

# BORROW THE MOON

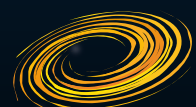


## TEACHER GUIDE

Overview, lesson plans and additional support material



Science & Technology  
Facilities Council



NATIONAL  
SPACE ACADEMY



# WELCOME TO BORROW THE MOON

Between 1969 and 1972, six manned Apollo missions successfully landed on the Moon, allowing the Astronauts to collect samples and bring them back to Earth for study. 382 kilograms of lunar material was returned, most of which was used for scientific research.

Some of these samples have been preserved in acrylic disks for educational use by NASA, and since the mid 1980s the Science and Technology Facilities Council (STFC) has been running a loan scheme to allow thousands of schools, museums, and outreach organisations across the UK to access not only these samples, but a range of other meteorites and interesting rocks.

The STFC is the only body that lends out these precious samples to educational and scientific institutions in the UK, and as such provides a unique and exciting opportunity to allow young scientists to engage with a true piece of space history.



This programme has now been expanded to 6 identical loan boxes with new specimens added including Lunar and Martian meteorites, magnaprobos, 4 USB microscopes and 5 sets of Earth rock kits to allow students to investigate rocks in groups.

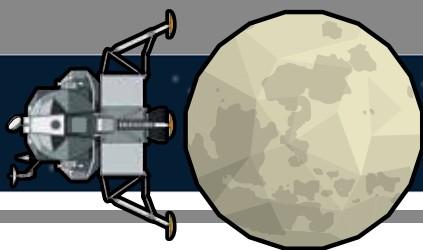
In 2017 the National Space Academy developed a new set of educational resources to accompany the sets.

The resources take the form of full lesson plans with curriculum links, that are supported by a full set of digital, downloadable resources including work sheets, PowerPoint presentations and additional support material to give educators the basic overview of meteorite and Lunar rock knowledge needed to make the most of these resources.

There are activities across the educational age range, from 5 years old to 18 years old, and the activities cover science, geography, mathematics, literacy, and drama.







## WELCOME TO BORROW THE MOON

### MANAGING THE LOAN

STFC is entrusted by NASA to run a secure educational loan service for the lunar rocks sample discs. Both the lender and the borrower must apply the highest standards of care for these unique objects.

STFC has six educational packages containing lunar samples and meteorites, which are available for periods of one or two weeks at a time, and can be booked up to a year ahead.

The lunar samples are presented in encapsulated discs and are of interest to everyone from a young child to a geology student. Thousands of schools, colleges, universities, museums and astronomical societies have enjoyed the samples since the scheme began.

Each package also contains different examples of meteorites and Earth rocks, put together by the National Space Academy. The loan is free of charge and is provided as part of STFC's commitment to the public understanding of space and planetary science.

### TRANSPORT AND SECURITY - TERMS AND CONDITIONS

1. Delivery and collection of the samples is by courier and will be arranged by STFC.
2. Each organisation must nominate one person (authorised official) to take responsibility for the loan, with a second person (co-official) to act in case of emergency.
3. The authorised official must telephone STFC (01793 442030) to confirm that the package has been despatched, quoting the courier's 12 digit bar code number.
4. The lunar samples are the property of the United States Government and are considered irreplaceable.
5. The security of all the samples, in transit and during the period of the loan, must follow the requirements laid down by NASA and the Natural History Museum and will need to be agreed following a visit to the site by the STFC administrator of the loan scheme. During the visit, any questions the borrower may have can be answered and the specific loan requirements discussed. The loan is subject to inspection by a STFC or NASA official at any time.
6. The authorised official is responsible for ensuring that the samples are correctly packed and clearly labelled for return either to STFC or to the next borrower and must be ready for collection by 9.00 am on the agreed date.
7. The authorised official is responsible for the receipt, use (including security during use), accountability, and return of the samples at the end of the designated time.
8. Only the authorised official may receive and open the package, although the co-official should be available in case of emergency.
9. Borrowers must complete the checklist supplied with the case on receipt of the specimens and on departure.
10. Under no circumstances should the samples be moved in any container other than the carrying case provided.
11. During use for instructional purposes, the samples must be under the continuous surveillance of the authorised official. At no time may the samples be left unattended. Borrowers are requested to complete the log sheet provided to record the transfer to and from the secure storage. The log sheet should be returned to STFC at the end of the loan period.
12. The samples must be handled with extreme care at all times. Every effort should be made to prevent the encapsulated discs becoming scratched or otherwise damaged. Extreme care should be taken not to break the thin sections.
13. When not in use, the samples must be locked in a safe or secure storage cabinet equipped with a combination padlock. Only the authorised official and co-official should have knowledge of the combination to the secure locks. No other items of high theft value may be stored in the safe with the samples.
14. The institution's security organisation must be informed of the presence and location of the samples. It is desirable that the security patrol periodically check the storage container outside normal working hours.
15. No admission charge may be made to view the lunar samples. If the organisation has an established general admission charge, no additional charge may be made to view the lunar samples.
16. Any damage to or loss of the samples should immediately be reported to STFC (Tel: 01793 442030, Fax: 01793 442002).
17. At the end of the loan period the borrower should complete and return a short report form to STFC.

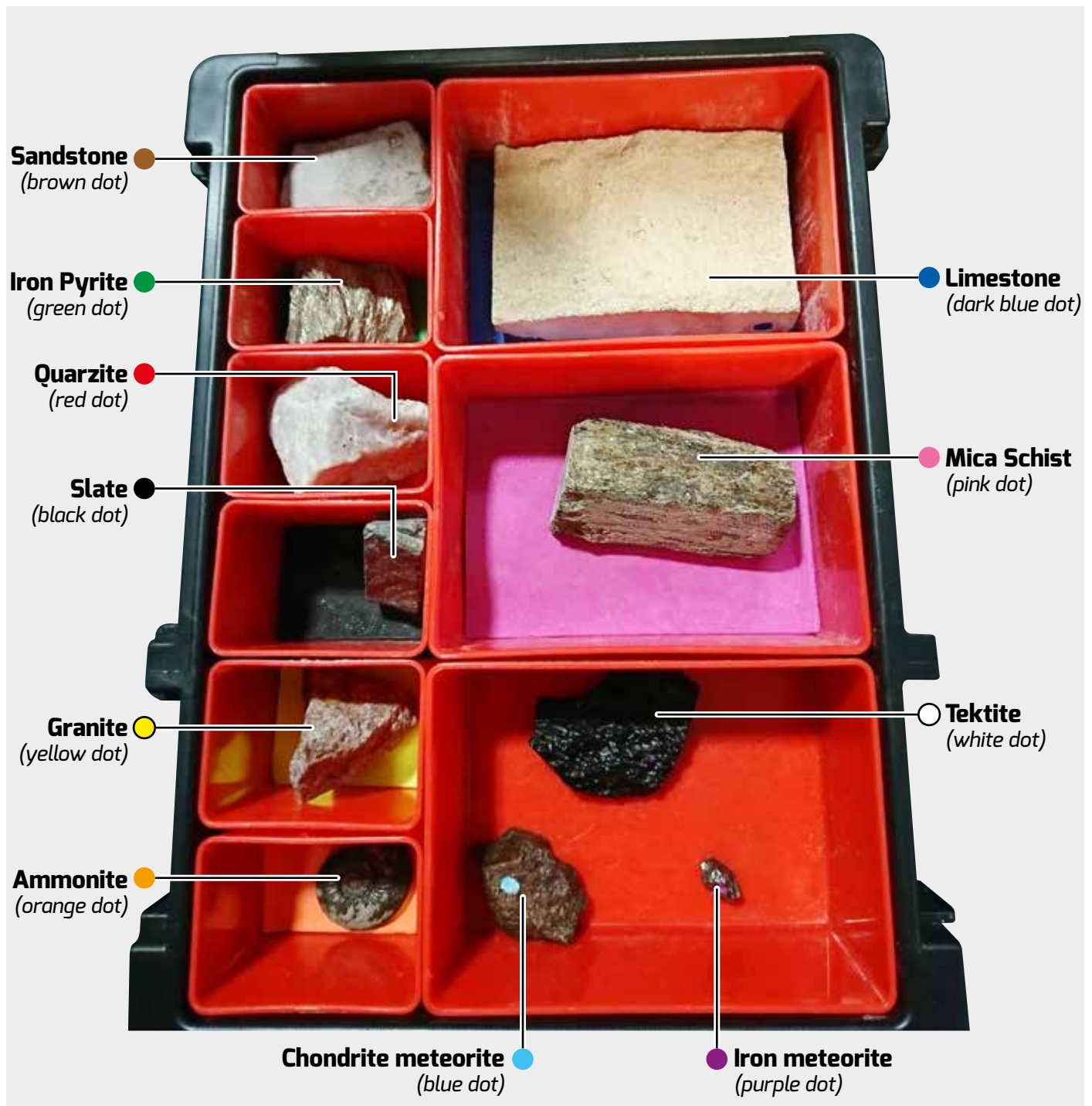


# THE METEORITE HUNTERS BOXES

## WHAT'S IN THE BOX?

The loan box contains 5 Meteorite Hunters boxes containing Earth, space, and fossil related rocks. These are designed to be handed out to students as kits for some of the activities (although a few activities in these resources require the selection of a limited number of these rocks).

Please ensure that all samples are counted back in by each group at the end of each activity.



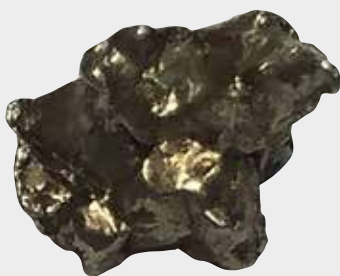




## GUIDE TO THE METEORITE HUNTERS BOXES

### ROCK INFORMATION

#### IRON METEORITE



Type of rock: **Iron meteorite**

This is a small fragment of the Campo de Cielo iron meteorite.

These were discovered in Argentina and are thought to have crashed down to Earth around 5000 years ago.

The meteorite is magnetic, melted metal (mainly iron) that has cooled into a droplet. You can see patterns caused by it streaming through the atmosphere while in a melted state.

**NOTE:** Please note that to avoid loss, the small iron meteorites have been glued to a piece of card.

#### CHONDRITE METEORITE



Type of rock: **Chondrite meteorite**

This ordinary looking rock is a chondrite meteorite.

This is a meteorite that contains chondrules, spherical shapes inside caused because of the meteorite slowly forming in space. In some of the samples, if you look carefully, you can make out some of these chondrules.

Many of the samples also have evidence of a fusion crust.

However, the biggest giveaway that these are meteorites is the fact that they are magnetic, and a little rusty due to oxidation of some of the iron content. They are also fairly dense.

#### AMMONITE



Type of rock: **Fossil**

This is a fossil of a now extinct marine mollusc, the Ammonoidea. These creatures died out at the same time as the dinosaurs, so this fossil is of a creature that was living at least 65 million years ago.



# THE METEORITE HUNTERS BOXES

## RED FELDSPAR GRANITE



Type of rock: **Igneous (Intrusive)**

**Features:** Course, interlocked grains visible to the naked eye. Feldspar crystals give it a pink/red colouring.

**Formation:** Forms from slow crystallisation of magma below the Earth's surface.

## LIMESTONE



Type of rock: **Sedimentary**

**Features:** A calcium carbonate rich (it will fizz if you expose it to dilute hydrochloric acid) rock, often with evidence of shell fragments and marine life fossils within.

**Formation:** Limestone forms in shallow, warm marine waters. It is formed largely from fragments of the calcium carbonate rich shells of marine animals that have died.

## QUARTZITE



Type of rock: **Metamorphic**

**Features:** Small, interlocked crystals. Incredibly strong.

**Formation:** Formed when heat and pressure alter quartz-rich sandstone. The sand grains get recrystallised and silica cement binds them together.

**NOTE:** This is one of the more difficult rocks to classify in the box as it could be mistaken for igneous rock.

## IRON PYRITE



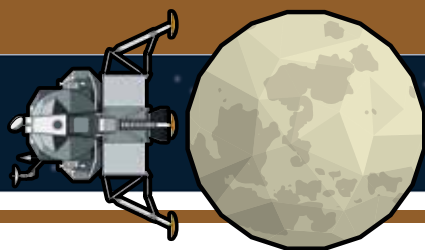
Type of rock: **Mineral crystal**

**Features:** Gold coloured mineral crystals growing on a base layer of rock. The colour comes from iron disulphide.

**Formation:** It can form in high and low temperatures and can be found across the planet in igneous, sedimentary, and metamorphic rocks.

It is also known as fool's gold.





## GUIDE TO THE METEORITE HUNTERS BOXES

### SLATE



Type of rock: **Metamorphic**

**Features:** Uniform colour, very hard. If you look closely with the hand lens or under a USB microscope, you can see the fine layers.

**Formation:** Made from clay/shale minerals heated and squashed under pressure inside the Earth.

### SANDSTONE



Type of rock: **Sedimentary**

**Features:** Composed of sand sized grains of material cemented together.

**Formation:** Weathering of rocks produces small grains of material which are transported to their depositional site by water. Over time, these grains settle in basins and becoming cemented together as the water evaporates and leaves behind solid crystals to hold the grains in place.

### GARNET MICA SCHIST



Type of rock: **Metamorphic**

**Features:** This rock has obvious layers, and plate shaped grains that are visible to the naked eye. Mica crystals give it a shiny appearance. It is also very soft.

**Formation:** This rock usually forms on continental convergent plate boundaries, where sedimentary rocks like shale and mudstone get subjected to intense heat and pressure. A schist will first be formed as a slate, and then a phyllite before taking its final form.

### TEKTITE



Type of rock: **Impactite**

**Features:** This rock is a low density, glassy black rock with bubbles of air trapped throughout. It has a smooth, bubbly, glassy appearance.

**Formation:** Tektites are formed when a meteorite impacts, melting the rock and throwing it a long way from the impact site.



# GUIDE TO THE HANDLING ROCKS

This is a brief guide with some additional information about the meteorites and associated rocks for handling and investigation in the loan boxes. Please note that the images may vary from your own samples depending on the box that you have.

## LARGE CAMPO DE CIELO IRON METEORITE

This is part of a group of iron meteorites that have been found about 1000 km Northwest of Buenos Aires in Argentina. Records exist as far back as 1576 for this meteorite, when one of the governors of a province in Argentina sent his men on a search for a huge mass of iron. The natives had been using this iron for their weapons, and claimed that it had fallen from the sky, which is where the name comes from (translated from "Field of Heaven").



## UDEI STATION IRON METEORITE

This is an iron meteorite with silicate inclusions (crystals found inside the meteorite). These are the darker, rougher sections that you can see. It was witnessed falling to the Earth in 1927. This meteorite has been sliced open to allow you to see the inclusions inside.



## MOLDAVITE IMPACTITE

This is a type of glass that is believed to have been formed 14.7 million years ago during the impact of a large meteorite in what is now Germany. When the meteorite hit, some of the energy of the impact caused the ground to melt into glass, and liquid glass droplets were thrown up into the atmosphere. These cooled as they fell to Earth, resulting in the objects we see today.



## LIBYAN GLASS IMPACTITE

Also known as Libyan desert glass, this material is found in the Eastern Sahara Desert. It can be found embedded in the bedrock, and is thought to have been created when a very large meteorite underwent an airburst explosion (where the meteorite blows itself up in the atmosphere before hitting the Earth) that had enough energy to melt and fuse the surface desert sand into glass.



## SAHARA CHONDRITE METEORITE

This meteorite was discovered in the Sahara desert and is part of a huge strewn field (the area over which fragments of a larger meteorite have fallen). On the samples in the loan boxes you can see evidence of a fusion crust, and in some, where the surface is chipped, you can make out some of the small chondrules within. It is weakly magnetic and may show a few rust spots on the outside, indicating the iron content within.

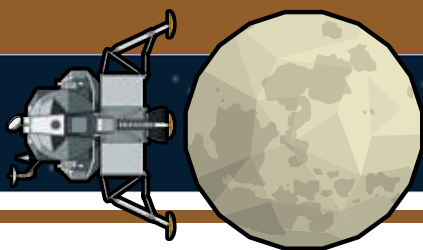


## TEKTITE IMPACTITE

Originally thought to be a new class of meteorite, tektites are actually material that has been melted when a meteorite impacts the ground. This material was ejected upon impact, and cooled as it fell back to Earth, often resulting in a droplet shape. They typically show bubbles of gas trapped within and have a surface that is similar in appearance to a fusion crust.







## GUIDE TO THE HANDLING ROCKS

### ANORTHOSITE

Anorthosite is an intrusive igneous rock composed mainly of silicates called feldspar. The Earth rock included is an analogue for the anorthosite that has been discovered on the Moon. Differences in the amount of volatile materials in Earth anorthosite and Moon anorthosite allow us to differentiate which is which. You will see that it is similar to the anorthosite that is contained within the Apollo Lunar Disks.



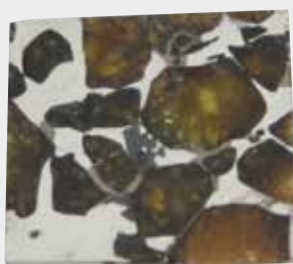
### CUT AND POLISHED SAHARA

This meteorite is the same as the Sahara chondrite whole stone, except it has been cut open and polished to expose the chondrules inside and to allow you to more accurately see the fusion crust.



### IMILAC PALLASITE (MEMBRANE BOX)

This stony-iron meteorite was found in the Atacama Desert of Northern Chile in 1822. You can clearly see the beautiful green-yellow olivine (magnesium iron silicate) crystals encase within the iron. These are extremely sought after for the purposes of jewellery making.



### ETCHED IRON METEORITE SLICE (MEMBRANE BOX)

This is a small section of an iron meteorite that has been etched with nitric acid to allow the Widmanstätten patterns to show up (showing the crystal structure of the iron). The larger the crystals, the slower the iron meteorite cooled.



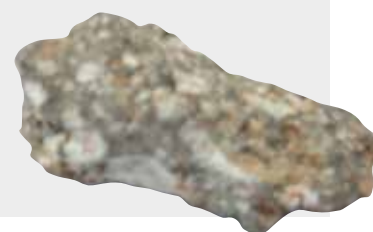
### BASALT

Basalt is an extrusive igneous rock formed by the rapid cooling of lava. This Earth rock has been included because it is an analogue for the basalt that has been discovered on the Moon. That the Moon is mainly made of anorthosite and basalt suggests that not only was it once volcanic (the Moon's Mares, or 'seas' contain fewer craters since they were filled with volcanic lava), but also that the Moon was originally part of our planet.



### LUNAR METEORITE (MEMBRANE BOX)

This is a piece of Moon rock that was ejected from the surface after a huge impact. It is classed as a melt breccia. It is formed from the fragments of Lunar rocks that have been shocked and broken up during an impact. You can see the similarities between this and the breccia in the Apollo Lunar Disk. You can still see the orange soil from the desert clinging its surface.



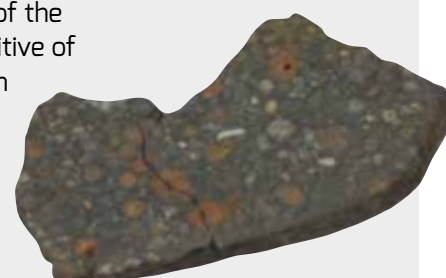
### SHERGOTTITE MARTIAN METEORITE (MEMBRANE BOX)

This small section of a Martian meteorite would have been part of a larger section, ejected from the surface of Mars following a huge impact. They are an igneous rock, suggesting that Mars was once geologically active.



### CARBONACEOUS CHONDRITE SLICE (MEMBRANE BOX)

This is a cut and polished section of a carbonaceous chondrite. This is one of the oldest, and most primitive of all meteorites. You can clearly see the well-defined, colourful chondrules in these samples.





