NATIONAL SCIENCE & ENGINEERING WEEK

nsew.org.uk

Genius inventions

Includes organisers' notes

Part of the British Science Association's National Science & Engineering Week activity pack series. **www.nsew.org.uk**

BIS Department for Business Innovation & Skills

BRITISH SCIENCE ASSOCIATION

Organisers' introductory notes

One of the defining characteristics of the human race is our thirst for knowledge. We continuously push ourselves to learn and achieve more. Ambition and innovation have filled human history with inventions and discoveries, which shape our lives today.

As an introductory exercise:

1. Challenge students to consider an everyday household item that they have used recently.
2. Ask them to do some brief research on how the item works and list the materials/technological components that make it up.
3. Ask students to discuss the separate inventions and discoveries that are behind each part of their chosen item.
4. Use this activity to introduce the idea that behind one invention lies an entire evolution of other inventions and discoveries, all of which link together to form a path in history.
5. Discuss how links between inventions and improvements to existing inventions can lead to revolutionary new products. You could use the evolution of communication and telecommunication technology to illustrate this. You can find descriptions of the evolution of communication throughout history at these websites: http://myxqq.blogspot.co.uk/2011/08/evolution-of-communication-infographic.html and http://library.thinkquest.org/26451/

About this pack

In this pack, you will explore some of the inventions and discoveries that have had a significant impact on the human race. Discussions and experiments will be complemented by Twig Science films and quizzes to give you a thorough understanding of these scientific breakthroughs.

Contents

These activities are designed for Key Stage 3 and 4 students (Levels 2 – 4 CfE). They can be carried out individually or in small groups, either on a standalone basis or as part of a session. The key in every activity is to get students thinking about the invention or discovery and sharing their ideas.

When undertaking any of the activities in this pack, first read through the instruction sheet to familiarise yourself with the experiments. Check the resources list and ensure that everything required is available. Make sure that students understand the activity and the idea behind it. There are organisers' notes at the end of each activity section that give information on equipment and science/ engineering principles.

CREST Awards

Activities 4 and 5 have extension activities that can count towards a Crest Award.

Could your students gain a CREST Award?

By extending the activities included here, or communicating them as part of a project, students could gain a CREST Bronze or maybe even a Silver Award.

CREST is Britain's largest national award scheme for project work in the STEM subjects (Science, Technology, Engineering and Mathematics). It gives young people aged 11-19 opportunities to explore **real world projects** in an exciting way. CREST **links closely to the curriculum** and is a great way to make STEM **creative and engaging** – both in and out of the class.

CREST Awards are extremely flexible – they can link into **work experience placements**, after-school clubs or several **linked schemes**. Some projects might be done in one day – others over several months. Students can **investigate** or **design and make**, **research** a subject, or design a **science communication** project.

CREST Awards are available at Bronze, Silver and Gold levels, depending on the amount and depth of work the student carries out. Bronze Awards need around 10 hours of project work and are usually completed by 11 to 14 year-olds.

In taking part in activities from this booklet students will already be demonstrating many of the skills they need to obtain a CREST Award, including working systematically, solving problems creatively and presenting work to others. Students participating in the 'Inventions that changed the world' activities may therefore be eligible to apply for a CREST Bronze Award. A CREST awards logo is used in the booklet next to sections which might provide ideas for a CREST award.

It is worth linking activities with a CREST Award for several reasons:

- It is a way of having project work recognised nationally – a Bronze CREST Award is a significant achievement.
- It provides evidence of problem-solving skills and motivates students to go on to CREST at Silver and Gold level.
- It can form part of a Progress File and can help with university applications later on.
- It motivates students of all ages and abilities.
- It develops students' understanding of 'how science works', preparing them for GCSE studies.

What do I/we need to do?

You can register your students for the Bronze CREST Awards through your local CREST coordinator. For more information and contact details call the British Science Association on 020 7019 4943 or go to www.britishscienceassociation.org/crest.

Health and safety

A risk assessment should always be carried out before starting any practical work. Specific considerations are also suggested in each of the activities.

Curriculum links

As each activity has a different content focus, targeted curriculum links will be given at the end of each activity section. However by the nature of invention and discovery, the activity pack as a whole also covers the following areas of the KS3 and KS4 curricula:

England KS4: How Science Works

1.1 Data, evidence, theories and explanations
1.2 Practical and enquiry skills
1.3 Communication skills
1.4 Applications and implications of science

Wales KS3: Skills – communication, enquiry, planning, How things work

Activity 1: Inventing the telescope

Telescopes let us see remote objects by collecting light. Since 1608, they have provided pictures of the Universe and helped us to better understand the science behind it. In this activity, students will understand how refractor telescopes work and build one of their own.

1. The history of telescopes

This 3-minute Twig Science film introduces the idea of telescopes.

All films in this activity pack are available for free from Twig exclusively for NSEW 2013.

Twig is an award-winning online resource with thousands of tailor-made films that bring subjects to life. Twig uses engagement and wonder to deliver deep-seated understanding.

You can sign up for a free 3-week trial of Twig for your school at www.twig-world.com quoting the voucher code REFBSA2013.

Students should then discuss the following questions:

- What are telescopes?
- What are they used for?
- How have telescopes evolved over time?
- How have telescopes changed our understanding of space?
- Why do scientists want to understand space?

The rest of the activity will allow students to investigate the workings of convex and concave lenses and build a refractor telescope.

2. How do convex lenses work?

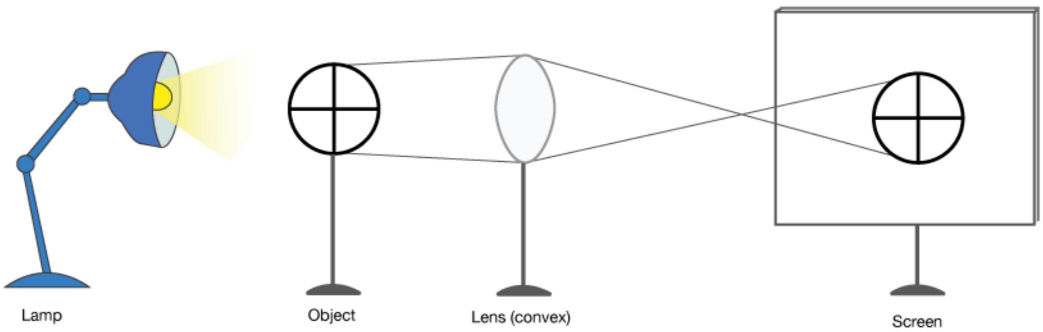
This experiment demonstrates how a convex lens works. Convex lenses are thicker in the middle than at the edges and converge light to form a real or virtual image. In this experiment, you will verify the focal length of a convex lens, which is a measure of how powerful the lens is. If parallel rays are incident on the lens, the focal length is the distance from the lens at which all of the rays meet.

You will need:

- A convex lens with focal length 30cm
- An object
- A desk lamp
- A white screen
- A ruler

Health and safety:

Desk lamps can get hot so avoid touching the bulb while switched on. The bright light from the bulb can also damage eyes so do not look directly into it.



What you need to do:

1. Set up the equipment so that the convex lens is 50cm in front of the object, which is lit from behind by the desk lamp.
2. Place the white screen another 50cm in front of the convex lens.
3. You should see an image of the object appear on the screen. Move the screen further from the lens until the image is sharpest and write down the distances between the object and lens and the lens and screen.
4. Move the object towards and away from the lens, each time readjusting the screen to produce the sharpest image. Write down the distances between the object and lens and the respective distances between the lens and screen.

