●●●○○ Level 3 · Science S3.10

Electricity and magnetism

Current flows round circuits, and a current in a wire can make a magnet.

Measure current with an ammeter, see how cells add their push, compare series and parallel circuits, make a dimmer from pencil lead, charge a comb, map a magnetic field, build an electromagnet, and learn how to stay safe near mains electricity.

YOU ARE READY FOR THIS BOOK IF

You can draw a circuit with a cell, a switch and a bulb using symbols.

One step up	S4.12 Circuits and Ohm's law
This book	**S3.10 Electricity and magnetism**
One step down	S2.8 Magnets and simple circuits

Contents

S3.10.1 Current in a circuit

S3.10.2 Cells and voltage

S3.10.3 Series and parallel circuits

S3.10.4 Resistance

S3.10.5 Static electricity

S3.10.6 Magnetic fields

S3.10.7 Electromagnets

S3.10.8 Electricity safety at home

Key words, A to Z

Written and drawn by attnom. Free to read, print and share.

S3.10.1 CHAPTER 1

Current in *a* circuit

When the bulb gives out light, is some of the electricity used up?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** No. The same current goes all the way round the loop.
- ☐ **B** Yes. The bulb uses up some of it, so less comes back to the cell.
- ☐ **C** The current only goes out of the cell. None comes back.

IF THIS FEELS HARD, READ THIS FIRST

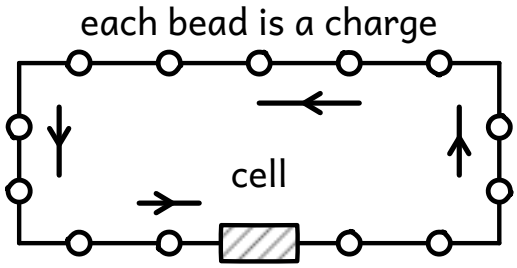
- Level 2, Magnets and simple circuits, S2.8.6. A circuit must be *a* complete loop.
- Level 2, Magnets and simple circuits, S2.8.8. You draw *a* cell, *a* bulb and *a* switch with symbols.

BY THE END YOU CAN

- Explain current as *a* flow of charge round *a* circuit
- Explain that current is measured in amps with an ammeter

Press the switch of *a* torch and the bulb lights at once. The cell, the wires and the bulb make one loop. Something moves round that loop. We call it the **current**.

A metal wire is full of tiny particles called **electrons**. Each electron carries *a* tiny amount of **charge**. The cell pushes all the electrons round the loop together. A flow of charge is *a* current.

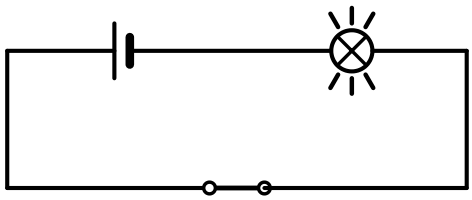


A model. The beads are charges in a loop of wire. The cell pushes them all round at once.

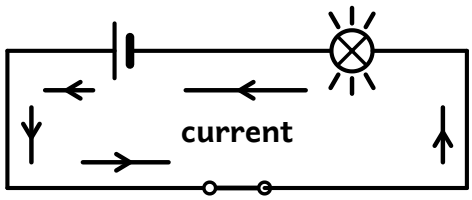
Think of a ring of beads in a tube. Push one bead and all the beads move. No bead is lost. The same number of beads pass every spot each second. A current is like that.

DRAW IT FIRST

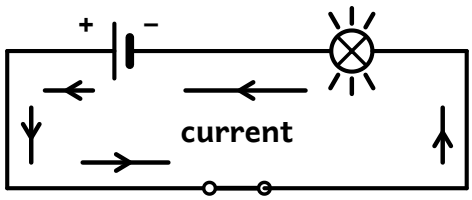
Draw the current round a loop



1 Draw a loop with a cell, a bulb and a closed switch. The bulb is lit.

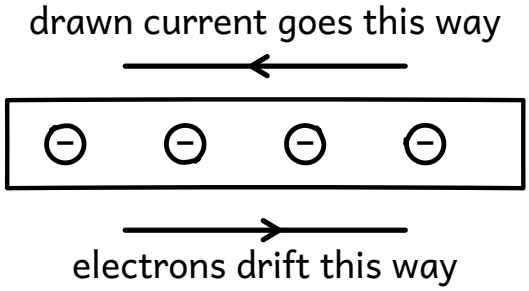


2 Draw arrows inside the loop. They leave the cell by the long plate and go round the loop. Write current.



3 Write + beside the long plate and − beside the short plate. The arrows run from + round to −.

In a drawing, the current runs from the + end of the cell, round the loop, to the − end. That is the rule.



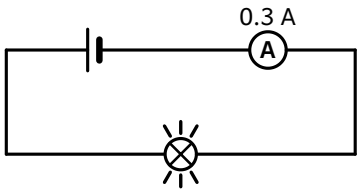
The electrons in the wire really drift the other way round. The sums come out the same either way, so we keep to the drawing rule.

Electrons are the moving charges in a metal wire. They carry a negative charge. They drift from the − end of the cell to the + end. We draw the current the other way round, from + to −. Keep the two ideas apart in your mind.

We measure current in ***amps***. We write A. A torch bulb might take 0.3 A. An ***ammeter*** is the meter that reads the current. It must be part of the loop, so the whole current goes through it.

SEE IT THREE WAYS

As a picture



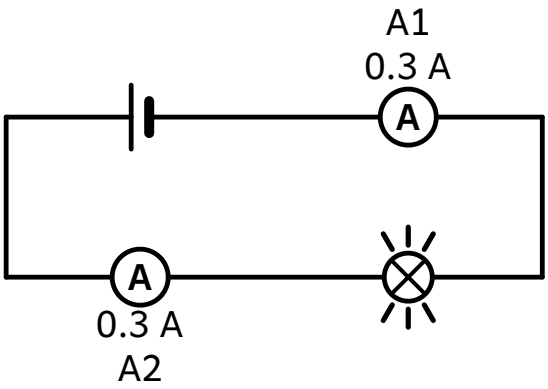
In words

The ammeter sits in the loop, so the current goes through it. It shows how much charge flows past each second. A bigger reading means a bigger current.

In symbols

The reading is 0.3 A. That is 0.3 amps. The symbol for amps is A.

Now put an ammeter on each side of the bulb. If the bulb used up current, the second ammeter would read less. Look.



Both ammeters read 0.3 A. The current is the same on each side of the bulb.

The current is the same all round the loop. The bulb does not use it up. The bulb changes energy from the cell into light and heat. The charges keep going round.

WORKED EXAMPLE

In the bead model, 30 beads pass spot A in 10 seconds. How many pass each second? How many pass spot B each second?

1. The current is how many beads pass a spot each second.
2. Spot A: 30 beads in 10 s. 30 ÷ 10 = 3 beads each second.
3. The beads are all in one loop and none is lost. The same number pass spot B each second.
4. Spot B: 3 beads each second.

Answer: 3 beads each second, at both spots

TRY IT

Count beads round a loop

You need: a string loop about 1 metre round, 12 beads, seeds or knots on the string, evenly spaced, two stones to mark spot A and spot B, a clock, or a friend who counts seconds.

Be safe: Keep the string loop off your neck and away from small children.

1. Fix the beads on the string loop at equal gaps. Lay the loop in a ring on the ground.
2. Put a stone beside the loop at spot A and another at spot B, on the other side.
3. Pull the string round with your fingers at a steady pace. You are the cell.
4. Count the beads that pass spot A in 10 seconds. Then count at spot B.

What you will see: The two counts are the same, or off by one if you lose count. Ours were 14 and 14. The string is one loop, so the same number of beads pass every spot. Your counts will differ from ours.

If you cannot try it, this is what happens.

place	beads in 10 s
spot A	14
spot B	14

A WRONG IDEA MANY PEOPLE HAVE

~~The bulb uses up the current, so less current comes back to the cell.~~

Why it feels right: The bulb gives out light and heat, so it feels as if something has been used up.

The test that breaks it: Put an ammeter on each side of the bulb. The first reads 0.3 A. The second also reads 0.3 A.

What is true: The bulb changes energy into light and heat. The charges are not used up. The same current goes all round the loop.

KEY WORDS

current
a flow of charge round a complete circuit.

charge
a tiny amount of electricity carried by a particle.

electrons
tiny particles that carry charge. They move in a metal wire.

amps
the unit of current. We write A.

ammeter
a meter that reads the current. It goes in the loop.

BACK TO YOUR GUESS

The answer is A: No. The same current goes all the way round the loop.

The same current goes all the way round the loop. The bulb changes energy into light and heat, but the charges are not used up. They keep going round.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What makes up the current in a metal wire?

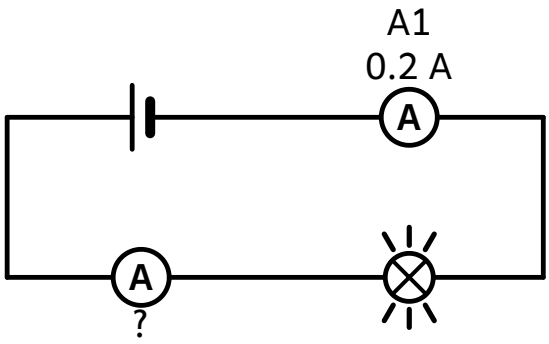
   A Electrons that the bulb uses up.

   B Electrons moving round the loop, each carrying a little charge.

   C Light that travels along the wire.

   Answer at the back of the book.

2. Ammeter A1 reads 0.2 A. What does ammeter A2 read, on the other side of the bulb?



   A 0.1 A

   B 0 A

   C 0.2 A

   Answer at the back of the book.

3. Where must you put an ammeter to measure the current through a bulb?

   A In the loop, so the current goes through the ammeter.

   B Across the bulb, with one wire to each side of it.

   C Only at the cell, because that is where the current starts.

   Answer at the back of the book.

4. Ravi reads 0.4 on his ammeter. Which unit does he write after the 0.4?

   A V, for volts.

   B A, for amps.

   C m/s, for metres per second.

   Answer at the back of the book.

5. A cell has a long plate (+) and a short plate (−). In a circuit drawing, which way do we draw the current?

   A From the − end of the cell round to the + end.

   B Out of both ends of the cell, meeting at the bulb.

   C From the + end of the cell round the loop to the − end.

   Answer at the back of the book.

6. Joseph's first ammeter reads 0.25 A. What does the ammeter on the other side of the bulb read?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Current is a flow of charge round a loop. We measure it in amps with an ammeter in the loop. It is the same all round and is not used up.

Draw: A loop with a cell, a bulb and two ammeters, both reading 0.3 A. Draw arrows from + round to −.

S3.10.2 CHAPTER 2

Cells and voltage

Why do some torches use two or three cells?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Cells in a line add their push, so more current flows and the bulb is brighter.
- ☐ **B** The extra cells are spares, used only when the first one goes flat.
- ☐ **C** Two cells give the same push as one, but they last longer.

IF THIS FEELS HARD, READ THIS FIRST

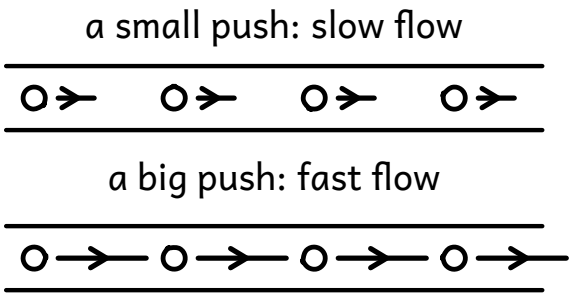
- Level 3, Electricity and magnetism, S3.10.1. The voltage is the push that makes the current.

BY THE END YOU CAN

- Explain voltage as the push that makes current flow
- Predict how adding cells changes the brightness of a bulb

In the last chapter the cell pushed the charges round the loop. How hard does it push? We measure the push as **voltage**.

We measure voltage in **volts**. We write V. One torch cell gives about 1.5 V. A bigger push makes a bigger current.



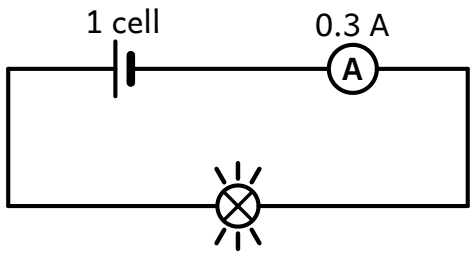
A model. The same beads are pushed harder in the bottom tube, so more beads pass each second.

Voltage is the push. Current is the flow that the push makes. They are not the same thing, and they have different units.

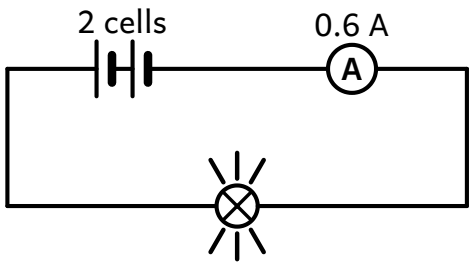
A **battery** is two or more cells joined in a line. The + end of one cell touches the − end of the next. Their pushes add up.

DRAW IT FIRST

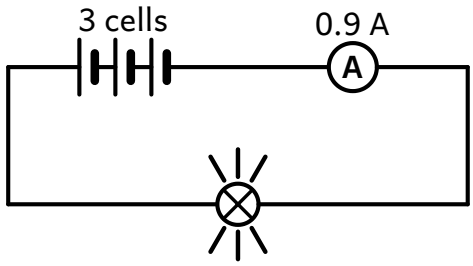
Draw one, two and three cells



1 Draw a loop with 1 cell and a bulb. The push is 1.5 V. The current is 0.3 A.

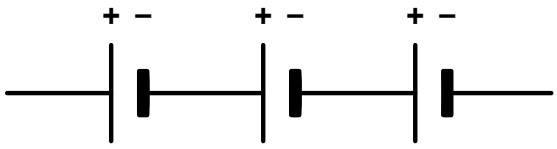


2 Add a second cell. The push is now 3 V. The current is about double, 0.6 A, and the bulb is brighter.

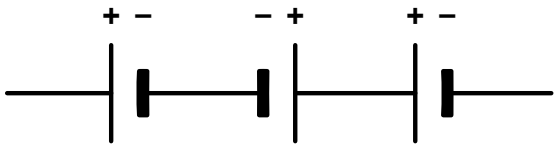


3 Add a third cell. The push is 4.5 V. The current is about three times as much, 0.9 A, and the bulb is brightest.

The push adds as you add cells, but only when they face the same way. Each cell has a + end and a − end. Join + to − all along the line.



