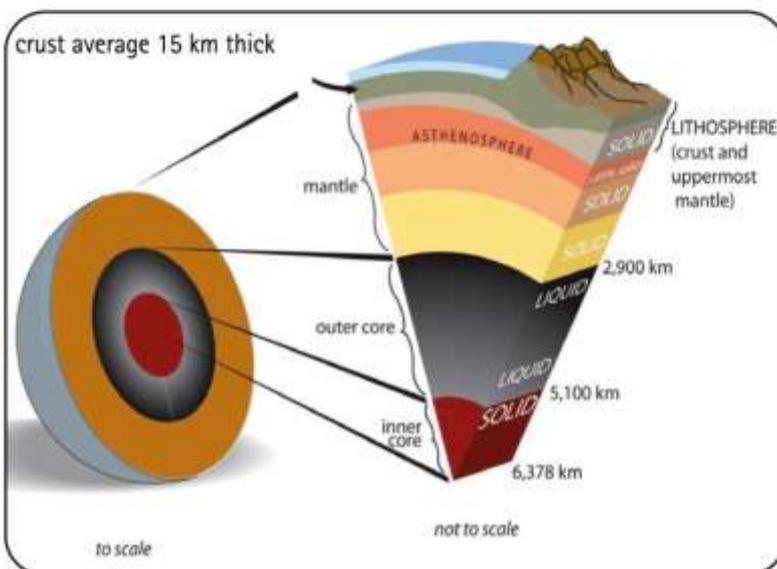


Teaching the Dynamic Earth

Investigating Earth's structure

ESEU KS3 science workshop material



Earth science for KS3





Edited by: Chris King with contributions by Bernadette Callan and Suzy Allen

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ESEU Secondary Workshops

Investigating Earth's structure Earth science for KS3 science

Contents

Workshop outcomes	4
Activity 1: Model Earth – plasticine™ spheres.....	5
Activity 2: Earthquakes - the slinky simulation.....	10
Activity 3: Wave motion – pupil molecules.....	15
Activity 4: Properties of the mantle – potty putty™	19
Activity 5: The seismic evidence for the structure of the Earth.....	23
Activity 6: From an orange to the whole Earth.....	28
Activity 7: Journey to the centre of the Earth – on a toilet roll.....	32
Activity 8: From magnetic globe to magnetic rock evidence	36
Resource list.....	43

Summary

Try a series of 'hands-on' demonstrations and activities to highlight key aspects of the structure of the Earth and the evidence we have for this structure. The practical activities address common misconceptions about the state (solid/liquid) of the Earth's layers and about the thickness of the crust and the Earth's dimensions.

Earth Science Education Unit workshops

These workshops have been devised for teachers and trainee teachers. They are intended to provide participants with a range of activities that can be used in the classroom, whilst helping them to develop the skills for using the activities in an engaging and motivating way that will enthuse and educate their pupils, whilst developing their critical thinking skills. The workshops should also develop the background Earth science knowledge and understanding of the teachers involved.

The workshop format may be transposed directly into a classroom, but often this is not appropriate. Similarly, individual activities, and the worksheets on which these are based, may be transferable directly into a classroom situation, but will often require modification for the classes and situations in which they are used, during which suitable risk assessments are undertaken.

Workshop outcomes

The workshop and its activities provide the following outcomes:

- insights into the structure of the Earth and the dimensions of the Earth's layers;
- discussions and demonstrations about the state (solid/liquid) of the layers;
- the evidence we have for the dimensions and state of the layers;
- means of addressing common misconceptions about the Earth's structure;
- links to the science and geography of Earth's structure;
- guidance on how the elements of Earth science in the curriculum can be taught most effectively.

Activity 1: Model Earth – plasticine™ spheres

Topic: Students explore and discuss the differences between two identical-looking Plasticine™ spheres – one with a ball bearing inside.

Activity:

Using Plasticine™ balls to ask key questions

Prepare two Plasticine™ balls of the same size for each group, one with a ball bearing in the centre. Then ask this series of questions.

1. Two Plasticine™ balls – what is the difference?

Give each group of pupils a pair of balls and ask them to use their senses to detect the difference between them, *without destroying the balls*. Most will soon realise that one ball is heavier than the other.

2. What could explain the difference?

Confirm that one ball is heavier than the other. Then ask each group the reason for this. Challenge them to suggest at least three different ideas.

The different hypotheses they suggest should include:

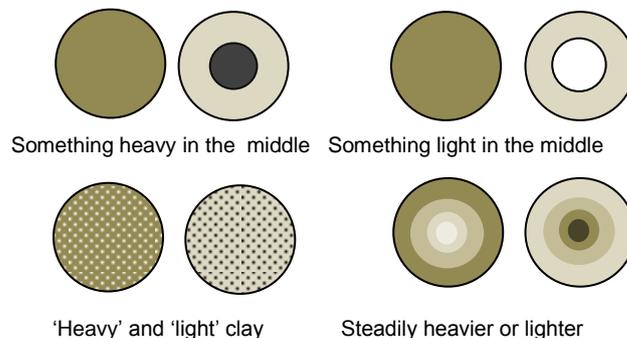
- one has something heavy in the middle (eg. a piece of metal);
- one has something light in the middle (eg. a hole or a piece of polystyrene);
- one is made of heavier Plasticine™ than the other.



“Weighing the evidence” (Peter Kennett)

They might even suggest:

- one ball becomes steadily heavier towards the middle (with layers like some gobstopper sweets); or
- one ball become steadily lighter towards the middle.



3. How could we find out which idea is right?

Now challenge each group to suggest how the balls could be tested *without destroying them*, to find out which of the suggested ideas is right. They can use any of the apparatus in the school or in the town.

Ideas usually suggested include using:

- something to stick into each ball;
- a small amount of Plasticine™ from each ball for weighing;
- a magnet (or a magnetic sensor);
- ultrasound (as used to examine babies before birth);
- electromagnetic resonance (many hospitals have a magnetic resonance imaging (MRI) machine; metal detectors use MRI too);
- X-rays;
- radiation (correctly called ionising radiation – alpha, beta or gamma radiation).

Some may also suggest testing differences in how the balls roll or spin. Incorrect suggestions include, that you could test whether the balls float or sink, or you could weigh them. These would only confirm what we already know – that one ball is heavier than the other.

The responses to the other ideas are:

- something to stick into each ball – *if you stick a matchstick into each ball, one will go through and the other will be stopped by the ball bearing;*
- a small amount of Plasticine™ from each ball to be weighed – *if this were done, the density of the Plasticine™ would be the same;*
- a magnet (or a magnetic sensor); ultrasound; electromagnetic resonance and X-rays – *these should all detect the metal ball bearing;*
- radiation – *alpha and beta radiation would not penetrate the Plasticine™, but the ball bearing would be detected by gamma radiation;*
- even though the ball with the bearing should roll and spin better, this is usually not detectable.

4. Which of these ideas could be used to find out if the Earth has a core?

Ask the groups to discuss and then suggest which of the ideas listed could be used to probe the Earth to find out if it has a core. The answers are:

- something to stick into the Earth – *this is not possible, as the deepest hole ever drilled into the Earth is 12 km deep, yet the outer edge of the core is about 3000 km below the surface;*
- a small amount of Plasticine™ from each ball to be weighed – *we can weigh the Earth, and so find it has a relative density of about 5.5, meanwhile crustal rocks have a relative density of 2.7-2.9, indicating that there is something of high density deep in the Earth;*
- a magnet (or a magnetic sensor) – *these will detect the Earth's magnetic field, so there must be something deep in the Earth causing it;*
- ultrasound – *this has too high a frequency to penetrate the Earth, but low frequency sound (possibly called 'infra-sound'), or seismic waves do penetrate the Earth, and provide the best evidence for the position and character of the core;*
- magnetic resonance and X-rays - *cannot penetrate the Earth;*
- ionising radiation – *even gamma radiation can only penetrate a few metres into concrete, and so cannot penetrate the Earth;*
- how the Earth spins (its rotational inertia) – *this does suggest that the Earth has a dense core.*

Summarise the findings – the best evidence we have for the core is seismic waves, but density-measurements, inertia and magnetism all play their part.

Pupil learning outcomes: Pupils can:

- identify which of the two balls is heavier;
- describe different hypotheses that could account for one ball being heavier than the other;
- explain different ways of testing these hypotheses, using equipment from low tech to high tech;
- explain which of these hypotheses could also be used on the Earth to find out whether or not the Earth has a heavy metal core.

Curriculum references:

England	Scotland	Wales	Northern Ireland
Science KS3 Working scientifically <ul style="list-style-type: none"> select, plan and carry out the most appropriate types of scientific enquiries to test predictions KS4 Science Working scientifically The development of scientific thinking: <ul style="list-style-type: none"> understanding how scientific methods and theories develop over time using a variety of models to develop scientific explanations and understanding Experimental skills and strategies <ul style="list-style-type: none"> using scientific theories and explanations to develop hypotheses. 	Sciences Experiences and outcomes Learning in the sciences will enable me to: <ul style="list-style-type: none"> develop the skills of scientific inquiry and investigation using practical techniques Processes of the planet By contributing to experiments and investigations, I can develop my understanding of models of matter and can apply this to changes of state and the energy involved as they occur in nature. SCN 3-05a	Science KS3 Enquiry Pupils should be given opportunities to carry out different types of enquiry, e.g. <i>pattern-seeking, exploring, classifying and identifying, making things, fair testing, using and applying models, by:</i> Planning Pupils decide on the most suitable type of enquiry to carry out and outline the planned approach/method	Science develop skills in scientific methods of enquiry to further scientific knowledge and understanding: planning for investigations GCSE Geography i) describe the structure of the Earth (core, mantle and crust); (ii) know that the Earth's crust is made up of a number of plates and understand how convection currents cause plate movement; (iii) demonstrate knowledge and understanding of the processes and landforms associated with plate margins: <ul style="list-style-type: none"> constructive plate margins: mid-ocean ridges; destructive plate margins: subduction zone and ocean trench; collision zones: fold mountains; and conservative plate margins: fault lines;

Age range of pupils: 11-18 years

Time needed to complete activity: 10 minutes

The story for teachers:

Our knowledge of the Earth's interior has mostly been obtained by "remote sensing". The deepest research borehole only penetrates about 12 km into the crust of the Earth. Clues may be obtained from rocks brought up from the upper mantle beneath by extreme Earth events, on relatively rare occasions, but after this we have to use geophysical methods. The materials which make up the Earth's core (thought to be largely iron and nickel) are only known from meteorites. Pupils are usually quick to spot that one sphere is heavier than the other, and their own experience of modelling Plasticine™ will lead them to say that one is normal, and the other has something heavy inside it. However, it is equally possible that the lighter sphere has something less dense in its core – not a model for the Earth, but good science for those who suggest this alternative.

Another possibility includes several increases in density within the ball – more likely within the Earth itself, but difficult to model with Plasticine™. It is also conceivable that Plasticine™ of a totally different density could have been used for one of the spheres.

It is important to make the model with the ball bearing to scale, so that the pin will hit the ball bearing roughly half way down from the surface of the sphere. Textbooks often show the Earth's core as too small - in reality, its outer margin lies at about 3000km down from the Earth's surface, i.e. roughly half the Earth's radius.

Pupils may suggest other valid methods of discovering what lies within the sphere, e.g. magnetism, X-rays; ultra sound; inertia; radioactivity. Of these, only magnetism, inertia and wave motion (seismic) are applicable to the Earth itself.

Formulating ideas to explain the mass/density difference involves skills of construction. Developing ideas to 'probe' the ball to discover the reason for the differences in mass/density is a challenge and discussion with probing by the teacher develops skills of explanation. Bridging skills are needed to relate Plasticine™ ball ideas to real Earth ideas.

Lead in ideas:

Any discussion which requires knowledge of the Earth's interior, e.g. how plates can move; where magmas come from; why seismic waves change in velocity with depth, etc.

Following up the activity:

The Earth can be "weighed" and the size has been known since about 250 B.C., so the overall density can be calculated.

Boreholes can only penetrate a few kilometres, so the Earth cannot meaningfully "have a pin stuck in it" to the mantle/core boundary at nearly 3000 km depth! Seismic work provides the detail about the depth of the core and the other layers.

Source: Earth Science Education Unit.

