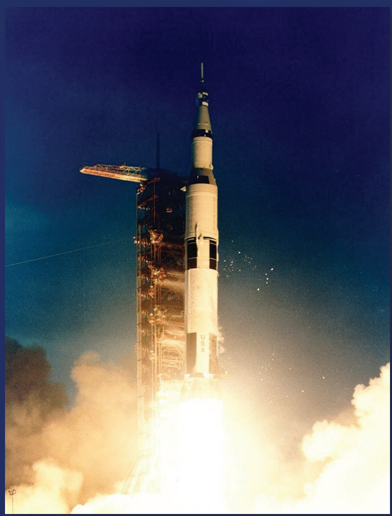
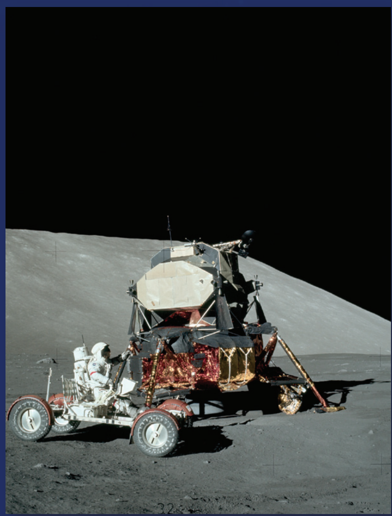
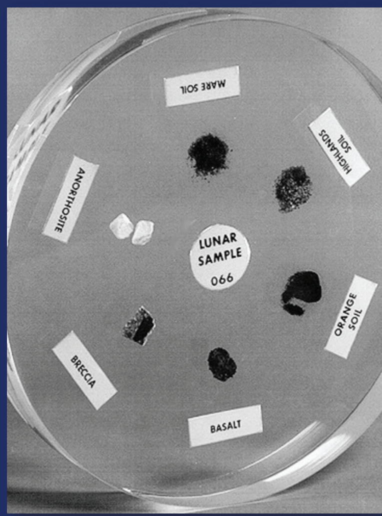
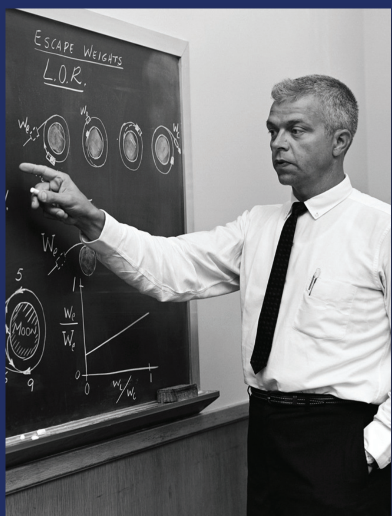
STFC

Lunar Samples and Meteorites Planning Pack & Support Notes









Science & Technology Facilities Council

NATURAL HISTORY MUSEUM

WELCOME TO THE STFC LUNAR ROCKS & METEORITES LOAN PACK

Moon Rocks

As part of NASA's programme of manned exploration of the Moon in the late 1960s and early 1970s, the Apollo astronauts brought back to Earth 382 kilograms of lunar materials. NASA used a small proportion of the rock and soil to develop lunar and planetary sciences educational packages. The Science and Technology Facilities Council (STFC) is the only body that lends out samples of this precious material to educational or scientific organisations within the United Kingdom.

The Natural History Museum Meteorites

Three rare and irreplaceable hand-held meteorites and three equally rare encapsulated meteorites in the kit are on loan from the Natural History Museum.

DVD-ROM and Websites

This book and the accompanying DVD-ROM provide suggestions for activities to support the loan period and downloadable files for printing out. In the run-up to the loan, this book and all the activity sheets can be downloaded from www.schoolscience.co.uk and www.stfc.ac.uk. All the files are free to copy and use for educational non-profit purposes.

It's not all science!

The activities cover language and imagination as well as science. Activities 1 to 6 are based on observation, language and an introduction to the science of the Moon and meteorites. Activities 7 to 11 deal with more advanced scientific ideas.

Age ranges

The activities are designed for a wide age range in formal and informal settings. The activities 7 to 11 are for secondary age ranges. The observation and language based activities can be used for any age range.

FRONT COVER IMAGES

1. Saturn V launch *Image NASA*

2. Lunar Rover and Apollo 17 Lunar Module - Gene Cernan driving *Image NASA*

3. NASA Lunar Samples Disc *Image NASA*

4. Dr K. Joy meteorite find Antarctica Dec 2012 *Image ANSMET/K.Joy*

5. John Houbolt - original advocate of Lunar Orbit Rendezvous (LOR) *Image NASA*

6. President John F. Kennedy - Rice University, Sept 12th 1962 *Image NASA*

The STFC Lunar Rocks and Meteorites Loan Scheme has been running since the mid 1980s. It has lent the NASA Moon rock discs and meteorites to thousands of schools, museums and outreach organisers. This book, the accompanying DVD-ROM and the STFC website provide a teaching support pack for the loan scheme. The pack has been produced by the ASE with the University of Manchester, Millgate House Education, the Natural History Museum and ESERO UK. There is almost limitless and highly accessible information online about the Moon, the Apollo missions and meteorites. The task of this book, DVD-ROM and web pages is to provide ideas for activities and an overview of the best internet sources that are helpful to a beginner in the field.

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NATURAL HISTORY MUSEUM

.uk esero

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. The kits have been supplemented by valuable meteorite samples on loan to STFC from the Natural History Museum. These are curated samples that remain the property of the Museum.
STFC has five 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.

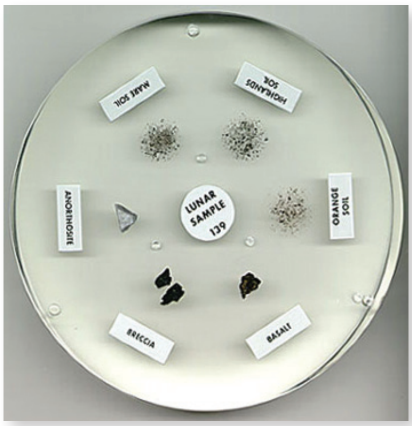
Each package also contains different examples of meteorites, put together by The Natural History Museum and part of the national collections. Some sets have sectioned samples, and every set has specimens of meteorites that can be handled. The loan is free of charge and is provided as part of STFC's commitment 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.

NASA Moon Rocks Disc

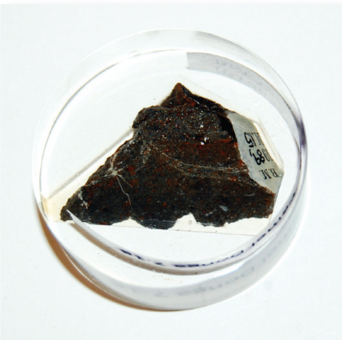
Basalt	Solidified lava found in the dark lowland maria or 'seas'.
Breccia	Rocks made of fragments of other rocks created in violent impacts.
Highland Soil (Regolith)	Fragments from the breakup of highlands rocks by meteorites.
Anorthosite	White rock consisting of feldspar crystals. Predominant rock of the lunar highlands.
Mare Soil (Regolith)	Fragments from the breakup of mare rocks by meteorites.
Orange Soil	Volcanic glass beads from a lunar eruption 3.5 billion years ago. Found by Apollo 17.



Natural History Museum Mounted Meteorites

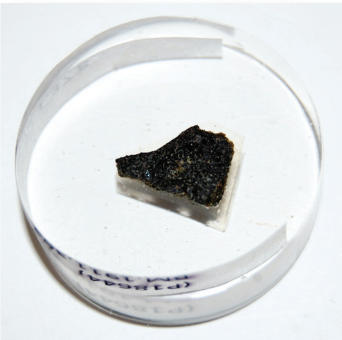
MURCHISON

Carbonaceous Chondrite
Observed Fall in Australia 1969
Total mass collected >100 kg
Murchison is an unmelted meteorite rich in organic molecules. Meteorites like this one could have seeded the early Earth with the chemical building blocks needed for life.



CAMEL DONGA

Achondrite
Found in Australia 1984
Total mass collected >2 kg
Camel Donga is a basalt similar to volcanic rocks on Earth. This indicates that the parent body from which it came underwent igneous geological processing similar to that on Earth.



NAKHLA

Achondrite
Observed Fall in Egypt 1911
Total mass collected >10 kg
Nakhla is a meteorite that came from Mars and shows evidence of aqueous processes.
A farmer claimed that a piece hit his dog.

Loan Kit Contents

Hand-held Meteorites

Henbury This is part of the Henbury iron meteorite that is made of an alloy of iron and nickel. One face of the meteorite has been cut and polished, to reveal the crystalline patterns of the two metallic minerals, kamacite and taenite, which formed in the slowly cooling core of an asteroid. To end up on Earth the asteroid must have undergone a catastrophic impact. The surface depressions called regmaglypts were caused by pockets of superheated air melting and vaporising the metal on entry into our atmosphere.

Parnallee This is an unmelted stony meteorite, or chondrite. It is part of the Parnallee meteorite that fell in India in 1857. The cut faces show small, round objects called chondrules. These are solidified droplets of silicate minerals that were produced during the very earliest stages of the formation of the Solar System. They are up to 150 million years older than the Earth. Chondrites never became part of objects that were large enough to differentiate into a core and mantle.

Imilac This is a stony iron pallasite formed at the core-mantle boundary of a large asteroid. It shows a snapshot of the process of differentiation of olivine crystallising in a matrix of iron and nickel at the core-mantle boundary. Henbury came from deeper inside a metallic core where no olivine was present. In small samples the olivine is often weathered away. The front cover of the *Meteorites* book has a spectacular picture of a pallasite. Like Henbury, a massive impact event would have blasted these fragments into space.

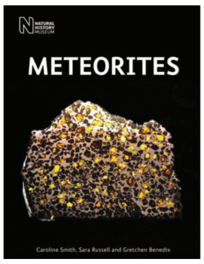
Geologist's Lenses

There are 10 lenses in each kit. x10 magnification, 21mm diameter.

USB 2.0 Digital Microscope

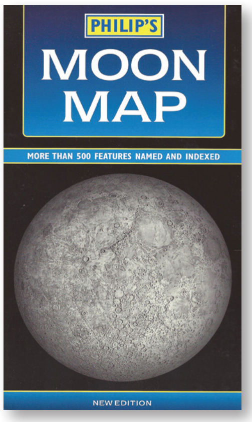
This gives excellent bright LED illuminated close-ups of all the meteorites and Moon rocks. Windows software is on a CD in the kit and Mac software is available on the Celestron.com site.

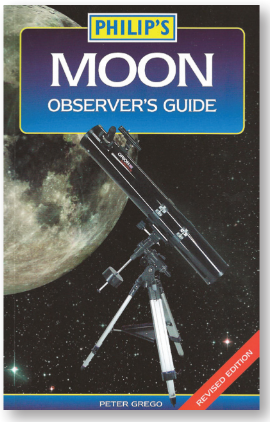
Meteorites Book



A compelling and beautifully illustrated introduction to meteorites by leading scientists at the Natural History Museum.

Moon Map and Observer's Guide





The Moon Map shows the whole near side of the Moon in fine detail. Mission landing sites are shown for Apollo, Ranger, Surveyor and Luna missions. The features on the map can be seen with binoculars or a telescope. The map shows the lunar latitude and longitude lines to help pinpoint features.

Try these activities with the map

Find and measure the latitude of the Apollo missions. Only the last three missions landed some distance from the equator. The equatorial orbit of Apollo spacecraft is different to the polar orbits of most Earth satellites such as the ISS. This orbit was chosen for many technical reasons, including a 'free return' to Earth if the mission had a problem as happened with Apollo 13.

Find famous names such as Faraday, Kepler and Kirchoff. There are plenty there! The names of features on the Moon are controlled by the International Astronomical Union.

The *Moon Observer's Guide* explains the types of features on the moon and where to find them. A popular feature is Rupes Recta, an elongate linear fault. Plato (51.6°N,9.4°W) is a dark lava filled crater that is easily seen on photographs of the Moon. Fresh crater rays from Kepler and Copernicus are HUGE! Can you work out how far ejecta were thrown? If you know the circumference of the Moon you can measure the distance per latitude and longitude line. Find and map your own craters and features using Moon Zoo (see page 8).

Apollo Missions leading up to the first landing on the Moon

"But if I were to say, my fellow citizens, that we shall send to the moon, 240,000 miles away from the control station in Houston, a giant rocket more than 300 feet tall, the length of this football field, made of new metal alloys, some of which have not yet been invented, capable of standing heat and stresses several times more than have ever been experienced, fitted together with a precision better than the finest watch, carrying all the equipment needed for propulsion, guidance, control, communications, food and survival, on an untried mission, to an unknown celestial body, and then return it safely to earth, reentering the atmosphere at speeds of over 25,000 miles per hour, causing heat about half that of the temperature of the sun--almost as hot as it is here today--and do all this, and do it right, and do it first before this decade is out--then we must be bold."

