Year 5 Earth and space sciences

Exploring the Solar System

Produced by the Centre for Learning Technology,
The University of Western Australia, for the SPICE program

spice
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Developed by the Centre for Learning Technology, UWA. Production team: Jan Dook, Alwyn Evans, Bob Fitzpatrick, Jenny Gull, Dan Hutton, Paul Luckas, Paul Ricketts, Kate Vyvyan, Jodie Ween and Michael Wheatley.

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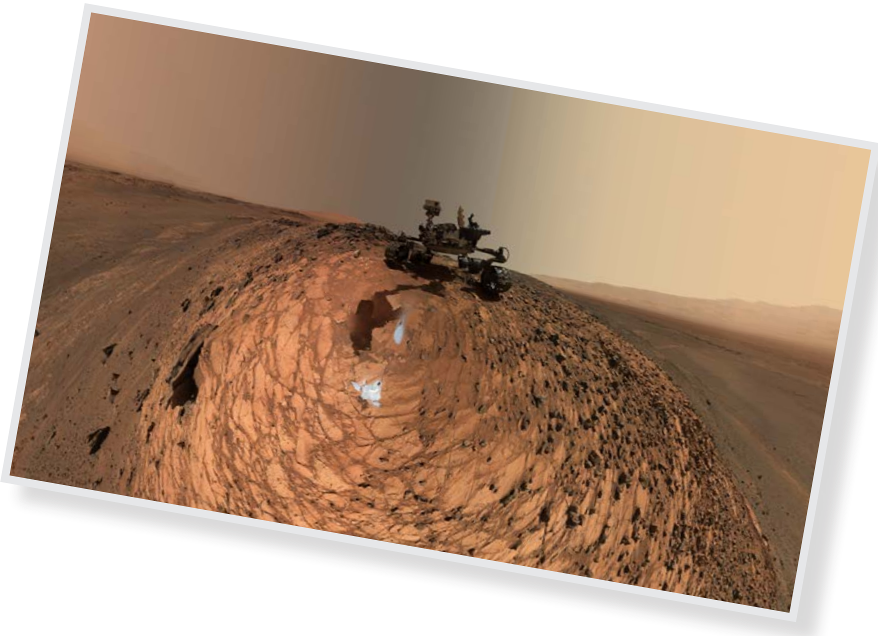
Web: spice.wa.edu.au
email: spice@uwa.edu.au
Phone: (08) 6488 3917

Centre for Learning Technology (M016)
The University of Western Australia
35 Stirling Highway
Crawley WA 6009



Curiosity low-angle self-portrait at 'Buckskin' drilling site on Mount Sharp, Mars
NASA/JPL-Caltech/MSSS

Contents: *Exploring the Solar System*

Digital resources

Digital resources for *Exploring the Solar System* are available on CD-ROM or USB. They include electronic copies of this teacher guide, worksheets and audiovisual resources (presentations, interactive model and video). Files are grouped by chapter in the folder, *digital-resources*.

Part 1: Environments for life	*Environments for life*	
Part 2: Postcards from space	*Postcards from space* *My space postcard*	
Part 3: Earth and Moon	*Earth and Moon*	
Part 4: Virtual astronomy	*Stellarium and Celestia* *Introducing Stellarium* *Introducing Celestia*	
Part 5: Surface models	*Where on Earth?* *Planet surfaces*	
Part 6: Race around the planets	*Race around the planets* (game board, game cards and playing sheet)	game board and cards also available for purchase in hardcopy
Part 7: Solar System model	*Interactive Solar System* *Planet facts* *Planet orbits*	
Part 8: Search for life	*Searching for life in the Solar System* *Extremophiles* *Jupiter's moons*	

How to use this guide

Introduction

The introduction contains general information, including how this package fits within the Australian Curriculum.

1. Environments for life

2. Postcards from space

3. Earth and Moon

4. Virtual astronomy

5. Surface models

6. Race around the planets

7. Solar System model

8. Search for life

The guide is divided into eight parts, each describing a set of related activities. You don't have to do all parts — each one stands alone.

You may wish to rearrange activities or include activities chosen from other programs.

Timings for activities are included in each part, but in general a part will take one or two lessons.

Student worksheets

Student worksheets are also available on USB, CD-ROM or download.

6. Race around the planets

- Purpose and outcomes
- Materials needed
- Activity summary

Each part follows the same structure.

It starts with the purpose and outcomes; materials you will need for activities described in this part; and a summary of activities.

- Science background

Not sure about the science? The **Science background** section gives teachers essential information to teach this lesson.

- Activity guide

The **Activity guide** contains detailed instructions on how to run activities in this part.

Background

Exploring the Solar System is a resource package that addresses the Year 5 Australian Curriculum science content for Earth and space sciences. It is designed to complement and supplement a *Primary Connections* resource, *Earth's place in space*.

It emphasises use of modelling, including accurate scale representation, to convey difficult concepts of size, in the Solar System. Modelling is also used to describe relative position and motion; physical modelling of surface features and their creation; and use of digital (software) models to represent the Solar System and beyond.

Classification is introduced informally through alternative grouping of Solar System objects.

Students are encouraged to use analogy and inference in systematic description of Solar System objects.

The package also contains engaging activities to encourage student participation and inquiry.

Learning pathway

The program is structured around a constructivist model, based on the 5-Es.

A summary of steps in the 5-E model appears below. A set of five A4 posters suitable for classroom display is available from the Centre for Learning Technology at The University of Western Australia: spice.wa.edu.au/5E

Further information about the 5-E model is available on many websites, including *Primary Connections*: www.primaryconnections.org.au/about/teaching.

STAGE	DESCRIPTION	TEACHER ROLE	STUDENT ROLE
Engage	Actively welcome students to the learning process; encourage participation and promote curiosity. Recognise prior learning and organise thinking towards learning outcomes to follow.	raise relevant questions and problems find out what is known, what is unknown and what can be learned make connections between past and present learning experiences	ask questions show curiosity show interest
Explore	Investigate new ideas through activities and research processes in collaboration with others.	provide time and space to work through problems ask questions to direct exploration act as a facilitator for investigations	ask questions gather evidence make inferences
Explain	Develop explanations from preceding experiences, allowing opportunities for the demonstration of new skills and competencies.	encourage self-generated explanations of concepts probe understanding through discussions add to explanations to develop deeper understanding	share explanations listen critically to others
Elaborate	Expand learning and skills to develop deeper and broader understanding.	provide learning opportunities for students to apply their knowledge in new situations probe understanding through guided questions encourage student-planned investigations to apply, consolidate and extend understandings	apply understanding to new contexts
Evaluate	Assess understanding to measure and celebrate success to plan for future learning.	assess acquired knowledge and skills to measure progress provide opportunities for review and reflection on learning, new understanding and skills use a variety of assessment strategies	demonstrate understanding self-evaluate

Introduction

Program summary

PART	TITLE	PURPOSE	DESCRIPTION
1	*Environments for life*	**ENGAGE**	Given a photo of an environment, students consider what life might be found there. This is related to the presence of water and light.
2	*Postcards from space*	**ENGAGE**	Students organise photos of objects and locations in the Solar System, according to their own criteria.
3	*Earth and Moon*	**EXPLORE**	Students form a model of the Earth and Moon that accurately represents their relative size and separation.
4	*Virtual astronomy*	**EXPLORE**	Teachers and students use virtual planetarium software, *Celestia* and *Stellarium*, to explore the Solar System.
5	*Surface models*	**EXPLORE**	Students create their own models, using various media, to reproduce surface features of planets in the Solar System.
6	*Race around the Solar System*	**EXPLAIN**	A board game introduces students to the arrangement of planets in the Solar System.
7	*Solar System model*	**EXPLAIN**	Starting from a representation of the Sun by a basketball, students create a scale model of the Solar System on school grounds.
8	*Search for life*	**ELABORATE**	Connections are made to the opening **Engage** activity by considering what forms of life might be found in the Solar System.

Technical requirements

The teacher guide requires Adobe Reader (version 5 or later), which is a free download from www.adobe.com. Worksheets are supplied in Microsoft Word and PDF format.

Presentations are in HTML 5 format and will run in any modern browser such as Firefox, Chrome or Safari (PDF versions are also included). Interactions and video also use HTML 5 format and support MP4 and WebM video formats.

An Internet connection is required for activities in Part 5 (*Where on Earth?*) and Part 7 (*Solar System model*).

Additional resources

Primary Connections	Year 5 package, *Earth's place in space*, available at https://primaryconnections.org.au
NASA	Website http://NASA.gov has extensive resources for the Earth and space sciences. Check options under 'NASA Audiences' for students and educators.
ESA	The European Space Agency's website, http://esa.int, has material for educators and kids.
Scitech	The Scitech planetarium has an educational program, see: http://scitech.org.au under Education and Scitech.
ICRAR	The International Centre for Radio Astronomy Research has resources for teachers. See Outreach and Education at icrar.org.
WASP	Woodside Australian Science Project has produced a collection of activities for Year 5 – Solar System. Material is available at: http://www.wasp.edu.au/mod/page/view.php?id=450

Links to Australian curriculum

SCIENCE UNDERSTANDING (YEAR 5)	PARTS
Earth and space sciences — The Earth is part of a system of planets orbiting around a star (the sun) (ACSSU078) • identifying the planets of the solar system and comparing how long they take to orbit the sun • modelling the relative size of and distance between Earth, other planets in the solar system and the sun • recognising the role of the sun as a provider of energy for the Earth	1 – 8
Biological sciences — Living things have structural features and adaptations that help them to survive in their environment (ACSSU043)	8
SCIENCE AS A HUMAN ENDEAVOUR (YEAR 5)	
Nature and development of science — Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contribution (ACSHE081) • researching how scientists were able to develop ideas about the solar system through the gathering of evidence through space exploration	5
SCIENCE INQUIRY SKILLS (YEAR 5)	
Questioning and predicting With guidance, pose clarifying questions and make predictions about scientific investigations (ACSIS231)	5
Planning and conducting Identify, plan and apply the elements of scientific investigations to answer questions and solve problems using equipment and materials safely and identifying potential risks (ACSIS086) Decide variables to be changed and measured in fair tests, and observe measure and record data with accuracy using digital technologies as appropriate (ACSIS087)	5
Processing and analyzing data and information Construct and use a range of representations, including tables and graphs, to represent and describe observations, patterns or relationships in data using digital technologies as appropriate (ACSIS090) Compare data with predictions and use as evidence in developing explanations (ACSIS218)	2, 4, 5, 7, 8
Evaluating Reflect on and suggest improvements to scientific investigations (ACSIS091)	5
Communicating Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal texts (ACSIS093)	5, 8
MATHEMATICS (Year 5)	
Number and place value Use estimation and rounding to check the reasonableness of answers to calculations (ACMNA099)	3, 7
Using units of measurement Choose appropriate units of measurement for length, area, volume, capacity and mass (ACMMG108)	3, 7
Shape Connect three-dimensional objects with their nets and other two-dimensional representations (ACMMG111)	5
Data representation and interpretation Construct displays, including column graphs, dot plots and tables, appropriate for data type, with and without the use of digital technologies (ACMSP119) Describe and interpret different data sets in context (ACMSP120)	7

SPICE and *Primary Connections*

The following table shows how this SPICE resource, *Exploring the Solar System*, may be used in conjunction with the *Primary Connections* package, *Earth's place in space*.

PURPOSE	SPICE *Exploring the Solar System*	PRIMARY CONNECTIONS *Earth's place in space*
ENGAGE	*Part 1: Environments for life* →	*Lesson 1: Model arguments* • Eratosthenes epiphany • Centred on the Sun
	Part 2: Postcards from space ←	
EXPLORE	*Part 3: Earth and Moon* →	*Lesson 2: Rising and setting*
	Part 4: Virtual astronomy ← →	*Lesson 3: Going in circles*
EXPLAIN	*Part 5: Surface models* ←	*Lesson 4: Galvanising Galileo*
	Part 6: Race around the planets	
ELABORATE		*Lesson 5: Chasing constellations*
EXPLAIN	*Part 7: Solar System model*	
EVALUATE		*Lesson 6: Solar System scientists* • Dealing with data • Size matters *Lesson 7: Sunning it up*
ELABORATE	*Part 8: Search for life*	

Follow-up activities

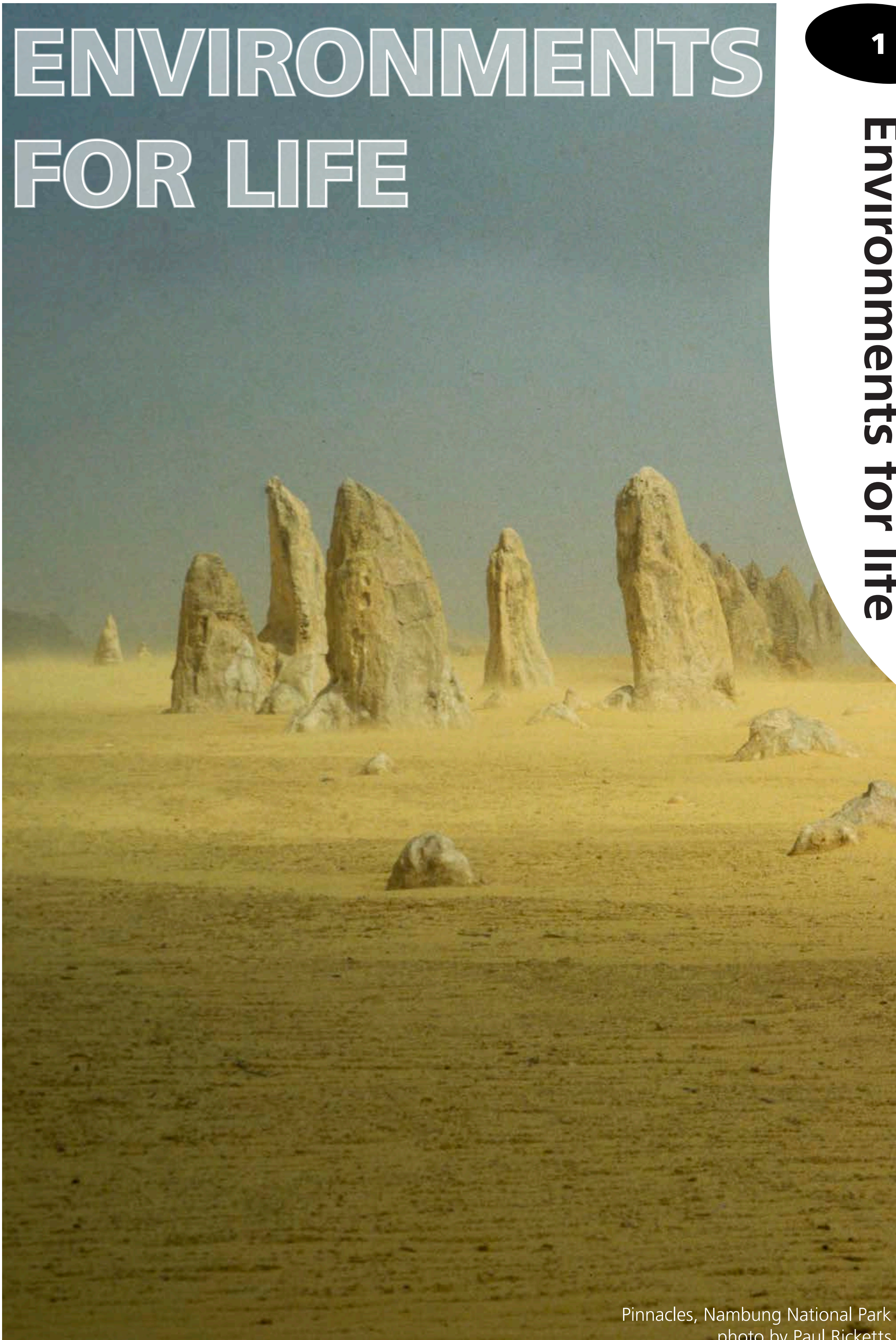
Interested students may be encouraged to pursue further study of the Solar System by researching any of the following topics.

- Current NASA and ESA missions: at time of writing, at least four missions are actively adding to our body of knowledge of the Solar System: *Cassini-Huygens* (launched by NASA in 1997 and still exploring the moons of Saturn); *Rosetta* (ESA's mission to study comet 67P/ Churyumov–Gerasimenko); *New Horizons* (NASA's mission to Pluto and the Kuiper belt); and *Dawn* (NASA's mission to minor planet Vesta and dwarf planet Ceres). At any time a wide range of missions will be current.
- Manned mission to Mars: *Mars One* is one of many missions to Mars currently in the planning stage, although there are significant hurdles to overcome.
- The search for life: *Breakthrough Listen* is a ten-year initiative to search for intelligent extraterrestrial life in the Universe, announced in 2015 with funding of US$100 000 000.

ENVIRONMENTS FOR LIFE

1

Environments for life



Pinnacles, Nambung National Park
photo by Paul Ricketts

Purpose

To **Engage** students in thinking about Earth, and what makes it unique.

Outcomes

Students understand that:

- there are many different environments on Earth;
- living things occupy a wide range of environments;
- some environments are more suited for life than others; and
- Mars has conditions too extreme to support life, as far as we know.

Materials needed

NAME	DESCRIPTION	LOCATION
Environments for life	This presentation contains images of different environments. It may be projected onto a whiteboard or displayed on a large screen.	digital-resources/ 1-exploring-the-solar-system/

Activity summary

ACTIVITY		POSSIBLE STRATEGY	SUGGESTED TIME
1.1	**Life all around us** Students consider the potential for life in different environments.	whole class	20 min
1.2	**Which is the odd one out?** How does Mars differ from Earth?	whole class	10 min

Science background

Earth is sometimes described as being in the 'Goldilocks zone'. This means Earth is close enough to the Sun that water isn't permanently frozen (as ice), or boiled away (as steam). Nevertheless many different environments are found on Earth: from the frozen poles to arid deserts, deep oceans and densely-populated cities.

Physical measurements may be used to describe an environment. Common measurements include: mean temperatures (min and max); annual rainfall; and hours of sunlight. The same measurements can be used with other planets in the Solar System, with the addition of less familiar measurements such as: composition and density of atmosphere; strength of gravity; or number of days in a year.

In general, a greater abundance and diversity of life is found in environments with more moderate conditions. However, life on Earth has adapted and evolved to meet challenges found in even extreme environments. Microorganisms are particularly widespread.