Copyright: © Earth Science Education Unit

Preparation and set-up: about 30 minutes to make several sets of Plasticine™ spheres

Resource List:

- a pair of Plasticine™ spheres per group of students; these are identical-looking pairs of Plasticine™ spheres, except that one sphere is Plasticine™ alone; the other has a ball bearing or similar dense object in its centre - try to ensure that the diameter of the ball bearing is approximately half that of the Plasticine™ which surrounds it, to model the correct proportions of the Earth's interior.
- a pin

Risk assessment:

Potentially Hazardous Activity	Who/What may be Harmed?	Hazard Rating (A)	Likelihood (B)	Risk (AxB)	Further Action Required?
Model Earth - Plasticine™ spheres	If students push a pin into a Plasticine™ sphere, be sure they don't do this on the palm of their hand, as the pin can go right through	1	1	1	Ensure the students don't push the pin into the Plasticine™ sphere while it is on the palm of their hands

Hazard Rating (A):

- 1 = Insignificant effect
- 2 = Minor Injury
- 3 = Major Injury
- 4 = Severe Injury
- 5 = Death

Likelihood of occurrence (B):

- 1 = Little or no likelihood
- 2 = Unlikely
- 3 = Occasional
- 4 = Probable
- 5 = Inevitable

Risk Priority (AxB):

- 12-25 = High risk – take immediate action
- 6-11 = Medium risk – take action as soon as possible
- Less than 6 = Low risk – plan future actions where required

ESEU activity guide sheet:

Model Earth – plasticine™ spheres

The two spheres are a model for the Earth and what may exist inside it.

Pick up and examine each sphere in turn, (without trying to remodel the Plasticine™ please!).



"Weighing the evidence" (Peter Kennett)

Say in what ways the spheres are similar, and in what ways they differ.

Does one sphere have anything inside it? If so, which one is it?

Could the answer be the other sphere? If so, why?

Once you have decided which sphere may have something inside it, discuss ways in which you could find out how far down it is, without cutting the sphere in half. These could be very simple methods, ranging up to high tech methods, if you had the apparatus available.

Finally use the low tech method of sticking a pin into the sphere, to see how far it will penetrate, before it hits whatever is inside the sphere. Take care that you do not push the pin right through and into your hand!

You clearly cannot push a pin through the Earth. Suggest ways in which scientists might really be able to find out what is inside the Earth.

Activity 2: Earthquakes - the slinky simulation

Topic:

Demonstrate the transmission of P- and S-waves using a slinky spring.

Activity:

1. Distinguishing waves



'P-wave' (ESEU)



'S-wave' (ESEU)

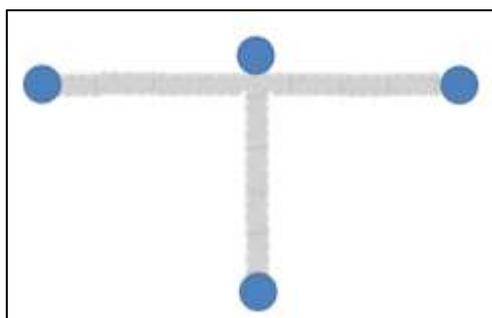
- Extend the slinky on the bench top and ask a student to hold the other end.
- Giving the slinky a sharp push-pull motion produces a longitudinal wave (known as a P or Primary wave (since it travels faster than other types of wave and arrives before the S or Secondary wave); also a Push/Pull or comPressive wave).
- Ask students to note the movement of the spots on the central coils; they move backwards and forwards in the direction of the wave as compression and rarefaction passes along the spring, as molecules vibrate in solids, liquids and gases during passage of a P-wave.
- Giving the slinky a sharp sideways shake produces a transverse wave (known as an S or Secondary wave; also a Sideways, Shake, Shear or Slow wave).
- The students should note the movement of the spots, this time, at right angles to the path of the waves; these simulate the shear movement of molecules as S-waves pass; since fluids (liquids and gases) cannot shear, they cannot transmit S-waves.
- Both P-waves and S-waves travel through the Earth and are known as body waves.
- Surface waves, which produce an undulation of the surface and cause most of the damage in an earthquake, are akin to sea waves and are impossible to imitate with the slinky.



Compression in a P-wave moving along a slinky © Geopix UK

2. Making waves

Ask two pupils to stand in a space and extend a slinky spring between them. Then ask a third pupil to hold the middle of the extended spring and then to hold the end of a second spring, which is then extended, by a fourth pupil, at right angles to the first spring, as shown in the diagram.



© ESEU

Move the pupil holding both springs briskly from side to side, generating a P-wave in the spring stretched between the three pupils, whilst an S-wave is generated in the spring at right angles. Similarly, moving the pupil briskly backwards and forwards will generate a P-wave in the spring in front whilst S-waves are generated in the spring to the sides. This illustrates how one shock, such as an earthquake, generates both P- and S-waves simultaneously.

Pupil learning outcomes: Pupils can:

- describe how slinky springs can simulate P- and S-waves;
- explain how the movement of the spring simulates the movement of the material it passes through, by the movement of the molecules;
- explain why P-waves are transmitted by solids, liquids and gases, but S-waves by solids only.

Curriculum references:

England	Scotland	Wales	Northern Ireland
<p>KS3 Chemistry – Earth and atmosphere</p> <ul style="list-style-type: none"> • the composition of the Earth. • the structure of the Earth <p>KS4 Science Working scientifically The development of scientific thinking:</p> <ul style="list-style-type: none"> • using a variety of models to develop scientific explanations and understanding <p>Physics Wave motion</p> <ul style="list-style-type: none"> • transverse and longitudinal waves. <p>Geography KS3 Human and physical geography</p> <ul style="list-style-type: none"> • physical geography relating to: geological timescales and plate tectonics; rocks, • understand how human and physical processes interact to influence, and change landscapes, environments 	<p>Sciences Second Vibration and waves Through research on how animals communicate, I can explain how sound vibrations are carried by waves through air, water and other media. SCN 2-11a</p> <p>Earth's Materials Having explored the substances that make up the Earth's surface, I can compare some of their characteristics and uses. SCN 2-17a</p> <p>Topical science I can report and comment on current scientific news items to develop my knowledge and understanding of topical science. SCN 2-20b</p> <p>Third Processes of the planet By contributing to experiments and investigations, I can develop my understanding of models of matter and can apply this to changes of state and the energy involved as they occur in nature. SCN 3-05a</p>	<p>Geography KS3</p> <ul style="list-style-type: none"> • the hazardous world: global distribution, causes, and impacts of extreme tectonic and other hazardous events 	<p>Science KS3 Forces and energy</p> <ul style="list-style-type: none"> • Forces and energy transfer <p>Earth and Universe</p> <ul style="list-style-type: none"> • The environment and human influences <p>GCSE Geography i) describe the structure of the Earth (core, mantle and crust)</p>

Age range of pupils: 12-18

Time needed to complete activity: 5 minutes

The story for teachers:

Seismic wave summary

Wave type	Primary wave	Secondary wave
Name meaning	fastest wave, so arrives first, called primary	slower wave, arrives second, called secondary
Other names	longitudinal – travels by vibration along the material	transverse – travels by lateral movement
	push/pull wave; comPressional wave	shake wave; shear wave; sideways wave; slow wave
Transmission	through solids and fluids (liquids and gases)	through solids only

Note: Earthquake damage is caused mainly by seismic surface waves, and not by primary or secondary waves

Lead in ideas:

Ask the pupils how we find out about the Earth's interior

Following up the activity:

Try the ESEU, 'Wave motion – student 'molecules' activity'.

Source: The Earth Science Teachers' Association, 'Investigating the Science of the Earth 2: Geological changes – Earth's Structure and Plate Tectonics' published by Geo Supplies, Sheffield.

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Preparation and set-up: None

Resources list:

- a slinky spring (or several for use by groups in the class); if possible, glue a few coloured spots on the central coils, or paint white spots on with Tippex™ to emphasise the movement of the spring
- a second slinky spring

Risk assessment:

Potentially Hazardous Activity	Who/What may be Harmed?	Hazard Rating (A)	Likelihood (B)	Risk (AxB)	Further Action Required?
Earthquakes – the Slinky simulation	No significant hazard	-	-	-	No

Hazard Rating (A):

- 1 = Insignificant effect
- 2 = Minor Injury
- 3 = Major Injury
- 4 = Severe Injury
- 5 = Death

Likelihood of occurrence (B):

- 1 = Little or no likelihood
- 2 = Unlikely
- 3 = Occasional
- 4 = Probable
- 5 = Inevitable

Risk Priority (AxB):

- 12-25 = High risk – take immediate action
- 6-11 = Medium risk – take action as soon as possible
- Less than 6 = Low risk – plan future actions where required

ESEU activity guide sheet:

Earthquakes - the slinky simulation

Demonstrate the transmission of P- and S-waves using a slinky spring.

1. Distinguishing waves



'P-wave' (ESEU)

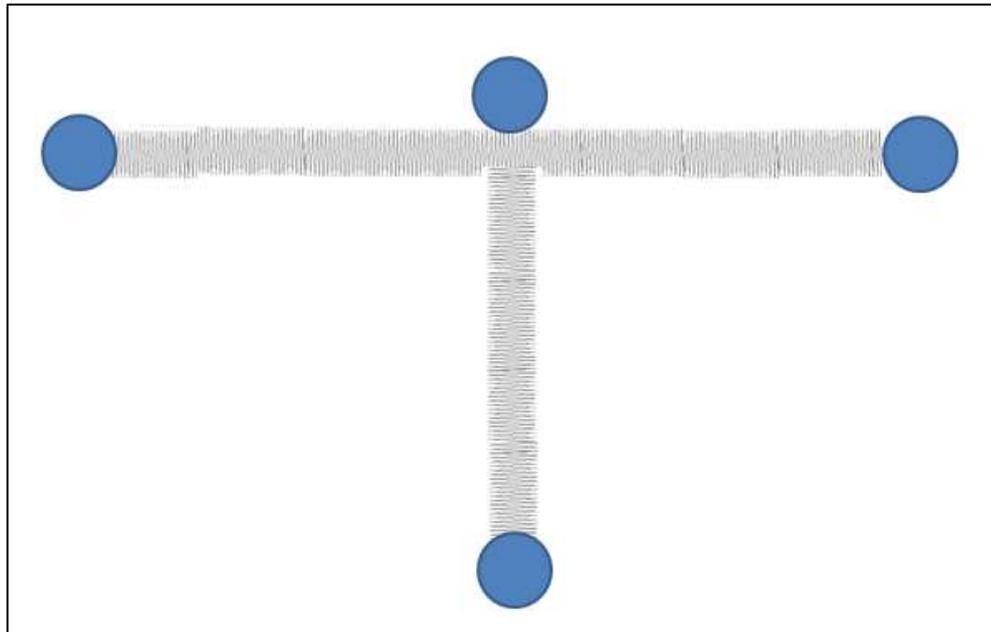


'S-wave' (ESEU)

- Extend the slinky on the bench top and ask a student to hold the other end.
- Giving the slinky a sharp push-pull motion produces a longitudinal wave (known as a P or Primary wave (since it travels faster than other types of wave and arrives before the S or Secondary wave); also a Push/Pull or comPressional wave).
- Ask students to note the movement of the spots on the central coils; they move backwards and forwards in the direction of the wave as compression and rarefaction passes along the spring, as molecules vibrate in solids, liquids and gases during passage of a P-wave.
- Giving the slinky a sharp sideways shake produces a transverse wave (known as an S or Secondary wave; also a Sideways, Shake, Shear or Slow wave).
- The students should note the movement of the spots, this time, at right angles to the path of the waves; these simulate the shear movement of molecules as S-waves pass; since fluids (liquids and gases) cannot shear, they cannot transmit S-waves.
- Both P-waves and S-waves travel through the Earth and are known as body waves.
- Surface waves, which produce an undulation of the surface and cause most of the damage in an earthquake, are akin to sea waves and are impossible to imitate with the slinky.

2. Making waves

Ask two pupils to stand in a space and extend a slinky spring between them. Then ask a third pupil to hold the middle of the extended spring and then to hold the end of a second spring, which is then extended, by a fourth pupil, at right angles to the first spring, as shown in the diagram.



© ESEU

Move the pupil holding both springs briskly from side to side, generating a P-wave in the spring stretched between the three pupils, whilst an S-wave is generated in the spring at right angles. Similarly, moving the pupil briskly backwards and forwards will generate a P-wave in the spring in front whilst S-waves are generated in the spring to the sides. This illustrates how one shock, such as an earthquake, generates both P- and S-waves simultaneously.