President John F. Kennedy, Rice University September 12th 1962

http://er.jsc.nasa.gov/seh/ricetalk.htm

January 27th 1967

The first Apollo mission was struck by disaster when a fire in the command module killed all three crew on the launchpad. The module was using pure oxygen during a training session, which caused the fire to burn uncontrollably.

Launched October 11th 1968

Apollo 7 was an Earth orbit mission to test the spacecraft and systems. This was the first manned mission after Apollo 1. The intervening missions were unmanned. They were 4, 5 and 6 (2 and 3 were not used to name other test flights). Mission patches were only made for manned flights.

Launched December 21st 1968

Apollo 8 was the first manned flight to the Moon, but without a lander. The crew were the first humans to escape Earth's gravity for the Moon. A rocket burn slowed the command module down to enter lunar orbit. After ten orbits another burn pushed it out of orbit onto the path home.

Launched March 3rd 1969

Apollo 9 tested all the main parts of a lunar mission in ten days of Earth orbit. The Lunar Module (LM) was tested in space for the first time. Without a heat shield it could not re-enter the atmosphere if anything went wrong. The mission was a success.

Launched 18th May 1969

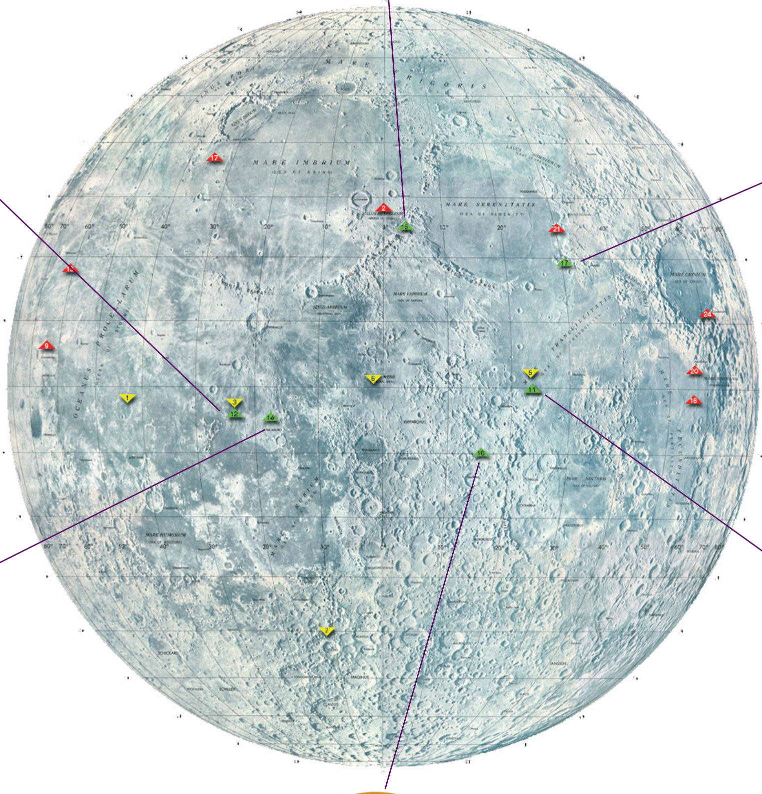
Apollo 10 was a full dress rehearsal for a Moon landing. The LM was undocked from the Command Module and taken into low lunar orbit by Stafford and Cernan.
It then jettisoned the landing stage and made a successful rendezvous with the Command Module.

Apollo Missions 11 to 17
Launch dates and landing sites

July 26th 1971
Hadley-Apennine region

November 14th 1969
Oceanus Procellarum

December 7th 1972
Taurus-Littrow Valley



January 31st 1971
Fra Mauro Highlands

July 16th 1969
Mare Tranquillitatis
Crew: Armstrong, Aldrin & Collins

April 16th 1972
Descartes Highlands

Crew: Lovell, Swigert & Haise

Apollo 13 has been called the successful failure. Almost at the end of the journey to the Moon an explosion in an oxygen tank blew out a section of the service module and caused most of the oxygen supply to leak away. The remarkable story of its safe return was told in the 1995 film *Apollo 13*.

The map also shows Soviet Luna missions (red) and NASA Surveyor missions (yellow). Apollo 12 was supposed to land close to Surveyor 3. It landed 200 metres away. This photograph shows Alan Bean inspecting the flimsy little Surveyor 3 with the LM in the backrgound.

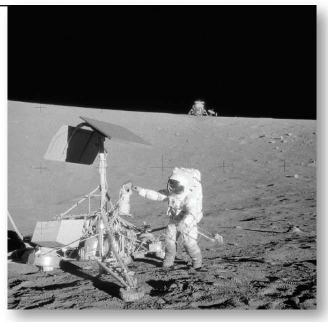
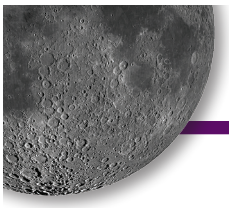
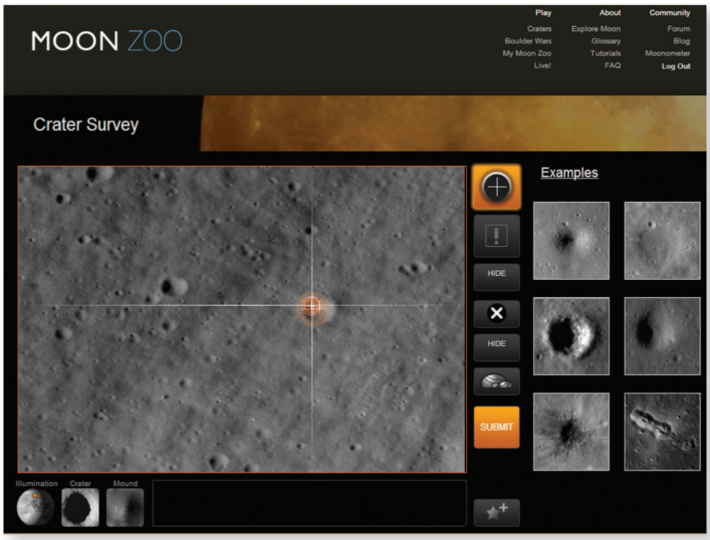


Image NASA

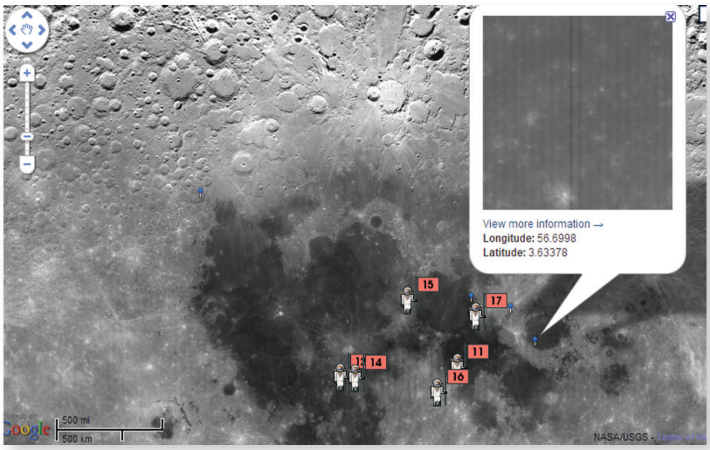


Moon Zoo
www.moonzoo.org.uk



Moon Zoo is a citizen science project run by Zooniverse (part of the Citizen Science Alliance). It allows you to look at images from the Lunar Reconnaissance Orbiter Camera (LROC) and use mapping tools to identify and measure features on the lunar surface. You can make your own image collection and discuss the images on a science forum. If your measurements match those of other users, they will be accepted as genuine data. This way you are contributing to a real science project. If you want to go into fine detail there are advanced tutorials. Otherwise you can use the basic tutorials to identify and measure craters, boulders or linear features as an individual or group exercise.

My Moon Zoo uses Google Moon to show whereabouts on the Moon you have been working. You can see how close you were to Apollo landing sites and other visible features that can be seen on the Moon Map and matched with latitude and longitude readings. This is Moon exploration using real data and contributing to real science.



Explore the Moon on the Moon Zoo website is the place to go for all lunar facts and science. Explore the Moon links to the relevant Lunar and Planetary Institute and NASA sites. It is an ideal resource for teachers and students and indeed anyone interested in the Moon.

Meteorite & Moon Activities

Activities 8-14 years

1. Moon Talk
2. Dusty Moon
3. Is That a Moon fact?
4. Living on the Moon
5. Meteorite Detective
6. Finding Meteorites

Activities 14 years +

7. Gloopy Liquids
8. Rock Density
9. Fiery Moon
10. Shiny Rocks
11. Dating the Moon

Additional activities are on the DVD-ROM included in the kit

1.1 Moon Talk

Organiser's Notes

Focus

Introducing ideas about the Moon by exploring its influence on our language. It is also an opportunity to discuss what idioms and expressions mean.

Exploring definitions of scientific vocabulary associated with the Moon.

Resources

The following can be found on the DVD-ROM:

Moon Talk Activity Sheet A

Cards for Activity B

Images of the Moon

Moon idioms and expressions

Safety notes

There are no safety issues with this activity.

Using the activity

These activities can be used to set the scene for the main project and the arrival of the Loan Kit. Alternatively, they can be used during the project as a literacy activity to make links between the Moon and everyday language.

Activity Sheet A focuses on Moon expressions and idioms and their meanings. Activity B introduces scientific vocabulary through two games: Astro-Bingo and Astro-Splat.

Set the scene by showing pictures of the Moon and talk about how the Moon has influenced people's ideas and language over the ages. Introduce a Moon expression, for example, 'Promise someone the Moon', and get groups to discuss what they think it means and why. There are Moon pictures on the DVD-ROM.

Moon Talk 1.2

Background Information

The Moon has always been used in language and music. Whereas the Sun is perhaps associated with bright, positive things, the Moon is used to express a wide range of emotions and ideas, from love to lunacy. These activities look at the way the Moon is used in our language.

To help groups to engage more effectively with discussions about the Moon and Apollo missions, it is important to give them time to explore their understanding of the scientific language associated with these. Astro-Splat and Astro-Bingo are fun ways of introducing words such as regolith, mare and anorthosite.

The Moon map has many Latin names that can be translated too. This can be a game in itself.

Expressions.pdf

Expressions

Ask for the Moon	Once in a blue Moon	Over the Moon	Honeymoon	Many Moons ago
Reach for the Moon	Promise the Moon	Moon something away	Moon about something	Moon about
Shoot for the Moon	Crying for the Moon	Its all Moonshine	Moonlighting	Moonstruck

LUNAR ROCKS activity sheets

1.3 Moon Talk

Activity 1A

Give out copies of Moon Talk Activity Sheet A, or show it on the whiteboard. Challenge groups to work out what the expressions mean and why people might use the word Moon in the expressions. On the Activity Sheet the term 'expression' is used. You might want to refer to idioms as well.

Ask the group what each expression means and then reveal the suggested definition. Sometimes even the accepted definitions are open to interpretation. Groups can look for more Moon expressions and their meanings. Groups could also make up their own. Finally, they work together to make up a short story using as many Moon expressions as possible. The idioms, expressions and stories can be illustrated and shared. There are useful web links, and examples of idioms and expressions on the DVD-ROM.

Activity Sheet 1A.pdf

Activity 1A - Moon Talk

Expression	What it means	Explanation
Ask for the Moon	Want something you can't have	You can't ever have something from the Moon on Earth
Once in a blue Moon	Something that happens rarely	
Over the Moon		
Honeymoon		
Many Moons ago		
Reach for the Moon		

R ROCKS activity sheets

Activity Sheet 1A

Moon Talk 1.9

Activity 1B

Astro-Splat is a word game designed to help with the vocabulary of the Moon and space exploration. There are different ways of playing it:

Wall cards Stick the word cards around the room. Give each group different coloured mini Post-its. Read out a description line and let them choose the matching word. Call out "SPLAT" and a runner from each group takes a Post-it to the word. There may be a difference of opinion. Can they argue their case?

Matching Game Give out the Astro-Splat description strips and word list. Call out a word and let the groups hold up the chosen description. They can be encouraged to expand on the description. Do other groups agree?

Whiteboard Put a word up on the whiteboard and hand out the word list to each group. They can call SPLAT when they have found the right description.

Astro-Bingo is a game using 6 x 3 bingo cards with words drawn from lists set at different levels.

astro-splat.pdf & astro-bingo.pdf

2.1 Dusty Moon

Organiser's Notes

Focus

Learning about the differences between the formation of sedimentary rocks (sand, chalk, clay) and lunar 'soil'.

Observing and drawing a real sample of lunar dust and comparing with sand and other small rock particles from Earth.

Resources

Lunar dust and rock samples in the NASA disc
Post-it notes
Clean sand and rock samples preferably sand, sandstone, and a sedimentary rock containing fossils
Geological magnifiers (included in the kit)
USB magnifier (included in the kit, but requires software. See introductory pages)
Stereo microscopes and lamps. Not essential, but ideal if you have them
Plastic trays

Safety notes

Sand and other rocks should be clean samples. Garden centres and builders merchants are good sources of a variety of rock and sand types.

