Welcome

Welcome to the BBC Learning and the Royal Institution Christmas Lectures Teacher’s Pack.

The Ri Christmas Lectures have been entertaining and educating children and adults alike since 1825 and have been an inspirational force for many budding scientists.

The 2010 Christmas Lectures were given by Dr Mark Miodownik, a materials scientist from King’s College London. He explored the extraordinary world of size and scale in a three-part lecture series called Size Matters. The three lectures – Why elephants can’t dance, Why chocolate melts and jet planes don’t and Why mountains are so small – were screened on BBC Four in December 2010.

“I am a very lucky person, I have my own lab and get to do experiments every day. It is these experiments that continually renew my love of materials science, which is my research area. New materials have revolutionised modern technology and in so doing have enriched all our lives.

When the Royal Institution and the BBC gave me the opportunity to present the Ri Christmas Lectures, I knew that above all, I wanted to recreate that delightful feeling of being in a laboratory and exploring how the world is made. I focused on scale because that is a key principle to understanding materials.

I hope these lesson plans help in sparking the curiosity and imagination of a new generation of materials scientists.”

Dr Mark Miodownik
About this pack

Purpose of the pack
We’ve designed this pack to work alongside the Ri Christmas Lectures which returned to the BBC in 2010. It features lesson plans created around themes from the lectures, tailor-made classroom resources and includes specific curriculum and learning links.

The resource has been designed by BBC Learning in collaboration with the Royal Institution and science education experts to:

— make it easy for teachers to deliver demonstration-packed science lessons themed around the lectures;

— encourage students to discover the extraordinary world of size and scale;

— inspire students to develop a life-long interest in science and engineering;

— work across the different curricula, syllabuses and exam boards in England, Scotland, Wales and Northern Ireland.

Further copies and a Welsh language version of this pack, as well as clips featured on the accompanying DVD, are available from bbc.co.uk/teachers/christmaslectures

How to use this pack
We have designed the material in this pack to be as flexible and adaptable as possible. There are 11 lesson plans and each of these has been devised to fit approximately within a 60-minute lesson. However, we understand that you will probably want to adapt the content to suit your learning priorities and the needs of your particular class. In addition, each lesson plan states for which age group it is appropriate, and in many cases has extension ideas that are more involved and suitable for further study.

The lesson plans have been designed to enable you to pick and choose topics that fit within your own scheme of work so that you can use this resource according to your own requirements. The learning objectives are deliberately broad to allow for the different curricular requirements across the UK.

Where relevant, worksheets have been produced to sit alongside the lesson plans and are designed to be easily photocopied so that they can be distributed to the whole class.

Health and safety
Please be aware that some of the video clips included on the DVD contain behaviour that could be imitated and is dangerous. Please always make it clear to your students that they should not, under any circumstances, attempt to imitate any of the experiments carried out in the films unless told to do so in class with proper supervision.
## Lesson plans

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Does size matter when falling?

You will need
— Clip 1 (2’39")
— Clip 2 (3’54")
— Clip 3 (7’56")
— Clip 4 (1’33")
— Making crash test animals activity
  – Worksheet (p. 6)
  – Balloons of different sizes
  – Warm water
  – Jelly
  – Large syringes and rubber tubing
  – Permanent markers
  – Buckets
— Paper helicopters activity
  – Worksheets (p. 7 and 8)
  – A4 paper
  – Scissors
  – Paperclips

Technician’s notes
— Jelly should be made as per the manufacturer’s instructions (usually one pack per approximately 568cm³/one pint of warm water) and cooled until solid at 4ºC. Cool the jelly animals in buckets of water to keep them spherical.
— The balloons can be difficult to fill with jelly. A large syringe and a short length of rubber tubing are useful for this.
— Dependent upon their size, the jelly animals will take several hours to set so they will need to be prepared in advance or the activity split into two sessions.
— Jelly animals should be dropped from a second-storey window or higher.

Suitable for: 11–16

Curriculum and learning links:
Adaptation and evolution, forces and gravity

Learning objectives:
— Investigate how volume and surface area affect falling objects.
— Explain why smaller objects have a higher surface area to volume ratio.

Health and safety
— It is the responsibility of the teacher conducting this lesson to carry out a full risk assessment.
— Normal laboratory rules apply.
— Large balloons filled with jelly are very heavy.
— Care must be taken when dropping jelly animals.

Above: Jelly, balloons and jelly animals.
Opening activity
1. Ask students if they think that size matters when falling.
2. Ask if any animals could survive a fall from the world’s tallest building.
3. Watch Clip 1.

Development activities
4. Give students the Making crash test animals worksheet.
5. Ask students to make both one small and one large jelly animal (5cm and 25cm diameters), or make an animal in a range of diameters between 5cm and 25cm. Please note, this can be a time-consuming and messy process. Teachers might like to have larger balloons prepared in advance and demonstrate the following activity rather than complete it as a class practical.
6. Animals can be decorated using permanent markers after being cooled at 4°C to allow the jelly to set. (This may take several hours – remember to set balloons in buckets of water to maintain a spherical shape.) Once set, the jelly animals can be dropped from a high safe point in your school to show that size does affect impact.

Students could film or photograph the impacts.
7. Watch Clip 2 to review.
8. Ask students why only the smaller jelly animals survived.
9. Watch Clip 3 for an explanation: doubling the diameter of a sphere increases the volume and so weight by eight times, but the surface area only increases by a factor of four.

More able students could use \( \frac{4}{3}\pi r^3 \) and \( 4\pi r^2 \) to calculate volume and surface area (respectively) of spheres with varying diameters.

10. Ask students if any other factors might affect whether an animal survives a fall.

   Explain that objects of the same mass but with a reduced surface area have a higher terminal velocity because of their lower air resistance and so hit the ground more quickly. This can be shown by simultaneously dropping two sheets of A4 paper: one flat and one folded a few times along its length and dropped lengthwise.

11. Ask students to relate this idea to dropping jelly animals of different sizes.

12. Watch Clip 4 to review.

Reflect and review
— Ask students to summarise how volume and surface area affect impacts using their findings from the experiment.
— Ask students to evaluate the reliability and validity of their experiment. They might correctly suggest that animals with larger volumes have a thinner covering of balloon latex and so might be more likely to split.

Want to explore further?
The effect of surface area on acceleration due to gravity can be investigated further by completing a practical activity making paper helicopters of different surface areas. Use the Paper helicopters worksheet to do this.
Making crash test animals

Follow these instructions to make crash test animal models out of balloons filled with jelly.

You will need
- Balloons of different sizes
- Warm water
- Jelly
- Large syringes and rubber tubing
- Permanent markers

Method
1. Identify the diameter of the animal that you are going to make from the table below.
2. Use the table below to determine the appropriate volume of warm water and number of packs of jelly you will need (one pack per 568cm³ of warm water).
3. Make the jelly solution by dissolving it in warm water.
4. Use the syringe and tubing to force the jelly solution into the balloon and seal.
5. Leave your jelly animal to cool until the jelly has set (ideally in a refrigerator), keeping it in a bucket of cold water to maintain its spherical shape. A bucket of iced water would be an alternative if there is insufficient space in the refrigerator.
6. Decorate your crash test animal using a permanent marker.