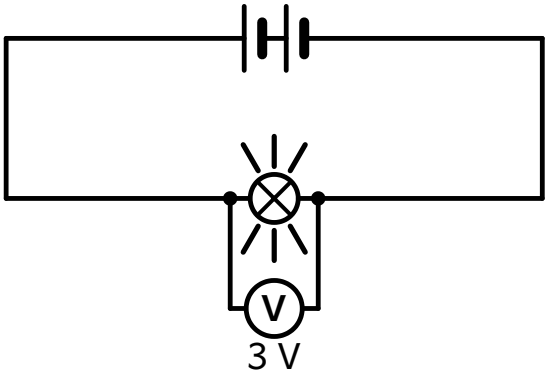
4.5 V in all



1.5 V in all

A cell turned the wrong way pushes against the others. It cancels one of them.

A **voltmeter** measures the push across a part. You join it across the part, side by side with it. It does not go in the loop.



The voltmeter is across the bulb, not in the loop. It reads the push across the bulb.

SEE IT THREE WAYS

As a picture

cells	volts	amps	light
1	1.5	0.3	some
2	3	0.6	more
3	4.5	0.9	most

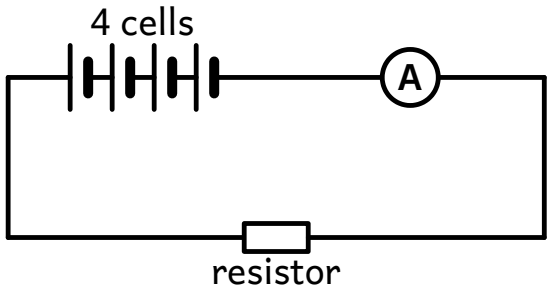
In words

Each new cell adds 1.5 V. The same bulb takes more current when the push is bigger, so it is brighter. In our sums a bulb keeps the same resistance. A real filament gets hotter as the current grows. So its current grows a little less than the sums.

In symbols

volts = cells × 1.5. For this bulb, 1 cell gives 0.3 A, so 3 cells give about 3 × 0.3 = 0.9 A.

A bulb is made for a certain push. Too many cells send too much current through its thin wire, and it burns out. Use only the cells the bulb is made for.



The loop for the next example. A resistor has the same resistance whatever the current.

WORKED EXAMPLE

Kofi's resistor takes 0.2 A on one cell. He joins 4 cells in a line, each 1.5 V. How many volts push, and how many amps flow?

1. Cells in a line add their volts. 4 × 1.5 = 6 V.
2. The push is 4 times bigger than for one cell.
3. For the same resistor the current grows in step. 4 × 0.2 = 0.8 A.

Answer: 6 V and 0.8 A

Be safe. Use only small torch cells of 1.5 V. Never use a car battery, a phone charger or the mains. Never join the two ends of a cell with only a wire.

TRY IT

Make a bulb brighter with a second cell

You need: two small torch cells, 1.5 V each, a small bulb made for 2.5 V or 3 V, two strips of kitchen foil, folded long and thin, tape.

Be safe: Join the strips for only a few seconds. The foil and the cells can get warm, so let them cool before you touch them. Never let the two strips touch each other.

1. Tape the + end of one cell to the − end of the other. Now they are in a line.
2. Touch one foil strip to the bulb side and the other to the bulb tip.
3. Touch the free ends of the strips to the cell you are using, for 3 seconds only. Look at the bulb.
4. Try one cell alone, then the two cells in a line. Compare the glow.

What you will see: One cell gives a dim glow. Two cells in a line make the bulb brighter. A weak cell gives less push, so an old cell gives a dimmer light too. Your looks may differ from ours.

If you cannot try it, this is what happens.

cells	bulb
1 cell	dim glow
2 cells	bright

A WRONG IDEA MANY PEOPLE HAVE

~~Voltage and current are the same thing.~~

Why it feels right: Both seem to be "how much electricity" a cell gives, and both grow when you add cells.

The test that breaks it: A 1.5 V cell with a 5 Ω bulb gives 0.3 A. A 1.5 V cell with a 10 Ω bulb gives only 0.15 A. The volts are the same, but the amps are not.

What is true: Voltage is the push, in volts. Current is the flow the push makes, in amps. The same push can make a bigger or smaller current.

KEY WORDS

voltage
the push that makes a current flow round a circuit.

volts
the unit of voltage. We write V.

battery
cells joined in a line, + to −. Their volts add up.

voltmeter
a meter that reads the push across a part. It goes across the part.

BACK TO YOUR GUESS

The answer is A: Cells in a line add their push, so more current flows and the bulb is brighter.

Cells joined in a line add their push. A bigger push makes more current flow round the bulb, so it is brighter. The extra cells are not spares.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What does the voltage of *a* cell tell you?

   A How big the cell is.

   B How hard it pushes the charges round the loop.

   C How many charges pass each second.

   Answer at the back of the book.

2. 4 cells of 1.5 V are joined in *a* line, + to −. What is the push in all?

   A 1.5 V

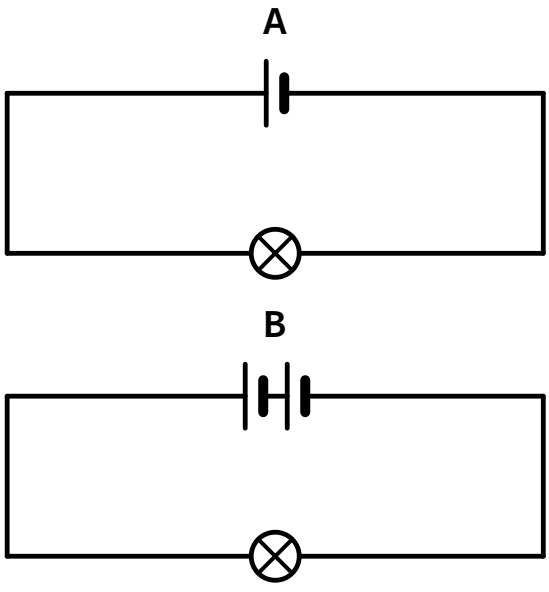
   B 5.5 V

   C 4 V

   D 6 V

   Answer at the back of the book.

3. Circuits A and B use the same bulb and the same kind of cells. Which bulb is brighter?



   A Circuit A

   B They are the same.

   C Circuit B

   Answer at the back of the book.

4. Ana joins one 1.5 V cell to a 3 Ω resistor. The current is 0.5 A. She swaps in a 6 Ω resistor and the current falls. What is the push of the cell now?

   A 1.5 V

   B 0.75 V

   C 3 V

   Answer at the back of the book.

5. **From an earlier chapter**

   Review: Mei puts an ammeter on each side of a bulb. The first reads 0.4 A. What does the second read?

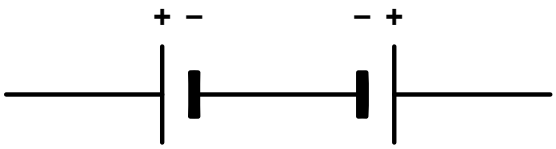
   A 0.2 A

   B 0.4 A

   C 0 A

   Answer at the back of the book.

6. Two 1.5 V cells are in a line with a bulb. One cell is turned the wrong way round. What push do they give?



   A 3 V

   B 1.5 V

   C 0 V, so the bulb stays dark

   Answer at the back of the book.

7. Joseph's resistor takes 0.5 A on one cell. How many amps does it take with 3 cells in a line?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Voltage is the push, in volts. Cells in a line add their volts. A bigger push means a bigger current and a brighter bulb. A voltmeter goes across a part.

Draw: Three cells in a line, labelled 1.5 V each, with 4.5 V in all. Mark + and − on each cell.

S3.10.3 CHAPTER 3

Series and parallel circuits

Why does one light going out not put all the lights in a house out?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** The lights are in parallel, so each has its own path and the full push.
- ☐ **B** Each light in a house has its own cell.
- ☐ **C** The wires in a house carry so much that nobody notices one light missing.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Electricity and magnetism, S3.10.2. A bigger push means a bigger current.
- Level 2, Magnets and simple circuits, S2.8.8. You draw circuits with symbols.

BY THE END YOU CAN

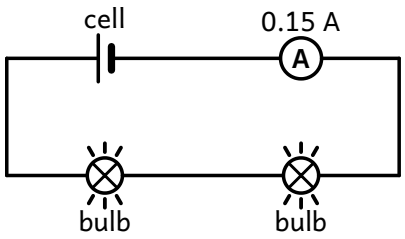
- Build a series circuit and a parallel circuit with two bulbs
- Explain why the lights in a house are wired in parallel

Two bulbs and one cell can be joined in two ways. The way you join them changes how bright they are. It changes what happens when one goes out.

In a **series** circuit the parts are in one loop, one after the other. There is only one path. The same current goes through every part.

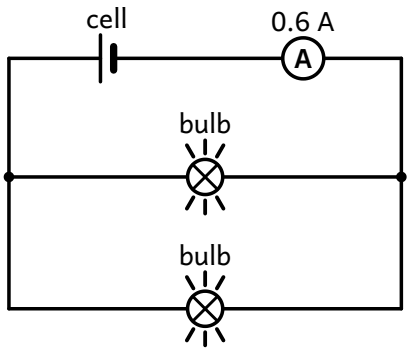
DRAW IT FIRST

Draw two bulbs in series, then in parallel



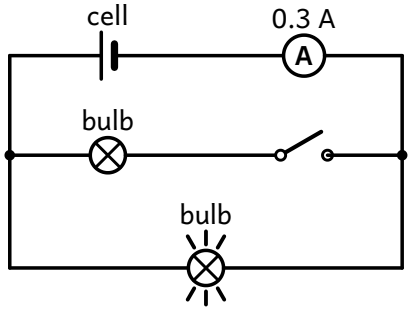
series

1 Series: draw one loop with the cell and two bulbs. The current is 0.15 A, and both bulbs are dim.



parallel

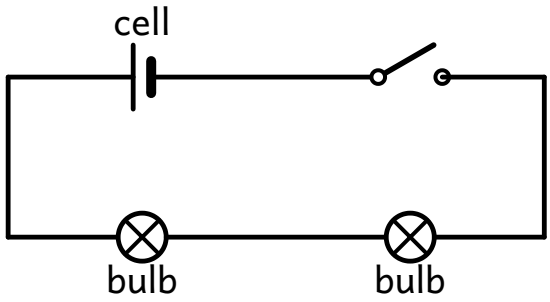
2 Parallel: draw two branches across the cell, one bulb on each. The cell gives 0.6 A, and both bulbs are bright.



one branch switched off

3 Put a switch in one branch and open it. That bulb goes out. The other bulb stays lit.

In series, the two bulbs share the push of the cell. Each gets only part of it, so each is dimmer than one bulb alone. If one bulb is taken out, or a switch opens, the loop has a gap. All the bulbs go out.



One gap in the loop stops the current everywhere. Both bulbs are dark.

In a **parallel** circuit the current has more than one path. Each path is a **branch**. Each branch is joined straight across the cell, so each bulb gets the full push.

Each bulb is as bright as one bulb alone. A switch can turn one branch off while the others stay on. The cell gives more current in all, because each branch takes its own share. So the cell runs down sooner.

SEE IT THREE WAYS

As a picture

circuit	amps	bulbs
one bulb	0.3	bright
series	0.15	dim
parallel	0.6	bright

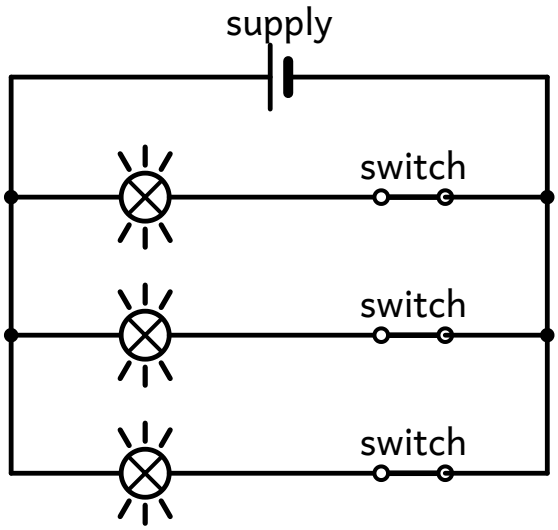
In words

Two bulbs in series take about half the current of one bulb, so they are dim. Two bulbs in parallel each take the full current. The cell gives double. In our sums a bulb keeps the same resistance. A real filament changes a little as it heats.

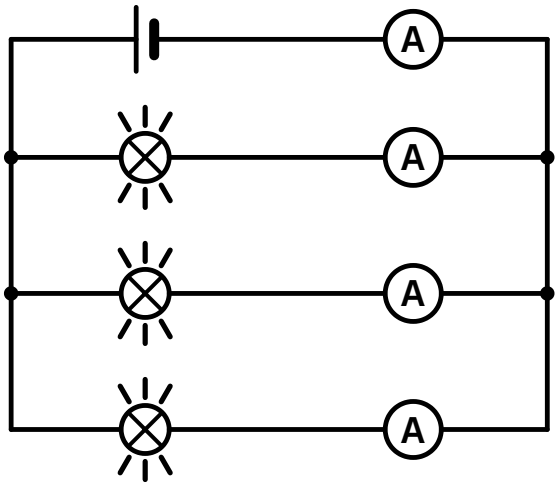
In symbols

Parallel: 0.3 A + 0.3 A = 0.6 A from the cell. Series: about 0.15 A, which is 0.3 A ÷ 2.

This is why houses are wired in parallel. Each light and socket is on its own branch. It gets the full push, so it works at full strength. You can switch one off without touching the others.



Three lamps in parallel, each with its own switch. A cell stands in for the supply here.



An ammeter in each branch and one on the supply wire. The next example finds the readings.