Using the activity

This activity encourages groups to engage with some of the materials in the box.

Activity Sheet A focuses on how soil and lunar dust are formed. Activity Sheet B extends this activity by drawing attention to the differences between sand on Earth and lunar dust (regolith). See Background Information.

Set the scene by looking at the lunar dust together, talking about where it has come from and about how astronauts were involved in collecting it. Try to create a sense of excitement about how special and rare it is to have lunar dust on Earth.

Dusty Moon 2.2

Background Information

A picture of Jack Schmitt from Apollo 17 shows him covered in grey dust. Other pictures in *Image folder Activity 2* show more images and microscope views of lunar regolith. These images show that the fine, dusty regolith is made from dry, very sharp crystalline material with no life. It looks very different from soil on Earth. Weathering and life processes on Earth create sand, clay, layered sediments, fossils and what we know as soil. These processes are absent on the Moon, so this layer of 'soil' must have been formed in other ways.

The Moon is now geologically inactive. Meteorites, micrometeorites and charged particles of the solar wind have slammed into the Moon for billions of years, pulverising the surface into a fine dust. With no atmosphere to protect it, these impacts are far more numerous and energetic than on the surface of Earth.

The Apollo missions found that this dust was like nothing they had seen on Earth. It created serious problems, for example, damaging seals, covering solar panels, sticking to space suits, floating in the spacecraft and getting into astronauts' eyes. In the lunar lander they could even smell it and taste it! Try Googling 'NASA + Cernan + dust' to read more.

Footprints and lunar rover tracks are still visible after more than forty years. Those marks on the Moon may still be there in centuries, even millennia, to come. Gradually more micrometeorite impacts will break them up. How long would they last in a desert on Earth? A day? A week? A month?

Apollo 17 astronaut Jack Schmitt. Grey dust covers his spacesuit.

Apollo 17 astronaut Gene Cernan covered in Moon dust.

2.3 Dusty Moon

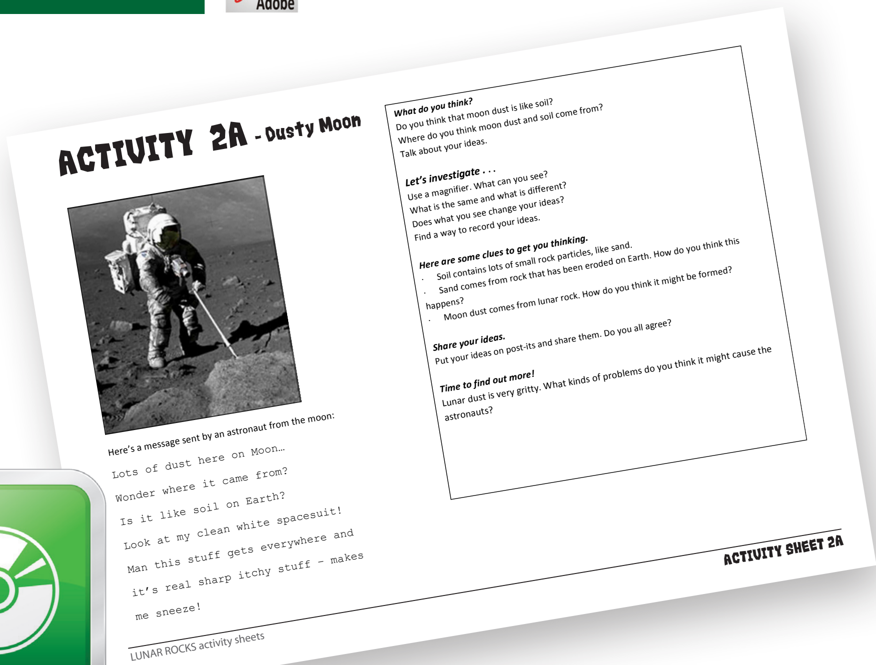
Activity 2A

Set the scene using the message from the astronaut and show the image of a very dusty Jack Schmitt. These are not his actual words, but he and Cernan had plenty to say about Moon dust.

Give out copies of Dusty Moon Activity Sheet A. Give groups time to talk about their ideas. Provide samples of rock and soil from Earth and the Moon to explore with hand lenses. Share ideas about what they think soil and lunar dust are and where they come from. Look for areas of agreement and disagreement between the groups. Allow time for groups to discuss the areas of disagreement. You can provide access to background information for them to check their ideas.

Good information sources include Moon Zoo, NASA History and the Lunar and Planetary Institute (LPI) websites. Encourage the group to think about how long the surface of the Moon has been exposed to bombardment without the protection of an atmosphere.

Activity Sheet 2A.pdf



ACTIVITY 2A - Dusty Moon

Here's a message sent by an astronaut from the moon:

Lots of dust here on Moon…
Wonder where it came from?
Is it like soil on Earth?
Look at my clean white spacesuit!
Man this stuff gets everywhere and
it's real sharp itchy stuff - makes
me sneeze!

What do you think?
Do you think that moon dust is like soil?
Where do you think moon dust and soil come from?
Talk about your ideas.

Let's investigate . . .
Use a magnifier. What can you see?
What is the same and what is different?
Does what you see change your ideas?
Find a way to record your ideas.

Here are some clues to get you thinking.
- Soil contains lots of small rock particles, like sand.
- Sand comes from rock that has been eroded on Earth. How do you think this happens?
- Moon dust comes from lunar rock. How do you think it might be formed?

Share your ideas.
Put your ideas on post-its and share them. Do you all agree?

Time to find out more!
Lunar dust is very gritty. What kinds of problems do you think it might cause the astronauts?

LUNAR ROCKS activity sheets

ACTIVITY SHEET 2A

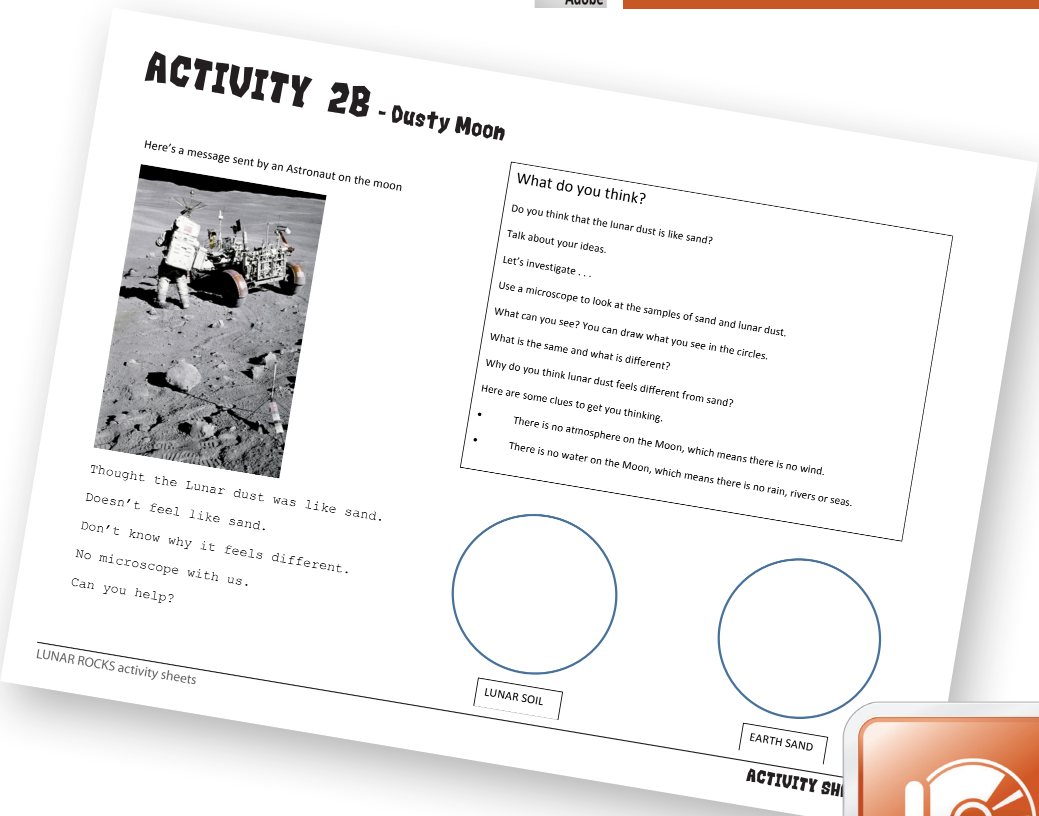
Dusty Moon 2.9

Activity 2B

Set the scene using the message from the astronaut. Give out Activity Sheet B. Give groups time to talk about their initial ideas. Compare sand and lunar dust samples using the lenses or microscopes. The USB microscope should enable differences to be seen and can take snapshots for printing or projecting.

Share ideas about differences they have spotted – e.g. by drawing what they see down the microscope on large paper circles and adding annotations. Look for areas of agreement and disagreement between groups. Allow more time for them to discuss and explore areas of disagreement. Provide access to images of lunar dust and sand, plus background information for them to check their ideas. You can use www.virtualmicroscope.org

Activity Sheet 2B.pdf



ACTIVITY 2B - Dusty Moon

Here's a message sent by an Astronaut on the moon

Thought the Lunar dust was like sand.
Doesn't feel like sand.
Don't know why it feels different.
No microscope with us.
Can you help?

What do you think?

Do you think that the lunar dust is like sand?

Talk about your ideas.

Let's investigate . . .

Use a microscope to look at the samples of sand and lunar dust.

What can you see? You can draw what you see in the circles.

What is the same and what is different?

Why do you think lunar dust feels different from sand?

Here are some clues to get you thinking.

- There is no atmosphere on the Moon, which means there is no wind.
- There is no water on the Moon, which means there is no rain, rivers or seas.

LUNAR SOIL

EARTH SAND

LUNAR ROCKS activity sheets

ACTIVITY SH

3.1 Is That a Moon Fact?

Organiser's Notes

Focus

Learning about the Moon and its exploration

Resources

Activity Sheet A or statements on cards for sorting

Activity B statements and information cards

True/Lie cards

Safety notes

There are no safety issues with this activity.

Using the activity

Use this activity as an engaging way to explore information about the Moon.

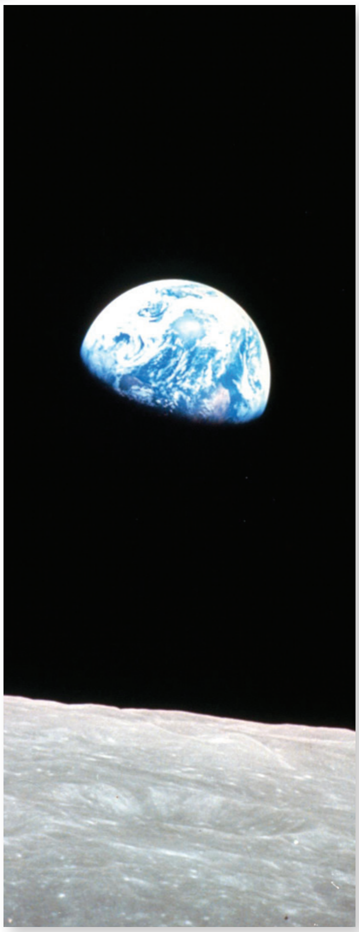
Activity A is a card sort about Moon facts to get groups talking and researching ideas about the Moon. The cards can be downloaded from the DVD-ROM.

Activity B is based on the BBC TV quiz show *Would I Lie to You.*

Groups are likely to find it more challenging than Activity A.

