =

- a) 20Ω
- b) 14Ω
- c) 70Ω

9.



Total resistance =

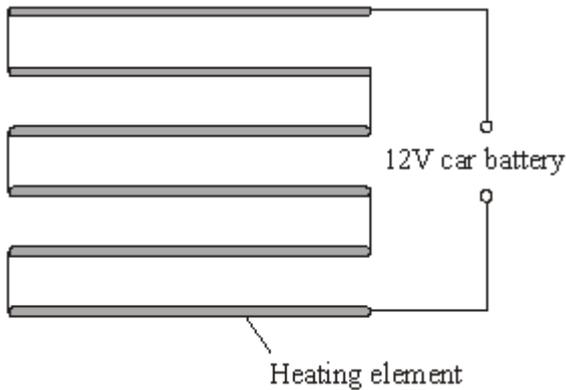
- a) 5Ω
- b) 22Ω
- c) 7Ω

10. Earlier in this unit you studied a circuit for determining the resistance of a circuit by experiment.

- Draw the circuit/s you would use to answer the following question:
“How does adding resistors in parallel affect the total resistance of a circuit?”
- Describe how you would use this circuit to answer the question, including the results table and any formulas you would use.
- Describe the main causes of error and how you would minimise these.

Practice questions

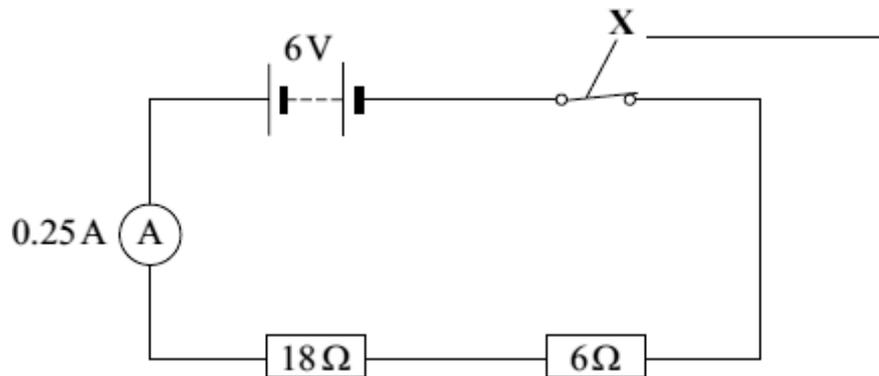
1. Some cars have heated windscreens. These work by having very thin heating elements embedded in the glass. The diagram shows the circuit for a heated windscreen:



Each heating element has a resistance of 6Ω . The current passing through each element is 0.3 A .

Calculate the total resistance of the six heating elements. Explain your answer.

2. A circuit diagram is shown below.



- (a) What is component X?
(b) Calculate the total resistance of the two resistors in the circuit.

Total resistance = _____ Ω

- (c) The reading on the ammeter is 0.25 A.

The current through the 6 Ω resistor will be:

bigger than 0.25 A equal to 0.25 A smaller than 0.25 A

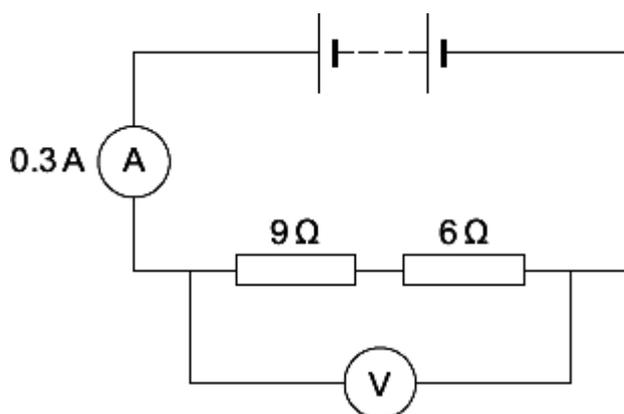
Draw a ring around your answer

- (d) The 6 V battery is made by correctly joining several 1.5 V cells in series.

Calculate the number of cells needed to make the battery.

Number of cells = _____

3. The diagram shows a simple circuit.



- (i) Calculate the total resistance of the two resistors in the circuit.
- (ii) Calculate the reading on the voltmeter.
- (iii) The 9Ω resistor is replaced with a 12Ω resistor. What effect will this have on the ammeter? Explain your answer.

Investigation: How do features of a wire affect resistance?