5. Plot a graph of your results and find the focal length of the lens using the lens maker's formula. Draw the associated ray diagram by noting on a diagram the path light takes from the lamp, through the lens and onto the screen.
6. Discuss the impact of the convex lens in the setup.

3. How do concave lenses work?

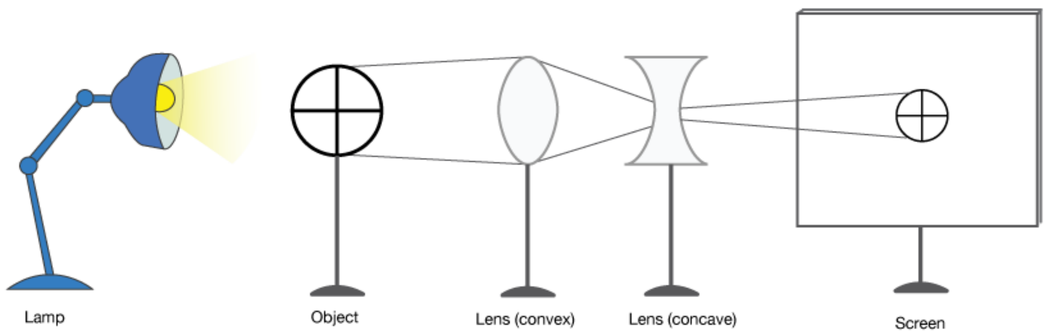
This experiment demonstrates how a concave lens works. Concave lenses are thinner in the middle than at the edges and diverge light to form a virtual image. In this experiment, you will assess the role of a concave lens in a basic telescope.

You will need:

- A convex lens with focal length 30cm
- A concave lens with focal length 5cm
- An object
- A desk lamp
- A white screen
- A ruler

Health and safety:

Desk lamps can get hot so avoid touching the bulb while switched on. The bright light from the bulb can also damage eyes so do not look directly into it.



What you need to do:

1. Set up the equipment as in experiment 1, with the convex lens 50cm in front of the object and the white screen at the focal point at 30cm. The image should be sharp at this distance.

2. Position the concave lens between the convex lens and the screen, around 25cm from the convex lens.
3. Adjust the position of the screen until the image produced is sharpest and note down the new distance between the convex lens and screen. How has this changed?
4. Move the concave lens towards and away from the convex lens, each time readjusting the screen to produce the sharpest image. What effect does this have on the setup?
5. Discuss the impact of the concave lens in the setup and draw the associated ray diagram.

4. Building a refractor telescope

This experiment demonstrates how to build a refractor telescope, which is based on the ability of lenses to refract light. You will use convex and concave lenses in a similar way to experiment 3, in order to collect incoming light and magnify distant objects

You will need:

- Two cardboard tubes, each of length 20cm – one should be able to slide inside the other
- A convex lens with focal length 30cm – this is the objective lens
- A concave lens with focal length 5cm – this is the eyepiece lens
- Two pieces of corrugated cardboard, larger than the lenses
- A blade/scissors, tape and glue

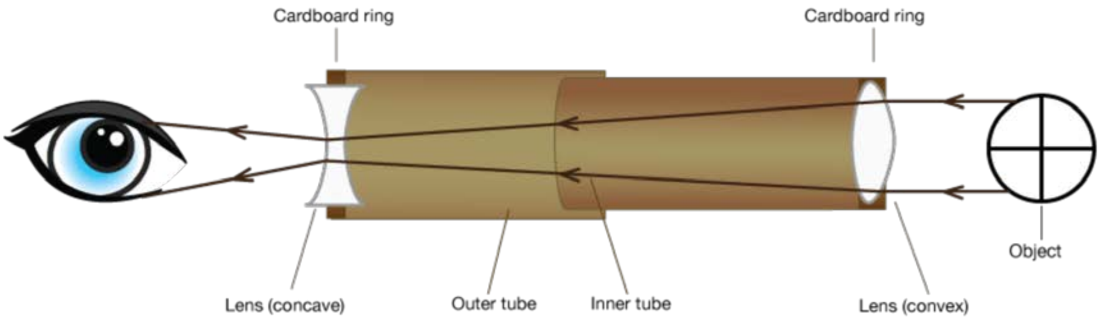
Health and safety:

Never point the telescope directly towards the Sun. Its magnified rays can result in blindness and may also damage the lenses in the telescope. Be careful when handling any blade/scissors in the classroom.

What you need to do:

1. Put one of the lenses on a large piece of corrugated cardboard and draw a circle around it. Cut the circle out using the blade/scissors and fit the lens into the resulting hole, using glue if this is needed to hold them in place.
2. Repeat with the other lens on the second piece of cardboard. You should now have two pieces of cardboard with lenses in the middle of each.

3. Now trim the cardboard around the convex lens so that it is the same diameter as the larger outer tube i.e. so that the cardboard fits into the outer tube perfectly.
4. Trim the cardboard around the concave lens so that it is the same diameter as the smaller inner tube i.e. so that the cardboard fits into the inner tube perfectly.
5. Glue each ring onto the end of its respective tube and slide the inner tube into the outer tube.
6. The telescope is complete! Look through the eyepiece lens and focus on distant



objects by sliding it towards the objective (convex) lens.

Organisers' notes

Top Tip!

- If you don't have two cardboard tubes that fit the size of your lenses, try making them out of card, scissors and tape. Roll the card lengthways into a tube shape, cutting off any excess material. Then tape the edges together
- You can also buy telescope making kits from various online sources (approx. £3-5 per kit) e.g. http://www.astromediashop.co.uk/Kits.html Note that with some kits, two convex lenses are used – the telescope still works, but the image will be upside down!
- Examples of ray diagrams for the convex and concave lens experiments can be found online to use as templates e.g. http://www.bbc.co.uk/schools/gcsebitesize/science/edexcel/visiblelight_solarsystem/telescopesrev1.shtml

Optional discussion: reflector telescopes over refractor telescopes

- Using lenses in refractor telescopes has significant disadvantages. Large glass lenses are difficult to make without imperfections and as lenses are made bigger they can deform under their own weight. Also, different wavelengths of light can be affected differently when they pass through the glass so this has to be corrected for, and some wavelengths, like ultraviolet, are blocked completely.
- Reflector telescopes use curved mirrors instead. These collect light over a wide area and focus it to produce an image. The advantage of this is that it is far easier to make a large curved mirror than to make a large polished lens with no imperfections. The largest lens used is around 1m; the largest mirrors exceed 8m.

Did you know?

- Galileo Galilei, the father of modern astronomy, used the refractor telescope to observe the phases of Venus and prove that the Earth is not the centre of our Solar System. You can read a little more about Galileo here and see stunning images of how telescopes have changed our view of the Universe: http://www.scientificamerican.com/article.cfm?id=ten-telescopes-galileo.
- As well as optical telescopes, there are other types of telescope that can detect radio waves, infrared, ultraviolet, X-rays and gamma rays from distant objects. Some of these are stationed on the Earth's surface, such as the Very Large Array in New Mexico, while some are located outside the Earth's atmosphere for a clearer picture, such as the Hubble Space Telescope, which brought us images such as these: http://www.spacetelescope.org/images/
- To look deep into space, visible light is no longer good enough. Images are built up using light of different wavelengths, which give us an insight into some of the most distant astronomical bodies and the origins of the Universe.

Curriculum links

This activity contributes towards the following curriculum outcomes.

England KS3:	3.4 The environment, Earth and universe b. astronomy and space science provide insight into the nature and observed motions of the sun, moon, stars, planets and other celestial bodies
CfE Third Level:	SCN 3-11a By exploring the refraction of light when passed through different materials, lenses and prisms, I can explain how light can be used in a variety of applications
CfE Fourth Level:	SCN 4-06a By researching developments used to observe or explore space, I can illustrate how our knowledge of the universe has evolved over time

Activity 2: Flying to the Moon

A great deal of science and innovation was used in putting man on the Moon. In this activity, students experience first-hand the obstacles scientists needed to overcome.

