scdi Scottish Council for Development and Industry

Young Engineers & Science Clubs Scotland

Reach for the Stars

Teacher Notes

Contents

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Introduction

Inspired by Tim Peake's Principia mission to the International Space Station in 2016, **Reach for the Stars** provides an exciting opportunity to launch into the topic of space exploration!

The project is designed to enthuse and inspire pupils about STEM subjects, in particular Physics and Maths, and related careers.

Here you'll find an introduction to the project including an overview of the activities, and guidance on where the project could support you, as you plan learning and teaching using the experiences and outcomes across the Sciences curriculum in the third and fourth level.

The activities and experiments can be delivered within an extra-curricular club, or within the curriculum, to suit your school. The activity summary below will give you an overview of what's included in the resource to help you plan for your club or class. You may wish to run the project over a term or have an Astronaut Training Day as an off-timetable day!

We'd be delighted to hear from you with examples of what you have done in your school.

The Pupil Notes can be used to guide pupils through the project, with sample worksheets to record results of experiments and investigations. Should you require any support when planning or using the project, please don't hesitate to get in touch with the Young Engineers and Science Clubs Scotland team by e-mailing: yesc@scdi.org.uk

Activity Menu

Section 1 **It's Astronomical**	This section is about understanding our place in the Universe. Activities include: **1.** Creating a Planetary Fact File **2.** Calculating gravitational field strength, mass and weight **3.** Understanding the term 'Light Year' **4.** Careering into space: learning about exciting careers in the space sector	**Page** 8 9 10 10
Section 2 **Signals from Space: Electromagnetic Spectrum**	This section focuses on the electromagnetic spectrum. Activities include: **1.** Comparing Optical and Radio Telescopes **2.** Making a model telescope **3.** Making and using a spectroscope **4.** Understanding CubeSats and the Scottish company Clyde Space as world leading innovator and supplier **5.** Positioning and retrieving a satellite	 13 15 18 20 21
Section 3 **Science in Space Exploration**	This section looks at the exciting science of space exploration with activities including: **1.** Simulation exercise for collecting scientific data from photovoltaic investigations for use in an EVA	 22

	2. Demonstrating how the solar powered electrolysis of melted ice could possibly provide Oxygen and Hydrogen for use on a moon base **3.** Glove box botanics **4.** Measuring growth of pondweed	24 26 28
Section 4 **Effects of Microgravity**	This section considers the impact of human space flight on the human body. Activities include: **1.** Researching physiological effects of microgravity **2.** Investigating the gravitational effect on blood pressure **3.** Weighing precisely in microgravity situations: using an inertial balance (Wig-Wag machine)	 34 35 36
Section 5 **Rover Design**	This section considers remote exploration with activities including: **1.** Designing a simple model Mars Rover or Lunar Buggy **2.** Adding the capability to collect rock samples **3.** Programming a Big Trak Rover (or similar)	 38 38 39
Section 6 **Astronaut Training Day**	This is a suggested selection of activities from sections 1-5 which could be used as a day event, for example as a transition event for Primary 7 pupils.	40

Curriculum for Excellence

Reach for the Stars is a STEM project using the exciting context of space exploration to support pupils to learn and be inspired by STEM subjects and careers, while developing valuable skills for learning, life and work.

Reach for the Stars has been designed for S1-3 pupils, however many of the activities will be appropriate for Primary 7 too. The activities and experiments support the following third and fourth outcomes across the Planet Earth and Topical Science areas of the Sciences curriculum, and the Technological developments in Society area of the Technologies curriculum.

Experiences and Outcomes

Section 1 – Spatial Awareness	By using my knowledge of our solar system and the basic needs of living things, I can produce a reasoned argument on the likelihood of life existing elsewhere in the universe. **SCN 3-06a**
Section 2 – Signals from Space: Electromagnetic Spectrum	By researching developments used to observe or explore space, I can illustrate how our knowledge of the universe has evolved over time. **SCN 4-06a** I have collaborated with others to find and present information on how scientists from Scotland and beyond have contributed to innovative research and development. **SCN 3-20a** I have researched new developments in science

	and can explain how their current or future applications might impact on modern life. **SCN 4-20a**
Section 3 – Science in Space Exploration	I have collaborated on investigations into the process of photosynthesis and I can demonstrate my understanding of why plants are vital to sustaining life on Earth. **SCN 3-02a**
Section 4 – Effects of Microgravity	I have collaborated in investigations into the effects of gravity on objects and I can predict what might happen to their weight in different situations on Earth and in space. **SCN 3-08a**
Section 5 – Rover Design	From my studies of technologies in the world around me, I can begin to understand the relationship between key scientific principles and technological developments. **TCH 3-01a** Having investigated a current trend of technological advance in Scotland or beyond, I can debate the short- and long-term possibilities of the technological development becoming a reality. **TCH 4-01b**

Space Careers

By participating in **Reach for the Stars** Young Engineers will learn about the diverse range of exciting careers available to **both boys and girls**.

Skills Development Scotland's My World of Work has case studies, videos, and a wealth of information for careers in all sectors to support pupils to find a career to suit their skills. The Engineering Industry page has job opportunities, and facts and figures on the needs and demands of the industry.

STEM Ambassadors are inspiring role models who volunteer to share their expertise and enthusiasm for Science, Technology, Engineering and Maths with local schools. If you would like a scientist or engineer to visit your school, you can request a STEM Ambassador from your local STEM Ambassador Hub.

Education Scotland – STEM Central illustrates for pupils a range of career opportunities through testimonials from current engineers of various disciplines who speak about how they became interested in engineering, their current role and work, and what they find so satisfying about their jobs.

Tomorrow's Engineers is a great source of information and resources about the amazing careers available in engineering including what qualifications you'd need and expected salaries.

Resources and Equipment

The majority of resources required are likely to be found in secondary school Science departments, however we have included below a list of additional resources with suggested suppliers and approximate costs:

	Item Cost (approx.)	Supplier
DIY Spectroscope Kit	£4 -£6	Maplin or SciChem
Helium Balloon Kit	£21	Supermarkets
Voltameter	£21	SLS Select Education
Rechargeable LED striplight	£22	Amazon
Timing switch	£5	Screwfix
Wig Wag machine	£15	SciChem
Blood pressure monitor x2	£50	Tesco
Big Track Rover	£10	Amazon (sale price)
Total	£150	

Health and Safety

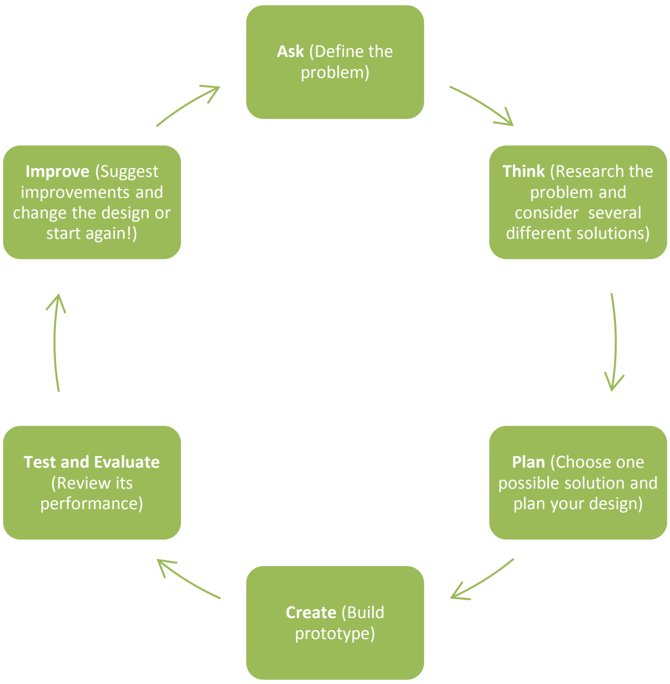
Please note that it is teachers' responsibility to ensure activities are carried out safely within the club or class, and to complete a risk assessment in accordance with usual practice before undertaking any practical activities. A sample template has been provided and please don't hesitate to get in touch if you require any further guidance. Support is also available from SSERC: sts@sserc.org.uk

Throughout the Teacher Notes you'll find reminders of specific Health and Safety requirements relating to each activity or experiment, **highlighted in red.**

Engineering Design Process

Young Engineers are encouraged to develop their communication skills as they discuss ideas and design solutions to solve problems together.

A sample **Engineering Report Sheet** has been included for use with the relevant challenges. In general, Young Engineers should use the following steps when tackling an Engineering project:



Engineering UK's Tomorrow's Engineers website has a range of resources including a PowerPoint presentation on Make a difference – be an engineer.