In this activity students make a subjective judgment of the amount of life found in selected environments, based on images of these environments. To structure their reasoning students are first asked to consider the amount of sunlight and water in each environment.

As far as we know water, in its liquid form, is essential for life. Biochemical processes that take place in cells require water to transport molecules and for cell reactions to occur. Organisms that survive in conditions of extreme aridity (dryness) must take steps to conserve this precious resource. Examples include thick-skinned leaves of desert plants, animals that shelter from the heat of the Sun, and organisms that slow down life processes in order to survive until the next rains arrive.

Sunlight is also essential for virtually all life. Energy in sunlight is converted into food by plants through the process of photosynthesis. Organisms that can't photosynthesise or don't have access to sunlight, perhaps because they live underground or in the deep ocean, get their energy from plants or animals that already contain this stored energy. Food chains and food webs describe pathways by which energy flows from producers (plants) to consumers (animals).

Extremophiles

A few organisms have evolved to survive in the most extreme environments. These organisms, known as extremophiles, generally have highly unusual and specialised biochemistry. Home for extremophiles might be three kilometres underground, where it's hot, dark and dry; in the boiling waters of a hot spring; or in acid as strong as the inside of a car battery.

Tardigrades, also known as waterbears, are perhaps the ultimate survivors. They can handle the vacuum of space, boiling water, temperatures close to absolute zero (-273°C), high radiation doses and ten years without food or water!

Extremophiles feature in part 8 of this resource, *Search for life*.

Figure 1.1 waterbear (Tardigrade) from the drainage of a hot spring in Lassen County, California (average length: 0.5 mm)
Darron Birgenheier. CC-BY-2.0

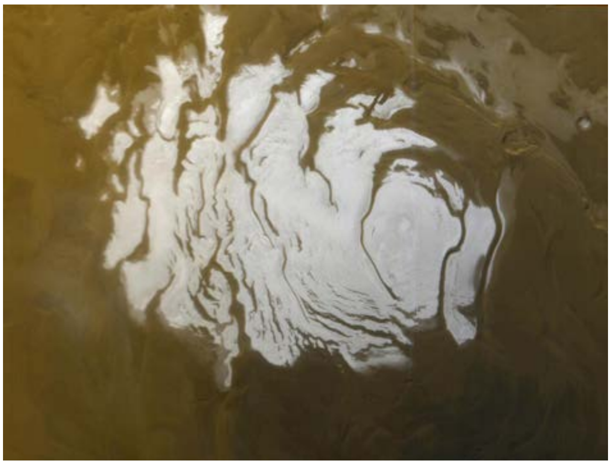


Figure 1.2 south polar cap on Mars in midsummer
NASA / Mars Global Surveyor

Extraterrestrial life

Environments pictured in this activity include one 'ring-in'. At first sight environment **G** looks like a typical desert. Students might expect to find lizards, insects and ground-hugging plants in such an environment. Environment meters give some clues: sunlight is a little lower than expected; there's little water and no life; and the sky is cloudless but grey. This is because the environment pictured is Martian, not terrestrial. It was captured by a Mars rover, *Curiosity*, in 2014. Conditions on Mars today are believed to be too extreme for life.

Table 1.1 Conditions on Mars today

atmosphere	effectively none
temperature	-50 °C This is about the same as the mean annual temperature at the South Pole on Earth.
radiation	high due to lack of protecting atmosphere Students may be familiar with the importamce of the ozone layer in protecting us from damaging UV radiation, but different layers of Earth's atmosphere protect us from a wide range of other types of damaging radiation.
water	Some water is present as ice in the polar caps; large amounts of ice occur below the surface in other areas.

Conditions on Mars may have been more temperate in the past, as there are signs of features formed by flowing water. For this reason several missions to Mars have looked for evidence of past and present life, so far unsuccessfully.

Not all of Mars looks like a desert: Figure 1.2 shows the Mars South polar cap during midsummer. Unlike Earth's polar caps it consists of water ice with a coating of frozen carbon dioxide (dry ice).

Activity guide

Links to *Primary Connections*

The activities described below are intended to introduce the Earth and space sciences section of the Year 5 Australian Curriculum. They may also be used to introduce the *Primary Connections* Year 5 resource, *Earth's place in space*.

Activity 1.1 Life all around us

Introduce this activity by showing the presentation, *Environments for life*, to the class. Explain that this presentation contains pictures of seven different environments. At this stage do not reveal where these environments are located, or that one of them is not on Earth.

QUESTION: What is an environment?

Ask the class (or individuals) to suggest how much sunlight; water; and life there might be in each environment. Consider the range of life that occurs there: plants, animals, microorganisms …

QUESTION: Why are water and sunlight important?

Each environment image is followed by a second image that overlays a measure of the amount of sunlight, water and life. Environments portrayed are listed in Table 1.2.

Activity 1.2 Which is the odd one out?

Show the presentation slide with all environments and brainstorm with class which environment is the odd one out. Lead them to think about what's different or unexpected about environment G. Sunlight is obviously present; there's little water (but it's desert-like, so that might be reasonable); but the complete absence of life is surprising.

Add the fact that this environment has no air. Does that explain why there's no life? Reveal that this image was taken on Mars.

QUESTION: What is Mars? Where is Mars?

QUESTION: How was this picture taken?

QUESTION: Is there any life on Mars?

Show the final image in *Environments for life*, which shows a Mars rover and the location where this image was taken. Record and define new words as they are used: eg terrestrial, planet, Mars, Martian…

About a hundred years ago people generally believed that there was life on Mars, maybe even intelligent civilisations. Nowadays we know there's no intelligent life on Mars, but several probes have been sent to look for evidence of past or present microscopic life. Nothing has been discovered so far, but it remains a topic of scientific investigation.

Table 1.2 Environments in presentation, *Environments for life*

ENVIRONMENT		CONDITIONS	NOTES
A	forest	high sunlight moderate water high life reading	Southwest Western Australia is a biodiversity hotspot. Not only is life abundant, there's also great variety of species. Organisms found in the forest include trees and other plants, insects, animals, birds and fungi.
B	urban	moderate sunlight moderate water high life reading	Although this is not a 'natural' environment life reading is high: not just due to humans. Animals live alongside people (e g cockroaches, rats and pigeons). We have introduced pets. Although this image was shot at night, without sunlight, the environment has plenty of daytime light. Artificial light sources provide light indoors and at night.
C	coastal	high sunlight high water high life reading	There's plenty of life here, on the border of two ecosystems (land and marine). Seabirds, crabs, shellfish, fish, dune plants and seagrass might all occur.
D	marine	low sunlight high water high life reading	There are many different environments in the ocean: from shallow marine to deep ocean. Organisms of every scale, from microscopic phytoplankton and zooplankton to giant whales, can be found.
E	polar	high sunlight low water low life reading	Although there's plenty of water here it's mostly frozen as ice, which makes this a difficult environment for life. Some microorganisms form coloured patches on snow, while a richer array of marine-based life is found on the edge of the continent.
F	cave	no sunlight high water low life reading	There's not much life in an underground cave, but some invertebrates have adapted to life in total darkness. These creatures depend on material being brought into the cave, perhaps through underground streams, for food.
G	Mars	high sunlight no water no life	See **Activity 1.2** notes for discussion of this environment.

POSTCARDS FROM SPACE

Outburst in action on comet 67P/ Churyumov–Gerasimenko
© ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

Purpose

To **Engage** students in space exploration and what makes up the Solar System.

Outcomes

Students:

- observe, describe, compare and group objects in the Solar System;
- identify questions they have about objects in the Solar System; and
- become familiar with what makes up the Solar System.

Materials needed

NAME	DESCRIPTION	LOCATION
Postcards from space	25 postcards of different space objects in the Solar System	digital-resources/ 2-postcards-from-space/ printed sets are available from http://spice.wa.edu.au
My space postcard	worksheet for use with the postcards	digital-resources/ 2-postcards-from-space/

Activity summary

ACTIVITY		POSSIBLE STRATEGY	SUGGESTED TIME
2.1	**What is found in the Solar System?** class discussion about objects that make up the Solar System	whole class	10 min
2.2	**Postcards from space** Students examine their 'postcard from space'.	individuals	30 min
2.3	**Grouping space objects** Class explores various ways of grouping space objects pictured on postcards.	whole class	10 – 30 min
2.4	**Display** class display of postcards and students' findings	teacher	30 min

Science background

What is the Solar System?

The Solar System consists of the Sun (Latin name, Sol, hence Solar System) and all celestial objects gravitationally bound to it. That is, the Sun and all objects orbiting it. Some objects directly orbit the Sun (planets, comets, asteroids); while others indirectly orbit the Sun by orbiting another body (moons).

The Solar System is one example of a planetary system (a system of planets orbiting a star, in this case, Sol or the Sun). Over 1000 planetary systems have been detected in our galaxy, the Milky Way, but there are many, many more, perhaps as many as a billion.

Table 2.1 Objects in the Solar System

Sun	The Sun is a fairly average star that's about 4.5 billion years old. It is the major component of the Solar System, accounting for almost 99.9% of the Solar System's total mass.
planets	The eight planets in the Solar System include four inner planets composed of rock and iron (Mercury, Venus, Earth and Mars); two gas giants (Jupiter and Saturn) made principally of hydrogen and helium; and two ice giants (Uranus and Neptune) made of water, ammonia and methane.
asteroid	Asteroids are bodies that orbit the Sun. They are not comets, but are too small to be considered planets or dwarf planets. Nowadays astronomers generally call them minor planets rather than asteroids.
asteroid belt	The asteroid belt occurs between Mars and Jupiter. This material never formed a planet, probably due to gravitational influence from Jupiter. Asteroids vary in size from almost 1000 km in diameter (the dwarf planet Ceres) to microscopic grains of dust. Asteroids may be displaced into new orbits. If they collide with Earth's atmosphere they become a meteor or 'shooting star'. Meteors that reach Earth's surface without completely burning up are called meteorites.
Kuiper belt	The Kuiper belt (rhymes with 'hyper') lies beyond Neptune. Like the asteroid belt this contains a vast collection of objects. It includes three dwarf planets (Pluto, Haumea, and Makemake). Most objects in the Kuiper belt are made of ices (water, ammonia and methane).
moons	Six planets, several dwarf planets and many minor planets are orbited by natural satellites known as moons. There are 173 currently known moons in the Solar System. Mercury and Venus are the only planets that don't have moons. Earth's moon is called the Moon.
dwarf planets	Dwarf planets are large enough for their own gravity to shape them into spheres, but not large enough to clear other objects from their orbit. The International Astronomical Union currently recognizes five dwarf planets: Ceres in the asteroid belt; Pluto, Haumea, and Makemake in the Kuiper belt; and Eris in an eccentric orbit beyond Pluto. Until recently Eris was believed to be the largest of the five, but recent discoveries have shown that Pluto is slightly larger, although Eris has greater mass.
minor planets	This term is used for anything that isn't a planet or a comet. It includes dwarf planets and asteroids.
comets	Comets are icy bodies that generate an atmosphere as they pass close to the Sun. This is visible as a comet's tail. The distinction between asteroids and comets is rather vague.

Of course, despite all the objects listed above, the Solar System is mostly empty space. The space between planets is a near vacuum, although it does contain streams of radiation, charged and neutral particles emitted by the Sun.

In 1946 a V-2 rocket first photographed Earth from space. Initially the former Soviet Union and USA were the only space explorers but now many countries, including Japan, India, Germany, Canada and the European Union, are involved in Solar System exploration, often through international collaboration. Space telescopes such as Hubble (1990) and James Webb (scheduled for launch in 2018) send back detailed images of the Solar System and beyond. As these telescopes orbit above Earth's atmosphere the images they send back are clear and undistorted by the atmosphere. Stars twinkling is an example of atmospheric distortion that affects ground-based telescopes.

Long running missions such as *New Horizons*, launched in 2006, only reached its targets of Pluto and its moons in 2015. *Voyager 1*, launched in 1977 to study the outer Solar System, is still returning data to Earth.

Images on the postcards (with the exception of the spacecraft, *Juno*, which is an artist's impression) are real photographs. Some images are composites or have used special equipment or digital processing, but all are the result of scientists and engineers sending spacecraft into the Solar System.

Table 2.2 Selected space missions

DATE	MISSION	TARGET	COUNTRY
1946	V-2 rocket	Earth	USA
1957	Sputnik	Earth orbit	Soviet Union
1959 – 1976	Luna 1 – 24	Moon	Soviet Union
1959 – 1973	Pioneer 4 – 11	Moon, Jupiter, Saturn, space weather	USA
1962 – 1973	Mariner 2 – 10	Venus and Mercury	USA
1965 – 1983	Venera 3 – 16	Venus	Soviet Union
1975	Viking 1 and 2	Mars	USA
1977	Voyager 1 and 2	Jupiter, Saturn, Uranus, Neptune	USA
1989	Galileo	Venus, asteroid belt and Jupiter	USA
1995	SOHO	Sun	USA and European Union
1997	Cassini-Huygens	Saturn	USA, European Union, Italy
2003	Mars Exploration Rovers	Mars	USA
2004	MESSENGER	Mercury	USA
2004 – 2015	Rosetta	comet 67P/Churyumov–Gerasimenko	European Union
2006 –	New Horizons (LORRI is the imaging instrument)	asteroid 132524 APL, Jupiter, Pluto	NASA

Activity guide

Links to *Primary Connections*

These activities may be used as a stand-alone Engage with the *Primary Connections* resource, *Earth's place in space*. They may also act as a useful introduction to **Lesson 6: Solar System scientists**.

Preparation

Make copies of the worksheet, *My space postcard* (one per student). Print out (and laminate) as many sets as required of the postcards.

Activity 2.1 What is found in the Solar System?

whole class

Make a list of what the class thinks they would find in the Solar System. Draw up a definition of what the Solar System is, based on what students already know.

- The Solar System includes the Sun and everything that goes around it. By some definitions this includes man-made objects, such as the International Space Station. Some space objects, such as moons, orbit planets. As planets orbit the Sun, moons also go around the Sun, indirectly.
- The Sun is the only star in the Solar System. Other stars visible in the night sky lie outside the Solar System.

Activity 2.2 Postcards from space

whole class, individually and in groups

Distribute postcards so each student has at least one.

Postcards contain images taken from space by spacecraft or telescopes sent to find out more about the Solar System. A message on the back of each card is written as if from the spacecraft or astronaut. The aim is for students to make observations, and possibly deductions, about what they can see in their image. Encourage students to record any questions that come to mind. Postcards include all Solar System planets, examples of moons, dwarf planets, asteroids, a comet and spacecraft.

A set of questions for students to answer, using the postcards, is included on the worksheet. Students may complete worksheets individually or in small groups. The worksheet asks students to:

- make observations about their image, including drawing a representation and using labels;
- make comparisons with things they know (e g 'This looks like a river.');
- make deductions about what the image shows (e g 'This moon has been hit by other space objects.'); and
- record questions they may have (e g 'Why does this planet have rings around it?').

With the class as a whole, ask students one at a time, or in their small groups, to present their postcard and what they observed, deduced, inferred and asked.

Collect common observations and questions to make a poster. Add unfamiliar words to a word wall for this project.

Discuss with the class what objects on the postcards are: planets, moons, satellites, asteroids and other Solar System bodies. Complete or update list of what is found in the Solar System, started in **Activity 2.1**.

Activity 2.3 Grouping space objects

Using their postcards ask students to sort Solar System objects into groups. There are several ways to go about this. You could do the exercise more than once using different approaches.

1. Do this as a whole class using whiteboard and/ or stations placed around the class. The class can agree on general groups, then individually decide where each postcard should go.
2. Alternatively each student can move around the room with their postcard (you might need a bit of space for this) to make groups with postcards that they think fit together.
3. If you have enough sets of postcards small groups of students could sort their postcards, through discussion with each other. Each group reports back to the whole class how they have grouped their cards. Groups may challenge each other on their placement of cards, leading to further discussion and practice of argumentation skills.

This isn't an activity with wrong or right answers. It's about revealing what students already know about the Solar System and stimulating peer discussion. It encourages students to use their own observations and deductions to make decisions. Suggestions for grouping are presented in Tables 2.3 – 2.6.

To conclude the activity, revisit the definition of what the Solar System is and modify if necessary.

Activity 2.4 Display

Display a selection of students' worksheets with some postcards and/or reproduce their questions onto a poster for display and future reference.

Alternative ways of presenting a summary, such as mind maps or Venn diagrams could be used.

Classes may also add to the postcard collection by making their own.

Table 2.3 Grouping Solar System objects by surface appearance

GROUP POSTCARDS BY SURFACE APPEARANCE OF OBJECT			
ROCKY	GASEOUS	MAN-MADE SPACECRAFT	MIXTURE rock, gas, liquid
Earth, Mars, Venus and Mercury (the rocky planets) dwarf planets, moons, asteroids *Comet appears rocky, but is made of ices.*	Sun Gas and ice giant planets (Jupiter, Saturn, Neptune, Uranus) – but this is not obvious from images. *Note: Venus appears gaseous because of its atmosphere, but it's actually rocky.*	ISS, Hubble, Juno	Earth – rocky, atmosphere and liquid water. *Note: Patterns on Io may be confusing (it's actually rocky).* *What might Saturn's rings be made of?*

This grouping raises the question of where Earth fits. It's classified as a rocky planet, but its combination of gaseous atmosphere, liquid oceans and rocky land make it unusual. It provides a starting point for considering how Earth is unique in the Solar System as an environment for life. Students may see 'oceans' on other planets, but only on Earth do they contain liquid water.

Students may put Venus into the gaseous surface group because of its appearance, but the inset shows it is actually rocky. It is difficult to tell what sort of surface Pluto and Io have due to their smooth, patterned appearance. Scientists believe Pluto is made of ice and rock, and Io is highly volcanically active.

Table 2.4 Grouping Solar System objects by shape

GROUP POSTCARDS BY SHAPE		
round or spherical	irregularly shaped	man-made
Ceres, Pluto, Europa, Earth, Moon, Jupiter, Mars, Charon, Neptune, Saturn, Sun, Uranus, Venus, Io, Mercury Tethys? Saturn's rings? Note: This includes all planets, dwarf planets and some moons.	Vesta, Hyperion, Phobos, Ida comet 67P Notes: Tethys has a big dent in it. This includes an asteroid, comet and some moons.	ISS, Hubble, Juno

This grouping by shape may raise questions as to why space objects are often spherical. Planets are approximately spherical because gravity pulled everything towards the centre as they formed. Smaller objects have smaller mass with less gravity, or may have been fragmented in collisions.