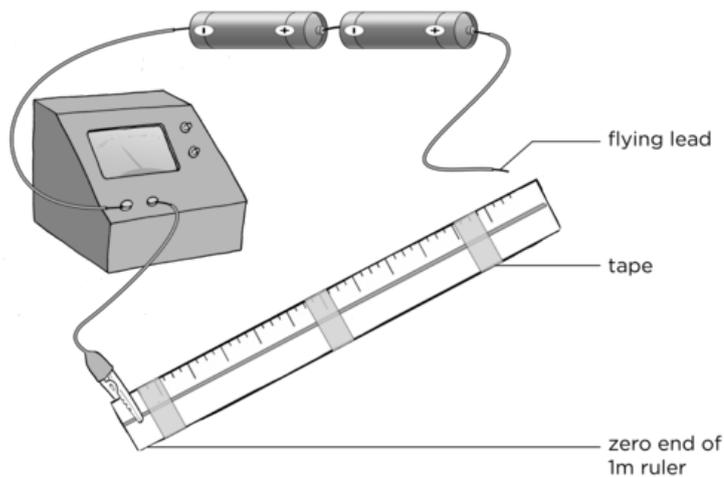
We can use the test circuit setup to investigate the following questions:

How does the length of a wire affect its resistance?

And

How does the diameter of a wire affect its resistance?

It is actually possible to predict the outcomes of these experiments using what we have learned about resistance in series and parallel. Which is like adding more resistors in series: using a longer wire or a fatter wire? Which is like adding more resistors in parallel?



Task:

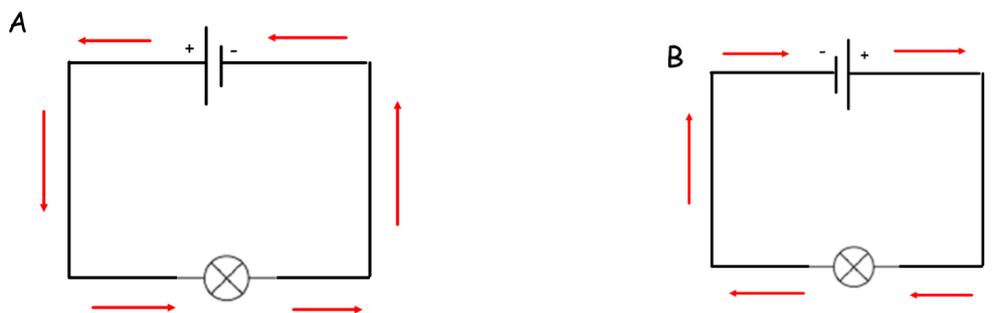
Describe how you would investigate both of these questions.

Draw out the results tables you would use.

Write 2 predictions applying what you have already learned about resistance.

Showing electrical quantities on a graph

In circuit A below, conventional current is flowing anti-clockwise as it goes from the positive terminal of the battery to the negative terminal. So the bulb experiences conventional current flowing from its left side to its right side.

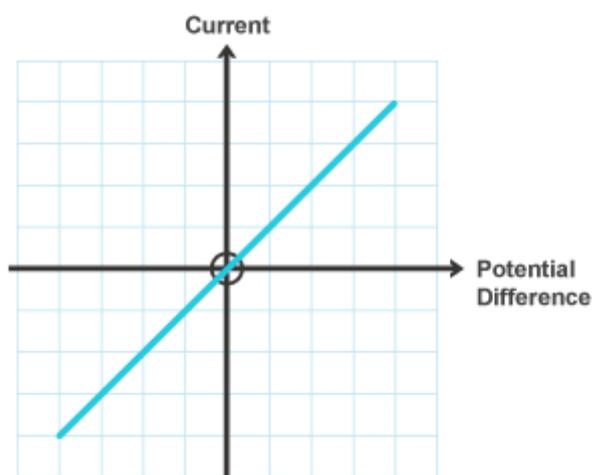


But in circuit B, we have flipped the battery round. Now conventional current is flowing clockwise, and the bulb experiences current flowing from its right side to its left side.

We can show these different directions using the different quadrants on a graph. We use the convention that "positive" means "forward" and "negative" means "backward".

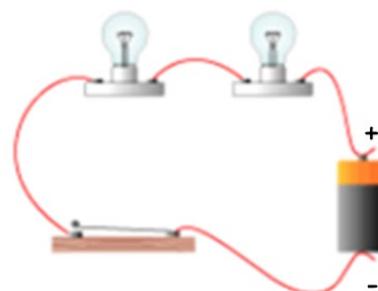
So for the component shown in the graph, when you put a positive potential difference across the component, conventional current flows forwards. If you swap the leads round at the battery terminals you would reverse the direction of the potential difference. The

graph shows us that for this component, a negative potential difference would create a negative conventional current: i.e. conventional current would flow backwards.