Is That a Moon Fact? 3.2

Background Information



Here is some brief information about each statement from Activity A. The full information is on the DVD-ROM so that you can share it with the group when they have completed all parts of Activity A. Background information cards relating to Activity B are on the DVD-ROM

One side of the Moon is always dark
The phrase the 'dark side of the Moon' is very common, but completely false

The Moon is extremely hot during the daytime and extremely cold during the night
A lunar day lasts about a fortnight. When one side faces the Sun the surface of the Moon can get very hot…

There is no gravity on the Moon
The gravity on the Moon is about one sixth of that on Earth…

Sometimes we see earthshine, when the Sun's light reflects off the Earth onto the Moon
In the right conditions when the Moon is a thin crescent, the Earth reflects enough sunlight onto the Moon to make it visible…

We always see the same side of the Moon from Earth
The Moon is in synchronous rotation

The Moon rotates much more slowly than the Earth
Earth takes 24 hours to turn once on its axis. The Moon takes about 29 .days to turn once on its axis…

It takes just over one second for moonlight to reach Earth
Light travels at 300,000,000 metres per second, taking 1.3 seconds to reach the Earth from the Moon…

You can't see the Earth from the Moon
The Earth can be seen very clearly…

In the Southern Hemisphere the Moon is upside down compared to the Northern Hemisphere
In the Southern Hemisphere the Moon is upside down and the phases are the opposite way round…

You only see the Moon at night
The Moon can be seen on average for 6 hours in daylight…

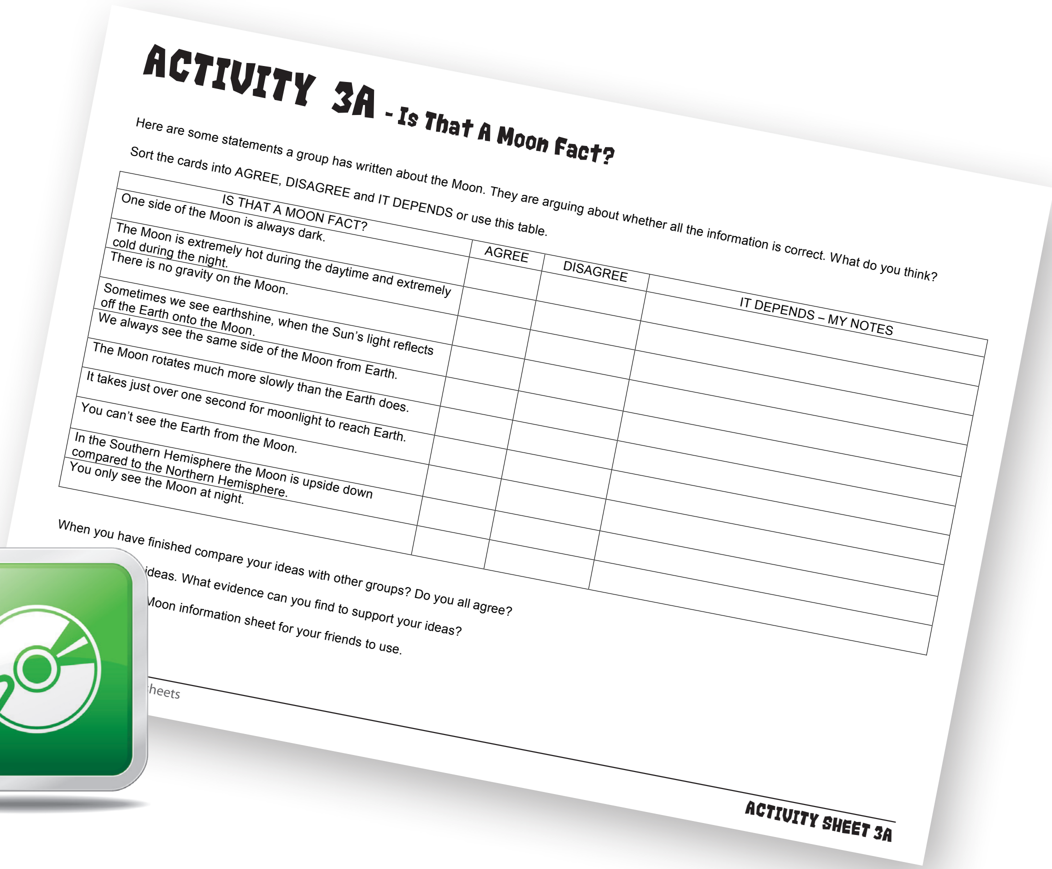
3.3 Is That a Moon Fact?

Activity 3A

Each pair, or small group, is given Activity Sheet A or the set of cards containing statements about the Moon. Challenge them to sort the cards into three sets: *Agree, Disagree* and *It depends*. Share the outcomes to highlight areas of disagreement. As you discuss each statement, a member of each group could stand by their chosen word displayed in different parts of the room i.e. *Agree, Disagree* and *It depends*.

Groups now look for evidence to support or refute the statements using any information sources available. This could be done as homework. Review the evidence, identify any changes in ideas and whether there is complete agreement about all of the statements. If there is still disagreement, the relevant statements can be left on display and additional ideas can be added using Post-it notes. You can share the background information with them at this point. Are there any surprises?

Activity Sheet 3A.pdf



ACTIVITY 3A - Is That A Moon Fact?

Here are some statements a group has written about the Moon. They are arguing about whether all the information is correct. What do you think?

Sort the cards into AGREE, DISAGREE and IT DEPENDS or use this table.

IS THAT A MOON FACT?	AGREE	DISAGREE	IT DEPENDS – MY NOTES
One side of the Moon is always dark.			
The Moon is extremely hot during the daytime and extremely cold during the night.			
There is no gravity on the Moon.			
Sometimes we see earthshine, when the Sun's light reflects off the Earth onto the Moon.			
We always see the same side of the Moon from Earth.			
The Moon rotates much more slowly than the Earth does.			
It takes just over one second for moonlight to reach Earth.			
You can't see the Earth from the Moon.			
In the Southern Hemisphere the Moon is upside down compared to the Northern Hemisphere.			
You only see the Moon at night.			

When you have finished compare your ideas with other groups? Do you all agree?

ideas. What evidence can you find to support your ideas?

Moon information sheet for your friends to use.

heets

ACTIVITY SHEET 3A

Is That a Moon Fact?

3.4

Activity 3B

This activity draws on the format of the *Would I Lie to You?* BBC television quiz show. Each pair, or small group, is given their own card containing a statement about the Moon to research. This could be done as homework. Tell them to keep it secret. First they need to find out whether it is the truth or a lie. They can use information sources such as the internet or you can give them the relevant information card provided on the on the DVD-ROM. They plan together how they will respond to questions about their statement to try to convince everyone that their statement is true. You might want to do one with them as an example.

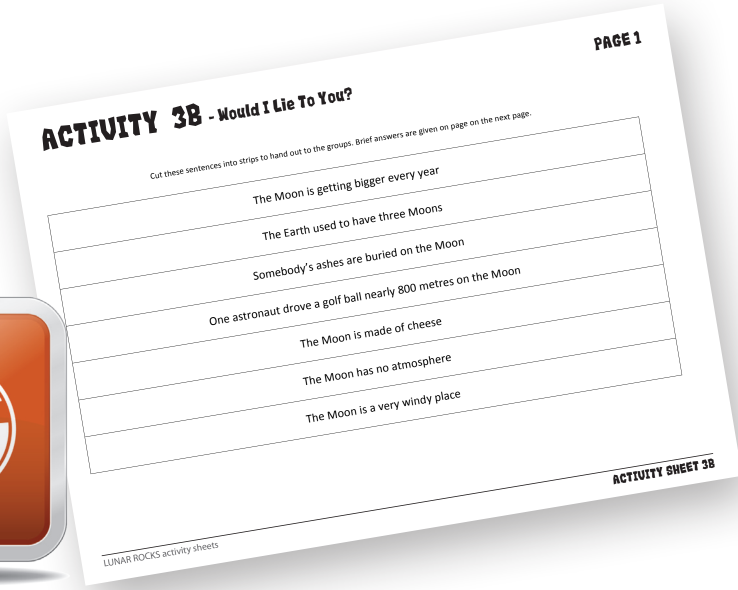
When everyone has done their research, one group at a time reads out their statement. Everyone else is challenged to work out whether it is true or a lie by asking questions about the statement. They then vote by holding up the appropriate card that can be printed from the DVD-ROM.

PDF Adobe **WILTYcards.pdf**

Extension:

Groups are challenged to create a statement of their own. Have a class vote on which statement was the most challenging to deal with.

Activity3B.pdf PDF Adobe



PAGE 1

ACTIVITY 3B - Would I Lie To You?

Cut these sentences into strips to hand out to the groups. Brief answers are given on page on the next page.

The Moon is getting bigger every year
The Earth used to have three Moons
Somebody's ashes are buried on the Moon
One astronaut drove a golf ball nearly 800 metres on the Moon
The Moon is made of cheese
The Moon has no atmosphere
The Moon is a very windy place

ACTIVITY SHEET 3B

LUNAR ROCKS activity sheets

4.1 Living on the Moon?

Organiser's Notes

Focus

Learning about the similarities and differences between the Earth and the Moon.

Resources

Reference material from books and/or websites

Safety notes

There are no safety issues with this activity.

Using the activity

Having found out more about the Moon in Activity 3, this activity explores what it might be like to live on the Moon. Would a Moon base ever be possible? What difficulties would people have to overcome to survive there?

Activity A uses a compare and contrast graphic organiser to explore how important aspects of life on the Moon compare with life on Earth.

Activity B explores in more detail how humans might function on the Moon, using poetry as a starting point. It is designed to provoke a creative response, and to provide an opportunity to apply what has been learnt about the Moon.

Living on the Moon?

9.2

Background Information

There are many problems to be overcome if astronauts are to spend long periods on the Moon. As this has never been done, children can speculate on many issues that help them to understand scientific ideas. These are some of the headings you might consider for discussion.

Physiology - low gravity may cause bone, heart and muscle failure
Life support - oxygen, food and water need to be found
Mission planning - robotic missions would be needed to deliver equipment and hardware before humans could survive for long periods
Water - for drinking and making hydrogen and oxygen
Supplies - regular service missions would be needed - what would they carry?
Rescue - can a rescue mission be launched quickly? Can you launch a rocket to the Moon at any time?
Accommodation - this has to be pressurised and protected from micrometeorites
Purpose - why would we go to the Moon again? A staging post? Research?
Cost - this would need to be a multinational project
International collaboration - can nations work together in space? Do they already?
Radiation - with no atmosphere, the radiation dose for astronauts is high
Hazards - dust, radiation, heat, cold, vacuum, disease, equipment failure
Temperature - extremes of hot and cold without atmospheric protection
Moon dust - Apollo astronauts had big problems. Can these be solved?

Using a 'What if….' exercise can stimulate discussion and the development of ideas.
What if a supply spacecraft crashed?

NASA has created a computer game called *Moonbase Alpha* that simulates conditions on the Moon.

There are some excellent images and animations at http://www.nasa.gov/externalflash/LunarOutpost/

Image NASA

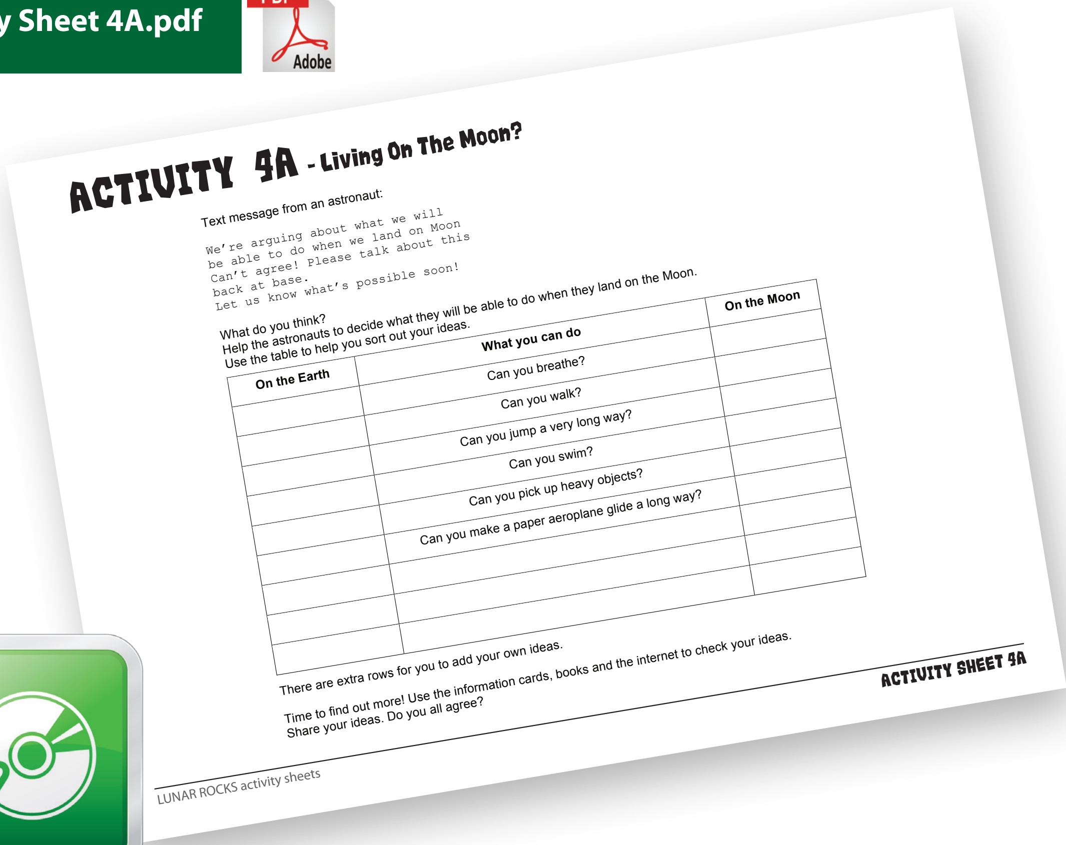
4.3 Living on the Moon?

Activity 4A

Set the scene using the message from the astronaut from Activity Sheet A. Give groups time to talk about what they think they already know about the astronaut's question. They then complete the comparison table to record information about the similarities and differences when they compare the Earth and the Moon, using what they know they can do on Earth as a starting point. Suggest that they discuss possibilities and decide what they agree on. Encourage them to research areas where they are uncertain and to add extra rows to the table with their own ideas about what the astronauts will be able to do on the Moon.

Let groups link together to compare their charts and get them to identify where there is disagreement or uncertainty. These can be explored further or put on a question board for later follow-up.

Activity Sheet 4A.pdf



ACTIVITY 4A - Living On The Moon?