Table 2.5 Grouping Solar System objects by relatedness

EARTH	JUPITER	SATURN	MARS	PLUTO	ASTEROID BELT	UNRELATED
Moon, ISS, Hubble	Juno, Europa, Io	Tethys, Hyperion, rings	Phobos	Charon	Ceres, Vesta, Ida	Sun, Mercury, Venus, Uranus, Neptune, 67P

Students may choose to group into related objects. This works well when students move about the classroom looking for postcards to group. The activity can be repeated several times by shuffling up the cards and re-distributing them.

Of course all objects are 'related' to the Sun because all objects in the Solar System go round the Sun, one way or another. The group that may cause discussion is the 'left overs': those with no partner. In this set of postcards there are no moons or spacecraft to go with Neptune or Uranus, although both have moons and rings and been visited by spacecraft.

Comets have very elliptical orbits so at times they are a long way from the Sun and at others close. They are unusual in this characteristic. Mercury and Venus don't have moons although they have been visited by spacecraft.

In order to understand how the Solar System is organised the following grouping is useful.

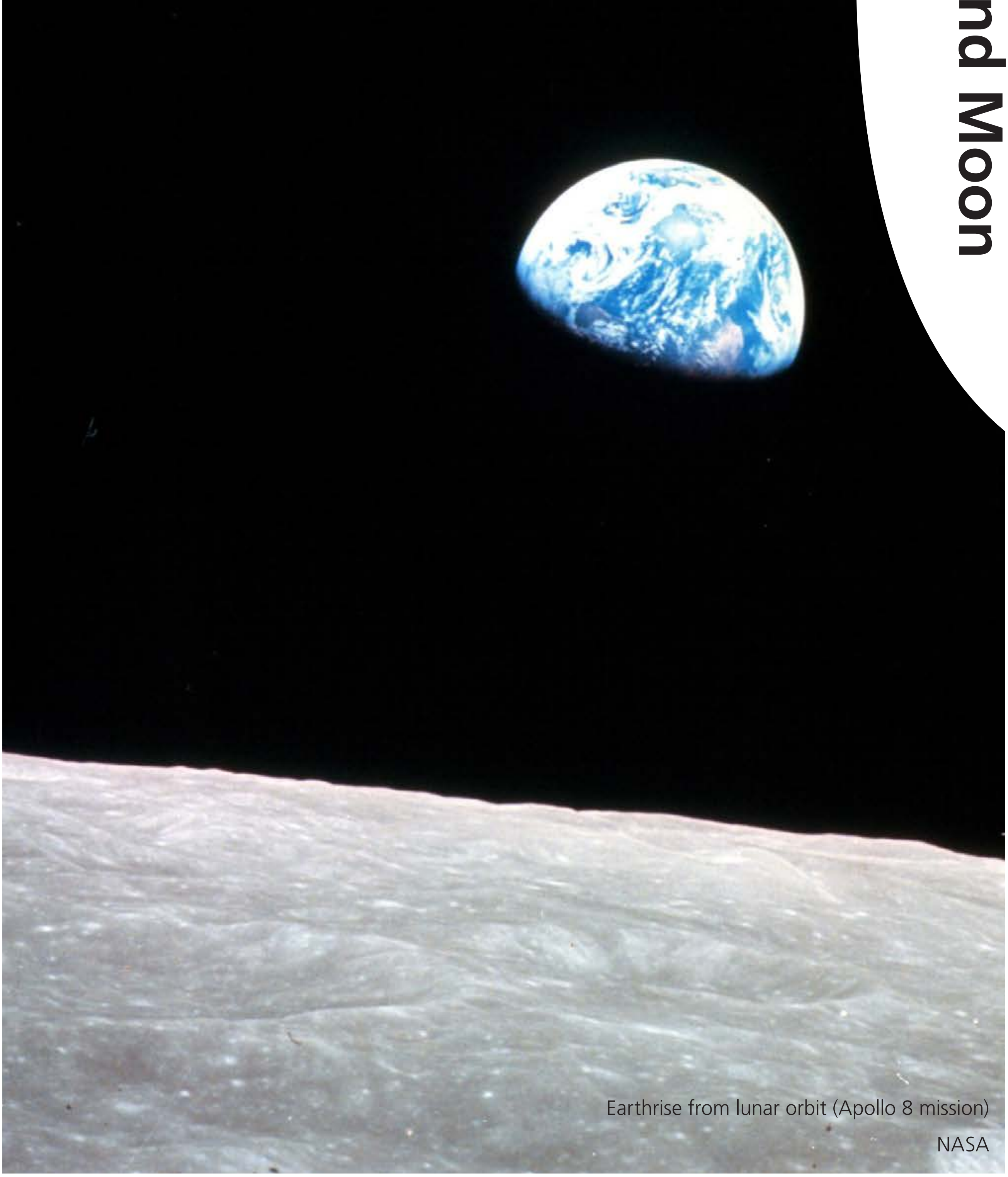
Table 2.6 Grouping Solar System objects by orbit

OBJECTS THAT ORBIT THE SUN	OBJECTS THAT ORBIT OBJECTS THAT ORBIT THE SUN
Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune (planets) Ceres and Pluto (dwarf planets) Ida and Vesta (asteroids) 67P/Churyumov-Gerasimenko (comet)	ISS, Hubble and Moon (orbit Earth) Europa, Io (moons) and Juno (spacecraft) orbit Jupiter Tethys, Hyperion and rings orbit Saturn Phobos orbits Mars Charon orbits Pluto

EARTH AND MOON

3

Earth and Moon



Earthrise from lunar orbit (Apollo 8 mission)
NASA

Purpose

Students **Explore** the size and scale of objects in the Solar System, focusing on Earth and the Moon.

Outcomes

Students:

- understand the principle behind a scale model;
- represent relative sizes of Earth and the Moon; and
- appreciate challenges involved in sending astronauts to the Moon.

Materials needed

NAME	DESCRIPTION	LOCATION
Earth globe	A globe of 25 cm diameter is ideal, but larger or smaller globes may be used.	Chart and Map shop in Fremantle has suitable inflatable globes.
balls	a collection of about 10 balls that vary in size from marble to basketball	school resources
Looking at the Moon	This presentation contains images of the Moon to promote class discussion. It may be projected onto a whiteboard or displayed on a large screen.	digital-resources/ 3-earth-and-moon/

Activity summary

	ACTIVITY	POSSIBLE STRATEGY	SUGGESTED TIME
3.1	**Scale model** What's meant by a scale model?	class discussion	5 min
3.2	**How big is the Moon?** The relative size of Earth and Moon are established.	whole class activity	10 min
3.3	**How far away is the Moon?** A model represents Earth and Moon with approriate size and separation.	whole class activity	10 min
3.4	**Looking at the Moon** A presentation shows features of the Moon and its exploration.	whole class introduction This may be followed by individual activities.	10 min

Science background

The Moon is Earth's only natural satellite. That means it's the only natural object that orbits Earth.

Galileo is generaly credited as the first person to point a telescope (invented in the Netherlands in 1608) towards the sky. In 1610 Galileo discovered that Jupiter also has natural satellites, not visible to the naked eye. Subsequent exploration has shown the Solar System contains many moons (173 at last count) but only one Moon.

Etymology

The name, Moon, comes from the old English word, mona. The same word gave rise to Monday (Moon's day), and also the word month, which is the period the Moon takes to make a complete orbit of Earth.

The Romans called it Luna, which we still use in phrases such as 'lunar exploration'. The Greek goddess of the Moon was Selene.

Origin of the Moon

Studies of rocks brought back from the Moon show many chemical similarities with those on Earth, however water and other volatile compounds are missing. There's also much less iron in the Moon as a whole, which doesn't have a metallic core like Earth's. The density of the Moon is about 60% that of Earth.

The most widely accepted theory for how the Moon formed is that a planet the size of Mars crashed into Earth in the early Solar System. Molten iron in the core of the colliding planet sank into the Earth, whilst a large amount of rocky mantle material from both bodies was ejected into orbit around Earth. Eventually this material coalesced to form the Moon.

Figure 3.1 Artist's depiction of collision between two planetary bodies. Such a collision may have led to the creation of the Moon.
NASA/JPL-Caltech

Features of the Moon

The Moon rotates once as it orbits Earth so we always see the same face pointed towards us. It wasn't until the first spacecraft orbited the Moon that we got to see what the other side (the 'far side') looked like. Surprisingly, the two sides appear quite different. The familiar dark areas (that make up the 'man in the Moon') are much less abundant on the far side.

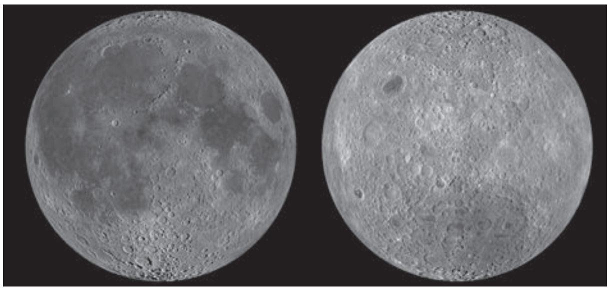


Figure 3.2 Near (left) and far (right) sides of the Moon.
NASA

The dark areas on the Moon, known as maria (Latin for sea), are younger rocks. They were formed when molten lava flowed from deep underground to fill massive crater sites. Because these rocks are younger they contain fewer impact craters.

The light areas are known as the lunar highlands. These older rocks are more heavily cratered.

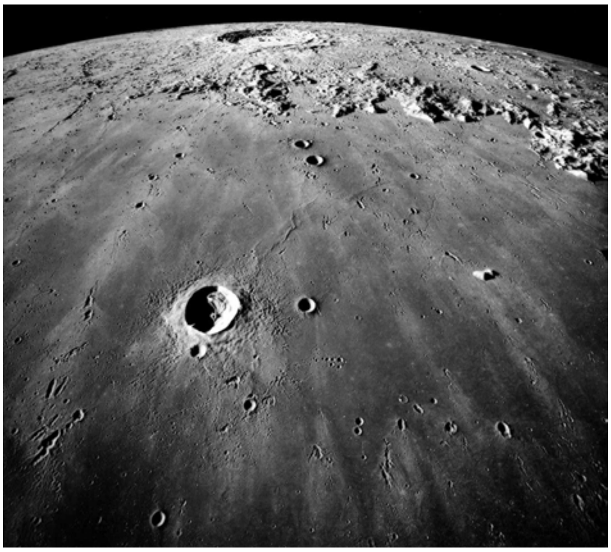


Figure 3.3 Mare Imbrium has a relatively young, smooth surface.
NASA

Figure 3.4 The ancient highlands are ruggedly cratered.
NASA

Phases of the Moon, blue moon and supermoon

Many people believe the phases of the Moon have something to do with Earth's shadow. This isn't the case. Phases arise because at all times one side of the Moon is brightly lit (the side that faces the Sun) whilst the other side (facing away from the Sun) is in the Moon's own shadow. As the Moon goes around Earth we see different amounts of the lit and unlit sides. The same effect is seen in pictures of Earth taken from the Moon or space.

Figures 3.5 and 3.6 show how phases of the Moon arise, seen from the point of view of an observer looking down on the Moon's orbit from above the North Pole.

At new moon the unlit side of the Moon faces Earth, so it appears dark. In fact the precise moment of new moon occurs during daytime on Earth when the Moon and Sun appear close to each other and the Moon will be hidden by the glare of the Sun.

At full moon we can see the entire lit side of the Moon. Figure 3.6 shows how intermediate phases (first quarter, third quarter) appear from Earth. Note that images appear upside down in the Southern Hemisphere, as observers are 'upside down' relative to Northern Hemisphere observers.

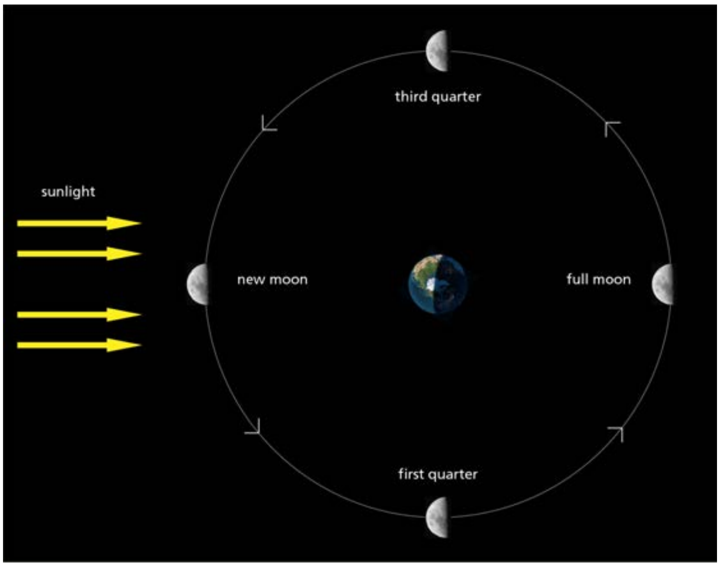


Figure 3.5 Phases on the Moon, viewed from a point above Earth's North Pole

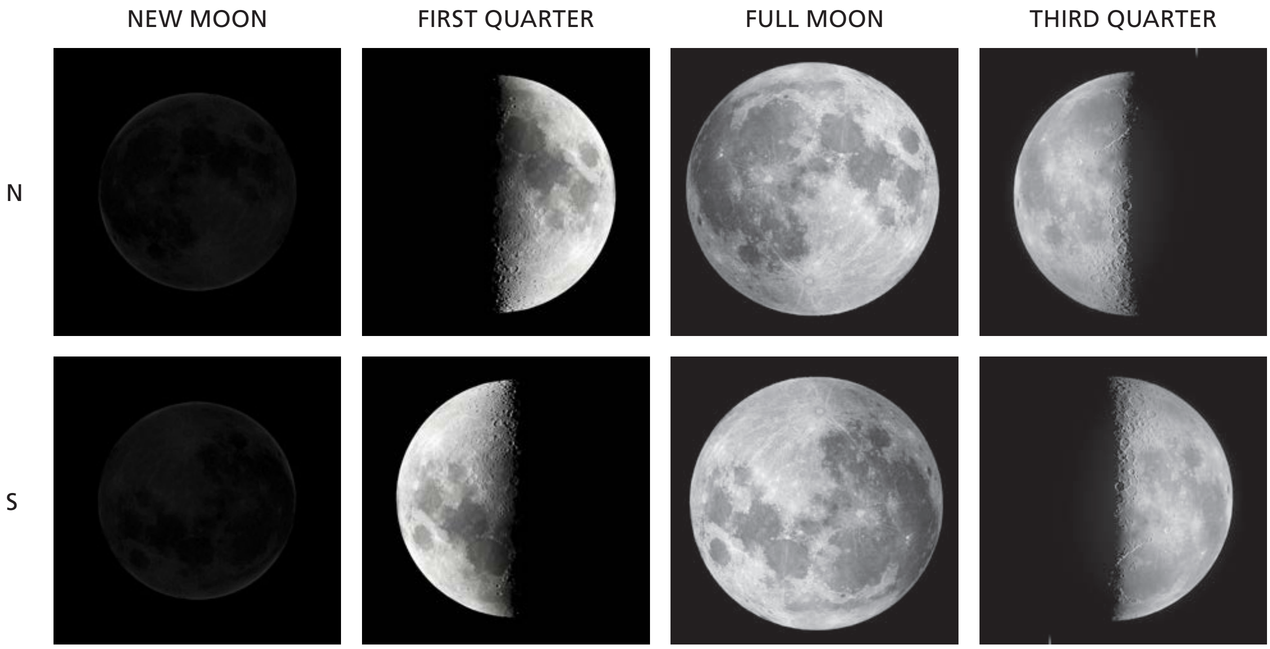


Figure 3.6 Appearance of the Moon from Northern (N) and Southern (S) Hemispheres

Incidentally there is no 'dark side' of the Moon. All parts of the Moon receive sunlight at various times. At full moon the far side of the Moon is in darkness; at new moon the far side is in full sunlight.

If the Sun, Earth and Moon happen to precisely align then it is indeed possible for Earth to cast a shadow that exactly covers the Moon, at full moon. This is known as a lunar eclipse. The alignment of bodies that causes this is called a syzygy.

The Moon goes through a complete phase cycle in a month, so there's generally one full moon per month.

Sometimes there are two full moons in a month (one at the start and one at the end). The second full moon may be called a 'blue moon', although it has nothing to do with colour. It doesn't happen very often, hence the expression 'once in a blue moon'.

The Moon's orbit isn't circular, it's slightly elliptical, so the distance between Moon and Earth varies. If a full moon happens to occur when the Moon is at its closest to Earth then this is called a supermoon, although this is not a scientific term. The apparent diameter of a supermoon in the sky is about 7% greater than when the Moon is at its farthest point from Earth. This amounts to about 14% greater area. Of course the Moon isn't actually larger, it just appears larger because it's closer to us.

Moon brightness

Objects appear bright in the night sky for one of two reasons:

- either they emit their own light (Sun, stars, star clusters, meteors); or
- they reflect sunlight (Moon, artificial satellites, planets, comets).

The Moon appears bright in the night sky because of reflected sunlight, which we call moonlight. The Moon reflects about 12% of the sunlight that falls on it.

Earth reflects about 30% of sunlight, so appears much brighter than the Moon when they're viewed together from space. Clouds, oceans and polar ice caps all contribute to Earth's higher reflectance (known scientifically as albedo).

If you look closely at a partial moon you'll see the dark area isn't completely black. It's lit by light that has travelled from Sun to Earth, been reflected onto the Moon (earthshine) and then reflected again back to Earth.

Moon gravity

The force on objects due to gravity on the Moon is about one sixth that of Earth. The Moon has a considerably smaller mass: just over 1% that of Earth. However the smaller radius of the Moon increases the effect of gravity for objects on its surface (effectively objects are 'closer' to the Moon's centre than an object on Earth's surface). Combining the two effects leads to the figure of one sixth.

Neil Armstrong's 80 kg spacesuit only weighed 13 kg on the Moon.