Questions:

1. Look at this circuit. In what direction is conventional current flowing? (Clockwise or anticlockwise)



2. How could you reverse the potential difference of the circuit?

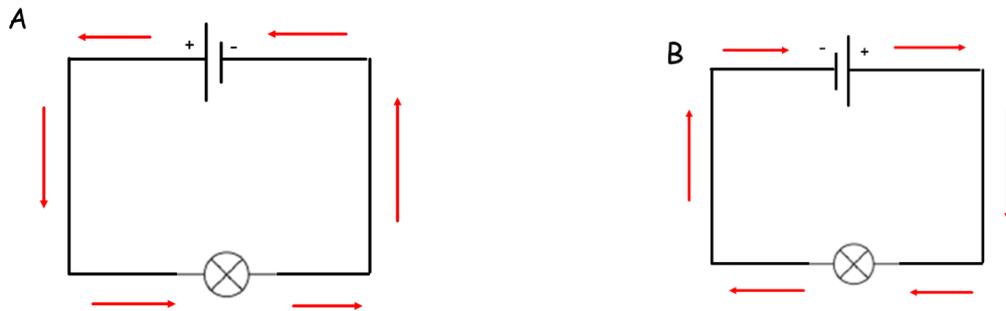
3. Draw a 4-quadrant set of axes and plot the following points:

Potential Difference (V)	Current (A)
-15	-6
-10	-4
-5	-2
0	0
+5	+2
+10	+4
+15	+6

4. Describe the relationship between potential difference and current for the component shown in this graph

Showing electrical quantities on a graph

In circuit A below, conventional current is flowing anti-clockwise as it goes from the positive terminal of the battery to the negative terminal. So the bulb experiences conventional current flowing from its left side to its right side.

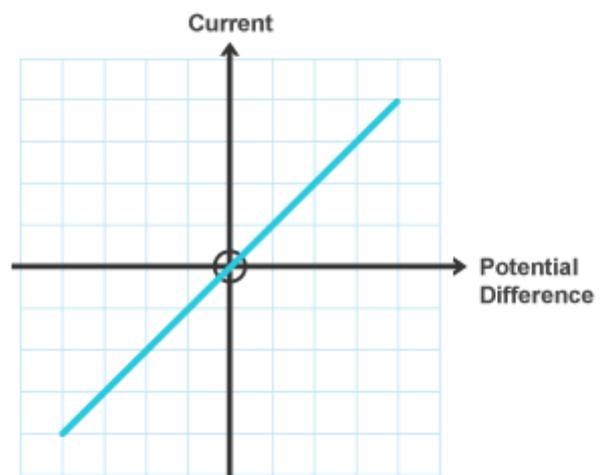


But in circuit B, we have flipped the battery round. Now conventional current is flowing clockwise, and the bulb experiences current flowing from its right side to its left side.

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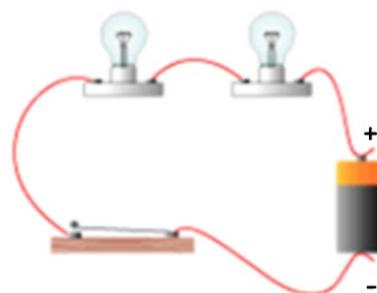
So for the component shown in the graph, when you put a positive potential difference across the component, conventional current flows forwards. If you swap the leads round at the battery terminals you would reverse the direction of the potential difference. The

graph shows us that for this component, a negative potential difference would create a negative conventional current: i.e. conventional current would flow backwards.



Questions:

5. Look at this circuit. In what direction is conventional current flowing? (Clockwise or anticlockwise)



6. How could you reverse the potential difference of the circuit?
7. Draw a 4-quadrant set of axes and plot the following points:

Potential Difference (V)	Current (A)
-15	-6
-10	-4
-5	-2
0	0
+5	+2
+10	+4
+15	+6

8. Describe the relationship between potential difference and current for the component shown in this graph

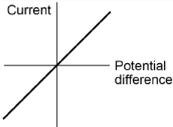
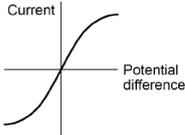
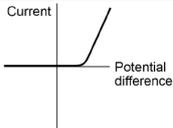
V-I characteristic graphs

So far we have studied resistors. Resistors are components that are specially designed to keep a constant resistance. It doesn't matter what potential difference you put across them, a 100Ω resistor will always have a resistance of 100Ω . A 200Ω resistor will always have a resistance of 200Ω .

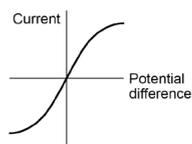
This means that resistors always have a straight line graph on an I-V plot:

The gradient is constant which means that V/I is always the same – $R = V/I$ so R is constant.

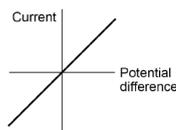
Most components do not have a constant resistance like this. Filament lamps, for example, become more resistive when a higher p.d. is applied. This allows them to get hot and glow, performing their function of emitting light. The graph for filament lamps look like this, see table

Component	Effect of potential difference on resistance:	Why?	Effect on current of increasing potential difference:	Graph:
Resistor (ohmic conductor at constant temperature) 	Constant resistance for all potential differences	Resistors are engineered so their particles give a constant obstruction to current.	The higher the potential difference, the higher the current. Direct proportion.	
Filament lamp 	Resistance increases when you increase potential difference	Wire heats up so particles move faster, getting in the way of moving charges more often.	Current increases less for higher potential differences	
Diode 	Diodes are sensitive to the direction of the potential difference. Resistance to negative p.d. is very high so current cannot flow. Resistance above 0.7V is constant and current can flow.	The particles inside the diode act like valves in a vein or a 1-way fire escape. They only allow charges to travel in one direction.	Current is 0 until p.d. = 0.7V, then current is directly proportional to p.d.	