# USING THE USB MICROSCOPES

The Borrow the Moon loan box comes with 4 USB microscopes and a set of 4 mini clamps, stands, bases and bosses to allow them to be held steady over your samples.

To view the image from the USB microscope you will need to install webcam viewing software such as VLC media player (*available for free from <https://www.videolan.org/index.en-GB.html>*).

## INITIAL SET UP

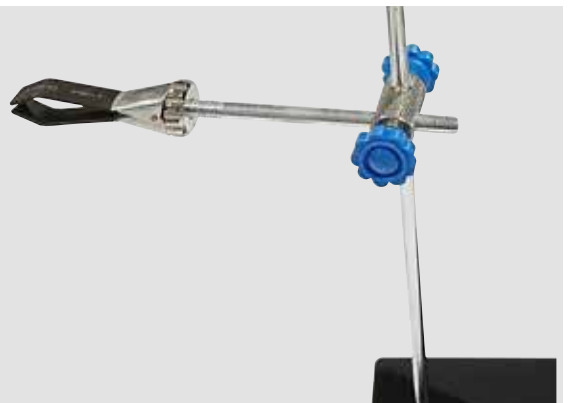
### 1 SETTING UP THE STAND

Take the long metal rod with a thread on one end and start to thread it through the hole in the black base. As soon as the metal rod emerges on the other side of the base, tighten the nut on top. If you allow the rod to go down too much, the stand will be unstable. Your rod and base should look like the image to the right, with some of the tread still visible.



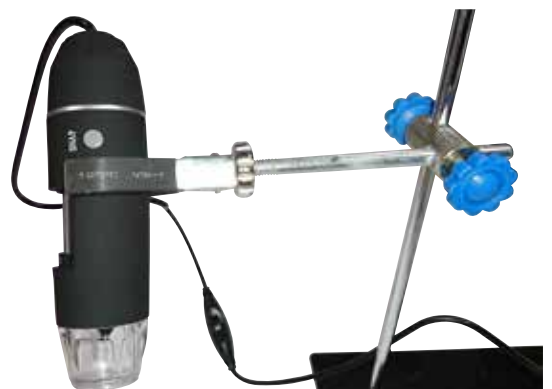
### 2 ATTACHING THE CLAMP

To attach the clamp to the stand, you will have to use the small boss (the cylinder-shaped objects with two holes). Twist the blue screw in an anticlockwise direction to increase the width of one of the holes until you can fit the rod through it. Once the rod is through, twist the blue screw in a clockwise direction to hold the boss tightly in place. Next take the other blue screw and loosen it until you can fit the clamp arm through the hole. Once you have done this, tighten the screw.



### 3 HOLDING THE USB MICROSCOPE

At the base of the clamp jaws there is a screw that can be turned to open and close the clamp jaws. Take the USB microscope and place it between the open jaws. Make sure that when you clamp it, the jaws are not putting pressure on the silver sliding ring as this needs to be free to move to allow you to focus the microscope.

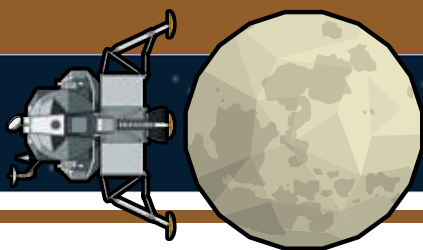


### 4 PLUGGING IN THE MICROSCOPE

Plug the USB cable into any USB port on your computer. This will also provide the power necessary to switch on, and change the brightness of the LED lighting ring. To turn the light on, simply use the dimmer switch that is partway up the cable.

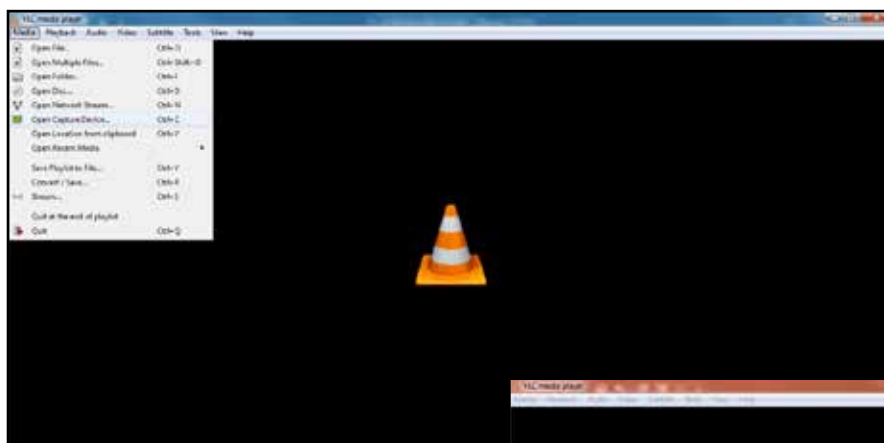






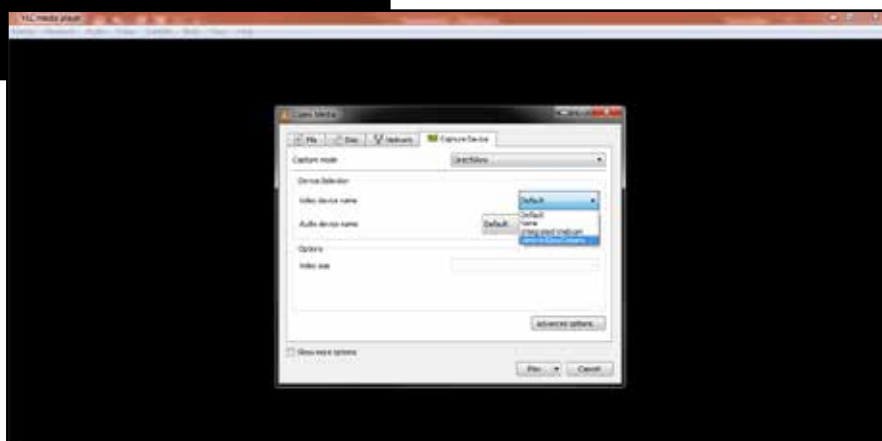
## USING THE USB MICROSCOPES

# OBSERVING YOUR SAMPLES



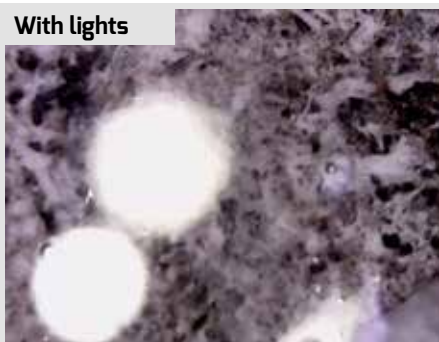
**1** Open VLC media player on your computer. Making sure that the microscope is connected to a USB port, go up to the left hand of the command drop down and click on media. From this menu click on Open Capture Device.

**2** From the video device name drop down menu, select Lenovo EasyCamera and then click on play. This will open a video streaming window. PLEASE NOTE: Depending on your computer there may be some lag between moving the microscope and the image on the screen moving.



**3** Now it's time to bring your sample into focus on the screen. With the front of the microscope facing you, twist the focus ring anticlockwise as far as it will go. Unscrew the boss where it holds on to the rod, and move the microscope down until it is approximately 1cm from the surface of your sample. Carefully, rotate the focus ring in small increments, keeping the stand as steady as possible, until the image is clear on the screen. If the image doesn't become clear before you run out of rotation on the focus ring, start again but this time slowly move the microscope away from the surface of the sample until the image becomes clear.

**With lights**



**Without lights**



Note: When viewing objects that are in the membrane boxes, if the lights are on you will see a reflection of these in the membrane. If the room is well lit you should not need the lights (as can be seen in the comparison picture below) since the software will try to autocorrect the brightness and contrast of the image. In a poorly lit room, you can get around this problem by placing the USB microscope at an angle to the sample, so that the light is not reflected directly back.



If you are getting your students to try this themselves, you may wish to get them to practice first in finding the focus for a coin or a ruler before you let them try it with the handling samples.



# EXPLORE THE MOON IN GOOGLE EARTH

Google Earth has options for exploring the surface of the Moon and Mars. Using images and data from orbiting satellites, students can explore these other celestial bodies in almost as much detail as they can our own planet! This mini-guide outlines the basics for using Google Moon to compliment the Lunar activities in these resources.

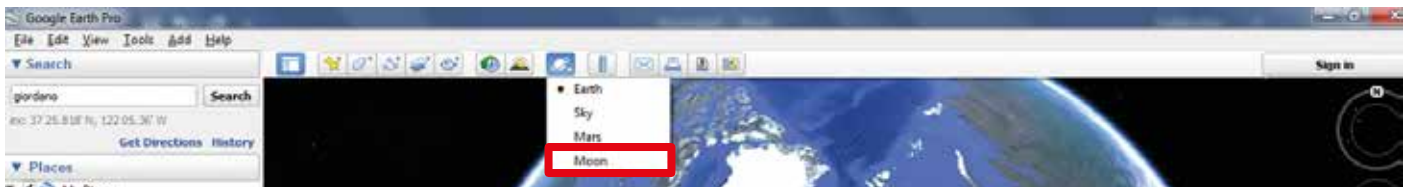
DOWNLOAD GOOGLE EARTH



[www.google.com/earth/download/gep/agree.html](http://www.google.com/earth/download/gep/agree.html)

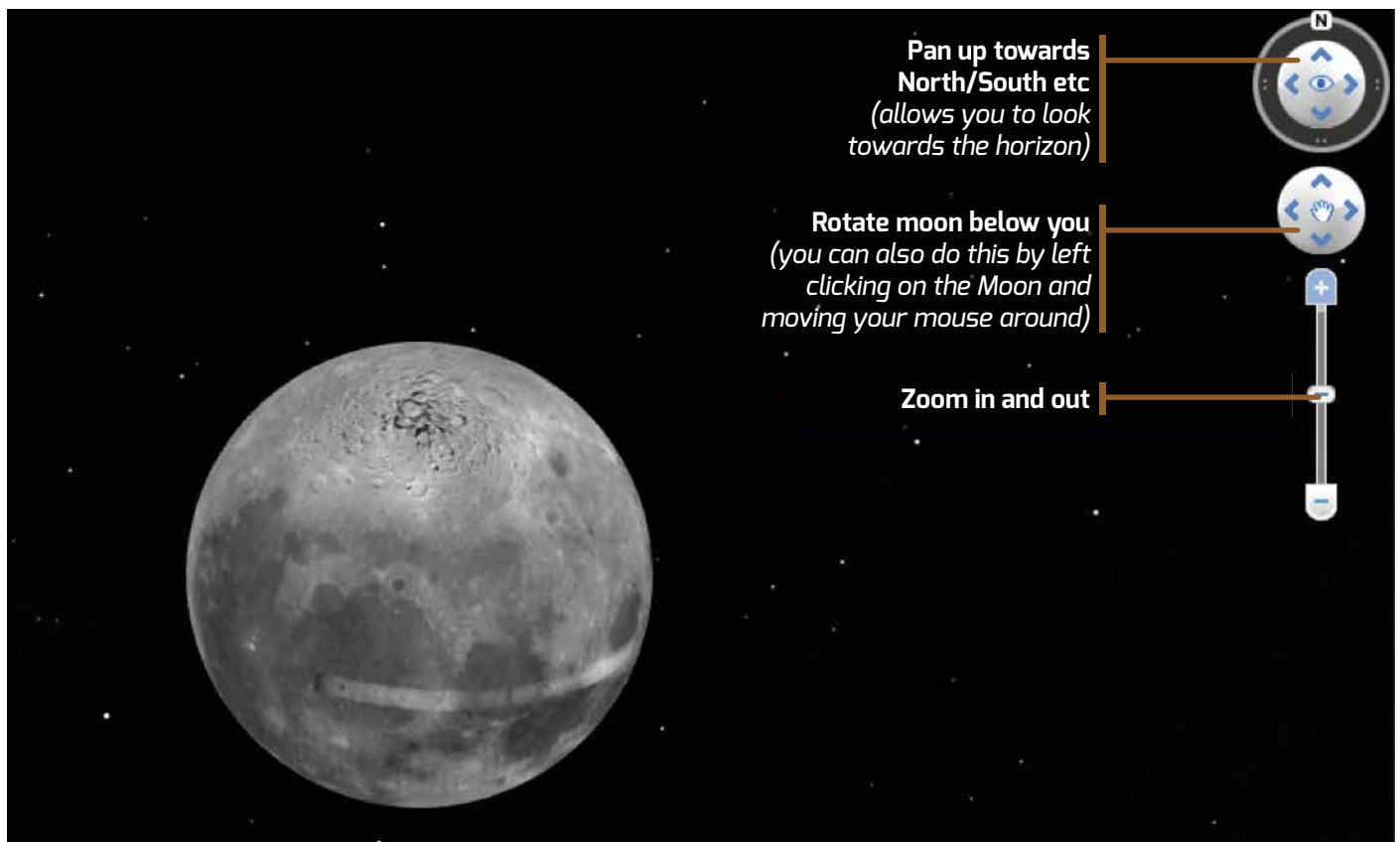
## 1 GOING TO THE MOON

Open Google Earth. Look at the icons just above the Earth image. Click on the one that looks like Saturn and select Moon from the dropdown. This will take you to Google Moon.

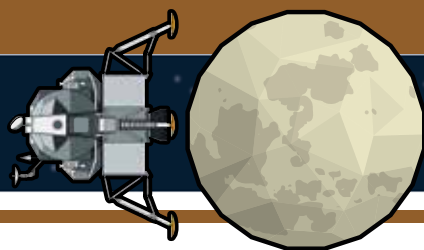


## 2 BASIC NAVIGATION

In the upper right-hand corner of the screen are the basic navigation controls. Placing your cursor over them makes them more visible.



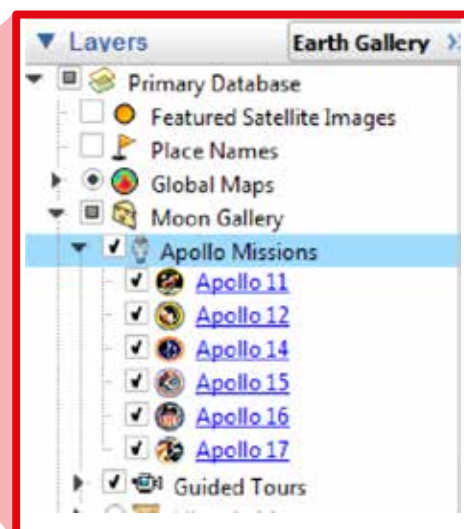
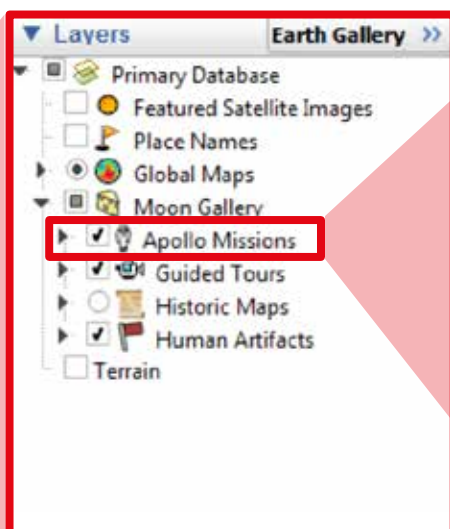
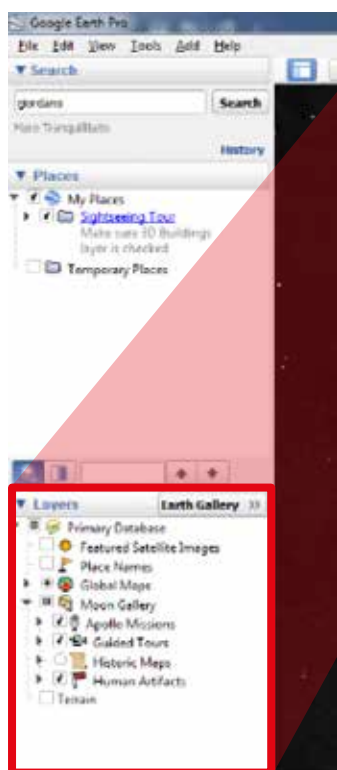




## EXPLORE THE MOON IN GOOGLE EARTH

### 3 VISITING THE APOLLO LANDING SITES

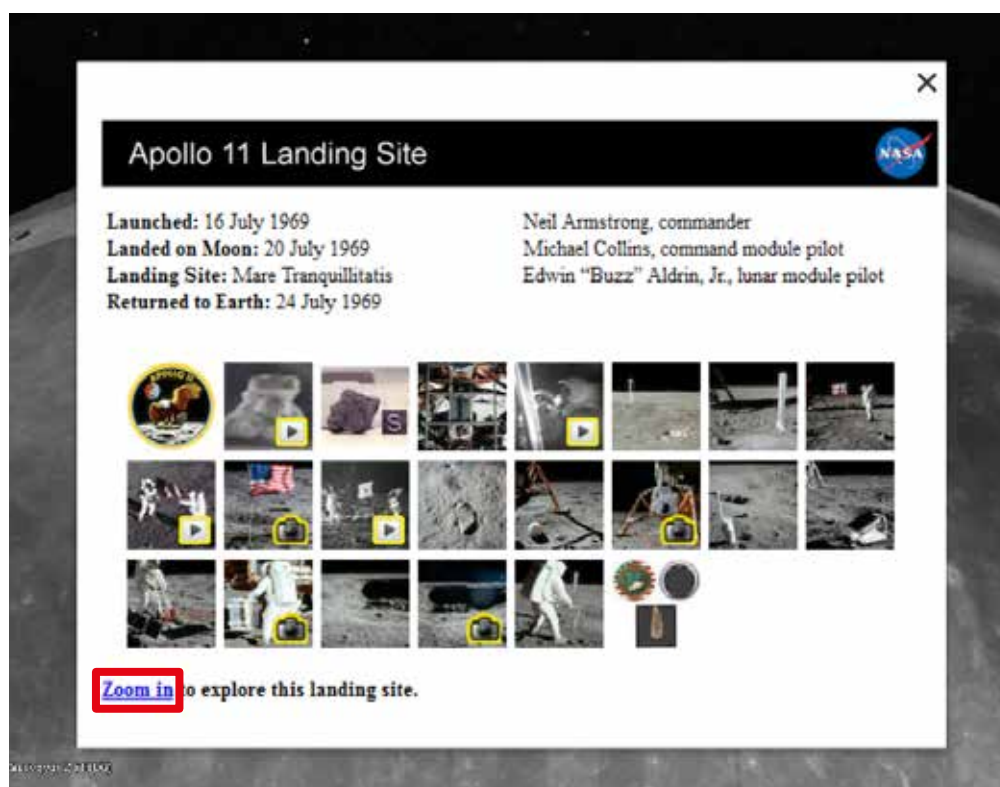
The Google Earth Moon map already has the Apollo landing sites added in the layers navigation bar on the left of the screen. Make sure that the Apollo Missions box is ticked. Double clicking on the Apollo Missions text will open a list of the Apollo missions.



Clicking on any of the Apollo missions will bring up an information links tab in the centre of your Moon map. This includes links to images and YouTube video clips that are embedded within the Moon map. Clicking on any of these will take you straight to the image or clip.

You can also zoom straight into the landing site by clicking on "zoom in" in the lower left-hand corner of the screen.

The area around the landing sites can then be explored as normal using the navigation tools outlined in part 2.