Activity 3: Wave motion – pupil molecules

Topic:

Simulate the ways in which seismic waves are transmitted in different states of matter.

Activity:



Pupil 'molecules' (ESEU)

- Pupils line up with straight arms, holding the shoulders of the person in front. The rear pupil (the most trustworthy!) applies a gentle push/pull motion, which ripples through the line, imitating a P-wave (primary wave) being transmitted by a solid.
- Shaking the pupils from side to side imitates an S-wave (secondary wave) in a solid.
- Pupils drop their arms. The trusted pupil waggles the one in front of him/her from side to side, but no motion passes down the line: an analogy for an S-wave not being transmitted through a liquid.
- Pupils close up together with arms down. A gentle push at the rear causes a P-wave to travel through a 'liquid', although the analogy breaks down when the front pupil falls over and the pulse is not sent back again!

Seismic wave summary

Wave type	Primary wave	Secondary wave
Name meaning	fastest wave, so arrives first, called primary	slower wave, arrives second, called secondary
Other names	longitudinal – travels by vibration along the material	transverse – travels by lateral movement
	push/pull wave; compResional wave	shake wave; shear wave; sideways wave; slow wave
Transmission	through solids and fluids (liquids and gases)	through solids only

Note: Earthquake damage is caused mainly by seismic surface waves, and not by primary or secondary waves.

Pupil learning outcomes: Pupils can:

- describe how a line of pupils can simulate P- and S-waves;
- explain how the movement of the pupils simulates the movement of material as the waves pass through, by the movement of the molecules;
- explain why P-waves are transmitted by solids, liquids and gases, but S-waves by solids only.

Curriculum references:

England	Scotland	Wales	Northern Ireland
<p>KS3 Chemistry – Earth and atmosphere</p> <ul style="list-style-type: none"> • the composition of the Earth. • the structure of the Earth <p>KS4 Science Working scientifically The development of scientific thinking:</p> <ul style="list-style-type: none"> • using a variety of models to develop scientific explanations and understanding 	<p>Sciences Second Vibration and waves</p> <p>Through research on how animals communicate, I can explain how sound vibrations are carried by waves through air, water and other media. SCN 2-11a</p> <p>Earth's Materials</p> <p>Having explored the substances that make up the Earth's surface, I can compare some of their characteristics and uses. SCN 2-17a</p> <p>Topical science</p>	<p>Geography KS3</p> <ul style="list-style-type: none"> • the hazardous world: global distribution, causes, and impacts of extreme tectonic and other hazardous events 	<p>Science KS3 Forces and energy</p> <ul style="list-style-type: none"> • Forces and energy transfer <p>Earth and Universe</p> <ul style="list-style-type: none"> • The environment and human influences

<p>Physics Wave motion</p> <ul style="list-style-type: none"> transverse and longitudinal waves. <p>Geography KS3 Human and physical geography</p> <ul style="list-style-type: none"> physical geography relating to: geological timescales and plate tectonics; rocks, 	<p>I can report and comment on current scientific news items to develop my knowledge and understanding of topical science. SCN 2-20b</p> <p>Third Processes of the planet</p> <p>By contributing to experiments and investigations, I can develop my understanding of models of matter and can apply this to changes of state and the energy involved as they occur in nature. SCN 3-05a</p>	<p>GCSE Geography</p> <p>i) describe the structure of the Earth (core, mantle and crust);</p>
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Age range of pupils: 11-16

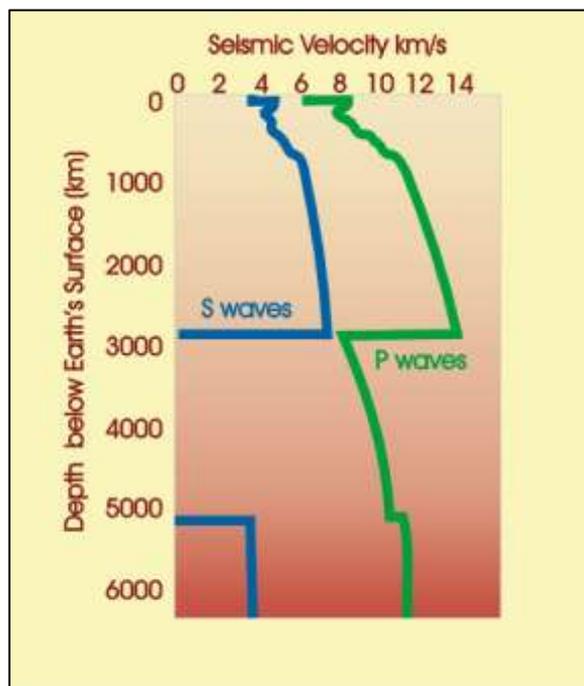
Time needed to complete activity: 5 minutes

Lead in ideas:

Demonstration of P- and S-wave transmission using a slinky.

Following up the activity:

Present the graphs of P and S seismic wave velocities through the Earth. Point out: solid mantle: liquid outer core: solid inner core. The crust is too thin to show on this scale, but the Low Velocity Zone (LVZ) in the upper mantle (asthenosphere) can usually be picked out where the velocities of the P and S waves dip. The crust and the part of the mantle lying above the LVZ are called the lithosphere. Plates are made of lithosphere and not crust alone.



The velocities of seismic waves in the Earth

Originally from The Earth Science Teachers' Association, 'Investigating the Science of the Earth 2: Geological changes – Earth's Structure and Plate Tectonics', redrawn by ESEU

Source: Earth Science Education Unit.

Copyright: © Earth Science Education Unit.

Preparation and set-up: None

Resources list:

- four or five willing pupils

Risk assessment:

Potentially Hazardous Activity	Who/What may be Harmed?	Hazard Rating (A)	Likelihood (B)	Risk (AxB)	Further Action Required?
Wave motion – pupil molecules	No significant hazard	-	-	-	No

Hazard Rating (A):

- 1 = Insignificant effect
 2 = Minor Injury
 3 = Major Injury
 4 = Severe Injury
 5 = Death

Likelihood of occurrence (B):

- 1 = Little or no likelihood
 2 = Unlikely
 3 = Occasional
 4 = Probable
 5 = Inevitable

Risk Priority (AxB):

- 12-25 = High risk – take immediate action
 6-11 = Medium risk – take action as soon as possible
 Less than 6 = Low risk – plan future actions where required

ESEU activity guide sheet:

Wave motion – pupil molecules

Simulate the ways in which seismic waves are transmitted in different states of matter.



Pupil 'molecules' (ESEU)

- Pupils line up with straight arms, holding the shoulders of the person in front. The rear pupil (the most trustworthy!) applies a gentle push/pull motion, which ripples through the line, imitating a P-wave (primary wave) being transmitted by a solid.
- Shaking the pupils from side to side imitates an S-wave (secondary wave) in a solid.
- Pupils drop their arms. The trusted pupil waggles the one in front of him/her from side to side, but no motion passes down the line: an analogy for an S-wave not being transmitted through a liquid.
- Pupils close up together with arms down. A gentle push at the rear causes a P-wave to travel through a 'liquid', although the analogy breaks down when the front pupil falls over and the pulse is not sent back again!

Seismic wave summary

Wave type	Primary wave	Secondary wave
Name meaning	fastest wave, so arrives first, called primary	slower wave, arrives second, called secondary
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	push/pull wave; compressional wave	shake wave; shear wave; sideways wave; slow wave
Transmission	through solids and fluids (liquids and gases)	through solids only

Note: Earthquake damage is caused mainly by seismic surface waves, and not by primary or secondary waves.

Activity 4: Properties of the mantle – potty putty™

Topic:

A demonstration of the properties of Potty Putty™, as an analogy for the rocks in the mantle.

Activity:

A demonstration of the elastic, plastic and brittle properties of Potty Putty™, showing that the behaviour depends on the scale and duration of the applied stress. Potty Putty™ therefore provides a useful analogy for the rocks in the mantle, which under short duration stress, act elastically, transmitting S-waves, but under longer stress duration, act plastically – flowing.

- Break up a lump of Potty Putty™ into small pieces (e.g. 1cm diameter) and distribute to group members.
- Invite members to roll the putty into a ball and gently bounce it on the bench (elastic deformation).
- Ask them to pull it out and let it droop under its own weight (plastic deformation)
- Ask them to roll it up again and try to snap with a short sharp pull (brittle deformation).
- Optional - demonstrate shattering of the putty when hit by a hammer (use a safety screen and collect all the shattered pieces. Do not allow the pieces to fall on carpet or clothing as it will flow into the material and can never be removed! Alternatively, put the Potty Putty™ into a transparent plastic bag before hitting).
- Ask them to roll it into a ball and leave it on the bench/desk for the rest of the lesson, the ball will collapse into a round blob – ask if this is demonstrating elastic, plastic or brittle behaviour (*A. plastic*) and what is causing the stress (*A. gravitational forces*).
- Gather up all the Potty Putty™ and return it to its container. Warn students not to put it into their pockets as it will flow into the material and be there for ever!



Bounce it (elastic deformation)



Bend it (plastic deformation)



Snap it (brittle deformation)



Shatter it (brittle deformation)

(Peter Kennett)

Pupil learning outcomes: Pupils can:

- appreciate that, under different scales and durations of stress a solid material can behave:
 - in an elastic way (and could therefore transmit earthquake waves);
 - in a plastic/ductile way (and can therefore flow or creep) and
 - in a brittle way (and can therefore fracture, which could create an earthquake);
- use the Potty Putty™ analogy to explain how the mantle can transmit S-waves, and yet flow.

Curriculum references:

England	Scotland	Wales	Northern Ireland
<p>Science KS3 Chemistry – Earth and atmosphere</p> <ul style="list-style-type: none"> the composition of the Earth the structure of the Earth <p>KS4 Working scientifically The development of scientific thinking:</p> <ul style="list-style-type: none"> using a variety of models to develop scientific explanations and understanding. <p>Physics Forces:</p> <ul style="list-style-type: none"> ...elastic and inelastic stretching <p>Geography KS3 Human and physical geography</p> <ul style="list-style-type: none"> physical geography relating to: geological timescales and plate tectonics; rocks 	<p>Sciences Second Earth's Materials Having explored the substances that make up the Earth's surface, I can compare some of their characteristics and uses. SCN 2-17a</p> <p>Processes of the planet By contributing to experiments and investigations, I can develop my understanding of models of matter and can apply this to changes of state and the energy involved as they occur in nature. SCN 3-05a</p>	No direct references	<p>GCSE Geography i) describe the structure of the Earth (core, mantle and crust); (ii) know that the Earth's crust is made up of a number of plates and understand how convection currents cause plate movement</p>

Age range of pupils: 12-16

Time needed to complete activity: 5 minutes

The story for teachers:

The Earth's mantle is almost completely solid (apart from a few areas near the top of the mantle where liquid magma has gathered in magma chambers). The fact that it transmits S-waves shows that it is solid (S-waves are not transmitted by fluids). Nevertheless, over the huge spans of geological time, and under the high temperatures and great pressures, the mantle flows. Flow rates are a few cm per year (as fast as your finger nails grow) – this flow enables tectonic plates to move.

After pupils have been taught for most of their lives that solids are identified by the property on not-flowing, many find it difficult to imagine how a solid can flow. A good analogy is that of ice. Ice shatters (brittle deformation) when hit with a hammer, but in a glacier on a mountainside, it flows downhill (plastic deformation). It also transmits S-waves through elastic deformation.

Lead in ideas:

Any discussion of the mantle:

- being able to transmit earthquake body waves (by elastic deformation);
- allowing movement of plates above (by plastic deformation);
- being the source of earthquakes, down to about 700km (by brittle deformation).

Seismic wave properties – P-waves (primary waves) can be transmitted through both solids and liquids, but S-waves (secondary waves) through solids alone.

Following up the activity:

Discussion of the rate of movement of plates as described above.

Source: Earth Science Education Unit.

Copyright: © Earth Science Education Unit

Preparation and set-up: None

Resources list:

- Potty Putty™ (or Silly Putty™) a silicone polymer available from toy shops, or your own version, made from PVA glue and borax using the recipe shown overleaf, that can be found on <http://www.esta-uk.net/jesei/index.htm>

'Recipe for making 'Potty putty'

Resources list:

- 20 cm³ PVA glue (not a rubberized variety from DIY shops, a simple glue as often used in school art rooms).
- a few cubic centimetres of dilute sodium tetraborate solution (borax) (approximately 25 ml).
- a small beaker or other container in which to mix the potty putty.