Facts and figures

Earth diameter	12 742 km
Moon diameter	3 476 km
Sun diameter	1 392 000 km
Earth to Moon average distance	384 400 km
Earth to Sun average distance	149 600 000 km

Table 3.1 Timeline of exploration of the Moon

DATE	MISSION
1959	Soviet spacecraft *Luna 2* crashes on the Moon.
1964	US space probe *Ranger 7* sends back detailed images before crashing into the Moon's surface.
1966	Soviet spacecraft *Luna 9* makes the first soft landing on the Moon.
1966–7	NASA *Lunar Orbiter* program makes detailed maps of the Moon's surface.
1968	*Apollo 8* makes the first manned mission to the Moon, circling it 10 times before returning to Earth.
1969	*Apollo 11* makes the first manned landing on the Moon, 'That's one small step for man, one giant leap for mankind.'
1972	*Apollo 17* was last manned landing on the Moon.
1998–9	NASA's *Lunar Prospector* mission makes detailed studied of the Moon from orbit.
2007–9	Japanese spacecraft *SELENE* (nicknamed *Kaguya*) studies geological evolution of the Moon.
2007–9	Unmanned Chinese lunar-orbiter *Chang'e 1* maps the lunar surface.
2008–9	Indian space probe *Chandrayaan-1* orbits the Moon, deploying a Moon impact probe that strikes the south polar region.
2013	Unmanned Chinese spacecraft *Chang'e 3* soft-lands on the Moon and deploys a rover, *Yutu* (*Jade Rabbit*).

Table 3.2 Common units used to describe astronomical distance

UNIT	DESCRIPTION
kilometre (km)	1000 metres
astronomical unit (AU)	average distance from Earth to the Sun, about 150 000 000 km
light-year (ly)	distance travelled by light in a vacuum in one year, about 9 500 000 000 000 km
parsec (pc)	distance at which one astronomical unit subtends an angle of one arcsecond, about 30 000 000 000 000 km

Activity guide

Links to *Primary Connections*

The activities described below provide a useful introduction to **Lesson 2: Rising and setting** from the *Primary Connections* Year 5 resource, *Earth's place in space*. This lesson describes an investigation students may perform to observe movement of the Sun, Moon and stars across the sky.

Activity 3.1 Scale model

Start this activity with a globe model of Earth, ideally about 25 cm diameter. Explain this is a scale model of Earth.

QUESTION: What do we mean by a scale model?

A distance of 1 cm on a 25 cm globe represents 500 km in real life. So Perth to Sydney (4000 km) would be a distance of 8 cm on our globe. As this is a scale model any distance of 1 cm on the globe represents 500 km in real life.

The globe's surface is probably flat, but we could try to represent ups and downs of Earth's surface (mountains and valleys), using the same scale.

QUESTION: How big would Mount Everest be on our globe?

Mount Everest is 8848 m high. Using the scale 500 km is represented by 1 cm on the globe we can calculate that Mount Everest is 0.2 mm high, on the globe, roughly the thickness of a sheet of paper.

Some other measurements:

- Deepest ocean (Mariana trench) is 10 971 m below ground level, or a 0.2 mm deep scratch in our 25 cm globe.
- Typical jet cruising altitude is 11 500 m, or 0.2 mm above the globe surface.
- International Space Station orbits about 400 km above Earth, or 8 mm above the globe.

These scaled dimensions may suprise students.

Activity 3.2 How big is the Moon?

Having established the size of Earth, this activity is about selecting an appropriate representation of the Moon, using the same scale.

Arrange a selection of ten or so balls, ranging from marble-sized to basketball, in size order, across the front of the classroom.

Ask students to place a sticky note in front of the ball they guess best fits the size of the Moon, using the same scale as the Earth globe used in **Activity 3.1**, to build a column graph. Can students explain their choice?

Add the following information to a whiteboard, then allow students to change their choice, if they wish.

diameter of Earth	12 742 km
diameter of the Moon	3 475 km

The correct answer will be whichever ball is closest to ¼ the diameter of the Earth globe (so for a 25 cm Earth globe the ball closest to 6 cm will be the best model Moon).

Activity 3.3 How far away is the Moon?

Now that we have an appropriate representation of the Moon, ask students to decide where it should be placed, again to scale. Place the Earth globe at one end of the classroom, next to the whiteboard, and ask students to stand where they think the Moon should be placed.

Once they've made their choice and justified it, add another line to the whiteboard:

distance to the Moon	384 400 km

Again, allow students to modify their original prediction. Most will probably realize their first estimate was too small.

The correct answer is to place the Moon a distance equal to 30 times the globe diameter. So for a 25 cm globe the distance should be 30 x 0.25 m = 7.5 m away.

Adjust this figure in Table 3.3, as required by the size of your globe.

Table 3.3 Scaled sizes of Earth-Moon system

GLOBE DIAMETER	MOON DIAMETER (globe / 4)	MOON DISTANCE (globe x 30)
25 cm	6 cm	7.5 m

Plan a trip to the Moon. What will we need? How will we get there?

- The first step would be to send a rocket to the International Space Station (ISS), which orbits Earth in space. Remember, in our model, it's only 8 mm above the surface of our globe.
- Compare the journey from Earth to ISS (8 mm in our model) with the journey ISS to the Moon (7.5 m in our model).

- In 1969 it took Apollo 11 three days (73 hours) to get from Earth orbit to the Moon. A five-minute burn of the rocket engine accelerated the spacecraft to almost 40 000 km/h in order to overcome Earth's gravity. From then on the spacecraft was 'coasting' through space. The pull of Earth's gravity gradually slowed the spacecraft down to a minimum of 3300 km/h. It reached this speed at the point where the pull of the Moon exactly balanced that of Earth. From then on the spacecraft accelerated under the increasing pull of the Moon's gravity until firing of the spacecraft's main rocket slowed it down to enter Moon orbit.
- Add Earth-Moon motion to the model. Leaving aside the rotation of each body, the Moon orbits Earth once in 30 days, so it isn't stationary.
- When Apollo 11 left Earth orbit it headed for where the Moon would be in three days.

Suppose we wanted to add the Sun to our model. How far away would it be?

Add another line to the whiteboard:

distance to the Sun 150 000 000 km

That's a very large distance — our model will extend outside the classroom. In fact it's well outside the school (400 x the Earth-Moon distance, so about 3 km away).

QUESTION: Our model is too big for the classroom. How can we change our model?

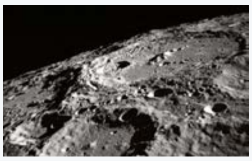
Activity 3.4 Looking at the Moon

The presentation, *Looking at the Moon*, contains images that can be used to stimulate further activities or discussion about the Moon. Images, which are in approximate chronological order to show our increasing knowledge of the Moon, are described in Table 3.4 below. The final four images may be used to reinforce learning about the relative size of Earth, Moon and Sun.

Suggested follow-up activities after viewing the presentation:

- **Lesson 2: Rising and setting** from the *Primary Connections* resource, *Earth's place in space*
- Find mythological or creation stories about the Moon (e g man in the Moon, rabbit in the Moon).
- *ABC Education for the juniors* has many suggestions for Moon-related activities. See http://www.abc.net.au/tveducation/juniors/pages/space/themoon/activity.htm
- Watch an ABC *Behind the news* video about the Moon landing at http://splash.abc.net.au/home#!/media/85360/ (4 min 4 sec)
- Create a story about the Moon that includes some of the science you've learnt. What would you like to do if you could go there?
- Part 7 of this guide contains suggestions for building a scale Solar System on a school oval.

Table 3.4 Images of the Moon from the presentation, *Looking at the Moon*

	This view of the Moon was taken by the *Galileo* spacecraft as it flew by on 7 December 1992. The left part of the Moon is visible from Earth; this region includes large dark patches (so-called 'lunar seas'). These relatively smooth areas were filled with molten lava from ancient volcanoes. There are no active volcanoes on the Moon now.
	*Apollo 8*, the first manned mission to the Moon, entered lunar orbit on Christmas Eve, 24 Dec 1968. That evening, the astronauts held a live broadcast from lunar orbit, in which they showed pictures of the Earth and Moon as seen from their spacecraft. Astronaut Lovell said, 'The vast loneliness is awe-inspiring and it makes you realise just what you have back there on Earth.'
	This view of craters on the Moon surface was photographed by the *Apollo 10* astronauts in May 1969. The rugged landscape forms part of the Moon's Highlands. These are brighter areas seen from Earth.
	An oblique view of Rima Ariadaeus on the Moon, as photographed by the *Apollo 10* astronauts in May 1969. This linear feature formed when a section of the Moon's crust sank between two parallel fault lines. It's relatively young, so there are few craters overlying it.

Astronaut Buzz Aldrin, lunar module pilot, walks on the surface of the Moon in July 1969. Astronauts Armstrong and Aldrin descended in the Lunar Module, *Eagle,* to explore the Sea of Tranquility region of the Moon, while astronaut Michael Collins remained with the Command and Service Modules, *Columbia*, in lunar orbit.

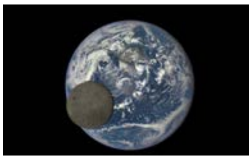
Astronaut Schmitt stands next to a large boulder during the *Apollo 17* mission.

Astronaut Eugene Cernan, commander, makes a short checkout of the Lunar Roving Vehicle (LRV) during the early part of the *Apollo 17* mission. Coloured parts of the rover stand out against the monotonous gray landscape.

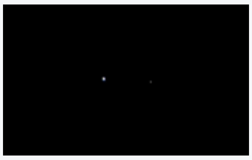
This picture of a crescent-shaped Earth and Moon — the first of its kind ever taken by a spacecraft — was recorded in 1977 by NASA's *Voyager 1* when it was 11.66 million kilometres from Earth. The Moon is beyond Earth, as viewed by *Voyager.*

On December 16, 1992, eight days after its encounter with Earth, the *Galileo* spacecraft looked back from a distance of about 6.2 million kilometers to capture this view of the Moon in orbit about Earth.

The Moon and Earth appear close in this image but this is not the case. The Moon was in front of Earth (closer to *Galileo*) when the image was taken.



This image of the Moon passing in front of Earth was taken by the *Deep Space Climate Observatory* (*DSCOVR*) satellite orbiting 1.6 million km from Earth. The far side of the Moon, which isn't visible from Earth, is shown. The Sun was behind the satellite when this image was captured, so it was taken at a time of new moon. The image emphasises the brightness of Earth compared with the Moon.



This image of Earth (on the left) and the Moon (on the right) was taken by the Juno spacecraft, three weeks after its launch on 5 August 2011. Eleven days later the spacecraft was almost 10 million kilometers from Earth.

The Sun and Moon appear about the same size in the sky when observed from Earth. Although the Sun is about 400 times larger than the Moon it is also about 400 times more distant.

An eclipse of the Sun occurs when the Sun, Moon and Earth are precisely aligned. This image shows an annular eclipse, which occurs when the Moon is at its farthest distance from Earth, so doesn't completely cover the Sun.

VIRTUAL ASTRONOMY

Purpose

To **Explore** movements of Solar System bodies using virtual planetarium software

Outcomes

Students:

- explore a digital model of the Universe;
- understand that motion of objects in the night sky can be predicted;
- understand how motion of objects in the night sky depends on their motion relative to Earth; and
- determine characteristics of some Solar System objects.

Materials needed

NAME	DESCRIPTION	LOCATION
Stellarium and Celestia	A short video demonstrates some capabilities of these programs.	digital-resources/ 4-virtual-astronomy/
Introducing Stellarium	worksheet to guide student use of *Stellarium*	digital-resources/ 4-virtual-astronomy/
Introducing Celestia	worksheet to guide student use of *Celestia*	digital-resources/ 4-virtual-astronomy/
computers or tablets with *Stellarium* loaded and preset to appropriate location		download from www.stellarium.org
computers with *Celestia* loaded		download from www.shatters.net/celestia

Activity summary

ACTIVITY		POSSIBLE STRATEGY	SUGGESTED TIME
4.1	**Working with *Celestia*** A worksheet guides students through use of *Celestia*.	individuals or small groups	30 min
4.2	**Working with *Stellarium*** A worksheet guides students through use of *Stellarium*.	individuals or small groups	30 min
4.3	Extension activity	individuals	20 min

Science background

A challenge in teaching astronomy is that Solar System objects, with the exception of the Sun, are not normally visible in school hours. A planetarium provides one solution by recreating the night sky under a domed roof. Through digital manipulation the night sky can be recreated for any location, on or away from Earth, at any time in the past, present or future.

Virtual planetarium software brings these capabilities to a computer or tablet.

A wide range of software is available, but this package focuses on two programs: *Celestia* and *Stellarium*, that are free to download. A video that highlights a few capabilities of these programs is included in this package. Whilst it takes some time to become familiar with the software this video will hopefully convince you that it's worth the effort.

Celestia is an excellent guide to objects in and beyond the Solar System. Its display is based on a catalogue of almost 120 000 stars and it can be used to show the orbits of planets, moons, asteroids and satellites. Download *Celestia* free from www.shatters.net/celestia.

Stellarium allows you to explore the night sky from any location on Earth, at any time of any year. It uses a catalog of some 600 000 stars and can display constellations from different cultures. Download *Stellarium* free from www.stellarium.org.

Versions of *Stellarium* are available for iOS and Android-based mobile devices, at low cost.

Stellar motion

All objects in the night sky are moving, but explaining their motion can be challenging. It's a composite of effects due to:

- an object's intrinsic motion (its orbit around the Sun or a planet for example);
- Earth's rotation on its axis; and
- Earth's orbit around the Sun.

Combining all these effects can lead to some unexpected results, such as planets reversing their direction of apparent movement in the sky and executing loops.

Time lapse images of the night sky clearly show stars moving in a circular pattern. The first few questions in the worksheet, *Stellarium*, highlight this movement.

Although stars have their own intrinsic motion, they are so far away from Earth that they can effectively be considered stationary in the sky. The circular motion visible in Figure 4.1 or *Stellarium* is a consequence of Earth's rotation.

Stars do change their position relative to each other in the sky, but this is a slow process that is only visible over timescales of thousands of years.

Figure 4.1 'The Night Sky' photographed facing north at 2000 m in the Mount Hood National Forest. CC-BY-SA-3.0. © Robert Knapp

Planetary motion

The name, planet, comes from a Greek word for wanderer. In the short term planets follow the same apparent circular motion as stars in the night sky (motion caused by Earth's rotation), but over a longer period they can be seen 'wandering' along a different path. The Sun also follows this path, known as the ecliptic. It arises because the planets all orbit the Sun in more or less the same plane.

Mercury and Venus are closer to the Sun than Earth is, so they are usually quite close to the Sun in the sky when viewed from Earth. This is why we're most likely to see them close to sunrise or sunset, when the Sun is hidden but the planet is still above the horizon. Venus is often known as the morning or evening star. It isn't, of course, a star, but shines with reflected sunlight.

Planets beyond Earth can appear close to the Sun or completely opposite it, depending on their orbital position.

Activity guide

Preparation for activities

Download *Stellarium* and/or *Celestia* to class computers.

Stellarium initially shows sky views from Paris. It will need resetting so it shows the sky as it appears from a town close to your school. Menu bars pop-up when the mouse is moved to the bottom left hand corner. The uppermost tool in the vertical menu bar opens a window where you can select Perth or a more appropriate location as default.

Make copies of the worksheets, *Introducing Stellarium* and/or *Introducing Celestia*, one per student.

Figure 4.2 Location window in Stellarium

Links to *Primary Connections*

The *Primary Connections* package, *Earth's place in space*, contains suggestions for use of *Stellarium* or *Celestia* at several points including **Lesson 2: Rising and setting, Lesson 4: Galvanising Galileo, Lesson 5: Chasing constellations** and **Lesson 6: Solar System scientists**.

The activities described below will help students become familiar with these programs.

Activity 4.1 Working with *Stellarium*

Give students a quick demonstration of what *Stellarium* is, what it can do, and what they will do as they follow their worksheet. Ensure students know how to find the menu bars by moving the mouse in the bottom left hand corner.

Students can be encouraged to 'play' around with options and explore how the mouse controls the display. By the end of this students may be able to:

- turn gridlines on/off;
- turn constellation lines and names on/off;
- turn atmosphere on/off to make stars visible in the day light;
- change time and date;
- make time move faster, backwards and forwards;
- change their view of the sky (left mouse down hold and move);
- zoom in and out (mouse wheel or page up/down keys); and
- find moons or planets with the search tool.

Students may like to use *Stellarium* to see what the night sky looked like on their birthday.

The worksheet, *Introducing Stellarium*, guides students through a series of questions that develop their understanding of the motion of objects in the night sky. It contains prompts for the correct tools to use, so students do not have to remember all commands.

If students get really stuck in a view or place the best escape may be to exit and reopen the program.

Activity 4.2 Working with *Celestia*

Students can use *Celestia* to get close up to Solar System objects.

Celestia initially displays a view of Earth. This view is in 3D: you can turn it around and view it from any direction and distance, as if you were in space. For example, by taking a position looking directly down on the north or south pole (right click and drag on Earth) and speed up time (press **L** three times) you will see day and night simultaneously.

The worksheet, *Introducing Celestia*, guides students through a series of questions that develop their understanding of planets and moons of the Solar System.

Activities in the worksheet encourage students to:

- Locate the Moon in relation to Earth and see how the Moon orbits Earth.

  The Moon is a long way from Earth. You will need to speed up time, then zoom out (move further away) until Earth is less than the size of 5 cents on the screen to catch sight of the Moon going past. Alternatively use the search tool to visit the Moon, then zoom out to find Earth.

- Move a long way back and play with the view of all the planets orbiting the Sun.

  Students will not see the planets in this view, just orbit lines and planet names.

  Look down on the orbits, or look sideways along the orbital plane, or use any intermediate setting.

- Look at the other planets in our Solar System.

  Explore their features and those of their moons.

- Find out what *Cassini* is doing.

  Cassini is a space probe that is studying Saturn and its moons.