Section 1:
It's Astronomical

Introduction

Activities include:

1. Creating a Planetary Fact File
2. Calculating gravitational field strength, mass and weight
3. Understanding the term 'Light Year'
4. Careering into space: learning about the exciting careers in the space sector

Astronomers have made huge discoveries about the structure of the universe, as shown in these videos from YouTube:

- Get shocked to see how small our Earth is
- National Geographic - 'How big is the Universe' documentary
- Journey through the Universe – HD Documentary
- Latest secrets of the solar system – full BBC documentary

Vimeo links

- The most detailed map to date of our place in the universe
- Scientists find evidence of a 9th planet lurking at the edge of our solar system

Or you might be able to visit a local observatory, for example:

- Scottish Dark Sky Observatory, Dalmellington, Ayrshire
- Mills Observatory, Dundee
- Royal Observatory Edinburgh

Or check out the Institute of Physics resource 'Teaching Astronomy and Space' videos

For 60 clips covering a wide range of Space Exploration/Astronomy topics, visit BBC Bitesize.

This news article highlights the major events in Space Exploration during 2016: A Year in Space.

Activity 1 – Creating a Planetary Fact File

See Pupil Notes page6.

Focus on the Solar System

An opportunity for some data handling and calculations as we take a look in more detail at the planets in our solar system.

Option1: Pupils can use the project PowerPoint, 'Our Solar System Introduction', to work through the activities and record the information requested. They can save the information as a complete presentation.

Option 2: Pupils can use the worksheets with reference to the PowerPoint as required.

Option 1 - Using the PowerPoint directly

- **Can you Talk the Talk? (Slide 3)**

Match the definition with the appropriate term

Solar System	Star	Planet	Moon	Satellite	Orbit
Galaxy	Milky Way	Comet	Meteor	Asteroid	Gravity
Microgravity	Weight		Mass	Day	Year
Astronaut	Light Year	Gravitational Field Strength			

- **Planetary Facts (Slides 4-12)**

Complete the Solar System PowerPoint slides with the data for each planet

- **Mass and Weight (Slide 13)**

Compare the strength of the gravitational pull on each planet

Calculate the Mass and Weight on each planet for an astronaut of mass of 80Kg on Earth

- **Orbiting times and its effect on Birthdays!**

If 1 day = time for a planet to spin round once on its own axis
And 1 year = time for the planet to complete one orbit of the sun
Use Slide 14 to calculate your 'age' on each planet.

- **Astronomical Distances /Travelling at the Speed of Light**

Seeing the Light!
Light travels through space at 300,000,000 metres per second. ($3x10^{8} ms^{-1}$)
Use slide 14 to calculate how long it takes for light from the sun to reach each planet.
(Take care with the units!)

Option 2 - Using the Worksheet

Can you Talk the Talk?

Cut out the squares to form two sets of cards – 1 with the astronomical terms and the other with the definitions and use as a matching activity.

Planetary Facts - Make your own Planet Fact File.

Activity 2 – Calculating gravitational field strength, mass and weight

See Pupil Notes page11.

Mass and Weight

The **mass** of an object is measured in kilograms but its **weight** is measured in Newtons.

Mass is a measure of the quantity of matter whereas **weight** is a measure of the downward force exerted by gravity on the object.

If the force of gravity changes then the weight (in Newtons) will change but the mass (in kilograms) will stay the same.

If there is zero gravity then the object will have the same mass (in kilograms) as before but it will be weightless.

Practical Activity Measuring 'g', the gravitational force on Earth

Materials: Newton Balance (0-30N), Scales (0-3kg)

Instructions:

Use a Newton Balance and a set of Kilogram scales to compare the mass and weight of everyday objects on planet Earth, including a one litre bottle of water.

The gravitational pull = **g** = the number of Newtons per Kilogram (approx. 10N/Kg on Earth)

Comparing 'g' on Other Planets:

Weighing up the situation!

Complete the table to compare an astronaut's mass and weight on each planet.

If 1 day = time for a planet to spin round once on its own axis
And 1 year = time for the planet to complete one orbit of the sun

To calculate your age on each planet:

for Mercury, Venus and Mars
calculate 'Age last birthday x 365' divided by length of 1 year
for Jupiter, Saturn, Uranus and Neptune
calculate 'Age last birthday' divided by length of 1 year

Activity 3 – Understanding the term 'Light Year'

See Pupil Notes page12.

Astronomical Distances/Travelling at the Speed of Light

Seeing the Light!

Light travels through space at 300,000,000 metres per second. ($3 \times 10^{8}\ ms^{-1}$) = **300,000Km/s**
If Speed = Distance / Time then Time = Distance / Speed
Calculate the time for light to travel from the sun to each of the planets in our Solar System

Light Years Away!

The **light year** is actually a measure of **distance** in astronomy

1 light year = distance travelled by light in one year

The speed of light = 300,000,000 metres/second

Number of seconds in one year = 365 x 24 x 60 x 60 approximately

= 31,536,000s

⇒ One light year = 300,000,000 x 365 x 24 x 60 x 60 metres

= 9,460,800,000,000,000m

= 9.46×10^{15} m in scientific notation

Activity 4 – 'Career'ing into Space

See Pupil Notes page13.

There are lots of very exciting career opportunities working within the space sector, and you don't have to be an astronaut! The UK Space Agency has created a useful Careers Leaflet with helpful websites.

Research a career in space and find out what entry requirements you'd need, how long the training process is, what companies/agencies you could work for, what tasks would be involved in the job and what salary could you expect?

The Institute of Physics has useful information on careers, while Skills Development Scotland's My World of Work will help you find this information for roles such as:

- Aerospace engineer
- Astronaut
- Astronomer
- Meteorologist
- Satellite Systems Technician
- Software developer

You can also find out more about working for space agencies here: National Aeronautics and Space Administration (NASA), European Space Agency (ESA), UK Space Agency, SpaceX

Glossary

1. Day	The time taken for a planet to turn once on its axis.
2. Year	The time taken for a planet to complete one orbit of its star
3. Orbit	The path of an object as it revolves round another body. One complete revolution of an object
4. Solar System	A system of planets or other bodies orbiting a star
5. Star	A large mass at the centre of a solar system (if there are other bodies present) that produces heat and light, e.g. the star at the centre of our solar system is called the Sun
6. Planet	A large ball of matter that orbits a star. They do not emit light themselves
7. Moon	A lump of matter that orbits a planet
8. Galaxy	A cluster of billions of stars, held together by gravity
9. Milky Way	The galaxy that contains our solar system
10. Gravity	The force of attraction between all objects. The more mass an object has, the larger the force of gravity it exerts
11. Gravitational field strength	Force per unit mass. Measured in newtons per kg.
12. Matter	Sub-atomic particles and anything made from them, such as atoms and molecules are matter. Energy and forces are not matter.
13. Mass	The amount of matter an object contains. Mass is measured in 'kg'.
14. Weight	The force acting on an object due to the pull of gravity from a massive object like a planet. The force acts towards the centre of the planet and is measured in newtons (N).
15. Light Year	The distance travelled by light in one year - a very large distance, usually used to describe distances between stars. The closest star to our own is about 4.3 light years away.
16. Comet	A chunk of ice and rock originating in the outer solar system, often accompanied by a coma and a tail
17. Meteor	A streak of light seen when a space rock enters the atmosphere and starts burning up
18. Asteroid	A celestial body bigger than 10m orbiting the sun generally between Mars and Jupiter
19. Satellite	A celestial body or man-made object that orbits a planet or a star
20. Astronaut	A person trained to travel beyond the Earth’s atmosphere

ESA: European Space Agency

NASA: National Aeronautics and Space Administration

EVA: Extra Vehicular Activity (Spacewalk)

ISS: International Space Station

Section 2:
Signals from Space

Introduction

This section focuses on the electromagnetic spectrum. Activities include:

1. Comparing Optical and Radio Telescopes
2. Making a model telescope
3. Making and using a spectroscope
4. Understanding CubeSats and the Scottish company Clyde Space as world leading innovator and supplier
5. Positioning and retrieving a satellite

The Electromagnetic Spectrum

Electromagnetic Spectrum – which waves reach the Earth from space?

Refer to 'The Electromagnetic Spectrum' on the next page to find out about the various sources of electromagnetic radiation found in space and identify the types of radiation which might be picked up as signals here on Earth.

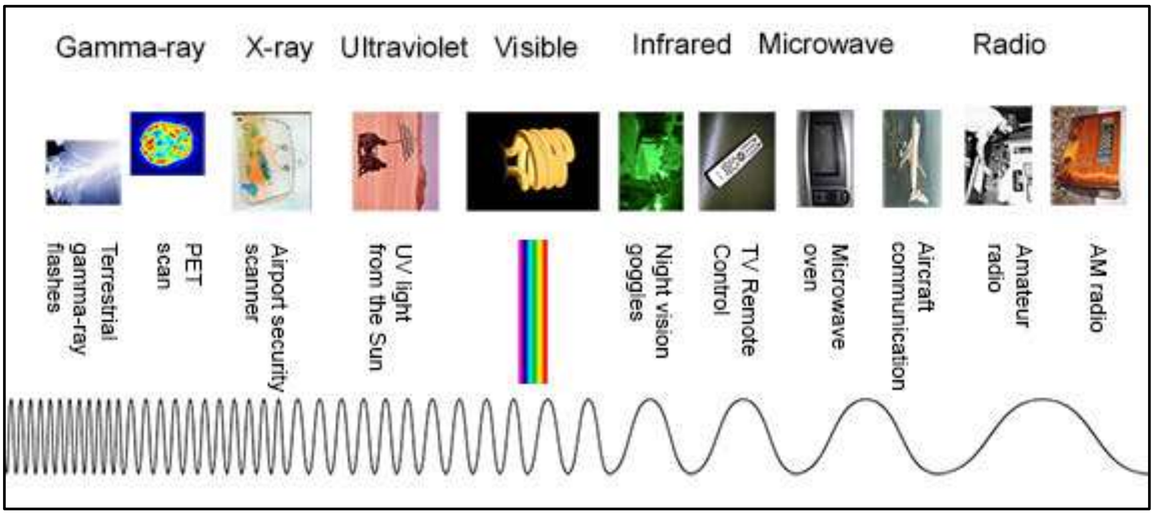
Light waves and Radio waves form part of a large 'family' of waves which all travel at the same speed but which have different wave lengths and frequencies.