<table>
<thead>
<tr>
<th>Diameter of animal (cm)</th>
<th>Volume of animal (cm³)</th>
<th>Packs of jelly needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>65</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>523</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>1,766</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>4,187</td>
<td>8</td>
</tr>
<tr>
<td>25</td>
<td>8,177</td>
<td>15</td>
</tr>
</tbody>
</table>
Paper helicopters

Use the template to make a paper helicopter with wings of 10cm length and 3cm width. Fold up the bottom 2cm of the helicopter and fix a paperclip as shown. Drop it three times from the same height (perhaps 1.5 metres) and time how long it takes to fall to the floor. Enter your results into table 1 below.

Make a second helicopter in which you have changed the area of the wings by either altering the length or the width. Record the new wing area on the dotted line above table 2. Drop this helicopter three times and record the time taken to fall to the floor. Compare your results and write a conclusion.

### Results table 1 (wing area: 60cm²)

<table>
<thead>
<tr>
<th>Time 1 (s)</th>
<th>Time 2 (s)</th>
<th>Time 3 (s)</th>
<th>Average time (s)</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
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</tbody>
</table>

### Results table 2 (wing area: ............ cm²)

<table>
<thead>
<tr>
<th>Time 1 (s)</th>
<th>Time 2 (s)</th>
<th>Time 3 (s)</th>
<th>Average time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

### Conclusion:

You might also like to investigate what happens when you change the number of paperclips you attach.
Lesson 1: Worksheet

Paper helicopter template

1. Cut out shape along solid straight lines

2. Fold one wing forward and the other backwards along the dashed line

3. Fold upwards along the dashed line and attach a paperclip
You will need

— Clip 5 (‘1'05”)

— Cooling down activity
  — Worksheets (p. 11 and 12)
  — Aluminium drinks cans of various shapes and sizes, including some that are very small or tall and thin
  — Hot water from a kettle at approximately 90°C
  — Thermometers or data loggers with temperature probes
  — Timers or stopwatches
  — Beaker or measuring jug
  — Tape measure

— Adaptations extension activity
  — Insulation material (e.g. sheets of bubble wrap or felt)
  — Aluminium foil
  — Adhesive tape

Technician’s notes

— Cans should be rinsed before use.
— Larger cans are ideal shapes for large animals with a proportionately small surface area.
— Cans that contain a widget to increase the size of a beer’s head should be avoided.
— Tall, thin cans used to contain caffeinated soft drinks have a relatively high surface area.
— Small cans of the size sold on aeroplanes and trains have a relatively high surface area.

Suitable for: 11–14

Curriculum and learning links:
Heat transfers, adaptation and evolution

Learning objectives:
— State that a smaller animal has a proportionately larger surface area.
— Describe the evolutionary adaptations that small and large animals possess to help them keep warm and cool down, respectively.
— Calculate the volume and surface area of different cylinders and hence calculate the surface area to volume ratio.

Health and safety

— It is the responsibility of the teacher conducting this lesson to carry out a full risk assessment.
— Normal laboratory rules apply.
— It is recommended that students do not try to fill their aluminium cans with water poured straight from the kettle. They should be encouraged to fill a beaker or kitchen measuring jug first and then pour the water carefully into their can. If they are using a beaker, it can be helpful to insulate their fingers using 2cm lengths of rubber tubing (of the kind used on gas taps) that have been carefully cut once down their length. These so-called ‘rubber fingers’ clip on to students’ fingers to insulate them.
**Opening activity**

1. Watch Clip 5 in which Mark describes feeling very cold as a small boy compared with his larger brothers.
2. Explain to students that they will be doing an experiment to find out how body size affects the speed at which a warm animal might cool down.

**Development activities**

3. Ask students to work in pairs or small groups to discuss ideas for how they might investigate how the size of an animal affects how quickly it cools down.

Pull together ideas and prompt them using questions about validity, reliability, and accuracy.

Explain that they will be using aluminium drinks cans as the ‘bodies’ of their animals and they will be carefully filling them with hot water.

A suggested method is on the **Cooling down** worksheet. Some students may need help with calculating the surface area and approximate volume of their cans. Students can either enter their data into the table, or plot their data on a graph in real time. Students can then repeat their experiment using a can of a different size and shape.

**Reflect and review**

— Encourage students to compare the data they have collected using cans of different sizes, shapes and hence surface area to volume ratio.

— Ask students whether their data support Mark’s comments about smaller children cooling down more quickly.

— What criticisms can students make of their method?

— How could they have tried to keep the volume of water the same?

— Ask students to work out the surface area of three cans that have the same volume (500cm³) if one has a diameter of 2cm (SA = 1,006 cm²), one has a diameter of 10cm (SA = 357 cm²) and the third has a diameter of 50cm (SA = 3,967 cm²).

— Which of these would cool the most quickly and which the most slowly?

— Ask students to explain how large animals, such as elephants, have adapted to live in hot habitats and how they effectively lose heat.

— What does this tell you about the ideal shape for a small animal living in a cold environment which needs to prevent itself from cooling?

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**Want to explore further?**

Students could be encouraged to investigate adaptations by insulating their cans or by creating ‘elephant ears’ for their cans from aluminium foil. The challenge when making ears is to ensure that there is sufficient contact area between the can surface and the aluminium foil to allow for effective thermal transfer by conduction.

A mathematical challenge could involve working out the dimensions of a cylinder of a given volume (e.g. 500cm³) that has the smallest surface area to volume ratio.
Cooling down

You will need
— 2 or 3 drinks cans of different sizes
— Hot water from a recently boiled kettle
— Thermometer
— Timer or stopwatch
— Measuring jug/beaker
— Tape measure
— Cooling down results sheet

Calculating the volume and surface area of your can:
These calculations assume that your can is a perfect cylinder.
1. Measure the diameter of your can in centimetres.
2. Divide the diameter of your can by 2 to work out the radius, r, of your can.
3. Measure the height, h, of your can in centimetres.