An IWB can be used to show students some of the things they will do before they start the worksheet. As with *Stellarium* it may be best for students to explore mouse actions and keyboard commands on their own for a while

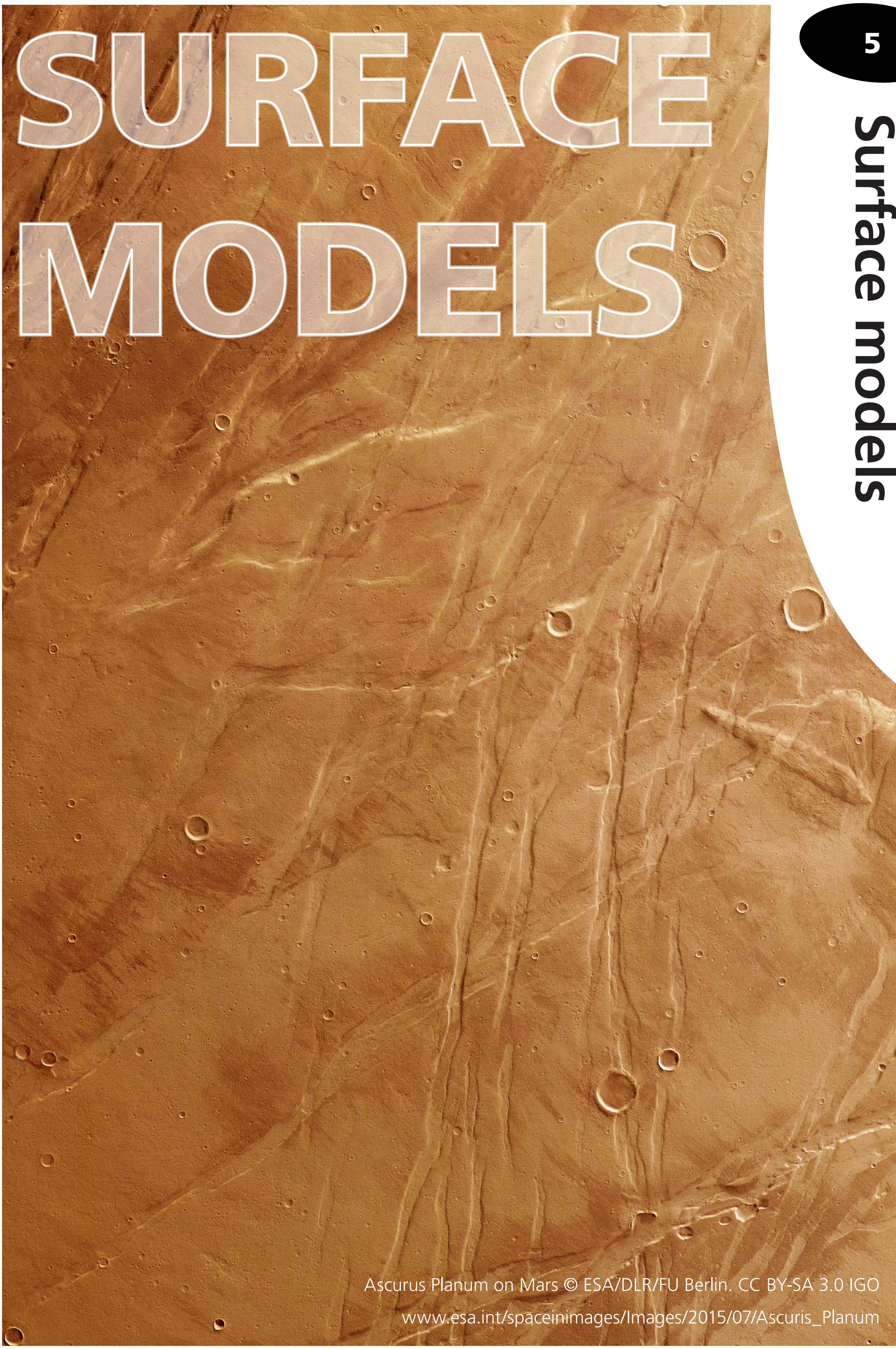
If you get lost in space, press **H** then **G** to go back to the Sun, or press **3 G** to return to Earth. Press <spacebar> to pause time.

Activity 4.3 Extension activity

Stellarium and *Celestia* are powerful programs that can be used at advanced levels. The following activity might be enjoyed by students looking for extension.

Using *Stellarium*, set date and time to shortly after sunset on 8 September 2040. Look west and describe what you see (close alignment of Mars, Venus, Saturn, Mercury and Jupiter and the Moon). Draw a diagram showing the orbits of these planets and predict where they might be to produce the pattern you see. Use *Celestia* to check your answer.

SURFACE MODELS


Ascurus Planum on Mars © ESA/DLR/FU Berlin. CC BY-SA 3.0 IGO
www.esa.int/spaceinimages/Images/2015/07/Ascuris_Planum

5

Surface models

Purpose

In this practical activity students try to **Explain** how surface features of Solar System objects may have been created.

Outcomes

Students:

- understand that the appearance of landforms may depend on the point of view;
- try to identify landform features from satellite photos; and
- create physical models of surface features in the Solar System.

Materials needed

NAME	DESCRIPTION	LOCATION
Where on Earth?	This presentation contains satellite images of landscapes in Western Australia and Mars. An Internet connection is required.	digital-resources/ 5-surface-models/
materials to simulate surface landforms	See **Activity 5.2** below for a comprehensive list.	
Surface models	This worksheet describes a student investigation to recreate surface features on moons, planets or asteroids.	digital-resources/ 5-surface-models

Activity summary

ACTIVITY		POSSIBLE STRATEGY	SUGGESTED TIME
5.1	**Where on Earth?** Students try to identify surface landforms from aerial images. This simulates processes involved in interpreting images of Solar System bodies returned by spacecraft.	whole class	10 min
5.2	**Modelling planet surfaces** Students try to recreate surfaces seen on Solar System bodies using common materials.	small groups	45 min

Science background

Our personal view of Earth is largely shaped from a ground-level perspective, but this is not the case for most bodies in the Solar System. In only a few cases have images been sent back from spacecraft landers. Instead, most information comes from orbiters and fly-bys that provide a view from above.

Everyday objects may appear quite different when viewed from different angles. A cube may appear as a square, rectangle or hexagon from different points of view.

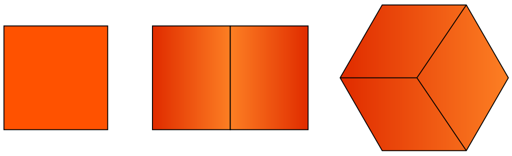


Figure 5.1 projections of a cube

The same is true of geographical features. Mount Fuji is a lot more recognizable in profile (side view) than in plan (vertical view).

Figure 5.2 Mount Fuji viewed in profile and from above
Yuno-yuno and Google Earth

In these activities students are asked to reproduce features seen on planets in the Solar System other than Earth.

Several levels of challenge are involved.

- Features observed on other planets are viewed from above, which may be an unfamiliar view for students. Links may be made to maths concepts of perspective and views of 3-D shapes.
- The scale of observed features may be unclear.
- Students will seek analogues on Earth for features they observe, but a good terrestrial analogue may not exist.
- Surface processes on Earth may be very different from those on other planets.
- There may be several ways to create a particular feature.

Figure 5.3 Sand ripples may be created by wind or water.

Activity guide

Links to *Primary Connections*

This activity may be used at any time with the *Primary Connections* resource, *Earth's place in space* as it is independent. It would work well with **Lesson 6: Solar System scientists**.

Activity 5.1 Where on Earth?

The presentation, *Where on Earth?*, runs in any browser and may be displayed on an IWB to promote class discussion. It is divided into three sections.

1. The first three images present a well-known Perth landmark (the West Australian Cricket Association oval) from three points of view: ground level; oblique (bird's eye); and plan (aerial) view. This illustrates how objects may look different, depending on the point of view. At ground level the lighting towers dominate; but an aerial view brings out the oval shape.

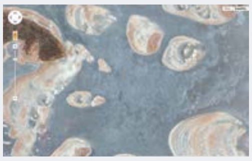
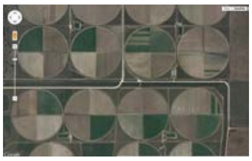
   In a similar way a river appears different when viewed from the bank compared with an aerial view that shows the overall drainage pattern. Students will need to keep this in mind when interpreting satellite photos of Earth and other planets.

2. Images that follow show landscape features in Western Australia (10 images) and Victoria (one image) through Google Maps satellite views.

   Students can try and identify what each image shows. Their suggestions should be justified (eg 'I think it's X because Y'). Zooming in or out of images may help. Table 5.1 contains explanations of all terrestrial images.

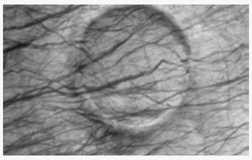
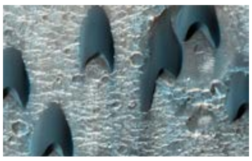
3. The last part of the presentation contains five images of Mars landforms. These are now quite well understood as a consequence of different missions to Mars. However other Solar System bodies frequently show features whose origins are unknown or contested. Table 5.2 contains explanations of all Mars images.

Table 5.1 Explanation of terrestrial images in *Where on Earth?*

	Wolfe Creek crater, Kimberley, WA This impact crater was created about 300 000 years ago by a meteorite with an estimated mass of 50 000 tonnes. The crater has average diameter of 875 m.
	Parallel sand ridges in the Western Desert, Pilbara, WA These sand ridges run parallel to the prevailing wind. Their roughly even spacing may be caused by eddy currents sweeping sand from intervening spaces.
	Salt lake (Lake Barlee) west of Menzies, Goldfields, WA Concentric rings are formed as water evaporates or is replenished.
	Tidal shallows, Shark Bay, WA Shades of blue represent shallow and deeper areas. The regular patterning that may be visible is an artifact. Scientists have to be careful interpreting satellite images that may show optical artifacts due to image compression.
	Sand dunes near Lancelin, WA The roughly straight lines are roads. Clouds or smoke trails may have a similar appearance.
	Irrigated farming area east of Lancelin, WA Circles are produced by irrigation arms, tethered at the central point.
	Fitzroy River, Kimberley Green, vegetated areas follow the line of the river and its tributaries.

	Drying lake near Fitzroy Crossing, Kimberley, WA Sunlight glints off small pools of water in a drying lake.
	Drainage pattern, King Leopold Ranges, Kimberley, WA The branching channels are referred to as a dendritic (tree-like) pattern. Regular geological faults in the rock create the alignment of channels in preferred directions.
	Perth, WA A typical urban landscape is shown.
	Crater Lakes, Victoria The circular structures are volcanic craters. Zooming out shows more circular structures extending along an east-west direction. These were caused by this part of the crust drifting over a volcanic hotspot (similar to present-day Hawaii island chain).

Table 5.2 Explanation of Mars images in *Where on Earth?*

	This image shows a small cone on the side of a giant shield volcano on Mars. The cone shows some layers of hard rock but most of it is made of relatively soft material. This appears to be an example of a 'cinder cone' composed of pieces of lava thrown into the air during a small volcanic eruption.
	Northern sand dunes on Mars emerge from their winter cover of seasonal carbon dioxide (dry) ice. Dark, bare south-facing slopes are soaking up the warmth of the sun
	Streaks occur both inside and outside this martian crater, so they must have been created after the crater-causing impact. Trails like these are probably produced by miniature wind vortices: martian dust devils. Such spinning columns of rising air heated by the warm surface are common in dry and desert areas on planet Earth. On Mars, dust devils can be up to 8 km high and leave dark trails as they disturb the bright, reflective surface dust
	This image shows a dune field on Mars in a large crater near Mawrth Vallis. Some of the dunes appear to be in a V-shaped formation
	This image shows part of Ius canyon on Mars. It's part of Valles Marineris, the largest known canyon system in the Solar System. Water once filled the Martian canyons, creating large layered deposits that fill their bases. Some canyons are 8 – 10 km deep.

Activity 5.2 Modelling planet surfaces

In this activity students build a layered surface using sand or food materials. Surfaces are then impacted using simulated meteors to create craters, or modified by liquid flow.

Students photograph resultant surfaces from overhead, print their images, cut out suitable shapes from the prints, and mount on black card to create their own moon, asteroid or planet. Finally they write a scientific report that explains how their space object was formed.

This is a messy activity so you may wish to use table covers, spread newspaper or do the activity outside. Dispose of sand thoughtfully. Have two bins for waste: one lined bin for perishables; the other for sand (you may need to sieve out stones first). Students may wish to try several different approaches, so have sufficient materials available and advise students not to use all resources in one go.

A copy of the student worksheet, *Planet surfaces*, may be given to each group as a summary of the investigation. Postcards and students' observations from **Activity 2.2: Postcards from space** may be used for reference.

Equipment you may use:

- baking trays (disposable) or recycle shop food trays (large for sand, smaller for food)
- bucket of orange brickies' sand
- bucket of white or beach sand
- packet of cactus potting mix or fish tank gravel
- trowels
- large packet of flour
- large packet of cocoa powder (cheap brand) or coloured powder for flavouring milk
- fairy sprinkles, poppy seeds or similar
- spoons
- small, hard items to be meteorites, such as marbles, rocks, golf balls …
- jugs of water
- camera or tablet
- drinking straws
- printer and white paper
- scissors and glue
- black card
- newspaper or table cloths
- dust pans
- bin for sand
- sieve

Working in small groups, ask students to build a planet surface in a baking dish. There are many different approaches possible, including those shown below.

1. Spread a 2 cm layer of orange brickies' sand in the bottom of a baking dish.

2. Sprinkle small stones evenly over the sand.
3. Cover sand and stones with a layer of white sand, 1 – 2 cm thick.

4. Roughly level out top surface.
5. Drop or throw 'meteorites' such as small stones or golf balls at the surface of the sand.
6. Carefully remove 'meteorites'.

Alternative ideas

There are many alternative approaches that can be used for this activity. Teachers (and students) may like to select from the following suggestions.

- Lift one end of the tray and slowly pour water from a jug into the raised end, so water flows down.
- Put white sand under the yellow sand.
- Orange brickies' sand holds water well. Handfuls of damp sand can be thrown into the sand tray to create a different surface effect.
- Build up layers using flour; sprinkles (100s and 1000s or similar); and cocoa. Drop marbles or other small objects onto the surface and remove carefully.
- Place rocks on the surface then use straws to blow flour into dune formations.

Presentation

Photograph completed planet surface from overhead (as if from a satellite) and print image(s).

Draw a moon, planet or asteroid shape on the back of the image and cut out the shape.

Stick cutout shape onto black card so that it looks like it is in space.

Objects in the Solar System are often named from different mythologies or literary figures such as Shakespeare's characters. Encourage students to name their space objects in a similar way.

Prepare a report that expains how the object was formed, using appropriate 'scientific' explanations.

Investigation

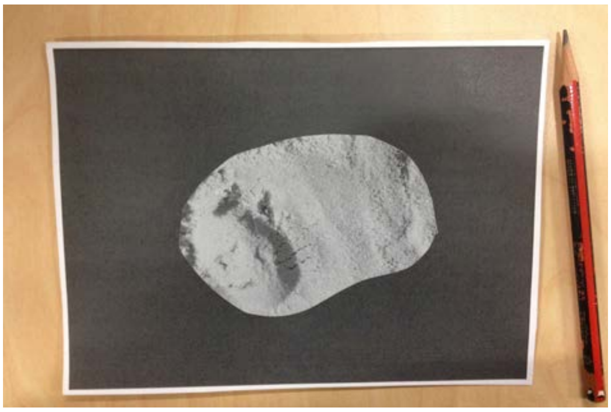
If time is available this activity may be developed into an open investigation into impact craters, for example: what determines the size of an impact crater?

Students will need to decide:

- How should size be measured?
- What variables will be measured?
- What variables will be varied?
- What variables will be controlled (fixed)?

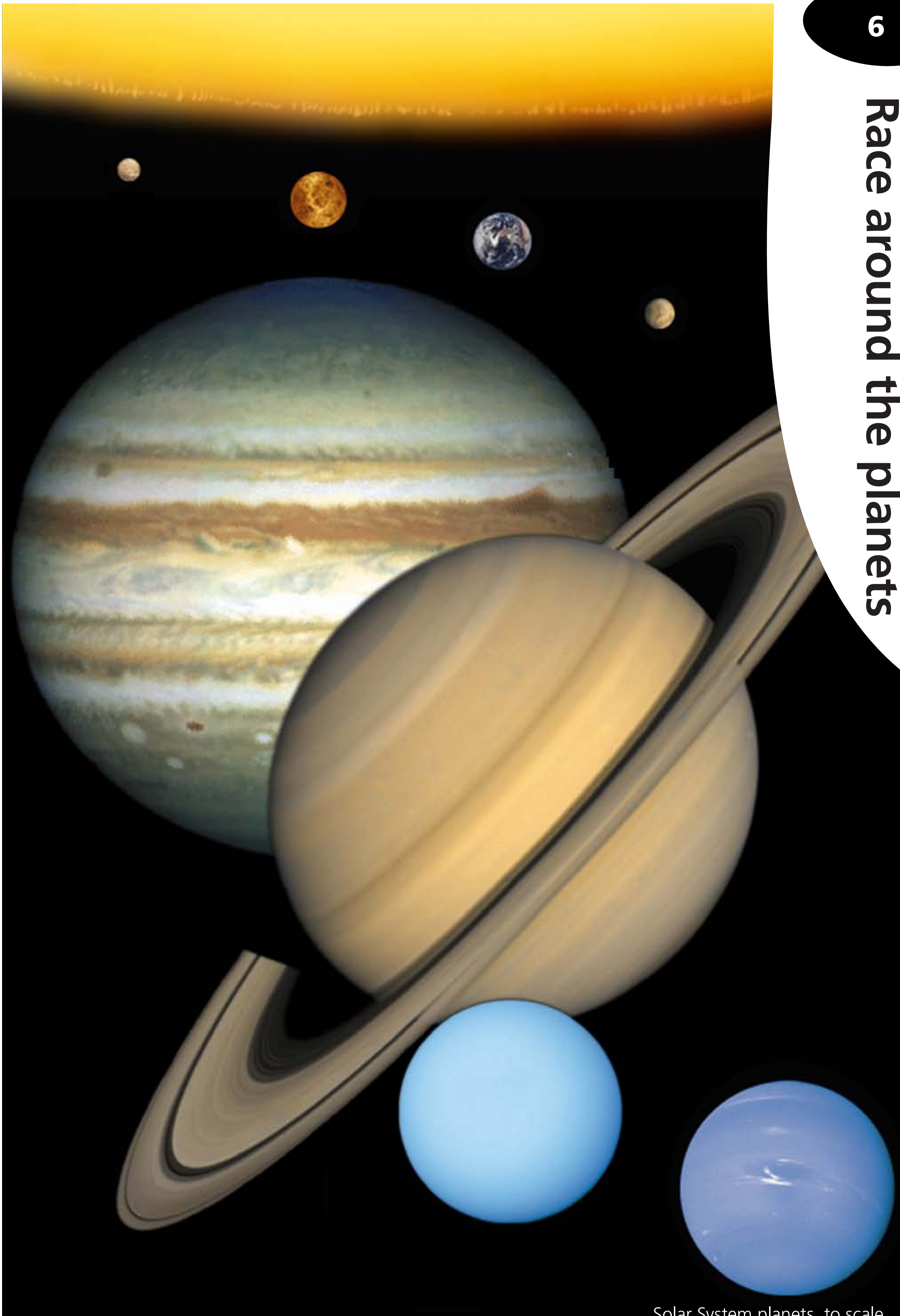
A detailed investigation into what controls crater size is available from NASA — *The Scientific Method: An Investigation of Impact Craters*, available from:

http://www.nasa.gov/pdf/473315main_The%20 Scientific%20Method%20DLN%20Module.pdf



6

Race around the planets



Solar System planets, to scale

Purpose

Students play a board game in order to **Explain** the arrangement and characteristics of the Solar System.