Method:

Add drops of the borax solution to the PVA glue in a small container and mix vigorously. When the polymer begins to crosslink (becomes less liquid and comes away from the sides of the container) it may be rolled between the hands to ensure complete mixing of the borax solution. If it remains sticky, then it has to be kneaded more vigorously. If it still remains sticky add a little more borax solution.

When left on the desk the potty putty will sink and spread.

However it will also bounce like a ball if enough borax is used.

It can be stretched far more than Plasticine™ if pulled gently, but can also be fractured if pulled suddenly.

Hints:

The trick is to mix the borax solution into the PVA well, rather than to add lots of it. Adding too much will result in a hard material that will not stretch.

If the mixture remains sticky, more borax solution is required.

You are recommended to try this in advance so that you can see when the mix starts to 'go'.

Often the potty putty improves if left on a surface for 20 minutes.

It will dry out eventually so to keep a good sample, keep it in a sealed plastic bag.

A few drops of food colouring can be added to make the final product more interesting. However adding too much will dilute your mixture and make it more difficult to make into potty putty. Also handling the coloured potty putty will result in food colouring staining the hands. This will wash off eventually, but not very easily!

Risk assessment:

Potentially Hazardous Activity	Who/What may be Harmed?	Hazard Rating (A)	Likelihood (B)	Risk (AxB)	Further Action Required?
Properties of the mantle – Potty Putty™	No significant hazard	-	-	-	No
Making Potty Putty™	Chemicals in the eyes	2	2	4	Wear eye protection

Hazard Rating (A):

- 1 = Insignificant effect
 2 = Minor Injury
 3 = Major Injury
 4 = Severe Injury
 5 = Death

Likelihood of occurrence (B):

- 1 = Little or no likelihood
 2 = Unlikely
 3 = Occasional
 4 = Probable
 5 = Inevitable

Risk Priority (AxB):

- 12-25 = High risk – take immediate action
 6-11 = Medium risk – take action as soon as possible
 Less than 6 = Low risk – plan future actions where required

ESEU activity guide sheet:

Properties of the mantle – potty putty™

A demonstration of the properties of Potty Putty™, as an analogy for the rocks in the mantle.

A demonstration of the elastic, plastic and brittle properties of Potty Putty™, showing that the behaviour depends on the scale and duration of the applied stress. Potty Putty™ therefore provides a useful analogy for the rocks in the mantle, which under short duration stress, act elastically, transmitting S-waves, but under longer stress duration, act plastically – flowing.

- Break up a lump of Potty Putty™ into small pieces (e.g. 1cm diameter) and distribute to group members.
- Invite members to roll the putty into a ball and gently bounce it on the bench (elastic deformation).
- Ask them to pull it out and let it droop under its own weight (plastic deformation)
- Ask them to roll it up again and try to snap with a short sharp pull (brittle deformation).
- Optional - demonstrate shattering of the putty when hit by a hammer (use a safety screen and collect all the shattered pieces. Do not allow the pieces to fall on carpet or clothing as it will flow into the material and can never be removed! Alternatively, put the Potty Putty™ into a transparent plastic bag before hitting).
- Ask them to roll it into a ball and leave it on the bench/desk for the rest of the lesson, the ball will collapse into a round blob – ask if this is demonstrating elastic, plastic or brittle behaviour (*A. plastic*) and what is causing the stress (*A. gravitational forces*).
- Gather up all the Potty Putty™ and return it to its container. Warn students not to put it into their pockets as it will flow into the material and be there for ever!



Bounce it
(elastic deformation)



Bend it
(plastic deformation)



Snap it
(brittle deformation)



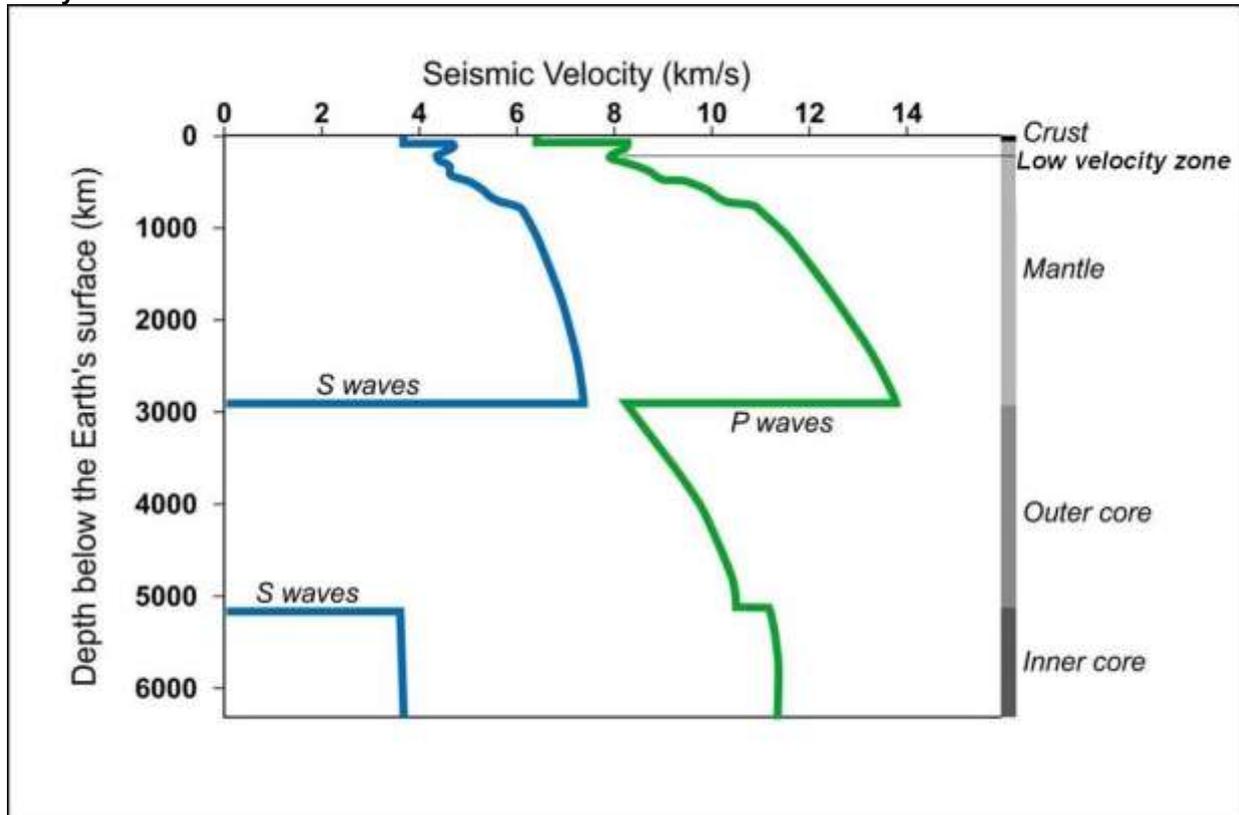
Shatter it
(brittle deformation)

(Peter Kennett)

Activity 5: The seismic evidence for the structure of the Earth

Topic: Analysis of cross section diagrams relating to Earth's structure.

Activity:



The velocities of seismic waves in the Earth

Originally from The Earth Science Teachers' Association, 'Investigating the Science of the Earth 2: Geological changes – Earth's Structure and Plate Tectonics', redrawn by ESEU.

The graph is a plot of the velocities of P- and S-waves as they penetrate the Earth. Note that it is an unusual graph in that the depth increases downwards. Use this, through discussion, to show that:

- there are no S-waves in the outer core – so this must be a fluid (since fluids don't transmit S-waves); the pressures are so intense at these depths that it cannot be gas, so it must be liquid;
- the inner core must be solid, since it transmits S-waves;
- the rest of the Earth, including the mantle and the crust, must be solid, since they transmit S-waves (contrary to the 'liquid mantle' or 'magma beneath the crust' stories of some textbooks);
- there is a zone near the outer part of the mantle where P-wave and S-waves velocities reduce, this is the Low Velocity Zone (LVZ) or asthenosphere ('weak sphere') which is able to flow plastically over geological time.

The following diagram shows a summary of the 'structure of the Earth' seismic evidence – with the thickness of the upper part of the Earth greatly exaggerated to show:

- the solid lithosphere (crust plus extreme upper mantle – averaging 100 km thick);
- the plastic asthenosphere which can flow;
- the solid rest of the mantle (which due to intense temperatures and pressures, can also flow);
- the liquid outer core;
- the solid inner core.

Depth, km	Compositional (chemical) layering	Mechanical (physical) layering
0	Crust	Lithosphere
mean of 15		
about 100	Mantle	Asthenosphere
about 250		The rest of the mantle

(ESEU)

Notes:

1. The crust has a mean thickness of 35 km beneath continents and 6 km beneath oceans giving an overall mean of about 15 km
2. The Earth's tectonic plates are made of solid, rigid lithosphere (around 100 km thick) comprising the crust (averaging 15 km thick) and the outer part of the mantle. Plastic deformation of the asthenosphere allows the plates to move.
3. Nearly all cross section diagrams of the Earth show the crust very much too thick – since in reality it's thickness on a diagram is less than the thickness of a line in the diagram – a good analogy is a postage stamp stuck on a football.

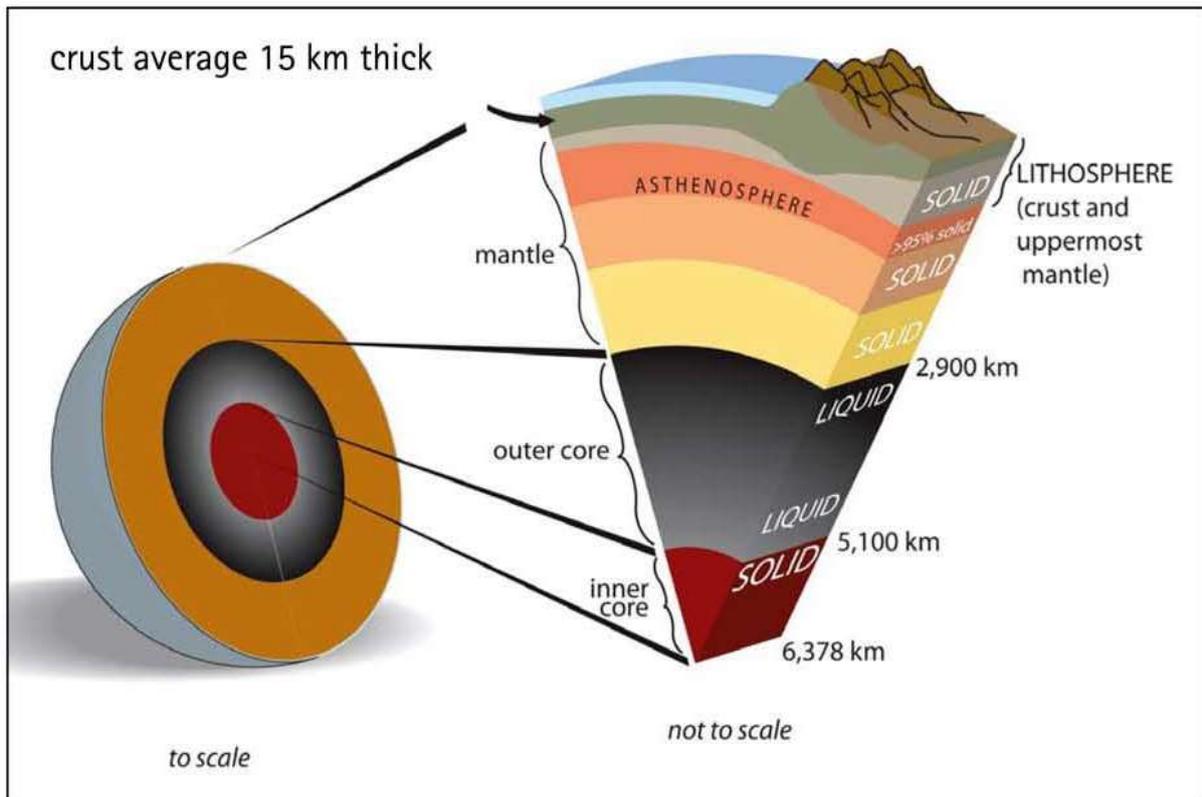


Diagram of the internal structure of the Earth, an example of a diagram showing the crust very much thicker than in reality.