Volume of can (cm³) = πr²h
Surface area of can (cm²) = (2πrh) + (2πr²)

Now calculate the surface area to volume ratio:
Surface area to volume ratio (cm⁻¹) = \frac{\text{surface area}}{\text{volume}}

Method
1. Calculate the surface area and volume of can 1.
2. Calculate the surface area to volume ratio for can 1.
3. Fill a measuring jug or beaker with hot water from a recently boiled kettle.
4. Carefully pour this hot water into can 1 and fill it to the very top.
5. Record the temperature of the water in the middle of can 1 on the Cooling down results sheet and start the timer.
6. Each minute for a further ten minutes, record the temperature of the water.
7. Select can 2 with a different size and shape.
8. Calculate the volume and surface area of can 2.
9. Calculate the surface area to volume ratio of can 2.
10. Repeat the experiment using can 2.
11. Plot the data from both cans onto the same graph, with time on the x axis and temperature on the y axis.
12. Repeat with can 3 if you have enough time.
Results

Record your data into two tables like these:

<table>
<thead>
<tr>
<th></th>
<th>Can 1</th>
<th>Can 2</th>
<th>Can 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (cm)</td>
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<td></td>
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<tr>
<td>Radius (cm)</td>
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<td></td>
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<tr>
<td>Height (cm)</td>
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<td></td>
</tr>
<tr>
<td>Volume (cm³)</td>
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<td></td>
<td></td>
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<tr>
<td>Surface area (cm²)</td>
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<tr>
<td>Surface area to volume ratio (cm⁻¹)</td>
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Water temperature (°C)

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Can 1</th>
<th>Can 2</th>
<th>Can 3</th>
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Conclusion

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How can geckos climb up windows?

You will need

- Clip 6 (2'56")
- Clip 7 (1'16")
- Clip 8 (2'53")
- Clip 9 (2'47")
- Clip 10 (1'51")
- Clip 11 (2'53")
- Access to the internet
- Two thick paperback books or catalogues
- Friction investigation
  - Ramps covered with coarse sandpaper
  - Wooden blocks of different sizes covered on one side with course sandpaper (to support masses as they are dragged down the ramp)
  - Masses
  - Newton meters
- Close-up of surfaces activity
  - Worksheet (p. 15)

Technician’s notes

- Newton meters will need to be the type that students hold, not stand on.
- Wooden blocks covered with sandpaper should range from 4cm by 4cm up to 20cm by 20cm increasing in 1cm increments.

Key to close-up of surfaces worksheet

1. Frost on glass
2. Rusty metal
3. Vinyl record
4. Carbon fibre
5. Wood
6. Bacteria on a pinhead
7. Geckos’ feet
8. Tissue paper

Suitable for: 11–16

Curriculum and learning links:
Adaptation and evolution, forces and friction

Learning objectives:
- Investigate the relationship between surface area and friction.
- Explain why giant geckos wouldn’t be able to climb up walls.

Health and safety
- It is the responsibility of the teacher conducting this lesson to carry out a full risk assessment.
- Normal laboratory rules apply.
- Care must be taken if using large masses.

Opening activity

2. Ask students to vote for the option they think is the most likely explanation for the adhesiveness of geckos’ feet and to come up with reasons for their choice.
Development activities
3. Show Clip 7 to explain the structure of geckos’ feet.
4. Ask students to research this using the internet. Many images can be found at www.sciencephoto.com and videos are available from the BBC Wildlife Finder at bbc.co.uk/nature.
5. Ask students to interlace the pages of two thick paperback books or catalogues and challenge them to pull them apart.
6. Watch Clip 8 to see students at the Ri lectures doing the same on a larger scale.
7. Ask students to explain why they are unable to separate the books.
8. Watch Clip 9 for the explanation.
9. Ask students to plan and carry out an investigation into friction using ramps covered with coarse sandpaper and a fixed mass spread over different areas of wooden block, also covered with coarse sandpaper. The sandpaper on the wooden blocks should be in contact with the sandpaper on the ramp.

The dependent variable (measured by dragging the mass down the ramp using a newton meter) is the force needed to pull the mass down the ramp. The independent variable is the area over which the mass is in contact with the ramp.

Reflect and review
— Ask students to summarise how surface area affects friction using their findings from the experiment.
— Ensure that your students evaluate the reliability and validity of their experiment. They should name the variables that they controlled (e.g. angle of ramp, mass).
— Review with students that increasing the surface area in both the paperback book and ramp activities increases friction, and link this to the structure of geckos’ feet.

Want to explore further?
— Ask students why sticky tack can be reused but adhesive tape cannot.
— Watch Clip 10 to show that sticky tack works in the same way as geckos’ feet.
— Ask students to explain this in their own words.
— To extend the idea of surface area to volume ratio limiting the size of organisms, ask students to research what adaptations mammals have to enable them to grow bigger than, for example, insects (e.g. lungs, double circulatory system).
— Watch Clip 11 for a practical demonstration of the surface area of human lungs.
— Give students the Close-up of surfaces worksheet and ask them to identify the pictures. They could use the internet for this.
Close-up of surfaces
Surface area and fireworks

You will need

— Clip 12 (2’35")
— Clip 13 (0’57")

— **Fireworks demonstration**
  - Metal powders: iron, magnesium, copper, aluminium
  - Turkey baster
  - Milk powder

— **Flame test activity**
  - Splints
  - Labelled solid samples of NaCl, Li₂CO₃, KCl, anhydrous CuSO₄, Sr(NO₃)₂ or SrCl₂, BaCl₂
  - The same compounds in Petri dishes labelled with letters only, e.g. A, B, C, D, etc.

— **Flame test demonstration**
  - Several pump-action plant mister bottles
  - Solid compounds as above
  - Ethanol, industrial methylated spirits, or industrial denatured alcohol

**Technician’s notes**

— To make the squirty flame test bottles, add a very small spatula of a soluble compound (NaCl, LiCl, KCl, CuSO₄, Sr(NO₃)₂, BaCl₂) to a clean plant mister bottle and dissolve it in a very small amount of distilled water. Now add sufficient ethanol (or colourless methylated spirits) to half-fill the bottle. Label with the identity of the metal ion and a flammable hazard sticker.

— The milk powder for the demonstration should be fine but non-clumping. Trial and error will allow you to identify the best product. For details of the instructions, hints and tips you can see a video clip on the Royal Society of Chemistry website www.rsc.org. For details of the weblink please see links and resources on page 44.

**Suitable for:** 14–16

**Curriculum and learning links:**
Rates of reaction, alkali metals and flame tests

**Learning objectives:**

— Describe how to perform a flame test to identify metal ions in mystery compounds.

— Explain why powders react more quickly than lumps using ideas about collisions between particles.

**Health and safety**

— It is the responsibility of the teacher conducting this lesson to carry out a full risk assessment.

— Normal laboratory rules apply.

— Powdered metals are highly flammable and if ignited in a flame may burn uncontrollably. Very small quantities should be used and a bucket of sand may be needed to extinguish a resulting fire.

— When using the plant mister bottles, remember that the carrier liquid is ethanol. Any unburnt ethanol will settle on the surfaces behind the Bunsen flame (e.g. laboratory bench) and may therefore pose a fire risk.
Opening activity
1. Ask students to suggest the most dangerous thing that you can do with custard powder (see point 5 below).
2. What metals can they think of that burn?
3. Watch Clip 12 in which Mark demonstrates that iron powder is flammable but a solid iron bar is not.
4. Repeat this demonstration by gently blowing small quantities of metal powders (e.g. Fe, Mg, Cu, Al) into a blue Bunsen flame. Using a turkey baster is a safe and effective way of doing this.
5. Demonstrate the effect of increasing surface area on reaction rate, and the combustibility of flammable powders by sprinkling milk powder onto a flame. A small pile of milk powder on a heat-proof mat will not ignite with a blue Bunsen flame. However, when the milk powder is sprinkled over a horizontally clamped burning splint, a huge fireball is created, in proportion to the height from which the powder is sprinkled. There is an instructional video clip for teachers on the Royal Society of Chemistry website (see Technician’s notes).