1. How did we get to the Moon?

This 3-minute Twig Science film tells the story of how scientists were able to send the Apollo 11 rocket, Buzz Aldrin and Neil Armstrong, to the surface of the Moon in 1969.

All films in this activity pack are available for free from Twig exclusively for NSEW 2013.

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Students should discuss the various difficulties encountered in sending a rocket to the Moon, which include:

- Issues with finding funding
- The expense of finding and training astronauts
- How to achieve high enough speeds to escape Earth's gravity
- How to control the direction of travel to reach an exact landing site
- Being able to land safely

In this activity students will undertake a series of practical activities that allow them to consider three of the key features of a rocket journey.

2. Launching a balloon rocket – achieving speed to leave Earth

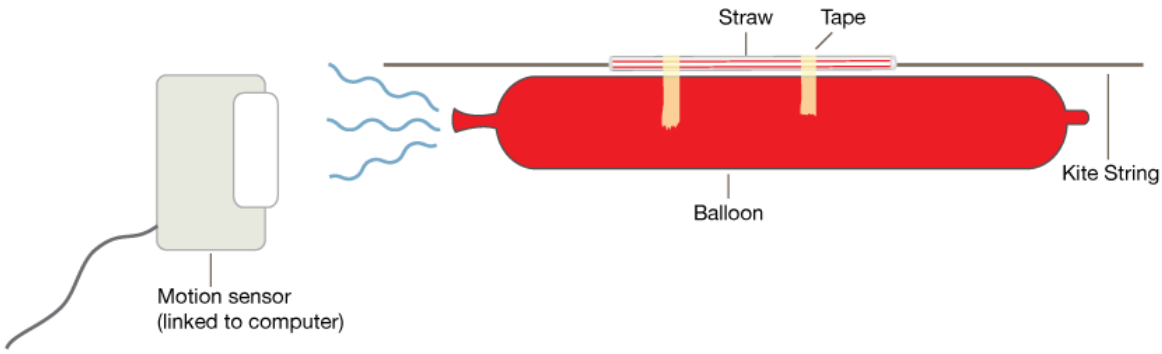
This experiment demonstrates the launch of a simple balloon rocket. The expulsion of air from the balloon forces it to fly. Can your group launch the balloon the fastest and make it travel the furthest?

You will need:

- A balloon
- A motion sensor with data logger
- A long piece of kite string
- A plastic straw
- Tape

What you need to do:

1. Tie one end of the string to a support such as a doorknob, chair, etc, with the motion sensor placed under it.
2. Thread the other end of the string through a straw.
3. Pull the string tight and tie it to a support on the other side of the room at the same height.
4. Blow up the balloon, pinch its end and tape the body to the straw.
5. Let go of the balloon and watch the rocket fly! Note down the speed and distance travelled from the data logger.



3. Launching a rocket - using precision to reach your destination

This experiment demonstrates the precision required to launch a rocket successfully. In reality, a rocket needs to break out of Earth's orbit and reach the Moon without overshooting. Can your group launch the balloon with the right speed to reach a destination without flying past it?

You will need:

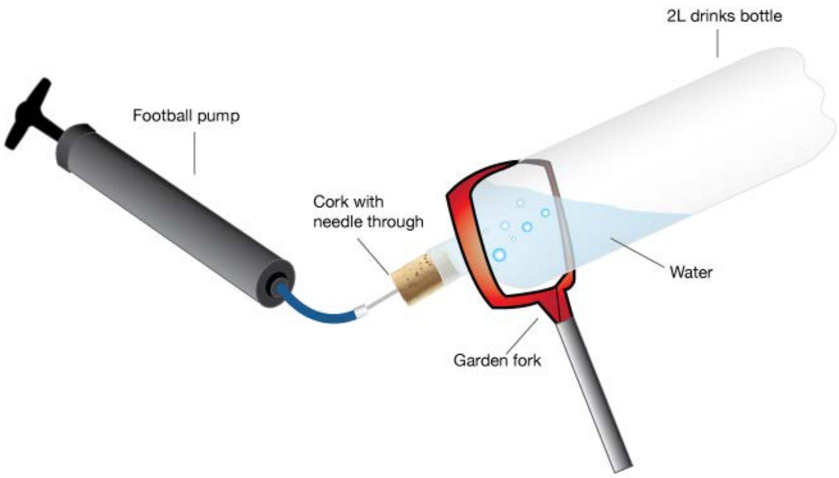
- A balloon
- A motion sensor with data logger
- A long piece of kite string
- A plastic straw
- Tape

What you need to do:

1. Set up the equipment as in experiment 1, but this time with the string angled slightly upwards.
2. Choose a point along the string and mark it – this will be your proposed destination.
3. Launch the balloon with the aim of making it stop on the mark. You will need to carefully judge the launch speed and distance of travel.
4. Consider the effects of gravity now that the string is angled upwards.

4. Launching a water rocket – overcoming gravity

This experiment ramps up the excitement with the launch of a water rocket. It is designed to be a teacher demonstration. By pumping air into a sealed plastic bottle, the pressure builds up until the bottle launches off the ground. You will observe the force with which the rocket leaves the ground and the pull of gravity on the bottle.



You will need:

- A 2-litre plastic drinks bottle
- A cork that fits snugly in the bottle neck
- A football pump with associated needle
- Something to hold the bottle upside down at an angle to the ground, e.g. the handle of a garden fork or a specially purchased launch pad
- 500ml of water

Health and safety:

The bottle is launched with a lot of force, so it should be angled away from people and fired into a deserted area. Students should stand back and let the teacher operate the rocket. Beware of the ejected cork when the bottle takes off.

What you need to do:

1. Construct a launch pad that holds the bottle upside down and lets you stand behind.
2. Fill the empty bottle with 500ml of water and seal it with the cork.
3. Pierce the cork with the pump needle, such that it feeds into the bottle.
4. Place the bottle on the launch pad and begin to pump air into it, keeping the bottle as steady as possible.
5. Keep pumping until the cork pops and the rocket launches into the air.

Organisers' notes

Top Tip!

- Motion sensors with data loggers can be purchased online (approx. £100) http://www.dataharvest.co.uk/products.php?g=sci&ppg=sci&a=sec&ppa=sec&t=sen&code=3270
- If you don't have a motion sensor with data logger, try using a stopwatch to time how long the balloon takes to travel a certain distance, e.g. 1m. This means you can find the average speed over the first metre.
- For a more professional rocket with added safety, you can purchase the Rokit Kit (approx. £10) http://www.rokit.com/order/
- To get the best from your rocket, try using a longer airship-shaped balloon instead of a traditional spherical one.
- Try changing the amount of water in the bottle to adjust the launch force and flying distance.
- Add fins and a nose cone to make the rocket more aerodynamic!

Additional information

- For more information about the Apollo 11 mission visit: http://spaceflight.nasa.gov/history/apollo/apollo11/index.html
- The Apollo 11 mission cost $355 million, which equates to around $1.75 billion in today's terms (2012).
- Astronauts were selected from military test pilots, who then had to undergo hundreds of hours of training.
- To be eligible for selection, candidates had to be 25-35 years old, weigh less than 180 pounds, be shorter than 5ft 11ins, hold a degree in engineering or physics sciences and have at least 2000 hours of flying experience in high performance jets. The selection procedure then involved numerous physical and psychological tests.
- To escape the Earth, the launch vehicle must achieve sufficient velocity to leave the surface and enter orbit. This was roughly 25,000mph.