Reproduced with the kind permission of the U.S. Geological Survey, redrawn by ESEU.

Pupil learning outcomes: Pupils can:

- describe the structure of the Earth;
- explain how the seismic evidence can be used to interpret the internal structure of the Earth.

Curriculum references:

England	Scotland	Wales	Northern Ireland
<p>Science KS3 Chemistry – Earth and atmosphere</p> <ul style="list-style-type: none"> the composition of the Earth the structure of the Earth <p>KS4 Science Working scientifically The development of scientific thinking:</p> <ul style="list-style-type: none"> understanding how scientific methods and theories develop over time using a variety of models to develop scientific explanations and understanding <p>Experimental skills and strategies</p> <ul style="list-style-type: none"> using scientific theories and explanations to develop hypotheses. <p>Physics Forces:</p> <ul style="list-style-type: none"> ...elastic and inelastic stretching <p>Geography KS3 Human and physical geography</p> <ul style="list-style-type: none"> physical geography relating to: geological timescales and plate tectonics; rocks, 	<p>Sciences Second Earth's Materials Having explored the substances that make up the Earth's surface, I can compare some of their characteristics and uses. SCN 2-17a</p> <p>Third Processes of the planet By contributing to experiments and investigations, I can develop my understanding of models of matter and can apply this to changes of state and the energy involved as they occur in nature. SCN 3-05a</p>	<p>No direct references</p>	<p>GCSE Geography</p> <p>i) describe the structure of the Earth (core, mantle and crust); (ii) know that the Earth's crust is made up of a number of plates and understand how convection currents cause plate movement; (iii) demonstrate knowledge and understanding of the processes and landforms associated with plate margins:</p> <ul style="list-style-type: none"> constructive plate margins: mid-ocean ridges; destructive plate margins: subduction zone and ocean trench; collision zones: fold mountains; and conservative plate margins: fault lines

Age range of pupils: 12-16

Time needed to complete activity: 5 minutes

Lead in ideas:

Demonstration of P- and S-wave transmission using ESEU activities with a slinky or pupil molecules

Source: Earth Science Education Unit.

Copyright: © Earth Science Education Unit

Preparation and set-up: None

Resources list:

- the diagrams contained in the activity

Risk assessment:

Potentially Hazardous Activity	Who/What may be Harmed?	Hazard Rating (A)	Likelihood (B)	Risk (AxB)	Further Action Required?
The seismic evidence for the structure of the Earth	No significant hazard	-	-	-	No

Hazard Rating (A):

- 1 = Insignificant effect
- 2 = Minor Injury
- 3 = Major Injury
- 4 = Severe Injury
- 5 = Death

Likelihood of occurrence (B):

- 1 = Little or no likelihood
- 2 = Unlikely
- 3 = Occasional
- 4 = Probable
- 5 = Inevitable

Risk Priority (AxB):

- 12-25 = High risk – take immediate action
- 6-11 = Medium risk – take action as soon as possible
- Less than 6 = Low risk – plan future actions where required

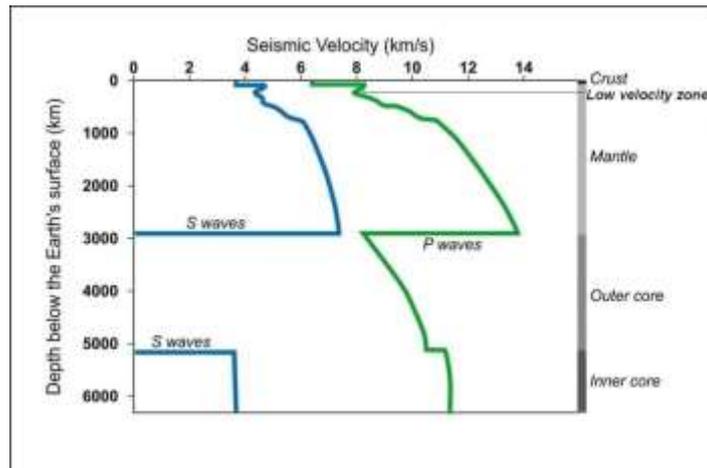
ESEU activity guide sheet:

The seismic evidence for the structure of the Earth

Analysis of cross section diagrams relating to Earth's structure.

The graph is a plot of the velocities of P- and S-waves as they penetrate the Earth. Note that it is an unusual graph in that the depth increases downwards. Use this, through discussion, to show that:

- there are no S-waves in the outer core – so this must be a fluid (since fluids don't transmit S-waves); the pressures are so intense at these depths that it cannot be gas, so it must be liquid;
- the inner core must be solid, since it transmits S-waves;



The velocities of seismic waves in the Earth. Originally from The Earth Science Teachers' Association, 'Investigating the Science of the Earth 2: Geological changes – Earth's Structure and Plate Tectonics', redrawn by ESEU.

- the rest of the Earth, including the mantle and the crust, must be solid, since they transmit S-waves (contrary to the 'liquid mantle' or 'magma beneath the crust' stories of some textbooks);
- there is a zone near the outer part of the mantle where P-wave and S-waves velocities reduce, this is the Low Velocity Zone (LVZ) or asthenosphere ('weak sphere') which is able to flow plastically over geological time.

The following diagram shows a summary of the 'structure of the Earth' seismic evidence – with the thickness of the upper part of the Earth greatly exaggerated to show:

- the solid lithosphere (crust plus extreme upper mantle – averaging 100 km thick);
- the plastic asthenosphere which can flow;
- the solid rest of the mantle (which due to intense temperatures and pressures, can also flow);
- the liquid outer core;
- the solid inner core.

Depth, km	Compositional (chemical) layering	Mechanical (physical) layering
0	Crust	Lithosphere
mean of 15		
about 100	Mantle	Asthenosphere
about 250		The rest of the mantle

(ESEU)

Notes:

1. The crust has a mean thickness of 35 km beneath continents and 6 km beneath oceans giving an overall mean of about 15 km
2. The Earth's tectonic plates are made of solid, rigid lithosphere (around 100 km thick) comprising the crust (averaging 15 km thick) and the outer part of the mantle. Plastic deformation of the asthenosphere allows the plates to move.
3. Nearly all cross section diagrams of the Earth show the crust very much too thick – since in reality it's thickness on a diagram is less than the thickness of a line in the diagram – a good analogy is a postage stamp stuck on a football.

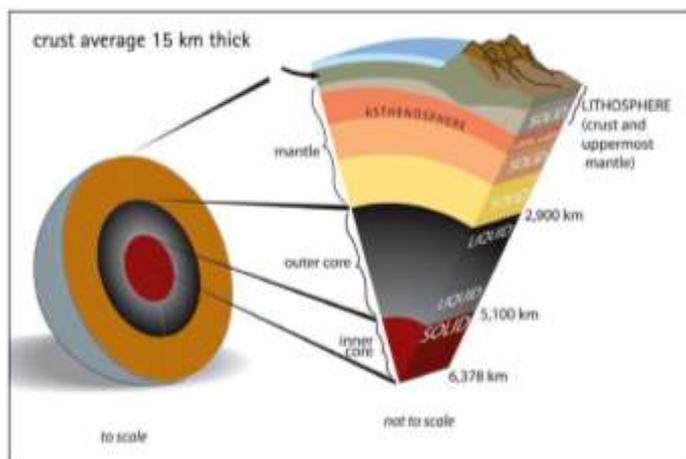
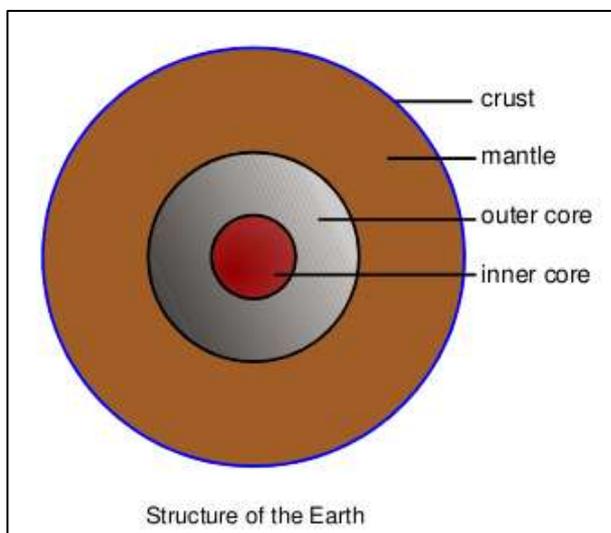


Diagram of the internal structure of the Earth, an example of a diagram showing the crust very much thicker than in reality. Reproduced with the kind permission of the U.S. Geological Survey, redrawn by ESEU.

Activity 6: From an orange to the whole Earth

Topic: Using an orange to model different densities of the Earth's layers.

Activity: This activity uses an orange as a model to show the evidence for the different densities of the Earth's crust and inner layers.

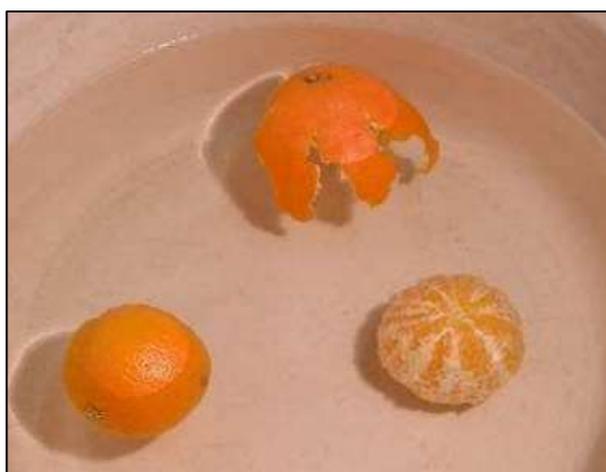


Ask the pupils:

- What will happen when you put a whole orange into a container of water?
- What will happen when you peel the orange and put the orange without its peel into water?
- What will happen when you put the orange peel into the water on its own?
- Then ask the pupils to carry out this investigation.

When they peel the orange, they should try to keep the peel in one piece if possible.

Tell your pupils that scientists can work out that the relative density of the whole Earth is 5.5 but the rocks of the crust of the Earth have a much lower average relative density of about 3.0. This means that the layers inside the Earth must be more dense than the crust, just like the orange.



Oranges and peel in water. (*Elizabeth Devon*)

Pupil learning outcomes: Pupils can:

- realise that one object may be made of layers of different density;
- use a model to demonstrate that the Earth is made of layers of different density.

Curriculum references:

England	Scotland	Wales	Northern Ireland
Science KS3 Working scientifically <ul style="list-style-type: none"> select, plan and carry out the most appropriate types of scientific enquiries to test predictions KS3 Chemistry Earth and atmosphere <ul style="list-style-type: none"> the composition of the Earth the structure of the Earth KS4 The development of scientific thinking: <ul style="list-style-type: none"> using a variety of models to develop scientific explanations and understanding 	Sciences Experiences and outcomes Learning in the sciences will enable me to: <ul style="list-style-type: none"> develop the skills of scientific inquiry and investigation using practical techniques Third Processes of the planet By contributing to experiments and investigations, I can develop my understanding of models of matter and can apply this to changes of state and the energy involved as they occur in nature. SCN 3-05a	Science KS3 Enquiry Pupils should be given opportunities to carry out different types of enquiry, e.g. <i>pattern-seeking, exploring, classifying and identifying, making things, fair testing, using and applying models, by:</i> Planning Pupils decide on the most suitable type of enquiry to carry out and outline the planned approach/method	Science develop skills in scientific methods of enquiry to further scientific knowledge and understanding: planning for investigations GCSE Geography i) describe the structure of the Earth (core, mantle and crust);

Age range of pupils: 10 - 16 years

Time needed to complete activity: 20 minutes

The story for teachers:

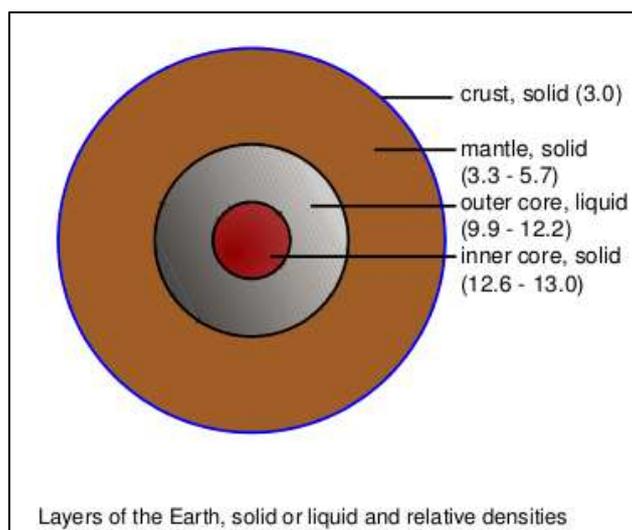
The orange is analogous to the Earth in having a relatively dense centre (mantle/core) and a much less dense skin (crust).