Text message from an astronaut:

We're arguing about what we will be able to do when we land on Moon
Can't agree! Please talk about this back at base.
Let us know what's possible soon!

What do you think?
Help the astronauts to decide what they will be able to do when they land on the Moon.
Use the table to help you sort out your ideas.

On the Earth	What you can do	On the Moon
	Can you breathe?	
	Can you walk?	
	Can you jump a very long way?	
	Can you swim?	
	Can you pick up heavy objects?	
	Can you make a paper aeroplane glide a long way?	

There are extra rows for you to add your own ideas.

Time to find out more! Use the information cards, books and the internet to check your ideas.
Share your ideas. Do you all agree?

ACTIVITY SHEET 4A

LUNAR ROCKS activity sheets

Living on the Moon?

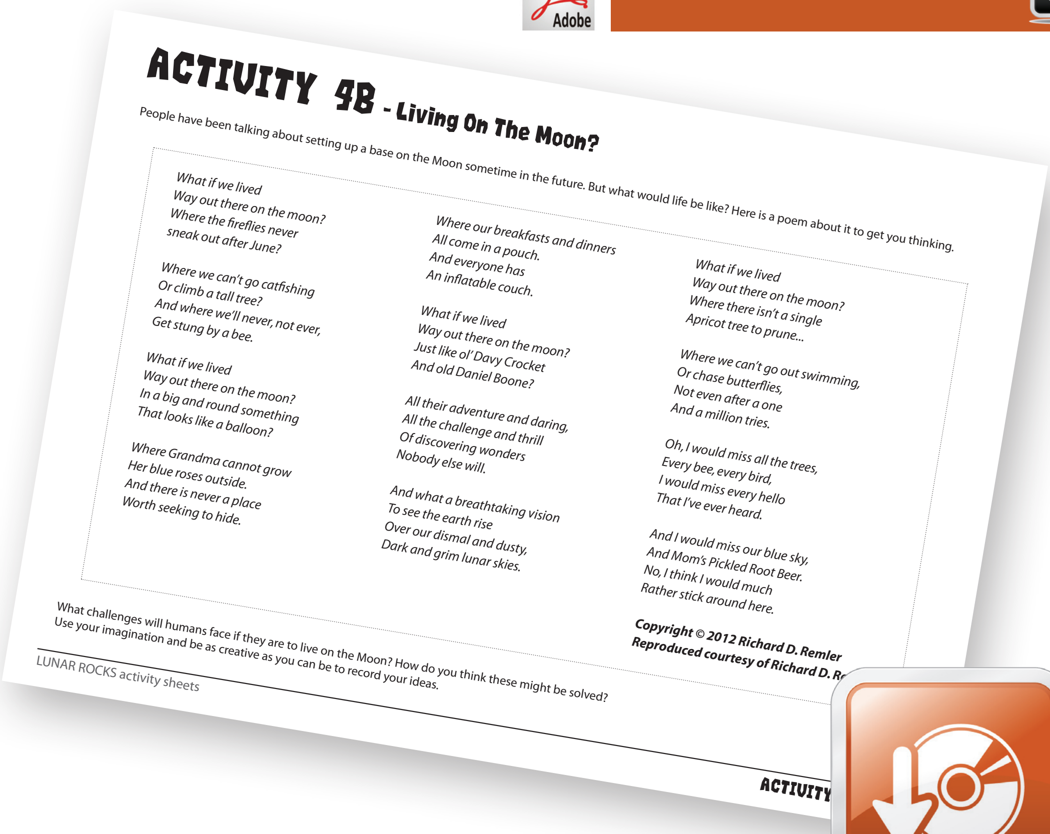
4.4

Activity 4B

This extension activity is intended to encourage groups to think more imaginatively about life on the Moon. The starting point of a poem is deliberate and opens up the possibility of creative responses. Share it using a whiteboard or a printed copy from the DVD-ROM.

Start by talking about the poem. What would they miss from Earth? What new possibilities does life on the Moon offer? Encourage them to create visual and written images of what life would be like. Remind them to take into account what they have learnt about the Moon. Share what they create. What do they think about each other's ideas?

Activity Sheet 4B.pdf



ACTIVITY 4B - Living On The Moon?

People have been talking about setting up a base on the Moon sometime in the future. But what would life be like? Here is a poem about it to get you thinking.

What if we lived
Way out there on the moon?
Where the fireflies never
sneak out after June?

Where we can't go catfishing
Or climb a tall tree?
And where we'll never, not ever,
Get stung by a bee.

What if we lived
Way out there on the moon?
In a big and round something
That looks like a balloon?

Where Grandma cannot grow
Her blue roses outside.
And there is never a place
Worth seeking to hide.

Where our breakfasts and dinners
All come in a pouch.
And everyone has
An inflatable couch.

What if we lived
Way out there on the moon?
Just like ol' Davy Crocket
And old Daniel Boone?

All their adventure and daring,
All the challenge and thrill
Of discovering wonders
Nobody else will.

And what a breathtaking vision
To see the earth rise
Over our dismal and dusty,
Dark and grim lunar skies.

What if we lived
Way out there on the moon?
Where there isn't a single
Apricot tree to prune...

Where we can't go out swimming,
Or chase butterflies,
Not even after a one
And a million tries.

Oh, I would miss all the trees,
Every bee, every bird,
I would miss every hello
That I've ever heard.

And I would miss our blue sky,
And Mom's Pickled Root Beer.
No, I think I would much
Rather stick around here.

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What challenges will humans face if they are to live on the Moon? How do you think these might be solved?
Use your imagination and be as creative as you can be to record your ideas.

LUNAR ROCKS activity sheets

ACTIVITY

5 Meteorite Detective

Focus

Encouraging observation and speculation about the origin of meteorites.

Safety

There are no safety issues with this activity.

Resources

Hand-held meteorites in the kit
Hand lenses in the kit
USB microscope in the kit (snapshots can be displayed in a presentation)
Magnets (not in the kit)
NHM *Meteorites* book in the kit
NHM website, meteorites section
PSRD presentations. Online at: http://www.psrd.hawaii.edu/Archive/Archive-Meteorites.html

Background Information

The hand-held meteorite fragments are not labelled. One is a primitive rock that formed in the early life of the solar system. It never became part of a body large enough to get hot and melt into a core. We know that there are many of these in space because they keep falling to Earth. This one is a chondrite.

One is purely metallic. It must have come from the core of a body that was large enough to form a molten core but small enough to cool down. Perhaps it was a large asteroid. Whatever it was, it must have had enough gravity to make heavy metallic elements sink to form a core, leaving a mantle and crust above.

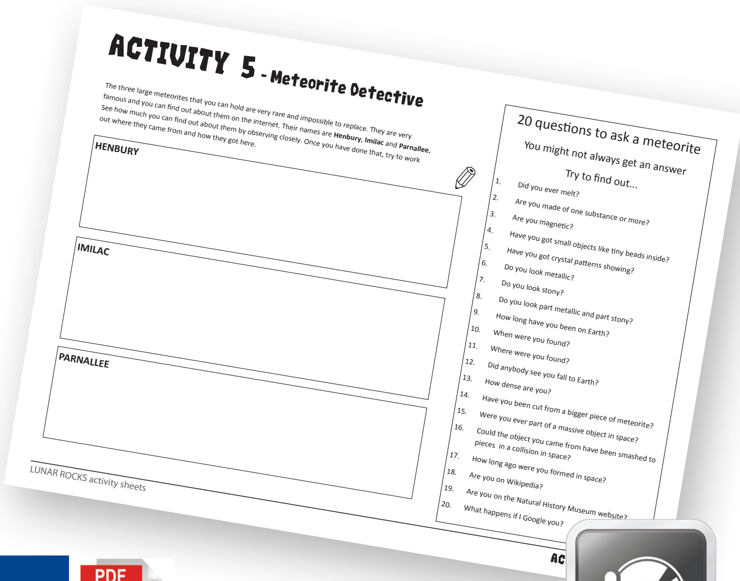
One seems to be halfway between the other two. It is a mix of metal and silicate minerals, which shows evidence of melting. In order to melt it must have been part of an asteroid or planetary body that became hot enough inside to melt and had enough gravity to make dense, molten metallic iron sink to form a core. Maybe it came from a core/mantle boundary.

If this is all true, then how could they end up on Earth?

The PSRD website at the University of Hawaii has excellent presentations showing how meteorites formed and how they got to Earth.

Using the activity

What groups can investigate:
Are the meteorites magnetic?
Which have the highest and lowest density?
Do they show any crystallising patterns? Crystallisation is evidence of slow cooling.
Can they speculate on how they got here and what their origin was?



ACTIVITY 5 - Meteorite Detective

The three large meteorites that you can hold are very rare and impossible to replace. They are very famous and you can find out about them on the internet. Their names are **Henbury**, **Imilac** and **Parnallee.** See how much you can find out about them by observing closely. Once you have done that, try to work out where they came from and how they got here.

HENBURY

IMILAC

PARNALLEE

20 questions to ask a meteorite

You might not always get an answer

Try to find out...

1. Did you ever melt?
2. Are you made of one substance or more?
3. Are you magnetic?
4. Have you got small objects like tiny beads inside?
5. Have you got crystal patterns showing?
6. Do you look metallic?
7. Do you look stony?
8. Do you look part metallic and part stony?
9. How long have you been on Earth?
10. When were you found?
11. Where were you found?
12. Did anybody see you fall to Earth?
13. How dense are you?
14. Have you been cut from a bigger piece of meteorite?
15. Were you ever part of a massive object in space?
16. Could the object you came from have been smashed to pieces in a collision in space?
17. How long ago were you formed in space?
18. Are you on Wikipedia?
19. Are you on the Natural History Museum website?
20. What happens if I Google you?

LUNAR ROCKS activity sheets

Activity Sheet 5.pdf

Finding Meteorites

6

Focus

Considering where meteorites are most likely to be found

Safety

There are no safety issues with this activity.

Resources

NHM *Meteorites* book

Data from the 'Why Antarctica?' page on the DVD-ROM

Using the activity

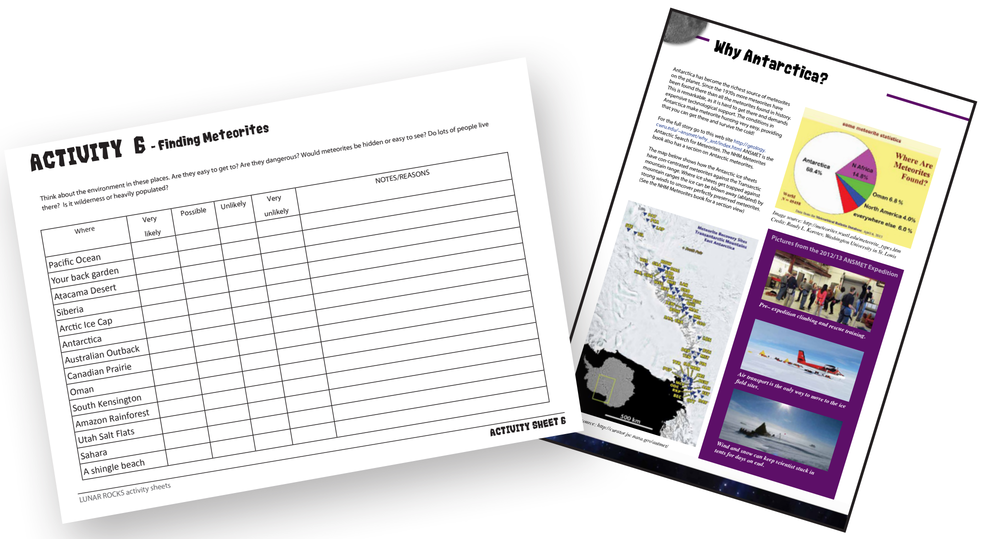
The table asks where meteorites are most likely to be found. Groups can fill in the table and compare answers. South Kensington is the joker in the pack. It is the home of the Natural History Museum and one of the biggest collections of meteorites in the world. The reasons are not just to do with terrain, but also accessibility and sometimes security.

Background Information

More meteorites are found in some places than others. The number found depends on some simple factors. Can they be seen on the ground? Were they seen as they fell? Is anybody looking for them? The NHM *Meteorites* book explains these factors very clearly.

The big story about meteorites is the rapid increase in Antarctic finds from the 1970s. This is partly because they are easy to see and partly due to a concentration mechanism in the ice fields. Increased scientific interest in meteorites, together with advances in technology and air transport, have led to a massive rise in finds since the 1970s.

Activity Sheet 6.pdf & why-antarctica.pdf



7.1 Gloopy Liquids

Organiser's Notes

Focus

This activity links to the formation of rocky bodies within the solar system and the process of 'differentiation' into layers caused by the pull of gravity on minerals of different density in a molten state.

Resources

Laboratory balance, black treacle, blue hand soap, water, red food dye, 500 cm^3 beakers.
Link to http://www.moonzoo.org/Lunar_Formation for a simulation of the formation of the moon.

Safety notes

Eye protection should be worn when handling glassware.