# EXPLORE THE MOON IN GOOGLE EARTH

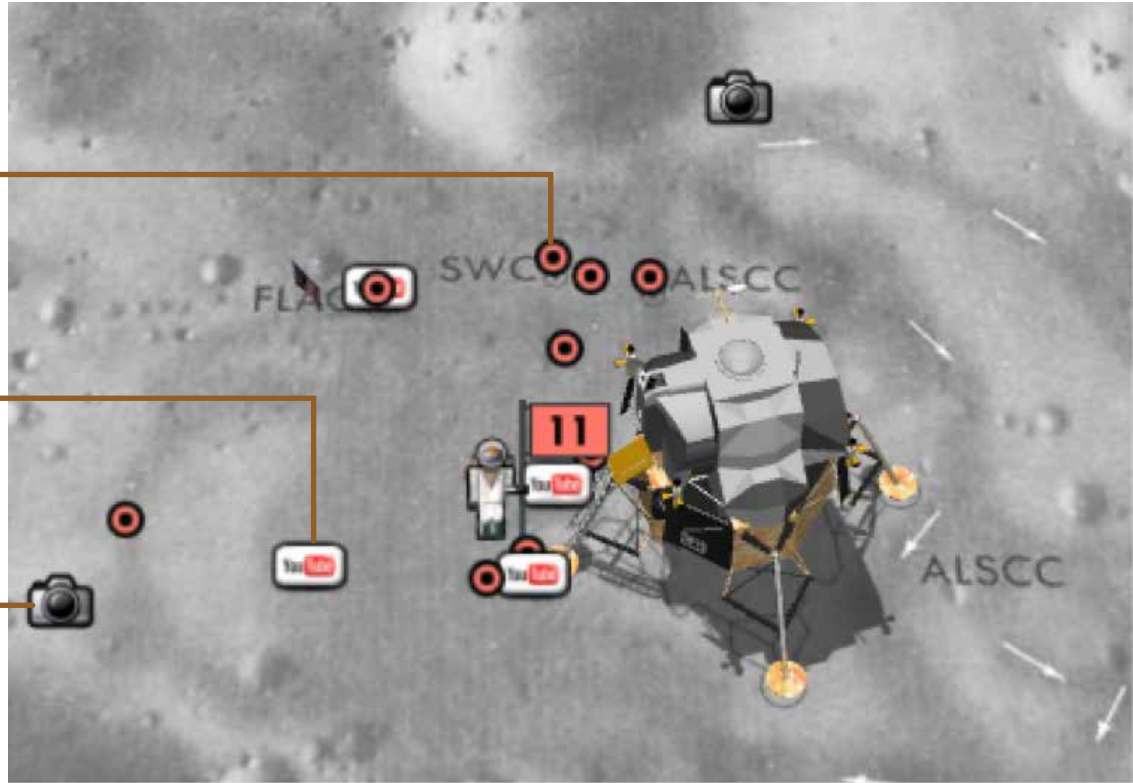
## 4 EXPLORING THE LANDING SITES

The landing sites are dotted with icons that link to extra content.

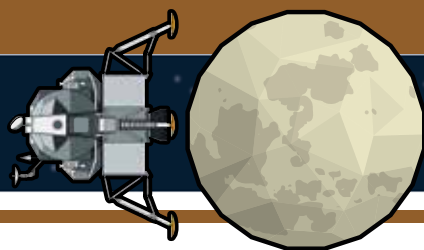
**Red dot:** Signifies where something interesting happened, such as an experiment. Clicking on this will bring up a text box with relevant information.

**YouTube Icon:** Clicking on this will take you to a relevant clip filmed at that spot.

**Camera:** Signifies that a high resolution, panoramic photo was taken at this spot. Clicking on it will give you the option to zoom into the panorama and look around you on the Moon (see image below)





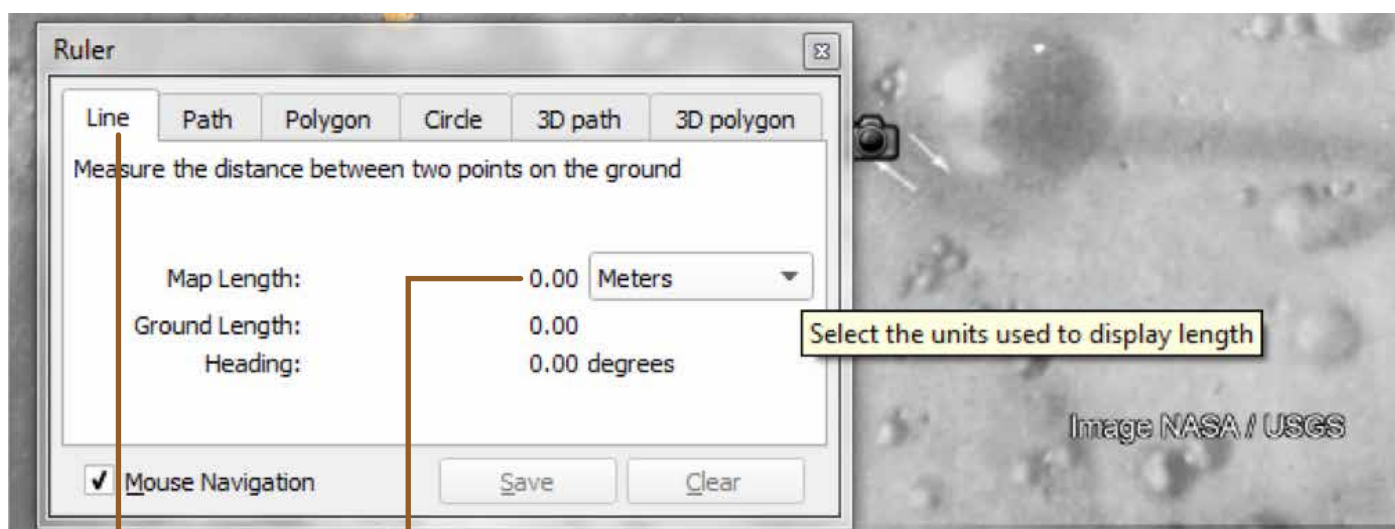


## EXPLORE THE MOON IN GOOGLE EARTH

### 5 MAKING MEASUREMENTS ON THE MOON

The ruler tool allows students to measure distances between objects, diameters of craters, and follow the paths that were taken by the Lunar buggies.

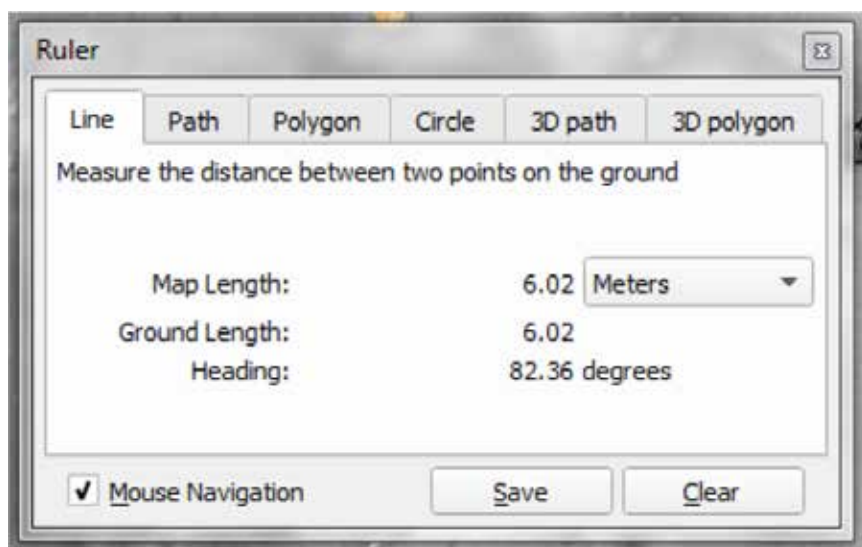
In the list of icons at the top of the page, click on the ruler (next to the planet icon that you used to enter Google Moon) to bring up the ruler pane.



You can choose to measure a single length, a path of multiple points and much more by selecting the tab at the top here.

You can choose the units that you want to measure in.

With the ruler selected, your mouse pointer should become a square target. To measure a distance, simply left click at the first point you want to measure from, move the cursor to the point you want to measure to and left click again. This will draw a yellow line between those two points and the length will show in the "Map Length" column of the Ruler box.





# SPACE ROCKS – A BEGINNER'S GUIDE

## ASTEROIDS

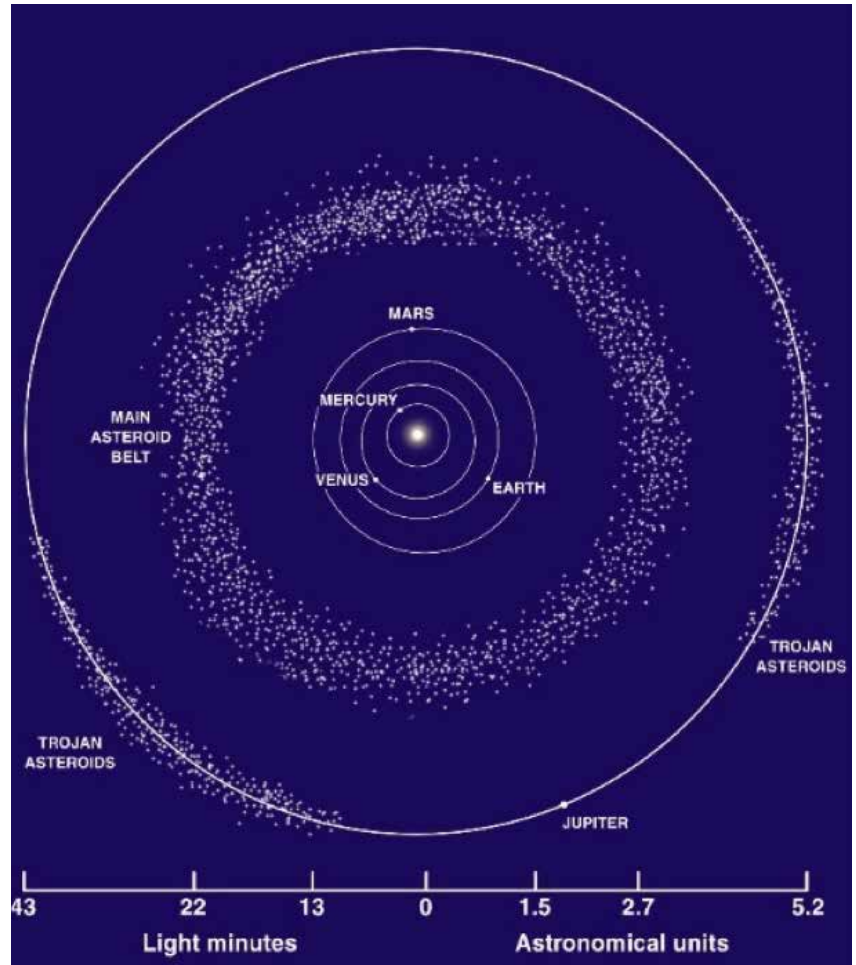
Asteroids are lumps of rock and metal that orbit our Sun, but are too small to be called planets. There are millions of asteroids. The largest, Ceres (which is so large it is now considered a dwarf planet) is 974km wide, whereas the smallest ever recorded was about 2m wide.

In our solar system, most asteroids can be found orbiting the Sun between Mars and Jupiter in a region of space we call the Asteroid Belt. The Asteroid Belt is 300 million km to 490 million km away from the Sun.

A collection of asteroids can also be found at about the orbit of Jupiter – we call these Trojan asteroids.

It is thought that some of the moons of the planets in the Solar System, such as Mars' Phobos and Deimos, are actually asteroids that were captured by the planet's gravity.

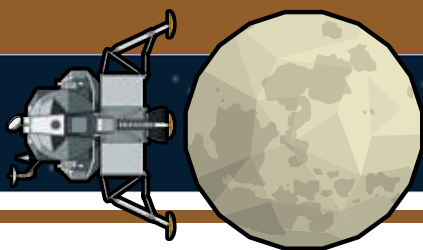
And in 2017, an asteroid unlike any we have ever seen before called Oumuamua (*translation: a messenger*



*from afar arriving first*) was observed – the first confirmed visitor from outside our solar system.







## SPACE ROCKS – A BEGINNER'S GUIDE

### HOW DID THEY FORM?

Asteroids are basically the leftover material from the formation of our Solar System 4.6 billion years ago. As the planets formed from a disk of dust and gas, small planet-like bodies called planetesimals formed. These continually collided with each other, fragmenting into smaller pieces – which became asteroids.

As Jupiter formed, its immense gravity stopped any other planets forming between itself and Mars, leaving only asteroids – the remnant building blocks of our Solar System.

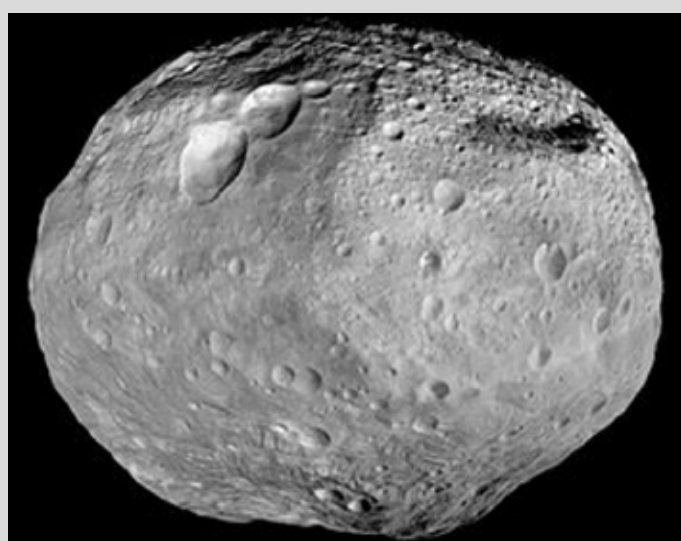
This is why we say if you get to handle a piece of an asteroid, you are probably holding the oldest thing you will ever hold.

### WHAT DO THEY LOOK LIKE?

The surface of an asteroid is thought to be covered in dust – bits of crushed up asteroid from previous impacts.

Most asteroids are too small for their gravity to pull them into a spherical shape meaning that most are irregular. The largest asteroids, such as Ceres are nearly spherical. They often have craters and dents from previous collisions with other asteroids. Vesta for example, has a crater 460km across.

Over 150 asteroids are known to have a small moon orbiting them, and some even have two moons!



### TYPES OF ASTEROID

Asteroids are classified into three groups, depending on the materials that they are made from.

#### C-TYPES (CARBONACEOUS)

These are the most common asteroids, making up around 75% of the Asteroid Belt. These are made of carbonaceous materials (materials containing a lot of carbon compounds). They also have very little metal in them.

#### S-TYPES (SILICATES)

These make up about 17% of the asteroids in the Asteroid Belt. They contain a lot of silicate rocks, and large amounts of metals including iron, nickel and magnesium.

#### M-TYPES (METAL)

As the name suggests, these asteroids are largely metal (mainly iron and nickel), including some rare metals like platinum. This is part of the reason why asteroid mining has been suggested by some as a possible future money-making enterprise.

There are also other rare types of asteroid, but these are extremely uncommon.

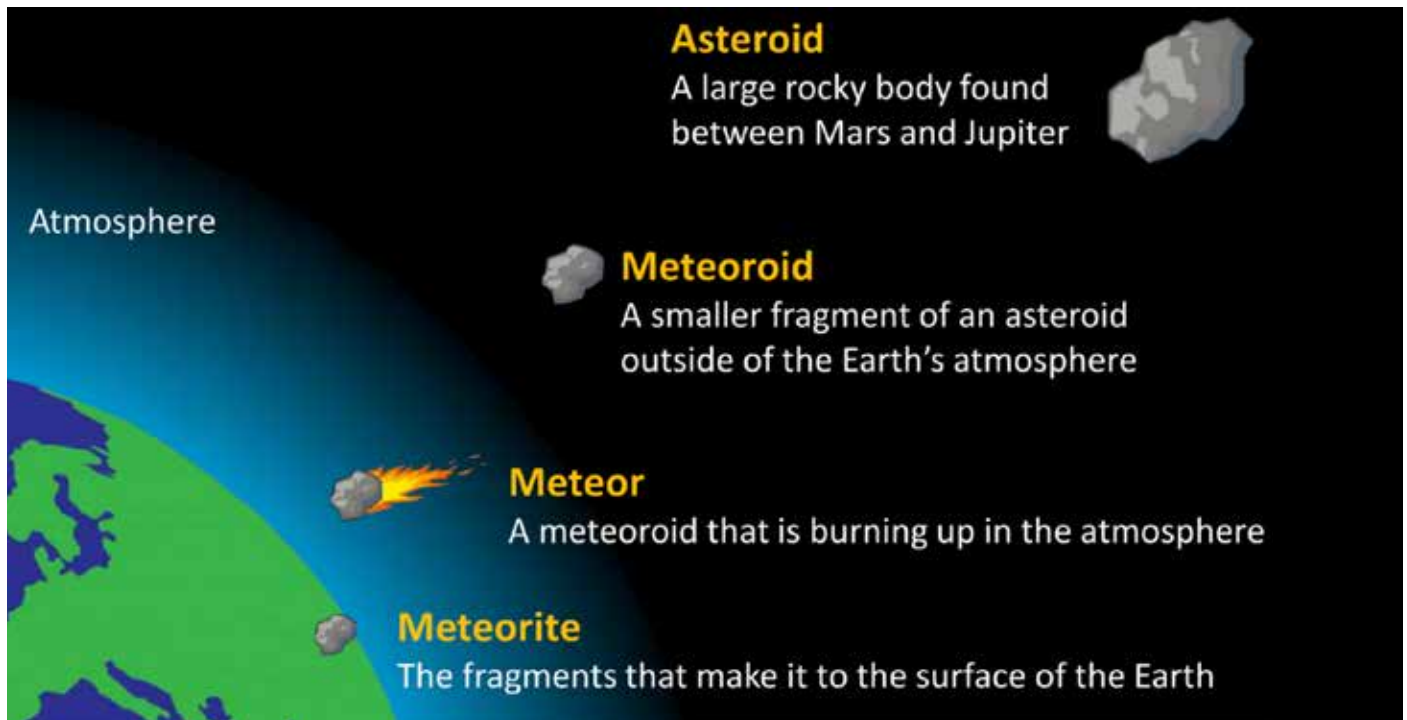


# SPACE ROCKS – A BEGINNER'S GUIDE

## SO MANY NAMES!

So, what is the difference between an asteroid and a meteorite? And what is a meteor? It is all to do

with where in space the object is with respect to the Earth. This is summarised in the image below.



Scientists are particularly interested in studying Near Earth Asteroids (NEAs). These are asteroids

that will pass fairly close to the Earth (closer than the orbit of the moon).