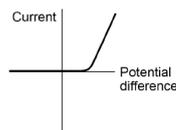
Questions



1. What component does this graph show? Copy the graph into your book.
2. Describe the effect of higher p.d. on current for this component.
3. Draw the symbol for this component.
4. Explain the effect of higher p.d. on current for this component.



5. What component does this graph show? Copy the graph into your book.
6. Describe the effect of higher p.d. on current for this component.
7. Draw the symbol for this component.
8. Explain the effect of higher p.d. on current for this component.

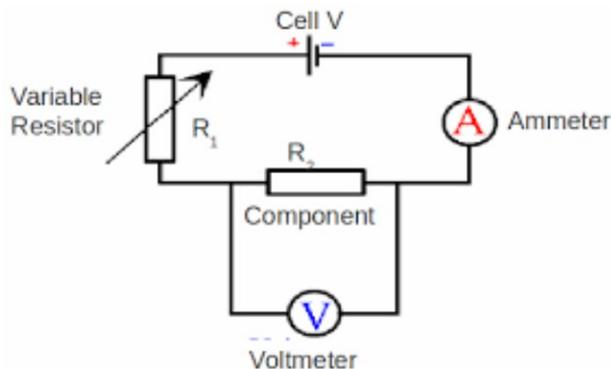


9. What component does this graph show? Copy the graph into your book.
10. Describe the effect of higher p.d. on current for this component.
11. Draw the symbol for this component.
12. Explain the effect of higher p.d. on current for this component.

Using Series Circuits for Testing Components

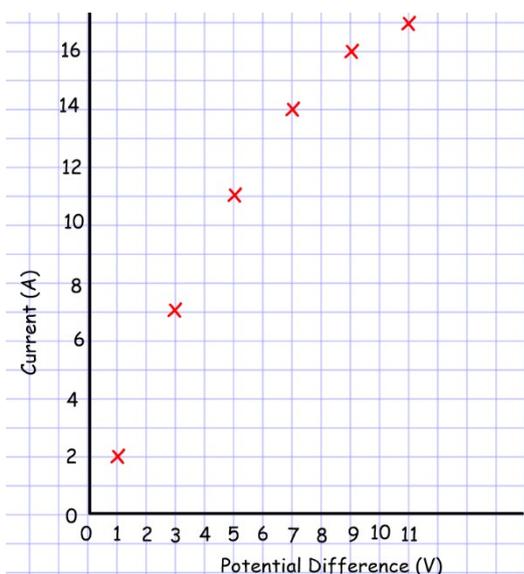
We can use series circuits to measure and test components:

In this circuit the input voltage from the cell is fixed. However we can slide the variable resistor to adjust the way the input voltage is split across the two components in series.



V across variable resistor (V)	V across component (V)	I through circuit (A)
11	1	2
9	3	7
7	5	11
5	7	14
3	9	16
1	11	17

This allows us to get a range of readings for V and I for the mystery component (shaded), so we can plot an I-V graph to identify the component. We can use $V = IR$ to determine the resistance of the component for any one set of readings.



We can see from the shape of our graph that the component is a filament lamp.

At any point on the graph, $V = IR$.

Example: What is the component's resistance when the potential difference = 2V?

Reading from the graph, at 2V the current = 5A

$$V = IR$$

$$2 = 5 \times R$$

$$2 \div 5 = 0.4$$

$$R = 0.4\Omega$$

Questions:

- Copy the circuit diagram above and write a method explaining how to use it to identify a mystery component.
- Plot an I-V graph for this mystery component. Identify the component and draw the symbol. Calculate its resistance at 8V.

V across component (V)	I through component (A)
1	2
3	6
5	9.8
7	13.6
9	17.2

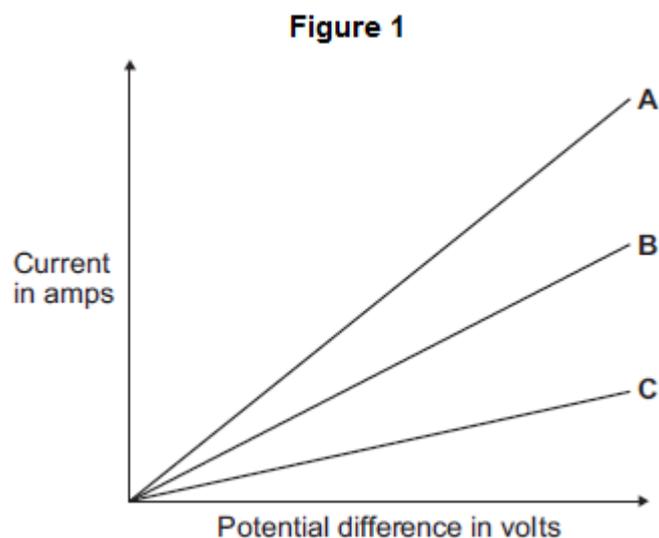
- Plot an I-V graph for this mystery component. Identify the component and draw the symbol. Describe how its resistance changes and give examples from the graph.