- The Apollo missions followed an approximate figure of 8 trajectory. They first used the massive Saturn V rockets to reach low Earth orbit. From there they increased their velocity in order to break orbit and head towards the Moon, where the spacecraft entered lunar orbit. This spacecraft then released the lunar module; firing its rockets to slow down, drop out of orbit, and land on the Moon.
- On reaching the Moon, the craft must slow down enough to make a ‘soft’ landing. To return, it must leave the Moon, and on reaching Earth it must then slow down enough to land safely.

Did you know?

- Space travel is a dangerous business. In 1967, three astronauts were killed in a fire on Apollo 1 during a launch test and in 1970, an accident on board Apollo 13 almost resulted in the loss of the three crew members. At around the same time four Soviet cosmonauts were also killed in two separate accidents. In 1986, seven astronauts were killed when the space shuttle Challenger disintegrated soon after launch, and in 2003 another seven were lost when the space shuttle Columbia broke up on re-entry.

Curriculum links

This activity contributes towards the following curriculum outcomes.

CfE Fourth Level: SCN 4-06a By researching developments used to observe or explore space, I can illustrate how our knowledge of the universe has evolved over time.

SCN 4-07 I can use appropriate methods to measure, calculate and display graphically the speed of an object, and show how these methods can be used in a select application.

Activity 3: Invention of Nylon

Polymers are long chains of individual molecules called alkenes, which are obtained from crude oil. They can span tens of thousands of carbon atoms in length and offer a variety of different properties.

1. What are plastics and polymers?

As an introduction students should watch this Twig Science film for an overview of the variety of plastics used in everyday life and how these are created.

All films in this activity pack are available for free from Twig exclusively for NSEW 2013.

Twig is an award-winning online resource with thousands of tailor-made films that bring subjects to life. Twig uses engagement and wonder to deliver deep-seated understanding.

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After the film, students should discuss the following questions:

- What are plastics and polymers?
- Where do plastics and polymers come from?
- What are the pros and cons of using polymers?

Students can also think about the plastics and polymers they use in their everyday lives (see organisers' notes for examples), to include:

- Polyethene
- Polystyrene
- Polypropene
- High-density polyethene (HDPE)
- Low-density polyethene (LDPE)

2. The invention of Nylon

Some examples of polymers may surprise you! Fabrics may be commonly thought of as natural products, such as cotton and silk. This 3-minute Twig Science film shows the invention of Nylon and how the new properties it offered created quite a stir in the fashion world!

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3. Synthesising Nylon

Polymers are materials made up of long molecules that have a repeating structure. You will know lots of polymers from your everyday life such as all plastics, which are man-made or synthetic polymers, and materials like cotton, which is a natural polymer. Chemists have worked out how to create many, many different synthetic polymers (plastics) and they all have different properties and functions, from plastic bags to bullet-proof vests!

You can find more introductory information about polymers and their chemistry here: http://www.nobelprize.org/educational/chemistry/plastics/readmore.html

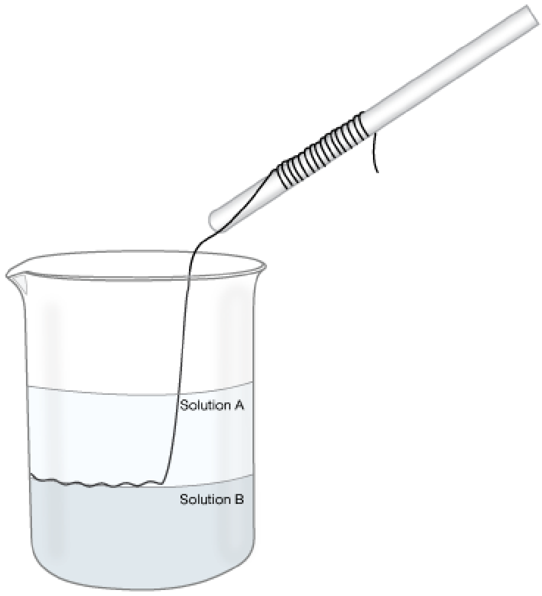
This experiment demonstrates how the polymer from the last film, nylon, is produced. Your teacher will explain a bit about the chemicals used but make sure you measure each out carefully and pay careful attention to the Health and Safety notes. Try different methods of unraveling the ‘rope’ to produce the longest strand of polymer in the class!

You will need:

- Cyclohexane, 50ml
- Sebacoyl dichloride, 1.5g
- 1,6-diaminohexane, 2.2g
- Distilled water, 50ml
- Three 50ml beakers
- A small beaker, 5ml
- A pair of forceps
- Glass stirring rods

Health and safety:

Sebacoyl dichloride and 1,6-diaminohexane are corrosive and harmful if swallowed or inhaled. Cyclohexane is highly flammable and harmful. Be careful and do not spill. Wear gloves and safety glasses at all times and avoid contact with the fibre.



What you need to do:

1. In another 50ml beaker, add 1.5g sebacoyl dichloride to 50cm3 of cyclohexane and stir to dissolve. You may need to heat the bottle gently in warm water and use a pipette to remove the decanedioyl dichloride. This is solution A.
2. In one 50ml beaker, add 2.2g of 1,6-diaminohexane to 50cm3 of distilled water and stir with a glass rod to dissolve. This is solution B.
3. Pour 10ml of solution B into the remaining 50ml beaker. Add 10ml of solution A gently down the side of the beaker so that it forms a layer above solution B.
4. A white solid will begin to form where the two solutions meet. Use the forceps to slowly pull this out of the beaker and wrap the fibre around a glass rod.
5. Continue to pull the fibre from the beaker by twisting the rod until one of the reactants is used up. This is nylon!

Organisers' notes

Top tips!

- The chemicals for this experiment can be bought from most school chemical suppliers e.g. www.timstar.co.uk

Additional information

- Plastics are polymers derived from crude oil and its products through the polymerisation of various alkenes.
- Low density polyethene (LDPE) is used in plastic bags and cling-film because it is low density, flexible and waterproof.
- High density polyethene (HDPE) is used in a wide variety of food packaging such as milk and juice bottles because it is lightweight and yet tough and strong.
- Polypropene is used in ropes, crates and furniture because it is hard, strong and can be moulded into a rigid shape.
- Polytetrafluoroethene (PTFE) is used to create non-stick surfaces and waterproof clothing because it is slippery and it is also unreactive and therefore safe for use in food preparation.
- Polyvinylchloride (PVC) is used in credit cards, drain pipes and toys because it is flexible and again cheap to produce.

Did you know?

- Plastics are used in enormous quantities around the world. 35 million tonnes a year are generated of PVC alone, with demand growing each year.
- Nylon is a polyamide made by reacting two monomer molecules A and B together. This is not the same as addition polymerisation, as the molecules do not have double bonds. Each of these molecules has reactive amide groups at both ends, and when they react they make a long chain of repeating units ABABABAB......
- Nylon was invented in 1939 by Wallace Carothers, a research scientist at an American chemical research company. Carothers was trying to invent a synthetic silk to reduce the dependency on import from natural sources.

- Other innovative polymer inventions include Kevlar, which is also a polyamide made up of repeating benzene rings. Kevlar is incredibly strong, five times as strong as steel, whilst still lightweight and also flame-resistant. It is used in bulletproof vests, sporting equipment and boats.
- Kevlar was invented by an American named Stephanie Kwolek in 1966, whilst studying and creating new synthetic polymers at the very same company as Carothers.

Curriculum links

This activity contributes towards the following curriculum outcomes.