Using the activity

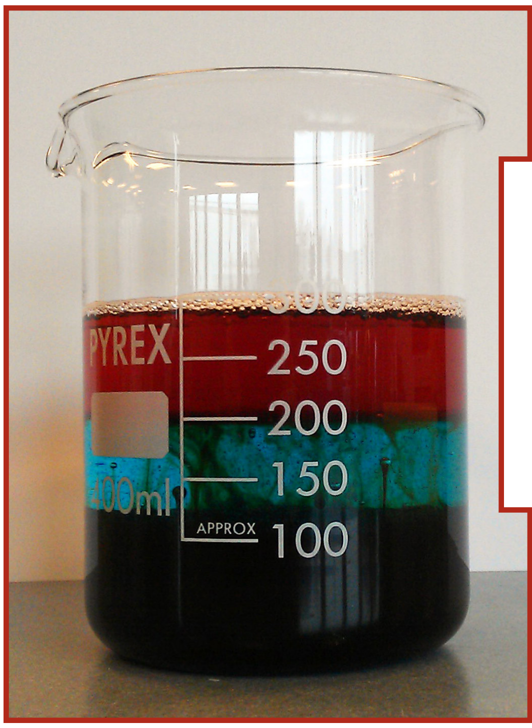
Gloopy Liquids can be used before or after the loan period. It is a good general physics activity on density and units. The process of differentiation is important in understanding formation of bodies with a metallic iron core and rocky mantle, like the Earth, from bodies where iron and rock were intimately mixed ('undifferentiated bodies', similar to the chondritic rocks). When we find a meteorite that must have come from a differentiated body it indicates that a differentiated body was disrupted by a collision, or by the gravity of a more massive planet causing tidal disruption.

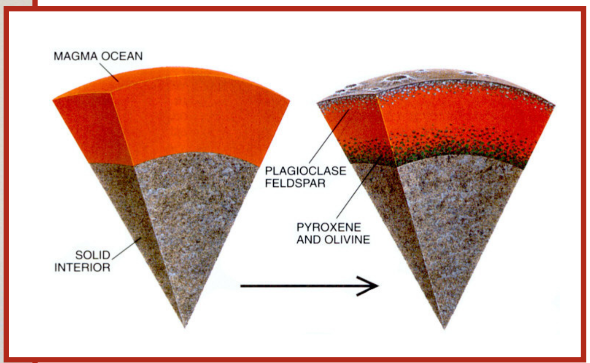
Gloopy Liquids 7.2

Background Information

Groups investigate how liquids of different densities will differentiate due to gravity. The suggested liquids for the experiment are black treacle, liquid soap and water containing red food colouring. The layers are analogous to the three main layers of the Moon: the core, mantle and crust. The core is mostly iron; the mantle mostly the minerals olivine, orthopyroxene and clinopyroxene; and the crust mostly anorthosite, an intrusive igneous rock. The average density of the Moon is around 3.3 gcm^{-3} (the core will be more than twice as dense) – groups can compare this value with that of the liquids.

The most widely accepted explanation for the formation of the Moon was the collision between a Mars-sized body and the Earth. The material that came off this collision was a mixture between the original Earth and the impactor. Over time the material came together to form the Moon. At this early stage, the Moon was a molten mass of material, but as it cooled, the denser minerals became concentrated at the centre – differentiating due to gravity. Further cooling led to the formation of a crust. The surface of the Moon we see today is heavily cratered, with large areas called mare, which are ancient basaltic lava flows.





Sinking and floating minerals in the magma ocean

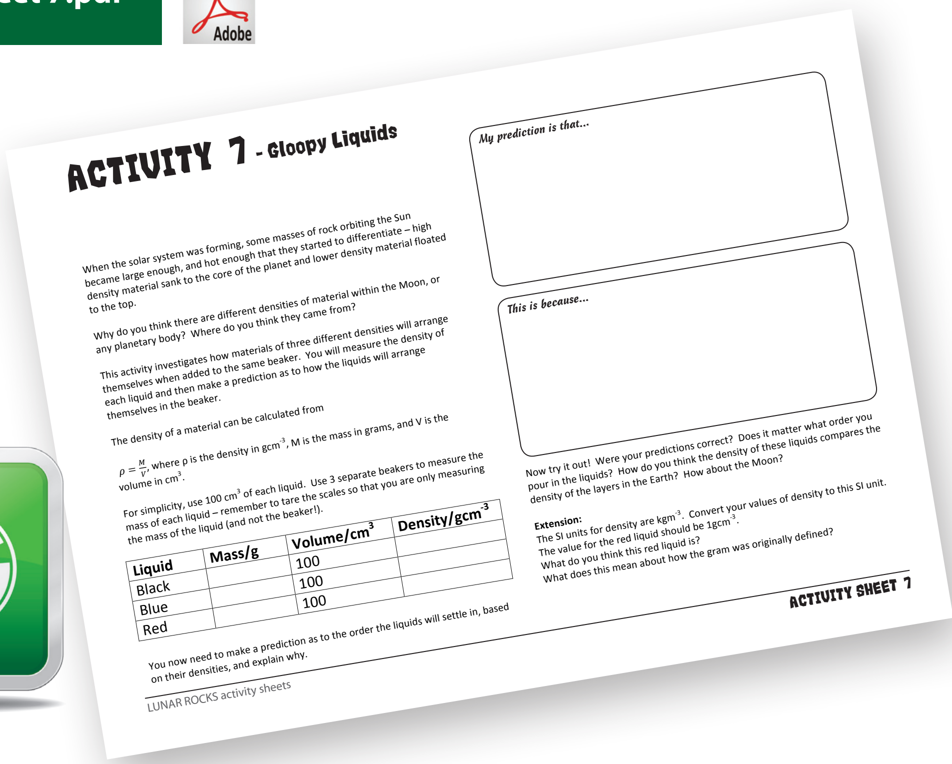
7.3 Gloopy Liquids

Activity 7

Groups should measure the mass of each liquid, calculate the density and make their prediction before the liquids are mixed together. Most groups will predict that the denser liquids will sink to the bottom – the real challenge here will be to explain why. Simple answers may include statements such as 'heavier things sink' or ' light objects float'. Higher level explanations may mention the force of gravity and may make links such as low density objects, like wood, floating in a higher density liquid, like water. Groups could research the composition and density profile of the Earth and Moon as a comparison.

The extension activities suggest converting gcm-^{3} to kgm-^{3}. This will be a challenge for many groups. They should be encouraged to think of it step-by-step, e.g. cm^3 to m^3 conversion is x100 three times, so 100x100x100 = 1000000 and for g to kg conversion we divide by 1000, so we have 1000000/1000 = 1000 times.

Activity Sheet 7.pdf



ACTIVITY 7 - Gloopy Liquids

When the solar system was forming, some masses of rock orbiting the Sun became large enough, and hot enough that they started to differentiate – high density material sank to the core of the planet and lower density material floated to the top.

Why do you think there are different densities of material within the Moon, or any planetary body? Where do you think they came from?

This activity investigates how materials of three different densities will arrange themselves when added to the same beaker. You will measure the density of each liquid and then make a prediction as to how the liquids will arrange themselves in the beaker.

The density of a material can be calculated from

$\rho = \frac{M}{V}$, where ρ is the density in gcm^{-3}, M is the mass in grams, and V is the volume in cm^3.

For simplicity, use 100 cm^3 of each liquid. Use 3 separate beakers to measure the mass of each liquid – remember to tare the scales so that you are only measuring the mass of the liquid (and not the beaker!).

Liquid	Mass/g	Volume/cm^3	Density/gcm^{-3}
Black		100	
Blue		100	
Red			

You now need to make a prediction as to the order the liquids will settle in, based on their densities, and explain why.

My prediction is that...

This is because...

Now try it out! Were your predictions correct? Does it matter what order you pour in the liquids? How do you think the density of these liquids compares the density of the layers in the Earth? How about the Moon?

Extension:
The SI units for density are kgm^{-3}. Convert your values of density to this SI unit.
The value for the red liquid should be $1gcm^{-3}$.
What do you think this red liquid is?
What does this mean about how the gram was originally defined?

LUNAR ROCKS activity sheets

ACTIVITY SHEET 7

Rock Density 8.1

Focus

To study the variation in density of different rocks and propose a theory about the differentiation of minerals in the molten stages of a planetary body.

Resources

Laboratory balance, beakers, selection of different rocks to fit in the beakers, water.

NOTE: The loan kit does not contain earth rocks. These can be bought from geological and science equipment suppliers.

Links to:
Back Down 2 Earth
http://education.down2earth.eu/
NASA's Dawn spacecraft
http://dawn.jpl.nasa.gov/

Safety notes

Eye protection should be worn when handling glassware

Using the activity

The density of rocks in your hand today depends on how they were formed. The processes of planetary differentiation that led to the sinking of dense minerals is not just a process of sinking, but also of crystallisation at various temperatures. In other words, it is complicated. This activity shows how densities vary between rock types and can be used as a starting point for discussion on how that came about. Comparing the densities of the hand-held meteorites in the kit shows how this process was not restricted to large planets.

WARNING If displacement methods are used to measure the density of the hand-held meteorites they MUST be completely dry before returning to their packaging.

8.2 Rock Density

Background Information

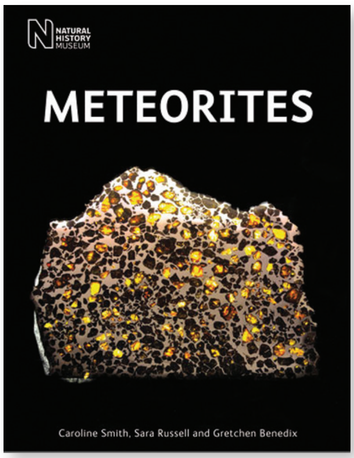
Meteorites found on Earth will generally be classified as iron, stony-iron, chondrites or achondrites.

Iron meteorites come from the interior of asteroids that have differentiated, producing an iron core. Collisions with other asteroids can cause the cores to be exposed. These contain the highest density elements and will give the highest density measurements compared to other meteorites.

http://education.down2earth.eu

Stony-iron meteorites are a mixture of stony and iron minerals. These were probably made in the intense temperatures and pressures created in the collision of large asteroids. For example, mesosiderites contain half iron and half silicate material.

Chondrites are stony meteorites that form the large majority of the meteorites found on Earth. They are called chondrites because they contain spherical objects called chondrules. Ordinary chondrites make up 90% of all chondrites. Many of them show evidence of having been heated, and they may come from asteroids that did not get hot enough to differentiate completely. They are made from silicates and some iron and iron oxide. Carbonaceous chondrites are from small undifferentiated asteroids and are mostly made from silicates, oxides and sulphides, but can contain water and organic compounds, which still remain since they have not undergone significant heating since their formation.



Achondrites are stony meteorites that do not contain chondrules. They are from the outer layers of differentiated meteorites and have melted due to thermal stress. Many have been traced back to the second most massive asteroid, Vesta, which was visited in 2011 by NASA's Dawn spacecraft. The *Meteorites* book from the Natural History Museum and the *Back Down 2 Earth*, downloadable booklet, are highly recommended reading for this activity.

Rock Density 8.3

Activity 8

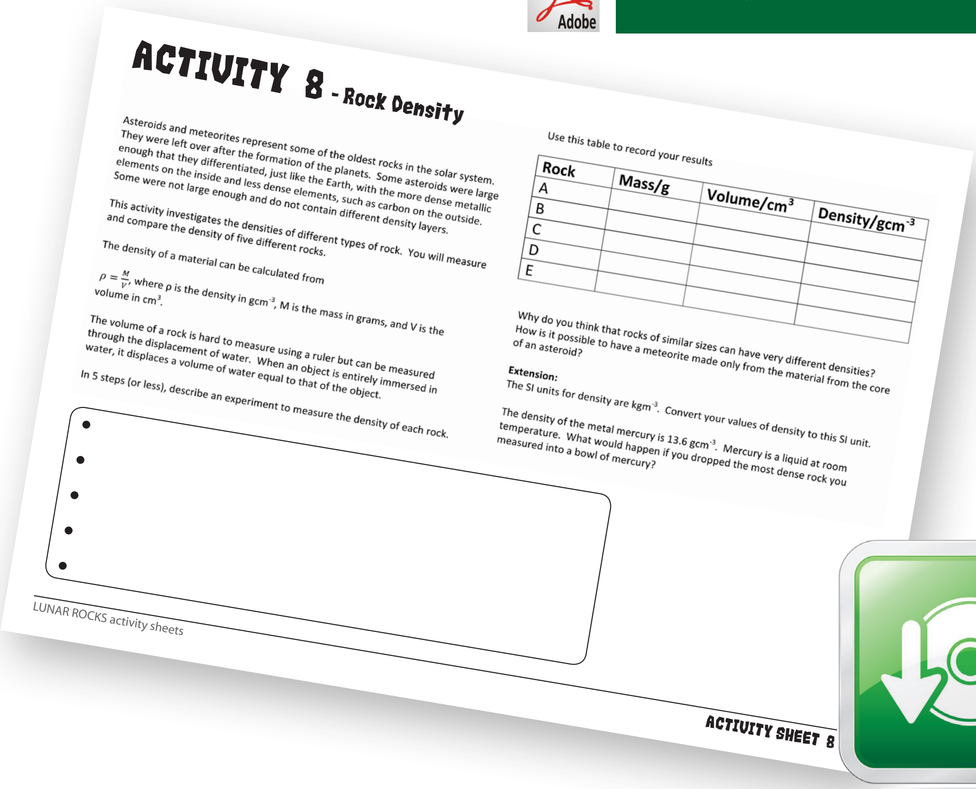
In this exercise, groups measure and compare the densities of different rock types with a view to linking this to the composition of the rock and its formation. Both Earth rock and meteorites can be used in this practical. The groups must design their own procedure to measure the density of each rock type. The steps should include:

- Weigh each rock in grams and record in the table
- Fill a beaker with water to a height at which the rock can be submerged and record the volume, V1
- Fully submerge the rock in the water and record the new volume, V2
- Take the difference between these volumes (V2 – V1) and record in the table
- Calculate the density of each rock

This exercise requires groups to think systematically about their procedure and write succinct instructions.