Outcomes

Students:

- know the name and arrangement of planets in the Solar System;
- understand that planets orbit the Sun; and
- understand that planets further from the Sun have longer orbits.

Materials needed

NAME	DESCRIPTION	LOCATION
Race around the planets	A3 game board, game cards Print one set per group.	digital-resources/ 6-race-around-the-planets/
Race around the planets	player sheet Print one sheet per player.	digital-resources/ 6-race-around-the-planets/
playing counters	set of one playing counter and planet marking counters or paperclips (8) per student	school equipment
dice	two per group	school equipment

Activity summary

ACTIVITY		POSSIBLE STRATEGY	SUGGESTED TIME
6.1	**Introducing *Race around the planets*** Teacher explains the game, *Race around the planets*.	whole class	5 min
6.2	**Playing the game** Students play the board game, in groups of four.	groups of 4 or less	25 min
6.3	**Quiz** A quiz reinforces students' understanding.	whole class	10 min

Science background

Viewed from a vantage point above Earth's and Sun's north poles the Earth orbits in an anti-clockwise direction around the Sun, as do all the other planets. Earth also spins on its own axis in an anticlockwise direction (as do most of the planets; Venus and Uranus spin clockwise).

An easy way to remember the direction of rotation is to curl the fingers on your right hand. If your thumb points up then your fingers show the anticlockwise direction of rotation and spin.

Race around the planets is a simple game that is played on a board that represents the Solar System. The board includes an indication of relative sizes of planets and their orbits; but it is not to scale. The title page of this chapter of the teacher guide contains a more realistic representation of the relative sizes of planets in the Solar System.

The game board shows the asteroid belt, which lies between Mars and Jupiter, but not the Kuiper belt, which lies beyond Neptune's orbit. The Kuiper belt is similar to the asteroid belt, but bigger. The dwarf planet, Pluto, is in the Kuiper belt.

Orbit jumping questions that feature in the game contain facts about the Solar System. Some of these touch on areas of student misconception, such as the length of a planet's day and year, while others are general facts about the Solar System. Questions repeat as the game is played, rewarding students that pay attention to questions and answers. Many answers can be gleaned from the player sheet.

Students will find it takes longer to complete orbits for planets further from the Sun. This reflects actual data, although it is once again not to scale.

Table 6.1 Length of a year for Solar System planets (in Earth days and years)

Mercury	Venus	Earth	Mars
88 days	225 days	365 days	687 days
Jupiter	**Saturn**	**Uranus**	**Neptune**
12 years	29 years	84 years	165 years

Activity guide

Preparation for all activities

Print out the required number of A3 playing boards, game cards and player sheets. One board and set of playing cards is required for each group of 4 or fewer students. Each student needs their own playing sheet. Boards, cards and playing sheets may be laminated for reuse.

Gather the required number of dice (two per group recommended), playing counters (one per student, with different colours for members of a playing group) and planet marking counters, paperclips or pencils.

Links to *Primary Connections*

Race around the planets could follow **Lesson 4: Galvanising Galileo** in the *Primary Connections* resource, *Earth's place in space*.

Activity 6.1 Introducing *Race around the planets*

Organise class into playing groups of four or fewer students. Show whole class the game board, cards and player sheet. Point out 'How to play' instructions, glossary and tally on the player sheet. Read rules to the class and demonstrate one or two plays so they know how to orbit jump and mark off planets on their player sheet.

For example: a player is 4 spaces from an orbit jump and throws a 12 (double-6). They move four spaces to the orbit jump space and another player reads the question to them from the top card. If the player answers it correctly they move 1 space into the new orbit and then 7 spaces around that orbit (continuing anti-clockwise). If they answer the question incorrectly then they continue 8 spaces in their current orbit.

If any part of their move takes them past a planet they can mark that planet on their player sheet (either by ticking the planet or placing a paperclip over it). Players do not mark Earth until they finish.

It's easiest if players start with their playing counters off the board and bring them on with their first move.

Activity 6.2 Playing the game

Students play the game in groups of four. If groups need to be larger then it is probably better to pair students up. The minimum is two students per game.

Ask one member of each group to collect playing materials. Suggest how students decide who will go first and the order they will play (e g highest die roll or alphabetical order).

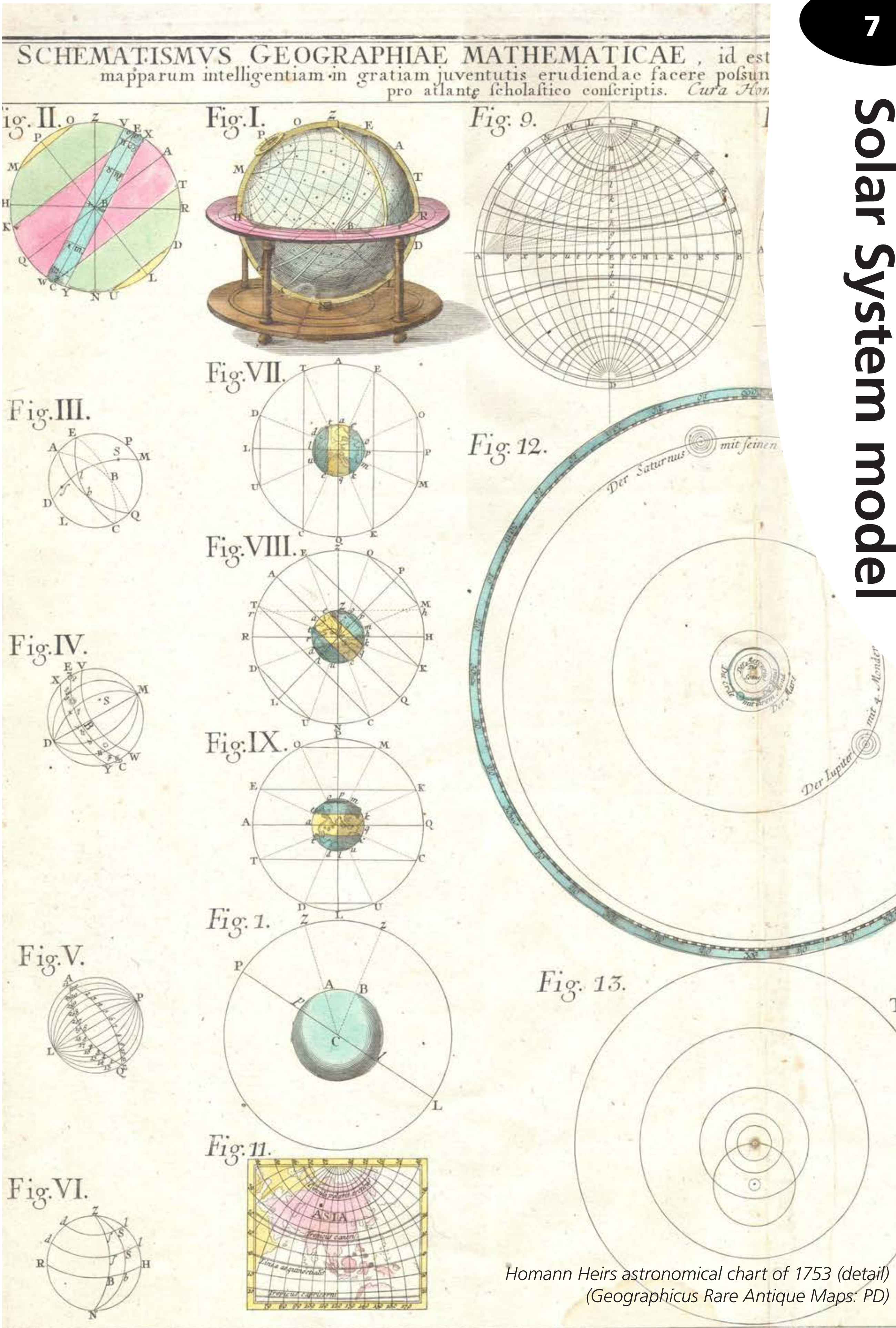
The winner is the first person to mark off all planets and return to Earth. If you have limited time the winner can be decided by how many planets have been visited when time is up.

Activity 6.3 Quiz

At the end of the game, while students still have their game board in front of them, ask the class some snap questions to consolidate their understanding. Questions you might like to use are listed below in Table 6.2. Alternatively, this may be done at the start of the lesson to introduce the activity.

Table 6.2 Suggested quiz questions

QUESTION	ANSWER
What is the Solar System?	the collection of space objects orbiting the Sun
What is the star in our Solar System?	the Sun
Which is the largest planet?	Jupiter
Which is the smallest planet?	Mercury
Where is the asteroid belt?	between Mars and Jupiter
Which planets are the gas or ice giants?	Jupiter, Saturn, Uranus and Neptune
Which planets are the rocky planets?	Mercury, Venus, Earth and Mars
Apart from the planets what other large rocky space objects are there in the Solar System?	asteroids (minor planets) and dwarf planets
What is a planet's year?	the time it takes the planet to orbit the Sun
What is a planet's day?	the time it takes for a planet to complete one rotation around its axis (one whole spin)
Do all the planets orbit the Sun in the same direction?	yes
Which planets don't have moons?	Mercury and Venus
What is the order of the planets, starting from the Sun?	Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune The International Astronomical Union suggests '**M**y **V**ery **E**ducated **M**other **J**ust **S**erved **U**s **N**achos' as mnemonic.
Which planet has rings around it?	All four of the gas/ice giants have rings around them, but Saturn has the most obvious ring system.
What is a comet?	An object of ice and dust, orbiting the Sun, that develops a tail from evaporation as it passes near the Sun.
What is at the centre of the Solar System	the Sun
Which planet is closest to Earth? (trick question)	It varies: the answer could be either Mercury, Venus or Mars, depending on where they are in their orbits around the Sun, relative to Earth. However most often it is Venus.



Homann Heirs astronomical chart of 1753 (detail)
(Geographicus Rare Antique Maps: PD)

Purpose

To **Explain** the relationship between a planet's distance from the Sun and length of its year by making a scaled representation of the Solar System.

Outcomes

Students:

- represent the Solar System to scale; and
- describe relationships between the length of planets' days and years, and distance from the Sun.

Materials needed

NAME	DESCRIPTION	LOCATION
Interactive Solar System	HTML-based web page to help students construct an accurately scaled model of the Solar System	digital-resources/ 7-solar-system-model/
Planet facts *Planet orbits*	worksheets for recording and graphing information about planets	digital-resources/ 7-solar-system-model/
100 m string		

Activity summary

These activities are best spread across two class periods.

ACTIVITY		POSSIBLE STRATEGY	SUGGESTED TIME
7.1	**Scaling the planets** Students choose an appropriate scale to represent the Solar System.	individuals working in small groups	20 min
7.2	**Solar System on an oval** Students create a scale model of the Solar System on the school oval.	whole class	30 min
7.3	**Solar System facts** Students research basic data about the Solar System to derive relationships between orbital distance and year length.	individuals	20 min

Links to *Primary Connections*

Activities 7.1 – **7.3** cover much of the content area as **Lesson 6: Solar System scientists** from the *Primary Connections* resource, *Earth's place in space*.
A combination of the activities would work well.

Science background

It's difficult to convey the size of the Solar System in a practical activity, especially if the activity is designed to demonstrate both the size of planetary bodies and their distance from the Sun.

If a basketball represents the Sun, then this dot '•' representing Mercury should be placed 10 metres from the basketball and Jupiter (shown to scale to the right) should be placed 134 metres away.

As Figure 7.1 shows, the inner planets are closely spaced when compared with the outer planets, which makes building a representation of all the planets challenging.

Using a basketball to represent the Sun should allow a scaled representation of at least the inner Solar System, within school grounds. In **Activity 7.2** a Google Map page is used to superimpose the outer planets over a map of the school environs.

Patterns in the Solar System

Although earlier scientists spent much time trying to find patterns in the positions of the planets there is no such relationship. Broadly, the smaller, denser planets are closer to the Sun; the larger, less dense planets farther away.

There is an exact mathematical relationship between the radius of a planet's orbit and the time taken to orbit the Sun (Kepler's third law of planetary motion).

If students plot year length against distance from the Sun in **Activity 7.3** (for a selection or all planets) they will find there isn't exactly a straight-line relationship. They will however observe a clear increase in year length with distance from Sun.

This can be related to the exercise in **Activity 7.2** where students pace out planet orbits. Venus is twice as far from the Sun as Mercury; and Venus has to travel twice as far as Mercury as it orbits the Sun.

There is no particular relationship between the planets and their day length, although the larger planets in the Solar System tend to have shorter day lengths.

Most moons are tidally locked to the body they orbit, so their length of day and year are the same (they present the same face towards the body they orbit).

The planets' orbits are not exact circles: they are ellipses. However Earth's orbit is quite close to a circle with a ratio of short axis to long axis of 0.97. Mercury has a much more elliptical orbit with ratio of about 0.66.

The amount of sunlight incident on a planet varies inversely by the square of its distance from the Sun. Venus is twice as far from the Sun as Mercury, so it receives a quarter the intensity of sunlight as Mercury. The amount of sunlight is one factor that contributes to the temperature of different planets — composition and density of planetary atmospheres are also important. Together these factors lead to Earth's position in the 'Goldilocks zone', where liquid water is common.

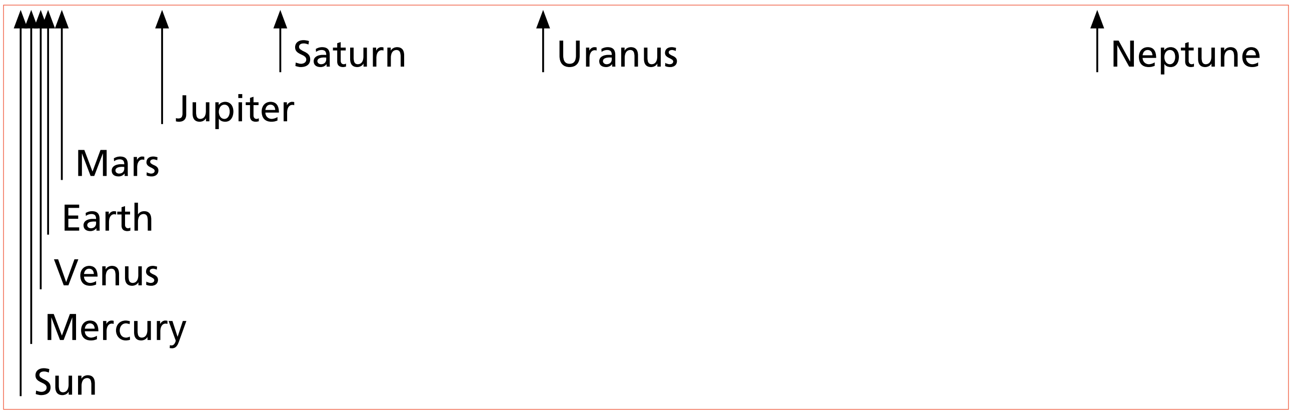


Figure 7.1 Spacing of planetary orbits in the Solar System

Activity guide

Activity 7.1 Scaling the planets

Students established in **Activity 3.3** that if Earth is represented by a 25 cm globe, the Sun may be represented by a sphere almost 30 m in diameter, over 3 km away.

Choose a different scale to represent the Solar System. Use the interactive HTML page, *Interactive Solar System*, to enter the diameter of your model Sun to get a table of scaled distances and diameters of the planets. A Sun diameter of 24 cm (a basketball) works well.

Ideally choose a scale that means the planets aren't too small to represent (e g with a drawn 'dot') and where the terrestrial planets (Mercury, Venus, Earth and Mars) can be fitted within your school site.

Students, in groups, prepare a card for each planet that includes the following information:

- planet name,
- scale drawing of planet,
- scaled distance from Sun,
- length of day (in hours or Earth days), and
- length of year (in Earth days or years).

This information may be copied down from the *Interactive Solar System* page.

Optionally, research some interesting facts about each planet. Add this information and a photo to cards.

Activity 7.2 Solar System on an oval

The second page in *Interactive Solar System* (Solar System map) allows planetary orbits to be superimposed on a Google map to visualize the outer planets' orbits, beyond the school grounds. Click on the planet images to display their names. Drag the Sun around the map to refine its position. Drag and zoom the map to see all the planets.

Given the size of your school oval, work out how many planets will fit onto it with the Sun in the middle. If there's not much room then place the Sun on the side of the oval and represent half orbits or in a corner and represent quarter orbits.

Position the model Sun and as many planet cards as possible on oval. Students can estimate where planets should be located using their scaled distances (eg estimate 26 m from the model Sun to position Earth).

Then use a trundle wheel, measure or pace out pieces of string to guide positioning of planets Mercury, Venus, Earth and Mars. How close were students' estimates?

Attach one end of each piece of string to a post at the Sun's location. Keep string taut as students pace out circles corresponding to each planet's orbit. How does the length of orbit (or number of paces) relate to the distance from the Sun? How does this relate to the length of a planet's year?

Incidentally, if the basketball model Sun is placed in Perth then the nearest star, Alpha Centauri, would be in Broome.

Table 7.2 Scaled diameter and orbit of planets, based on a 24 cm model Sun

	Sun	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
diam	24 cm	0.8 mm	2.1 mm	2.2 mm	1.2 mm	2.4 cm	2 cm	8.7 mm	8.5 mm
orbit	—	10 m	19 m	26 m	39 m	134 m	247 m	496 m	777 m

Activity 7.3 Solar System facts

Instruct students to write a report that describes how the planets are spaced from the Sun, either using observations made on the oval or using data from *Interactive Solar System*.