England KS3:	3.2 Chemical and material behaviour b. elements consist of atoms that combine together in chemical reactions to form compounds
England KS4:	2.2 Chemical and material behaviour c. new materials are made from natural resources by chemical reactions d. the properties of a material determine its uses
CfE Fourth Level:	SCN 4-15a Through gaining an understanding of the structure of atoms and how they join, I can begin to connect the properties of substances with their possible structures SCN 4-16a I have carried out research into novel materials and can begin to explain the scientific basis of their properties and discuss the possible impacts they may have on society SCN 4-17a I have explored how different materials can be derived from crude oil and their uses. I can explain the importance of carbon compounds in our lives

Activity 4: Invention of antimicrobials and the advent of 'Superbugs'

Antibiotic resistance is one of the great concerns in medicine in the developed world. In this activity students will think about the existence of harmful microbes, the role of basic hygiene and advanced hygiene products in minimising the risk of disease, and the use of antibiotics in stopping the spread of bacterial disease.

1. Avoiding pathogens using basic hygiene

Every day we are exposed to millions of microorganisms, some are harmless while others are disease-causing (pathogens). Infectious diseases are the result of microscopic, disease-causing microorganisms entering and attacking your body. These microorganisms are called pathogens and include bacteria and viruses.

This Twig Science film reminds us about the importance of hygiene in keeping surfaces and ourselves free from microbes to limit the risk of ingesting harmful pathogens.

All films in this activity pack are available for free from Twig exclusively for NSEW 2013.

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Ask the students to talk about the different ways they know about to keep surfaces clean from microbes. Encourage students to suggest a variety of methods, including using kitchen sprays, hand-gels, toothpastes or simply washing with soap and water.

2. Antimicrobials in the supermarket

Present students with various antimicrobial products bought from the local supermarket e.g. mouthwash, face wash, antiseptic wipes, hand-soap, hand gels, kitchen surface sprays. You may also provide other substances known for antimicrobial properties such as tea-tree oil, iodine solution or silver.

Ask the students to list and discuss the terms that manufacturers use to describe the effects of these products and the claims that they make about effectiveness. These may include very similar descriptors such as:

- Antiseptic (adj.) – describes a substance applied to the surface of skin that can kill bacteria or stop their grown.
- Antibacterial (adj.) – describes a substance that can kill bacteria or stop their growth.
- Antimicrobial (adj.) – describes a substance that can kill or stop the growth of a range of microbes including bacteria, fungi and viruses.

3. How well do different antimicrobials perform?

Your challenge is to design an experiment that tests the antibacterial properties of household antimicrobials. This will help to inform your friends, family and school about how best to keep their hands clean and microbe-free.

Your teacher would provide different antimicrobial products to test. You should choose three of these products to compare and consider the most effective comparisons to make.

You will need:

- Pre-prepared agar plates seeded with bacteria (standard preparation)
- Sterile paper discs (3-4mm diameter discs which can be purchased sterile or created from chromatography paper and sterilised in an autoclave)
- Bunsen burners
- Samples of three chosen antibacterial hand-washes (A), (B) and (C)
- Masking tape
- Sterile forceps
- Disinfectant solution (for sterilizing forceps in between use)
- Distilled water
- Marker pens

Health and safety:

Take care with open Bunsen burner flames. Once the bacteria has been seeded on the dishes make sure you keep the growing petri dishes sealed. You must also destroy grown bacteria colonies in bleach before throwing away or cleaning petri dishes- ask your teacher to help you with this.

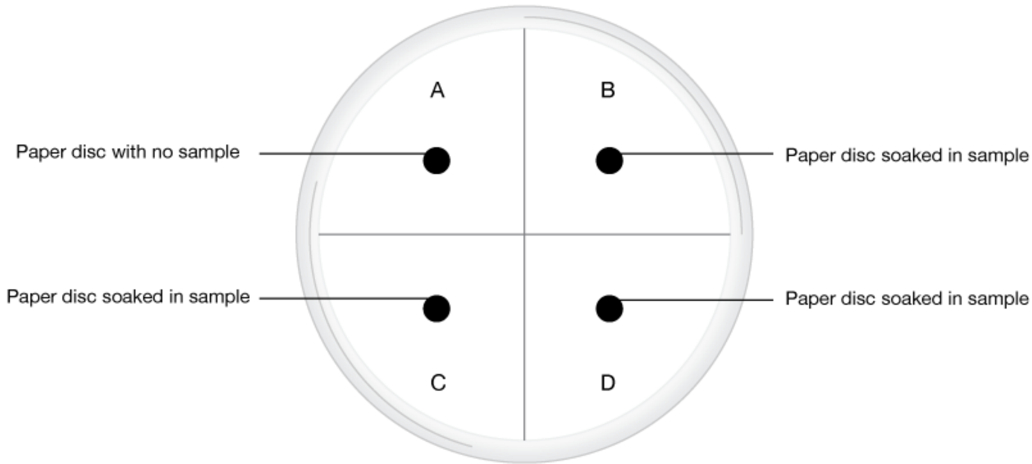
What you need to do:

Create antibacterial discs

1. Turn on the Bunsen burner and light it with an orange flame. This creates a sterile environment around the Bunsen burner.
2. Soak one paper disc in each of the three solutions to be tested. If the solution to be tested is flammable, perform this step away from the Bunsen flame.
3. Using the sterile forceps, transfer each disc to a sterile petri dish to dry near the Bunsen flame. Make sure the position of each disc is clearly noted so each sample can be identified.

Label the agar plate

1. Without opening, divide the petri dish into four quarters using masking tape on the base.
2. Use a marker pen on the base to label the quarters A – D. Also label the dish with your name.



Place the samples in the vicinity of the Bunsen burner

1. Turn the agar plate petri dish the right way up and remove the lid.
2. Using sterile forceps place a new sterile disc in the centre of quarter A as a control. Be careful not to break the surface of the agar.
3. Using forceps place the three sample discs into quarters B – D, sterilizing by rinsing with disinfectant and distilled water in between each sample if the forceps touch the seeded agar.
4. Replace the lid and tape it down to secure.

Grow bacterial colonies

1. Invert the petri dish and store upside down in an incubator or in a warm environment (~25° C) for 2-3 days.
2. After this time, remove the petri dish and observe the colony growth.
3. Measure the radius of any bacteria-free zones around the four sample discs.
4. Evaluate the relative antibacterial properties of each solution.

4. What are the adverse effects of frequent use of antimicrobials?

In this Twig Science film students will learn about the discovery of penicillin as an antibacterial agent, and how this has changed the world we live in.

All films in this activity pack are available for free from Twig exclusively for NSEW 2013.

Twig is an award-winning online resource with thousands of tailor-made films that bring subjects to life. Twig uses engagement and wonder to deliver deep-seated understanding.

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However the film also shows that excessive use of antimicrobial agents may not be a perfect solution. Students should go on to discuss the following questions:

- Are the variety of antimicrobials good to public health?
- What are the potential dangers of over-use of antimicrobials?
- What guidelines would you offer to avoid the emergence of resistant bacterial strains?

Crest Extension. How is antimicrobial activity impacted by other factors?

As extension work you might like to develop the above experiment further. By varying the samples and the protocol, you could try testing the following…

- Which brand of antimicrobial soap is most effective at eradicating bacteria?
- Which everyday objects carry the most bacteria (e.g. keys, mobiles, wallets)?
- What techniques for hand-drying are the most effective?
- Does the effect of the antimicrobial vary with other factors such as pH and temperature?
- Which techniques are the most effective at getting people to wash their hands?