WORKED EXAMPLE

One bulb alone takes 0.2 A from a 1.5 V cell. Three of these bulbs are joined in parallel across the cell. How many amps does the cell give?

1. In parallel, each branch gets the full push of the cell.
2. So each branch takes the same current as one bulb alone: 0.2 A.
3. The cell gives the sum of the branch currents.
4. 0.2 + 0.2 + 0.2 = 0.6 A.
5. That is 3 times the current for one bulb, so the cell runs down sooner.

Answer: 0.6 A

Be safe. Use only small torch cells of 1.5 V and small bulbs. Join the strips for only a few seconds, because foil and cells can get warm.

TRY IT

Join two bulbs two ways

You need: one torch cell, 1.5 V, two small torch bulbs of 1.5 V, six strips of kitchen foil, folded long and thin, tape.

Be safe: Join for only a few seconds. Foil and cells can get warm, so let them cool before you touch them. Never let the two strips from the cell touch each other.

1. Series: join the cell, bulb 1 and bulb 2 in one loop with foil strips. Hold the joins for 3 seconds. Look at both bulbs.
2. Lift bulb 1 out of the loop. Look at bulb 2.
3. Parallel: join each bulb across the cell with its own two strips. Each bulb has its own loop to the cell. Look at both bulbs.
4. Lift bulb 1 away. Look at bulb 2.

What you will see: In series both bulbs glow dimly, and lifting one puts the other out. In parallel both glow more brightly, and lifting one leaves the other lit. If you have no bulbs, draw the two circuits and trace each path with your finger. Your looks may differ from ours.

If you cannot try it, this is what happens.

bulbs	series	parallel
all on	dim	bright
lift one	all out	one lit

A WRONG IDEA MANY PEOPLE HAVE

~~Two bulbs in parallel are dimmer, because the cell has to share its push between them.~~

Why it feels right: In series that is true. Two bulbs in a loop do share the push.

The test that breaks it: Join one bulb across the cell: the cell gives 0.3 A. Join a second bulb in parallel: each branch still takes 0.3 A, and the cell gives 0.6 A. Both bulbs are as bright as one alone.

What is true: Each branch is joined straight across the cell, so it gets the full push. The cell gives more current in all, so it runs down sooner.

KEY WORDS

series
parts joined in one loop, one after the other.

parallel
parts joined on separate branches across the cell.

branch
one of the paths a current can take in a parallel circuit.

BACK TO YOUR GUESS

The answer is A: The lights are in parallel, so each has its own path and the full push.

The lights are wired in parallel. Each light is on its own branch, joined straight across the supply. One branch can be off while the others stay on.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Two bulbs are in series with one cell. Ravi unscrews one bulb. What happens to the other?

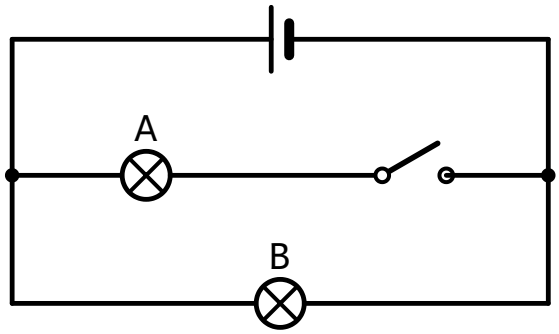
   A It stays lit, because it has its own path.

   B It goes out, because the loop is broken.

   C It gets brighter, because it has all the current.

   Answer at the back of the book.

2. Bulbs A and B are in parallel. The switch on bulb A is open. What happens to bulb B?



   A It goes out, because the circuit is broken.

   B It gets dimmer, because the push is shared.

   C It stays lit at full brightness.

   Answer at the back of the book.

3. Each of 2 bulbs takes 0.4 A when joined alone to a cell. The 2 bulbs are joined in parallel across the cell. How many amps does the cell give?

   A 0.8 A

   B 0.2 A

   C 0.4 A

   Answer at the back of the book.

4. Why are the lights in a house wired in parallel?

   A So that the lights use less electricity.

   B So that each light gets the full push and can be switched off alone.

   C So that the house needs only one wire.

   Answer at the back of the book.

5. Two identical bulbs are joined in series with one cell. How do they glow, compared with one of these bulbs alone on the cell?

   A The first bulb is brighter than the second, because it uses up some of the current.

   B Both are as bright as one bulb alone.

   C Both are dimmer than one bulb alone, and they glow alike.

   Answer at the back of the book.

6. **From an earlier chapter**

   Review: 3 cells of 1.2 V are joined in a line, + to −. What is the push in all?

   A 3.6 V

   B 1.2 V

   C 4.2 V

   Answer at the back of the book.

7. One resistor alone takes 0.6 A from a cell. Two of these resistors are joined in series with the cell. How many amps flow in the loop?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Series: one loop, the same current everywhere, and one gap puts all out. Parallel: each branch has the full push, and the cell gives more. Houses are parallel.

Draw: A cell with two bulbs in series, then a cell with two bulbs on two branches. Write series and parallel.

S3.10.4 CHAPTER 4

Resistance

How can I make a bulb dimmer, like the dimmer on a lamp?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Put a longer piece of copper wire in the loop. That dims the bulb a lot.
- ☐ **B** Put a longer piece of pencil lead in the loop. It slows the current.
- ☐ **C** A dimmer takes electrons out of the loop, so less comes back.

IF THIS FEELS HARD, READ THIS FIRST

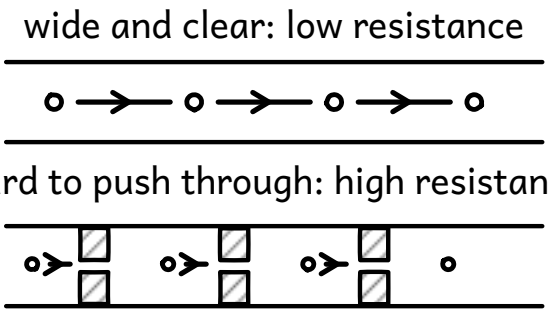
- Level 3, Electricity and magnetism, S3.10.2. The push of the cell makes the current.
- Level 3, Electricity and magnetism, S3.10.3. You add parts in a series loop.

BY THE END YOU CAN

- Explain resistance as how much a part slows the current
- Make a dimmer from pencil lead in a circuit
- Explain why wires get warm when current flows

Some parts let a current through with little trouble. Others slow it down. The amount a part slows the current is its **resistance**.

We measure resistance in **ohms**. We write Ω. A part with a big number of ohms slows the current a lot. A part with a small number slows it only a little.

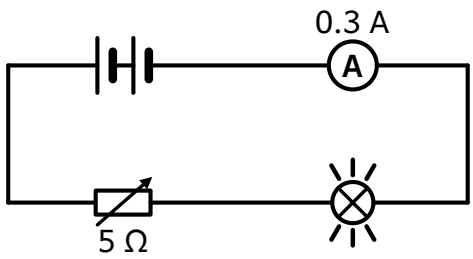


A model. With the same push, the beads move slowly through the tube with lumps in it.

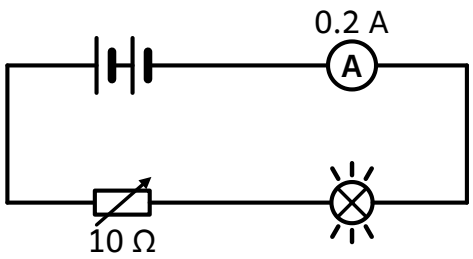
A part with high resistance slows the current, even when the push is the same. A part with low resistance lets the current through freely.

DRAW IT FIRST

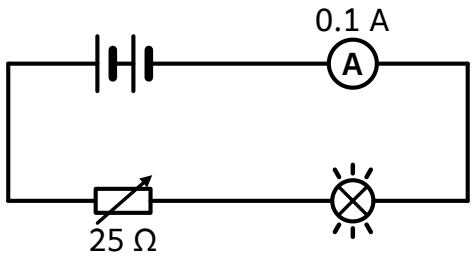
Draw *a* dimmer and turn it up



1 A variable resistor can be set to more or less resistance. At 5 Ω the current is about 0.3 A and the bulb is bright.



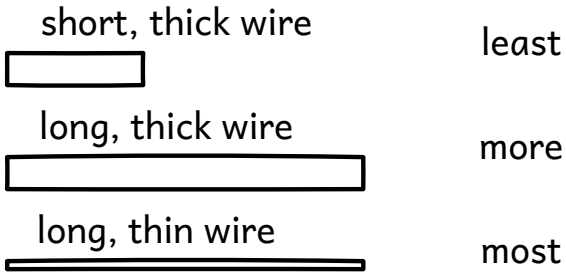
2 Turn it up to 10 Ω. The current falls to 0.2 A, and the bulb is dimmer.



3 Turn it up to 25 Ω. The current falls to 0.1 A, and the bulb is dim. This is how a lamp dimmer works.

Parts in one loop add their resistances. And the current is the voltage divided by the resistance. A bigger resistance gives a smaller current.

What makes the resistance of a wire big? A longer wire has more resistance. A thinner wire has more resistance. A short, thick wire has the least.



Resistance grows with the length of a wire and falls as it gets thicker.

The middle of a pencil is called lead, but it is not metal. It is mostly **graphite**, a form of carbon, mixed with clay. Graphite lets a current through, but with a high resistance. A longer piece of lead has more resistance.

SEE IT THREE WAYS

As a picture

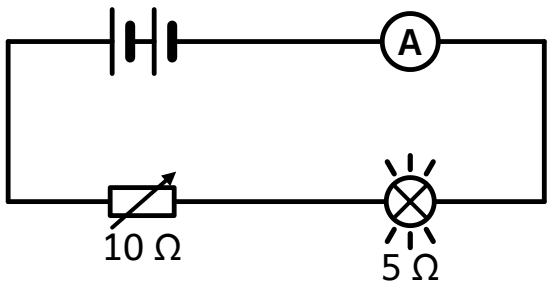
dimmer	total	amps
5 Ω	10 Ω	0.3
10 Ω	15 Ω	0.2
25 Ω	30 Ω	0.1

In words

A bigger resistance in the loop gives a smaller current. The bulb is dimmer when the current is smaller.

In symbols

current = voltage ÷ resistance. For the first row: 3 ÷ 10 = 0.3 A.



The loop for the next example. The bulb and the dimmer are in series. In our sums the bulb keeps a fixed 5 Ω. The resistance of a real bulb rises as its wire gets hot.

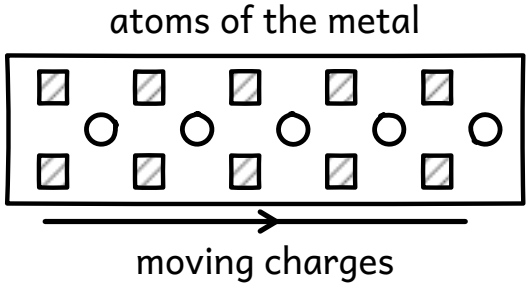
WORKED EXAMPLE

Mei has two cells of 1.5 V in a line. Her bulb is 5 Ω and her dimmer is set to 10 Ω, all in one loop. What is the current?

1. The push is 2 × 1.5 = 3 V.
2. In one loop, the resistances add.
3. Total resistance = 5 + 10 = 15 Ω.
4. Current = voltage ÷ resistance.
5. Current = 3 ÷ 15 = 0.2 A.
6. The bulb is dimmer than before. At 5 Ω the current was 3 ÷ 10 = 0.3 A.

Answer: 0.2 A

A current through a resistance makes it warm. The moving charges bump into the atoms of the metal and make them shake more. Energy goes to the thermal store. The wire gets warmer.



The charges bump into the atoms, so the atoms shake more. The wire warms up.

That is how a heater works. A heater has a wire with a high resistance, so it gets hot. A bulb has a very thin wire, called the **filament**. It gets so hot that it glows. Ordinary wires have a low resistance, so they warm only a little.

Be safe. Use only small torch cells of 1.5 V. The lead and the cells can get warm. Connect for only a few seconds, then let go. Never join the two ends of a cell with only a wire.

TRY IT

Make a dimmer from pencil lead

You need: two torch cells of 1.5 V, taped + to −, a small bulb made for 3 V, a soft pencil with the wood shaved away along one side by an adult, three strips of kitchen foil, folded long and thin, a ruler.

Be safe: Ask an adult to shave the wood off with a knife, or use a pencil already shaved. Connect for only a few seconds. The lead and the cells can get warm, so let them cool before you touch them.

1. Make a loop with the cells, the bulb and the foil. Leave a gap, and lay one end of the lead in the gap.
2. Hold a foil strip on the lead 2 cm from the other foil strip. Count 3 seconds. Look at the bulb.
3. Slide the strip to 6 cm, then 12 cm. Look at the bulb each time. Do not hold for more than 3 seconds.
4. Let everything cool for a minute. Do not touch the lead or the foil while it may be warm.

What you will see: A longer length of lead dims the bulb more. The lead and the foil may get a little warm, because a current warms a resistance. That is why you leave them to cool. Your results may differ from ours.

If you cannot try it, this is what happens.

lead	bulb
2 cm	bright
6 cm	dim
12 cm	faint

A WRONG IDEA MANY PEOPLE HAVE

~~A resistor uses up the current, so less current comes out.~~

Why it feels right: The resistor gets warm, so it seems as if something has been used up in it.

The test that breaks it: Put an ammeter on each side of a 10 Ω resistor in the loop. Both read 0.2 A. The current is the same on both sides.

What is true: A resistor slows the current in the whole loop. The energy goes to the thermal store, which warms it. The current is not used up.

KEY WORDS

resistance
how much a part slows the current.

ohms
the unit of resistance. We write Ω.

graphite
the soft black stuff in a pencil. It carries a current with a high resistance.

filament
the thin wire inside a bulb. It gets so hot that it glows.

BACK TO YOUR GUESS

The answer is B: Put a longer piece of pencil lead in the loop. It slows the current.

A longer piece of pencil lead slows the current more. Copper wire hardly slows it at all. And no electrons are taken out of the loop. The current is not used up.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What does the resistance of a part tell you?

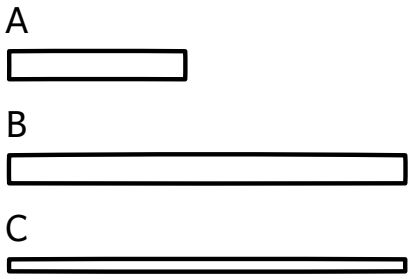
   A How hard the cell pushes the charges.