They all form part of what is called the Electromagnetic Spectrum.

The higher the frequency of the wave, the shorter the wavelength.

Each type of wave has different properties and different means of detection

Those signals which our eyes can detect – from Red to Violet light - form the Visible Spectrum



The electromagnetic spectrum from lowest energy/longest wavelength (to the right) to highest energy/shortest wavelength (to the left). (Credit: NASA's Imagine the Universe)

Radio: Your radio captures radio waves emitted by radio stations, bringing your favourite tunes. Radio waves are also emitted by stars and gases in space.

Microwave: Microwave radiation will cook your popcorn in just a few minutes, but is also used by astronomers to learn about the structure of nearby galaxies.

Infrared: Night vision goggles pick up the infrared light emitted by our skin and objects with heat. In space, infrared light helps us map the dust between stars.

Visible: Our eyes detect visible light. Fireflies, light bulbs, and stars all emit visible light.

Ultraviolet: Ultraviolet radiation is emitted by the Sun and is the reason skin tans and burns. "Hot" objects in space emit UV radiation as well.

X-ray: A dentist uses X-rays to image your teeth, and airport security uses them to see through your bag. Hot gases in the Universe also emit X-rays.

Gamma ray: Doctors use gamma-ray imaging to see inside your body. The biggest gamma-ray generator of all is the Universe.

Activity 1 Comparing Optical and Radio Telescopes

See Pupil Notes page16.

Picking up Light and Radio waves:

Optical Telescopes: Focusing light with a convex lens
Building a model refracting telescope
Radio Telescopes: Modelling a satellite dish (Parabolic Reflector)
Finding the focus of a curved reflector

Astronomers rely on instruments such as telescopes to pick up light and radio signals from space.

Other signals from space which would normally be absorbed by the Earth's atmosphere can be picked up by detectors positioned in space.

X-rays are partly blocked by the Earth's atmosphere and so X-ray telescopes need to be at high altitude or flown in balloons.

Light signals can be detected using an Optical telescope.

Radio signals can be detected using a Radio Telescope.

An **optical telescope** is a telescope that gathers and focuses light, mainly from the visible part of the electromagnetic spectrum, to create a magnified image for direct view, or to make a photograph, or to collect data through electronic image sensors.

Optical telescopes

Optical telescopes observe visible light from space.

Optical telescopes on the ground have some disadvantages:

- they can only be used at night
- they cannot be used if the weather is poor or cloudy

Refracting telescopes consist of a closed tube. At one end of the tube is an object glass also known as the objective lens and at the opposite end of the tube there is the eyepiece lens. Light from a distant star or planet enters the objective lens and the rays are refracted and an image is formed at the point of focus at the lower end of the tube. This image becomes the object for the eyepiece which acts as a magnifying lens enlarging the bright image. The observer views the object through the eyepiece or can attach a camera to the telescope to record images.

Other telescopes

Radio telescopes detect radio waves coming from space.

Although they are usually very large and expensive, these telescopes have an advantage over optical telescopes. They can be used in bad weather because the radio waves are not blocked by clouds as they pass through the atmosphere. Radio telescopes can also be used in the daytime as well as at night.

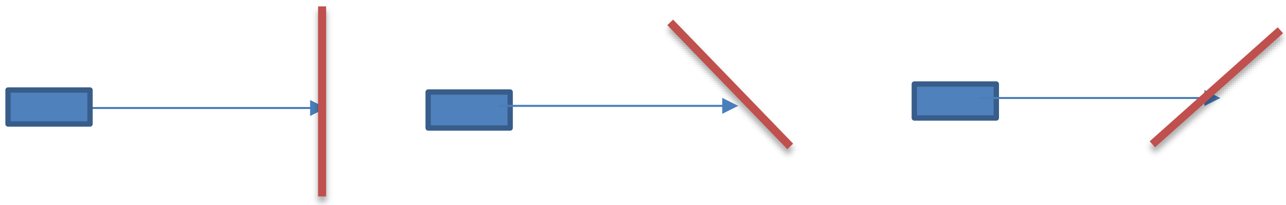
Ref: **http://passmyexams.co.uk/GCSE/physics/Earth-based-telescopes-radio-telescopes.html**

Activity 2 – Making a Model Telescope

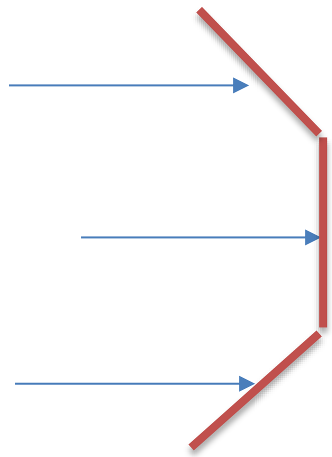
See Pupil Notes page18.

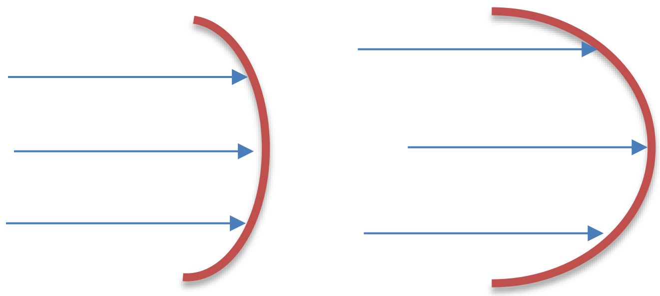
Use a ray box to investigate the path of light in the following situations:

1. A single beam directed towards a plane mirror placed at different angles



2. One beam of light directed at each of three mirrors arranged as shown





3. Adjust the angle of the mirrors so that all the rays pass through one point (the FOCUS)

4. Replace the three mirrors with a single curved mirror and measure the Focal Length – the distance from the focus to the centre of the mirror

5. How can you increase/decrease the focal length?

The ………………………… the curvature of the mirror, the …………………………… the focal length.

Curved (Parabolic) reflectors are used to detect Radio signals from space.

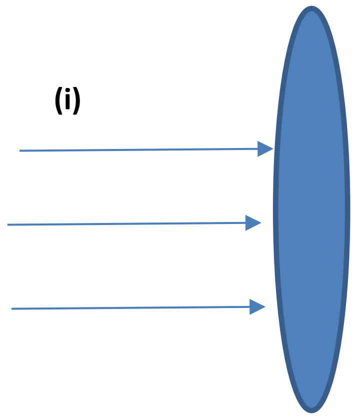
A much stronger signal is picked up if a series of parabolic reflectors are arranged in an array

https://public.nrao.edu/telescopes/radio-telescopes

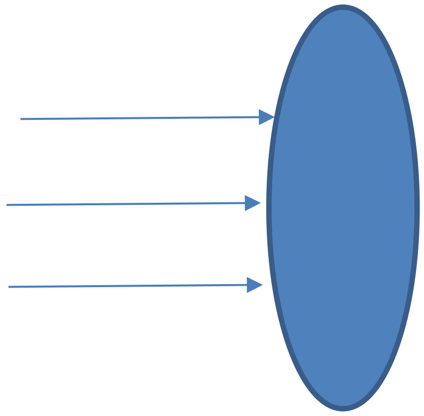
http://www.bbc.co.uk/news/science-environment-32523768

6. Using a convex lens: Trace out the path of parallel rays of light through convex rays of different thickness

(i)

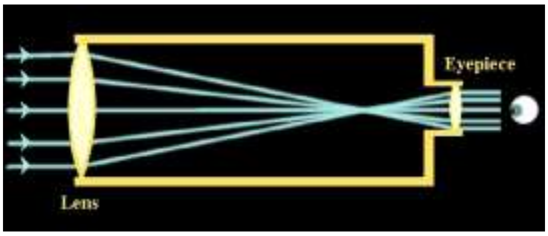


(ii)



The ……………………………. the lens, the ……………………………. the focal length

Refracting telescopes use lenses to produce a magnified image.



http://www.schoolsobservatory.org.uk/astro/tels/raydiagrams

Finding the focal length of a convex lens

This short video explains how to determine the focal length of a convex lens by focusing a distant object.