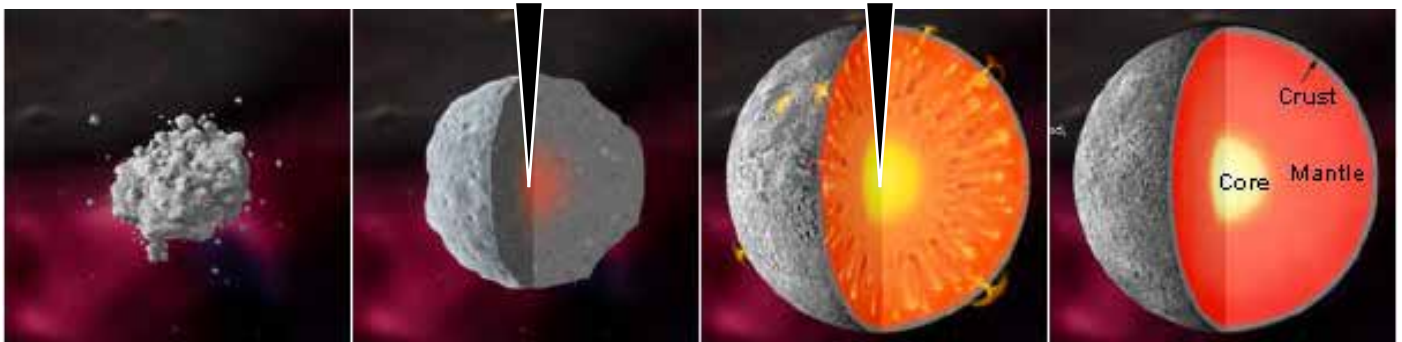
## DIFFERENTIATION OF LARGE ASTEROIDS

The largest asteroids are mini worlds – in some ways like the Earth. Like the Earth, heat was generated billions of years ago when the material the asteroid is made from was pulled together by gravity. More heat was generated by the decay of radioactive atoms and so the asteroid started

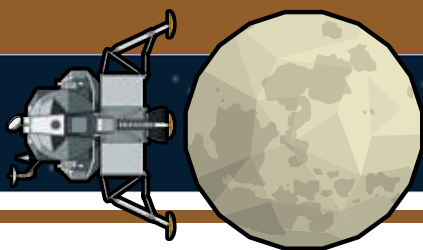
to melt. Dense iron can fall towards the centre of the asteroid, leading to a layered, or differentiated asteroid with a similar structure to the Earth. This differentiation helps to explain why we get such different types of asteroid.

Large asteroids heat up as they are squashed by gravity

Dense iron falls to the centre







## SPACE ROCKS – A BEGINNER'S GUIDE

# TYPES OF METEORITE

Meteorites fall into three main categories; stony, iron and stony-iron. Their features and content tell a story of how and where the meteorite formed.

## STONY: CHONDRITES

Chondrites are the most common type of meteorite, making up over 85% of all meteorites that fall to Earth.

These originate from small asteroids in the asteroid belt, in which differentiation has not occurred. Their defining feature is the coloured, spherical crystals of materials like olivine, iron and silicon which began life as floating droplets of these materials in space. Over time, gravity and other forces pulled these small spherical shapes together, forming a chondrite. Isotopic ratio dating of chondrites gives their age as 4.566 billion years old!

They come in four divisions; ordinary (which despite the name are actually very complex),



carbonaceous (*see carbonaceous asteroids*), enstatite (lacking metals and very rare) and rumuruti (lacking any metals at all).

## STONY: ACHONDRITES

These are thought to originate from the crust of very large asteroids. Since they have been heated as the asteroid formed under gravity, they have melted leading to a lack of chondrules. Most, known as HEDs are known to have originated from the large asteroid Vesta, the product of a massive collision with that asteroid in the past.



## STONY-IRON: PALLASITES

These are beautiful combinations of iron-nickel and silicate crystals. Potentially formed at the core-mantle boundary of large asteroids that have undergone differentiation, or as the result of large impacts between different types of asteroid, these meteorites with greenish olivine crystals are very sought after by collectors.





# SPACE ROCKS – A BEGINNER'S GUIDE

## IRON

These are, as the name suggests, lumps of iron and nickel that originated in the core of asteroids large enough for differentiation to occur. When such a large asteroid experiences a suitably large collision, core material can be scattered into space producing these meteorites.

They only make up around 5% of all meteorites that fall to Earth, yet are surprisingly common to find. This is due to their properties – very dark, highly magnetic, dense and large enough to survive the journey through the atmosphere and good at withstanding weathering. For this reason they are one of the easier types of meteorite to find.



When you etch a slice of an iron meteorite (by pouring a nitric acid/alcohol solution over it) a pattern emerges called a Widmanstätten pattern. This crystal, interlaced pattern of layers (or lamellae), is produced when one of the minerals in the iron meteorite called taenite cools, loses nickel atoms, and allows layers of another mineral called kamacite to form. The thicker the layers, the longer the meteorite took to cool.

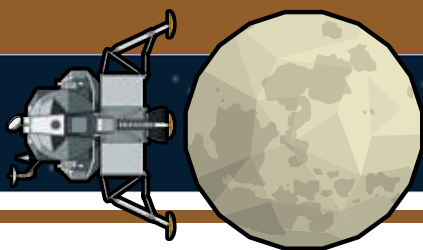


## NON-ASTEROID BELT

Not all meteorites originated in the asteroid belt. Sometimes, very large collisions between an asteroid and a planet or moon can allow material from the surface to be ejected into space and sent on a trajectory that will overlap with the Earth's. This is, thus far, the only way we are able to get our hands on material from Mars.







## SPACE ROCKS – A BEGINNER'S GUIDE

# METEORITE HUNTERS

The Earth is constantly being bombarded by meteorites. Estimates vary but it is thought around 50 000 tonnes of material hit the Earth per year. Many of these will land in the oceans, but some do fall over land.

If you want to stand a good chance of finding a meteorite, your first step is to find a large, barren area with very few terrestrial rocks. Deserts are particularly good for this, especially since with a

low water content, meteorites can go longer before they start to rust and can be easily seen against the light, uniform background. Many meteorite gathering expeditions also happen in Antarctica, where again, meteorites are easy to spot and often get carried down by glaciers.

So, let's say you are meteorite hunting in the desert and you find a rock. How will you determine whether it is worth picking up or not?

### 1. IT'S VERY DENSE

Meteorites tend to have a high iron content, and as a result often weigh more than an Earth rock of similar size.

### 2. IT'S MAGNETIC

As a result of this high iron content, meteorites will usually attract a magnet. Just be careful – several Earth rocks are also magnetic, so attracting a magnet is not a guarantee that you have found a meteorite.

### 3. IT'S QUITE SMOOTH

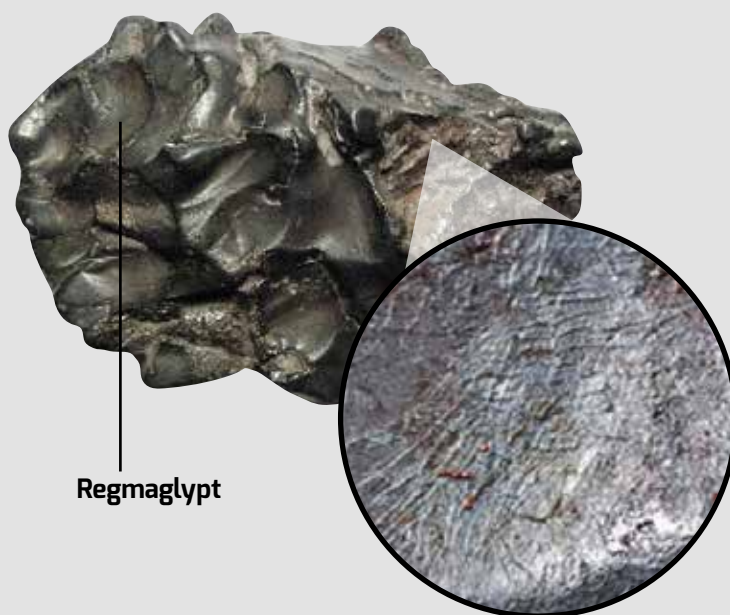
Since meteorites get very hot as they tear through the atmosphere, the outside of the meteorites will melt. As a result, most jagged edges will be smoothed out.

### 4. IT HAS A FUSION CRUST

This same heating process causes the outside of the meteorite to become dark, forming a crust of melted material around the outside of the meteorite. Often you can even see small lines a bit like mini rivers where the melted material flowed over the surface, or small bubble-like features where gasses in the rock expanded.

### 5. IT HAS "THUMB PRINTS"

These are indentations in the surface of a meteorite that look as if someone has pressed their thumbs into the once squishy surface of the rock. The proper name for these marks is regmaglypts.



### 6. WHEN YOU CRACK IT OPEN YOU CAN SEE COLOURED SPHERICAL FORMATIONS

As previously mentioned, these are chondrules and they are unique to meteorites. Sometimes these can even be visible in the cracks of a fusion crust.



# GLOSSARY

**Accretion:** Process of growth due to gradual build-up of material. In astrophysics this is generally due to gravitational attraction.

**Achondrite:** A stony meteorite that does not contain chondrules.

**Asteroid:** Large rocks that have accreted together over millennia but never became large enough to form into a planet.

**Chondrite:** A stony meteorite that was originally part of a small asteroid and contains chondrules. The most common type of meteorite to fall to the Earth.

**Chondrules:** Spherical grains that formed during the early accretion of the Solar System and are the building blocks of the solar system. These are the most prominent feature in a chondrite meteorite.

**Crater:** A depression or hole on the surface of the Earth caused by the impact of a comet or meteorite.

**Density:** A dense object is one that is heavy for its size.

**Fusion crust:** Smooth, black surface of a meteorite formed by the exterior melting as it tears through the atmosphere which cools quickly after it has made it through the atmosphere.

**Igneous:** A type of rock formed from cooling magma/lava.

**Inclusion:** A particle that is found within something else.

**Kuiper belt:** A disc shaped region of icy objects beyond the orbit of Neptune. Comets which take less than 200 years to orbit the sun (short period comets) originate here.

**Lunar:** Anything pertaining to the Moon

**Metamorphic:** A type of rock that has been altered due to experiencing extreme pressures and temperatures within the Earth.

**Meteor:** The bright light given off by a meteoroid as it burns through the atmosphere.

**Meteor showers:** A regularly occurring rain of meteors that radiate from a point in the sky. These meteors are the remnants of the tail of a comet.

**Meteoroid:** A small rock that is travelling through space.

**Meteorite:** A rock from space that has survived re-entry and landed on the Earth's surface.

**Mineral:** A naturally occurring, crystalline solid with a fixed chemical composition.

**Oort cloud:** A disc shaped region of icy objects beyond the orbit of Neptune. Comets which take more than 200 years to orbit the sun originate here.

**Orbit:** The motion of an object around a gravity point in space, such as the motion of the Earth around the Sun.

**Organic molecules:** Molecules made of carbon chains and other organic elements such as oxygen or nitrogen.

**Rock:** A naturally occurring solid made up of minerals.

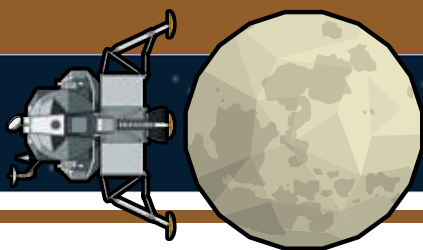
**Scale:** The ratio of length in a model to the length of the real object.

**Sedimentary:** A type of rock formed by the build-up of sediment in a body of water over time.

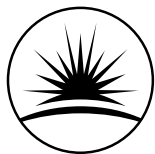
**Solar system:** A star and all the objects that orbit it.

**Trajectory:** Path of a moving object in air or space.





## ABOUT THE DEVELOPMENT TEAM



**Science & Technology  
Facilities Council**



**NATIONAL  
SPACE ACADEMY**

### **National Space Academy Development Team:**

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**Design and illustration:**  
**Ben Gilliland**

**Other images:**  
**NASA, ESA**

*The National Space Academy is based at the National Space Centre in Leicester, but through its network of outstanding Lead Educators and Project Scientists operates nationwide to work with secondary level teachers and their students to boost understanding, attainment and enjoyment in STEM subjects using space contexts as a novel approach to tackling the curriculum. Their aim is to develop subject knowledge and understanding with memorable hands on activities and innovative teaching ideas.*

*Their student masterclasses can be tailored to support all age groups and abilities, with a key focus on 11 to 19 year olds. The National Space Academy has experience in supporting GCSE, A Level, Scottish Standards and Highers and International Baccalaureate curricula within the UK and other national curricula overseas.*

*The National Space Academy also works directly with teachers, developing subject knowledge, building confidence and enhancing curricula. Their work extends from one day courses for individual teachers to full consultancy for new schools looking to develop an exciting STEM offer. Supporting non-specialist physics teachers is their speciality.*

*They also work closely with industry and academia in the space sector to support them in finding and developing the next generations of talent that they need so that the sector can continue to grow. Through careers conferences and talks they share direct messages from the sector on careers pathways with young people.*

*For more information on the National Space Academy, please visit:*

**<https://nationalspaceacademy.org/>**



# ACTIVITIES MENU

ACTIVITY	AGE RANGE					PAGE
	5-7	7-11	11-14	14-16	16-18	
<b>1</b> <b>Apollo Scene Setting</b> – Introducing the Apollo missions and thinking about a mission to the Moon						<b>24</b>
<b>2</b> <b>Hitting the Moon</b> – Investigating impact craters						<b>26</b>
<b>3</b> <b>Earth rocks and space rocks</b> – Identifying rock samples						<b>28</b>
<b>4</b> <b>Edible rocks</b> – Making edible models of different types of rock						<b>30</b>
<b>5</b> <b>Apollo scene setting</b> – Introducing the Apollo missions and building a timeline of events						<b>32</b>
<b>6</b> <b>Footprints on the Moon</b> – Analysing soil from the Earth and the Moon						<b>34</b>
<b>7</b> <b>Meteorite hunters</b> – Investigating different types of rock						<b>36</b>
<b>8</b> <b>Edible meteorites</b> – Building an edible model of a meteorite						<b>38</b>
<b>9</b> <b>Meteorite scientists</b> – Investigating and describing space rocks						<b>40</b>

## ACTIVITY KEY:

## WHAT THE ACTIVITY SYMBOLS MEAN:

<b>Moon</b>
<b>Space rock</b>
<b>Earth</b>

On each activity you will find three symbols that are designed to give you an 'at a glance' guide to the activities.

Each activity page is also colour-coded for each activity type.




Activity type

Age range

Does it require the meteorite hunters box?


LESSON PLAN

**1 APOLLO – SETTING**

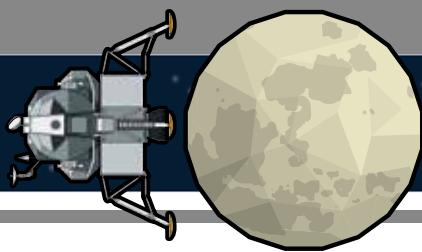




**OVERVIEW**  
 This lesson sets the scene for the study of the Lunar Discs, and gets students to think about the contexts and history leading to the collection of the Lunar samples in the loan boxes. By considering the events of the space race, role playing taking a moonwalk, and considering the actions of the astronauts, students will have a greater understanding of the significance of the Lunar samples.

**WHAT YOU NEED**  
 A1 PowerPoint


**STA**  
 Show 11 PowerPoint of what

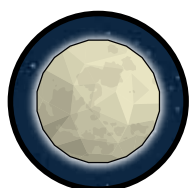




## ACTIVITIES MENU

ACTIVITY	AGE RANGE					PAGE
	5-7	7-11	11-14	14-16	16-18	
<b>10</b> <b>Moon conspiracies</b> – Critical thinking						<b>42</b>
<b>11</b> <b>Locating lunar landers</b> – Coordinate systems						<b>44</b>
<b>12</b> <b>Meteorite hunters</b> – Rock cycle and identifying types of rock						<b>46</b>
<b>13</b> <b>Following the astronauts</b> – A Google Moon activity involving speed, distance and time						<b>48</b>
<b>14</b> <b>Leaving the Moon</b> – Speed, distance, time graphs						<b>50</b>
<b>15</b> <b>Meteorite scientists</b> – Investigating Earth and Space rocks, density by displacement						<b>52</b>
<b>16</b> <b>Meteorite investigators</b> – Estimating density and investigating space rocks						<b>54</b>
<b>17</b> <b>Our Earth under threat?</b> – Virtual mission to protect our planet						<b>56</b>
<b>18</b> <b>Armageddon time</b> – Critical thinking and physics breakdown of the Armageddon movie						<b>58</b>

### Activity type



Moon



Space rock



Earth

### Does it require the meteorite hunters box?



No



Yes



## 1

## APOLLO – SETTING THE SCENE



## OVERVIEW

This lesson sets the scene for the study of the Lunar Discs, and gets students to think about the contexts and history leading to the collection of the Lunar samples in the loan boxes. By considering the events of the space race, role playing taking a moonwalk, and considering the actions of the astronauts, students will have a greater understanding of the significance of the lunar samples.



## CURRICULUM LINKS

History - the lives of significant individuals in the past who have contributed to national and international achievements.

Science – describe the basic needs of animals, including humans

## WHAT YOU NEED

A1 PowerPoint

Paper and pencils/  
crayons

Apollo 11 Introduction  
video

Moon themed music  
or audio of the moon  
landings

1.1 Things to take to the  
Moon sheet



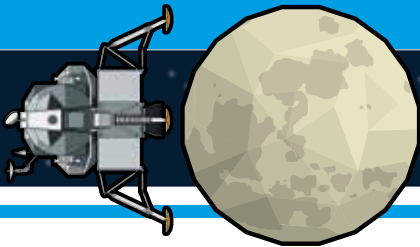
## STARTER

Show the first slide of the Moon imagery PowerPoint. Ask students to draw a picture of what they think it is like on the surface of the Moon. Use the pictures to find out what student's conception of the Moon is and its surface. Go through the Moon Imagery PowerPoint and get the students to compare the images to their own. What words can they use to describe the surface of the Moon?



A1 PowerPoint





## APOLLO – SETTING THE SCENE



### MAIN ACTIVITY

Mention to students that they are very lucky that they will be able to look at some samples of rocks and soil that were brought back from the Moon. But to set the scene, they need to think about what it was like for the astronauts that first set foot on an alien world.

Watch video of the Apollo 11 Moon landings 'Apollo 11 Introduction'. Discuss the excitement about the mission and how unique it was. To this day only 12 men have walked on the Moon.

Ask children if the Moon landings were as they expected or different in any way.



Apollo 11 Introduction video

**ACTIVITY 1.1 THINGS TO TAKE TO THE MOON**

During the Apollo missions, astronauts were allowed to take some personal items with them. These included photographs, a gold brooch and even golf balls and clubs.

If you were going on a mission to the Moon, what 5 items would you take with you? Give a reason for why you would take each item.

ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5
WHY?	WHY?	WHY?	WHY?	WHY?

THINGS TO TAKE TO MOON

### 1.1 Things to take to the Moon

Play Moon themed music or <http://www.firstmenonthemoon.com/> the recordings of the Apollo 11 landings for background.

As a class get all children to imagine getting ready for their own space mission putting on imaginary space boots. Stepping into the space suit, pulling on the helmet, attaching the gloves. Switch on the air, open the hatch and take an imaginary space walk.

Working in pairs or threes ask children to talk about the feelings the astronauts may have had before the mission took place, during the landing and once they landed on the Moon successfully. Share their thoughts with the class.

Children should now write/ draw a list of the 5 most important articles they would want to take with them to space if they were an astronaut. Make sure students think about the weight and size of the items they would want to take, which are the most important and why. You may wish to say air and food is already taken care of.



### PLENARY

Discuss children's priorities for items they need/ want for space and see if you can agree on a class list which

you can display in your classroom.

Refer to the drawings children did at the beginning of the class is there anything they would change?



# HITTING THE MOON



5-11



## OVERVIEW

In this lesson, students will learn about solar system orbits and how asteroids can become dislodged and sent on a collision course with the Earth.

They will then conduct an investigation into the relationship between impact speed and crater size in the context of Moon impacts. This activity is differentiated for older students to bring in ideas of controlling variables.

Finally, as a class you can simulate different impacts on the Moon using the down2earth impact simulator, and pass around the real Lunar return samples and Moon meteorite.

## CURRICULUM LINKS

Recording data and results using tables.

Reporting findings from enquiries, including oral and written explanations of results, explanations involving causal relationships, and conclusions.

Conducting a fair test.

Describe the movement of the Earth relative to the Sun in the solar system.