   B How much current the part uses up.

   C How much the part slows the current.

   Answer at the back of the book.

2. Which of these three wires has the most resistance?



   A Wire C

   B Wire A

   C Wire B

   Answer at the back of the book.

3. Why does a wire get warm when a current flows in it?

   A The wire uses up some of the current, and that turns into heat.

   B The moving charges bump into the atoms of the metal and make them shake.

   C The light from the bulb heats the wire.

   Answer at the back of the book.

4. Mei makes a dimmer from pencil lead. She slides the foil strip farther along the lead, so more lead is in the loop. What happens to the bulb?

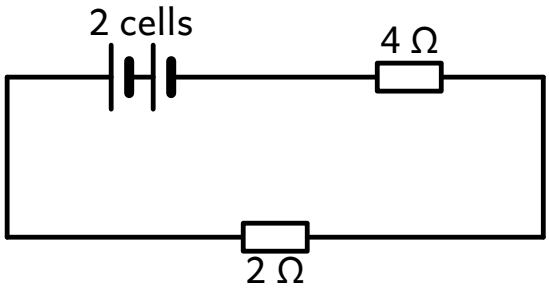
   A It gets brighter, because there is more lead to carry the current.

   B Nothing changes, because lead is just a wire.

   C It gets dimmer, because a longer piece of lead has more resistance.

   Answer at the back of the book.

5. Amina joins two cells of 1.5 V in a line. She adds a 4 Ω resistor and a 2 Ω resistor in one loop. What is the current?



A 0.5 A

B 0.75 A

C 18 A

Answer at the back of the book.

6. **From an earlier chapter**

Review: one bulb alone takes 0.5 A from a cell. 3 of these bulbs are joined in parallel across the cell. How many amps does the cell give?

A 0.5 A

B 1.5 A

C 0.17 A

Answer at the back of the book.

7. A 6 V supply is joined to a resistor of 12 Ω. What is the current?

Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Resistance is how much a part slows the current, in ohms. Longer or thinner wire has more. Current = voltage ÷ resistance. Current warms a resistance.

Draw: A loop with a cell, a bulb and a variable resistor. Write 3 V, then 3 ÷ 15 = 0.2 A.

S3.10.5 CHAPTER 5

Static electricity

Why does a rubbed comb pick up bits of paper?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Rubbing makes the comb into a magnet, and paper is magnetic.
- ☐ **B** Rubbing makes the comb sticky, so the paper sticks to it.
- ☐ **C** Rubbing gives the comb an electric charge, and the charge pulls the paper.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Electricity and magnetism, S3.10.1. You know charge is carried by electrons.

BY THE END YOU CAN

- Charge a comb by rubbing it and use it to lift paper bits
- Explain that like charges repel and unlike charges attract

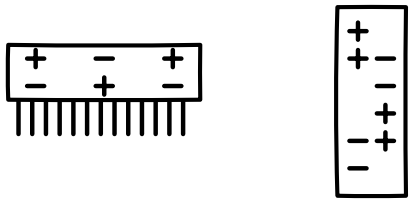
Pull a woolly jumper off in the dark and you may hear a crackle. Rub a plastic comb and it can pick up paper. This is **static electricity**. The charge stays in one place. It does not flow round a loop.

Everything is made of tiny parts. Some carry a plus charge and some carry a minus charge. Most of the time they balance, so a thing has no charge overall.

Rubbing two materials together can move electrons from one to the other. The material that gains electrons has more minus charges. We say it is **negative**. The material that loses electrons has more plus charges. We say it is **positive**.

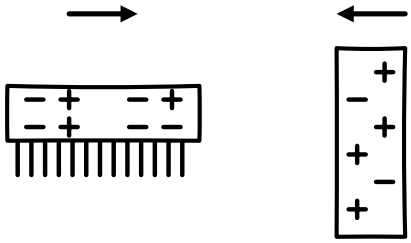
DRAW IT FIRST

Draw a comb being charged



comb wool

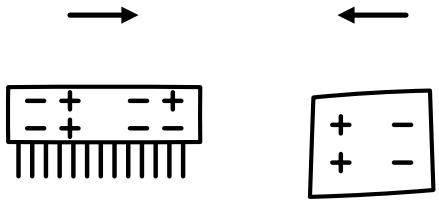
1 Draw a comb and wool. Each has equal plus and minus: 3 and 3 on the comb, 4 and 4 on the wool.



comb wool

attract

2 Rub them. 2 electrons move from the wool to the comb. The comb now has 5 minus marks and the wool has 2. They attract.

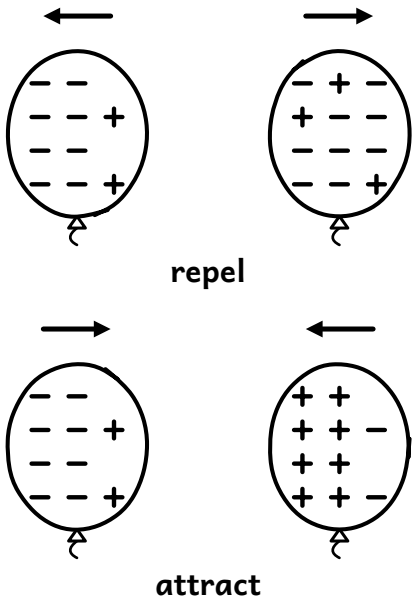


comb paper

attract

3 Hold the comb near bits of paper. The comb pulls on the paper. The paper has equal plus and minus marks, but they move a little.

There is a rule for the pulls and pushes between charges. Charges of the same sign **repel**, which means they push apart. Charges of different signs **attract**, which means they pull together.



Two negative balloons repel. A negative and a positive balloon attract.

SEE IT THREE WAYS

As a picture

pair	force
+ and +	repel
− and −	repel
+ and −	attract

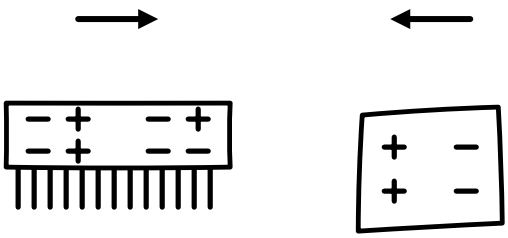
In words

Charges of the same sign push each other away. Charges of different signs pull each other together.

In symbols

+ and + repel. − and − repel. + and − attract.

Why does a charged comb lift paper that has no charge? The comb is negative. It pulls the plus charges in the paper a little nearer. It pushes the minus charges a little away.

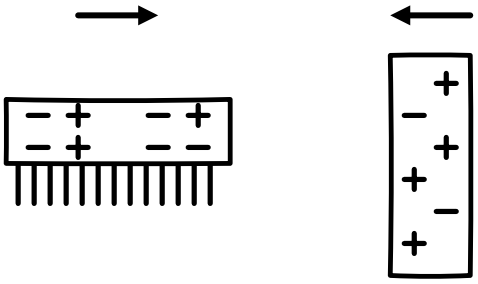


comb paper

attract

The paper has no charge overall. Its plus marks move to the side nearest the comb.

The plus charges are now nearer to the comb than the minus ones. A pull from nearby is stronger than a push from farther away. So the paper is pulled to the comb.



comb wool

attract

After rubbing, the comb has 2 more minus marks than plus. The wool has 2 more plus marks than minus.

WORKED EXAMPLE

A comb has 3 plus and 3 minus charges. Rubbing moves 2 electrons onto it. How many more minus than plus charges does the comb have now?

1. Before rubbing: 3 plus and 3 minus. They balance.
2. Rubbing adds 2 electrons. Each is a minus charge.
3. Minus charges now: 3 + 2 = 5.
4. The plus charges are still 3.
5. 5 − 3 = 2, so the comb has 2 more minus than plus. It is negative.

Answer: 2 more minus than plus, so the comb is negative

Static electricity works best on a dry day. In damp air the charge leaks away into the moisture, so a comb loses its charge fast.

TRY IT

Lift paper with a comb

You need: a plastic comb, or a plastic pen or ruler, dry hair or a woollen cloth, tiny bits of paper, each the size of a fingernail, a dry day.

1. Tear the paper into tiny bits and spread them on a table.
2. Hold the comb above the bits without rubbing it. Does anything move?
3. Rub the comb on dry hair or wool, 20 quick strokes in one direction.
4. Hold the comb just above the paper, not touching. Count the bits that jump up.

What you will see: The comb that was not rubbed lifts nothing. The rubbed comb pulls up several bits. Some bits may jump off again. They take the comb charge and are pushed away. Your counts will differ from ours.

If you cannot try it, this is what happens.

comb	bits lifted
not rubbed	0
rubbed	7

A WRONG IDEA MANY PEOPLE HAVE

~~The comb picks up paper because the comb becomes a magnet.~~

Why it feels right: A magnet also picks things up without touching them, so the two seem alike.

The test that breaks it: A magnet does not move bits of kitchen foil. A rubbed comb pulls them. The two kinds of pull are different.

What is true: The comb has an electric charge. It pulls the charges in the paper. A magnet works in a different way.

KEY WORDS

static electricity

charge that stays in one place and does not flow.

negative
having more minus charges than plus charges.

positive
having more plus charges than minus charges.

repel
to push apart.

attract
to pull together.

BACK TO YOUR GUESS

The answer is C: Rubbing gives the comb an electric charge, and the charge pulls the paper.

Rubbing moves electrons onto the comb, so it has a charge. The charge pulls on the paper. Paper is not magnetic, and the comb is not sticky.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. A plastic comb is rubbed on wool. What happens?

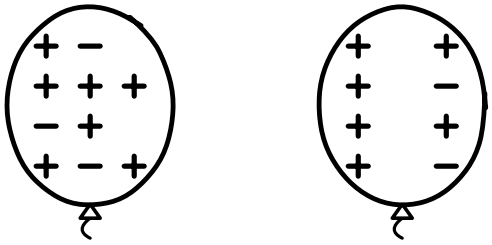
   A Electrons move from the wool to the comb.

   B The comb makes new electrons.

   C Electrons move from the comb to the wool.

   Answer at the back of the book.

2. Two balloons have charges as shown. Do they attract or repel?



A They attract, because both are charged.

B They repel, because both are positive.

C Nothing happens, because only paper reacts.

Answer at the back of the book.

3. Why does a charged comb pick up paper that has no charge?

A The paper is magnetic, so the comb pulls it.

B The paper takes the same charge as the comb and sticks.

C The comb pulls the opposite charges in the paper nearer, so the paper moves to it.

Answer at the back of the book.

4. On which day does a rubbed comb lift paper best?

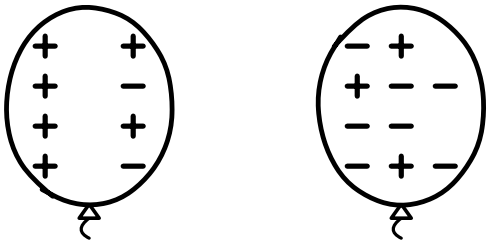
A A dry day, because dry air lets the charge stay on the comb.

B A damp day, because wet air carries the charge.

C It makes no difference what the weather is.

Answer at the back of the book.

5. Two other balloons have charges as shown. Do they attract or repel?



A They repel, because both are charged.

B They attract, because one is positive and one is negative.

C Nothing happens, because the plus and minus marks cancel.

Answer at the back of the book.

6. **From an earlier chapter**

Review: a 9 V supply is joined to a resistor of 15 Ω. What is the current?

A 135 A

B 24 A

C 0.6 A

Answer at the back of the book.

7. A comb has 7 minus charges and 3 plus charges. How many more minus than plus charges does it have?

Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Rubbing moves electrons. The one that gains them is negative. Like charges repel and unlike charges attract. A charged comb pulls paper. Dry days work best.

Draw: A comb with more minus marks near bits of paper, with an arrow of attract. Write + and − on both.

S3.10.6 CHAPTER 6

Magnetic fields

How can I see the invisible push and pull around a magnet?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** A magnet has a field all round it, and a compass or steel wool can show it.
- ☐ **B** A magnet acts only at its two ends and nowhere else.
- ☐ **C** The pull stops at the surface of the magnet, so there is nothing to see.

IF THIS FEELS HARD, READ THIS FIRST

- Level 2, Magnets and simple circuits, S2.8.2. A magnet has a north pole and a south pole.
- Level 2, Magnets and simple circuits, S2.8.4. A compass needle is a small magnet.

BY THE END YOU CAN

- Map a magnet's field with a compass or bits of steel wool
- Explain that the Earth has a magnetic field

A magnet can pull a pin across a table without touching it. The push or pull reaches out into the space round the magnet. That space is the **magnetic field** of the magnet.

You cannot see a field. But a small magnet, such as a **compass** needle, feels it. The needle turns until it lines up with the field.

We draw a field with **field lines**. They run from the north pole of the magnet round to the south pole. An arrow on each line shows the way a north pole would be

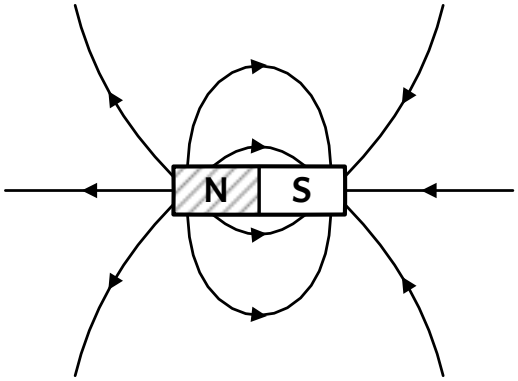
pushed.