Parallel light passing through a convex lens will produce an image exactly one focal length from the lens.

Light coming through a window can form an image on the wall (or a screen).

Hold a convex lens between a window and a wall so that a sharp image of a distant object is formed on the wall.

The distance from the lens to the wall is the Focal Length of the lens.

Measure the focal length of an assortment of convex lenses – the thicker the lens the shorter the focal length.

Making a model telescope

To make a model telescope you need one thick lens for the eyepiece and a thin lens for the objective lens.

Position them on an optical bench so that the distance between them is equal to the sum of their focal lengths.

Look through the eyepiece lens at a distant object. The image produced by the objective lens becomes the object for the eyepiece lens and so a magnified image is seen through the eyepiece.

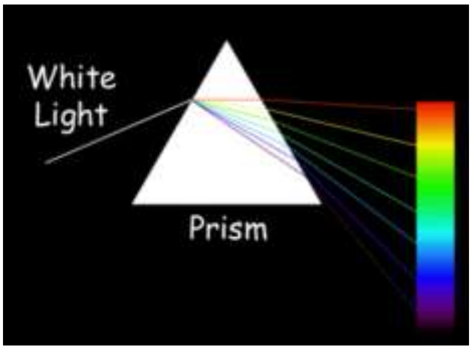
Alternatively, fix the lenses into cardboard tubes which can slide. This video from the Canada Science and Technology Museum shows how.

Activity 3 - Making and using a Spectroscope

See Pupil Notes page21.

Information Sheet: Spectroscopy in Space
Ref: https://solarsystem.nasa.gov/deepimpact/science/spectroscopy.cfm

When a beam of white light strikes a triangular prism it is separated into its various components (ROYGBIV). This is known as a spectrum.

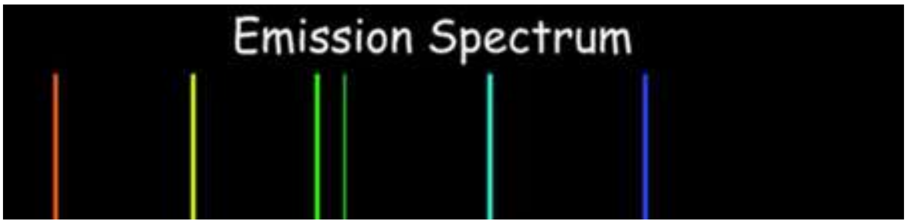


The optical system which allows production and viewing of the spectrum is called a spectroscope.

When light is absorbed or reflected by materials, not all of the light behaves the same. Only certain wavelengths of light get absorbed, others get reflected.

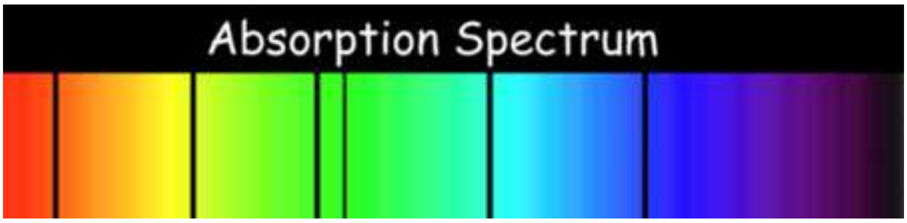
When you separate the light that is passing through a sample, or reflecting off a sample, you end up with an emission spectrum or absorption spectrum, as opposed to the continuous spectrum you would get if you break up a source of all wavelengths of light.

An emission spectrum in the visible light range may look like the picture below. Such a spectrum would be created when material is given extra energy somehow (it's heated, electrified, radiated with light, etc.) and that extra energy is later emitted as light energy.

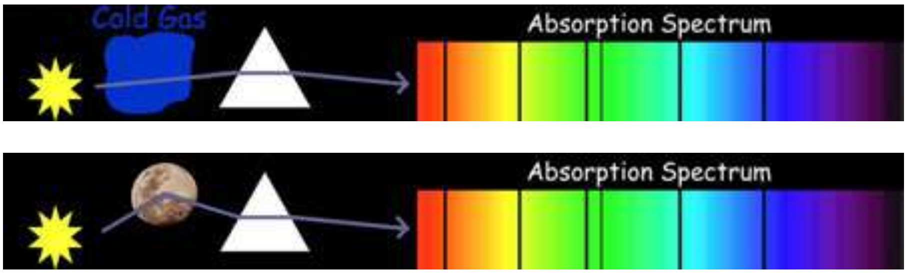


If that light is separated into its component parts, you can see the spectrum of the emission. In this case, only the wavelengths of light which are emitted come out in the spectrum.

An absorption spectrum in the visible light range may look like the picture below. Such a spectrum would be created when light is passed through a gas or a liquid, or strikes a solid. Certain wavelengths of light will be absorbed by the material, and later emitted in random directions. Most of the wavelengths, however, will pass through the gas or liquid (or be reflected off the solid) without being absorbed.



If the light that passes through (or reflects off) is then separated into its component parts, you can see the spectrum of the absorption. In this case, the wavelengths of light absorbed by the material are absent in the spectrum, leaving blank spaces behind.



Spectroscopy and Starlight

This BBC film clip shows Professor Brian Cox explaining how we can discover what stars are made from by analysing the light that arrives on Earth from the stars. Elements are shown to emit certain colours when they are burnt. Star light can be analysed using spectroscopy which generates a bar code style pattern, unique for each element. This shows up as black lines on the rainbow spectrum from white light. It can be used to show all stars only contain the same 92 elements as we find here on Earth.

Using/Building your own spectroscope:

There are several web sites which give instructions on how to make your own spectroscope, such as:

Live Science

Sci-toys

Buggy and Buggy

There may be a supply of simple hand held spectroscopes in the physics department which can be used to investigate the spectra produced by different light sources, or ready-made kits are available from suppliers such as SciChem (OPT050020) and Maplin (A60RQ).

Activity 4 – Understanding CubeSats

See Pupil Notes page23.

Signals from Satellites

CLYDESPACE is Scotland's global leading cube-sat and satellite design and production company. Check out their website (www.clyde.space/about-us) and search for Cubesat Pioneers Born to Engineer on YouTube to find out more about satellite engineering.

Challenge pupils to research:

Who founded the company?

Where are they based?

What are CubeSats? What size are they, how much do they cost, what can they do?

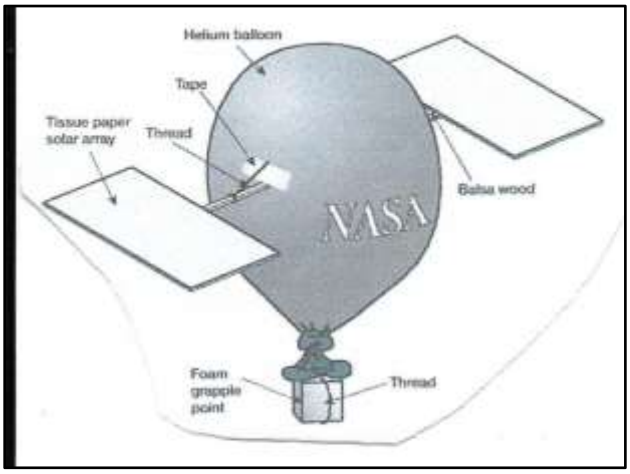
How many flight-ready satellites they can make each month?

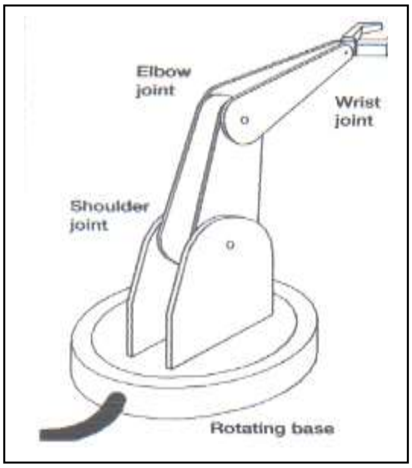
Activity 5 - Satellite Positioning and Retrieval

See Pupil Notes page24.