## WHAT YOU NEED

**A2 PowerPoint**

**2.1 Investigating craters worksheet** (younger)

**2.2 Investigating craters worksheet** (older)

**Marbles/ball bearings**

**Deep trays** (one per group)

**Flour**

**Cocoa Powder**

**Metre rulers or tape measure** (older students only)

**Tea strainer** (one per group)

**Sieve**

**Rulers** (older students only)

**Magnet** (optional)

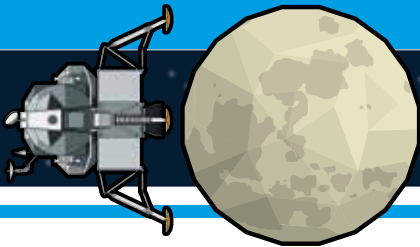
**Before the lesson, sieve flour into trays (one per group) and place three tablespoons of cocoa powder into plastic cups (one per group).**

*Note: for younger groups you may wish to prepare the cocoa powder surface for them)*



*Note – for more information on the Down2Earth simulator and some excellent resources incorporating it, visit <http://education.down2earth.eu/>*





## HITTING THE MOON



### STARTER

Go through the solar system slides on the powerpoint with students and introduce the asteroid belt. Ask students what they think would happen if one of the asteroids were to get pushed out of the asteroid belt towards the Sun. Where would it go? What might it hit?

Go through the Moon introduction slides and explain that the students are going to investigate what affects the size of the impact craters by dropping



A2 PowerPoint

marbles into a 'Moon tray' and observing the size of the craters.



### MAIN ACTIVITY

Demonstrate the investigation that the students are going to perform.

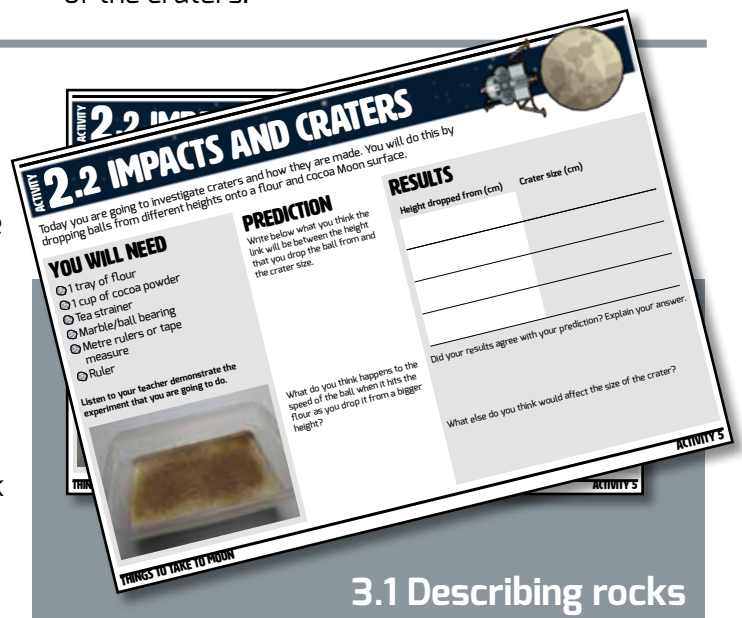
Give each group a tray of sieved flour. Ask them to carefully put a coating of cocoa powder on top, using the tea strainer (you may want to help for younger groups).

Ask students what they think the link will be between the height that they drop their marble and the crater size.

Students predict what the relationship will be between the height the marble is dropped from and the impact crater size (older students will explain why).

Older students will measure the height that they drop the marbles

*Note: when students remove the marble it can often cause indentations in the crater. To eliminate this you may wish to use ball bearings which will be attracted to a magnet for easy removal)*



3.1 Describing rocks

from (at least 30cm between drops to get a noticeable difference in crater size) using a meter ruler or tape measure. They can also use a ruler to measure the diameter of the craters (going from the edges of the white rings around the crater).



### PLENARY

Click on the link to go to the Down2Earth impact calculator and allow students to select the meteorite criteria and where it will land. By changing one variable about the meteorite (either speed or size and

therefore mass) as a class you can get them to predict, based on their own experiment, what the relationships will be and test this prediction out.

Alternatively, you may wish to hand around the lunar returned samples and the Moon meteorite at this point and explain that one impact in the Moon's history was big enough that it threw bits of the Moon out into space, and one of them hit the Earth.



# EARTH ROCKS AND SPACE ROCKS



## OVERVIEW

In this activity, pupils will consider some properties of different rocks. They will also learn about classifying, or sorting things into groups to help them identify which rock is which.

They can then take a closer look at the meteorites, tektite and ammonite in their sample boxes.

There are two versions of the worksheets – one with suggested description words, and one without to allow for differentiation.

## CURRICULUM LINKS

Describe the simple physical properties of a variety of everyday materials.

Compare and group together a variety of everyday materials on the basis of their simple physical properties.

*Working Scientifically*  
Observing closely, using simple equipment.

- performing simple tests.
- identifying and classifying
- using their observations and ideas to suggest answers to questions.
- gathering and recording data to help in answering questions.

## WHAT YOU NEED

**Meteorite hunters boxes**  
(one per group)

**3.1 Describing rocks sheet**  
(Middle/lower ability)

**3.1 Describing rocks sheet**  
(Higher Ability)

**3.2 Classification cards**  
(in colour and cut out for each table)

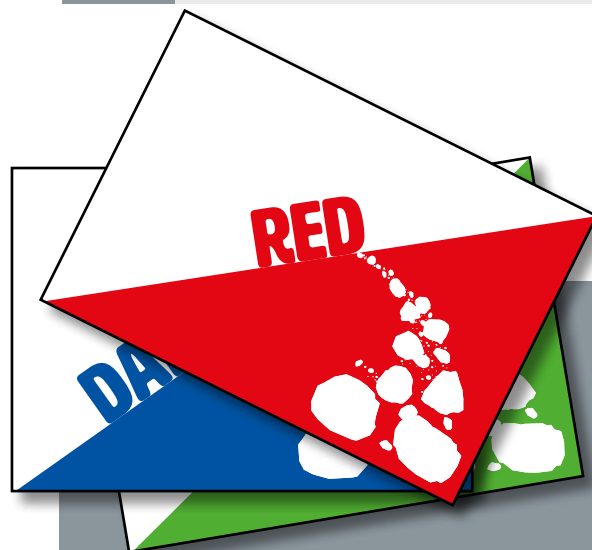
**3.3 Station colours**  
(one set, printed in colour)

**A3 Earth rocks space rocks powerpoint presentation**

**Large Campo de Cielo iron meteorite**

**All the hand lenses**

Before the lesson set up 5 plastic trays with the coloured label and hand lenses and the 5 samples of rock or meteorite that correspond to the colour. You will need the red, green, light blue, orange and purple rocks.



3.3 Station colours





# EARTH ROCKS AND SPACE ROCKS

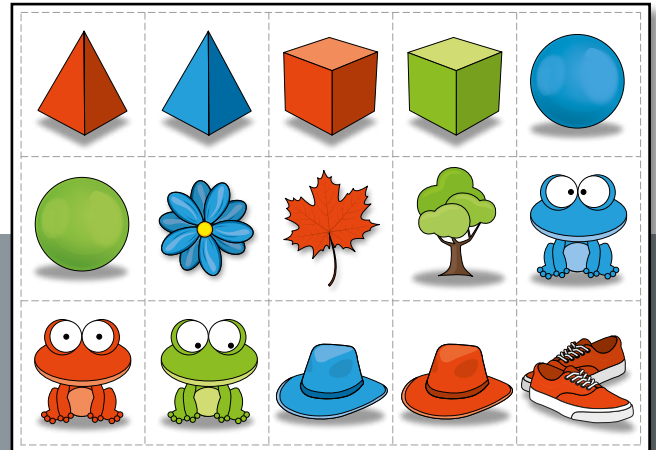


## STARTER

Explain to the class that in science it is very important to be able to group items together by similarities that they have. This then allows scientists to ask questions, to allow us to identify what an object or sample is.

Give an example such as sorting the cars in the car park (colour, make, number of doors). Split the students into pairs/threes and hand out the classification cards. Ask them to sort the objects into groups of their choosing by qualities of the object, such as size, shape, light or dark.

Get them to explain the reasoning



3.2 Classification cards

behind the sorting, and compare different groups. There is more than one way to sort objects! You can use the slides on powerpoint A3 to help you.

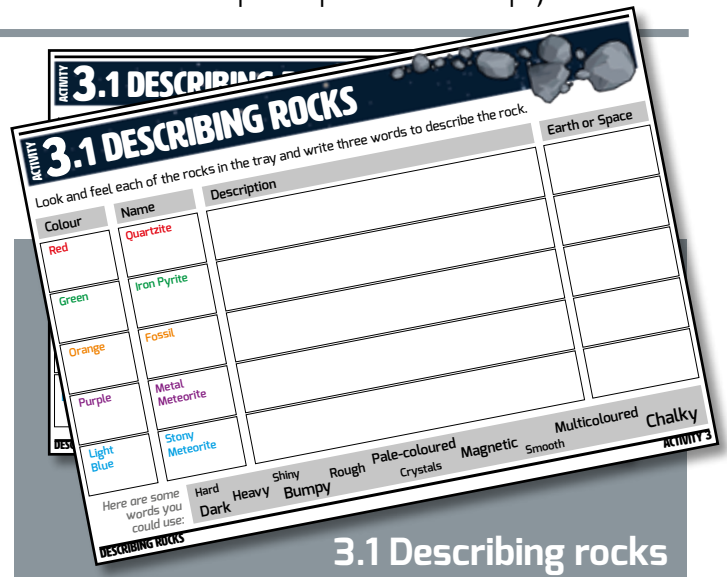


## MAIN ACTIVITY

Divide the class into 5 groups. Hand each group a tray labelled either red, green, light blue, orange or purple.

Ask the students to use the hand lenses to look closely at the samples, and also to feel them. Get them to look for grains, layers, crystals and to comment on whether they are shiny or not. For each coloured dot sample, they should write X number of words (teacher to decide how many words) that they feel best summarises the rock (for lower abilities there are worksheets with the words on to help or the words can be cut out in advance to stick on).

They will then use the describing



3.1 Describing rocks

rocks sheet to follow these questions and decide which rock is which, writing the colour dot that corresponds to each rock. Once they have described the rocks in one tray, they can move around to the next tray.



## PLENARY

With the students gathered around explain what each rock was and that the purple (iron meteorite) and the

light blue (stony meteorite) have come from space. Explain that the orange rock was a fossil.

Show the students the large iron meteorite, observing the weight and the fusion crust.



# 4 EDIBLE MODEL ROCKS



## OVERVIEW

In this activity, students will learn about the three main types of Earth rocks and make edible analogues to help explain how they form.

They will then use the ideas from this activity to investigate and suggest what some of the samples in the meteorite hunters boxes might be.

## CURRICULUM LINKS

Performing simple tests.

Identifying and classifying.

Find out how the shapes of solid objects made from some materials can be changed by squashing, bending, twisting and stretching.

Compare and group together a variety of everyday materials on the basis of their simple physical properties.

## WHAT YOU NEED

**Meteorite hunter's boxes**

**A4 PowerPoint**

**4.1 Edible rock diagram sheet**

**4.2 Rock making guide**

**4.3 Rock bingo cards**

**Clear plastic cups** (one per group shot glasses are best)

**Different coloured Fondant icing** (sliced up before the lesson)

**Coloured sprinkles**

**Different types of biscuit crumbs**

**Mini marshmallows, chocolate**

**Plastic (microwavable) bowl and spoon**

**Clear resealable sandwich bags** (one per group)



## STARTER

Using the powerpoint to help, introduce the three main different types of rock and how they are formed.

Explain that students are going to make edible versions of these to explain how they form. Hand out some of the rock samples to students to look at. As a class discuss what they look like and feel like and create a word bank of key words on the white board.



A4 PowerPoint





## EDIBLE SPACE ROCKS

### 4.1 Edible rock diagram sheet



## MAIN ACTIVITY

Use sheet 4.2 – Rock making guide to see how to make the edible rocks.

For this activity work as a class to make the igneous rock sample. This requires a large amount of time to cool, so it is best to start with this one.

In small groups of 2 or 3, students can then make the metamorphic and sedimentary rocks.

Pupils can then work in groups to draw a diagram of each of their different types of rocks using sheet 4.1.

### 4.1 EDIBLE ROCKS

Draw a picture of each of your samples

SEDIMENTARY ROCK

METAMORPHIC ROCK

IGNEOUS ROCK

### 4.2 EDIBLE ROCK MAKING GUIDE

#### SEDIMENTARY ROCK

These are formed from deposits settling at the bottom of seas, lakes and rivers.

- Water bed: for this use blue fondant icing (have slices ready at the beginning of the class)
- Fossilized bones (possibly dinosaurs) for this you can use coloured sprinkles.
- The bones get covered in layers of mud and sediment. For this alternate with layers of chocolate mousse until you have up to six layers.
- Pupils can then look through the side of the cup and describe what they see – layers built up over time, just like with sedimentary rocks.

#### METAMORPHIC ROCK

These are rocks that have been changed by heat and pressure.

- For this you will need different coloured fondant icing (3 or more colours).
- Have slices of coloured icing portioned out ready for each later you will need to use a plastic bag and make sure that pupils wash their hands first!
- Squeeze and fold the layers of icing.
- Once the rocks have been made, cut them in half and can you see swirls or layers where the rocks have been pushed together?

#### IGNEOUS ROCK

These are formed when molten (melted) rock or magma is cooled.

- Children to mix up mini marshmallows, broken up biscuits and chocolate drops in a heat-proof bowl.
- An adult will then need to heat for long enough to melt the chocolate and then leave until it has solidified again. This may be towards the end of the session.

**WARNING!** check with your teacher about food allergies before you do this activity.

### 4.2 Rock making guide



## PLENARY

Ask pupils to look at the following rock samples from the meteorite hunter's boxes using the hand lenses:

Dark blue

Black

Pink

Red

Yellow

Brown.

(You may wish to remove these beforehand and place in a separate tray to aid counting back in).

Ask them to guess which types of rock they might be on the basis of the activity they have just done.

## EXTENSION

Play a game of rock bingo using cards 4.3



### 4.3 Rock bingo guide



# THE RACE TO LAND ON THE MOON



7-11



## OVERVIEW

This lesson sets the scene for the study of the Lunar Discs, and gets students to think about the contexts and history leading to the collection of the Lunar samples in the loan boxes.

By considering the events of the space race, role playing taking a moonwalk, and considering the actions of the astronauts, students will have a greater understanding of the significance of the lunar samples.

## CURRICULUM LINKS

History - discussing significant events.

Communicating ideas.

Placing events on a timeline.

Literacy - giving and explanation for a choice.

## WHAT YOU NEED

**A5 Space race PowerPoint**

**5.1 Space race timeline** (printed A3, one for each group)

**5.2 Timeline picture cards** (printed and cut out)

**5.3 Things to take to the Moon**

**Apollo 11 Introduction video**

**Moon-themed music or audio of the moon landings**



## STARTER

Each group of 4 or 5 students, needs an A3 printed timeline and a set of space race events cards. Get the students to match the events to the dates on the timeline.

Once they have completed the task, go through the timeline PowerPoint, asking students what they think comes next. You can also split the class into America and the Soviet Union, getting them to cheer every time their nation has a Space Race Achievement. Discuss as a class the different events and those they think are most important and why. Focus specifically on the Russian and American space firsts.

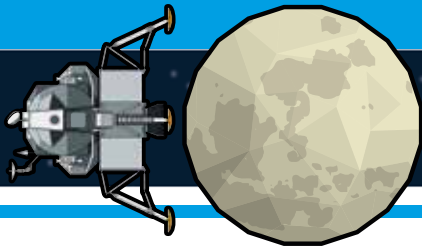


5.1  
Timeline  
picture  
cards

5.1 Space race  
timeline







# THE RACE TO LAND ON THE MOON



## MAIN ACTIVITY

**Scene setting:** Ask the class to imagine the most exciting event in their life so far.  
 What have they stayed up late to see or do?  
 What did they spend days talking to their friends and families about?  
 How did it feel to be so excited? Explain that in 1969, the Moon Landings were the most exciting thing to happen in the lives of many people. Watch the 'Apollo 11 introduction' video and explain that families stayed up all night glued to small black and white TV screens to watch this amazing, unique achievement. To this day only 12 men have walked on the Moon.

**Role play:** How would it feel to be Neil Armstrong and Buzz Aldrin as you were just about to step out of your lander and become the first people to step foot on an airless, low gravity world?  
 As a class get all children to imagine getting ready for their own space mission putting on imaginary space boots, stepping into the space suit, pulling on the helmet, attaching the gloves etc. Switch on the oxygen, open the hatch and take an imaginary space walk. While students do this, play Moon themed music, or the audio of the moon landings (download).

Working in pairs or threes ask children to talk about the feelings the astronauts may have had before the mission took place, during the landing and once they landed on the Moon successfully. Students can use the feelings cards to help them convey how they think the astronauts felt.

Children should now write/ draw a list of the 5 most important articles they would want to take with them to space if they were an astronaut. Make sure students think about the weight and size of the items they would want to take, which are the most important and why. You may wish to say air and food is already taken care of.

**5.3 THINGS TO TAKE TO THE MOON**

During the Apollo missions, astronauts were allowed to take some personal items with them. These included photographs, a gold brooch and even golf balls and clubs.

If you were going on a mission to the Moon, what 5 items would you take with you? Give a reason for why you would take each item.

ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5
WHY?	WHY?	WHY?	WHY?	WHY?

ACTIVITY 5

**Extension/homework idea:** Students write a postcard home about their mission to the Moon.



## PLENARY

Discuss children's priorities for items they need/ want for space. In pairs and using the '5 things to take to space' sheets, students list the 5 most important things that they would want to take with them. For this activity

you can assume that air and food are taken care of. As a class, compare these lists and try to come up with a whole class top 5 items to take to the Moon. This could then be made into a poster or a display to tie in with the topic.



# FOOTPRINTS ON THE MOON



## OVERVIEW

In this lesson, students will learn a bit more about the Apollo missions and what the Astronauts did at the landing sites.

They will then perform an experiment to determine which material, sand or flour, is most like the lunar soil, and observe samples of these under the usb microscopes to determine which is most like the actual soil samples returned from the Moon.

By looking at the shapes of the particles, they will then explain why the Apollo astronaut's footprints are still on the Moon 50 years later.

## CURRICULUM LINKS

Making observations.

Reporting findings from enquiries, including oral and written explanations of results, explanations involving causal relationships, and conclusions.

## WHAT YOU NEED

**A6 PowerPoint**

**Apollo Lunar Disk**

**6.1 Leaving a footprint worksheet**

**2 plastic trays** (per group)

**Sand to fill one tray**  
(per group)

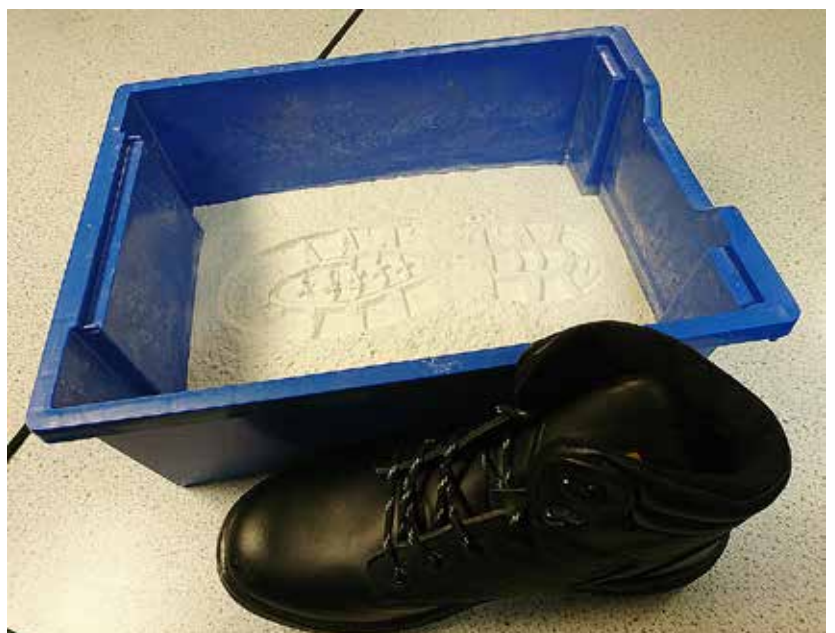
**Flour to fill one tray**  
(per group)

**A shoe with a good grip/print** (per group)

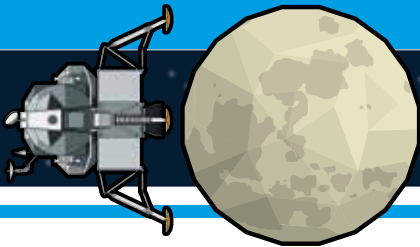
**Baby wipes** (for cleaning shoes)

**USB microscope connected to a laptop with VLC media player installed**

Before the lesson, for each group prepare two trays, one with sand and one with flour. Have one of the USB microscopes set up at the front of the room connected to a computer running VLC media player (if you have enough laptops you may wish to set up multiple USB microscopes so there are more for students to share).







