# Unit 9J Gravity and space

## About the unit

In this unit pupils:

- learn about the gravitational pull between bodies; how it depends on the masses of bodies and the distance between them
- relate the movement of planets around the Sun, and that of satellites around the Earth, to gravitation
- study how artificial satellites are used to observe the Earth and provide information about the solar system and the universe
- find out about space exploration

In scientific enquiry pupils:

- consider different views of the nature of the solar system and evaluate them against relevant evidence
- how scientists work together to gather and interpret evidence from space
- make predictions from patterns in data
- consider and evaluate conflicting evidence

This unit is expected to take approximately 7.5 hours.

### Where the unit fits in

This unit builds on unit 7K 'Forces and their effects' and unit 7L 'The solar system and beyond'.

The unit relates to unit 9K 'Speeding up'.

It lays the foundation for work in key stage 4 on theories about the nature and evolution of the universe.

The historical impact of discoveries in astronomy is covered in unit 21 'Scientific discoveries' in the history scheme of work.

## Expectations

### At the end of this unit

### in terms of scientific enquiry

**most pupils will:** use a model of gravitational attraction to explain orbiting; describe how ideas of the nature of the solar system have changed over time and relate these to available evidence; make effective use of secondary sources to find information from recent space exploration about the nature of the solar system

**some pupils will not have made so much progress and will:** describe some early ideas about the solar system

**some pupils will have progressed further and will:** explain how experimental evidence has led to changes over time in models of the solar system; evaluate recent information and ideas about the origin of the Moon

### in terms of physical processes

**most pupils will:** recognise that gravity is a universal force of attraction between objects and that this force depends on their masses and distance apart; describe how weight is different on different planets; give examples of the use of artificial satellites

**some pupils will not have made so much progress and will:** recognise that weight is less on the Moon; describe gravity as a force which acts throughout the solar system; give examples of the use of artificial satellites

**some pupils will have progressed further and will:** use data to compare gravity on different planets; describe how the forces on rockets or satellites vary as they travel away from the Earth

## Prior learning

It is helpful if pupils know:
- that the gravitational attraction of the Earth on a mass causes weight
- about the planets of the solar system, how they orbit the Sun, and how satellites, *eg moons,* orbit them
- that forces affect the motion of bodies

## Health and safety

Risk assessments are required for any hazardous activity. In this unit pupils:
- use a fast-moving object to explore orbits

Model risk assessments used by most employers for normal science activities can be found in the publications listed in the *Teacher's guide*. Teachers need to follow these as indicated in the guidance notes for the activities, and consider what modifications are needed for individual classroom situations.

## Language for learning

Through the activities in this unit pupils will be able to understand, use and spell correctly:
- words with similar but distinct meanings, *eg mass, weight, gravitational attraction, orbit, revolve*
- words relating to planetary motion, *eg satellite*

Through the activities pupils could:
- understand the effect of different aspects of formality (*passive verbs, third person, abstract nouns*)

## Resources

Resources include:
- secondary sources on aspects of the solar system, space travel and satellites, *eg CD-ROMs, video clips, internet*
- a water rocket
- food packs labelled with the weight they would have on other planets
- information on early ideas and alternative models of the solar system and the universe from a range of cultures

## Out-of-school learning

Pupils could:
- visit libraries or museums to find out more about space travel and the exploration of other planets
- find out how reception dishes for satellite TV are aligned to the position of the satellite
- use the internet to communicate with space scientists online and access images from satellites, *eg NASA's websites www.nasa.gov*
- read books and watch films about space exploration and travel, *eg Apollo 13*