DRAW IT FIRST

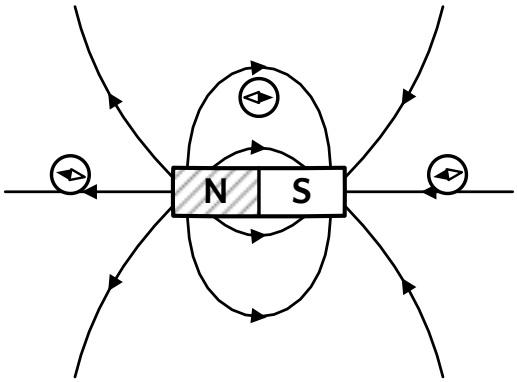
Draw the field of a bar magnet



1 Draw a bar magnet. Write N on one end and S on the other.

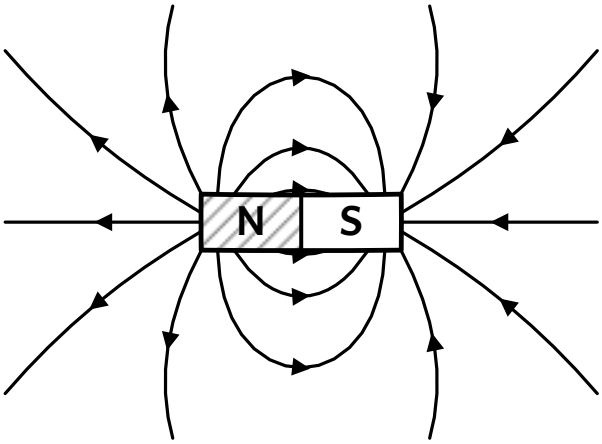


2 Draw lines that leave the N end, curve round and come into the S end. Put an arrow on each line, pointing from N to S.



3 Put a compass on a line. The black end of the needle points the way the arrow points.

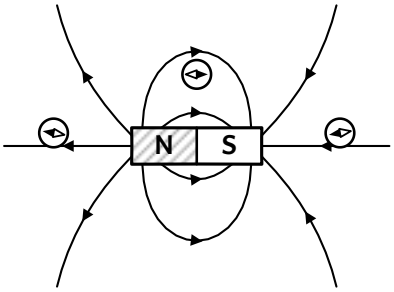
The lines are closest together near the poles. That is where the field is strongest. Far from the magnet the lines are far apart, and the field is weak.



The lines crowd together near the poles, where the field is strongest.

SEE IT THREE WAYS

As a picture



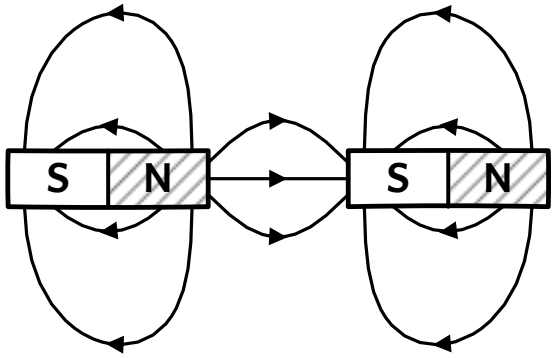
In words

A compass needle lines up with the field. Its black end points the way the field line points. Near the N pole it points away from the magnet. Near the S pole it points towards it.

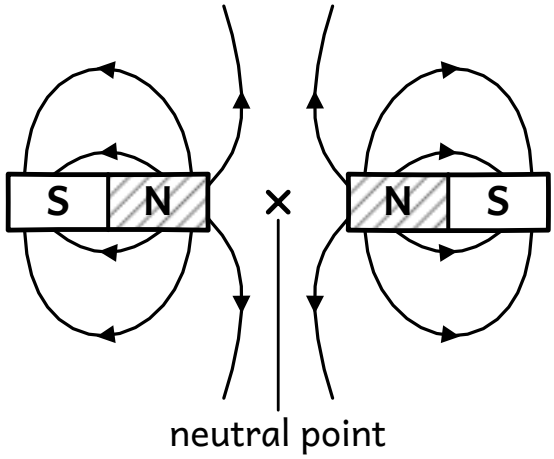
In symbols

Outside a magnet, field lines run from N to S.

Two magnets make a joined field. If a N pole faces a S pole, the lines join across the gap. The magnets pull together. If two N poles face each other, the lines push apart. The magnets repel.

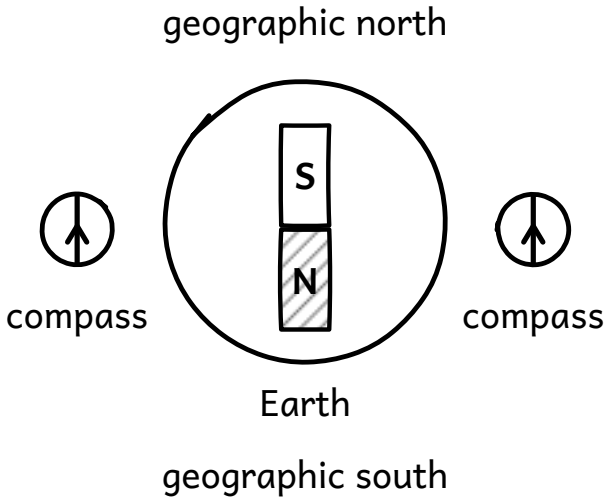


N facing S: the lines join across the gap and the magnets attract.



N facing N: the lines push apart. At the neutral point the field of one magnet cancels the other.

The Earth has a magnetic field too. It is as if a huge bar magnet were inside the Earth. A compass needle lines up with this field. The black end points roughly to the geographic north.



The Earth acts like a huge magnet. Almost everywhere, a compass needle points roughly north.

The end of the Earth's magnet near the geographic north is a magnetic S pole. It pulls the black north end of a compass towards it. This works in most places. Very near the magnetic poles, compasses are not reliable.

Be safe. Keep magnets away from phones, cards and watches. Do not put steel wool or iron filings near your eyes or mouth. Wash your hands after you touch them.

TRY IT

Map a magnet's field

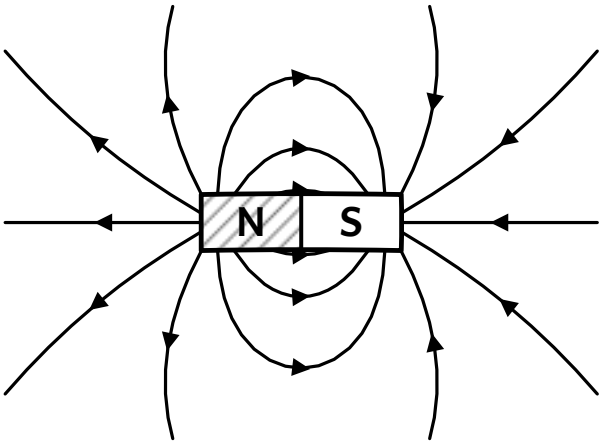
You need: a bar magnet, a plain sheet of paper, tiny bits of steel wool, cut small by an adult with scissors, a compass, if you have one.

Be safe: Steel wool is sharp. Ask an adult to cut it. Keep it away from your eyes and mouth, and wash your hands after.

1. Lay the magnet flat on the table. Put the paper over it.
2. Sprinkle the bits of steel wool over the paper. Tap the paper gently.
3. Look at the pattern. Which way do the lines curve? Where are they thickest?
4. With a compass, move it slowly round the magnet. Watch the needle turn.

What you will see: The steel wool lines up in curves from one end of the magnet to the other. It is thickest near the ends of the magnet, where the field is strongest. The compass needle turns as you move it, always along the lines. Your pattern will look like this, but not exactly.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~A magnet acts only at its two ends.~~

Why it feels right: Pins stick to the ends of a magnet. The ends seem to be the only places that pull.

The test that breaks it: Put a compass above the middle of a bar magnet. The needle turns to line up with the magnet. The field is there, too.

What is true: The field is all round the magnet. It is strongest near the poles, but it is not zero anywhere near the magnet.

KEY WORDS

magnetic field
the space round a magnet where it pushes or pulls.

field lines
lines that show a field. Outside a magnet they run from N to S.

compass
a small magnet on a pivot. It lines up with a field.

BACK TO YOUR GUESS

The answer is A: A magnet has a field all round it, and a compass or steel wool can show it.

A magnet has a magnetic field all round it. The field is strongest near the poles, but it spreads out in every direction. A compass or bits of steel wool can show it.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Which way do field lines run outside a bar magnet?

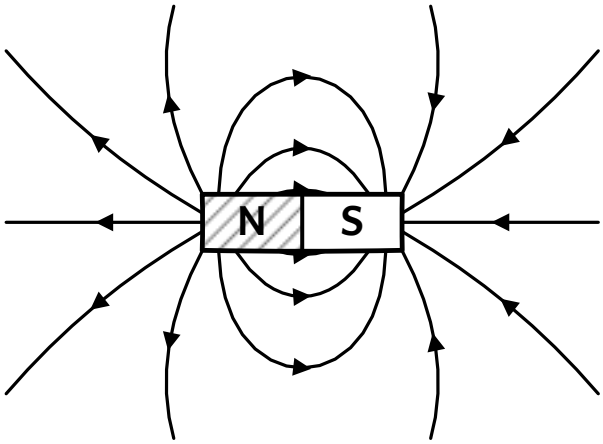
   A From the S pole round to the N pole.

   B From the N pole round to the S pole.

   C They go straight out from both poles and never meet.

   Answer at the back of the book.

2. Where is the field of a bar magnet strongest?



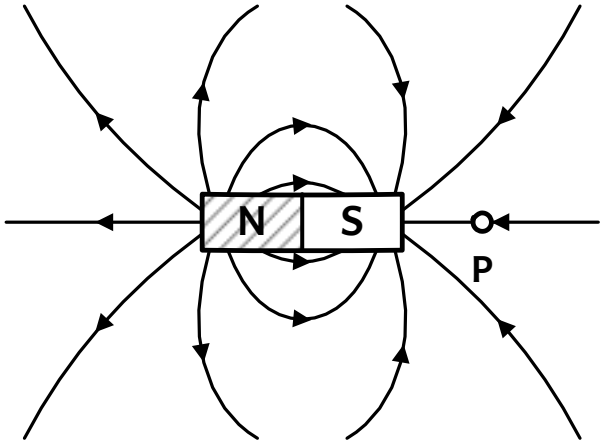
   A Far from the magnet, where the lines are far apart.

   B Nowhere. The field is the same everywhere round a magnet.

   C Near the poles, where the lines are closest together.

   Answer at the back of the book.

3. A small compass is put at P, to the right of the magnet. The N pole is on the left. Which way does the black end point?



A Towards the S end of the magnet.

B Away from the magnet, because it is pushed off by the S pole.

C Up the page, whatever the field is.

Answer at the back of the book.

4. Why does a compass needle point roughly north in most places on the Earth?

A The ice at the North Pole pulls the needle.

B The Earth is like a huge magnet, and the needle lines up with its field.

C The Sun pulls the needle towards it.

Answer at the back of the book.

5. Kofi lays a bar magnet on a table with its N pole on the left. He puts a small compass to the left of the N pole, on the line of the magnet. Which way does the black end of the needle point?

A Towards the magnet, because the black end is a north pole and the magnet pulls it.

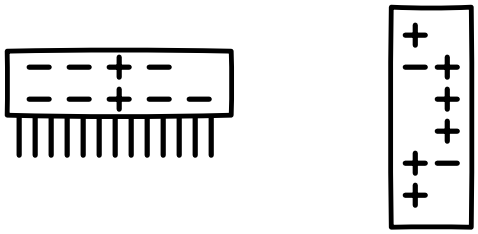
B North, as a compass always does.

C Away from the magnet, along the field line.

Answer at the back of the book.

6. **From an earlier chapter**

Review: a comb and a piece of wool have the charges drawn here. Do they attract or repel?



A They attract, because one is negative and one is positive.

B They repel, because both are charged.

C Nothing happens. Only paper is pulled.

Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

A magnet has a field all round it. Field lines run from N to S, closest near the poles. A compass lines up with them. The Earth has a field too.

Draw: A bar magnet marked N and S. Three curved lines with arrows from N to S. A compass on one line.

S3.10.7 CHAPTER 7

Electromagnets

Can I make a magnet that I can switch on and off?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** No. A magnet is always a magnet and cannot be switched off.
- ☐ **B** Yes. A current in a coil of wire makes a magnet, and it stops when the current stops.
- ☐ **C** Yes. Rubbing a nail on wool makes a magnet that you can switch off.

IF THIS FEELS HARD, READ THIS FIRST

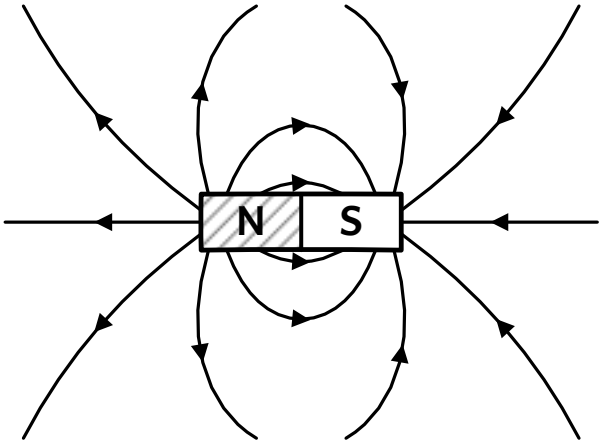
- Level 3, Electricity and magnetism, S3.10.6. An electromagnet has a field like a bar magnet.
- Level 3, Electricity and magnetism, S3.10.1. A current is a flow of charge in a loop.

BY THE END YOU CAN

- Make an electromagnet with a nail, wire and a cell
- Test how more turns of wire change its strength

A wire that carries a current has a magnetic field round it. The field of one wire is weak. Wind the wire into a **coil** and the fields of all the **turns** add up.

A coil with a current acts like a bar magnet. It has a N pole at one end and a S pole at the other. Turn the current off and the field goes.



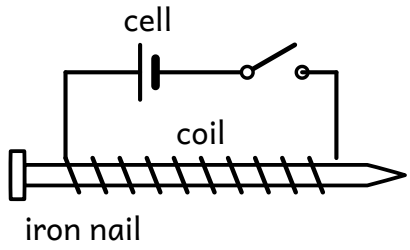
A bar magnet, standing in for the coil. A coil with a current has a field like this one. Reverse the current and the N and S ends swap.

Put an iron nail inside the coil. The nail is the **core**. Iron becomes a magnet when it is in a field. The nail adds its own field to that of the coil. Together they are much stronger.