Development activities
6. Watch Clip 13 in which Mark explains why the powdered iron reacts faster than the iron bar. He finishes by briefly discussing fireworks, which is the context of the main activity.
7. Demonstrate to students how to perform a flame test on solid samples. The simplest method involves dipping the end of a splint into some distilled water to moisten it slightly, picking up a very small number of crystals on the very tip of the splint, and then bringing the end of the splint towards a blue Bunsen flame until a coloured flare is seen. The splint should not ignite. The end of the splint can then be snapped off before testing the next compound.
   Note that potassium gives a very pale purple colour which is often obscured by the intense orange from sodium impurities and sodium compounds in the splint. The concluding demonstration gives a more reliable result for potassium.
8. After students have tested the labelled compounds and linked a colour with a particular ion, they can then test the ‘mystery’ compounds.

Reflect and review
— Review the identity of the ‘mystery’ compounds and discuss the limitations of the method (e.g. risk of contamination and similar flame colours of lithium and strontium compounds).
— Spray the squirty bottles of metal ion solutions through a Bunsen flame in a darkened laboratory.
— Ask students to identify the metal ion present in each one.
— Challenge students to use their new knowledge and understanding to design a rocket firework, including the sequence of colours that it will display as it launches and explodes.

Want to explore further?
Outline the use of atomic emission spectroscopy and its role in analytical chemistry and the discovery of helium.
Lesson 5

How strong is Velcro?

You will need

— Clip 14 (1'48")
— Clip 15 (3'01")
— Clip 16 (3'15")
— Demonstration
  — Two 10cm x 10cm pads of Velcro attached to wood/hardboard with handles on
— How strong is Velcro? activity
  — Worksheet (p. 20)
  — Mass holders
  — Masses
  — Clamps
  — Velcro pads of different sizes stuck to wood/hardboard strips with attachments to suspend masses (see bottom image on right)

Technician’s notes

— Sticky Velcro pads are easily attachable to wood or hardboard. No additional glue is needed.
— Velcro pads stuck to wood/hardboard should range in size between 1cm² and 10cm².
— Handles must be securely attached to the wood/hardboard to which the 100cm² Velcro pads are stuck. If screws are used to fix handles, they must be countersunk if Velcro is stuck over them.

Health and safety

— It is the responsibility of the teacher conducting this lesson to carry out a full risk assessment.
— Normal laboratory rules apply.
— Care must be taken if using large masses.

Suitable for: 11–16

Curriculum and learning links:
Forces and gravity, mass and weight, designer polymers

Learning objectives:
— Explain how Velcro works.
— Investigate the relationship between area of Velcro and mass needed to pull it apart.

Above: Equipment needed to investigate the strength of Velcro (including Velcro stuck to wood/hardboard lengths of different sizes).

Above: A close-up of Velcro stuck to wood/hardboard lengths of different sizes.
Opening activity
1. Watch Clip 14 which introduces how the design of Velcro came from studying plant burrs. Students could be told that this walk in the countryside inspired a new invention. They are very familiar with this product in their everyday lives. Can they guess what it is?
2. Watch Clip 15 to see if they are right.

Development activities
3. Challenge two students to pull apart the 100cm² Velcro pads stuck to wood/hardboard squares. (This should be impossible.)
4. Ask students to use the How strong is Velcro? worksheet to determine the mass needed to pull apart different areas of Velcro.
5. Ask students to determine the relationship between mass (or force) and area, and then write a conclusion.
6. Ask students whether Velcro would be as effective if it were scaled up in size, as opposed to a larger area used.
7. Watch Clip 16 which proves that scaling up Velcro isn’t as effective (elasticity is lost and so unhooking can’t occur).

Reflect and review
- Ask students to share and discuss their conclusions from the experiment. As a part of this, they should evaluate the reliability and validity of their experiment.

Want to explore further?
Students can research silent Velcro (called Slidingly Engaging Fastener) as mentioned by Mark in Clip 17. Students can also investigate whether there is a difference in the mass needed to pull Velcro apart when it is peeled (weak force needed) or sheared (greater force needed).
**How strong is Velcro?**

Follow these instructions to investigate the relationship between the area of Velcro and the mass needed to pull it apart.

**You will need**
- Mass holders
- Masses
- Clamps
- Velcro pads of different sizes stuck to wooden squares with attachments to suspend masses

**Method**
1. Set up the apparatus as shown in the diagram with one area of Velcro pad. Your teacher will advise you if you need to protect the bench below the hanging masses.
2. Gradually add masses to the hook on the bottom of the Velcro until it is pulled apart.
3. Record this mass in the results table below.
4. Repeat using a different size of Velcro pad.

**Results**
Record your data below

<table>
<thead>
<tr>
<th>Size of Velcro pad (cm²)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

**Conclusion**

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You will need
— Clip 17 (4’52”)
— Egg impact activity
  — Worksheet (p. 23)
  — Bubble wrap or foam (to model airbag)
  — Metre rulers
  — Eggs
  — Trays to collect mess
— Marble impact activity
  — Worksheet (p. 24)
  — Marbles
  — Sheets of modelling clay
  — Blocks of wood, polystyrene and foam that are the same size as each other and the same size as the sheets of modelling clay
— Car safety features extension activity
  — Ramp and trolleys
  — Waste material (small boxes, paper, bubble wrap, etc.)
  — Eggs

Technician’s notes
— Modelling clay needs to be warmed before being used to see suitable crater depths.

Suitable for: 14–16

Curriculum and learning links:
Forces and gravity, energy transfers, car safety features

Learning objectives:
— Know how accelerometers are used in smart phones and car safety features.
— Understand why airbags, seatbelts and crumple zones help to prevent injuries.
— Investigate the relationship between collision time and force of impact.

Health and safety
— It is the responsibility of the teacher conducting this lesson to carry out a full risk assessment.
— Normal laboratory rules apply.
— Hands must be washed after handling raw eggs.
— Care must be taken when dropping objects from heights.
Opening activity
1. Ask students to list car safety features.
2. Challenge students to identify links between airbags and smart phones (both use accelerometers).

Development activities
3. Watch Clip 17 which explains how accelerometers are used in smart phones and to deploy airbags.
4. Ask students to explain the link in their own words.
5. Ask students to explain how airbags, seatbelts and crumple zones work. Draw out that they all reduce the force of impact by increasing the time taken for the passenger to come to rest (i.e. dissipate the kinetic energy). The link between kinetic energy and energy transferred (work done) can be made here if appropriate.
6. Ask students to complete one of the two practical activities using either the Egg impact worksheet or the Marble impact worksheet.