V across component (V)	I through component (A)
1	1
3	6
5	10
7	13
9	15
11	16

- Plot an I-V graph for this mystery component. Identify the component and draw the symbol. Describe how its current changes and give examples from the graph.

V across component (V)	I through component (A)
-2	0
-1	0
0	0
+1	1
+2	3
+3	5

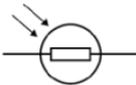
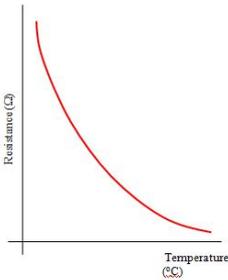
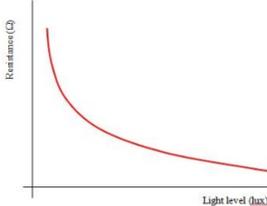
5. **Figure 1** shows the current–potential difference graph for three wires, **A**, **B** and **C**.



- (i) Using **Figure 1**, how can you tell that the temperature of each wire is constant?
- (ii) Which **one** of the wires, **A**, **B** or **C**, has the greatest resistance? Explain your answer

Thermistors and LDRs

Thermistors and LDRs are special types of resistor whose resistance changes depending on external conditions. Thermistors respond to changes in temperature, while LDRs (light dependent resistors) respond to changes in light. Both experience a decrease in their resistance when the energy incident upon them increases: i.e. when the temperature or light levels increase:

	Thermistor	LDR
		
When temp/light increases...	Resistance decreases 	Resistance decreases 
	Therefore current increases	Therefore current increases

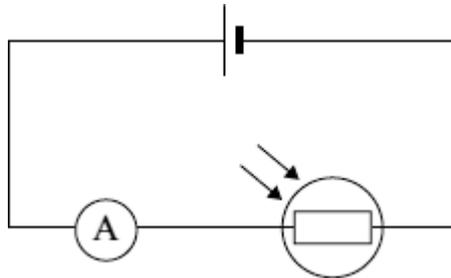
Thermistors are often used in circuits to switch other components on or off when the temperature gets below or above a certain point. The thermostat for your central heating and the sensor in your oven both use thermistors.

LDRs are used in similar circuits to switch things on or off depending on the light level. Examples include street lights that only come on when it gets dark and phone camera flashes that sense whether they are needed.