# FOOTPRINTS ON THE MOON



## STARTER

Go through the Moon images on the slide and ask students what the differences are between the Earth and the Moon. The Moon has no atmosphere and therefore no weather. It has no active volcanoes. There is nothing on the Moon that will cause weathering or changes to the surface, except for impact events. As a result, the Apollo Astronauts have left a lasting legacy on the Moon in the form of their footprints, and this is what they are going to investigate today.



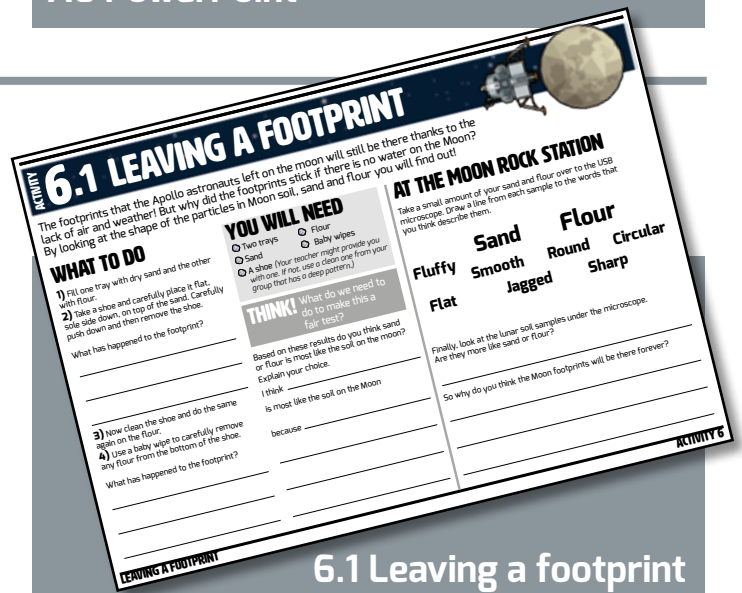
A6 PowerPoint



## MAIN ACTIVITY

Sort the students into groups of 4 and hand each group worksheet 6.1. Each group will need one set of the group equipment listed above. Students will recreate the first footprints on the moon and note down what they observe in differences between the sand and the flour. They then predict which of the materials is closest in nature to the lunar soil.

They then take a small sample of the sand and the flour (or one can be pre-set up at the USB microscope) and they observe these samples under the USB microscope. They draw the shape of the particles of each and comment on how the shape will affect how easily a footprint can be held in



6.1 Leaving a footprint

the material. Finally, as a class you can observe the actual lunar return samples under the USB microscope (as well as passing these and the Moon meteorite around) to take a closer look at, and determine whether the sand or the flour is most like the Moon soil, and therefore why the footprints are still there after so long.



## PLENARY

To finish with, either as a class or in groups on laptops/tablets (if available) students can choose which

of the Apollo landing sites to explore in Google Earth. Discuss as a class what they found and any interesting things that they have noticed at the sites.



# 7 METEORITE HUNTERS



7-11



## OVERVIEW

In this lesson, pupils learn about where meteorites come from, how they form and what the different classifications of meteorites are.

Pupils then use this knowledge and ideas of classification to identify samples from the meteorite hunters box, and to find the real meteorites in their samples.

## CURRICULUM LINKS

**Classification**  
Meteorite properties and origin.

Compare and group together different kinds of rocks on the basis of their appearance and simple physical properties. (Y3-4)

Describe in simple terms how fossils are formed when things that have lived are trapped within rock. (Y3-4)

Compare and group together everyday materials on the basis of their properties, including their hardness, and response to magnets. (Y5)

Describe how living things are classified into broad groups according to common observable characteristics and based on similarities and differences. (Y6)

**Working Scientifically**  
**Observing**  
Observing objects, using simple equipment making accurate measurements using standard units using a range of equipment.

Gathering, recording, classifying and presenting data in a variety of ways to help in answering questions.

Recording findings using simple scientific language, drawings, labelled diagrams, keys.

Identifying scientific evidence that has been used to support or refute ideas or arguments. (Y5,6)

## WHAT YOU NEED

**A7 Powerpoint**

**7.1 Meteorite hunter worksheet**

**7.2 Classification cards**

**Meteorite hunters sample box** (five samples to be used from the box – white, light blue, purple, orange and green)

**Magnaprobe** (one per group)

**2 hand lenses per group**

**Classification activity cards**

**Before the lesson set up each group a tray containing 2 hand lenses, a magnaprobe and one of each rock (white, light blue, purple, orange and green).**





# METEORITE HUNTERS



## STARTER

Split the class into 8-10 groups (so that each group has about 3 pupils in). Hand each group a set of classification cards and ask them to sort them into groups of like properties from what they can see.

Get them to discuss in their groups what the qualities that they can see are. Pupils feedback and explain the reasoning behind their chosen groupings and discuss the merits of their approaches.

Explain that what they have just done is to classify the objects – sort them into groups depending on their properties. This is something that scientists do to make identifying



A7 PowerPoint

objects, and explaining what they are easier.

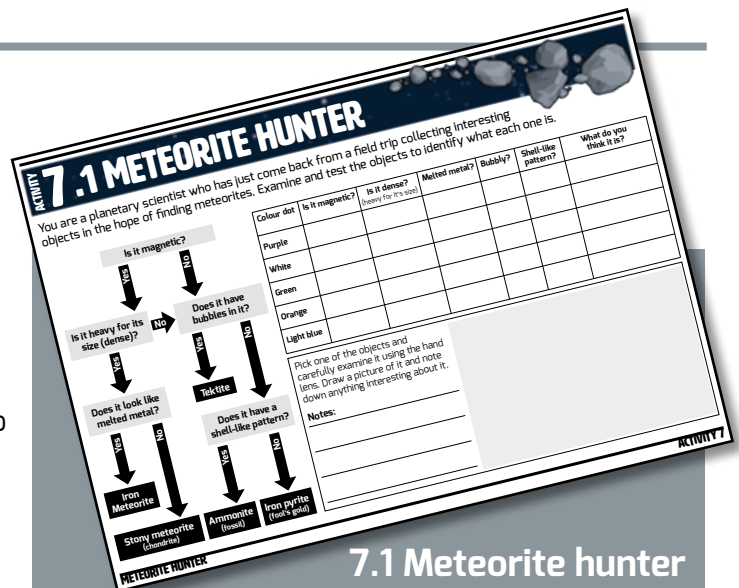
Go through the A7 meteorite hunters powerpoint to introduce the new terminology that they will be using today, and to set their challenge.



## MAIN ACTIVITY

Now split the class into 5 groups and hand each group the tray of items. If pupils are not familiar with classification charts then you can use the power point to demonstrate this. Pupils follow the classification chart to identify what each of the 5 samples is, and to find the real meteorites. Pupils should know that there is only one of each type.

Pupils feedback their findings in groups, stating what they thought each sample from the meteorite



7.1 Meteorite hunter

hunters box was. They discuss any difficulties they had – were any of the samples very similar?



## PLENARY

Give each group one of the large rocks/meteorites from the loan box (if they have the large stony meteorite

then also give the cut through) get the groups to use their knowledge and charts to identify the large rocks/meteorites.



## EDIBLE METEORITES



7-11



## OVERVIEW

In this lesson, students will learn about the properties of the different types of meteorites.

They will then use this knowledge to make their own edible analogue of a chondrite meteorite to test their understanding.

This lesson can be used as a general introduction to meteorites prior to obtaining the loan box.

## CURRICULUM LINKS

Observing objects, using simple equipment making accurate measurements using standard units using a range of equipment.

Classification.

Meteorite properties and origin.

Creating a model of a scientific object.

## WHAT YOU NEED

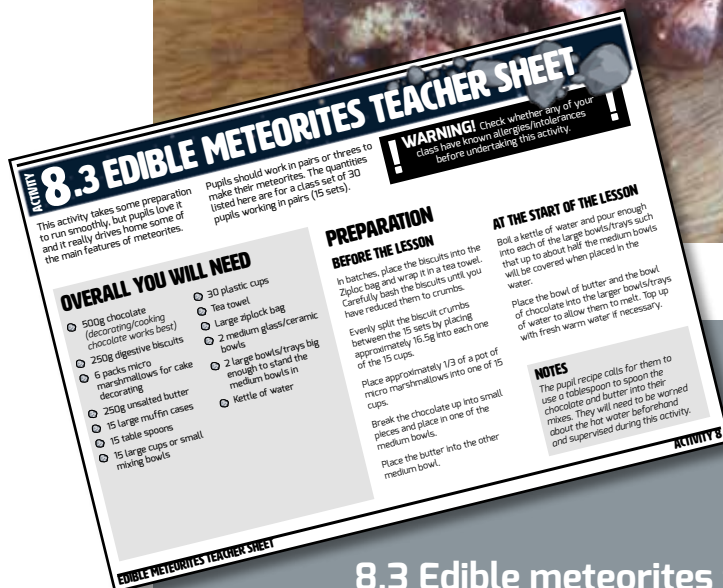
A8 powerpoint

8.1 Edible meteorites worksheet

8.2 Meteorites! worksheet

8.3 Edible meteorites teacher sheet

Ingredients to make edible meteorites (please see teacher sheet)



8.3 Edible meteorites teacher sheet



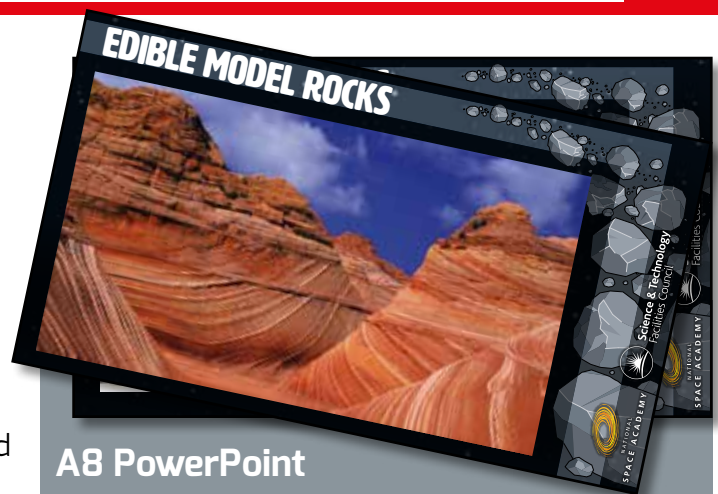
## EDIBLE METEORITES



## STARTER

Go through the what is a meteorite slides with the students, focusing on how the names of the object change depending on whether they are in space, in the atmosphere, or on the Earth.

Introduce the idea that there are different types of meteorite, classified by what they are made of.



A8 PowerPoint



## MAIN ACTIVITY 1

Hand out worksheets 8.1 to the students, and as you go through the presentation, ask them to complete and label the key features of the different types of meteorites. Tell them that they will be making an edible model of a chondrite meteorite and will need to label this, so they need to pay attention.



8.1 Meteorites! &amp; 8.2 Edible meteorites



## MAIN ACTIVITY 2

Students follow the instructions on the sheet to make their own edible meteorites.

These will then be allowed to cool and set, and at the end of the lesson/start of the next lesson they can cut through their meteorites and compare them to a real chondrite, drawing a picture of their meteorite and labelling it.

Students will need to be accompanied for this activity, so it is recommended that

a part of the classroom gets turned into a 'meteorite kitchen' so that the students can be together for this.



## PLENARY

Ask the students to draw a comic strip detailing the journey of a meteorite from the Asteroid Belt to the surface

of the Earth. Ask them to include some of the key words from their worksheet.



# 9 METEORITE SCIENTISTS



## OVERVIEW

In this lesson, students will learn about where meteorites come from and the different types of meteorites. They will then use this knowledge to describe the rocks in the lunar loan box and try to work out what they are.

## CURRICULUM LINKS

Observing closely, using simple equipment.

Making measurements.

Literacy – assigning adjectives to samples.

## WHAT YOU NEED

**A9 Meteorite Scientists PowerPoint**

**5 Magnaprobe**

**10 hand lenses**

**5 plastic trays**

**9.2 Tray labels** (one set printed)

**9.1 Adjectives cards** (one set, printed and cut out for each tray)

**The following rocks from the loan box:**

**Tray 1: Campo de Cielo Iron meteorite** (plus a magnaprobe)

**Tray 2: Saharan chondrite whole stone and cut and polished chondrite slice** (plus a magnaprobe and two hand lenses)



**Tray 3: Libyan glass impactite** (plus a magnaprobe and two hand lenses)

**Tray 4: Tektite** (plus a magnaprobe and two hand lenses)

**Tray 5: Udei station iron meteorite** (plus two hand lenses)



## METEORITE SCIENTISTS



## STARTER

Ask the students what they think a meteorite is and use the slides on the powerpoint to help explain what meteorites are and where they come from.

Explain that they are going to investigate 5 different rocks from the loan box and use describing words (adjectives) to help them identify which rocks are meteorites and which rocks were made by meteorites.



A9 PowerPoint

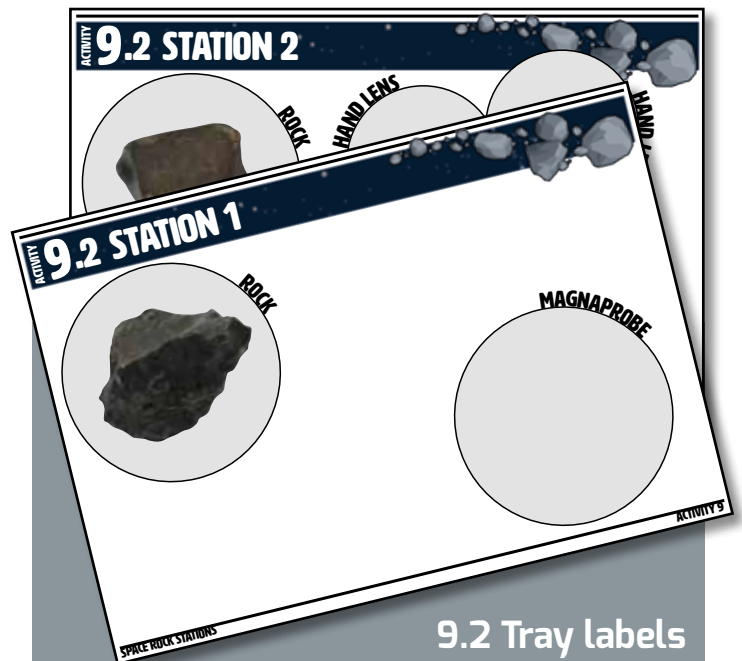


## MAIN ACTIVITY

Split the class into 5 groups and hand each group a tray. Show the students how to use the magnaprobe and explain that they need to take the correct describing cards and put them in the tray. They then need to choose either the meteorite, or not meteorite cards to put on the sample.

Once they are done, they can record whether they think it is a meteorite or not on the large sheet at the front of the room, and move on to the next tray. Each group should aim to spend about 4 or 5 minutes observing, discussing, and describing each rock.

At the end of the circuit, you will have a table at the front with the collated answers of each group.



9.2 Tray labels

Bring the class back together and ask the class to pick the describing words that they used. Tell the class what type of meteorite each one is.



## PLENARY

Show the the samples in the membrane boxes and ask them to choose their own words to describe them.



# 10 MOON CONSPIRACIES



## OVERVIEW

This lesson is designed to generate discussion in students regarding the common Lunar conspiracy theories.

Through looking at statements, analysing the reliability of the sources, and critically analysing the comments and applying scientific principles, students will come to their own conclusions about whether the US really did land on the Moon.

## CURRICULUM LINKS

Critical thinking.

Analysing sources for reliability.

Any theory must be tested and peer reviewed.

## WHAT YOU NEED

**A10 Moon conspiracies PowerPoint**

**10.1 Moon hoax briefing sheet** (one per student)

**10.2 Statements sheets** (one set, printed and cut in half)

**10.3 Conspiracies analysis worksheet** (two per student)

**10.4 Evidence cards** (one set per group of 4 – cut out)

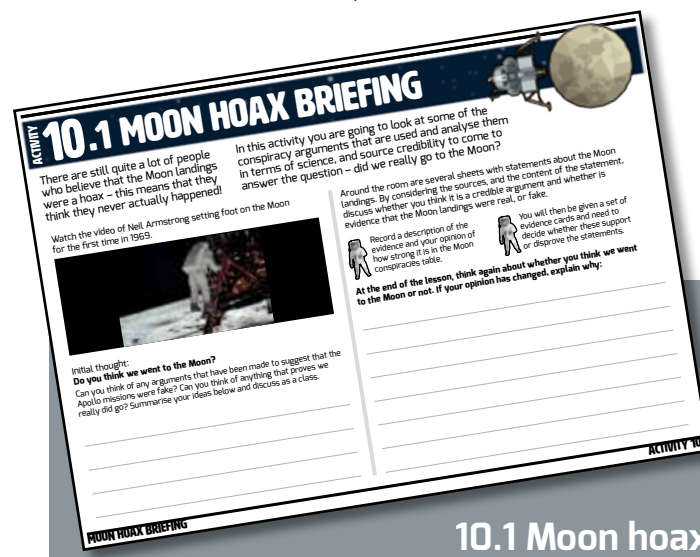


## STARTER

Show students the first 5 slides of the Moon conspiracies powerpoint to set the scene of the space race within the cold war.

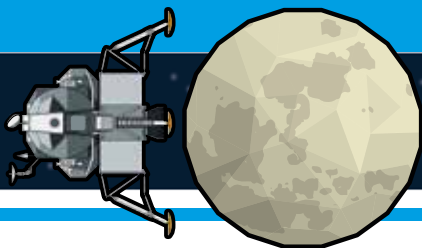
Explain that there are some people who believe that the US never did successfully land on the Moon, and in this lesson they are going to investigate some statements to decide whether they are in support of, or against the Moon landings, and to think about the reliability of the sources.

Ask students whether they think we did go to the Moon and why and fill this in on their sheet.



10.1 Moon hoax briefing





## MOON CONSPIRACIES



### MAIN ACTIVITY 1

**Analysing the statements:** Working in pairs, students go around the room and read the conspiracy statements. They discuss the statements and sources, and summarise these in their tables, deciding whether the statement is for or against the lunar landings.

Once they have done this, show the statements summary PowerPoint slide. Give each student a post it note and ask them to stick in on the statement that they think is the most compelling. Compare the whole class results and discuss.