Use information on lengths of a year and a day for each planet to plot a line graph that compares each planet's distance from the Sun and the length of its year. Is there any relationship? Do the same for day length. As year 5 students may not be familiar with line graphs a template is included on the worksheet, *Planet orbits*, to simplify this graphing activity.

Students should describe any other patterns they see amongst the planets. For example, are there relationships between the size or composition of planets and their distance from the Sun? (The four closest planets to the Sun are also the four smallest; the four closest planets to the Sun are rocky planets; the four farthest away are gas and ice giants).

Planet facts

PLANET NAME	Mercury	SCALE DRAWING:
REAL DIAMETER	4879 km	
REAL DISTANCE FROM SUN	57,910,000 km	
MODEL DIAMETER	0.8 mm	
MODEL DISTANCE FROM SUN	10 m	
DAY LENGTH	58 days	
YEAR LENGTH	88 days	

INTERESTING FACTS ABOUT THIS PLANET

Mercury is the nearest planet to the Sun.
The side that faces the Sun is the hottest planet surface in the Solar system, up to 427°C.
The side that faces away from the Sun is very cold, -173°C.

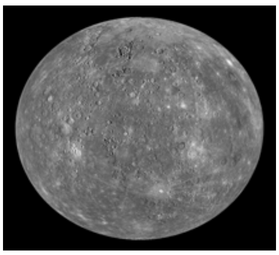


Image of Mercury taken by MESSENGER spacecraft

Planet orbits

Use this graph to compare variables for the four inner planets (Mercury, Venus, Earth and Mars).
Shaded vertical bars show how far each planet is from the Sun, to scale.
Choose your own variable to plot on the vertical axis (for example, how long a planet takes to orbit the Sun).

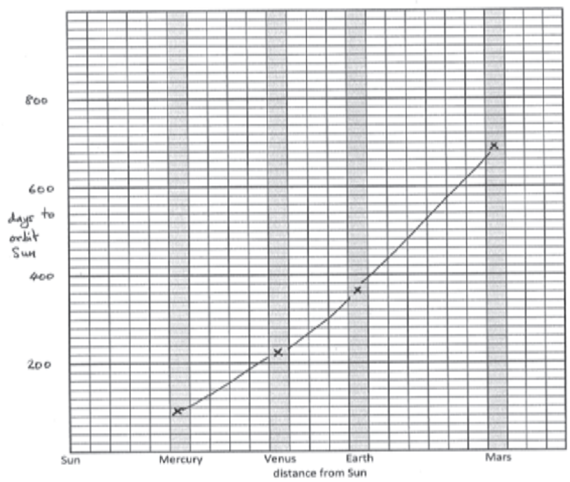


Figure 7.2 example worksheets, *Planet facts* and *Planet orbits*

8

Search for life

Anomoeoneis - an alkaliphile

D J Patterson

Purpose

To show that life is found even in extreme conditions on Earth and that similar conditions, potentially containing life, occur elsewhere in the Solar System.

Outcomes

Students:

- understand that living organisms, known as extremophiles, are found in extreme environments on Earth;
- appreciate that scientists are looking for life in similar conditions elsewhere in the Solar System;
- apply techniques developed to model the Earth-Moon system to create a representation of Jupiter and its four largest moons; and
- design their own alien with features appropriate for a particular environment.

Materials needed

NAME	DESCRIPTION	LOCATION
Searching for life in the Solar System	video-podcast	digital-resources/ 8-search-for-life/
Extremophiles	HTML-based presentation	digital-resources/ 8-search-for-life/
Jupiter's moons	worksheet	digital-resources/ 8-search-for-life/

Activity summary

Activities in this section draw together a number of themes presented earlier. These include: environmental conditions that support life (part 1); scale representation of Solar System bodies (parts 3 and 7); and landforms found in the Solar System (part 5).

Activities 8.3 and 8.4 may be used for summative assessment to demonstrate students' ability to draw on their new learning to tell a coherent and scientifically valid story.

ACTIVITY		POSSIBLE STRATEGY	SUGGESTED TIME
8.1	**Searching for life in the Solar System** A video-podcast provides a brief introduction to the search for life beyond our planet.	whole class	15 min
8.2	**Extremophiles** A presentation features terrestrial extremophiles and considers where life might occur in the Solar System.	whole class	15 min
8.3	**Jupiter's moons** Students construct a scale representation of the four largest moons of Jupiter given basic data and descriptions of conditions on the moons.	groups of 4 students	20 min
8.4	**Design an alien** Students design an alien lifeform that might live on one of Jupiter's moons. What features (adaptations) might it require to survive?	individuals	40 min

Science background

Some of the hottest, driest, darkest and most radioactive places on Earth are home to specialised organisms known as extremophiles. These organisms are tough: they live under conditions generally considered uninhabitable.

Home for extremophiles might be three kilometres under ground, where it's hot, dark and dry; or in the boiling waters of a hot spring at a phenomenal 113°C; or in acid as strong as the inside of a car battery.

Most extremophiles are single-celled organisms, such as bacteria.

Since the 1970s scientists have investigated this amazing group of organisms, all capable of flourishing in exceptionally harsh environments. The discovery of extremophiles has effectively challenged our ideas about conditions necessary for life.

Many environments extremophiles inhabit are thought to be similar to those of early Earth, helping scientists investigate how life first appeared and survived.

Extremophiles also provide vital clues about life on other planets. If organisms can exist on Earth under hostile extremes, maybe they can survive in space. Astrobiologists believe studying extremophiles on Earth can guide the search for life elsewhere in the Solar System.

Survivors

Some organisms, such as lichens, whilst not extremophiles, are capable of enduring extreme conditions. They do this by entering a state of inactivity, or suspended animation.

Lichens are found in some of the most inhospitable places on Earth: mountains, deserts and even Antarctica.

In 2005 lichen survival skills were trialled in space. For 16 days two species of lichen had to deal with extreme cold, intense solar and cosmic radiation, desiccation and the space vacuum.

Although unable to function under these hostile conditions, once back on Earth the lichens returned to normal functioning within 24 hours.

The adventurous journey of these lichens shows that multicellular organisms can exist outside Earth's atmosphere, and might even survive the varied atmospheric conditions of other planets.

There are many types of extremophiles and it's possible to group them on the basis of conditions they like best. One thing that's important to note is that most extremophiles live under a number of extreme conditions.

Acidophiles

These organisms live in highly acidic conditions, with pH $\leq$ 5.

Places you might find them:

- Crater Lake, New Zealand
- Rio Tinto River, Spain

Halophiles

These organisms live in places where salt concentrations are 2–5 times the concentration of seawater, up to 30% salinity.

Places you might find them:

- Dead Sea, Middle East
- Great Salt Lake, Utah, USA

Psychrophiles

These organisms literally live in the freezer, flourishing in extremely low temperatures.

Places you might find them:

- Lake Vostok (subglacial lake in Antarctica)
- Kolyma Lowlands, Siberia (frozen in permafrost)

Thermophiles

These organisms like the temperature extreme, anything above 45°C. Hyperthermophiles like it even hotter, thriving in temperatures ranging from 70 - 113°C.

Places you might find them:

- Grand Prismatic Spring, Yellowstone National Park, Wyoming, USA
- Deep sea hydrothermal vents, Galapagos Rift, Ecuador

Figure 8.1 Lichen

Activity guide

Links to *Primary Connections*

The activities in this section may be run independently of *Primary Connections*. They may be used for summative evaluation as they require students to draw together prior learning.

Activity 8.1 Searching for life in the Solar System

The video-podcast, *Searching for life in the Solar System,* provides a brief introduction to key concepts around the search for life beyond our planet.

The following ideas are raised by the video.

- People have wondered whether there is life beyond Earth, but in the absence of scientific evidence this remains speculation.
- From the 1950s planetary probes and landers have provided concrete evidence of conditions on other planets and moons.
- Scientists believe that if there is life beyond Earth in the Solar System it will be microscopic, however no evidence for life has yet been observed.
- Although conditions on other planets and moons are extreme there are comparable conditions on Earth that do support life.
- Water appears to be essential for life.

Class discussion following the video could involve the following topics:

- Where might we look for life in the Solar System?
- How would we know if life was present?
- Are there non-living things that might show that life is or was present? (e g fossils, tracks and traces)

Activity 8.2 Extremophiles

The presentation, *Extremophiles*, contains images of organisms that thrive in extreme environments on Earth.

This may be used to extend the discussion around conditions for life. Connections may be made to the opening **Engage** activity in part 1 of this resource where it was stated that conditions on Mars are too extreme for life. At the end of this activity students may realise that this may not be true.

Table 8.1, opposite, contains background information on each of the images used in the presentation.

Activity 8.3 Jupiter's moons

A worksheet, *Jupiter's moons*, contains basic data on Jupiter's four largest moons (the Galilean moons). First observed by Galileo in 1610, the discovery of these moons was pivotal in Galileo's rejection of a geocentric universe.

Students may use these data to make a scale representation of Jupiter and its moons. This will be easiest if a circular piece of butchers' paper, 140 cm diameter, is used to represent Jupiter. The moons will then range between 3 cm and 5 cm in diameter.

Divide students into groups of four, one for each moon, so they work cooperatively to decide on an appropriate scale.

Ask students to compare their models with that of the Earth-Moon system prepared in part 3 of this package.

Activity 8.4 Design an alien

Some scientists believe Jupiter's moons may harbour life, especially in the liquid oceans that are believed to lie below the surfaces of Europa and Ganymede.

In this activity students are asked to design an alien that could live on one of these environments. Assessment can be based on students' creativity, quality of scientific explanations, and inclusion of appropriate features for specific environments.

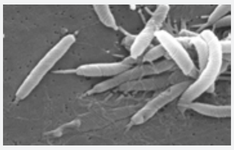
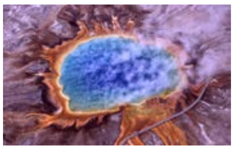
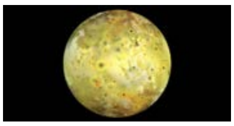
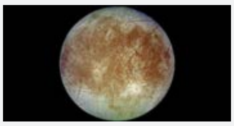
Connections may be made to the Year 5 Australian Curriculum for biological sciences:

> Living things have structural features and adaptations that help them to survive in their environment (ACSSU043)

Does the alien display analogues of characteristics indicative of Earth-based life?

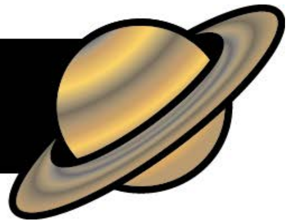
- Living things are composed of cells.
- Living things are organised (cells, organs, systems, organism).
- Living things use energy.
- Living things respond to their environment.
- Living things grow.
- Living things reproduce.
- Living things adapt to their environment.

Table 8.1 Images from the presentation, *Extremophiles*.

	*Surirella* is a microorganism that thrives in the hypersaline environment of salt lakes. Typical length: 200 μm (about the width of a human hair)
	The scaly-foot gastropod lives on hydrothermal vents in the deep Indian Ocean. Its 'feet' are reinforced with so much iron sulfide that the animal sticks to a magnet. They can withstand high temperatures. Average diameter: 35 mm
	Tardigrades, also known as waterbears, are perhaps the ultimate survivors. They can handle the vacuum of space, boiling water, temperatures close to absolute zero (-273°C), high radiation doses and ten years without food or water! Average length: 0.5 mm
	Methane ice worms like to live around methane ice mounds deep on the ocean floor. Temperature, pressure, and methane levels – all extreme! Typical length: 2 – 4 cm
	Snottites are found in some of the toughest environments on Earth. These bacterial extremists line the walls and ceilings of caves, where acid levels exclude all other life, and the only thing to eat is sulfur.
	*Helicobacter pylori* is a bacteria that thrives in the acidic conditions of your stomach, where it can cause ulcers. Scientists Barry Marshall and Robin Warren, working at The University of Western Australia, received the 2005 Nobel prize for medicine for this discovery. Typical size of bacteria: 1 – 5 μm
	The bright colours of the Grand Prismatic Spring in Yellowstone National Park are caused by bacteria, known as thermophiles, that grow in waters that are nearly boiling. Different colours are caused by bacteria that prefer different temperatures.
	When Galileo pointed his newly invented telescope at Jupiter he was surprised to see four 'moons' going around the planet. Until then most people believed everything in the Universe went around Earth.
	Io (pronounced 'eye-oh') has over 400 active volcanoes that produce sulfur plumes and lava flows. Io has a rocky surface with a yellow coating of sulfur.
	Europa is a rocky moon with a very smooth, icy surface. Scientists believe there is a vast ocean just under Europa's surface.
	Ganymede is made of a mixture of rock and ice. It has an underground ocean and a surface covered in impact craters.
	Callisto is made of a mixture of ice and rock. It has a very ancient surface that is covered in more craters than any other body in the Solar System.

Student worksheets

My space postcard

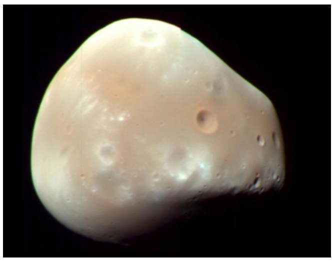


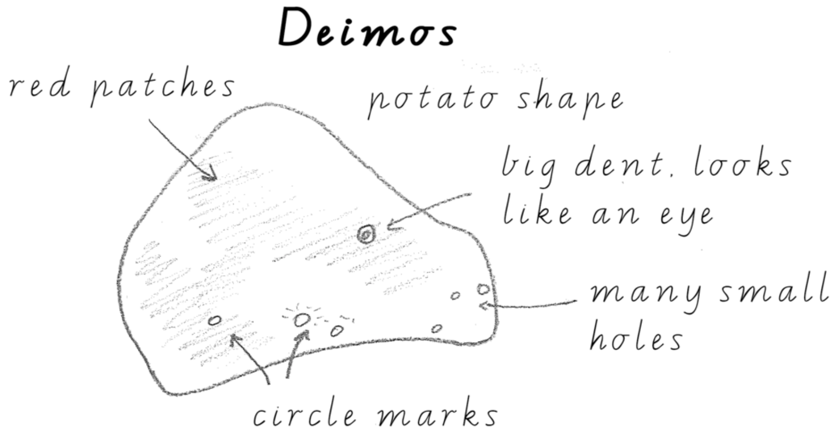
Look closely at the picture on your postcard and read the message on the back.

Observe

Draw and label a diagram of the space object on your postcard.
Look for patterns, shapes, colours and shades.

Example:





Compare

How do features on your postcard compare to things that you are familiar with, such as mountains and oceans on Earth?

This space object ....

looks like ....

Deduce or infer

What do you think about this space object, and why? For example, I think this space body has rivers because it has patterns like rivers on Earth.

I think this space object ....

because ....

....

Questions

What questions do you have about your postcard? For example, how was this picture taken? Why is there a shape like a bear on it?

How ....

.... ?

Why ....

.... ?

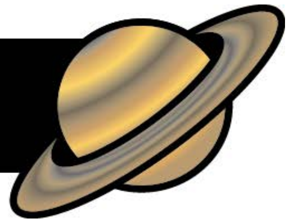
Where ....

.... ?

What ....

.... ?

Introducing *Celestia*



Use *Celestia* to explore the Solar System.

Keyboard shortcuts and mouse actions will help you get around. You can also use drop-down commands in the tool bar.

ACTION	MOUSE ACTION	KEYBOARD COMMAND
zoom in or out	scroll wheel	**home** or **end** keys
move selected object	hold left button down while moving mouse (Macintosh: hold button down while moving mouse)	
move object to centre	double-click	**C** (with object selected)
tilt up or down, or rotate around object		keyboard arrows
show or hide information text		**V**
move around an object	hold right button down while dragging mouse (Macintosh: hold **option** key and button down while moving mouse)	
speed up time		**L** (10 times faster for each press)
slow down time		**K** (10 times slower for each press)
changes time direction		**J**
normal speed		****
pauses or resume		**spacebar**
synchronises with object		**Y**
normal viewing state: 'follow'		**F**
current date and time		**!**
go to a planet		press <planet number> then **G** Mercury is 1, Venus 2, Earth 3, Mars 4 …
go to the Sun ('Home')		**H** then **G**
orbit lines on or off		**O**
planet labels on or off		**P**
Moon labels on or off		**M**
go to a named object		Type <**return/enter**>, name of object, <**return/enter**>, **G** Eg <**return**> Cassini <**return**> **G**

Earth

1. Experiment with your view of Earth using different keyboard and mouse commands. Change the speed of time.

   When it's daytime in Australia, which continent is in darkness?

   ....

2. Centre your view of Earth (**C**) and make sure information display is on (**V**). Speed up time (**L**) until you can see the Moon travelling in its orbit.

   Move away from Earth (**end**) until the Moon passes in front of you in its orbit. How far from Earth are you now?

   ....

Moon

3. Find the Moon (<**return**> moon <**return**> **G**).

   Does the Moon have night and day?

   ....

4. Does the Moon go around Earth?

   ....

5. Does the Moon go round the Sun?

   ....

6. How big is the Moon (what is its radius)?

   ....

Planets

7. Turn on orbit lines (**O**), centre on the Sun (**H**, **G**), and zoom out several times (**end**). Use the mouse (right click hold and drag) to move around until you are looking down on the planets' orbits. Use the menu bar to set the date to the day you were born. Zoom out further until you can see at least the four inner planets (Mercury, Venus, Earth, Mars).

   Sketch the Solar System with the position of the planets on the day you were born. Think of a clock face to help you copy from *Celestia* to paper.

8. Which was the closest planet to Earth when you were born? Compare with other students and your teacher. Do your answers vary?

   Your answer: *(birthday: ....)* *closest planet:* ....

   student 1: *(birthday: ....)* *closest planet:* ....

   student 2: *(birthday :.....................)* *closest planet:* ....

   teacher: *closest planet:* ....

9. Speed up time. Do all the planets orbit Earth in the same direction?

   ....

Planets

10. Turn text on (**V**), then visit each planet (<planet number> **G**) to complete the table below. Type **M** to turn Moon names on or off.

NUMBER	PLANET	COLOUR	RADIUS km	TYPE rocky, gas/ice giant	MOONS 0, 1, 2, many
1					
2					
3	Earth	blue and green	6,378 km	rocky	1
4					
5					
6					
7					
8					

Satellites and spacecraft in the Solar System

11. Satellites and spacecraft sent into space have sent back some of the pictures used in *Celestia*. Find out where spacecraft *Cassini* is now (<**enter**> Cassini <**enter**> **G**). Zoom out (a long way) and move around to find which planet *Cassini* is studying.