Answers to the questions:

- What happens when the pupils put a whole orange into a container of water?
A. *The whole orange floats. The mass of the orange is less than the mass of the same volume of water.*
- What happens when they put the orange peel into the water?
A. *The orange peel floats because the peel is made of low density, non-absorbent material.*
- What happens when they put the orange without its peel into the water?
A. *The orange without its peel sinks. This is because the mass of the orange is greater than the mass of the same volume of water.*

Notes for teachers:

- the Earth is made of concentric layers of different density ...
- it can be concluded from the overall relative density of the Earth (5.5) that the centre must be more dense than the crust (average relative density about 3.0)



The facts that an orange has an outer layer around its core and the Earth also has an outer layer and a core demonstrates pattern. The whole orange floats while the orange without its peel does not; this can create cognitive conflict. Explanation of the reasons why the whole orange floats but the central core does not involves metacognition. The density of parts of the orange can be related to the density of layers of the Earth; this is bridging.

Lead in ideas: A discussion about different densities of everyday materials could lead into a discussion about the density of the Earth.

Following up the activity:

If equipment is available the pupils could find the mass, the volume and therefore the density of the whole orange, the peel on its own and the orange without its peel.

$$\text{density (gml}^{-1}\text{)} = \frac{\text{mass (g)}}{\text{volume (ml)}}$$

They could be challenged to find out how we know the size and mass of the Earth. (The size is now measured by satellites, but the Earth's circumference was first measured by Eratosthenes in around 250BC by measuring the angle of the Sun at midday on Midsummer's Day at two different points in Egypt, and then measuring the distance between them. His figure was only about 1% in error! The mass of the Earth is calculated using Newton's gravitation equations.)

Try the other Earthlearningidea (<http://www.earthlearningidea.com>) activities related to Earth structure, including: 'A core activity'.

Source: Developed from an activity devised by Abigail and David Brown.

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Preparation, set-up time: 10 minutes

Resource List:

- containers, each large enough to hold an orange floating in water
- some oranges
- water supply

Risk assessment:

Potentially Hazardous Activity	Who/What may be Harmed?	Hazard Rating (A)	Likelihood (B)	Risk (AxB)	Further Action Required?
From an orange to the whole Earth	No significant hazard	-	-	-	No

Hazard Rating (A):

- 1 = Insignificant effect
2 = Minor Injury
3 = Major Injury
4 = Severe Injury
5 = Death

Likelihood of occurrence (B):

- 1 = Little or no likelihood
2 = Unlikely
3 = Occasional
4 = Probable
5 = Inevitable

Risk Priority (AxB):

- 12-25 = High risk – take immediate action
6-11 = Medium risk – take action as soon as possible
Less than 6 = Low risk – plan future actions where required

ESEU activity guide sheet:

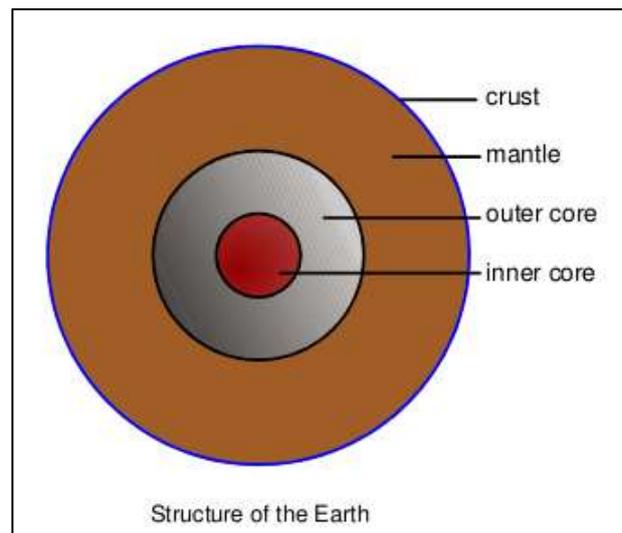
From an orange to the whole Earth

Using an orange to model different densities of the Earth's layers.

This activity uses an orange as a model to show the evidence for the different densities of the Earth's crust and inner layers.

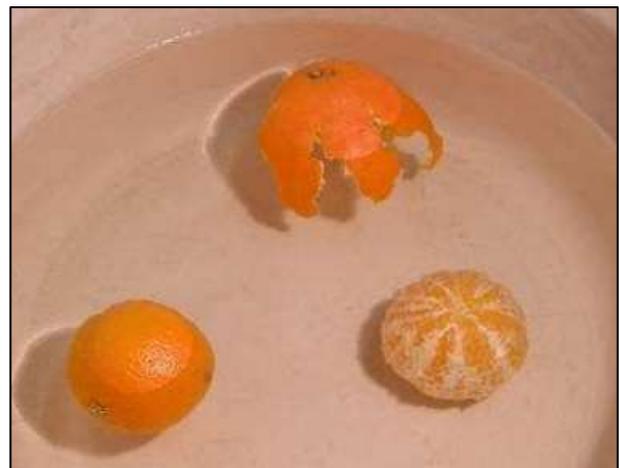
Ask the pupils:

- What will happen when you put a whole orange into a container of water?
- What will happen when you peel the orange and put the orange without its peel into water?
- What will happen when you put the orange peel into the water on its own?
- Then ask the pupils to carry out this investigation.



When they peel the orange, they should try to keep the peel in one piece if possible.

Tell your pupils that scientists can work out that the relative density of the whole Earth is 5.5 but the rocks of the crust of the Earth have a much lower average relative density of about 3.0. This means that the layers inside the Earth must be more dense than the crust, just like the orange.

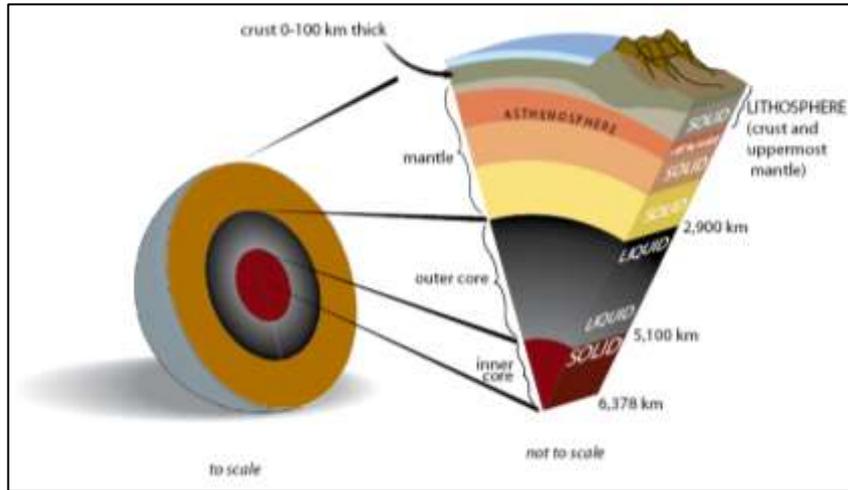


Oranges and peel in water. (Elizabeth Devon)

Activity 7: Journey to the centre of the Earth – on a toilet roll

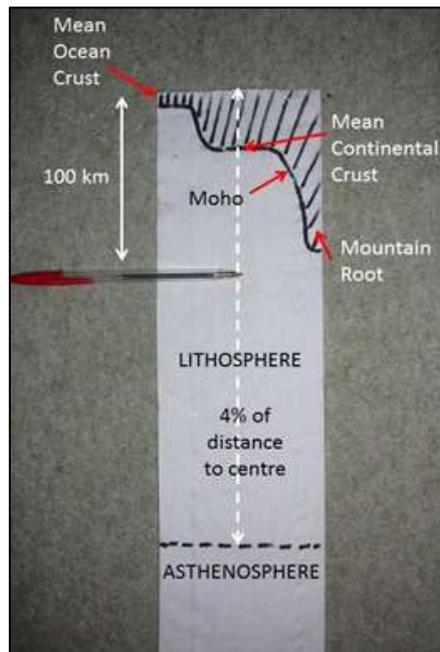
Topic: A scale model of the size of the Earth, emphasising the thinness of the crust and other uppermost layers.

Activity:



Diagrams of the Earth's internal structure, like the one above, are often found in school textbooks. However, although the smaller diagram is drawn to scale, it is difficult to get a feel for the real thickness of the Earth's crust. This crust, of course, provides the basis for our human existence on the planet. The enlarged diagram gives the impression that the lithosphere (the crust and upper mantle) is much, much thicker than it really is.

Use a toilet roll to make a scale 'model' of the structure of the Earth, from its surface to its centre. The Earth's mean radius is about 6400 km. If one sheet of toilet paper is taken to represent 100 km, then 64 sheets will take us to the centre of the Earth. Unroll three sheets and mark them up to represent the outermost layers of the Earth, as shown in the photograph.



The top part of the toilet roll, showing the crust and lithosphere drawn to scale.
 The red pen marks the end of the first sheet. (*Pete Loader*)
 The base of the lithosphere is 2½ sheets down from the top.

Ask a pupil to walk away, slowly unrolling the toilet roll, whilst someone else counts down 29 sheets. Mark the boundary between the mantle and the core at the bottom of sheet 29. Continue unrolling until sheet 51 is reached and mark the boundary between the outer and inner core. Finally, unroll as far as sheet 64, and you

have finished your journey to the centre of the Earth!

A different approach is to give a toilet roll to each small group of pupils and ask them to mark the boundaries for themselves. Whichever method is used, discuss the 'model' with the class and ensure that they have appreciated the true scale of the Earth's different layers.

Pupil learning outcomes: Pupils can:

- visualise the true dimensions of the different layers of the Earth's internal structure;
- gain an idea of the size of the Earth;
- appreciate that the crust is extremely thin, in relation to the rest of the Earth.

Curriculum references:

England	Scotland	Wales	Northern Ireland
<p>Science KS3 Working scientifically</p> <ul style="list-style-type: none"> • select, plan and carry out the most appropriate types of scientific enquiries to test predictions <p>Chemistry Earth and atmosphere</p> <ul style="list-style-type: none"> • the composition of the Earth • the structure of the Earth <p>KS4 Working scientifically The development of scientific thinking:</p> <ul style="list-style-type: none"> • using a variety of models to develop scientific explanations and understanding 	<p>Sciences Experiences and outcomes Learning in the sciences will enable me to:</p> <ul style="list-style-type: none"> • develop the skills of scientific inquiry and investigation using practical techniques <p>Third Processes of the planet By contributing to experiments and investigations, I can develop my understanding of models of matter and can apply this to changes of state and the energy involved as they occur in nature. SCN 3-05a</p>	<p>Science KS3 Enquiry Pupils should be given opportunities to carry out different types of enquiry, e.g. <i>pattern-seeking, exploring, classifying and identifying, making things, fair testing, using and applying models, by:</i></p> <p>Planning Pupils decide on the most suitable type of enquiry to carry out and outline the planned approach/method</p>	<p>Science develop skills in scientific methods of enquiry to further scientific knowledge and understanding: planning for investigations</p> <p>GCSE Geography i) describe the structure of the Earth (core, mantle and crust); (ii) know that the Earth's crust is made up of a number of plates and understand how convection currents cause plate movement</p>

Age range of pupils: 11 – 18 years

Time needed to complete activity: 10 minutes

The story for teachers:

We seldom stop to consider the true scale of many features of the Earth. This activity aims to enable pupils to visualise the thickness of the crust in relation to the rest of the Earth. It also helps them to appreciate the difference in depth between the oceanic crust and the continental crust. It introduces the terms 'lithosphere' and 'asthenosphere' to help in understanding plate tectonic theory.