Reflect and review
— Ask students to summarise the relationship between collision time and force of impact using their findings from the experiment. As a part of this, they should evaluate the reliability and validity of their experiment.
— Ask students how diving into water and stuntmen falling from great heights onto cardboard boxes relate to this lesson (the same principle applies: increased deceleration time).

Want to explore further?
— Students could complete a practical activity in which they use a variety of waste material (small boxes, paper, bubble wrap, etc.) to make a container to stop an egg cracking when dropped from a large height (perhaps a second-storey window).
— Students could also build crumple zones and airbags to protect an egg placed in a ‘car’ made from a shoebox on a trolley rolling down a ramp.
— Students could be challenged to devise a method of measuring the depth of the marble impact crater.
Lesson 6: Worksheet

Egg impact

Follow these instructions to investigate the minimum height from which you can drop an egg without breaking it. You will complete the experiment twice, once with a model airbag and once without.

You will need
— Bubble wrap or foam (to model airbag)
— Metre rulers
— Eggs
— Trays to collect mess

Method
1. Set up the apparatus as shown in the diagram with one area of bubble wrap or foam.
2. Start by dropping the egg from a very low height.
3. Increase the height by small amounts each time until the egg breaks.
4. Repeat the experiment without bubble wrap or foam.
5. Record your results below.

Results
The minimum height for the egg to break with the ‘airbag’ was _____ cm.
The minimum height for the egg to break without the ‘airbag’ was _____ cm.

Conclusion

What is the link between this experiment and car safety features?


Marble impact

Follow these instructions to investigate how depth of impact is affected by using different types of material placed underneath a piece of modelling clay.

You will need
— Modelling clay
— Same-sized blocks of wood, polystyrene and foam
— Metre ruler
— Marble

Method
1. Set up the apparatus as shown placing a block of polystyrene underneath the modelling clay.
2. Drop the marble from a suitable height onto the modelling clay.
3. Repeat the experiment using the foam block and the wooden block underneath the modelling clay.
4. Compare the depth of the marble imprint.

Results

Conclusion

What is the link between this experiment and car safety features?
Lesson 7

Invisibility cloaks

You will need

— Clip 18 (2'04")
— Clip 19 (2'21")
— Clip 20 (2'52")
— Demonstrations
  — Small toy car
  — Sand
  — Water pearls (clear)
  — Large beaker and water trough
  — Vegetable oil (approximately 1.5 litres)
  — Two different sized Pyrex (borosilicate glass) beakers
— Refracting light activity
  — Worksheet (p. 28)
  — Light boxes with slits
  — Power packs
  — Rectangular glass blocks
  — Protractors
  — Rulers
  — White A4 paper
— Reflection and refraction activity
  — Worksheet (p. 29)
  — Light boxes with slits
  — Power packs
  — Semicircular glass blocks
  — Protractors
  — Rulers
  — White A4 paper

Suitable for: 11–14

Curriculum and learning links:
Refraction of light

Learning objectives:
— Describe how light changes direction at the boundary between two different substances.
— Explain why this happens.

Health and safety
— It is the responsibility of the teacher conducting this lesson to carry out a full risk assessment.
— Normal laboratory rules apply.

Technician’s notes
— As in Clip 18, the water pearl ball demonstration works best when transferring the balls from a smaller vessel to a larger one.
— Water pearls are frequently used in floral displays and can be easily purchased online at minimal cost.
— The refraction experiment detailed on page 28 can be completed using gelatin blocks cut to have smooth, flat surfaces and a laser pen. Gelatin should be made according to the instructions supplied with the powder.
Opening activity
1. Watch Clip 18 which introduces refraction and refractive indices in the context of an invisibility cloak.

Development activities
2. Complete the practical following the Refracting light worksheet.
   Use the analogy of a car diagonally hitting a sand trap to illustrate refraction of light (see Information sheet on p. 27).
3. Ask students how refraction could help make an invisibility cloak.
   Complete the water pearl ball demonstration or watch Clip 19.
4. Ask students to explain why the pearl balls appear invisible (they have the same refractive index as water meaning no refraction occurs).
5. Ask students why this would not work as an invisibility cloak (light would need to be bent around something that isn’t transparent).
6. Watch Clip 20 which introduces the novel technology behind microwave invisibility shields.

Reflect and review
— Fill a large Pyrex beaker with vegetable oil. Slowly immerse a second smaller Pyrex beaker into the first. The second beaker will ‘disappear’ because the refractive indices of Pyrex and vegetable oil are the same. Ask students to explain this in their own words.
— Ask students to explain what refraction is and what might affect the angle of refraction (both the type of materials being used and the angle of incidence).

Want to explore further?
The difference between reflection and refraction could be investigated using the Reflection and refraction worksheet.
How light bends (refracting light)

1. Light bends when moving at an angle into a medium with a different refractive index, like a car hitting sand at an angle. At the angle of approach in the diagram below, the car’s right wheel gets slowed down first and this turns the car to the right – towards the normal.

2. Leaving the sand, the right wheel speeds up first and this turns the car to the left – away from the normal.

3. If both wheels hit the sand together, they slow down together so the car goes straight through, without turning.

4. Light acts in the same way.
Lesson 7: Worksheet

Refracting light

Follow these instructions to investigate how light changes direction at the boundary between two different substances.

You will need
— Light box with slits — Power pack
— Rectangular glass block — Protractor
— Ruler — Pencil
— White A4 paper

Method
1. Draw around the glass block on the white A4 paper.
2. Set up the apparatus as shown in the diagram.
3. Draw the normal line where the light enters the block (as shown).
4. Mark the path of the light as it enters and exits the glass block (with small crosses).
5. Remove the glass block and use a ruler to draw in the complete path of light.
6. Draw a second normal line where the light leaves the block.
7. Measure the angles at which the light enters and exits the glass block to the normal lines.
8. Repeat the experiment changing the angle at which the light enters the block.

Results
Record your data below.

<table>
<thead>
<tr>
<th>Angle that light enters the glass block (°)</th>
<th>Is the light refracted towards or away from the normal line?</th>
<th>Angle that light exits the glass block (°)</th>
<th>Is the light refracted towards or away from the normal line?</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Conclusion
Lesson 7: Worksheet

Reflection and refraction

Follow these instructions to investigate the difference between reflection and refraction using a semicircular glass block.

You will need
- Light box with slits
- Semicircular glass block
- Ruler
- White A4 paper

Method
1. Draw around the glass block on the white A4 paper.
2. Set up the apparatus as shown in the diagram.
3. Draw the normal line.
4. Mark the path of the light as it enters and exits the glass block (with small crosses).
5. Remove the glass block and use a ruler to draw in the complete path of light.
6. Measure the angles at which the light enters and exits the glass block to the normal line.
7. Repeat the experiment changing the angle at which the light enters the block.

Results
Record your data below.