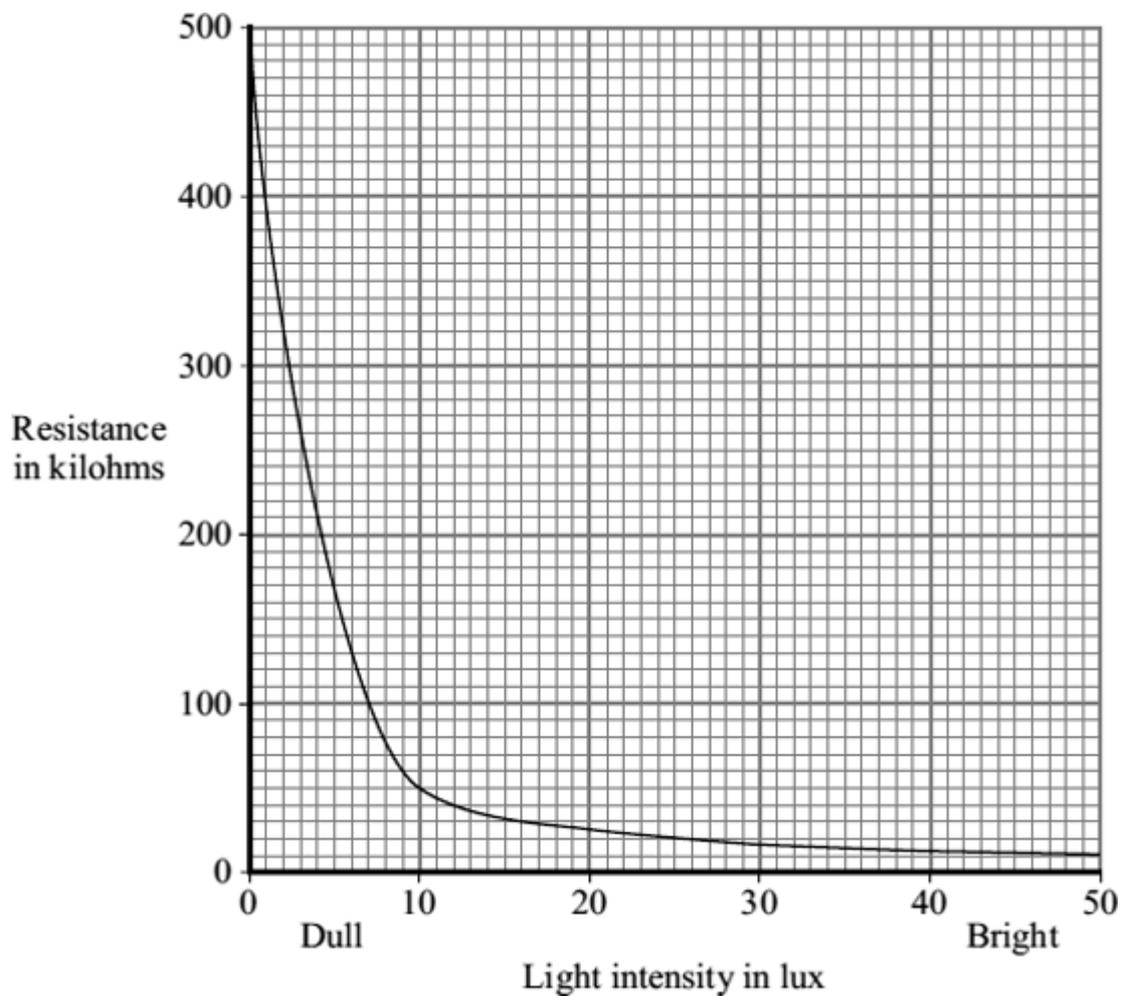
Questions

1.

The diagram shows a simple circuit.



- (a) Name the components in this circuit and explain what they do.
- (b) The graph shows how the resistance of an LDR changes with light intensity.



Describe in detail how the resistance of the LDR changes as the light intensity increases from 0 to 50 lux.

(c) Complete the following sentence:

A decrease in the light intensity of light on the LDR will cause the reading on the ammeter to _____ because _____

(d) An LDR can be used to switch a circuit on and off automatically.

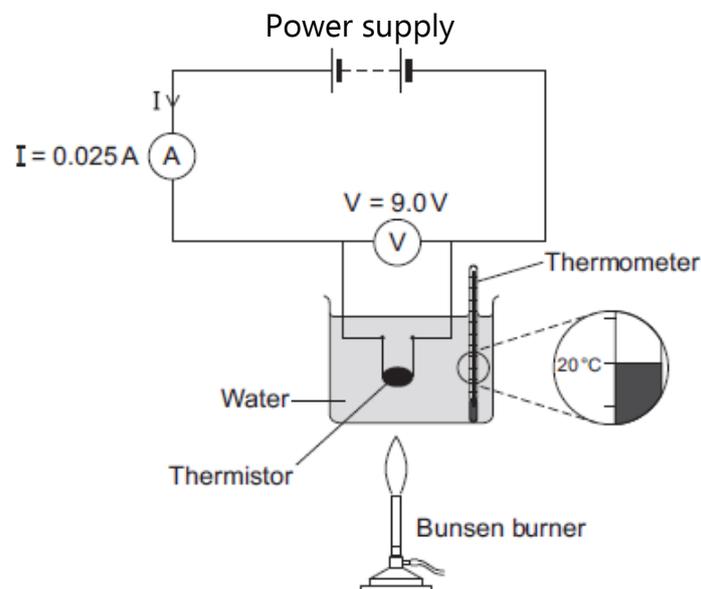
In which **one** of the following would an LDR be used?

a circuit to switch on central heating when it gets cold; a circuit to switch on security lighting when it gets dark; a circuit to switch on a water sprinkler when the soil in a greenhouse is dry

2.

(a) **Figure 1** shows the apparatus used to obtain the data needed to calculate the resistance of a thermistor at different temperatures.

Figure 1



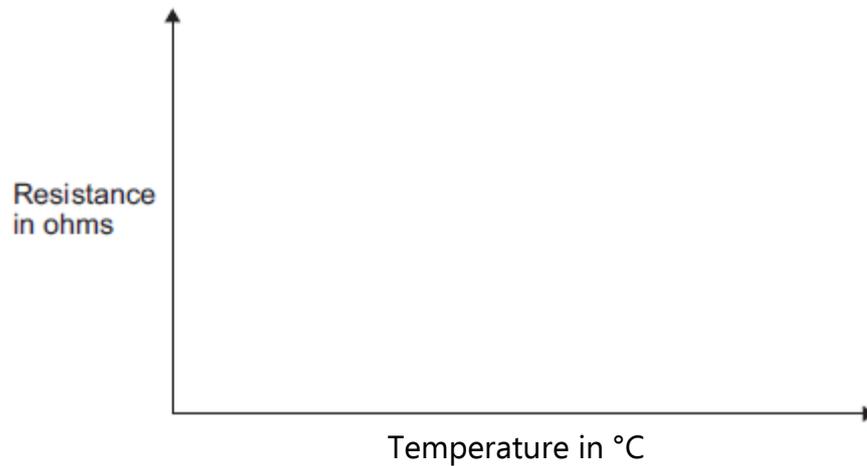
(i) Draw the circuit symbol for a thermistor.