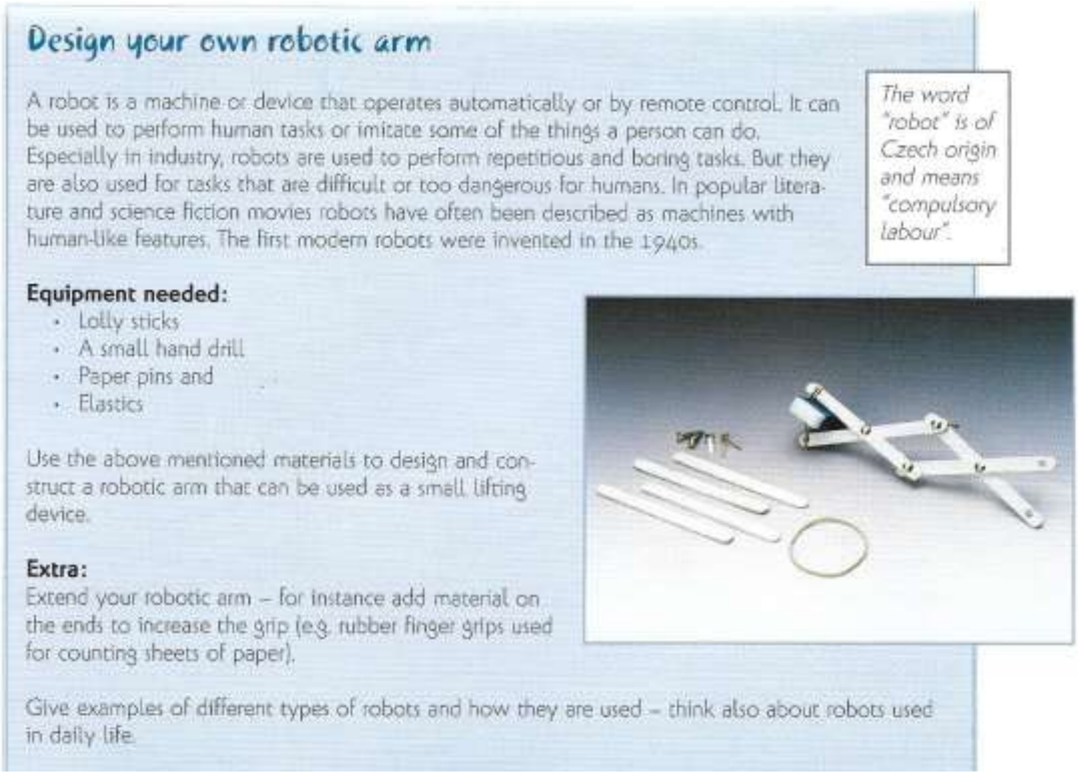
Positioning a satellite in a simulated microgravity environment.

In this challenge, teams are required to build a model satellite using a helium balloon as shown in the diagram. When in position it should be neutrally buoyant and therefore remain in one place, not floating up or falling down.





The next task is to design and build a simple grabber – a robotic arm which will allow you to move or retrieve the model satellite. The pictures illustrate suggestions from NASA and ESA publications.



Design your own robotic arm

A robot is a machine or device that operates automatically or by remote control. It can be used to perform human tasks or imitate some of the things a person can do. Especially in industry, robots are used to perform repetitious and boring tasks. But they are also used for tasks that are difficult or too dangerous for humans. In popular literature and science fiction movies robots have often been described as machines with human-like features. The first modern robots were invented in the 1940s.

The word "robot" is of Czech origin and means "compulsory labour".

Equipment needed:

- Lolly sticks
- A small hand drill
- Paper pins and
- Elastics

Use the above mentioned materials to design and construct a robotic arm that can be used as a small lifting device.

Extra:
Extend your robotic arm – for instance add material on the ends to increase the grip (e.g. rubber finger grips used for counting sheets of paper).

Give examples of different types of robots and how they are used – think also about robots used in daily life.

In the NASA lab, astronauts practice raising and lowering helium filled balloon mock ups of satellites or payloads. Balloon mock ups are used because even lightweight mock ups would be too heavy for the robot arm mock up to lift. In the NASA lab the balloons are picked up from the ground or inside the shuttle mock up.

Section 3:
Science in Space Exploration

Introduction

Inspired by reports of Tim Peake's scientific investigations while in space, this unit seeks to provide investigations and technology challenges in a Space context. Activities include:

1. Collecting scientific data from photovoltaic investigations to use in an EVA simulation exercise
2. Investigating how the solar powered electrolysis of melted ice could possibly provide oxygen and hydrogen for use on a moon base
3. Glove Box 'botanics' : Making a glove box then using it to investigate the effect of changing the exposure to light on the development of cress seedlings
4. Measuring growth of pondweed

Activity 1 - EVA Simulation Exercise

See Pupil Notes page25.

An astronaut who had once been on a spacecraft repair mission jokingly described working in weightless conditions as like changing a small fuse of your car's battery with ski gloves on and all the while standing on a skateboard.

This activity aims to simulate an EVA (extra-vehicular activity) and highlight the need for teamwork.

Imagine the arrangement of an array of 4 solar panels has to be adjusted on the outside of the space craft.

Scientists on the ground need to pass the results of their investigations on the output of solar panels to the Mission Controller who will then transmit the data to the space craft commander. They will then pass the data on to the astronauts doing the spacewalk who will adjust the solar panels accordingly. The Astronauts always work as a team of two when outside the spacecraft.

Team Members:

- **Scientists in a lab on Earth** – experiment with solar panels to provide data for Mission Control to pass on to the Astronauts about to do the spacewalk.

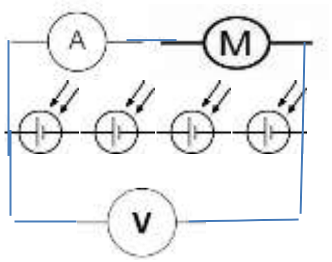
How does the arrangement of the cells (series or parallel circuits) affect the output voltage? (Table of results). How does the angle of a cell affect the voltage? (Graph)

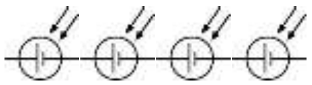
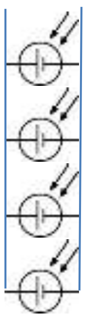
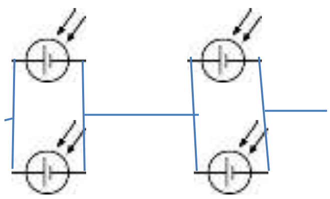
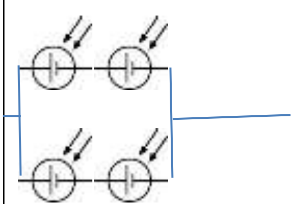
- **Mission Controller** – review the scientific data and select the circuit combination required for the solar panel array. (Series or parallel?)Transmit this information to the Mission Commander (e.g. Voltage required to charge a capacitor to then power a model lunar buggy?)

- **Mission Commander** – Pass on the information to the Astronaut(s) (Via walkie talkie or mobile phone), control the rope joining the astronauts to the spacecraft and each other and give step by step instructions.
- **Astronaut(s)** – each one wearing big gloves, cycle helmet, goggles and a tool belt and balanced on skateboards/ wearing roller blades. One must hold all the equipment and pass items to the other as and when instructed by the mission commander.

The solar panels could be arranged on a board which is fixed above head height but just within their reach. Teams compete to see which one completes the task in the shortest time and most efficiently.

To compare the output current, voltage and power of 4 photovoltaic cells connected, for example, to an electric motor.



Cell arrangement	Voltage (volts)	Current (amps)	Power (watts)
			
			
			
			

Activity 2 - Investigating how the solar powered electrolysis

See Pupil Notes page27.

Investigating how the solar powered electrolysis of melted ice could possibly provide oxygen and hydrogen for use on a moon base.

The surface temperature of the moon varies between 105 degrees Celsius in direct sunlight and – 155 degrees Celsius in deep shadow. There are areas close to the moon's poles that never get any sun at all. In these areas are craters where ice from comets has accumulated in large quantities.

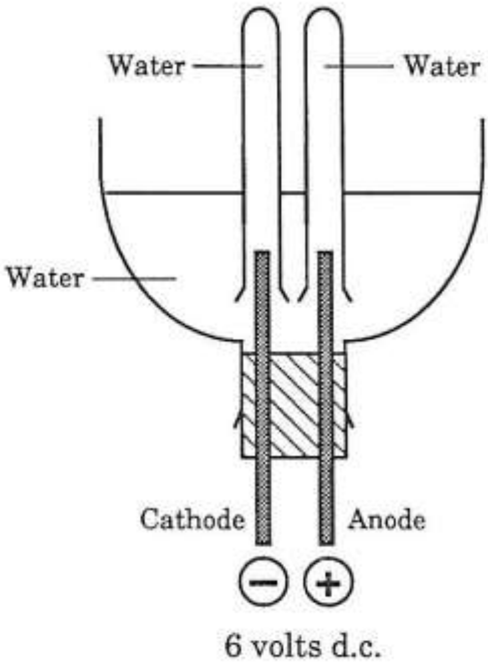
It has been suggested that the ice could provide a source of oxygen and hydrogen for a possible moon base in the future.

Challenge pupils to decompose water by passing an electric current through it. Using the materials below, teams could demonstrate how solar power can be used to electrolyse water (melted ice) to produce these gases and explain how they could identify the gas produced at each electrode.

Materials: a large water bottle, a stopper or rubber bung with two holes, two small test tubes, 2 pencils and a solar panel array.

A commercially available **voltameter** costing £21 can be supplied by SLS Select Education.

The Chemistry Department may have a Voltameter which is used to demonstrate Electrolysis but a model one can be made using a large water bottle as shown below:



(**Ref:** CIEC, University of York ‘Making Use of Science and Technology, series ‘Hydrogen as an energy carrier’)

While carbon rods are shown here as the electrodes, they could be replaced by pencils which have been sharpened at both ends.