| 1 | Learning objectives<br>Pupils should learn: | Possible teaching activities | Learning outcomes<br>Pupils: | Points to note |
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| | **What is gravity?** | | | |
| | • that gravity is an attractive force which acts on the Earth towards the centre of the planet<br>• that gravity is an attractive force between objects with mass<br>• about how the idea of gravity was related to empirical observations | • Remind pupils of the distinction between mass and weight and that weight is the force due to gravity. Present pupils with a picture of the Earth and ask them to indicate what would happen to a ball dropped at different positions. Establish that the ball would fall towards the Earth and that this is the definition of 'downwards'. Generalise that gravity is an attractive force between any masses, but that we feel its pull only with very large masses, such as the Earth.<br>• Use the historical association of the newton to highlight that the concept of gravity was a very difficult one for scientists to understand. Explain that while Newton did not 'discover' gravity, he formulated the concept mathematically and realised its importance, at levels ranging from apples falling from trees to the orbits of planets. Drop an apple into pupils' hands to feel the gravitational force of 1 newton. Ask pupils to lift masses of a known value and feel the attractive force of the Earth's gravity pulling them back. | • state that a ball dropped anywhere on the Earth will fall towards the centre of the planet, due to the attractive gravitational force between masses<br>• use the idea of gravity to explain a range of observations both familiar and novel | • It is important for pupils to realise that gravity is associated with physical bodies, and not with a concept of 'down-ness'.<br>• Whilst there is some doubt over the accuracy of the story involving the falling apple, it is one which pupils may know and be interested in. It is a curious coincidence that the force of gravity on an average apple is about 1 newton.<br>• Pupils could use the value of the gravitational field strength of the Earth ($10 Nkg^{-1}$) to work out the force in newtons on different masses (relates to unit 7K 'Forces and their effects'). |
| | **How does gravity change?** | | | |
| | • that where the gravitational force is lower than on the Earth, the mass of an object remains the same, but its weight is less<br>• to use quantitative relationships | • Pupils may have been introduced to the idea that they would weigh less on the surface of the Moon in unit 7K 'Forces and their effects'. Remind them of this using video images of lunar exploration. Ask them to explain why they think this is, ensuring that they recognise that mass is unchanged. Encourage inference, *eg The gravity is less on the Moon*. Using questions, *eg Why should it be less?,* helps pupils to relate the decrease to the lesser mass of the Moon.<br>• Tell pupils that the Moon's gravitational pull is about one sixth that of the Earth's and ask them to calculate the weight of everyday objects if taken to the Moon. Ask them to imagine how this might affect daily life on the Moon, *eg What things would be easier to do? What would be more difficult?* Extend by providing data on the gravitational pull on different planets in the solar system. Reinforce this by showing pupils a number of cereal packs or bags of sugar, which look the same but are labelled with the weight they would be on each of the planets. Label each with the planetary name, and ask pupils to handle them to get an idea of the differences. | • use information provided to determine the mass and weight of objects on the Moon and other planets<br>• describe the implications of this for visitors to those places<br>• calculate and describe variation in weight | • The use of thought experiments, ie 'imagine what would happen if', is a good means of eliciting pupils' ideas and understanding about what is an abstract and difficult concept.<br>• Extension: ask pupils to consider the journey from the Earth to the Moon and back. As the Moon is approached, its gravity starts to aid the spacecraft by exerting a pull on it. This helped NASA to get Apollo 13 back to the Earth.<br>• Extension: pupils could work out their weights on other planets. |

| 2 | Learning objectives<br>Pupils should learn: | Possible teaching activities | Learning outcomes<br>Pupils: | Points to note |
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| | • that gravitational attraction between bodies decreases as the distance between them increases<br>• about some examples of space exploration | • Ask pupils to think about how rockets get away from the Earth. Illustrate using secondary sources, *eg using software simulations or video clips of space shuttles,* or demonstrate with a water rocket.<br>• Establish that, for a rocket to get off the ground, a thrust force greater than the rocket's weight is needed. It is clear that it gets easier the higher the rocket travels (less fuel is needed). However, the rocket has less mass, having shed some of its load, so it would be accelerating even if gravity were the same.<br>• Ask pupils to use secondary sources to present an account of space exploration. | • show, *eg by a force diagram*, that a rocket needs a large upward force to rise against gravity<br>• describe, *eg using annotations*, that the gravitational force decreases as the rocket gets further from the Earth<br>• describe some of the landmarks of human exploration of space, *eg Yuri Gagarin, Valentina Tereshkova, Neil Armstrong, Helen Sharman* | • There are many reference sources, including CD-ROM encyclopedias and internet sites, available to support this activity, *eg www.russianspace.com* and *www.exosci.com*, which pupils could research for themselves. Some pupils may need specific questions to answer.<br>• Extension: show a film of floating astronauts. Explain that they are not in a gravity-free region but are actually falling freely in the space capsule. Show video clips of free-fall skydivers or a demonstration of an object on a forcemeter 'losing its weight' (ie reading zero) as it falls. |
| | **Checking progress** | | | |
| | • that the weight of an object can vary whilst the mass remains the same | • Provide pictures of stages in a mission to the Moon. Ask pupils to sequence these and to write about how gravity is influencing the journey at different points, *eg at take-off, in orbit, leaving orbit, halfway to the Moon, etc.*<br>• Extend by providing cards with possible weight and mass of astronauts, and ask pupils to write captions about how it would feel at different stages. | • describe how the effects of gravity change during a voyage to the Moon and relate this to mass and weight of astronauts | • The relationship of the attraction between two masses and their sizes is observed on Earth by the great discrepancy in size between the planet and typical masses. Pupils are likely to think that larger masses are simply heavier, rather than realising that there is a greater attraction between them and Earth. |
| | **How have our ideas about the solar system changed?** | | | |
| | • that our ideas about the solar system have changed over time<br>• to consider and evaluate conflicting evidence to arrive at a view<br>• to use more formal language appropriate to objectivity and impartiality | • Present, using secondary sources, some alternative models of the solar system, *eg the ideas of the ancient civilisations of Egypt, India, Greece, and the contributions of Thales, Aristarchus of Samos, Copernicus*. Ask pupils to consider a model and to use secondary sources, *eg internet sites, encyclopedias,* to suggest the evidence for and against it. Pupils could be asked to participate in a class debate defending a particular model, *eg that the Earth is the centre of the universe.*<br>• With the class, summarise the main strengths and weaknesses of each model and ask pupils to write up their own conclusion. | • describe an early model of the solar system and how it differs from our present model<br>• argue a point of view in defence of a model of the solar system, providing evidence for their position<br>• use more formal language in their summary, *eg passive verbs, third person* | • This activity provides an opportunity to illustrate early ideas about the solar system from a range of cultures. Pupils will not find it easy to provide evidence which contradicts some of these theories.<br>• A heliocentric model with orbiting planets requires an understanding of what maintains the planets in motion at fixed distances round the Sun. This was a major challenge to scientists. |