(ii) Use the data given in **Figure 1** to calculate the resistance of the thermistor at 20°C.

(iii) **Figure 2** shows the axes for a sketch graph.

Copy and complete **Figure 2** to show how the resistance of the thermistor will change as the temperature of the thermistor increases from 20 °C to 100 °C.

Figure 2



(iv) Which **one** of the following is most likely to include a thermistor?

An automatic circuit to switch a plant watering system on and off; an automatic circuit to switch an outside light on when it gets dark; an automatic circuit to switch a heating system on and off. .

(b) The ammeter used in the circuit has a very low resistance.

Why is it important that ammeters have a very low resistance?

(c) The table below gives the temperature of boiling water using three different temperature scales.

Temperature	Scale
100	Celsius ($^{\circ}\text{C}$)
212	Fahrenheit ($^{\circ}\text{F}$)
80	Réaumur ($^{\circ}\text{Re}$)

Scientists in different countries use the same temperature scale to measure temperature.

Suggest **one** advantage of doing this.

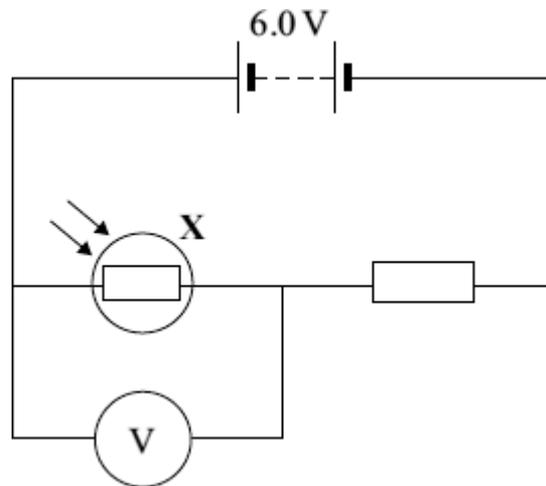
(d) A student plans to investigate how the resistance of a light-dependent resistor (LDR) changes with light intensity.

The student starts with the apparatus shown in **Figure 2** but makes three changes to the apparatus.

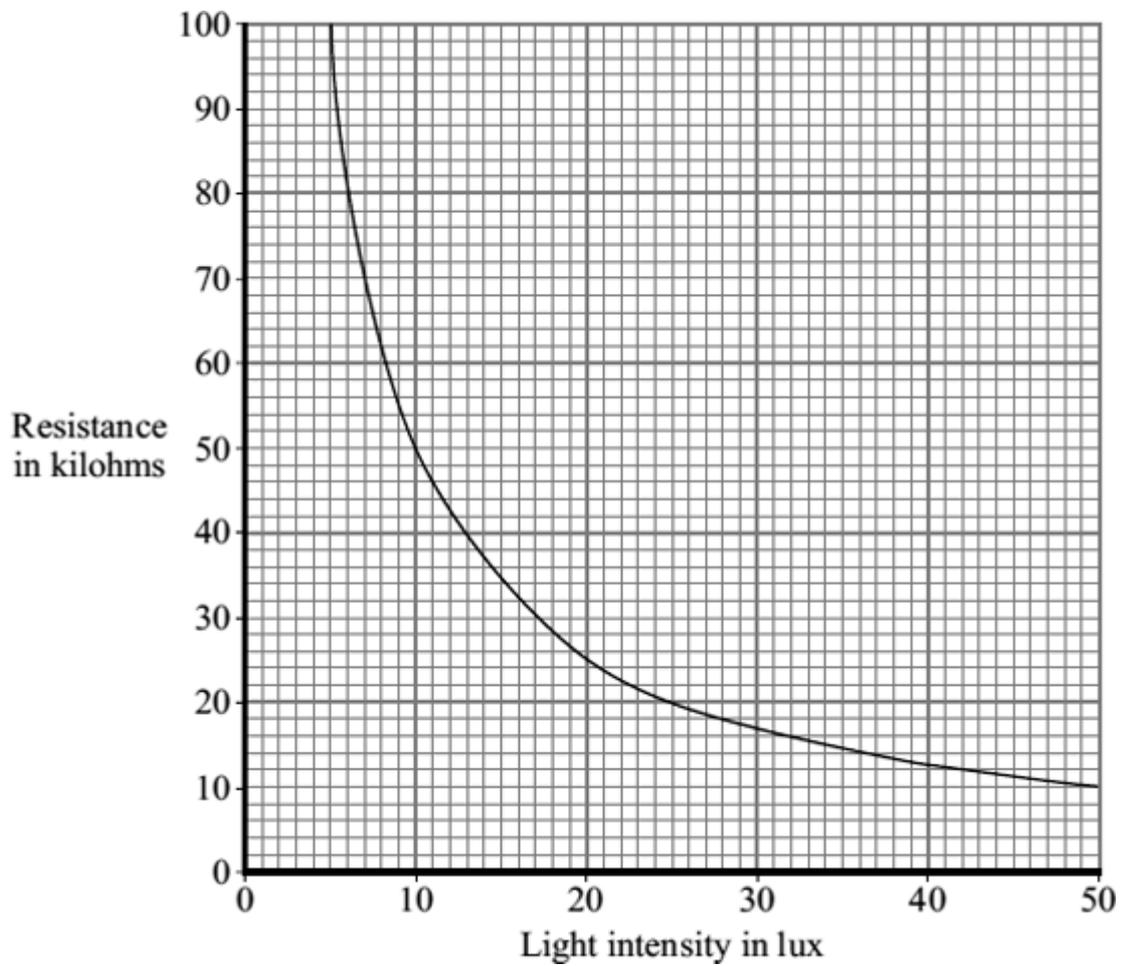
One of the changes the student makes is to replace the thermistor with an LDR.