The 6v DC supply can be provided by solar cells.

Pure water itself is not a good conductor of electricity so add a pinch of baking soda to the water. You could repeat the experiment with alternative additives as described at Education.com.

Other useful web links:

Home training tools

Electrolysis of Water video on YouTube

Testing the gases produced - questions to ask pupils:

Which gas should be produced in greater volume?

Which gas relights a glowing splint AND has no effect on Lime water?

Which gas burns with a ‘pop’ and a blue flame?

Which additive may produce chlorine at one of the electrodes?

Activity 3 – Glovebox Botanics

See Pupil Notes page28.

A glovebox is a sealed container with built-in gloves. Astronauts perform small experiments and test hardware inside of them. Gloveboxes have flown on the space shuttle and Mir. The International Space Station has a permanent glovebox on the U.S. Laboratory, Destiny. There are good reasons for doing an experiment in a glovebox on orbit. The sealed glovebox keeps flames, particles, fumes, and spilt liquids away from crew members and out of the cabin air. Fumes or particles can irritate crew members' skin and eyes or make the crew sick. Spills could damage electrical equipment.

A glovebox is a valuable research tool. Any work with flames requires precautions, especially on a spacecraft. For some studies, it is important to protect experiment samples from the cabin air and crew. A closed environment may be essential to control experiment variables. Using a glovebox helps scientists find more effective methods for performing an experiment, like growing better crystals. Scientists can use the glovebox to make sure small parts of a large experiment work. This helps build more reliable equipment. For example, they can see if a part like a nozzle will work on orbit and see which nozzle shape works the best.

One reason NASA created the glovebox was so researchers could fly simple investigations into space more quickly. Normally, science teams work with NASA about 7 years before their experiment is ready to go into space. Seven years may seem long, but the process is complex and takes careful planning. Glovebox research has a shorter development time, usually taking 3 to 5 years.

Useful web links:

Microgravity Science Glovebox (MSG)

European Space Agency

NASA

MakeZine

Design and Construct a Glovebox model

Points to explain to pupils before starting:

- There should be enough room to perform the experiment inside the box *(possibly an A4 paper box or a plastic container)*
- The top should be transparent so that pupils can see what they are doing inside the glovebox *(cling film or acetate a 'window')*
- The gloves should be attached in such a way that no air can escape *(Use cut-down paper cups to wedge the wrists of the gloves in the holes cut in the box)*
- The glovebox needs an opening that can be closed tightly to seal the materials inside

On the ISS the astronauts experience 'Day and Night' in 90 minute cycles. It takes the space station one and a half hours to fly around the planet, making for 16 complete laps a day. For those on board, the visual effect is spectacular. Open the covers over the windows and the light can be so blinding that astronauts reach for their sunglasses. But after 45 minutes of daylight, a dark line appears on the planet, dividing Earth into night and day. For a couple of seconds, the space station is bathed in a coppery light and then complete darkness. Another 45 minutes later, and just as abruptly, the sun rises to fill the station with brilliant light again.

Space Agencies often invite tenders from agencies such as academic institutions for the opportunity to have scientific investigations carried out in space – check out AstroPi from Tim Peake's Principia mission.

Experiment Design Challenge: Simulating the growing conditions on the ISS

Teams are invited to submit their proposal for an investigation into the effect of the 90 minute light cycle on the ISS on the growth of cress seedlings:

Design an experiment you could carry out, preferably using your glove box, to see how changing the 'length of day' experienced by the seedlings affects their growth.

Team proposals should include:

- A description of the experimental set up
- A description of any control experiment to be included.
- Their choice of light source
- The method to be used to produce the continuous 90 minute cycle of light and dark.
- How the results will be recorded

Proposals should then be compared before selection of the chosen investigation method.

Why Choose Cress?

Cress is generally quick and reliable to germinate, which makes it a useful choice for experiments looking at the germination process and factors that affect it, such as pollution. However, it is always worth considering the use of white mustard *(Sinapsis alba*) seeds instead, as they are frequently cheaper, are easier to handle, do not have the distinct odour of cress, and their germination has been found to be more reliable in schools.

Note that 'cress' sold in a supermarket is not necessarily *Lepidium sativum*: it is often another brassica, such as white mustard or oil seed rape. These are still suitable for use in the 'photosynthesis with leaf discs' experiment.

Propagating: An excellent, inexpensive plant easily grown from very small, red-brown seeds. Each seed has deep, three-lobed cotyledons and takes between 10-14 days to grow.

Compost: Damp cotton wool or filter paper provides an ideal growing medium as does damp paper towel. You can use petri dishes in a modified plastic bottle.

Light: Keep the seeds dark until after germination and then move to a warm well-lit spot making sure the growing surface stays moist.

Water: Keep damp without soaking.

Temperature: Keep in room temperature.

Feeding: There is no need to feed these seedlings.

Notes: Look out for signs of "Damping-off" in your seedlings.

What are the options for a light source? (Bank of LEDs, Reading lamp, ray box etc.)

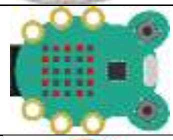
Leyton linkable striplight available on Amazon.

How can it be switched on and off every 45 minutes? 24 hour timers readily available in supermarkets, Screwfix, B&Q etc.)

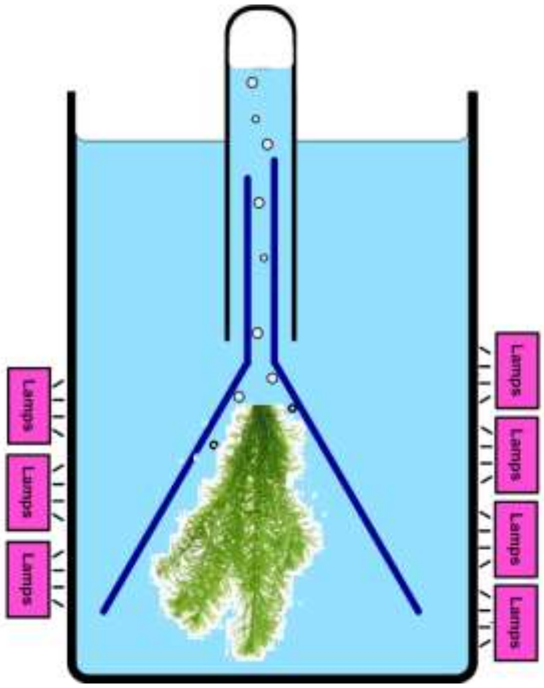
For more information on plants in space, check out the Science & Plants for Schools website.

Activity 4 – Measuring growth of pondweed

See Pupil Notes page32.

Parts List			
	Supplier	**Cost**	
Bonlux LED Grow Strip Light Kit 12V 5W LED with 2A Adapter	Bonlux EU via Amazon	£13.66 for 4 strips and a power supply	
CodeBug Wearable Programmable Computer Board	Rapid Electronics	£15:00	
Leads with croc clips	SciChem (ELA130011)	£1.46 for 10 leads	
Mosfet STP36NF06L N 60V 30A	Rapid Electronics	£3.20 for Qty5 (gives you 3 spares)	
Female Jack Connector Adapter 2.1mm Inner, Screw Terminal	Amazon	£1.49	
Pondweed Elodea Densa (Egeria Densa)	Local Aquarium shop or Plants Alive	£2.09 for 5	

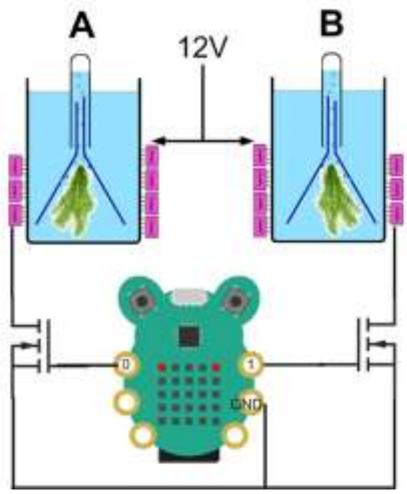
This experiment has been demonstrated using a CodeBug, however, we recommend challenging pupils to use a Micro:Bits and we'd love to see images of this!



Instead of measuring the carbohydrate added to the plant, it is easier to measure the amount of oxygen gas produced.

This is easy to do with Pondweed (Elodea Densa).

In the equation above, we want to vary only the light. To ensure plenty of CO_2 is available, add 1% by weight of sodium bicarbonate (baking soda) to the water. Also keep the temperature constant.



You might compare two identical arrangements, side by side, using different flash frequencies. If the flashes are 50% ON and 50% OFF, the same total energy is being supplied to both experiments.