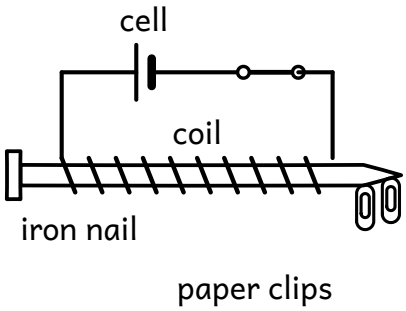
An **electromagnet** is a coil with a current in it, usually wound round an iron core. It is a magnet that you can switch on and off.

DRAW IT FIRST

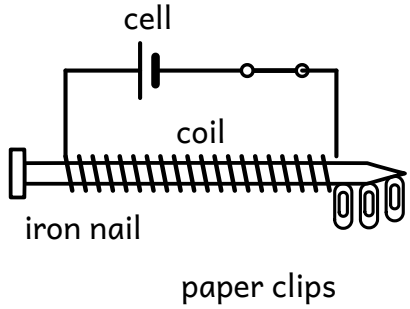
Draw an electromagnet and switch it on



1 Wind wire round an iron nail and join it to a cell and a switch. Leave the switch open. No current flows, so no clips stick.



2 Close the switch. A current flows in the coil and the nail becomes a magnet. With 10 turns it holds 2 clips.



3 Wind more turns. With 20 turns, the same cell holds 3 clips. The magnet is stronger.

When the switch is opened, the current stops. The iron nail loses nearly all of its magnetism, and the clips fall. A steel nail may keep a little magnetism.

coil	clips
coil alone	0
coil with iron nail	3

One learner's test, 20 turns and one cell. The iron nail makes the coil much stronger.

Two things make an electromagnet stronger. One is more turns of wire. The other is a bigger current, which you get from more cells. The results below are one learner's. Yours will differ.

SEE IT THREE WAYS

As a picture

turns	cells	clips
5	1	1
10	1	2
20	1	3
20	2	6
20	3	8

In words

More turns, or more cells, lift more clips. Clip counts are rough, so do not expect them to grow exactly in step.

In symbols

5 turns: 1 clip. 20 turns: 3 clips. More turns, more clips.

---

turns	clips
5	1
10	2
20	3

The results for the next example. One cell each time.

WORKED EXAMPLE

One learner's electromagnet picks up 1 clip with 5 turns and 3 clips with 20 turns. How many times as many turns is that, and how many times as many clips?

1. Read the table: 5 turns pick up 1 clip. 20 turns pick up 3 clips.
2. The turns grew 20 ÷ 5 = 4 times.
3. The clips grew 3 ÷ 1 = 3 times.
4. More turns picked up more clips. Clip counts are rough, so they do not grow exactly in step.

Answer: 4 times as many turns and 3 times as many clips

Electromagnets are used in scrapyard cranes, door locks and electric bells. They are useful because they can be switched off. A crane drops its load when the current stops.

Be safe. Use only small torch cells of 1.5 V. A coil is only a long wire. A big current flows, so the wire and the cell warm fast. Join it for only a few seconds, then lift it off and let it cool.

TRY IT

Make an electromagnet

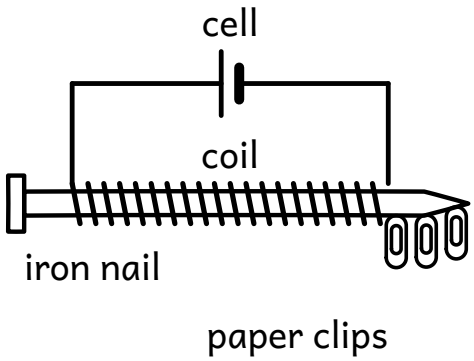
You need: a long iron nail, about 8 cm, about 1 metre of thin wire, with the ends bared by an adult, one or two torch cells of 1.5 V, tape, small paper clips or pins.

Be safe: The wire and the cell can get hot. Connect for only a few seconds, then let go. Let them cool before you touch them. Keep the nail tip and the pins away from your face.

1. Wind the wire in 10 neat turns round the nail. Leave a tail at each end. An adult bares the ends, with care, as the blade is sharp.
2. Tape one end of the wire to one end of the cell. Hold the other end on the other end of the cell for 3 seconds. Count the clips the nail tip lifts.
3. Lift the wire off the cell. Do the clips fall? Let the wire and the cell cool for a minute.
4. Now wind 20 turns and count again. Then try two cells in a line.

What you will see: With more turns the nail holds more clips. With two cells it holds more again. When you lift the wire off the cell, most clips fall. Our 20 turns and one cell held 3 clips. Your counts will differ.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~An electromagnet is a permanent magnet that stays on once it is made.~~

Why it feels right: A nail with a coil looks like any other magnet, and a bar magnet never switches off.

The test that breaks it: Lift some clips with the electromagnet. Lift the wire off the cell and the clips drop. Join it again and they stick again.

What is true: An electromagnet works only while a current flows. An iron core loses nearly all its magnetism when the current stops.

KEY WORDS

coil
wire wound round and round.

turns
the loops of wire in a coil.

core
the iron nail inside a coil.

electromagnet
a coil with a current in it, usually round an iron core.

BACK TO YOUR GUESS

The answer is B: Yes. A current in a coil of wire makes a magnet, and it stops when the current stops.

A current in a coil of wire makes a magnetic field. Switch the current off and the field goes. That is an electromagnet.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. An iron nail has a coil round it joined to a cell. Mei opens the switch. What happens to the nail?

   A It stays a strong magnet for ever.

   B Its poles swap over.

   C It loses nearly all of its magnetism.

   Answer at the back of the book.

2. Kofi wants to make his electromagnet stronger. What should he do?

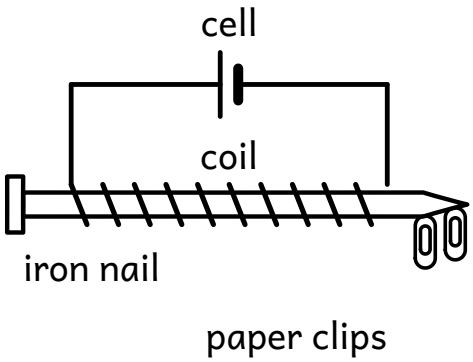
   A Wind more turns of wire round the nail.

   B Take the iron nail out of the coil.

   C Use a plastic nail instead of an iron one.

   Answer at the back of the book.

3. In one learner's test, an electromagnet with 10 turns and one cell held 2 clips, as shown. She winds 20 turns and keeps the one cell. Using the table in this chapter, how many clips does it hold?



   A 2 clips

   B 3 clips

   C 4 clips

   Answer at the back of the book.

4. Why is an iron nail put inside the coil?

   A The nail carries the current, so the wire is not needed.

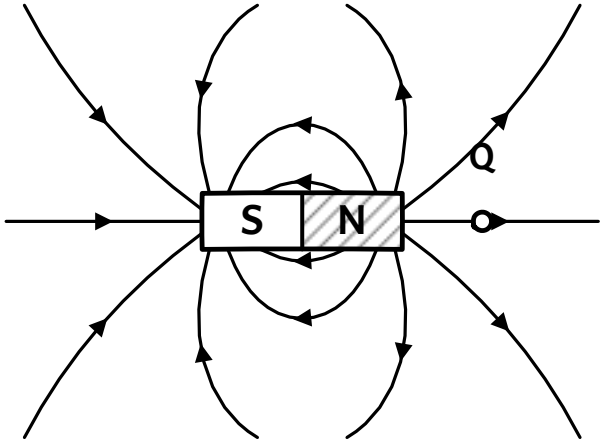
   B The nail only holds the wire in place.

   C The nail becomes a magnet in the field of the coil, so the whole thing is stronger.

   Answer at the back of the book.

5. **From an earlier chapter**

   Review: the point Q is to the right of the N end of a bar magnet. Which way does the black end of a compass point at Q?



   A Away from the magnet.

   B Towards the magnet.

   C Up the page.

   Answer at the back of the book.

6. Ana tests her electromagnet with a cell. What is the safe way to do it?

   A Keep it joined until the cell is flat, so she can count slowly.

   B Join it for a few seconds, count the clips, then let go.

   C Tape the wire to the cell so it stays on while she counts.

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

A current in a coil makes a magnet. An iron core makes it stronger. More turns or more cells make it stronger. Switch off and an iron core loses most of its magnetism.

Draw: An iron nail with a coil of wire. A cell and a switch. Paper clips under the tip.

S3.10.8 CHAPTER 8

Electricity safety at home

Why must I never touch a switch with wet hands?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Water makes the mains electricity stronger.
- ☐ **B** Clean water cannot carry electricity, so wet hands are safe.
- ☐ **C** Water with things in it carries current, and wet skin lets far more current through.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Electricity and magnetism, S3.10.4. Current depends on resistance.
- Level 3, Electricity and magnetism, S3.10.3. Home circuits are in parallel.
- Level 2, Magnets and simple circuits, S2.8.5. You met the safety rules for cells and mains.

BY THE END YOU CAN

- Explain why water and electricity are a dangerous mix
- Explain how a fuse protects a home circuit

The electricity in a home socket is called the **mains**. It is very different from a torch cell. A cell gives 1.5 V. The mains gives about 110 to 240 V, depending on where you live.

Mains electricity can kill. A torch cell is safe to touch, but never touch the mains. This chapter is about staying safe and about the part that guards a home circuit, the fuse.

The current through your body depends on the voltage and on the resistance of your body. Current = voltage ÷ resistance. Dry skin has a high resistance. Wet skin

has a much lower one.

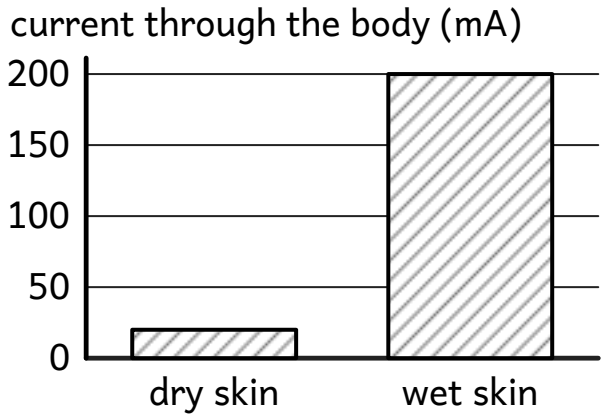
Water with anything dissolved in it carries a current. Tap water, sweat and rain all have things dissolved in them. Water on your skin lowers the resistance of your body.

WORKED EXAMPLE

Take the mains as 200 V. Where you live it may be nearer 110 V or 240 V. Dry skin has about 10 000 Ω and wet skin about 1 000 Ω. How much more current passes through wet skin?

1. Current = voltage ÷ resistance.
2. Dry skin: 200 ÷ 10 000 = 0.02 A.
3. Wet skin: 200 ÷ 1 000 = 0.2 A.
4. Wet skin against dry skin: 0.2 ÷ 0.02 = 10 times as much current.

Answer: 10 times as much current



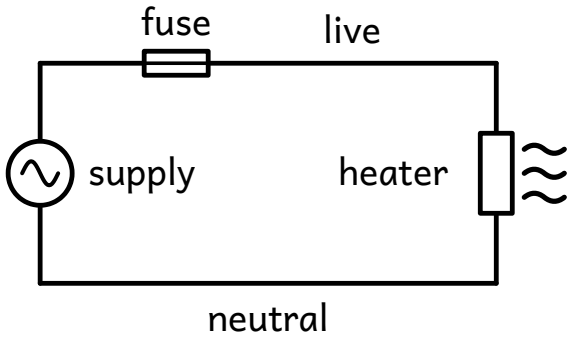
A made up sum. A milliamp, mA, is 0.001 A, so 20 mA is 0.02 A. Real skin varies, but wet skin always lets far more current through.

A current of 0.02 A can lock your muscles, so you cannot let go. More than about 0.05 A through the body can kill. With wet skin the current in the sum is far above both. Even with dry hands the mains can kill. At mains voltage the resistance of the skin breaks down.

So never touch a switch, a plug or an appliance with wet hands. Never use electric things near water.

Now the fuse. Many things can send too much current round a circuit. Too many appliances on one socket do it. A fault does it too. Too much current makes wires hot, and hot wires can start a fire.

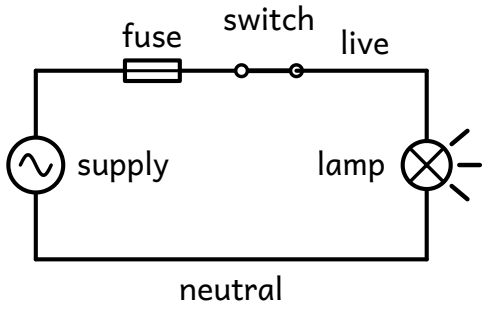
A **fuse** is a thin wire in the live wire of the circuit. It is made to melt when the current is too big. The wire melts and breaks the circuit before the other wires get hot.



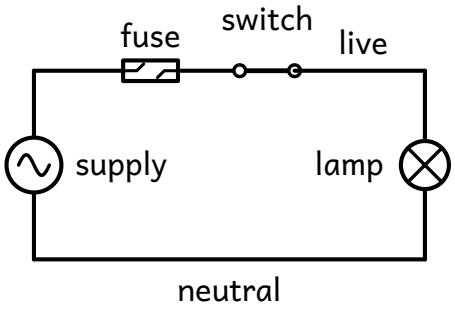
The fuse is in the live wire. All the current for the heater goes through it.

DRAW IT FIRST

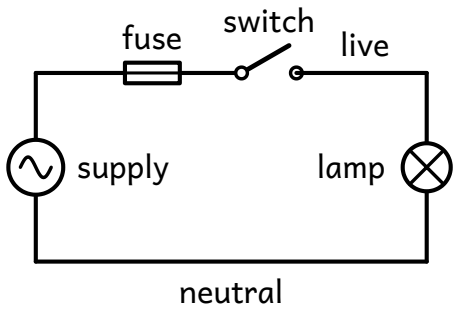
Draw a home circuit and a blown fuse



1 working: the fuse is whole. The lamp is on.