10.2 Statement sheets



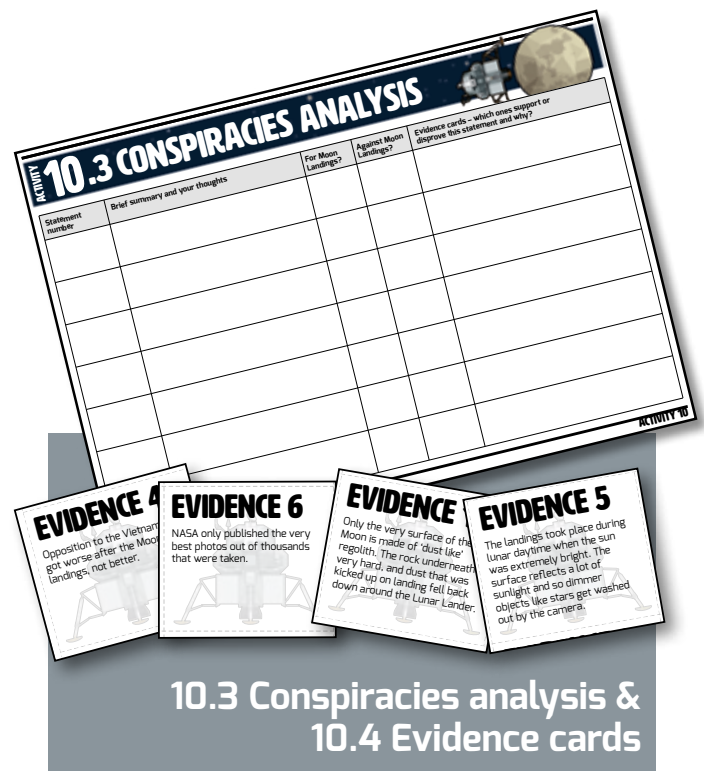
### MAIN ACTIVITY 2

**Applying the evidence:** Get two pairs to work together as a group of 4.

Now hand out the evidence cards and ask the students to read through them, deciding which of the statements these cards support or disprove and filling their answers in on the table. In their pairs they should now discuss which of the statements are most compelling in the light of new evidence.

Again, bring up the statement slide and again ask students to place a post-it note on the most compelling statement.

Discuss any changes.



10.3 Conspiracies analysis & 10.4 Evidence cards



### PLENARY

**Mythbusting:** Run through the slides on mythbusting the three most common Moon conspiracies using scientific reasoning and working with the class to establish explanations.

If there is time, show the

Mythbusters clips to support the explanations. Finish with asking the class what their view is now on the Moon landings and discuss whether any one's view has changed in the face of ideas and evidence.



## 11

## LOCATING LUNAR LANDERS



10-13



## OVERVIEW

This lesson goes into more detail about the specific Apollo missions that returned the Lunar samples in this kit. It also combines coordinate systems with high resolution Lunar Reconnaissance Orbiter images to challenge students to locate the lunar landing sites and hardware that was left behind on the surface of the Moon.

This lesson can be used both to introduce coordinate systems or as a reinforcement lesson since an explanation of how to find coordinates is given in the presentation.

## CURRICULUM LINKS

Understanding coordinate systems.

Using map grid systems.

Giving coordinates for items on a set of axes.

## WHAT YOU NEED

A11 PowerPoint

11.1 Locating Lunar landers worksheet

11.2 Returning to the Moon worksheet

Computer with Google Earth installed and connected to the internet

Google Moon activity guide

(Optional) A5 Space race PowerPoint



*If you have not done Activity 5 with your students, you may wish to give this lesson some additional background by going through the space race PowerPoint presentation.*

## STARTER

Explain to students that in this lesson they are going to use a combination of high resolution images taken of the surface of the Moon, and coordinate systems to locate the landing sites and left-over hardware from the four Apollo missions that brought back the samples in this kit (slides 1-10).

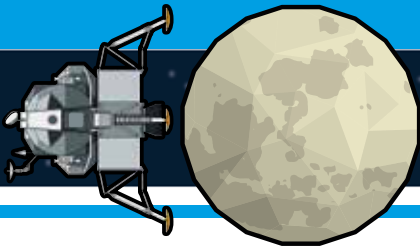
Then introduce the two activities the students will be doing (slides 11-13). If pupils are new to the idea of coordinates, you can also use these slides to show them how to read and locate coordinates.



A11 PowerPoint



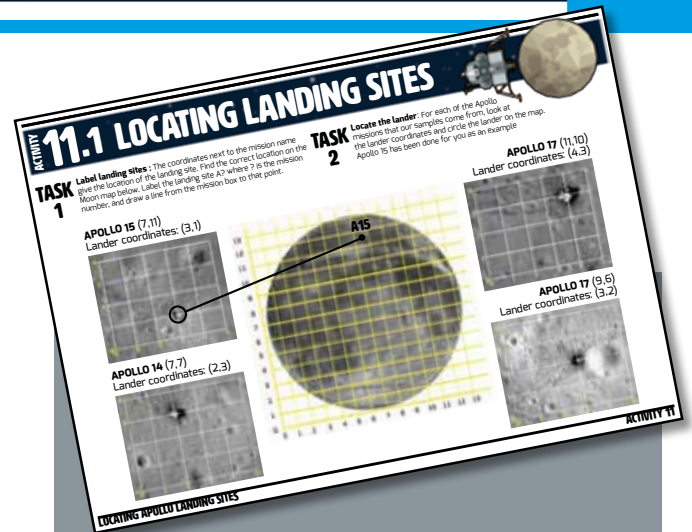
# LOCATING LUNAR LANDERS



## MAIN ACTIVITY 1

Students locate the Apollo landing sites and the hardware that was left behind for Apollo missions 14-17, following the guidance on the worksheets.

Students can complete this individually or in pairs.



11.1 Locating Lunar landing sites



## MAIN ACTIVITY 2

Students locate and give the coordinates for the four pieces of hardware left behind Apollo 15.

If students finish early, ask them to think about what it would be like to drive the Lunar Roving Vehicle on the surface of the Moon.

What would happen as you drove over bumps in the lower gravity?

Would the risk of puncturing your suit in the event of a crash make you more careful?

What would they like to try if they were on the surface of the Moon within the limits of a space suit?

They could note these ideas on the back of their worksheet and feedback at the



11.2 Returning to the Moon

end of the lesson. Once activity 1 and 2 are complete, run through the answers using the PowerPoint (slides 14-16).

Get the pupils to mark each other's work and feedback to each other.



## PLENARY

Using the Google Moon activity guide, explore the Apollo landing sites using Google Earth. While looking at the view from the landing sites, get students to think about what their first words on the Moon would be. Perhaps these could be written down on coloured speech bubbles and used as part of a display.

Emphasise the point that the four Apollo missions focused on in this lesson were the ones that brought back the samples in the loan box, and that they will get to look at the real life Lunar samples as well as other interesting rocks in the next lesson.





## OVERVIEW

In this activity, students will learn about the properties of the different types of Earth rocks and the rock cycle.

They will also learn the basics of meteorite hunting.

They will then apply this, along with the use of a classification chart and scientific testing, to identify the samples in their meteorite hunter boxes, and to find the meteorites within their samples.

## CURRICULUM LINKS

Observing objects, using simple equipment making accurate measurements using standard units using a range of equipment.

Classification.

Rock cycle.

Types of rock.

## WHAT YOU NEED

**A12 PowerPoint**

**5 meteorite hunters boxes** (one per group)

**5 magnaprobes** (one per group)

**12.1 worksheet** (one per student)

**12.2 rocks cheat sheet** (one per group)

(Optional) **USB microscopes attached to a computer running VLC media player**

**2 hand lenses per group**



## STARTER

Use the introduction slides to summarise the rock cycle and the different types of rock.

Ask students what kind of rocks they think asteroids would be most like and why. Then run through the basic qualities of a meteorite.

**Prior to the lesson, remove and set aside the tektites (white dots) from the meteorite hunters boxes for use later in the lesson.**



A12 PowerPoint



## METEORITE HUNTER



## MAIN ACTIVITY 1

Students use the cheat cards to attempt to identify the TYPES of rock that each sample is. By testing for magnetism, and observing the samples with the hand lenses they can attempt to classify the rocks into groups.

This works best if the group splits into two, and shares the work (and the hand lenses) and then checks to see that they agree with each other.

Discuss their answers. If you wish you can take a further look at some of the samples under the USB microscope to get



12.2 Rocks cheat sheet

a better view of grain size and shape.



## MAIN ACTIVITY 2

Students will now use a classification chart to answer a series of yes or no questions to enable them to identify exactly what each sample is. To begin with, go through the chart with the class using the green dot rock (iron pyrite) to show them how such a chart works.

The groups then complete the activity. You may wish to have a copy of the guide to the meteorite hunters boxes on hand to help answer any questions about the samples.



12.1 Meteorite hunter



## PLENARY

Run through the answers on the powerpoint and ask students whether these agree with their original decisions about the types of rock in the boxes.

What was difficult? Were any of the samples very similar or hard to identify?

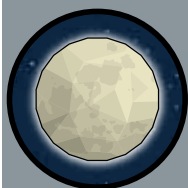
Stress that with so many different processes forming rocks, some very different rock types can have, on the surface, very similar features.

If you wish, you can finish by placing the tektites (white dots) on each table and asking students what they think these are.

**As soon as the box is no longer needed, please check that each group has returned all of the items to the meteorite hunters boxes, especially the small iron meteorite.**



## FOLLOWING THE ASTRONAUTS



11-14



## OVERVIEW

This lesson is designed to introduce students to the Apollo missions and set the scene for the Lunar samples by investigating the landing sites where some of the samples in the Lunar disk came from.

Students will use Google Earth to explore the Apollo 15 landing site, finding out information about the samples collected at the site, flying into panoramic images, and using the ruler tool to measure the distance the astronauts covered while exploring the surface, and work out how long it took them to make this journey.

## CURRICULUM LINKS

Speed, distance, and time.

Calculating time given a speed and distance.

Making measurements.

## WHAT YOU NEED

Laptop with Google Earth installed (one per group)

A13 PowerPoint

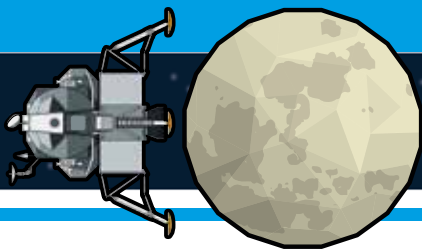
13.1 Following the astronauts worksheet

Explore the Moon with Google Earth guide

Explore the Moon with Google Earth guide







## FOLLOWING THE ASTRONAUTS



### STARTER

Run through the Apollo introduction slides on the PowerPoint to set the scene and show where the Moon samples in the box came from.

Demonstrate to the students the basics of navigating around the Moon in Google Earth (you will want to practice this prior to the lesson).



A13 PowerPoint



### MAIN ACTIVITY

Students follow the instructions on their sheets to explore the Apollo 15 landing site and find out information about the samples collected.

They then use the ruler tool to follow the path that the astronauts took and use this information and the average speed of the Lunar Roving Vehicle to calculate how long it took, and how much time the astronauts had to collect their samples as a result.

#### 13.1 FOLLOWING THE ASTRONAUTS

##### 2. EXPLORE AN EVA

You are going to focus on EVA 2. Zoom in on the bottom part of the route using the navigation tools (see Exploring the Moon in Google Earth guide).

b) Now click on the red dot by 7 and read the information. **Explain briefly what the Astronauts found here, and why it was important.**

**How much time did they have for science?**

The astronauts spent 7 hours and 12 minutes performing EVA 2. A good chunk of that time was spent in driving the LRV to interesting points. You are going to measure how far they travelled in total on the EVA. You will then calculate how much time they had to spend on collecting samples and doing experiments.

Use the ruler tool to measure the total distance that the LRV travelled during the EVA. Make sure you have selected the path tab. Make a note of how many points you have used to map out the path.

Note: when drawing your path, do not click on a point you have already made. If two routes cross over, put the new point next to the old one.

**Number of points:** \_\_\_\_\_

**Total distance (in metres):** \_\_\_\_\_

The average speed of the LRV was 9km per hour. (Hint: there are 3600 seconds in one hour)

**What is this speed in metres per second?** \_\_\_\_\_ **m/s**

Distance you mapped out? \_\_\_\_\_

#### 13.1 FOLLOWING THE ASTRONAUTS

In this activity you are going to follow in the footsteps of the astronauts of Apollo 15 using the Google Earth Google Moon map. You will find out about the experiments that they did, and work out how much time they had to do them.

##### 1. LOADING GOOGLE MOON

a) Launch Google Earth and open Google Moon (see Exploring the Moon in Google Earth guide for details).

b) In the layers tab, double click on Apollo Missions and then click on Apollo 15 to bring up the information box.

c) Click on the "zoom in" text in the bottom left-hand corner of the information box to go to the landing site. Close the text box by clicking the "X" in the top right-hand corner.

d) The black lines show the three EVAs (Extra Vehicular Activities) that the astronauts made during their mission. They were able to cover so much ground because they had a LRV (Lunar Roving Vehicle) – a battery powered Moon buggy that they could use to explore much further than they could on foot.

*Continued on next sheet...*

13.1 Following the astronauts



### PLENARY

Get the students to seek out other interesting features on the Moon and ask some of them to come up

and show the class what they have found. You could use this as a prompt point for a research homework.



# 14 LUNAR LIFT OFF



## OVERVIEW

In this lesson, students will consider the differences in gravity between the Earth and the Moon and the meaning of mass, weight and gravity.

They will then use stills from footage of the Apollo 17 Lunar lift off to calculate the speed during the initial ascent.

## CURRICULUM LINKS

Reading and taking measurements from a graph.

Speed, distance, and time.

Calculating time given a speed and distance.

Making measurements.

Gravity, weight and mass.

## WHAT YOU NEED

**A14 PowerPoint**

**14.1 Weight and gravity worksheet**

**14.2 Lunar lift off worksheet**

**Optional – empty plastic bottles and scales**



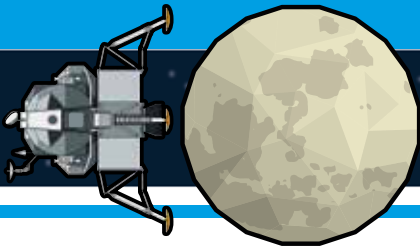
## STARTER

Go through the recap slides on mass, weight and gravity on the PowerPoint, asking students what they think the differences will be between the Earth and the Moon.



A14 PowerPoint

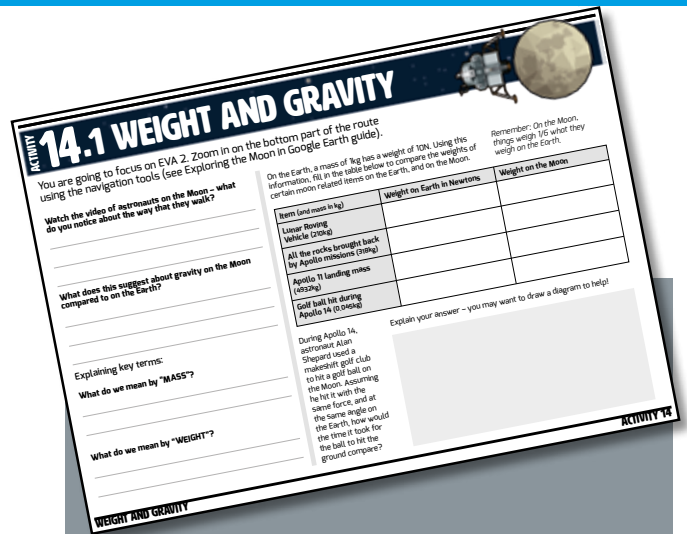




## MAIN ACTIVITY 1

Hand out sheet 14.1 to students and get them to answer the questions, referring to the information that has just been covered.

**Extension activity:** Hand students some empty plastic bottles and a set of scales. Get them to fill one of the bottles up with water and weigh it. Then get them to calculate how much water they would need to put in the second bottle to simulate how much lighter this would feel on the Moon. Students can then compare their models.



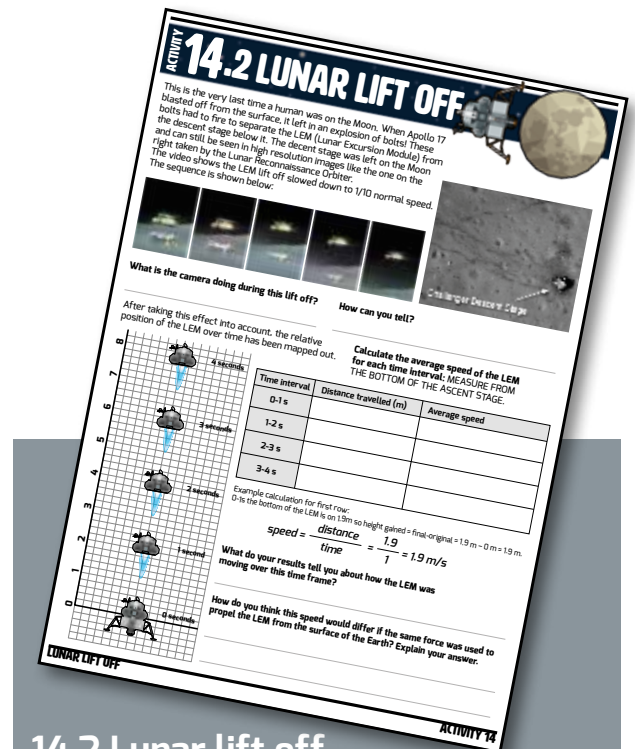
14.1 Weight and gravity



## MAIN ACTIVITY 2

Hand out sheet 14.2 for students to work through. Get them to calculate the average speeds at various points on the Apollo 17 Lunar lift off course.

**Extension activity:** 14-16 year old students can then plot a graph of average speed against time for each of the intervals. Get them to explain what is happening in terms of acceleration (gradient of the graph) and in terms of the initial explosion to boost the Lunar Module upwards.



14.2 Lunar lift off



## PLENARY

Get students to think about some every day activities that they do on the Earth that would be significantly different in the low gravity environment of the Moon.

Discuss their ideas and make sure that they explain HOW and WHY these would be different.





11-14



## OVERVIEW

In this lesson, students will investigate some of the loan box's meteorites and associated rocks.

They will test them for magnetism and perform a visual analysis of the samples. In addition, they will make a to scale model of the samples out of plasticine and perform a displacement test to allow them to determine the density of the samples when combining this information with the mass.

They will then use the meteorite identification cards to help them select which object is which.

## CURRICULUM LINKS

Making measurements and examining objects.

Calculating density.

Displacement of water to find volume.

Replicating shape and space.

## WHAT YOU NEED

### A15 PowerPoint

**4 trays containing:** a magnaprobe, 2 hand lenses, the relevant tray labels (15.4) and a copy of the 15.1 Identify the samples task sheet. In addition, the trays require the following from the loan box:

**Tray 1:** Large iron meteorite and basalt rock

**Tray 2:** Chondrite cut through meteorite and anorthosite rock

**Tray 3:** Etched iron cut through meteorite and Libyan glass impactite

**Tray 4:** Whole chondrite and tektite

### A class set of 15.2 worksheet

**15.3 Space rocks identification hint sheets** (2 per group)

**One set of scales per group** (or easy access to a set of scales)

**One or two USB microscopes** set up at the front of the room connected to a computer running VLC media player (optional)

**Clamp and stands for usb microscopes** (optional)

**Selection of measuring cylinders including 1 large measuring cylinder\*** (big enough to fit a to scale model of the largest sample in)

**Enough plasticine per group for each student to make a to scale model of their rock samples.**

**Paper towels**

*\*If you do not have a sufficiently large measuring cylinder available, you can make your own using an empty 2 litre bottle of pop. Please see additional sheet in the resources folder for instructions on how to do this.*



## MORE METEORITE SCIENTISTS

Before the lesson begins, set up a 'volume measuring station' near a sink with a variety of different sized measuring cylinders. Students should bring their models over to here to establish the volume of their models, rather than having water near the actual meteorites which can rust if they come into contact with water. Alternatively, if you have large enough Eureka cans, you can use these to identify the volume of the models.