An alternative method for this experiment is using sterile swabs to brush fingers after different treatments and to brush a clean agar surface (instead of using the soaked discs). An example of this style of testing different factors can be found here: http://www.super-science-fair-projects.com/microbiology/scifair-experiment-antibacterial-hand-soap.html

You may also want to undertake some research online and in textbooks and journals into commonly used antimicrobial agents. At the end, prepare a presentation in more detail about:

- How do these work to target bacteria, fungi and viruses?
- What are the differences between different antimicrobial agents?
- How many different antimicrobial agents are there?
- What is the future of antimicrobial agents? Are there new developments being worked on?

Organisers' notes

Optional discussion: defending the human body

- We have evolved a variety of defence systems to block pathogens from entering our bodies. Skin provides a thick, strong barrier, while hairs in our lungs (cilia) sweep away pathogens trapped in mucus.

- Not brushing your teeth regularly has been linked to an increase in heart disease. It is thought that oral bacteria can enter the blood stream through inflamed gums, where they produce protein that causes platelets in the blood to clot; this can lead to heart attacks and strokes.

- Washing hands frequently is of particular importance given the frequency with which we touch our face and mouth.
- Antibiotics are medicinal drugs that have been developed to kill bacteria or stop their growth. For example, amoxicillin targets certain bacterial cells and prevents them from building cell walls. Without the cell wall the bacterium burst open.

Did you know?

- The notion that hygiene was important in limiting the spread of disease was proposed by Ignaz Semmelweis, a doctor in the mid-1950s who was concerned by the number of women dying shortly after giving birth. He realised that doctors were passing on infections to their patients because they weren't washing their hands in between seeing patients. Perhaps surprisingly, Semmelweis was mocked when he suggested that doctors should wash their hands, and it took years before his ideas were accepted.
- Bacteria can mutate to become resistant to antibiotic treatment. Methicillin-Resistant Staphylococcus Aureus (MRSA) is one such bacterium. In most people MRSA does not do any harm. However, if someone with a weak immune system becomes infected, it is very serious as the bacterium cannot be treated with antibiotics and it can prove fatal.

Curriculum links

This activity contributes towards the following curriculum outcomes.

England KS4:	2.1 Organisms and health e. human health is affected by a range of environmental and inherited factors.
CfE Third Level:	SCN 3-13b I have contributed to investigations into the different types of microorganisms and can explain how their growth can be controlled.
CfE Fourth Level:	HWB 4-33a Having explored the conditions for bacterial growth, I can use this knowledge to inform my practice and control food safety risks.

Activity 5: Discovery and use of electromagnets

Electromagnets are produced using electricity. They play an important role in everyday life, with applications spanning from cars to televisions to scrap yards. In this activity, students can build and try out a simple electromagnet.

1. Watch a Twig Science film about electromagnets and take the quiz

Students can learn about the basics of electromagnets through watching this film, as a background to this activity.

All films in this activity pack are available for free from Twig exclusively for NSEW 2013.

Twig is an award-winning online resource with thousands of tailor-made films that bring subjects to life. Twig uses engagement and wonder to deliver deep-seated understanding.

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After the films they should recap and discuss:

- What are electromagnets?
- How do they work?
- What are their practical uses?

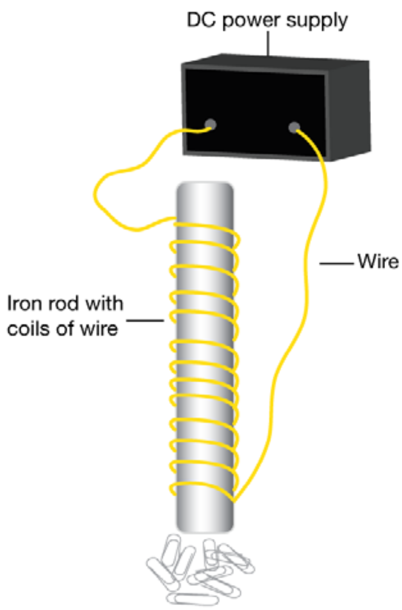
Students can also take the Twig quiz on electromagnets to assess their understanding!

2. Creating an electromagnet

This activity gives you the chance to build an electromagnet from first principles and verify its amazing properties. When electricity is run through coils of copper wire, a strong magnetic field is created within. This turns an iron core placed inside the coils into an electromagnet.

You will need:

- Insulated copper wire
- A large soft iron nail/rod
- A variable DC power supply
- Iron filings and paper clips



Health and safety

Be careful when handling electrical devices.

Keep iron nails and filings away from eyes.

What you need to do:

1. Wind the insulated copper wire 20-30 times around the soft iron nail/rod, leaving enough wire at each end to plug into the power supply.
2. Plug the wire into the variable DC power supply and set to a low voltage.
3. Turn the power supply on and test the magnet by trying to pick up iron filings and heavier paper clips.
4. Adjust the voltage of the power supply and the number of coils around the iron nail/rod to vary the strength of the magnet and try to pick up more iron filings and heavier paper clips.
5. Discuss which setup creates the strongest magnet and why. What happens to the electromagnet when the power is turned off?

3. Inventing the electric buzzer

This experiment demonstrates one of the many practical applications of electromagnets – the electric buzzer. You can even try turning it into an electric bell with just a few tweaks.

You will need:

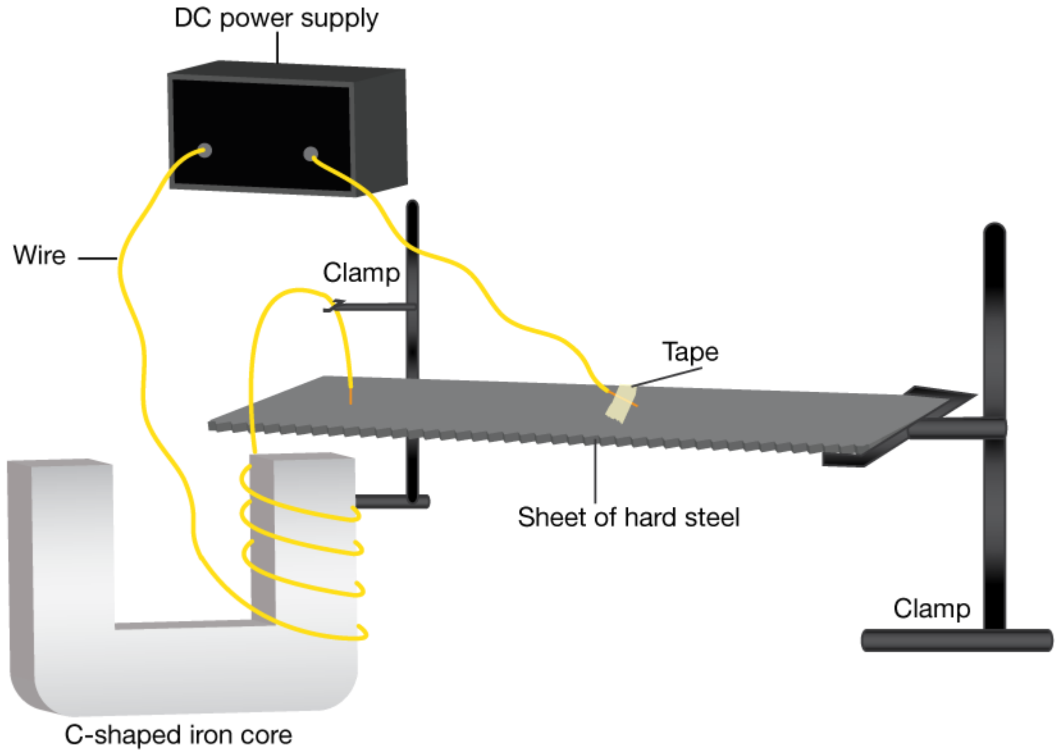
- A C-shaped iron core
- A long, thin strip of hard steel, such as a hacksaw blade
- Two insulted copper wires, each with 1cm of insulation stripped off the end of one side
- A variable DC power supply
- Two clamps
- Tape

Health and safety:

Be careful when handling electrical devices. Hacksaw blades can have sharp teeth and might be considered too dangerous for this activity – other types of steel strips are available, which might be safer.