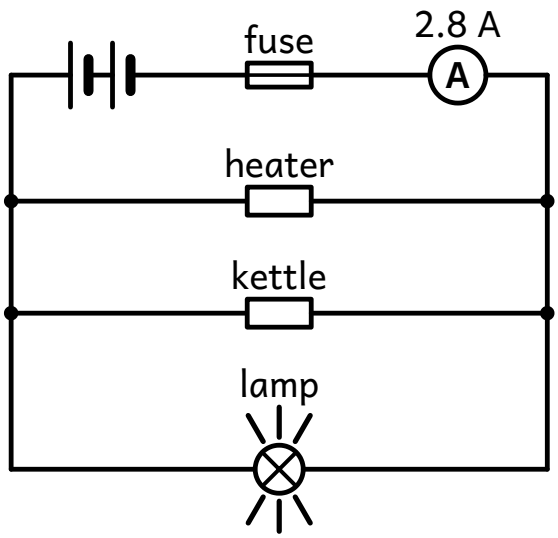


2 blown: the fuse wire has melted. The circuit is broken, and the lamp is off.



3 switched off: the fuse is whole. The switch is open, so the lamp is off.

Appliances on one circuit are in parallel. Each takes its own current, and the fuse carries the total. Look at a socket circuit with a heater, a kettle and a lamp.



A model of a socket circuit with a 3 A fuse. Two cells stand in for the mains, and the currents are small model ones. The fuse carries the current of all three.

WORKED EXAMPLE

A 3 A fuse guards the circuit. The heater takes 1.2 A, the kettle 1 A and the lamp 0.6 A. Ravi plugs in a fourth appliance that takes 0.6 A. What is the new total, and does the fuse blow?

1. In parallel, the currents add up.
2. Before: 1.2 + 1 + 0.6 = 2.8 A.
3. With the fourth: 2.8 + 0.6 = 3.4 A.
4. The fuse is 3 A. 3.4 A is more than 3 A, so the fuse wire melts.

Answer: 3.4 A, so the fuse blows

A **circuit breaker** does the same job as a fuse. It is a switch that flips off when the current is too big. You can switch it back on once the fault is fixed. A fuse wire must be replaced.

SEE IT THREE WAYS

As a picture

do	do not
dry hands	poke sockets
plugs dry	touch lines
tell adult	climb poles

In words

Keep water away from electric things. Keep your hands dry. Tell an adult about a damaged wire or a hot plug. Never touch a power line that has fallen.

In symbols

Wet skin: resistance low, current large. Fuse: current too large, wire melts, circuit breaks.

Be safe. Never poke anything into a socket. Never touch a power line that has fallen, and stay far away from it. Keep kites and long poles away from overhead lines. If someone is hurt by electricity, do not touch them. Switch off the supply if you safely can, and call for help.

TRY IT

Survey the places water and electricity meet

You need: paper and a pencil, a walk round your home, looking only.

Be safe: This activity uses no electricity. Look from a safe distance and do not touch plugs, sockets, switches or wires. If you see a damaged wire, tell an adult.

1. Walk round your home with the paper. Do not touch any plug, switch or wire.
2. Look for each place where water and electricity are close. Think of the sink, the bathroom, a tap near a socket, and a cable outside in the rain.
3. Draw each place. Mark where the water is and where the electric thing is. Keep to a safe distance as you draw.
4. For each place write one habit that keeps them apart. Tell an adult about any damaged wire.

What you will see: Most homes have several places where water and electricity are close. A habit, such as drying your hands or keeping plugs off the wet floor, keeps each one safe. Your places will differ from ours.

If you cannot try it, this is what happens.

place	habit
sink	plugs away
bathroom	dry hands
rain	cables up

A WRONG IDEA MANY PEOPLE HAVE

~~It is safe to touch a switch with wet hands if the water looks clean.~~

Why it feels right: Clean water looks harmless, and the water does not change the switch.

The test that breaks it: Do not test it with electricity. Use the sum instead. With dry skin, 0.02 A passes. With wet skin, 0.2 A passes, which is 10 times as much. Dry hands are not safe on the mains.

What is true: Water on your skin lowers its resistance. Even clean-looking water has things dissolved in it. Dry your hands before you touch any electric thing.

KEY WORDS

mains
the electricity supply to a home. It can kill.

fuse
a thin wire that melts when too much current flows.

circuit breaker
a switch that flips off when too much current flows. It can be reset.

BACK TO YOUR GUESS

The answer is C: Water with things in it carries current, and wet skin lets far more current through.

Water with anything dissolved in it carries a current. Wet skin lets far more current through the body. The mains is not stronger, but the body lets more current pass.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Why is it dangerous to touch a switch with wet hands?

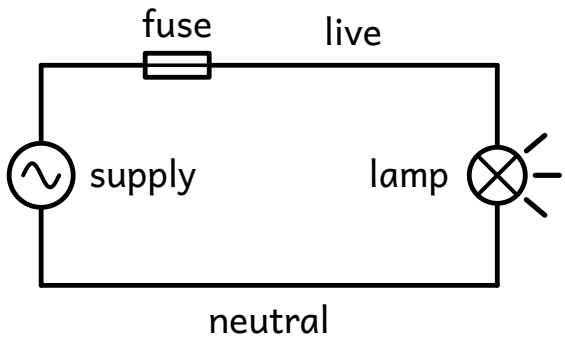
   A Wet skin lets much more current pass through the body.

   B Water makes the mains voltage bigger.

   C Pure water carries current well, so any water will do.

   Answer at the back of the book.

2. What does a fuse do when too much current flows?



   A It makes the current smaller, so the appliance keeps working.

   B Its thin wire melts and breaks the circuit.

   C It switches off, then back on by itself when it cools.

   Answer at the back of the book.

3. A socket circuit has a 5 A fuse. A heater takes 3 A and a kettle takes 4 A. Both are plugged in. What current flows in all, and what happens to the fuse?

   A 4 A, so the fuse holds

   B 12 A, so the fuse blows

   C 7 A, so the fuse blows

   Answer at the back of the book.

4. Mei is flying a kite. The string tangles in an overhead power line. What should she do?

   A Let go, move far away and tell an adult.

   B Pull the string hard to free the kite.

   C Climb up to free the kite.

   Answer at the back of the book.

5. Joseph's 5 A fuse keeps blowing when he runs the heater and the kettle on one socket. He wants to put a thick wire where the fuse goes, so it never blows. Is that a good idea?

   A Yes. The thick wire carries the current easily, so the appliances keep working.

   B No. Use one appliance at a time. Ask an adult to fit a new fuse of the same size.

   C Yes. The fuse only gets in the way, and the other wires can take the current.

   Answer at the back of the book.

6. **From an earlier chapter**

   Review: a 8 V supply is joined to a resistor of 20 Ω. What is the current?

   A 160 A

   B 28 A

   C 0.4 A

   Answer at the back of the book.

7. A heater takes 1 A and a kettle takes 5 A. They are on one circuit in parallel. What total current flows through the fuse?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Mains can kill. Wet skin lets far more current through, so keep hands dry. A fuse is a thin wire that melts when the current is too big. A circuit breaker can be reset.

Draw: A home circuit with a supply, a fuse, a switch and a lamp. Mark the fuse wire.

Key words, A to Z

Every key word in this book, what it means, and the chapter that teaches it.

ammeter
a meter that reads the current. It goes in the loop. S3.10.1

amps
the unit of current. We write A. S3.10.1

attract
to pull together. S3.10.5

battery
cells joined in a line, + to −. Their volts add up. S3.10.2

branch
one of the paths a current can take in a parallel circuit. S3.10.3

charge
a tiny amount of electricity carried by a particle. S3.10.1

circuit breaker
a switch that flips off when too much current flows. It can be reset. S3.10.8

coil
wire wound round and round. S3.10.7

compass
a small magnet on a pivot. It lines up with a field. S3.10.6

core
the iron nail inside a coil. S3.10.7

current
a flow of charge round a complete circuit. S3.10.1

electromagnet
a coil with a current in it, usually round an iron core. S3.10.7

electrons
tiny particles that carry charge. They move in a metal wire. S3.10.1

field lines
lines that show a field. Outside a magnet they run from N to S. S3.10.6

filament
the thin wire inside a bulb. It gets so hot that it glows. S3.10.4

fuse
a thin wire that melts when too much current flows. S3.10.8

graphite
the soft black stuff in a pencil. It carries a current with a high resistance. S3.10.4

magnetic field
the space round a magnet where it pushes or pulls. S3.10.6

mains
the electricity supply to a home. It can kill. S3.10.8

negative
having more minus charges than plus charges. S3.10.5

ohms
the unit of resistance. We write Ω. S3.10.4

parallel
parts joined on separate branches across the cell. S3.10.3

positive
having more plus charges than minus charges. S3.10.5

repel
to push apart. S3.10.5

resistance
how much a part slows the current. S3.10.4

series
parts joined in one loop, one after the other. S3.10.3

static electricity
charge that stays in one place and does not flow. S3.10.5

turns
the loops of wire in a coil. S3.10.7

voltage
the push that makes a current flow round a circuit. S3.10.2

voltmeter
a meter that reads the push across a part. It goes across the part. S3.10.2

volts
the unit of voltage. We write V. S3.10.2

Answers

S3.10.1. Current in a circuit

1. **Electrons moving round the loop, each carrying a little charge.**

   A current is a flow of charge. In a metal wire the charges are electrons, and they keep moving round the whole loop.

   - **If you chose A:** The bulb does not use up electrons. It changes energy into light and heat while the electrons keep going round. Go to S3.10.1.
   - **If you chose C:** The light is made in the bulb. The current is charge moving in the wire. Go to S3.10.1.

2. **0.2 A**

   The current is the same all round a series loop. The bulb does not use it up, so A2 reads 0.2 A.

   - **If you chose A:** You may think the bulb uses up half the current. It does not. The same current goes all round the loop. Go to S3.10.1.
   - **If you chose B:** If the bulb used it all up, no current would come back. But the same current goes all round the loop. Go to S3.10.1.

3. **In the loop, so the current goes through the ammeter.**

   An ammeter measures the current that goes through it. So it must be part of the loop.

   - **If you chose B:** That is how a voltmeter is joined. An ammeter must be in the loop, so the current goes through it. Go to S3.10.1.
   - **If you chose C:** The current is the same all round the loop, so the ammeter can go anywhere in it. It must be part of the loop. Go to S3.10.1.

4. **A, for amps.**

   Current is measured in amps, written A. An ammeter reads in amps.

   - **If you chose A:** Volts measure the push of a cell, which is the next chapter. An ammeter reads current. Go to S3.10.2.
   - **If you chose C:** Metres per second measure speed. Current is measured in amps. Go to S3.7.1.

5. **From the + end of the cell round the loop to the − end.**

   We draw the current from + round to −. The electrons drift the other way, but the sums come out the same.

   - **If you chose A:** Electrons do drift that way, but the drawing rule is the other way round, from + to −. Go to S3.10.1.
   - **If you chose B:** A cell pushes the current one way round the loop. It does not leave by both ends. Go to S3.10.1.

6. **0.25 A**

   The current is the same on each side of the bulb, so it also reads 0.25 A.

S3.10.2. Cells and voltage

1. **How hard it pushes the charges round the loop.**

   Voltage is the push, measured in volts. The current is the flow that the push makes.

   - **If you chose A:** A big cell and a small cell can both give 1.5 V. Voltage is the push, not the size. Go to S3.10.2.
   - **If you chose C:** That is the current, in amps. Voltage is the push that makes the current. Go to S3.10.1.

2. **6 V**

   Each cell adds 1.5 V. 4 × 1.5 = 6 V.

   - **If you chose A:** You may think the volts stay the same. Cells joined in a line add their volts. Go to S3.10.2.
   - **If you chose B:** You added the number of cells to the volts. Multiply the cells by the volts of each cell. Go to S3.10.2.
   - **If you chose C:** That is the number of cells, not the volts. Each cell adds 1.5 V. Go to S3.10.2.

3. **Circuit B**

   B has two cells, so a bigger push and a bigger current. A bigger current makes the bulb brighter.

   - **If you chose A:** You may think one cell is stronger. Two cells in a line add their push, so B has the bigger push. Go to S3.10.2.
   - **If you chose B:** The bulbs are the same, but the push is not. More push makes more current, and a brighter bulb. Go to S3.10.2.

4. **1.5 V**

   The cell is the same, so its push is still 1.5 V. The resistor changed, so the current changed, from 0.5 A to 0.25 A.

   - **If you chose B:** You halved the volts because the current fell. Voltage and current are not the same thing. The cell pushes as hard as before. Go to S3.10.2.
   - **If you chose C:** You doubled the volts because the resistor doubled. A bigger resistor slows the current, but it does not change the push of the cell. Go to S3.10.2.

5. **0.4 A**

   The current is the same all round the loop, so the second ammeter also reads 0.4 A.

   - **If you chose A:** You may think the bulb uses up half the current. It does not. The same current goes all round the loop. Go to S3.10.1.
   - **If you chose C:** If the bulb used it all up, none would come back. But the same current goes all round the loop. Go to S3.10.1.

6. **0 V, so the bulb stays dark**

   The turned cell pushes against the other one with the same strength, so the pushes cancel.

   - **If you chose A:** You added both cells. The turned cell pushes the other way, so it cancels the first. Go to S3.10.2.
   - **If you chose B:** Only one cell does not count. The turned cell works against the first, so they cancel. Go to S3.10.2.

7. **1.5 A**

   3 cells give 3 times the push, so 3 times the current. 3 × 0.5 = 1.5 A.

S3.10.3. Series and parallel circuits

1. **It goes out, because the loop is broken.**

   A series circuit is one loop. A bulb taken out leaves a gap, so the current stops everywhere.

   - **If you chose A:** That is how a parallel circuit works. In series there is only one path, and unscrewing a bulb breaks it. Go to S3.10.3.
   - **If you chose C:** With the loop broken, no current flows at all. In series every part is in the same loop. Go to S3.10.3.

2. **It stays lit at full brightness.**

   Bulb B is on its own branch, joined straight across the cell. It gets the full push, so it stays lit.

   - **If you chose A:** Only the branch with the open switch is broken. Bulb B is on its own branch, so the current still goes round it. Go to S3.10.3.
   - **If you chose B:** Each branch gets the full push from the cell. B does not share its push with A. Go to S3.10.3.

3. **0.8 A**

   Each branch takes 0.4 A. The cell gives 0.4 + 0.4 = 0.8 A.