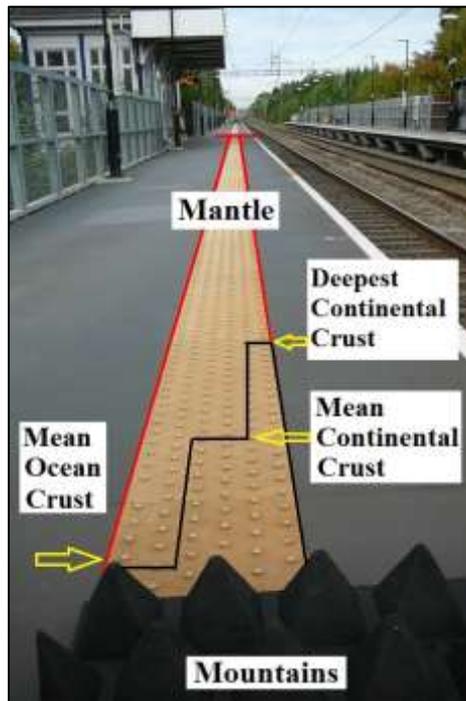
Note these key points.

- The Earth's radius is approximately 6400km (6378km at the Equator and 6357km at the poles, on the slightly flattened sphere which is the Earth).
- The Earth's internal structure is divided into layers, - crust, mantle, outer and inner core.
- The crust is very thin. The mean oceanic crust is about 6km thick. The mean continental crust is about 35km thick. It reaches a maximum beneath some high mountain ranges of about 100km. The overall average crustal thickness is only 0.3% or so of the Earth's radius.
- The junction of the crust and mantle is known as the Mohorovičić Discontinuity ('Moho').
- The crust and upper mantle act as one physical unit, known as the lithosphere, but even this is no more than 250km thick – at most 4% of the total radius of the Earth.

Understanding the true scale of the Earth involves cognitive conflict, when pupils have the standard (often wrongly drawn) diagram in mind. Relating a toilet roll to the whole Earth may require a considerable skill in bridging.

Following up the activity:

- Use any area round the school with regularly spaced floor patterns or paving slabs to count out a similar 'model' of the Earth. See if permission can be gained to mark the boundaries of the Earth's layers as a permanent reminder to the school.



Paving slabs on a railway platform, with labelling superimposed to show the structure of the Earth to scale. (Pete Loader)

- Try the other Earthlearningidea (<http://www.earthlearningidea.com>) activities related to Earth structure, including: 'A core activity'.

Source: Based on an original idea developed at the Geological Society's Geoscience Education Academy 2013 and adapted by Pete Loader.

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Preparation and set-up time:

20 minutes to prepare your own toilet roll, no time if the pupils do it for themselves

Resource List:

- 64 continuous sheets of a toilet roll
- writing materials

Risk assessment:

Potentially Hazardous Activity	Who/What may be Harmed?	Hazard Rating (A)	Likelihood (B)	Risk (AxB)	Further Action Required?
Journey to the centre of the Earth – on a toilet roll	No significant hazard	-	-	-	No

Hazard Rating (A):
 1 = Insignificant effect
 2 = Minor Injury
 3 = Major Injury
 4 = Severe Injury
 5 = Death

Likelihood of occurrence (B):
 1 = Little or no likelihood
 2 = Unlikely
 3 = Occasional
 4 = Probable
 5 = Inevitable

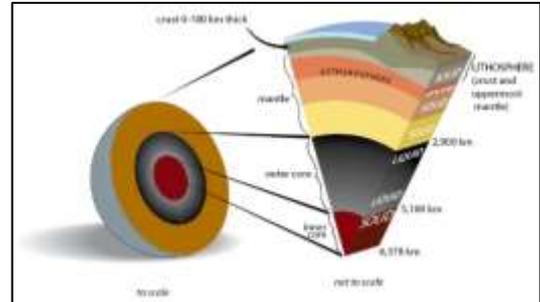
Risk Priority (AxB):
 12-25 = High risk – take immediate action
 6-11 = Medium risk – take action as soon as possible
 Less than 6 = Low risk – plan future actions where required

ESEU activity guide sheet:

Journey to the centre of the Earth – on a toilet roll

A scale model of the size of the Earth, emphasising the thinness of the crust and other uppermost layers.

Diagrams of the Earth's internal structure, like the one opposite, are often found in school textbooks. However, although the smaller diagram is drawn to scale, it is difficult to get a feel for the real thickness of the Earth's crust.

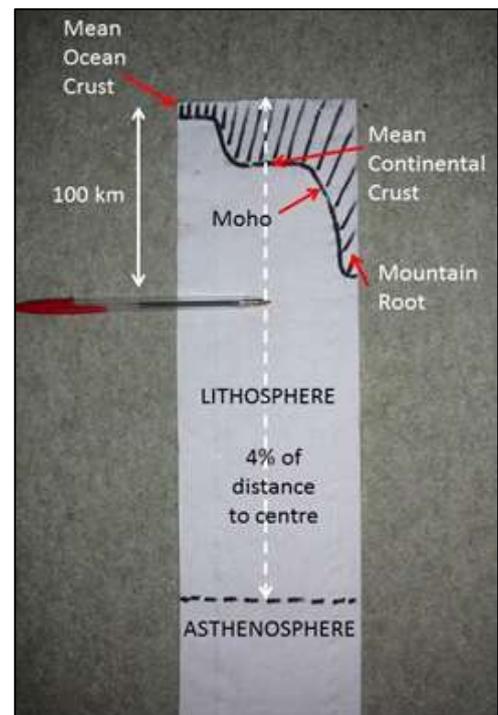


The internal structure of the Earth (ESEU)

This crust, of course, provides the basis for our human existence on the planet. The enlarged diagram gives the impression that the lithosphere (the crust and upper mantle) is much, much thicker than it really is.

Use a toilet roll to make a scale 'model' of the structure of the Earth, from its surface to its centre. The Earth's mean radius is about 6400 km. If one sheet of toilet paper is taken to represent 100 km, then 64 sheets will take us to the centre of the Earth. Unroll three sheets and mark them up to represent the outermost layers of the Earth, as shown in the photograph.

Ask a pupil to walk away, slowly unrolling the toilet roll, whilst someone else counts down 29 sheets. Mark the boundary between the mantle and the core at the bottom of sheet 29. Continue unrolling until sheet 51 is reached and mark the boundary between the outer and inner core. Finally, unroll as far as sheet 64, and you have finished your journey to the centre of the Earth!



The top part of the toilet roll, showing the crust and lithosphere drawn to scale. The red pen marks the end of the first sheet. The base of the lithosphere is 2 ½ sheets down from the top. (Pete Loader)

A different approach is to give a toilet roll to each small group of pupils and ask them to mark the boundaries for themselves. Whichever method is used, discuss the 'model' with the class and ensure that they have appreciated the true scale of the Earth's different layers.

Activity 8: From magnetic globe to magnetic rock evidence

Topic: A Plasticine™ ball containing a magnet is used to demonstrate how the inclination of the Earth's magnetic field is related to latitude, and how this can then be used to discover the latitude of rocks at the time when they formed.

Activity:

a) A model magnetic Earth

- Take the solid sphere of Plasticine™ containing a bar magnet.
- Use a Magnaprobe™ (or a plotting compass or a magnetised needle on a thread) to locate the North and South Poles (the places where the probe points vertically to the surface of the sphere) and mark these positions by pushing the matchsticks into the Plasticine™ vertically at these points.
- Use the Magnaprobe™ to locate the magnetic equator (where the probe is horizontal to the surface of the globe) and mark the position using another matchstick pushed into the Plasticine™ parallel with the surface.
- Use the Magnaprobe™ along a 'line of longitude' (a line joining the North and South poles) to find out the varying angle of magnetic dip. Mark the angle at about nine points by pushing in matchsticks parallel to the Magnaprobe™ magnet. The result should look like the diagram below.

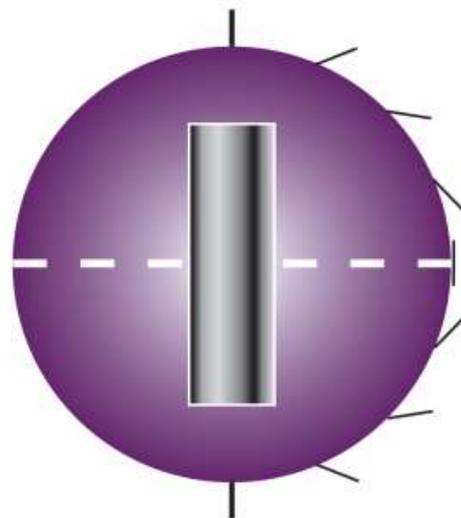
This activity indicates the **inclination** of the Earth's magnetic field at different latitudes (the dip of the Earth's magnetic field, as measured using a freely floating needle or a dip needle), it is vertical at the poles, horizontal at the Equator and dips at different angles in between.

You can test student understanding of what they have seen by asking them by how many degrees a magnet would rotate through, in being carried from the North Pole to the South Pole. Many will answer that the angle is 180 degrees, not realising that it would rotate through 180° from the North Pole to the Equator and a further 180° to the South Pole, a total of 360° .

Note that this activity demonstrates the magnetic field around a bar magnet hidden inside a sphere of Plasticine™; it only gives a rough idea of what the magnetic field of the Earth is like. The Earth's magnetic field is probably caused by currents in the outer core; the Earth certainly does not have an enormous bar magnet in the middle!



Model magnetic Earth (ESEU)



Model of the Earth's magnetic field (ESEU)

b) Preserving remanent magnetisation



'Petri-dish magnetic field preserved in iron filings in wax' (Michèle Bourne, ESEU)

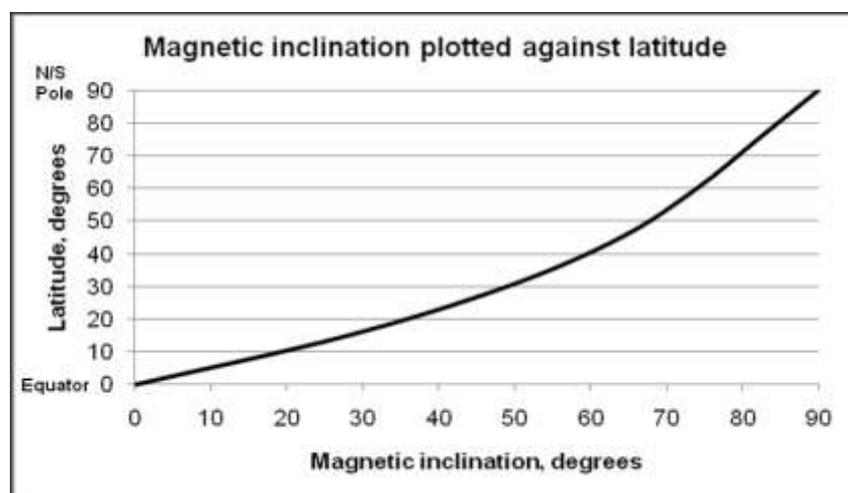
Demonstrate how magnetism can be preserved using the pre-prepared petri-dish of wax with iron filings, cooled in the presence of the magnet. The dish has clearly preserved the magnetic field of the magnet as it solidified. It doesn't matter how much the dish is later moved, the 'remanent magnetisation' of the magnet is still preserved.

Explain that when molten rocks containing magnetic elements (like iron minerals) cool, they take on and preserve any magnetic field in which they cool down. As all such rocks cool in the Earth's magnetic field, they preserve the inclination of the Earth's magnetic field at the time; this is the remanent **magnetisation** of the rocks.