<table>
<thead>
<tr>
<th>Angle that light enters the glass block (°)</th>
<th>Angle that light exits the glass block (°)</th>
<th>Is the light reflected or refracted?</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. 80</td>
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</tr>
</tbody>
</table>

The critical angle is the angle at which light is reflected and not refracted. What is the critical angle in this experiment? _____°

Conclusion

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
Lesson 8

Crystals and chocolate

You will need

— Clip 21 (4’25")
— Clip 22 (3’27”)

— Taste test
  — Two large bars of quality branded milk chocolate with sufficient pieces for each student to have a piece from each bar

— Melting point activity
  — Worksheet and Crystal structure information table (p. 32 and 33)
  — Two large bars of quality branded milk chocolate
  — Thermometers or data loggers with temperature probes
  — Timers or stopwatches
  — Hot water (at approximately 50°C)
  — Beakers/boiling tubes

Technician’s notes

— Large bars of quality branded chocolate that are sealed in plastic foil wrappers work well. Place one large bar in a warm place to melt it without raising its temperature over 50°C. When it has melted, refreeze it quickly in a refrigerator and then store it at room temperature until the lesson.

— A similar quantity of chocolate will be required for the melting point tests. Again, one bar should be melted and refrozen before the lesson for the taste test.

— A copious amount of hot water at 50°C will be required for melting the chocolate.

Suitable for: 11–16

Curriculum and learning links:
Cooking chemistry, composite materials, changes of state, latent heat

Learning objectives:
— Describe melting and freezing as endothermic and exothermic respectively.

— Describe the structure of chocolate as a composite matrix of crystals arranged in cocoa butter.

— Explain how the microstructure of a material (in this case cocoa butter) can affect its properties.

Health and safety

— It is the responsibility of the teacher conducting this lesson to carry out a full risk assessment and to check whether any students have allergies to milk products.

— It might be preferable to do the taste test in a classroom rather than a laboratory to avoid confusion over laboratory rules. Students must not eat the chocolate during the second activity due to the potential risks of contamination from laboratory apparatus.
Lesson 8

Opening activity
1. Hand out to each pair of students two joined chunks of milk chocolate. Ask them to break the chocolate in half and investigate how brittle the chocolate is.

2. Watch Clip 21 in which Mark discusses the structure and ingredients in chocolate and what happens when it melts on your tongue.

3. Ask students to perform this taste test at the same time as the audience on the video clip. See if students can detect a temperature decrease on their tongue as the chocolate melts.

4. After drinking some water, repeat step 1 using chocolate that has been melted and then quickly refrozen (see Technician’s Notes). The chocolate is likely to be less brittle.

5. Ask students to repeat the taste test using the refrozen chocolate. The texture should be different and the cooling effect less noticeable. The taste may also be different.

Development activities
6. Watch Clip 22 which reviews the composite structure of chocolate. A key ingredient is cocoa butter, which comes in six crystal structures.

7. Show students the Crystal structure information table. Explain that Form V has the best taste and texture, but when chocolate melts and cools again, it can change into other crystal structures.

8. Ask students to follow the method on the Crystals and chocolate worksheet to investigate the melting points and cooling curves of two samples of chocolate, one of which has been melted and refrozen. The plateau in their cooling curve should help them to identify the melting point alongside their observations of the cooling chocolate. Touching the surface of the chocolate with a splint or mounted needle may help them to see if it has turned back into a solid.

Reflect and review
— Review the results of the experiment from different groups of students. Is the evidence sufficient to identify which crystal structures of cocoa butter might be present in the two samples of chocolate?

— The results of this experiment are subject to a certain amount of variability, partly due to differing room temperatures and chocolate compositions. It is likely that the ordinary sample of chocolate has a melting point between 33 and 35°C, suggesting that it contains Form V. The melted and refrozen sample is likely to contain Form II or III and as a result usually has a lower melting point.

Want to explore further?
Ask students to research online to see if they can find out exactly how chocolate is made.
Health and safety

It is important that you carefully follow your teacher’s instructions about when you can and cannot eat chocolate. Remember that laboratory equipment is often used with poisonous substances and so it is very easy for the chocolate used in this experiment to become contaminated.

You will need

— 250 cm³ beaker
— 200 cm³ of hot water
— One or two chunks of chocolate
— Thermometer
— Boiling tube
— Stopwatch/timer

Method

1. Collect a 250 cm³ beaker and fill it with approximately 200 cm³ of water at 50°C.

2. Collect a boiling tube and insert one or two chunks of milk chocolate, broken up into small pieces.

3. Place a thermometer into the boiling tube along with the pieces of chocolate. Record the temperature of the air and chocolate in the boiling tube.

4. Place the boiling tube into the beaker of hot water and record the temperature in the boiling tube every 30 seconds. Record your observations in the results table to see at what temperature the chocolate melts. Carefully move the thermometer from side to side in the boiling tube every 30 seconds to see if the chocolate has melted.

5. One minute after the chocolate has melted, remove the boiling tube from the hot water bath. Continue to record the temperature for the next few minutes as the chocolate cools back down to room temperature.

6. Carefully clean your thermometer and then repeat the experiment using a clean boiling tube and pieces of chocolate that have been melted and refrozen.
Results
Record your data into a table like this one

<table>
<thead>
<tr>
<th>Time (minutes and seconds)</th>
<th>Normal chocolate</th>
<th>Melted and refrozen chocolate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temperature inside boiling tube (ºC)</td>
<td>Observations</td>
</tr>
<tr>
<td>00:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:30</td>
<td></td>
<td></td>
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<tr>
<td>01:00</td>
<td></td>
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<tr>
<td>01:30</td>
<td></td>
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</tr>
<tr>
<td>02:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>02:30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The melting point of the normal chocolate was:_________ºC  
The melting point of the chocolate that had been melted and refrozen was:_________ºC

Use the crystal structure table below to identify the most likely crystal structure present in each sample of chocolate.

Crystal structure information table
Below is a table containing some information about the six forms of cocoa butter. Form V is the best one for high quality chocolate because it has the best taste and texture.

<table>
<thead>
<tr>
<th>Crystal structure</th>
<th>Conditions needed to make the crystal structure</th>
<th>Melting point (ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form I</td>
<td>Rapidly cooling molten chocolate</td>
<td>17.3</td>
</tr>
<tr>
<td>Form II</td>
<td>Cooling the molten chocolate at 2ºC</td>
<td>23.3</td>
</tr>
<tr>
<td>Form III</td>
<td>Solidifying the molten chocolate at 5–10ºC or storing Form II at 5–10ºC</td>
<td>25.5</td>
</tr>
<tr>
<td>Form IV</td>
<td>Solidifying the molten chocolate at 16–21ºC or storing Form III at 16–21ºC</td>
<td>27.3</td>
</tr>
<tr>
<td>Form V</td>
<td>Solidifying the molten chocolate while stirring (a special process called ‘tempering’)</td>
<td>33.8</td>
</tr>
<tr>
<td>Form VI</td>
<td>Storing Form V for four months at room temperature</td>
<td>36.3</td>
</tr>
</tbody>
</table>
Can we build a tower into space?