Groups should be encouraged to think about how the bulk (overall) density of a rock is linked to the elements that it is made from. They can then be led toward the possible origin of the rocks. In molten state heavier minerals will sink and lighter minerals will float leading to differences in composition with depth.

Activity Sheet 8.pdf



ACTIVITY 8 - Rock Density

Asteroids and meteorites represent some of the oldest rocks in the solar system. They were left over after the formation of the planets. Some asteroids were large enough that they differentiated, just like the Earth, with the more dense metallic elements on the inside and less dense elements, such as carbon on the outside. Some were not large enough and do not contain different density layers.

This activity investigates the densities of different types of rock. You will measure and compare the density of five different rocks.

The density of a material can be calculated from

$\rho = \frac{M}{V}$, where ρ is the density in gcm^{-3}, M is the mass in grams, and V is the volume in cm^3.

The volume of a rock is hard to measure using a ruler but can be measured through the displacement of water. When an object is entirely immersed in water, it displaces a volume of water equal to that of the object.

In 5 steps (or less), describe an experiment to measure the density of each rock.

-
-
-
-
-

Use this table to record your results

Rock	Mass/g	Volume/cm^3	Density/gcm^{-3}
A			
B			
C			
D			
E			

Why do you think that rocks of similar sizes can have very different densities? How is it possible to have a meteorite made only from the material from the core of an asteroid?

Extension:
The SI units for density are kgm^{-3}. Convert your values of density to this SI unit.

The density of the metal mercury is 13.6 gcm^{-3}. Mercury is a liquid at room temperature. What would happen if you dropped the most dense rock you measured into a bowl of mercury?

LUNAR ROCKS activity sheets

ACTIVITY SHEET 8

9.1 Fiery Moon

Organiser's Notes

Focus

Lunar volcanic processes and the difference in geological effects caused by low gravity, low lava viscosity and absence of atmosphere. Relative permanence of volcanic features due to lack of weathering processes.

Resources

These are listed on the Activity Sheet.

Safety notes

See the Activity Sheet.
This activity should only be carried out or supervised by a qualified science teacher.

Using the activity

This is a demo or group practical that models the process of magma intrusion. It can be related to volcanism on earth and on the Moon. Some volcanic activity creates eruptions from the surface and some remains underground. This experiment models both types.

Fiery Moon 9.2

Background Information

The lunar maria are large deposits of iron-rich basalt. They are located mostly in large impact basins, into which the lava flowed. Most maria are on the near side of the Moon, but there is currently no consensus as to why this might be. The basalt is similar to that produced in eruptions in the islands of Hawaii.

As it is on Earth today, the main heating mechanism for magma on the Moon, was through radioactive decay of isotopes of potassium and uranium deep within the lunar mantle. Heating causes the material to rise up through weak points in the crust, leading to volcanic eruptions.

Another possible mechanism to trigger lunar volcanism is called pressure release melting (or decompression) – this occurred when impact basins were formed. The removal of material from the basin causes a release in pressure in the rocks beneath. Under lower pressure, the rock can melt at a lower temperature, helping to generate magma. These impact basins are huge. When you add up all the impact basins they make up 20% of the lunar surface.

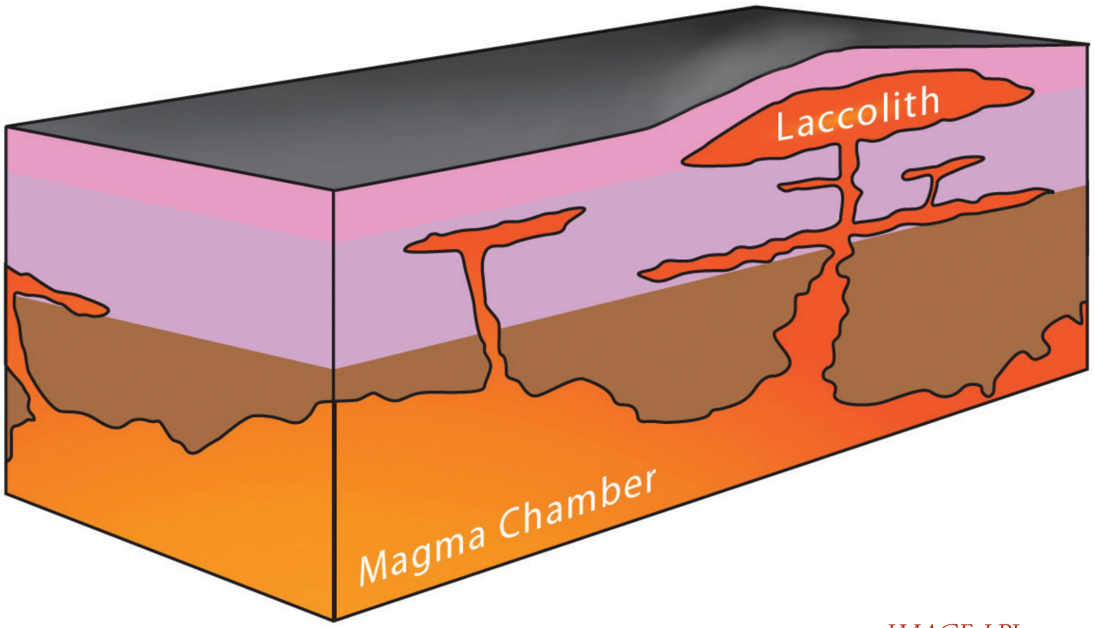


IMAGE: LPI

9.3 Fiery moon

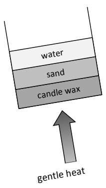
Activity 9

This experiment requires the candle wax to be melted beforehand, poured into the beakers and allowed to set. 10 cm^3 should be sufficient, per beaker.

This experiment requires the groups to think of the sand and water as different layers of a solid crust. As the wax melts, it rises through the layers of crust to reach the surface. The lower density wax (magma) rises and flows out like lava on the surface.

The wax may pass through the surface in one or two thin tubes (similar to volcanoes), above the Bunsen burner. If the heating is gentle, and stops before all the wax has reached the surface, it may be possible to see magma chambers forming in the water.

Activity Sheet 9.pdf



ACTIVITY 9 - Fiery Moon

When we look at the Moon, we can see vast dark patches across the surface. Early astronomers thought that these dark patches may be ancient seas. The Latin for sea is mare, and these areas still bear that name today. We now know that these dark areas are huge plains of basalt, created from ancient lava flows. From about 3.5 to 3 billion years ago, the Moon was not cold and still, as it is today, but was subject to intense volcanic activity.

This experiment models volcanic activity and asks you to think about the processes involved.

Materials:
- Eye protection
- 250 cm^3 beaker containing red candle wax
- Sand
- Water
- Bunsen burner
- Tripod
- Gauze
- Heat proof mat

Safety: Wear eye protection when using a Bunsen burner and when looking in to the hot beaker

Procedure:
- Cover the set candle wax with about 15 cm^3 of sand and then add 25cm^3 of water
- Warm the beaker gently over the Bunsen burner
- Watch the side of the beaker carefully.
- When the wax starts to pool on top of the water, turn off the Bunsen and continue to watch the beaker

The sand and the water in this experiment can be thought of as layers of solid crust on the Moon. The candle wax is like the magma.

Think about what you observed and answer these questions:

1. Why does the candle wax rise to the surface?
2. What does this tell you about the volcanic activity on the Moon?
3. Do your observations show how you could find cooled regions of magma beneath the crust?

Extension:

Use a map of the Moon to compare the maria (seas) to other areas on the Moon. What do you notice about the number of craters over the same area in each part of the Moon?

How can you explain the difference in appearance between the surfaces?

LUNAR ROCKS activity sheets

ACTIVITY SHEET 9

Shiny Rocks 10.1

Focus

Investigating the periodic variation in reflectance from a body rotating in space.

Resources

Light meter, (LuxMeter Pro 2 is an iPhone app that emulates a lux meter. Other light meters are available from science suppliers usually as datalogging sensors), retort stands, sheet of white paper, torch, selection of different coloured rocks, potato painted black one side and white the other.

Safety notes

Use a safe shielded light source in a stable lab bench configuration.

Using the activity

This experiment allows groups to investigate the relative albedo of rock samples. Repeated readings are used to reduce random uncertainty and demonstrate good scientific method. The ability of groups to calculate percentages is also an important skill addressed. The experiment does not measure the true albedo of the rocks, since they are measured with reference to a control value and not the luminosity of the source at that distance. However, groups can make comparisons between the percentages that they calculate and inferences about the type of material. The painted potato gives an exaggerated version of an asteroid to allow groups to measure an appreciable difference in the reflected light from the light and dark surface. The groups can rotate the potato to help them to sketch the graph. In reality, astronomers will only take snapshot readings of the reflected light and so graphs will be built up over a longer period of time than the rotational period of the asteroid.

10.2 Shiny Rocks

Background Information

Ground- and space-based telescopes can measure the size of larger asteroids and their distance from Earth. The luminosity from these objects can also be measured to calculate the percentage light reflected from the Sun, also called the albedo. Different types of asteroid will have different albedos depending on their type. Three main groups have been defined: C-type (carbonaceous), S-type (silicate) and M-type (metals). C-types make up about 75% of all asteroids in the Asteroid Belt. They are rich in carbon-based compounds and reflect very little light (less than 10%). S-types contain silicates and metals and constitute 17% of the asteroids, and are relatively bright. The M-types make up most of the rest and are also fairly bright due to their metallic surface.

Since the angle of the faces of the asteroid with respect to the Sun and Earth change, the luminosity will change over time. By detecting a periodic change in luminosity, the rotation rate of an asteroid can be determined. The light curve produced will be a sine wave – the period of rotation can be measured by the time between the peaks.

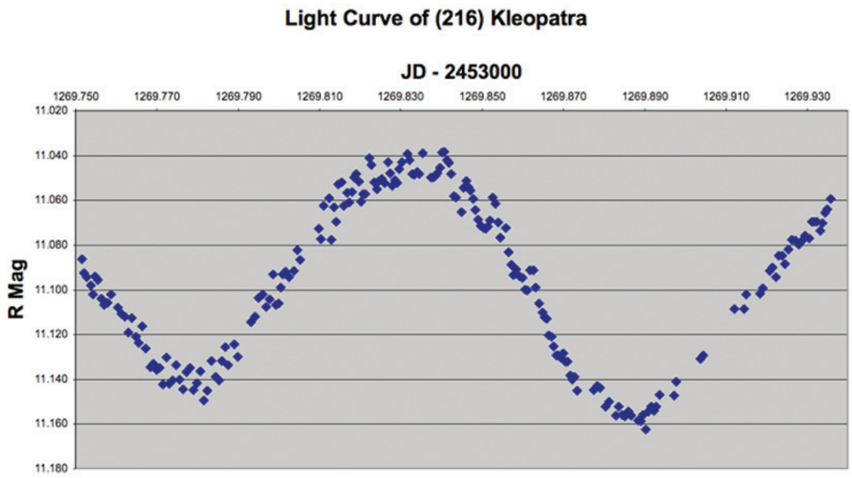


Image courtesy of Faulkes' Telescope Project/LCOGT

The observations above were taken by UK schools using the robotic Faulkes' Telescope. The timescale is in Julian days, so the entire duration of that light curve will be ~4-5 hours. The rotation period of Kleopatra is 5.4 hours, and what the curve shows is almost two peaks. It is a double-peaked rotation curve, so there is almost one full rotation with that data set.