**IMPORTANT!** The reason we are asking students to make a model of their rock samples for this activity is because the meteorites contain iron, and if they are exposed to water they will start to rust! You could make a big point of this, asking students why they think they are not allowed to drop the rocks in the water. Please also make sure students do not handle any of the samples with wet hands.



## STARTER

Using the powerpoint to help you, briefly explain what a meteorite is, and what we look for when trying to identify them.

Ask the class what is meant by density. Hand around two objects of similar size but very different masses (for example, a foam ball and a cricket ball) and explain that dense items are

ones that are very heavy for their size. This will be important information to help them with identifying the objects that they have.

Go through the Archimedes slide and get the class to explain how you would work out the density of an object by using mass and displacement of water. You may wish to demonstrate this method to the class.



## MAIN ACTIVITY

Split the class into 4 groups, and hand each group a tray with the relevant worksheet, space rocks identification hint sheet, magnaprobe, hand lenses and the samples listed above.

Explain that each group will have to investigate their two samples and try to identify whether they think it is a meteorite, or another type of rock. The tray sheets will tell the students which object they need to calculate the density of. To do this, they will

need to make a to scale model of the sample out of plasticine. Get each student to perform this task so that they can then obtain an average of their results.

Once they have made their model meteorite, they will perform a water displacement test by noting the initial volume of water, dropping their model into the measuring cylinder, and recording the final volume. They will then calculate the change in volume and from this determine the volume of their model, and an average volume for the group.



## PLENARY

Each group now feeds back to the rest of the class, explaining their findings and what they believe each sample to be and allowing the rest of the class to see their items. You may wish to

supplement what they say with some additional information from the meteorites guide in the teacher handbook. You can then hand round the pallasite, moldavite and lunar/martian meteorite samples for students to observe.



# METEORITE INVESTIGATORS



**14-18**



## OVERVIEW

In this lesson, students will investigate some of the meteorites and associated rocks in the loan box.

They will test them for magnetism, do a visual analysis and measure their mass to calculate the densities of their items.

This activity is particularly geared towards getting students to estimate the volume of the rocks in order to obtain a value for density as close to the real values as possible.

They will then use the meteorite identification cards to help them identify which object is which.

## CURRICULUM LINKS

Making measurements and examining objects.

Calculating density.

Estimating the volume of an object.

## WHAT YOU NEED

**A16 PowerPoint**

**16.1 and 16.2 worksheets**  
(one per student)

**16.3 Space rock information cards**  
(one per group)

**16.4 Space rock station sheet**

**16.5 Volumes of shapes sheet**  
(one per station)

**4 USB microscopes connected to laptops with VLC media player installed**

**8 hand lenses** (one at each station)

**5 magnaprobes** (on their assigned station sheets)

**Cloth or bubble wrap underneath the rock samples for protection**

**Spare paper for calculating volumes of objects**

**The following samples from the loanbox placed on the appropriate Station information sheet:**

- Campo de cielo iron meteorite (*Station 1*)
- Libyan glass impactite (*Station 2*)
- Sahara chondrite (whole chondrite) (*Station 3*)
- Udei station and etched iron meteorites (*Station 4*)
- Sliced chondrite (*Station 5*)
- Tektite (*Station 6*)
- Pallasite (*Station 7*)
- Moldavite (*Station 8*)

**Prior to the lesson, place the 8 station cards around the room with their associated rock in the box, a hand lens in the hand lens box and, where stated, a magnaprobe in the magnaprobe box.**



# METEORITE INVESTIGATORS



## STARTER

Go through the introduction slides on the powerpoint with the class. Build up the students understanding of the different types of meteorites and associated rocks. Set the scene for the investigation

and emphasise how important it is to be very careful when handling these samples. Show the students the USB microscopes and explain how to vary the focus. These can be used to help in the study of any of the objects – they simply have to go over to a free microscope station.



## MAIN ACTIVITY

In eight groups, the students go around the room, spending 3-4 minutes with each sample and completing the table on the worksheet.

Make sure that the USB microscopes are placed with the stations where the table requires a drawing of the surface. Students then match up the specific meteorite to its name.

### 16.1 METEORITE INVESTIGATION

Around the room are 8 stations with rocks that have either come from space or been produced as a result of an impact between a meteorite and the Earth. It is your job to study these rocks, perform tests, and calculate densities (of some of the rocks) in order to identify which rock is which.

**KEY EQUATION:**  
Density =  $\frac{\text{Volume}}{\text{Mass}}$

To calculate the densities, you will need to estimate the volume of the objects. At each station there is a sheet that will help you with this by providing you of how to calculate the volumes of certain shapes.

Station	Is it magnetic?	Density/Additional task	Written Observations Does it have a fusion crust? Does it show bubbles? Can you see metal? Is it glass-like or crystalline?
1	Most needed	Mass (g): Volume (cm <sup>3</sup> ): Density:	
2	Not needed	Mass (g): Volume (cm <sup>3</sup> ): Density:	
3		Mass (g): Volume (cm <sup>3</sup> ): Density:	
4		Mass (g): Volume (cm <sup>3</sup> ): Density:	
5	Not needed	Mass (g): Volume (cm <sup>3</sup> ): Density:	
6		Mass (g): Volume (cm <sup>3</sup> ): Density:	
7	Not needed		
8	Not needed		

### MATCH YOUR SPACE ROCKS

Station 1
Station 2
Station 3
Station 4
Station 5
Station 6
Station 7
Station 8

16.1 Meteorite investigation & 16.2 Match your space rocks

Please reiterate the importance of carefully handling the meteorites, and of replacing everything in the correct place on the sheet before moving on to the next station.

### 16.3 SPACE ROCKS INFORMATION

**Meteorites: General information**

- Most meteorites contain iron and so they are **MAGNETIC**.
- Meteorites are **MORE DENSE** than most Earth rocks.
- Meteorites have a fusion crust – a dark outer coating that can show bubble pits or waves from where the outer rock has melted as the meteorite burns up in the atmosphere.

IRON METEORITES	CHONDRITE METEORITES
<b>Description:</b> Large pieces of iron-nickel. <b>From:</b> The core of large asteroids. <b>Density:</b> The densest meteorites. <b>Magnetic?</b> Yes.	<b>Description:</b> Chondrules – small spherical rock formations from where the small asteroids gradually came together under the forces of gravity and charge attraction. <b>From:</b> Small asteroids. <b>Density:</b> The least dense meteorites. <b>Magnetic?</b> Yes.

TEKTITES	PALLASITE (STONY-IRON) METEORITES
<b>Description:</b> Rock that melted when a meteorite hit the Earth. <b>From:</b> The Earth – fall back as droplets of melted rock. <b>Density:</b> Low density. <b>Magnetic?</b> No.	<b>Description:</b> Iron/nickel with non-metallic crystals inside. <b>From:</b> The core/mantle boundary of large asteroids. <b>Density:</b> Medium density. <b>Magnetic?</b> Yes.

GLASS IMPACTITES	MOLDAVITES
<b>Description:</b> Silica rich rock that melted when a meteorite hit the Earth. <b>From:</b> The Earth – fall back as droplets of melted rock. <b>Density:</b> Medium density. <b>Magnetic?</b> No.	<b>Description:</b> Rock that melted when a meteorite hit the Earth. <b>From:</b> The Earth – fall back as droplets of melted rock. <b>Density:</b> Low density. <b>Magnetic?</b> No.

### 16.5 VOLUMES OF SHAPES

Figure	Formula	Variables
<b>CUBE</b>	$a^3$	$a$ = length of edge
<b>REGULAR PRISM</b>	$l \times w \times h$	$l$ = length $w$ = width $h$ = height
<b>CYLINDER</b>	$\pi \times r^2 \times h$	$r$ = radius of circular face $h$ = height
<b>CONE</b>	$\frac{1}{3} \times \pi \times r^2 \times h$	$r$ = radius of circular base $h$ = height from tip to base
<b>SPHERE</b>	$\frac{4}{3} \times \pi \times r^3$	$r$ = radius

16.3 Space rocks information  
16.5 Volumes of shapes



## PLENARY

Go through the answers with the students on the powerpoint slide and discuss. Get the students whose density calculations were closest for

each one to explain how they estimated the volume of the object.

Finish off with showing them the Martian meteorite and ask students how it is possible for a piece of Mars to get to the Earth. What can we say about the energy of such a collision?



# OUR EARTH UNDER THREAT



14-16



## OVERVIEW

This activity is designed as a 'virtual mission'. Students will play the part of Near Earth Asteroid (NEA) scientists to the scenario of a possible asteroid impact with the Earth. By following the story of the mission (led by an automated powerpoint), students will apply their understanding of kinetic energy, density and probability to perform calculations and research possible methods of deflecting the asteroid.

This mission is decision based – at several points they will have to make decisions about how to tackle the asteroid, and the outcome for each group will depend on the decisions that they have made.

## CURRICULUM LINKS

Reading and taking measurements from a graph.

Speed, distance, and time.

Calculating time given a speed and distance.

Making measurements.

Gravity, weight and mass.

## WHAT YOU NEED

**Laptop with "Our Earth Under Threat" PowerPoint running and internet access** (one per group)

**17.1 Earth Under Threat student sheet** (one per student)

**17.2 Near Earth Asteroid report** (one per student)

**A17 Earth under threat briefing Powerpoint**



## STARTER

Run through the briefing PowerPoint and explain to the students that in groups, they will work through the simulated scenario to apply the physics that they have learnt to the protection of the planet. Also point out that at every step, there will be hints that they can click on to help them if they are necessary.



# OUR EARTH UNDER THREAT



## MAIN ACTIVITY 1

Students run through the virtual mission.

### BORROW THE MOON NEWS

## ROCK ALERT!

**4,700 Potentially Dangerous Asteroids Lurk Near Earth, NASA Says**

This image shows the difference in the orbits of a typical near-Earth asteroid (blue) and a potentially hazardous asteroid, or PHA (orange). A new NASA survey by the WISE telescope has pinned down the number of asteroids that could pose a collision threat to Earth in what scientists say is the best estimate yet of the potentially dangerous space rocks.

The survey found there are likely 4,700 potentially hazardous asteroids, plus or minus 1,500 space rocks, that are larger than 330 feet (100 meters) wide and in orbits that occasionally bring them close enough to Earth to pose a concern, researchers said. To date, only about 30 percent of these objects have actually been found, they added.

Potentially hazardous asteroids, or PHAs in NASA-speak, are space rocks in orbits that come within 5 million miles (8 million kilometers) of Earth and are large enough to cause damage on regional or global scale if they were ever to hit our planet. According to the survey, about twice as many asteroids are in so-called "lower-inclination orbits" — which are more closely aligned with Earth's path around the sun than other objects — than previously thought researchers said.

"A possible explanation is that many of the PHAs may have originated from a collision between two asteroids in the main belt lying between Mars and Jupiter," NASA officials explained in a statement. "A larger body with a low-inclination orbit may have broken up in the main belt, causing some of the fragments to drift into orbits closer to Earth and eventually become PHAs."

"Because they will tend to make more close approaches to Earth, these targets can provide the best opportunities for the next generation of human and robotic exploration."

During its asteroid hunt, the WISE telescope searched for space rocks within about 20 million miles (32 million km) of the sun. For comparison, the Earth is about 93 million miles (150 million km) from the sun.

The data from NEOWISE, when combined with other asteroid data observations, helped NASA announce in 2010 that about 90 percent of the largest near-Earth asteroids that come close to our planet had been identified.

Source: Space.com

A17 Earth under threat PowerPoint

17.2 NEO report

### ACTIVITY 17.1 EARTH UNDER THREAT!

**TASK 1: WHAT IS A PHA?**

Read through the report on potentially hazardous asteroids (PHAs) and answer the questions below:

What is the definition of a Potentially Hazardous Asteroid (PHA)?

How many PHAs are thought to be in orbits that would cause concern?

Where is it believed many of these PHAs originated from?

Initial parameters of object:

Mass =

Radius =

Probability of impact =

**TASK 2: WHAT TYPE OF?**

Using the information you have been given of the object to determine the type of P with. The circle the type of object below on the mission screen.

Density =

Stony meteorite density range: 3000–3700 kg/cm<sup>3</sup>

Stony-iron density: 5600–6000 kg/cm<sup>3</sup>

### ACTIVITY 17.1 EARTH UNDER THREAT!

## TASK 3: CALCULATING THE KINETIC ENERGY OF THE OBJECT

Where  $m = \text{mass in kg}$  and  $v = \text{velocity in metres per second}$

$1 \text{ Megaton} = 4.18 \times 10^{15} \text{ J}$

Kinetic energy in Joules =  $\frac{1}{2}mv^2$

Kinetic energy in megatons =

**TORINO SCALE RATING:**

**TASK 2: WHAT DO WE DO?**

Click on the link in the console panel and research three methods of dealing with the threat. Briefly summarise the methods below and use this to help you make a choice as to your course of action.

Method	How it works	Pros and cons

17.1 Earth under threat



## PLENARY

Ask the students what the outcome of their mission was and run through the answers on the powerpoint. Did they experience any problems? Do they think

we should invest more time and money into researching the risk of NEAs?

If students have time, they can spend some time at the end of the lesson using the Down2Earth impact calculator (linked to in their powerpoint) to investigate impacts on the Earth.



# ARMAGEDDON TIME?



14-16



## OVERVIEW

This activity uses the context of asteroids and meteorites, and the film Armageddon, to allow students to explore kinetic energy, momentum, and critical thinking by asking them to establish whether the information presented in the film is correct.

## CURRICULUM LINKS

Kinetic energy.  
Unit conversion.  
Problem solving.  
Critical analysis.

## WHAT YOU NEED

**A18 Powerpoint**

**18.1 Armageddon time? worksheets** (one per student)

**Optional – meteorites from the loan box** (if you have it at the time of this lesson)



## STARTER

Go through the introduction slides on meteorites and show the images of Barringer crater. Ask students to estimate the size of the object that created this crater.

Run through the answers and get students to reflect on any errors they may have made during their calculation.



A18 PowerPoint



# ARMAGEDDON TIME?



## MAIN ACTIVITY 1

Explain that Armageddon was a 1998 film where Bruce Willis and his team saved the world from an impact event by an asteroid.

Set out the parameters of the object (as defined by the movie). Students then calculate how much energy the bomb would need to have to blow the asteroid into two halves that will both just miss the Earth. Ask them to state any assumptions that they have made.

Look at their answers and get them to compare this amount of energy to other known amounts (on the slide). On this basis, and by discussing the simplified assumptions that they have made, get them to comment on how realistic the movie was.

### 18.1 ARMAGEDDON TIME?

In the 1998 film Armageddon, Bruce Willis and his team of oil drillers are asked to save the world from a massive asteroid impact by going to the asteroid, drilling down into the asteroid, and placing a nuclear weapon to blow it into two fragments that will miss the Earth.

In this lesson you will learn about asteroids and meteorites, calculate the kinetic energy of a previous Earth impact, and extend these ideas to establishing whether you think the premise of the movie is realistic or not.

#### ACTIVITY 1: HOW BIG WAS THE BARRINGER CRATER?

Kinetic energy =  $2500\text{kt TNT}$  ( $1\text{kt TNT} = 4.3 \times 10^{12}\text{J}$ )

Entry velocity =  $12.8\text{ km/s}$

Density of iron meteorite =  $7\text{g/cm}^3 = 7000\text{kg/m}^3$




Impactor diameter = \_\_\_\_\_

### 18.1 Armageddon time

1. Texas has a diameter of about 1000km. Explain in terms of the size of the asteroid whether we can truly say that the bomb would be INSIDE the asteroid.

2. The movie states that once the asteroid is less than 3 hours and 56 minutes away from the Earth, it is too late to divert it. Use this information along with the information given below to calculate how much energy would be required to safely split the asteroid in two, and have both pieces miss the Earth, just before this deadline. State any assumptions that you have made.



Distance of asteroid:  $1 \times 10^8\text{ m}$

Density of an iron asteroid:  $8\text{kg m}^{-3}$

Radius of the Earth:  $6400\text{ km}$

Diameter of asteroid:  $1100\text{ km}$

Minimum energy required: \_\_\_\_\_

3. Here are some figures for various energy sources. Compare these to your answer and make a statement about the energy that would be required and the likelihood of this being possible.

Hiroshima nuclear bomb:  $6.3 \times 10^8\text{ J}$

Biggest ever nuclear weapon test:  $2.092 \times 10^{13}\text{ J}$

Energy output of the Sun:  $3.846 \times 10^{26}\text{ J s}^{-1}$

#### So what could we do?

Think about, and discuss with your table, what other options there might be open to scientists and engineers when it comes to destroying or deflecting an asteroid that might hit the Earth.

- How could we use gravity?
- How could we use kinetic energy and momentum?
- How could we use nuclear weapons?

Use your understanding of physics to explain how your options would work and how feasible you think they are.



## MAIN ACTIVITY 2

Ask students what other methods they can think of that can be used to deflect or destroy an asteroid.

Get them to consider, and attempt to explain, the principals behind gravity tractors, laser ablation and kinetic impactors.

You can then use the slides that cover these topics to summarise and reinforce the physics concepts.



## PLENARY

If you have the Borrow the Moon loan box, you could use this as an opportunity to get some of the samples out and view them. If not, get students to write a short

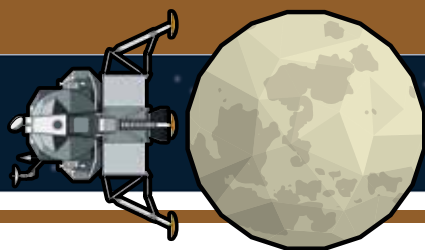
piece detailing why it is important to focus on research into protecting our planet from impacts.

They could extend this into a report for the government detailing the physics behind impacts as a homework task.



## A PLACE TO MAKE SOME NOTES

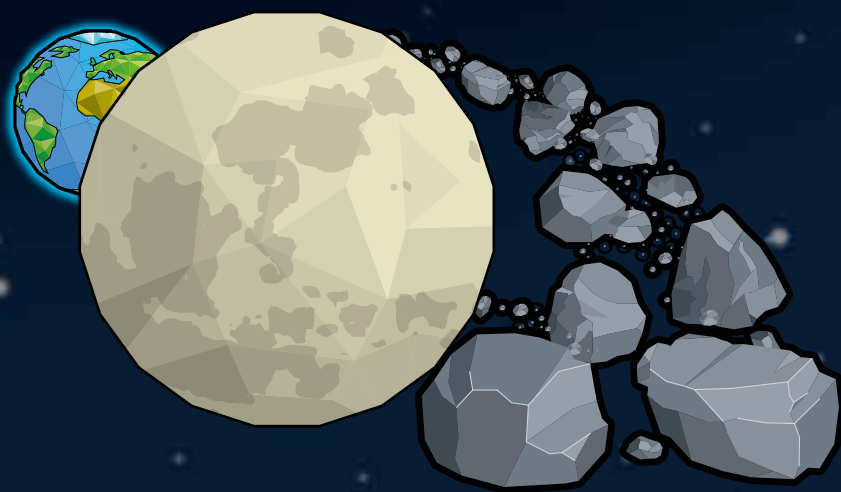




## A PLACE TO MAKE SOME NOTES



# BORROW THE MOON



**STFC**

**Polaris House, North Star Avenue,  
Swindon, Wiltshire, SN2 1SZ**

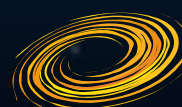
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