What you need to do:

1. Wind one of the insulated copper wires 20-30 times around one arm of the C-shaped iron core.
2. Clamp the steel strip at one end so that the other end is just above the wound arm of the iron core.
3. Connect one end of the wound copper wire to the DC power supply. Clamp the stripped end of the wire just above the free end of steel strip, so that the exposed copper just touches the steel.
4. Connect the second copper wire to the DC power supply and tape the stripped end to the centre of the steel strip.
5. Set the power supply to a low voltage and turn it on – the buzzer should start to sound.



Top Tip!

- Try varying the voltage of the power supply and number of coils around the iron core to optimise the sound of your buzzer.
- Move the iron core along the steel strip and place a bell under the free end, turning your buzzer into an electric bell!

Crest Extension. Maglev Trains

Electromagnets can be used to overcome limitations met by other technologies. One example is where electromagnets are used to overcome the speed limits encountered by high-speed trains due to excessive friction.

This Twig Science film shows students Maglev trains, the incredible inventions that use electromagnetic technology to allow the train to levitate and thereby achieve astonishing speeds.

All films in this activity pack are available for free from Twig exclusively for NSEW 2013.

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As an extension activity, students should research and present another extraordinary and innovative use of electromagnets. This research project should be presented to an audience in any format, whether this is a podcast or a poster. It is important that students evaluate and reflect on the effectiveness of their presentation as part of the CREST process. The audience should understand:

- What is the invention that you have chosen that uses electromagnets? What does it do?
- What was used to perform this task before the use of electromagnets?
- What have been the benefits of using electromagnets in this invention? Does the new process save money? Save time? Save energy?
- How does the invention use electromagnets?
- Why do electromagnets provide better results that the previous solution?

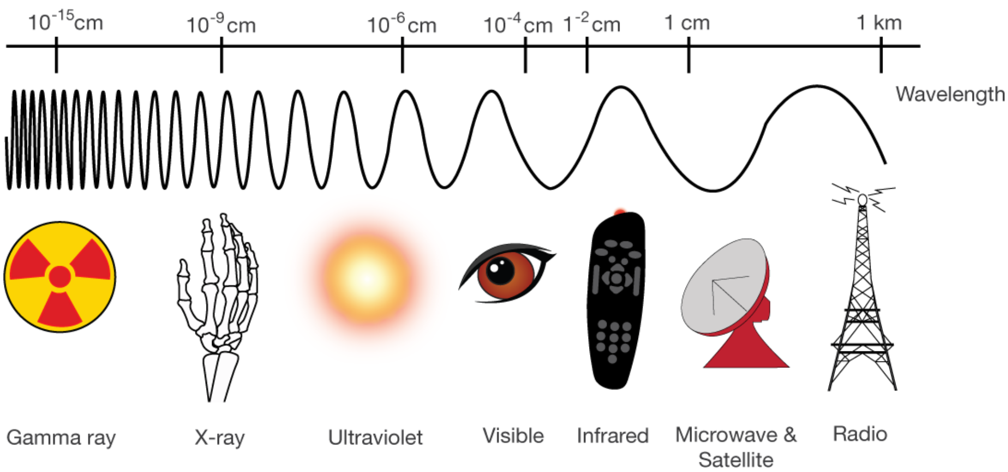
- Do you have any ideas of your own for new technologies/ inventions that could use electromagnets?

Some starter information for student research into uses of electromagnets can be found here: http://www.s-cool.co.uk/gcse/physics/magnetism-and-electromagnetism/revise-it/uses-of-electromagnetism

Organisers' notes

Additional information

- A moving charge generates a magnetic field. For current flowing in wires these are generally weak unless the current is very large. However, a larger magnetic field can be produced by winding the wire into a coil. In an electromagnet this can be further increased by adding a core of ferromagnetic material such as iron.
- Electromagnets are useful as the strength of the field can be controlled by increasing or decreasing the current in the wire or changing the number of turns and, unlike permanent magnets, can be switched on and off.
- Electromagnets have many applications, including in motors, loudspeakers and powered door locks, such as those used in the central locking systems of cars.
- Electromagnetic radiation travels as waves and transfers energy from one place to another. All electromagnetic waves can travel through a vacuum, and they all travel at the same speed in a vacuum.
- The electromagnetic spectrum is a continuous range of wavelengths. The types of radiation that occur in different parts of the spectrum have different uses and dangers, which depend on their wavelength and frequency.



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The electromagnetic spectrum

Optional discussion: magnetic levitation and Maglev trains

- Materials which are diamagnetic are repelled by magnetic fields and so can be made to levitate above magnets, as long as the force of the repulsion is greater that the weight of the object. This is hard to achieve without very powerful magnets or materials which are very strongly diamagnetic. Superconductors are extremely diamagnetic and so can be levitated above magnets relatively easily.
- Maglev trains use magnetic levitation. The train is suspended above the track, which reduces friction and allows it to reach very high speeds.
- In ElectroDynamic Suspension (EDS), superconductors are placed on the train and these are repelled by electromagnets in the track.
- Alternatively, in ElectroMagnetic Suspension (EMS), electromagnets can be used in an arrangement where part of the train reaches around and under the track. Electromagnets on this part are attracted to coils on the underside of the track. This pulls the train upwards, lifting it off the track.

Did you know?

- Powerful electromagnets can be made by using superconducting wire. This allows very large currents to be used as superconductors have no resistance and so large currents do not cause heating. Unfortunately superconductors only work at very low temperatures.

Curriculum links

This activity contributes towards the following curriculum outcomes.

England KS3:	3.1 Electricity, energy and forces c. electric current in circuits can produce a variety of effects
CfE Third Level:	SCN 3-07a By contributing to investigations of energy loss due to friction, I can suggest ways of improving the efficiency of moving systems
CfE Fourth Level:	SCN 4-08a I can help to design and carry out investigations into the strength of magnets and electromagnets. From investigations I can compare the properties, uses and commercial applications of electromagnets and supermagnets.

Activity 6: Three inventions to save the Earth

Global warming is the increase in temperatures of the Earth's oceans and atmosphere. Most scientists believe that some of the warming over the past century is due to human activity. In this activity, students can discuss the science behind global warming, its possible consequences and ways to slow this process before it's too late.

1. The threat of global warming and climate change

Students should discuss the following questions:

- What is global warming and why are we concerned about it?
- How does the greenhouse effect work?
- How have humans driven this process?
- What is the current evidence for global warming?
- What are the potential future impacts?
- What steps are people, companies and governments taking to solve the problem?

2. Some incredible inventions to combat climate change

Students should watch this film to see some examples of incredible inventions that have been suggested to counter global warming.

All films in this activity pack are available for free from Twig exclusively for NSEW 2013.

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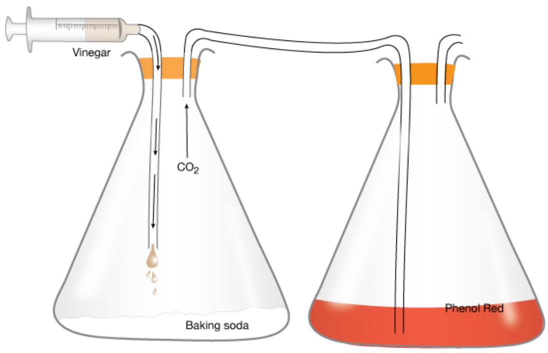
Although these examples are too expensive or otherwise unfeasible at present, scientists are constantly considering new alternatives to solve the problem. Students can explore some of these alternatives in the next practicals.