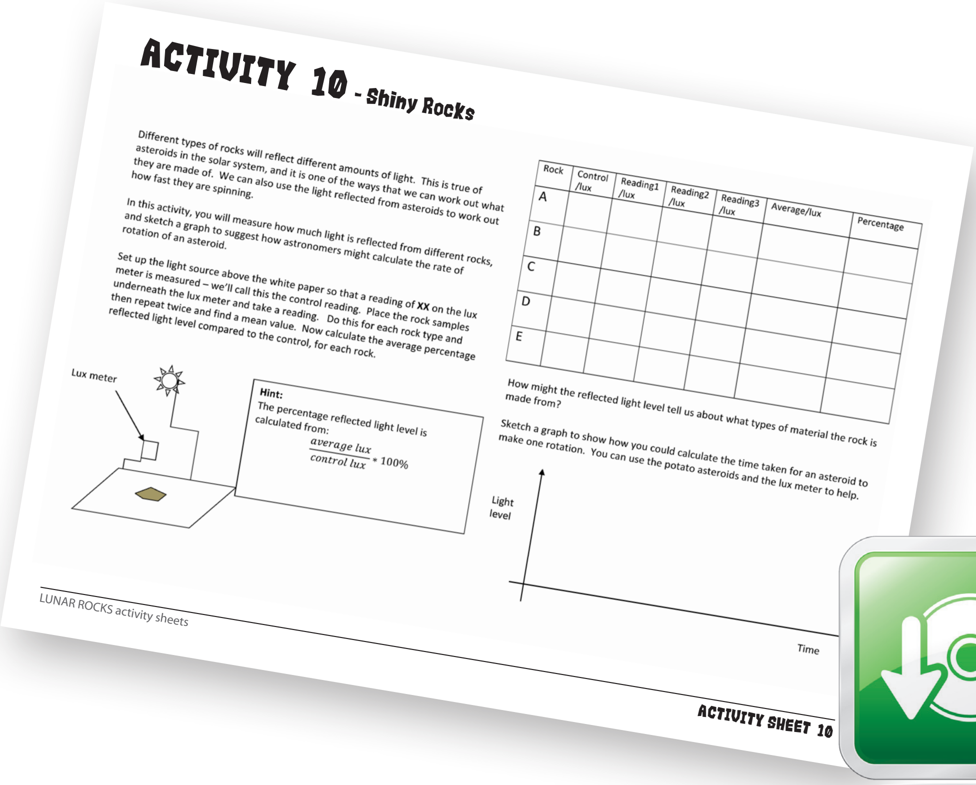
Shiny Rocks 10.3

Activity 10

This activity models the periodic variation in light reflected from rotating bodies in space such as asteroids. Showing this effect with rocks can be quite difficult, so a painted potato simulates an asteroid quite well.

Visible light albedo will tell us something about the rock type. This is clear from looking at the variation in albedo between highland and mare regions on the Moon. This activity works in the visible part of the electromagnetic spectrum. Astronomers also use radar frequencies to measure the 'radar albedo' of objects. Just as aircraft show up well on radar, so do asteroids with a high metal content. Rocky ones have a lower radar albedo. One day it may just be worth capturing metallic objects in space.

Activity Sheet 10.pdf



ACTIVITY 10 - Shiny Rocks

Different types of rocks will reflect different amounts of light. This is true of asteroids in the solar system, and it is one of the ways that we can work out what they are made of. We can also use the light reflected from asteroids to work out how fast they are spinning.

In this activity, you will measure how much light is reflected from different rocks, and sketch a graph to suggest how astronomers might calculate the rate of rotation of an asteroid.

Set up the light source above the white paper so that a reading of **XX** on the lux meter is measured – we'll call this the control reading. Place the rock samples underneath the lux meter and take a reading. Do this for each rock type and then repeat twice and find a mean value. Now calculate the average percentage reflected light level compared to the control, for each rock.

Lux meter

Hint:
The percentage reflected light level is calculated from:

$$\frac{average\ lux}{control\ lux} * 100\%$$

Rock	Control /lux	Reading1 /lux	Reading2 /lux	Reading3 /lux	Average/lux	Percentage
A						
B						
C						
D						
E						

How might the reflected light level tell us about what types of material the rock is made from?

Sketch a graph to show how you could calculate the time taken for an asteroid to make one rotation. You can use the potato asteroids and the lux meter to help.

Light level

Time

LUNAR ROCKS activity sheets

ACTIVITY SHEET 10

11.1 Dating The Moon

Organiser's Notes

Focus

Learning how crater observation and radioactive isotope measurements can be used to date rocks and how radioactive decay can be modelled using dice.

Resources

30 six-sided dice (not in the kit)

Computers running spreadsheet software

Safety notes

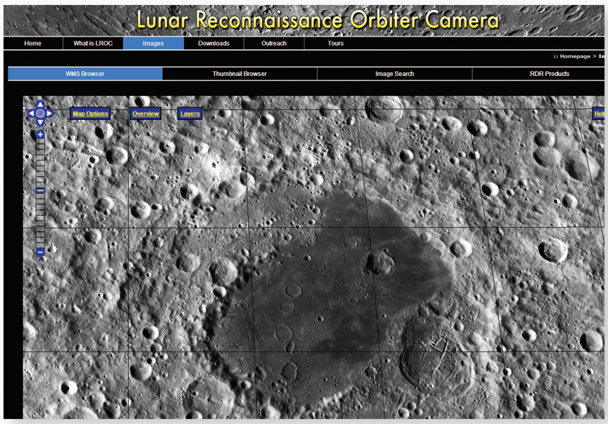
There are no safety issues with this activity.

Using the activity

This activity models radioactive decay using dice and relates this to radioisotope dating of rocks. Radioactive decay is a random process, just like the roll of a die. Each nucleus within a particular isotope will have a certain probability of decay. Each die can be thought of as a nucleus, with a 1 in 6 probability of decay to a stable isotope. Students must roll all the dice every 15 seconds and record the number of decayed nuclei. The decayed dice are removed each time. This decay is random but, in general, should show more decays at the beginning of the time period than at the end. Pooling results from the whole class shows how the random nature of radioactive decay is smoothed out to an exponential curve if the number of decaying nuclei (dice) is large enough. This should enable them to see that a larger sample will reduce the uncertainty in the measurements. They should also be able to see that the half-life is not dependent on the starting number of nuclei, only on the probability of decay per second.

Dating The Moon 11.2

Background Information



Explore the lunar surface at http://www.lroc.asu.edu/

One way of dating the Moon is by observation. We can look at a bit of the Moon's surface and see how many craters there are per unit surface area. The more craters there are, the longer the surface has been there. It is a bit like looking at a paving slab at the start of a rainstorm. The longer it has been raining the more spots you will see. After it has been raining for a while, though, some spots have been covered up by others. Eventually the paving slab is saturated and more rain does not lead to more identifiable spots. The density of craters cannot get any higher. This is called saturation. The lunar highland surface is saturated, so we do not know what the impact history was in the early part of the solar system. We know that surfaces younger than about 4 billion years are not saturated. We do not know whether before this the 'crater rain' was very heavy and just declined since the solar system was born, or whether there was a sudden storm that occurred about 4 billion years ago. Because it is hard to see where all the material could have come from if the cratering rate had just declined from 4.5 billion years ago to 4 billion years ago, many people think there was a short, intense increase in bombardment at about this time. This is called the *late heavy bombardment*.

A second way (and we need both) is radio isotope or radiometric dating. A useful isotope decay scheme for dating Moon rocks is that of potassium-40 to stable argon-40, since the half-life of potassium-40 is around 1.26 billion years and the stable daughter product, argon-40 gas, gets trapped in the rock. The half-life in the activity using the dice is around 60 seconds. Comparing this to ^{40}K decay means that each second that passes during the activity represents about 20 million years. Students need to make the link between a die and an atomic nucleus, and should be aware that only 40 grams of ^{40}K contains 6 x 10^{23} atoms. 6 x 10^{23} dice could only just fit inside a pot the size of Pluto.

This experiment introduces the idea of radioactive half-life as a guide to the age of rocks. The maths of throwing dice is not quite the same as the maths of isotope decay, but it is a good approximation.

11.3 Dating The Moon

Activity 11

For the question on the age of the rock where 1/8 of K-40 remains, encourage groups to think about half-life, 1/8 = 1/2 x 1/2 x 1/2 so 3 half-lives: 1.26+1.26+1.26 = 3.78 billion years

Extension Material

The extension material is designed for post-16 level. The equations given to the students are standard for most A-level syllabi: $t_{1/2} = \frac{ln2}{\lambda}$, and $N = N_0 e^{-\lambda t}$, where $t_{1/2}$ is the half-life (average time taken for half the nuclei to decay), λ is the decay constant or probability of decay per second, N is the number of un-decayed nuclei at time t, and N_0 is the number of un-decayed nuclei at t=0.

Solutions:

a) Using $t_{1/2} = \frac{ln2}{\lambda}$ and the value given for the decay constant

$t_{1/2}$ = ln2 x 6 x 15 = 62 seconds

b) Using $N = N_0 e^{-\lambda t}$ and taking natural logs

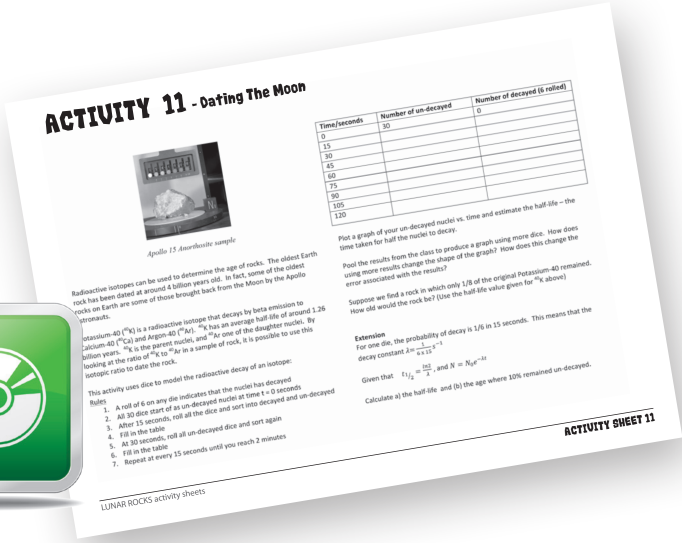
for 10% un-decayed remaining, N/N_0 = 0.1

ln 0.1 = - λt

2.3/λ = t

t = 2.3 x 6 x 15 = 207 seconds

Activity Sheet 11.pdf

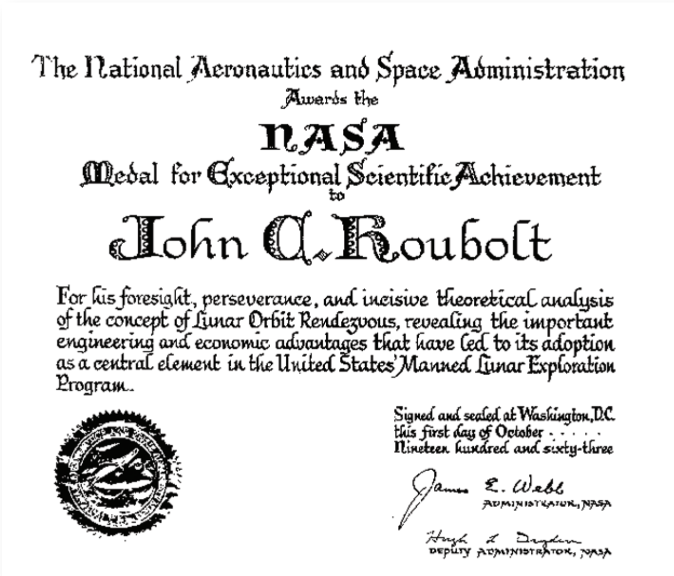


And finally......

Science takes small steps and giant leaps and there is a Santa Claus.

In preparing for this book I read the history of the Apollo programme in some detail. One person stood out in my mind and he appears on the front cover. His name is John Houbolt and he had strong views on how to get man to the Moon and home safely. He is a legendary figure because he stood up for his ideas at all costs. He was the champion of Lunar Orbit Rendezvous and that is almost certainly why the Apollo programme met its goals. I hope that this will inspire you to read about his contribution to the most outstanding scientific, mathematical, astronomical, engineering and human feat in history.
Thank you John.

Nick Swift-Editor



The National Aeronautics and Space Administration
Awards the
NASA
Medal for Exceptional Scientific Achievement
to
John C. Houbolt

For his foresight, perseverance, and incisive theoretical analysis of the concept of Lunar Orbit Rendezvous, revealing the important engineering and economic advantages that have led to its adoption as a central element in the United States' Manned Lunar Exploration Program.

Signed and sealed at Washington, D.C.
this first day of October
Nineteen hundred and sixty-three

James E. Webb
Administrator, NASA

Hugh L. Dryden
Deputy Administrator, NASA

BACK COVER IMAGE NOTES

From left to right:

The Esquel Pallasite
The Esquel pallasite, composed of gem-quality olivine crystals embedded in metal.
Pallasites are perhaps the most beautiful of all meteorites.
Credit: © The Natural History Museum, London

Slice of Canyon Diablo Meteorite
Iron meteorites, when sliced open and etched with acid, typically show a distinctive criss-cross pattern called a Widmanstätten pattern. This slice is 15cm across.
Credit: © The Natural History Museum, London

The Parnallee Ordinary Chondrite
The Parnallee ordinary chondrite, part of the Parnallee meteorite that fell in India in 1857.
Credit: © The Natural History Museum, London

STFC
Lunar Samples and Meteorites Loan Scheme

Science & Technology Facilities Council

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