   - **If you chose B:** You may have shared the current between the bulbs. Each branch takes its full current, and the cell gives the sum. Go to S3.10.3.
   - **If you chose C:** That is the current of one bulb. A second branch adds its current to it. Go to S3.10.3.

4. **So that each light gets the full push and can be switched off alone.**

   Each light is on its own branch across the supply. It gets the full push and works alone, even when others are off.

   - **If you chose A:** Parallel branches each take their own current, so the supply gives more in all. The reason is that each light works on its own. Go to S3.10.3.
   - **If you chose C:** Parallel needs a pair of wires to each branch. The reason is that each light works on its own, at full strength. Go to S3.10.3.

5. **Both are dimmer than one bulb alone, and they glow alike.**

   In series the two bulbs share the push, so each gets about half of it. The same current goes through both, so they glow alike, and less brightly than one bulb alone.

   - **If you chose A:** No bulb uses up the current. The same current goes through both bulbs in the loop, so they glow alike. Go to S3.10.1.
   - **If you chose B:** That is how bulbs in parallel glow. In series the two bulbs share the push of the cell, so each gets only part of it. Go to S3.10.3.

6. **3.6 V**

   Each cell adds 1.2 V. 3 × 1.2 = 3.6 V.

   - **If you chose B:** You may think volts do not add. Cells joined in a line add their volts. Go to S3.10.2.
   - **If you chose C:** You added the number of cells to the volts. Multiply the cells by the volts of each cell. Go to S3.10.2.

7. **0.3 A**

   The two resistors share the push, so the current is half. 0.6 ÷ 2 = 0.3 A.

S3.10.4. Resistance

1. **How much the part slows the current.**

   Resistance is how much a part slows the current, measured in ohms.

   - **If you chose A:** That is the voltage, in volts. Resistance is how much a part slows the current. Go to S3.10.2.
   - **If you chose B:** No part uses up the current. The same current goes all round a series loop. Go to S3.10.1.

2. **Wire C**

   A longer wire has more resistance, and so does a thinner wire. C is both long and thin.

   - **If you chose B:** A is short and thick, which gives the least resistance, not the most. Go to S3.10.4.
   - **If you chose C:** B is long, but it is as thick as A. The thin wire C is also long, so it slows the current more. Go to S3.10.4.

3. **The moving charges bump into the atoms of the metal and make them shake.**

   Energy goes from the moving charges to the atoms. The atoms shake more, so the wire warms. The energy goes to the thermal store.

   - **If you chose A:** The current is not used up. The same current goes all round the loop. Go to S3.10.1.
   - **If you chose C:** Wires joined to a buzzer or a motor warm up too, with no light at all. The warming comes from the charges bumping into the atoms. Go to S3.10.4.

4. **It gets dimmer, because a longer piece of lead has more resistance.**

   The longer the lead in the loop, the more the resistance. A bigger resistance gives a smaller current, so the bulb is dimmer.

   - **If you chose A:** More lead means more resistance, not less. More resistance slows the current. Go to S3.10.4.
   - **If you chose B:** Pencil lead is graphite, which has a high resistance. A longer piece slows the current more than a short one. Go to S3.10.4.

5. **0.5 A**

   The push is 2 × 1.5 = 3 V. The resistances add: 4 + 2 = 6 Ω. Current = 3 ÷ 6 = 0.5 A.

   - **If you chose B:** You used only the 4 Ω resistor. In one loop the resistances add, so both count: 4 + 2 = 6 Ω. Go to S3.10.4.
   - **If you chose C:** You multiplied the volts by the ohms. Divide instead: current = voltage ÷ resistance. Go to S3.10.4.

6. **1.5 A**

   Each of the 3 branches takes 0.5 A. 3 × 0.5 = 1.5 A.

   - **If you chose A:** That is the current for one bulb. Each branch takes its own current, and the cell gives the sum. Go to S3.10.3.
   - **If you chose C:** You shared the current between the bulbs. In parallel each branch gets the full push and takes its full current. Go to S3.10.3.

7. **0.5 A**

   Current = voltage ÷ resistance = 6 ÷ 12 = 0.5 A.

S3.10.5. Static electricity

1. **Electrons move from the wool to the comb.**

   Rubbing moves electrons. The comb gains them and becomes negative. The wool loses them and becomes positive.

   - **If you chose B:** Rubbing does not make charge. It moves electrons from one material to the other. Go to S3.10.5.
   - **If you chose C:** It is the other way round. The comb gains the electrons and becomes negative. Go to S3.10.5.

2. **They repel, because both are positive.**

   Each balloon has more plus marks than minus marks, so both are positive. Like charges repel.

   - **If you chose A:** Charged things do not always attract. Only unlike charges attract. Go to S3.10.5.
   - **If you chose C:** Any two charged things push or pull each other. Both of these have a charge. Go to S3.10.5.

3. **The comb pulls the opposite charges in the paper nearer, so the paper moves to it.**

   The charges in the paper shift. The unlike charges are nearer the comb, and a near pull beats a far push.

   - **If you chose A:** Paper is not magnetic. A magnet cannot lift paper. Go to S3.10.6.
   - **If you chose B:** Like charges repel. A paper bit that takes the comb's charge jumps off. Go to S3.10.5.

4. **A dry day, because dry air lets the charge stay on the comb.**

   In damp air the charge leaks away into the moisture. In dry air it stays on the comb.

   - **If you chose B:** Damp air lets the charge leak away. The comb loses its charge fast. Go to S3.10.5.
   - **If you chose C:** The weather matters. Moisture in the air takes charge away from the comb. Go to S3.10.5.

5. **They attract, because one is positive and one is negative.**

   The left balloon has more plus marks, so it is positive. The right balloon has more minus marks, so it is negative. Unlike charges attract.

   - **If you chose A:** Charged things only repel when their charges are alike. One of these is positive and the other is negative. Go to S3.10.5.
   - **If you chose C:** The marks cancel only inside one thing that has equal plus and minus. Each balloon here has more of one sign, so each has a charge. Go to S3.10.5.

6. **0.6 A**

   Current = voltage ÷ resistance = 9 ÷ 15 = 0.6 A.

   - **If you chose A:** You multiplied the voltage by the resistance. Divide instead: current = voltage ÷ resistance. Go to S3.10.4.
   - **If you chose B:** You added the voltage and the resistance. Divide the voltage by the resistance. Go to S3.10.4.

7. **4**

   7 − 3 = 4. The comb is negative.

S3.10.6. Magnetic fields

1. **From the N pole round to the S pole.**

   Outside a magnet the field lines run from the N pole round to the S pole.

   - **If you chose A:** It is the other way. Outside the magnet the lines leave the N pole and come into the S pole. Go to S3.10.6.
   - **If you chose C:** The lines curve round. Those that leave the N pole come back into the S pole. Go to S3.10.6.

2. **Near the poles, where the lines are closest together.**

   Field lines crowd together where the field is strong. They are closest near the poles.

   - **If you chose A:** Lines far apart mean a weak field. The field is strongest where the lines are closest. Go to S3.10.6.
   - **If you chose B:** The field gets weaker as you move away. The lines spread out, and the field falls. Go to S3.10.6.

3. **Towards the S end of the magnet.**

   The black end points the way the field line points. At P the line points into the S pole, so the needle points towards the S end.

   - **If you chose B:** The black end is a north pole, and a north pole is pulled towards a S pole. Go to S3.10.6.
   - **If you chose C:** The needle lines up with the field. At P the field points along the axis, not up the page. Go to S3.10.6.

4. **The Earth is like a huge magnet, and the needle lines up with its field.**

   The Earth acts like a huge magnet. A compass needle lines up with its field, so its black end points roughly north.

   - **If you chose A:** Ice is not magnetic. The needle lines up with the magnetic field of the whole Earth. Go to S3.10.6.
   - **If you chose C:** A compass points the same way at noon and at night, with no Sun in the sky. The Earth's own field turns the needle. Go to S3.10.6.

5. **Away from the magnet, along the field line.**

   Field lines leave the N pole, and the black end points the way the line points. To the left of the N pole, the line runs away from the magnet.

   - **If you chose A:** A north pole is pushed away by a N pole. The needle follows the field line, and near the N pole the lines point away from the magnet. Go to S3.10.6.
   - **If you chose B:** Close to a magnet, its field is far stronger than the field of the Earth. The needle lines up with the field of the magnet, not with the Earth. Go to S3.10.6.

6. **They attract, because one is negative and one is positive.**

   The comb has more minus marks, so it is negative. The wool has more plus marks, so it is positive. Unlike charges attract.

   - **If you chose B:** Charged things only repel when their charges are alike. Here one is negative and the other positive. Go to S3.10.5.
   - **If you chose C:** Any two charged things push or pull each other. Unlike charges attract. Go to S3.10.5.

S3.10.7. Electromagnets

1. **It loses nearly all of its magnetism.**

   The magnetism comes from the current. Switch it off and an iron core loses nearly all its magnetism, so the clips fall.

   - **If you chose A:** That is how a permanent magnet works. An iron core in a coil loses nearly all its magnetism when the current stops. Go to S3.10.7.
   - **If you chose B:** The poles swap when you turn the current round, not when you stop it. Go to S3.10.7.

2. **Wind more turns of wire round the nail.**

   More turns add more fields together. More cells would also help, because they give a bigger current.

   - **If you chose B:** The iron core makes the field much stronger. Without it the coil is weak. Go to S3.10.7.
   - **If you chose C:** Plastic does not become a magnet. Iron does, and that is why the nail makes the field stronger. Go to S3.10.7.

3. **3 clips**

   The table gives 20 turns and one cell as 3 clips. More turns help, but clip counts are rough, so they do not grow exactly in step.

   - **If you chose A:** More turns give a stronger magnet, so it holds more clips than before. Go to S3.10.7.
   - **If you chose C:** That doubles the clips exactly. Clip counts are rough, so read the table. It gives 3. Go to S3.10.7.

4. **The nail becomes a magnet in the field of the coil, so the whole thing is stronger.**

   Iron becomes a magnet when it is in a field. Its field adds to the coil's, so the electromagnet is much stronger.

   - **If you chose A:** The current flows in the wire. The nail does not carry it. The nail becomes a magnet and makes the field stronger. Go to S3.10.7.
   - **If you chose B:** It does more than that. The iron adds its own field to the coil's, which makes the electromagnet much stronger. Go to S3.10.7.

5. **Away from the magnet.**

   Field lines leave the N pole. At Q the field points away from the magnet, so the black end does too.

   - **If you chose B:** Field lines leave the N pole. At Q the line points away from the magnet, and the needle points that way. Go to S3.10.6.
   - **If you chose C:** The needle lines up with the field. At Q the field points along the axis, not up the page. Go to S3.10.6.

6. **Join it for a few seconds, count the clips, then let go.**

   The wire and the cell can get hot. A few seconds is enough to count the clips.

   - **If you chose A:** The wire and the cell get hot. Connect for only a few seconds, then let go. Go to S3.10.7.
   - **If you chose C:** Taped on, the current keeps flowing. The wire and the cell get hot and the cell goes flat. Join it only while you count. Go to S3.10.7.

S3.10.8. Electricity safety at home

1. **Wet skin lets much more current pass through the body.**

   Water on the skin lowers its resistance. With the same voltage, a lower resistance means a bigger current.

   - **If you chose B:** The voltage of the mains stays the same. It is the resistance of your body that falls when your skin is wet. Go to S3.10.4.
   - **If you chose C:** Pure water is a poor conductor. The water we use has things dissolved in it, and they carry the current. Go to S3.10.8.

2. **Its thin wire melts and breaks the circuit.**

   The fuse wire is thin, so it gets hot first and melts. The circuit is broken before the other wires get dangerously hot.

   - **If you chose A:** A fuse cannot make the current smaller. Its wire melts and stops the current. Go to S3.10.8.
   - **If you chose C:** A melted fuse wire stays broken. It must be replaced. A circuit breaker is the part you can switch back on. Go to S3.10.8.

3. **7 A, so the fuse blows**

   The currents add up: 3 + 4 = 7 A. That is more than 5 A, so the fuse melts.

   - **If you chose A:** You took the larger current only. In parallel the currents add, so both appliances count. Go to S3.10.3.
   - **If you chose B:** You multiplied the currents. In parallel the currents add up. Add them. Go to S3.10.3.

4. **Let go, move far away and tell an adult.**

   A power line is at a very high voltage. Never touch it, the string, or anything that touches it. Keep away and tell an adult.

   - **If you chose B:** The string may carry electricity from the line. Never touch it. Let go and move away. Go to S3.10.8.
   - **If you chose C:** Never go near a power line. The current can jump and can kill. Leave the kite and tell an adult. Go to S3.10.8.

5. **No. Use one appliance at a time. Ask an adult to fit a new fuse of the same size.**

   The fuse blows because the heater and kettle together take too much current. One appliance at a time cuts the current. A new fuse must be the same size, so it still melts before the wires get hot. A thick wire would let the wires overheat.

   - **If you chose A:** The fuse is thin on purpose. With a thick wire nothing melts. The wires in the walls can get hot and start a fire. Go to S3.10.8.
   - **If you chose C:** The other wires are made for a smaller current than the heater and kettle take together. Without the fuse they overheat. Go to S3.10.8.

6. **0.4 A**

   Current = voltage ÷ resistance = 8 ÷ 20 = 0.4 A.

   - **If you chose A:** You multiplied the voltage by the resistance. Divide the voltage by the resistance. Go to S3.10.4.
   - **If you chose B:** You added the voltage and the resistance. Divide the voltage by the resistance. Go to S3.10.4.

7. **6 A**

   The currents add up in parallel. 1 + 5 = 6 A.

About this book

For learners who can draw a circuit with symbols and do sums with the four operations. In many schools this fits children of about 11 to 13, and older learners can use it too. Activities use one or two small torch cells (1.5 V), a small torch bulb, foil or wire, a pencil, a plastic comb, paper, a magnet, a compass or a needle, an iron nail and thin insulated wire. Connect cells for only a few seconds, because wires and cells can get warm. No activity uses mains electricity, a car battery or a phone charger, and the last

chapter has no hands-on electricity at all. A learner can work alone: every exercise has its answer and the reason for it.

Written and drawn by attnom. Edition 1.0, 2026-11-12.

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