Describe what other changes the student should make to the apparatus.

The diagram shows a simple light-sensing circuit.



(a) The graph, supplied by the manufacturer, shows how the resistance of the component labelled **X** varies with light intensity.



(i) What is component **X**?

(ii) Use the graph to find the resistance of component **X** when the light intensity is 20 lux.

(iii) When the light intensity is 20 lux, the current through the circuit is 0.0002 A.

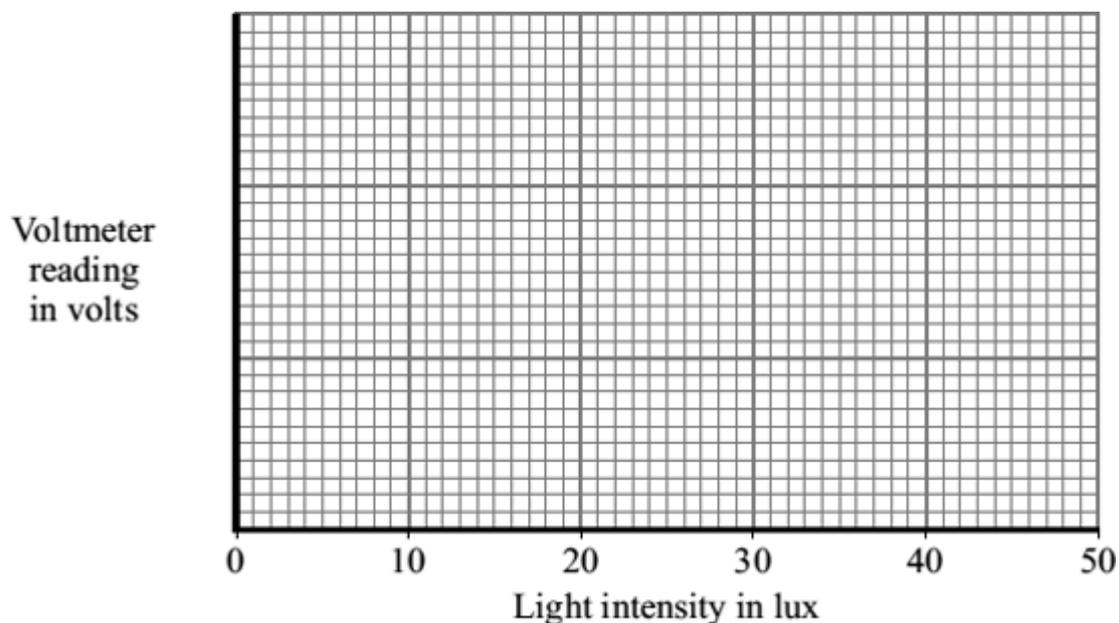
Calculate the reading on the voltmeter when the light intensity is 20 lux.

Show clearly how you work out your answer.

(b) Use the grid below to show how the voltmeter reading in the light-sensing circuit varies with light intensity.

(i) Add a suitable scale to the y -axis (vertical axis).

(ii) Complete the sketch graph by drawing a line on the grid to show how the voltmeter reading will vary with light intensity.



(c) The following passage is taken from the technical data supplied for component **X** by the manufacturer.

For any given light intensity, the resistance of this component can vary by plus or minus 50% of the value shown on the **graph of light intensity and resistance**.

(i) Calculate the maximum resistance that component **X** could have at 20 lux light intensity.

(ii) Explain why this light-sensing circuit would **not** be used to measure values of light intensity.