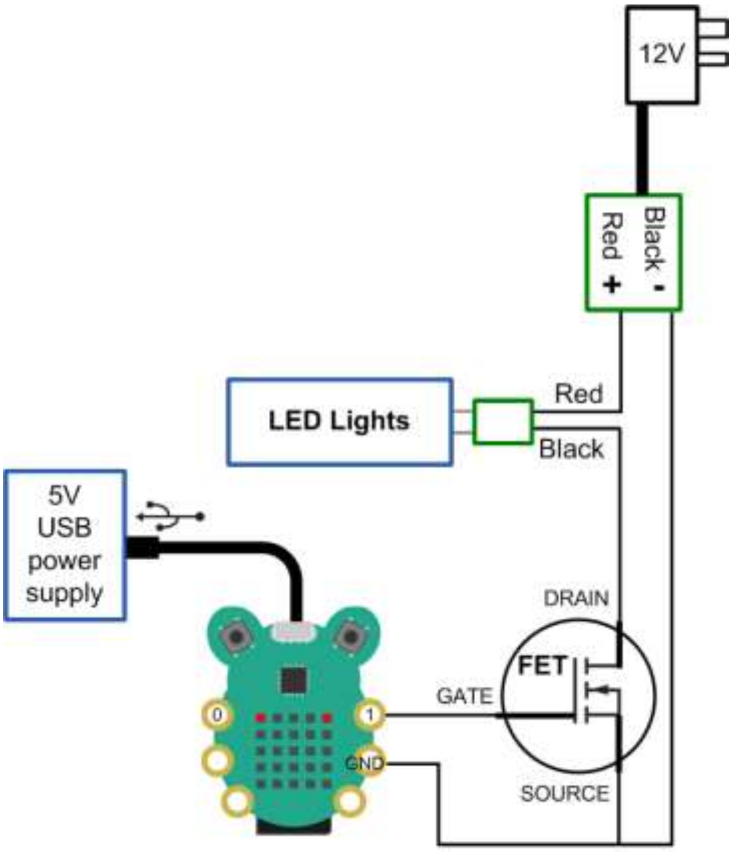
Since the plants may be sightly different, swap the CodeBug leads, repeat the experiment, and add the two results together.

The equation for photosynthesis is:
$CO_2 + H_2O$ + light --> O_2 + glucose
The pondweed is invasive: Don't dispose of it in ponds or streams.
Useful web links:

Brilliant Biology Student
BBC Bitesize
Science & Plants for Schools

Using a CodeBug and a MOSFET switch to control the LED lights

CodeBugs can be programmed using Blockly on the CodeBug website. You can complete the registration process to allow you to save your code but note that you need an e-mail address as you will be sent an activation e-mail. However, you can still use the website and write code without signing in.



For safety, ensure water cannot spill onto the mains power supplies.

Use a logic level MOSFET such as an STP36NF06L (see parts list).

Soldering is the most reliable way of connecting to the legs of the MOSFET, but crocodile clips can be used for trying things out.

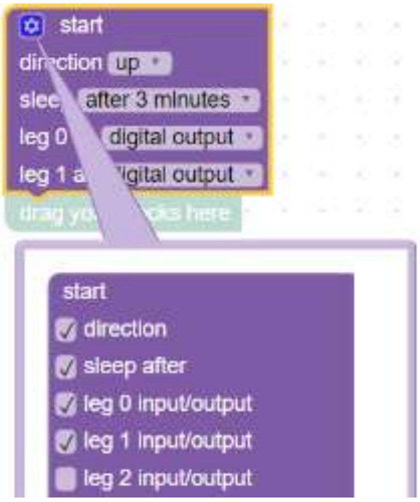
Plants like a mixture of blue and red LEDs, and they need to be fairly bright (a few watts). See parts list.

Developing a CodeBug timer using Blockly code

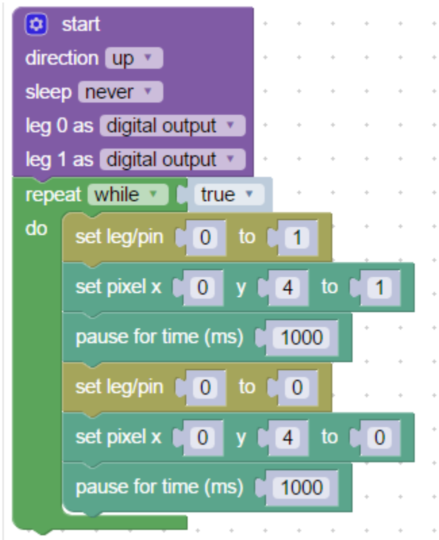
Work in small steps, debugging each step before moving on.

1. First steps.

- Click the Tools button and enable legs 0 and 1 as digital outputs.
- Change ‘sleep’ from its default value of 3 minutes to ‘never’ – or else your timer will stop after 3 minutes!

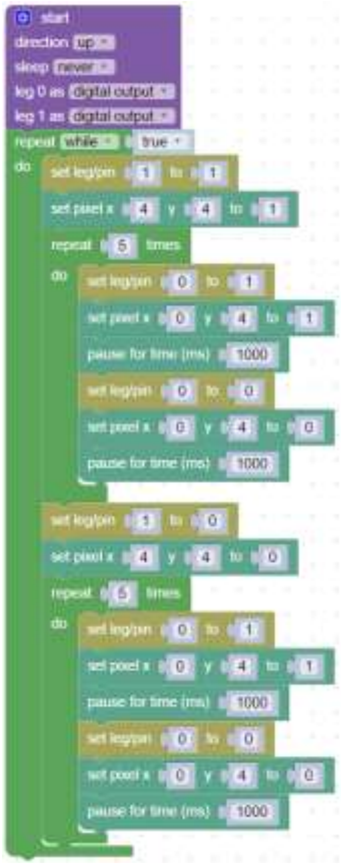


2. Make leg ‘0’ go High and Low at 1 second intervals.



- To assist debugging, set a neighbouring LED to come on and off at the same time as the output leg.
- Check the voltage on leg 0 with a voltmeter. It should be switching between +4.7V and 0V.
- Keep the ON time the same as the OFF time. This means the power is always applied for half the time, no matter what frequency you choose.
- For safety, don’t set Pause times of less than 250ms. Flashing bright lights faster than this can provoke epilepsy in sensitive people.

3. Make leg ‘0’ switch 5 times while leg ‘1’ switches once.

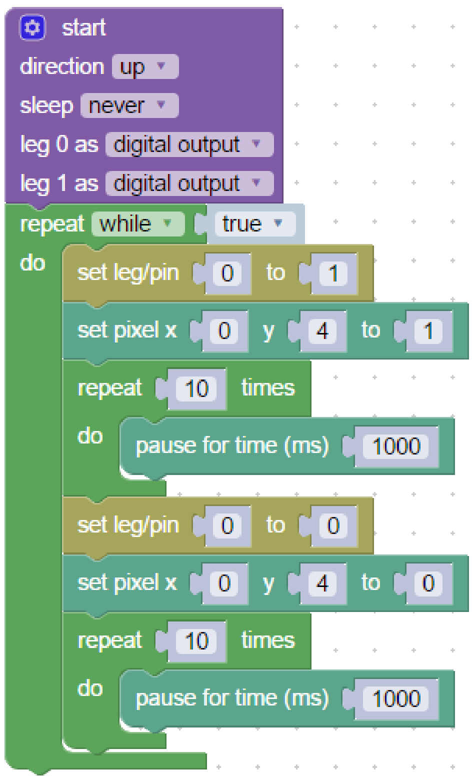


- Watch the LEDs to check that both outputs are doing what you want.

- Leg ‘0’ should be going ON and Off every second, while leg ‘1’ goes ON and OFF every 5 seconds.

4. The maximum value for Pause is 65536, which is about 1 minute.

Test out a workaround like this, using smaller numbers to start with so you don’t have to wait too long.



Section 4:
Effects of Microgravity

Introduction

This section considers the impact on human space flight on the human body. Activities include:

1. Researching physiological effects of microgravity
2. Investigating the gravitational effect on Blood Pressure
3. Weighing precisely in microgravity situations : using an inertial balance

Activity 1 - Researching physiological effects of microgravity

See Pupil Notes page37.

Before researching the effects of microgravity, could pupils find out what microgravity means on the ISS?
The ISS orbits Earth between 330 and 435km at a speed of 17,500 miles per hour. So the ISS is kept in orbit by gravity (the ISS will experience a gravitational field about 88% of the strength at the Earth's surface). This article on the NASA website article provides a great explanation of how an apple dropped by an astronaut wouldn't appear to fall, only because the apple, astronaut and space station are all falling at the same rate, around Earth.

Task pupils to **research** the effects of microgravity on astronauts, then produce a **checklist/information sheet/poster/video** to show how astronauts are affected by microgravity (moving around, sleeping, eating and drinking, doing the toilet, washing, physical appearance etc.)

Useful web links:
NASA
Science in School
BBC
Guardian article on ISS

Activity 2 - Investigating the gravitational effect on blood pressure

See Pupil Notes page38.

What changes occur in blood flow under microgravity conditions?

When doctors and nurses take a blood pressure reading, they look at two different types of blood pressure. Diastolic pressure is the pressure exerted on the walls of the arteries when the heart is in the relaxation phase, or diastole. A reading of over 90 is considered abnormal for diastolic pressure. Systolic pressure is the pressure exerted on the walls of the arteries when the heart is in the contraction phase. A reading of over 150 is considered abnormal for systolic pressure, but can vary by age, size, and gender.