This is most common when basalt lavas cool at the Earth's surface, since basalts are rich in iron. Ask the students, if a basalt had a remanent magnetisation with a vertical inclination, where must it have been formed? *A. At one of the two poles.* Then ask, if it had a horizontal inclination, where must it have formed? *A. At the equator.*

Ask the students the meaning of this data from outcrops of rock in the UK:

- A rock of Precambrian age, about 1000 million years old (Ma) has vertical inclination (North up), corresponding to a former latitude at the South Pole.
- A rock of Carboniferous age (300 Ma) has horizontal polarity, corresponding to a former equatorial latitude.
- A red sandstone of Triassic age (220 Ma) has a gently inclined polarity (North down) corresponding to tropical northerly latitudes.
- *The data show the plate tectonic movement of the UK over geological time.*
- Finally ask, if a basalt lava formed and cooled in the UK today, latitude between 50 and 60°N (this is geologically highly unlikely), what magnetic inclination might the preserved magnetism have?
- *The answer can either be measured from the graph below or shown using the Magnaprobe™ to be around 70°.*



Pupil learning outcomes: Pupils can:

- describe how a Magnaprobe™ can be used to detect and mark a magnetic field;
- describe how a Plasticine™ ball with a magnetic field indicated shows magnetic field lines in three dimensions;
- explain how the ball provides an analogy with the magnetic field of the Earth;
- explain how the magnetic field of the time can be 'fossilised' in cooling magnetic rocks;
- explain how remanent magnetism in rocks can be used to show the latitude at which they formed;
- explain how this evidence can be used to support plate tectonic theory.

Curriculum references:

England	Scotland	Wales	Northern Ireland
<p>KS3 Science Working scientifically Several aspects of Working Scientifically may be developed in this activity.</p> <p>Chemistry Earth and atmosphere</p> <ul style="list-style-type: none"> • the composition of the Earth • the structure of the Earth <p>KS3 Physics Forces Magnetism</p> <ul style="list-style-type: none"> • magnetic poles, attraction and repulsion. • magnetic fields by plotting with compass, representation by field line. • Earth's magnetism, compass and navigation <p>KS4 Science Working scientifically Several aspects of Working Scientifically may be developed in this activity.</p> <p>Physics Magnetism</p> <ul style="list-style-type: none"> • exploring the magnetic fields of permanent and induced magnets, and the Earth's magnetic field, using a compass. 	<p>Sciences Forces, electricity and waves First By exploring the forces exerted by magnets on other magnets and magnetic materials, I can contribute to the design of a game. SCN 1-08a</p> <p>Second I have collaborated in investigations to compare magnetic, electrostatic and gravitational forces and have explored their practical applications. SCN 2-08a</p> <p>Second Forces I have collaborated in investigations to compare magnetic, electrostatic and gravitational forces and have explored their practical applications. SCN 2-08a</p> <p>Earth's Materials Having explored the substances that make up the Earth's surface, I can compare some of their characteristics and uses. SCN 2-17a</p> <p>Third Processes of the planet By contributing to experiments and investigations, I can develop my understanding of models of matter and can apply this to changes of state and the energy involved as they occur in nature. SCN 3-05a</p> <p>Geography People, place & environment Second I can describe the major characteristic features of Scotland's landscape and explain how these were formed SOC 2-07a.</p> <p>Third Having investigated processes which form and shape landscapes, I can explain their impact on selected landscapes in Scotland, Europe and beyond. SOC 3-07a</p> <p>I can use a range of maps and geographical information systems to gather, interpret and present conclusions and can locate a range of features within Scotland, UK, Europe and the wider world. SOC 3-14a</p>	<p>Science KS2</p> <ul style="list-style-type: none"> • forces of different kinds, e.g. gravity magnetic and friction 	<p>GCSE Geography i) describe the structure of the Earth (core, mantle and crust)</p>

Age range of pupils: 11-16 years

Time needed to complete activity: 10 – 15 minutes

The story for teachers:

Recognition of the magnetic pattern shown by the matchsticks is a pattern-seeking activity. Finding the equator is a challenge, and relating the activity to the real world involves bridging skills.

Lead in ideas: Ideas for leading into the activity:

You could set up this activity by asking these questions:

- In which direction does the needle of a magnetic compass point? *A. The needle of a magnetic compass is constrained by its pivot and can only point north-south.*

- If you could hang a magnet from its centre of mass by a piece of cotton, in which direction would you expect it to point? Why? *A. A dip circle or a freely suspended magnet (so long as it is suspended at the centre of mass) will point north-south but will also dip down into the ground. In the UK, this is around 70°; this can be demonstrated using the Magnaprobe™ later.*
- Why wouldn't it point in the same direction as the needle of a magnetic compass? *A. Because the needle of a magnetic compass has one end weighted so that it remains horizontal in the Earth's 3D magnetic field; for this reason, magnetic compasses designed for use in the Northern Hemisphere do not work in the Southern Hemisphere because the wrong side of the magnetic needle is weighted for Southern Hemisphere work.*
- The needle of the magnetic compass is a magnet. Is the red end of the compass that points northward a south pole or a north pole? *A. The 'red end' is a south pole that is attracted to the Earth's north magnetic pole; it can also be called a north-seeking pole.*

Following up the activity:

Follow up this activity by asking this question:

- Most Ordnance Survey maps of the UK state that the 'magnetic variation' is changing slightly from year to year. Magnetic variation is the angle between the true North Pole and the Magnetic North Pole, which is in a different place. How does this information tell you that the Earth's magnetic field is NOT caused by a bar magnet buried deep within it? *A. Ordnance Survey maps show the magnetic variation from Grid North, but also state the rate at which it is changing. The change indicates that there is something dynamic inside the Earth and not a solid lump of iron like a bar magnet!*

Source: Taken from ESEU's 'Model Earth – Plasticine™ balls' activity and from 'What is the Earth's Magnetic Field Like?' in ESEU's workshop publication 'Through the Lab Window to the World: teaching KS3 physics through an Earth context'

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Preparation and set-up:

It takes a few minutes to make the Plasticine™ ball containing a magnet, plus a few minutes to prepare the petri-dish, as described below.

Resource List:

a) a model magnetic Earth

- a strong bar magnet, enclosed as centrally as possible in a large solid sphere of Plasticine™ (e.g. a 7cm magnet in a 12cm diameter sphere)
- a Magnaprobe™ (tiny magnet suspended in gimbals – currently around £10 each) a plotting compass or a magnetised needle hanging from a thread
- 15 spent matchsticks

b) preserving remanent magnetisation

- a pre-prepared plastic petri dish into which molten candlewax has been poured, iron filings have been sprinkled on the surface, the dish has been placed on top of a bar magnet, and the wax allowed to solidify, thus preserving the shape of the magnetic field in the pattern of the iron filings

Risk assessment:

Potentially Hazardous Activity	Who/What may be Harmed?	Hazard Rating (A)	Likelihood (B)	Risk (AxB)	Further Action Required?
From magnetic globe to magnetic rock evidence	No significant hazard	-	-	-	No

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ESEU activity guide sheet:

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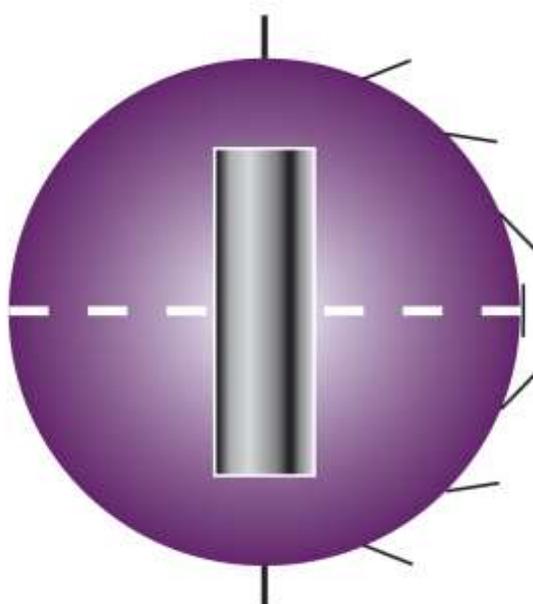
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Model of the Earth's magnetic field (ESEU)



Marking the points and direction of magnetism using cocktail sticks (ESEU)

b) Preserving remanent magnetisation



'Petri-dish magnetic field preserved in iron filings in wax' (Michèle Bourne, ESEU)

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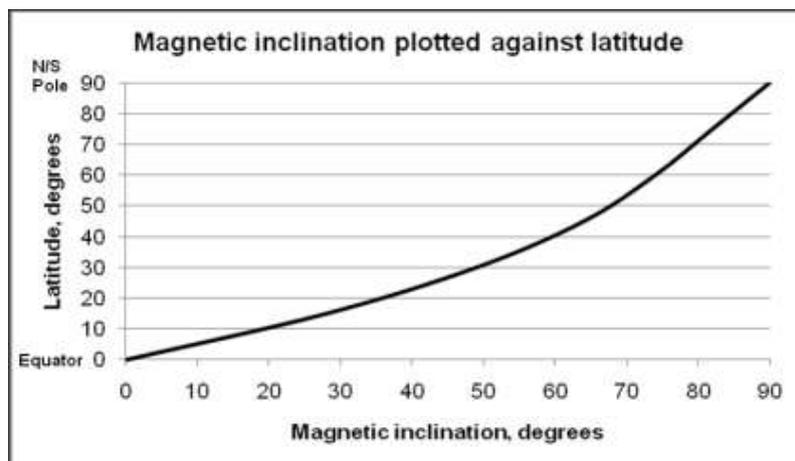
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Resource list

Resource list: Activity 1: Model Earth – plasticine™ spheres	Supplied By	
	Facilitator	Institution
One per small group:		
<ul style="list-style-type: none"> a pair of Plasticine™ spheres per group of students; these are identical-looking pairs of Plasticine™ spheres, except that one sphere is Plasticine™ alone; the other has a ball bearing or similar dense object in its centre - try to ensure that the diameter of the ball bearing is approximately half that of the Plasticine™ which surrounds it, to model the correct proportions of the Earth's interior. 	✓	
<ul style="list-style-type: none"> a pin 	✓	

Resource list: Activity 2: Earthquakes - the slinky simulation	Supplied By	
	Facilitator	Institution
One set:		
<ul style="list-style-type: none"> a slinky spring (or several for use by groups in the class); if possible, glue a few coloured spots on the central coils, or paint white spots on with Tippex™ to emphasise the movement of the spring 	✓	

Resource list: Activity3: Wave motion – student molecules	Supplied By	
	Facilitator	Institution
One set:		
<ul style="list-style-type: none"> four or five willing individuals 	N/A	

Resource list: Activity 4: Properties of the mantle – potty putty™	Supplied By	
	Facilitator	Institution
One set:		
<ul style="list-style-type: none"> Potty Putty™ (or Silly Putty™) a silicone polymer available from toy shops 	✓	
'Recipe for making 'Potty putty' from PVA glue and borax using the recipe that can be found on http://www.esta-uk.net/jesei/index.htm		
<ul style="list-style-type: none"> 20 cm³ PVA glue (not a rubberized variety from DIY shops, a simple glue as often used in school art rooms). 	N/A	
<ul style="list-style-type: none"> a few cubic centimetres of dilute sodium tetraborate solution (borax) (approximately 25 ml). 	N/A	
<ul style="list-style-type: none"> a small beaker or other container in which to mix the potty putty 	N/A	

Resource list: Activity 5: The seismic evidence for the structure of the Earth	Supplied By	
	Facilitator	Institution
One set:		
<ul style="list-style-type: none"> the diagrams contained in the activity 	✓	

Resource list: Activity 6: From an orange to the whole Earth	Supplied By	
	Facilitator	Institution
One set:		
<ul style="list-style-type: none"> containers, each large enough to hold an orange floating in water 	✓	
<ul style="list-style-type: none"> some oranges 	✓	
<ul style="list-style-type: none"> water supply 		✓

Resource list: Activity 7: Journey to the centre of the Earth – on a toilet roll	Supplied By	
	Facilitator	Institution
One set:		
<ul style="list-style-type: none"> 64 continuous sheets of a toilet roll 	✓	
<ul style="list-style-type: none"> writing materials 	✓	

Resource list: Activity 8: From magnetic globe to magnetic rock evidence	Supplied By	
	Facilitator	Institution
One set:		
a) a model magnetic Earth		
• a strong bar magnet, enclosed as centrally as possible in a large solid sphere of Plasticine™ (e.g. a 7cm magnet in a 12cm diameter sphere)	✓	
• a Magnaprobe™ (tiny magnet suspended in gimbals – currently around £10 each) a plotting compass or a magnetised needle hanging from a thread	✓	
• 15 spent matchsticks		
b) preserving remanent magnetisation		
• a pre-prepared plastic petri dish into which molten candlewax has been poured, iron filings have been sprinkled on the surface, the dish has been placed on top of a bar magnet, and the wax allowed to solidify, thus preserving the shape of the magnetic field in the pattern of the iron filings	✓	