You will need
— Clip 23 (2'31")
— Clip 24 (2'50")
— Clip 25 (2'38")
— Clip 26 (2'18")

— Tower building activity
  — 20 or 30 paper straws for each small group of students
  — Adhesive tape
  — Metre rulers

Technician’s notes
— 40cm long art straws are particularly well suited for this lesson.
— It is helpful if the straws are counted out before the lesson into bundles of the correct number, secured by an elastic band.

Health and safety
— It is the responsibility of the teacher conducting this lesson to carry out a full risk assessment.
— Normal laboratory rules apply.
— The teacher will need to decide if standing on tables is acceptable.

Suitable for: 11–14

Curriculum and learning links:
Forces and gravity, strength of materials

Learning objectives:
— Recognise design features of strong building structures.
— Explain why gravity is one of the most significant restricting factors when designing and constructing very tall buildings due to the increasing weight of the building crushing the material at its base.

Above: Equipment needed to build a straw tower.
Opening activity
1. Ask students if they know which is the tallest building in the world.
2. Watch Clip 23 in which Mark describes the Burj Khalifa in Dubai and introduces some of the challenges of constructing very tall buildings.

Development activities
— Challenge students to work in small groups to build the tallest tower, incentivising with a prize if appropriate.
— Explain to students that they will be using paper to build their tower.
— Demonstrate that cylinders (paper straws) are a strong structure when compared with strips or sheets of paper, but that when the straws are bent, they permanently lose their strength.
— Students are allowed to anchor their straw towers to the table using adhesive tape, but they must not be attached to the ceiling, lights, walls or any other object or surface.

Reflect and review
— Allow sufficient time at the end of the lesson to measure each tower with the whole class as an audience.
— Review the construction concepts for each tower (e.g. triangular sections, wide base, multiple parallel straws for reinforcement low down, single straw peak for light weight) and deduce a common set of principles.
— Discuss the forces acting on the building, especially the base and joints between the straws.
— Watch Clip 24 in which Mark explains that pyramids are very stable structures, but they require a huge area for the base.

Want to explore further?
— Many tall structures are required to carry a load, so the activity could be developed by challenging groups to support a small foam ball as high as possible from the ground.
— The activity could be developed to incorporate financial constraints as well, with more points being awarded for taller structures, unused materials refunded for points, or additional materials purchased using points.
— Watch Clip 25 in which Mark compares some different composite materials and evaluates their suitability for building a tower. Repeat the main activity, allowing students to reinforce straws using lengths of adhesive tape fixed along their length or spiralled around the straws.
— Ask students to research the world’s tallest buildings and find out what they are made from and how the architects and engineers coped with the massive forces acting on them.
— Is there another way of building into space? How about starting from a satellite in space and sending down a cable? Watch Clip 26 in which Mark discusses the challenges that this would face.
Concrete and other composite materials

You will need
- Clip 27 (5’15”)
- Clip 28 (1’48”)
- Clip 29 (4’16”)

- **Making and testing composites activity**
  - Net of mould worksheet for plaster of Paris tiles, copied onto card (sufficient copies for students to work in pairs) (p. 38)
  - Scissors
  - Adhesive tape
  - 80g of plaster of Paris (CaSO₄·½H₂O) per pair of students, already weighed out into plastic cups
  - Spatulas
  - Possible reinforcing materials: e.g. scrap paper, string, wire, wiremesh, wooden splints, etc.
  - Wooden blocks or books
  - Selection of heavy masses (see Technician’s notes)

- **Demonstration**
  - Sheet of woven carbon fibre or Kevlar fibre
  - Items of sports equipment made from rigid carbon fibre epoxy composite

Technician’s notes
- Students should be encouraged to wash their spatulas promptly after mixing the plaster of Paris.
- Plastic cups are recommended to mix the plaster of Paris in so that they can be simply thrown away at the end of the lesson, or flexed until the dry plaster cracks and is easily tipped out.
- Woven carbon fibre fabric, glass fibre and Kevlar are available online from specialist educational science teaching resource suppliers.
- The heavy masses required to test the strength of the tiles would ideally include 0.5, 1, 2 and 5kg masses, with a total mass available of 15kg.

Suitable for: 11–16

**Curriculum and learning links:**
Construction materials, composite materials, properties of materials

**Learning objectives:**
- State that a composite is a mixture of two or more materials that has different properties from its constituent materials.
- Give examples to explain why composites are useful, using ideas about their properties.

**Health and safety**
- It is the responsibility of the teacher conducting this lesson to carry out a full risk assessment.
- Normal laboratory rules apply.
- The reaction of plaster of Paris (CaSO₄·½H₂O) with water is exothermic. Students should be told not to touch the plaster as it sets.
- Care should be taken with heavy masses.

Above: Equipment needed to test the strength of plaster of Paris, together with woven Kevlar and carbon fibre sheets, and a carbon fibre pole.
Opening activity

1. Ask students which is stronger: concrete or steel. How can you decide? What do we mean by strength?
2. Introduce the idea that there are different types of strength, e.g. compressive and tensile.
3. Watch Clip 27, in which Mark discusses this idea and demonstrates that ceramics are strong under compression but very brittle and weak when flexed. What can be added to them to improve their strength under tension?

Development activities

4. Explain to students that they will be working in pairs to make a composite from a ceramic that is called plaster of Paris, reinforced with a material of their choice. Meanwhile, the teacher (and perhaps one or two groups) will make a control sample of unreinforced plaster of Paris.
5. Demonstrate how to cut out, score and construct the mould from the net supplied.
   It is recommended that the tabs are secured on the outside of the mould using adhesive tape, not on the inside using glue.
6. Ask students to write their names and the material they have used for reinforcing on the outside of their mould.
7. Demonstrate how to add 50cm³ of water to the plaster of Paris and stir quickly to make a smooth slurry. The wet plaster should then be poured quickly into the mould before it begins to set (within 30 seconds).
8. Explain to students that they will want to have their reinforcing materials ready to add after half of the plaster has been added to the mould.

   The tiles will take about 24 hours to set if put in a warm place. The card can be carefully removed from the sides of the tiles and then they can be tested upside down (to prevent the card stuck to the base from providing extra strength) by spanning a gap of approximately 15cm between two piles of books or wooden blocks and placing heavy masses on them. Typically, the tiles can support a weight equivalent to 5–15kg.

Reflect and review

— After testing the tiles to destruction, discuss what additional materials provided extra strength to the plaster of Paris and why – did they provide tensile strength to supplement the compressive strength of the ceramic?
— Ask students to research and discuss other uses of composite materials.
— Watch Clip 28 in which Mark discusses the properties of concrete and Clip 29 in which Mark meets a paralympic cycling champion who has a prosthetic leg and bicycle both made from carbon fibre. If possible, demonstrate a piece of woven carbon fibre or Kevlar and compare it with a rigid piece of carbon epoxy composite.

Want to explore further?