| 3 | Learning objectives<br>Pupils should learn: | Possible teaching activities | Learning outcomes<br>Pupils: | Points to note |
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| **What keeps the planets and satellites in orbit?** | | | | |
| | • that the Sun is massive and exerts a very large gravitational force, which keeps planets in orbit<br>• to relate the model of circular motion to data on the orbits of planets and satellites | • Show pupils a video on the formation of the solar system. Ask them to extract information about the effects of gravity on the resultant shapes and motions of the planets and other bodies. Discuss the main points with pupils.<br>• Help pupils to make the link between circular motion and inward force by swinging a rubber bung on a string in a circular motion. Point out the tension in the string, which suggests an outward pull by the bung. Help them to realise that the bung's circular motion can only be maintained by an inward force, which is exerted by the string. Ask pupils what would happen if the string were cut. This is a model of the gravitational pull exerted on the planets by the Sun. | • extract relevant information from a video<br>• explain that it is the Sun's gravitational force that keeps planets in orbit | • Pupils will find the link between the Sun's gravity and planetary motion difficult to accept. Many pupils think that something moving in a circle has an inherent circular motion and would continue to move in a circle of its own accord.<br>⚠ **Safety** – care is needed with fast-moving objects |
| | • that the Moon is a natural satellite of the Earth, whose orbit is maintained by the Earth's gravitational pull | • Relate the orbit of the Moon round the Earth to that of the planets round the Sun. Explain that since the Moon is so close to the Earth, its orbit is influenced by the Earth's gravity rather than that of the Sun.<br>• Help pupils to visualise how an asteroid could be captured into an orbit by the gravitational field of a planet, *eg using a software simulation*. | • state that the Moon is a natural satellite of the Earth, kept in orbit by the Earth's gravitational pull | • Pupils need to recognise that the Moon would travel in a straight line if it were not for the pull of the Earth's gravity. A software or video simulation would be useful to show this.<br>• Extension: the origin of the Moon in its current orbit has been of interest to astronomers for many years. Two opposing theories are:<br>– gravitational capture of an asteroid by the Earth<br>– an interplanetary collision during the early formation of the Earth, which threw off a ball of hot gases that have since coalesced to become the Moon<br>Pupils could find out about these two theories. Recent evidence supports the latter proposal. |

| 4 | Learning objectives<br>Pupils should learn: | Possible teaching activities | Learning outcomes<br>Pupils: | Points to note |
|---|---|---|---|---|
| | • about some uses of artificial satellites<br>• about information that can be gained through the use of satellites<br>• how scientists work together to collect information and make predictions | • Ask pupils to suggest ways in which we use artificial satellites, and to use secondary sources to find out more about these, *eg meteorological, communications, scientific research, telescopes, observatories.*<br>• Provide starting points for activities, *eg*<br>– *Produce a time line showing the main events in satellite technology*. Ask pupils to consider *What is the Global Positioning System (GPS) and how does it work? What impact have satellites had on everyday life?*<br>– *Make models or diagrams of satellites and find out what their different parts are for.* Ask pupils to consider *How are weather satellites used? What is a space station used for? How do scientists interpret information from satellites to make predictions?*<br>• Ask pupils to find out whether the satellites studied are geostationary or in polar orbit, and explain the significance of this. Discuss with pupils how information from satellites is sent back to Earth, emphasising the large distances. | • describe some uses of artificial satellites, *eg to assist weather forecasting, TV transmissions*<br>• explain why some satellites need to be in geostationary orbits<br>• describe how satellite probes provide information about the solar system and how this information is used | • Pupils could use an internet search engine to find out about satellites, including downloading live images from satellites showing weather conditions around the world.<br>• Pupils may have considered the use of weather satellites in unit 10 'Weather patterns over Europe' in the geography scheme of work and in unit 8 'Public information systems' in the ICT scheme of work.<br>• This topic could be enhanced by a visit to an establishment that makes use of data from satellites, or by a visit from a scientist. Hand-held GPS finders are available from equipment suppliers.<br>• Extension: pupils could be asked to answer questions using reference sources such as a CD-ROM, *eg*<br>– *How is a satellite maintained in orbit around the Earth?*<br>– *How is a satellite put into orbit?*<br>– *What different types of orbit are there and how are satellites maintained in them?* |
| | **Reviewing work** | | | |
| | • to review their knowledge and understanding of planetary and satellite motion | • Review pupils' understanding of work in this unit by asking them to work in groups, using their books, to make a list of five or six key points about gravity and space. Ask pupils to present their points and agree a summary of them as a class. | • produce key points related to mass and weight, the solar system, satellites | |