3. Storing carbon dioxide in the ocean

This experiment demonstrates a potential solution to global warming; capturing carbon dioxide and storing it in the ocean. You can also compare fresh water against seawater to see which is most effective.

You will need:

- Vinegar, 100ml
- Phenol red, 300ml
- Sea salt, 5g
- Baking soda
- Distilled water
- Two flasks, 250ml
- Two rubber bungs for the flasks, each with two holes and plastic straws
- Rubber tubing, 45cm
- A beaker, 250ml
- A syringe, 30ml
- Safety glasses



Health and safety:

Wear safety glasses at all times and do not ingest reactants.

What you need to do:

1. Place enough baking soda in a flask to cover the base and seal with a rubber bung.
2. Pour 50ml of vinegar into the beaker and use this to fill the syringe, ensuring there are no air bubbles present. If you do get air bubbles in the syringe, empty it and repeat the procedure.
3. Pour 150ml of phenol red into the other flask and seal with a rubber bung.
4. Connect the two flasks by attaching rubber tubing to one of the plastic straws in each bung. Ensure that the straw in the phenol red flask dips into the solution towards the bottom of the flask. This is to allow gas to bubble through the solution.
5. Fix the syringe to the other plastic straw in the baking soda flask.
6. Add 5ml of vinegar from the syringe to the baking soda, watching as the reaction happens and gas bubbles into the phenol red.

7. When the reaction stops, add another 5ml of vinegar and repeat until the phenol red turns yellow. Note down the amount of vinegar used to complete the test.
8. Rinse out the equipment and repeat the experiment, however this time dissolve 5g of sea salt into the 150ml phenol red before carrying out the procedure. Record the amount of vinegar used to complete the new test.
9. Discuss students' results – is fresh water or ocean water better for storing carbon dioxide? What are the benefits and drawbacks of this process?

4. Storing carbon dioxide underground

This experiment demonstrates another potential solution to global warming; capturing carbon dioxide and storing it underground in an oil well.

You will need:

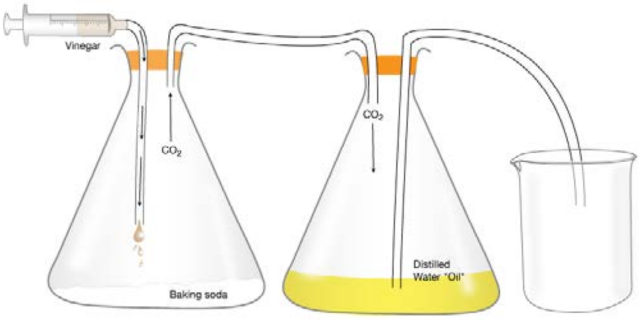
- Vinegar, 100ml
- Yellow food colouring
- Baking soda
- Distilled water
- Two flasks, 250ml
- Two rubber bungs for the flasks, each with two holes and plastic straws
- Two pieces of rubber tubing, 45cm
- Two beakers, 250ml
- A syringe, 30ml
- Safety glasses

Health and safety:

Wear safety glasses at all times and do not ingest reactants.

What you need to do:

1. Place enough baking soda in a flask to cover the base and seal with a rubber bung.
2. Pour 50ml of vinegar into a beaker and use this to fill the syringe, ensuring there are no air bubbles present. If you do get air bubbles in the syringe, empty it and repeat the procedure.



3. Pour 200ml of distilled water into the other flask and add some yellow food colouring to represent oil.
4. Seal this flask with a rubber bung – it represents an underground oil reservoir.
5. Connect the two flasks by attaching rubber tubing to one of the plastic straws in each bung. This time use the plastic straw that is not submerged below the oil surface.
6. Connect the oil reservoir to the second beaker attaching rubber tubing to the plastic straw that is submerged below the oil surface and running it into the beaker.
7. Fix the syringe to the baking soda flask.
8. Add 5ml of vinegar from the syringe to the baking soda, watching as the reaction happens. The gas produced will push the oil out of the underground reservoir into the second beaker.
9. Add more vinegar to the baking soda until the oil stops flowing into the beaker.
10. Note down the amount of vinegar used to complete the test.
11. Discuss your results – which method is better for storing carbon dioxide? What are the benefits and drawbacks of this process?

Organisers' notes

Top tips!

- Most of the chemicals here can be bought from the supermarket, and phenol red can be purchased from chemical suppliers such as www.timstar.co.uk

Additional information

- Global warming is the increase in temperatures of the Earth's oceans and atmosphere.
- World temperatures have risen by about 0.8°C in the last 140 years; 10 of the warmest recorded years have occurred in the last 12 years.
- Global warming has occurred throughout geological history, as ice ages give way to warmer interglacial periods. Most scientists believe that some of the global warming that has occurred in the previous century is due to human activity. This is known as anthropogenic global warming (warming due to humans rather than nature).
- The greenhouse effect is essential to life on Earth. As the Sun burns at a high temperature (roughly 5500°C), it radiates energy at short wavelengths, which can pass through greenhouse gases in the Earth's atmosphere to reach the surface. This warms the Earth, causing it to radiate energy at longer wavelengths. These wavelengths are

more easily absorbed by the greenhouse gases in our atmosphere and reflected back down towards Earth. Greenhouse gases therefore act like a filter, letting lots of energy in but much less of it out.

The electromagnetic spectrum

- Many human activities release greenhouse gases. Carbon dioxide is released by burning fossil fuels and forests. Methane is produced by cattle farming, landfill sites and rice agriculture. The release of other greenhouse gases, such as nitrous oxide, ozone and CFCs, occurs as a result of pollution by transport and manufacturing.
- We worry about global warming for several reasons: rising ocean temperatures are causing more violent hurricanes; other weather events, such as drought and flooding, are becoming more extreme; sea levels are rising due to melting ice sheets and thermal expansion of the oceans.
- Scientists are concerned that 'tipping points' may be reached that represent the sudden and dramatic change in the way the oceans and the atmosphere circulates. For example, the Gulf Stream current that warms north-west Europe may be 'cut-off' like a switch, rather than gradually.
- The Kyoto Protocol is an international agreement that sets out a path for tackling global warming. Current ideas involve reducing future emissions through a carbon credit trading scheme, which inspires companies to invent and adopt 'clean' technology with financial gains, and capturing current emissions through technology that absorbs carbon dioxide.
- It has been difficult to address the issue properly because it is not fully understood and climate sceptics argue that any warming we have experienced may be natural variation in the Earth's oceans and atmosphere. Unfortunately, reducing emissions is hard to do because of the lack of alternatives to fossil fuels.

Did you know?

- Nitrogen and oxygen make up about 99% of the atmosphere and have nothing to do with the greenhouse effect. It is actually mostly caused by the presence of water vapour, as well as other naturally occurring gases like carbon dioxide and methane. The levels of these gases in the atmosphere are regulated naturally.
- Sea levels rose 15-20cm in the 20th century due to global warming.

- In the experiments, the role of baking soda and vinegar is to create carbon dioxide gas. Baking soda dissolves in distilled water to form sodium and bicarbonate ions, while vinegar dissociates into hydrogen and acetate ions. The hydrogen and bicarbonate ions then reach, forming carbonic acid. This then decomposes into carbon dioxide gas and water.

Curriculum links

This activity contributes towards the following curriculum outcomes.

England KS3:	3.4 The environment, Earth and universe c. human activity and natural processes can lead to changes in the environment
CfE Fourth Level:	TCH 4-01c I can debate the possible future impact of new and emerging technologies on economic prosperity and the environment