    Which planet is *Cassini* studying?

    ....

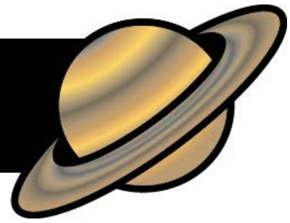
12. Turn on orbit lines. Describe *Cassini's* orbit (the red lines).

    ....

    ....

    ....

Introducing *Stellarium*



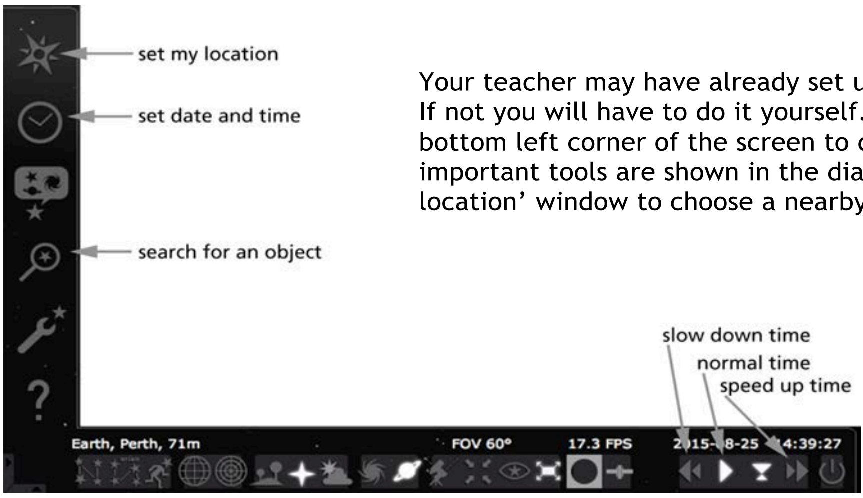
Stellarium is a computer program that shows what you can see in the night sky, from any place, at any date and time in the past, present or future.

Open *Stellarium*.

Check the information bar at the bottom of the screen. It gives the location and time.

In this example we're on Earth, in Perth, 71 m above sea level. It's just after half past two in the afternoon, on 25 August 2015.

Your teacher may have already set up *Stellarium* for your location. If not you will have to do it yourself. Move the mouse into the bottom left corner of the screen to display two tool bars. Some important tools are shown in the diagram below. Use the 'set my location' window to choose a nearby city.



Experiment with *Stellarium* for a while so you are familiar with the main keyboard commands, listed below, as well as moving around with the mouse.

If you get stuck in space anytime just quit the program and start again.

KEY	COMMAND
J	slow down time
K	normal time
L	speed up time
-	go back 1 day
8	go to present time
=	go forward 1 day
A	turn atmosphere on/off
G	turn ground on/off
B C R V	display constellation boundaries / lines / artwork / names
E	show a grid in the sky
<**page up**>/<**page down**>	zoom in/out
<**space bar**>	move selected object to screen centre (click an object to select it)
/ or ****	zoom in or out of selected object

When you start *Stellarium* will probably be looking south over a pleasant green field. *Stellarium* knows a lot about stars and other objects in the sky, but generally uses this same view for every location on Earth!

Use the mouse to drag the view around until you are looking west (the letter **W** is visible on the horizon) and the screen shows half sky and half ground. Not much seems to be happening, but if you check the information bar at the bottom of the screen you will see time is passing by, at its usual rate.

Looking at the night sky

1. Speed up time by pressing the **L** key four times and then wait for the Sun to set. Describe how the Sun and stars move in the sky when you are looking west.

   ....

   ....

   ....

2. Some of the objects moving in the sky are labelled. Do you recognise any of these names? Write down three objects that you see moving and what you think they are.

   1. ....

   2. ....

   3. ....

3. Use the mouse to change your view so you are looking north, then east, and finally south. Describe the direction stars move in the night sky.

   When I look north the stars move:

   ....

   When I look east the stars move:

   ....

   When I look south the stars move:

   ....

4. Keep facing south, but use the mouse to drag the view so you are looking higher in the sky. The sky should just about fill the screen, with only a small amount of ground at the bottom. Describe how the stars move in the night sky. (Turning the grid on, **E**, might help).

   ....

   ....

5. Imagine stars are painted on your classroom ceiling. You are sitting in a swivel chair, looking up at them, and someone spins your chair around. What would you see?

   ....

   ....

   ....

6. Why do you think stars move in the night sky? Are they really moving?

   ....

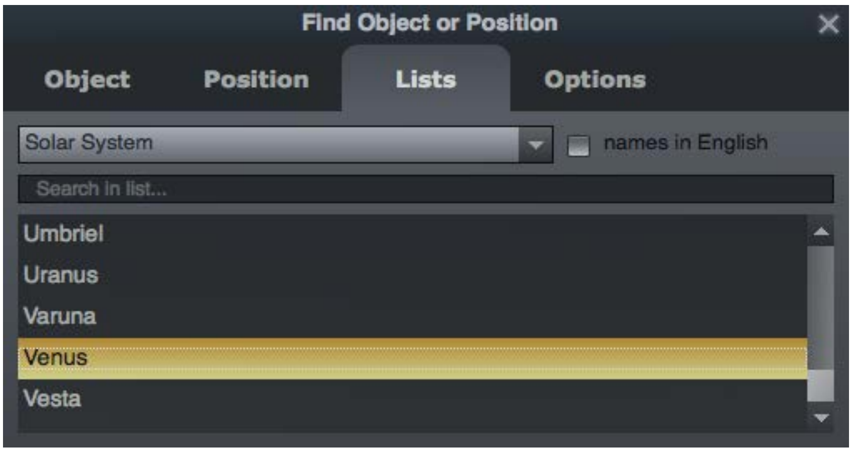
   ....

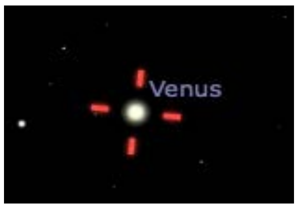
   ....

Looking at planets

Reset time to the present (**8**) and normal rate (**K**).

Now you will use *Stellarium* to look at the planet Venus. This is one of the inner planets (the planets closest to the Sun). There are several ways to choose objects in *Stellarium*: an easy way is to open the search window and choose Venus from the list of Solar System objects. Double-click to select it.





The view will change so Venus is in the middle of the screen, marked by four red lines, but you may not be able to see the planet at first.

7. Why might Venus be hidden from view at first?

....

....

....

8. Speed up time by typing **L** four times. Describe how Venus moves through the sky over 24 hours.

....

....

....

9. Venus is often known as the morning star or the evening star (although it is a planet, not a star). Why do you think it has these names?

....

....

....

10. Use this diagram to explain why inner planets like Venus are sometimes only visible in the night sky for a short time.

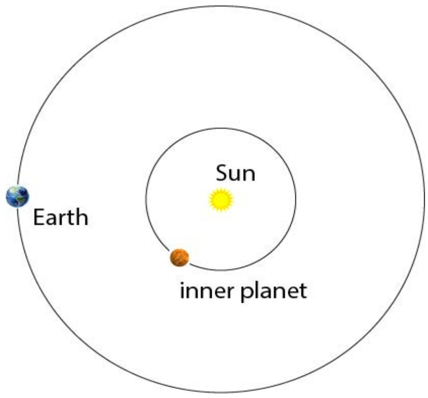
....

....

....

....

....



Use a *Stellarium* trick to make it easier to see Venus.
Type **A** to turn off the atmosphere: now you can see stars and planets, including Venus, even when its day. Wait until Venus is clearly visible above the horizon, then set normal time (type **K**).

11. Type the equals sign (=) to jump forward one day. Keep advancing one day at a time to see how Venus moves in the sky. Turning on constellation display (**B** and **C**) may help. Describe how Venus moves in the night sky, compared with the stars.

....

....

....

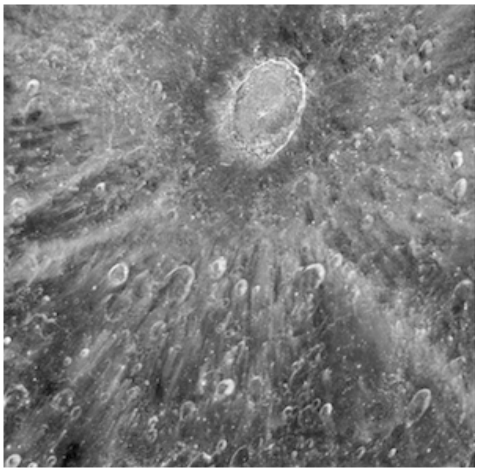
Planet surfaces

When you look at images of the Moon and some planets the most obvious feature is often craters. The Moon is covered in craters. Even craters sometimes have craters! Craters on the Moon often have 'rays', lighter streaks that surround them.

Craters can be made in several ways, but on the Moon they are known as impact craters. They are created when asteroids slam into the Moon's surface. Material from deep underground is thrown out to make the rays.

In this activity you are going to recreate a landscape with craters. You will need to start by making the ground layers. What will you use: white and yellow sand, or flour and cocoa powder?

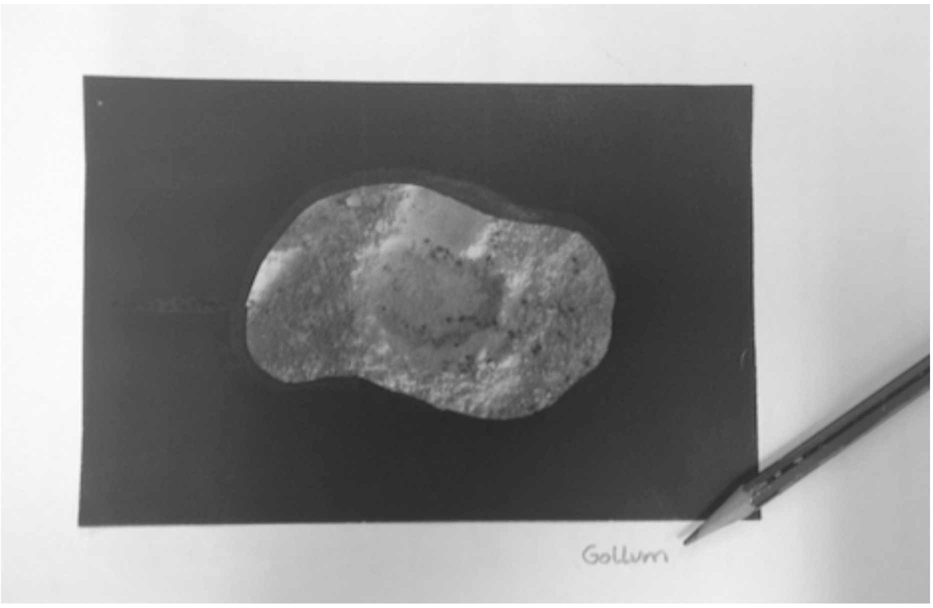
Perhaps you could include some 'rocks' in your ground. Then you will need some asteroids. How big or heavy should they be? From what height will you drop or throw them?



Tycho crater on the Moon

NASA, ESA, D. Ehrenreich
IPAG/CNRS/Université Joseph Fourier

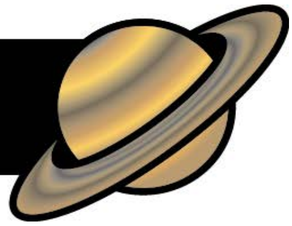
Your task is to investigate how craters are made. Take photos of your successful craters and print them out on paper. Draw a planet shape on the back, cut it out and stick it onto black card to create your own space object. Don't forget to name it: astronomers often name space objects after characters from mythology or books.



Not all features on planets and moons are created by impacts. Astronomers also see evidence of action by wind and water. Can you modify your investigation to look at these effects? Perhaps you can tilt your landscape and pour water from a jug along the surface. Can you blow loose sand into sand dunes using a straw? Look at space images of moons, planets and asteroids for ideas.

Write an explanation of how your space object and its features formed. Use scientific terms to describe the object and its features.

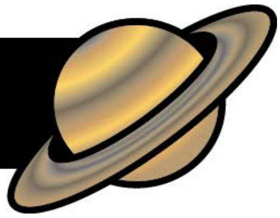
Planet facts



PLANET NAME		SCALE DRAWING:
REAL DIAMETER		
REAL DISTANCE FROM SUN		
MODEL DIAMETER		
MODEL DISTANCE FROM SUN		
DAY LENGTH		
YEAR LENGTH		

INTERESTING FACTS ABOUT THIS PLANET

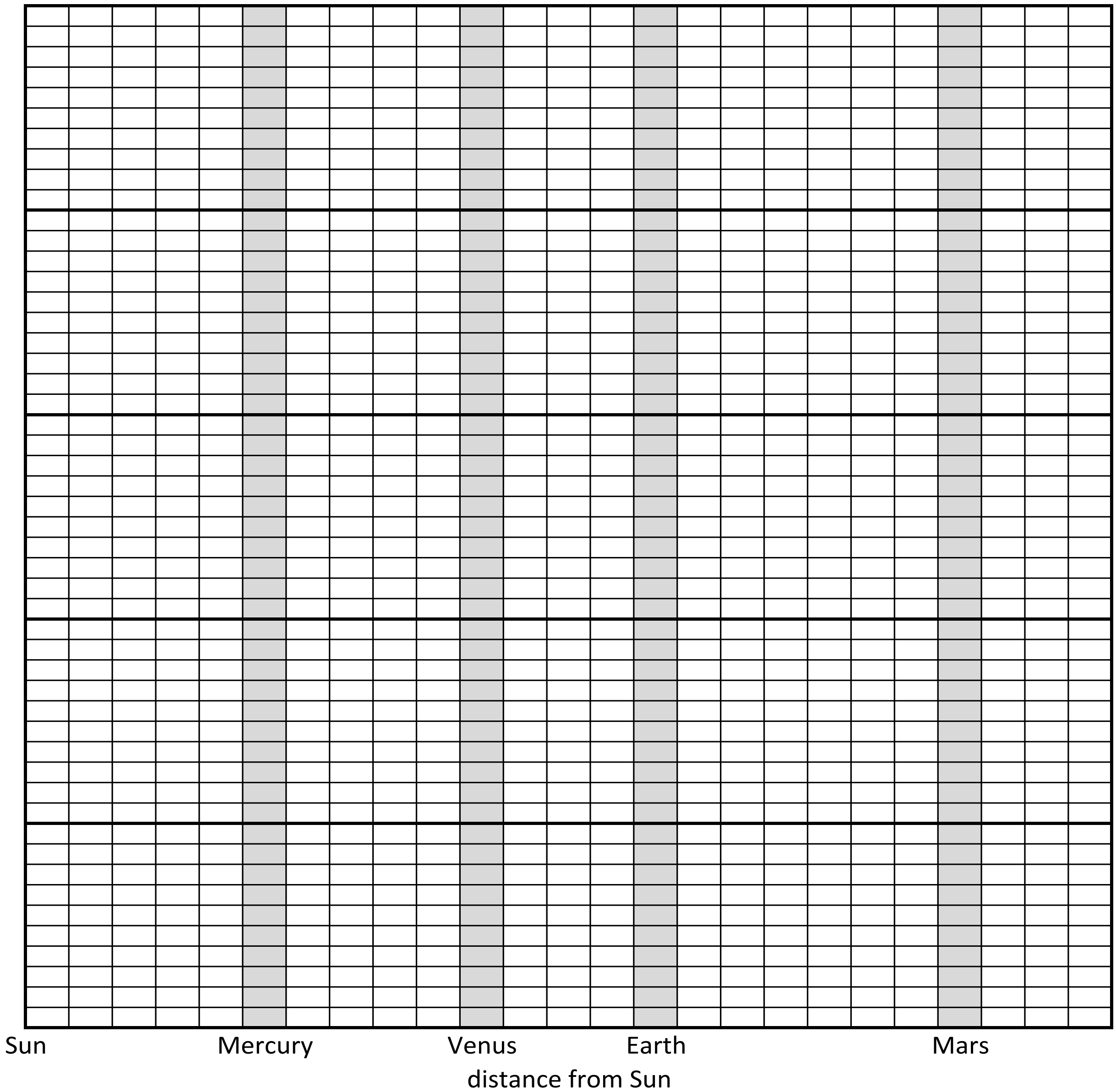
Planet orbits



Use this graph to compare variables for the four inner planets (Mercury, Venus, Earth and Mars).

Shaded vertical bars show how far each planet is from the Sun, to scale.

Choose your own variable to plot on the vertical axis (for example, how long a planet takes to orbit the Sun).



Describe any patterns you see:

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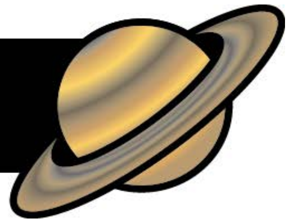
Jupiter’s moons



Jupiter has 63 moons, but many of them are small. The smallest have a diameter of only a few kilometres. Jupiter’s four largest moons are known as the Galilean moons, after their discoverer, Galileo. He was the first to see them with the newly invented telescope in 1610.

Use the table below to make a scale model or drawing of Jupiter and its four largest moons.

	DIAMETER	DISTANCE FROM JUPITER	TIME TO ORBIT JUPITER	CHARACTERISTICS
Jupiter	140 000 km	-	-	Jupiter is the largest planet in the Solar System. Like the Sun, Jupiter is mostly made of hydrogen, but unlike the Sun Jupiter is very cold. Jupiter’s surface is a mixture of liquid hydrogen and hydrogen gas.
Io	3 600 km	422 000 km	42 hours	Io has over 400 active volcanoes that produce sulfur plumes and lava flows. Io has a rocky surface with a yellow coating of sulfur.
Europa	3 200 km	671 000 km	85 hours	Europa is a rocky moon with a very smooth, icy surface. Scientists believe there is a vast ocean just under Europa’s surface.
Ganymede	5 300 km	1 000 000 km	172 hours	Ganymede is made of a mixture of rock and ice. It has an underground ocean and a surface covered in impact craters.
Callisto	4 800 km	1 880 000 km	247 hours	Callisto is made of a mixture of ice and rock. It has a very ancient surface that is covered in more craters than any other body in the Solar System.