— Ask students to find some examples of natural composite materials, for example bone.
— Ask them how the properties of bone differ from the properties of its components (collagen and calcium phosphate).
Net of mould
You will need
— Clip 30 (2'50")
— Clip 31 (0'35")
— Where did the continents come from? activity
  — Continents of the Earth diagram for each student to cut up (p. 41)
  — Worksheet (p. 42)
  — Scissors
— Plate tectonics demonstrations
  — A large tub of golden syrup poured into a large beaker (ideally 2dm³) and placed in a refrigerator for 24 hours
  — One biscuit
  — Lava lamp

Technician’s notes
— Turn the lava lamp on at least one hour before the lesson.
— If the biscuit can be retrieved from the surface of the syrup, the syrup can be reused for future lessons by covering and storing in a refrigerator.

Suitable for: 11–16

Curriculum and learning links:
Geological processes, plate tectonics, igneous rocks

Learning objectives:
— Describe how tectonic plates can interact to form mountains, volcanoes and earthquakes.
— Explain how convection currents in the mantle cause the tectonic plates to move.

Health and safety
— It is the responsibility of the teacher conducting this lesson to carry out a full risk assessment.
— Normal laboratory rules apply.

Opening activity
1. Ask students to suggest how mountains are formed.
2. Explain that early scientific ideas concluded that the mountains were formed when the Earth shrank as it cooled, a bit like the saggy skin of an old dried apple.
3. Ask students to complete the Where did the continents come from? worksheet.
### Development activities

4. Explain that tectonic plates float on the mantle below. The mantle is a semi-solid, so it can flow very slowly over thousands of years.

5. Ask students to work in pairs to model how two tectonic plates might be able to interact with each other at a boundary, sliding their exercise books around on the surface of the table to make conservative (transform) boundaries, divergent (constructive) boundaries and convergent boundaries that might result in mountain building or subduction.

6. Demonstrate to students what makes the tectonic plates move. Take a large beaker containing cooled golden syrup and show that it is a semi-solid by inverting it. Snap a biscuit in half and place it in the centre of the surface of the syrup. Now place the beaker on a tripod over a very small blue Bunsen flame (control the gas flow by using the gas tap). Leave this demonstration until the end of the lesson.

7. Show students the lava lamp and ask them to explain what causes the wax blobs to move through the water.

8. Ask them if they can use their understanding of convection currents to explain what might happen to the model tectonic plates (biscuit fragments) on the mantle (syrup).

9. Explain using diagrams how these convection currents cause volcanoes and mountain ranges to be formed (over cool spots where the mantle is sinking and thus dragging the plates together).

10. Ask students to think about why mountains don’t keep getting higher and higher.

11. Watch Clip 30 in which Mark explains that the taller a mountain gets, the heavier it becomes, so it simply sinks deeper into the mantle.

### Reflect and review

— Review the golden syrup demonstration. Do not invert the beaker this time, but encourage students to come to look at the beaker themselves. The biscuit halves should either have separated, or moved together towards one side of the beaker.

— Remind students that geological processes are very slow. Tectonic plates move at approximately the same speed as your fingernails grow – typically a few centimetres each year.

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### Want to explore further?

— Ask students to suggest and justify which planet might have the biggest mountain: Mars or Earth.

— Watch Clip 31 in which Mark explains that Olympus Mons on Mars is taller due to the weaker gravity of the smaller planet.

— Ask students to research the life of Alfred Wegener using The history of continental drift and plate tectonics worksheet. Ask students to summarise their findings as a poster or a presentation.
Lesson 11: Worksheet

Continents of the Earth
1. Do you notice anything about the shapes of North and South America and Africa?
2. Cut out the continents.
3. As early as 1596, it had been noted that the shapes of the continents suggested that they might have once been part of a supercontinent, which we now call Pangaea, meaning All-Lands or All-Earth. See if you can work out what Pangaea might have looked like.
4. Glue your continents below to show how the modern continents might have been arranged many millions of years ago.
Lesson 11: Worksheet

The history of continental drift and plate tectonics

In 1912, Alfred Wegener, a German meteorologist, suggested that the continents had ‘drifted’ around on the surface of the Earth. Why do you think his theory was rejected by the majority of scientists?

Wegener died in 1930 and it wasn’t until the 1950s and 60s that the scientific community realised that he was right. Why do you think that this was?
Links and resources

Further educational resources from the BBC

- Programme clips selected from BBC content to work with the national curriculum: bbc.co.uk/learningzone/clips
- BBC science learning resources and online courses: bbc.co.uk/learning/subjects/science.shtml
- BBC science revision resources for KS3, GCSEs and Standard Grades: bbc.co.uk/schools/gcsebitesize/science
- BBC science resources for teachers: bbc.co.uk/schools/websites/11_16/site/science.shtml
- Portal for up-to-the-minute news on science programmes and content from across the BBC: bbc.co.uk/science
- Natural history content from the BBC: bbc.co.uk/wildlifefinder
- BBC Bang Goes the Theory. Putting science and technology to the test: bbc.co.uk/bang
- Download the BBC Bang Goes the Theory teacher’s pack from: bbc.co.uk/schools/teachers/bang
- Subscribe to the BBC Schools newsletter for all learning resources for home and school: bbc.co.uk/schools

Further science education resources

The BBC is not responsible for the content of external websites.

- The Royal Institution of Great Britain: www.rigb.org
  Independent charity dedicated to connecting people with the world of science.
  Includes free educational resources and behind-the-scenes clips of the 2010 Christmas Lectures.

- The Royal Society of Chemistry: www.rsc.org
  Designed for chemistry and science teachers, the site provides resources from the Royal Society of Chemistry (RSC) and elsewhere to use in the classroom. To watch the milk powder experiment mentioned on p. 16 go to www.chemistryteachers.org and search for ‘Burning milk powder’ using the free text option.

- Invigorate: invigorate.royalsociety.org
  All KS2 and KS3 resources are based on the life and scientific work of a past Fellow of the Royal Society, and the KS4 resources are based on cutting-edge scientific exhibits from the Royal Society’s Summer Science Exhibition.

  A wealth of resources and ideas for the classroom with KS3 and KS4 activities based around Materials.

- Institute of Physics: www.iop.org
  Professional body actively working to promote developments in physics. Includes support for teachers and classroom resources.

- CLEAPSS: www.cleapss.org.uk
  Advisory service providing support in science and technology for local authorities and schools.

- UK Association for Science and Discovery Centres: www.sciencecentres.org.uk
  Represents over 50 science centres in the UK and a similar number of discovery centres in museums, botanic gardens, aquariums and zoos.

- Science Learning Centres: www.sciencelearningcentres.org.uk
  National network for professional development in science teaching.

- STEMNET (Science, Technology, Engineering and Mathematics Network): www.stemnet.org.uk
  STEM resources for teachers and students.

- Society of Biology: www.societyofbiology.org
  Acts to engage and encourage public interest in the life sciences. Resources for teachers are available from www.practicalbiology.org
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