Our bodies have adapted to gravity by keeping blood constantly flowing to the brain and other organs and tissues. Special stretch receptors in the carotid (neck artery) and other arteries sense changes in blood pressure and flow. If blood pressure in the arteries that lead to the head goes down, these sensors send a signal to the body to increase blood flow to the brain. In microgravity, all those highly tuned mechanisms that our cardiovascular systems use to keep pumping blood against gravity aren't necessary. Hearts no longer have to pump uphill to the head, and blood doesn't tend to pool downhill in the legs. Instead, blood pools around the heart and thorax, a condition known as fluid shift.

When astronauts return to Earth and stand up, the blood flows right down to the legs, and the proper signals aren't sent to replenish the brain's blood supply causing the returning astronauts to faint. NASA scientists hope to remedy this problem by studying animals such as the giraffe, which is able to offset the pull of gravity on its very tall body even when standing still. Scientists have found that the giraffe's tight skin and the muscles in its legs keep blood from pooling in its lower body. Additionally, the arterial pressure near the giraffe's heart is about twice that in humans to provide adequate blood pressure and blood flow to the brain.

How does gravity affect blood pressure?

If a blood pressure monitor is available, pupils can compare measurements of blood pressure for someone in three different positions: standing, sitting and lying down.

Average three sets of readings for each position.

They could then compare the blood pressure readings taken at the points of the body: e.g. at the wrist with the arm held up, at the wrist with the arm resting on a table, at the ankle with the person standing up.

In each case the person being tested should have been sitting still for a few minutes before starting the tests.

Pupils could record their results on the table provided or make their own.

Monitor position	Reading 1	Reading 2	Reading 3	Average blood pressure
Sitting				
Standing				
Lying Down				

Conclusion: ---

Monitor Position	Reading 1	Reading 2	Reading 3	Average blood pressure
Wrist held high				
Wrist horizontal				
Ankle standing				

Conclusion: ---

Activity 3 - Weighing precisely in microgravity situations: using an inertial balance

See Pupil Notes page39.

Mission Control is keen to find out more about how microgravity conditions affect digestion. Astronauts are finding that food takes much longer to digest. In order to monitor the astronaut's intake the items of food must be 'weighed' in advance.

How can you weigh an object which is 'weightless'? It will have no downward force to give a reading on conventional scales.

Mass is measured in Kilograms and is a quantity of matter while weight is measured in Newtons and is a measure of the downward force due to gravity acting on the object. What the astronaut can do is measure the mass.

Mass can be measured in the absence of gravity, for example, using an Inertial Balance or 'Wig Wag Machine'.

This relies on the fact that larger masses have more inertia and therefore will continue to vibrate for longer once they have been set in motion. The time taken for a set number of oscillations will depend on the mass of the object being tested.

Useful web links:

Partical Physics

ArborScientific – inertial balance This article describes how to use the Inertial Balance but suggests a more complicated analysis of the results. All that is required here is a graph of mass against average time for a fixed number of oscillations which can then be used to find the mass of an 'unknown' object.

Challenge: Calibrate a wig-wag machine and use it to calculate the mass of a suitable food item.

Instructions:

Clamp the balance to a suitable table/workbench. Using the 1, 2, and 3 kg masses in turn, and keeping the same starting point each time, measure the time taken for the balance to complete 50 oscillations. Repeat the measurement three times and calculate the average time for each of the masses.

Graph the results to give a Best Fit line or curve.

Replace the given masses with the unknown item and repeat the procedure to find the average time for 50 oscillations of the machine.

Use the graph to determine the mass of the unknown item.

Object	Time 1 (s)	Time 2 (s)	Time 3 (s)	Average time (s)
1 Kg				
2 Kg				
3 Kg				
Unknown mass				

From your graph, the unknown mass = ……………….Kg

Section 5: Rover Design

Introduction

This section considers remote exploration with various activities including:

1. Designing a simple model Mars Rover (or Lunar Buggy).
2. Adding the capability to collecting rock samples.
3. Programming a Big Trak Rover (or similar).

Research: NASA and ESA missions to Mars

Mars Exploration Rovers : Mars.nasa.gov

Activity 1&2 – Designing a Model Mars Rover and Collecting Rock

See Pupil Notes page41.

Engineering Challenge: Using materials normally found in the home (or choosing from the resources available) design and build a simple model Mars Rover or Lunar Buggy.

It should be solar powered and any other rules should be agreed in advance by the participants.

Rovers can then be tested over different types of terrain, and on slopes etc.

Once the design has been tested, can it be modified to collect small samples of rock to be brought back for analysis?

NASA Design Squad has space related engineering challenges which could be adapted for this activity, for example – for a rubber band powered rover, rather than a solar powered device.

Down to the Core is a Design Squad challenge to design and build a device that can take a core sample from a potato "asteroid."

Activity 3 – Programming a Big Trak Rover

See Pupil Notes page42.

Astronauts on board the ISS have been practicing using remote control to manipulate model rovers from a distance in preparation for the future use of Mars Rovers – see BBC article.

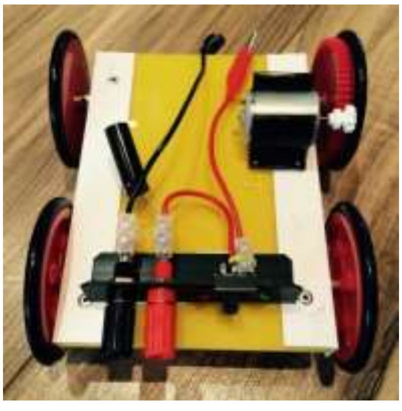
Pupils can simulate such astronaut training exercises using a ready-made model such as a Big Trak Rover (available from Amazon) or even a Bee-Bot floor robot.

Many primary schools have Bee-Bot floor robots which are an excellent tool for teaching directions and positioning by programming through sequences of forwards, backwards, left and right 90 degree turns. If iPads are available, this Bee-Bot Pyramid app (available from iTunes) gives an opportunity to practise:

Big Track Rovers are available to purchase.

Tomorrow’s Engineers Energy Quest includes a solar buggy challenge – the diagrams below show how a capacitor on their model would be charged using solar panels before it can then be used to provide the power supply for the motor.

Solar powered car kits are available online: e.g. from Amazon, Maplin, e-bay, Kitronik (requires soldering).



Section 6:
Astronaut Training Day

Astronaut Training Day: e.g. as a transition event/project for P7/S1 collaboration with **senior pupil mentors and / or STEM Ambassador support.** This would fit in well with **British Science Week** (March) and/or **World Space Week** (October).

Introduction – Mission Patch Design

See Pupil Notes page 43.

Activities in this section will increase awareness of our place in the Universe.

1. Extracting data from information provided to compile a Planetary Fact File
2. Measuring the gravitational field strength on Earth
3. Using data to carry out calculations on gravitational field strength, mass and weight
4. Demonstrating understanding of the term 'Light Year'
5. Careering into space: focus on who is doing what in the space sector

This section could be set as a 'qualifying' stage before 'potential Astronauts' proceed to selected activities/challenges, e.g. on an **'Astronaut Training Day'**. Teams would be expected to come up with their own Mission Patch design as part of their team building at the start of such an event.

Search 'astronaut mission patches' online for examples.

Each patch shows the names of the crew members and some information about their specific mission.

Teams are asked to design a patch for use as team logo for any display or presentation they may give.

Teams should consider several designs before choosing the best.

Suggested components selected from the main menu

- Introduction: Mission Patch Design
- Section 1: 'It's Astronomical!' PowerPoint activities - Possibly as homework/completed in advance as a 'qualifying round'.
- Section 2: Measuring focal length of lenses and building a model Telescope
- Section 3: Satellite positioning and retrieval challenge
- Section 4: EVA exercise, with solar cell investigations
  - Wig Wag machine,
  - BP investigation
- Section 5: Mars Rover / Core Sampling device

Elements of Section 1 could be set as a 'qualifying' stage for teams before teams of 'potential Astronauts' proceed to selected activities /challenges, on an 'Astronaut Training Day'.

Teams would be expected to come up with their own Mission Patch design as part of their team building at the start of such an event.

Session 1: Each team (possibly 6 pupils) would be supplied with a list of scientific investigations to be carried out in a set time. They would require to be split into smaller groups (e.g. 3 groups of 2) in order to complete the tasks on schedule

Investigations might be:

1. Measuring the focal length of a range of convex lenses
2. Calibrating the Wig Wag machine
3. Solar Cell circuit investigation

Session 2 - Technology

Teams again divide into smaller groups to carry out the tasks:

1. Building a model telescope
2. Measuring an unknown mass in microgravity conditions
3. Satellite Positioning

Session 3 - Engineering

1. Design and make a satellite grabber
2. Design and build a NASA Launchpad Rover
3. Design and make a NASA Launchpad core sampler

Session 4 - Mission Control! EVA Activity – a fun Finale!

Sample planning/recording sheets are included in the Pupil Activities section

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