Part 1: Gravity on Earth

Learning Objectives

All	• Comprehend the terms mass and weight • Use the formula weight = mass x gravity • Run a scientific investigation, taking repeat readings to collect meaningful results
Most	• Identify anomalous data to generate more accurate results • Compare everyday evidence with evidence from the Moon to conclude air resistance prevents objects falling at the same rate
Some	• Rearrange the formula weight = mass x gravity • Analyse data to conclude that objects fall at the same rate regardless of mass (depending on choice of practical activity)

Suggested timeline of activities (times dependent on group)

Time & Activity	Activity details	Slide	Teaching notes	Differentiation
0-3 mins Introduction	Introduce topic, structure of lesson and lesson objectives (if required).	1 & 2	• Part 1 focuses on our experience of gravity on Earth and includes a practical investigation to measure the strength of gravity on Earth. • Part 2 describes how Big Telescopes are used to collect data about objects in space. • Part 3 uses a model to investigate how gravity behaves over large distances between planets and stars.	N/A
3-8 mins Part 1: Starter	Watch Felix Baumgartner's record breaking jump in 2012.	3	*Use the hyperlink on the slide to be taken to the official video on YouTube.* Felix Baumgartner is an Austrian skydiver. On 14th October 2012, he set the world record for skydiving by falling from 39 kilometres (24 miles) above the Earth's surface. On his descent he reached an estimated speed of 1,357.64 km/h (843.6 mph), or Mach 1.25. He became the first person to break the sound barrier without vehicular power.	N/A

8-10 mins Introduce Newton and mass	Introduce Newton's theory of gravity and set the lesson in historical context. Define the term mass.	4	Newton developed the first mathematical description of the force of gravity. Newton said that he started thinking about gravity after watching an apple fall from a tree (*it did not actually hit him on the head, as it is often claimed!*). After much work he realised it was the same force that was holding the Moon in orbit around the Earth. His theory perfectly described the force between the Earth and Moon and how they moved. *NB: Newton did not discover gravity; this is a common misconception. He was the first to realise that gravity extended out into space; that it was gravity which kept the Moon in orbit around the Earth and the planets in orbit around the Sun. Previous to this, it was thought to perhaps be a magnetic force.*	N/A
		5	Newton realised that any object which has mass produces a force of gravity and attracts other objects with mass. The size of that force increase as the object's mass increases. Mass refers to the amount of matter an object is made from. Mass is measured in grams and kilograms.	N/A
10-12 mins Introduce weight	Assess pupils' prior knowledge of weight.	6	*Present pupils with the image of the dog (there is no reason for it to be a dog, I just like dogs). Ask them to choose the force acting on the dog (represented by a force arrow), and then name the force. Most pupils would probably name the force as 'gravity'. This answer would be accepted in most KS3 tests; however the correct name for the force is 'weight'. This activity requires pupils to have a prior knowledge of representing forces with force arrows.*	Pupils could vote on their choices using voting cards, or mini-whiteboards. For higher achieving pupils the options could be deleted and pupils could draw their answer on the board, if using an IWB. Alternatively side 6 could be printed out for pupils, to answer individually or in pairs/groups.

12-14 mins Summary	Summarise the difference between the terms mass and weight.	7	*Summarise the difference between the terms mass and weight using the table and introduce the equation which relates the two. Some pupils often struggle to understand 'mass' and the difference from 'weight', since the terms are used in everyday life interchangeably.*	Peer support could be used for pupils who are struggling. Pupils could be asked to consider situations where weight would be different, but mass the same.
14-20 mins Questions	Assess pupils understanding of mass and weight, by using the equation.	N/A	*See the accompanying document 'Mass and Weight Worksheet'. The questions require pupils to use the formula W=mg. The Earth is not used as an example on this worksheet, since measuring the strength of gravity on Earth is the objective of the following practical activity. For the answers go to Answers to the Mass and Weight worksheet.*	The questions supplied become gradually harder. Select and use the questions suitable for your group.
20-32 mins Practical activity 1	Practical investigation measuring the strength of gravity on Earth.	8	*See section Practical activity 1 for more information about the various practical activities available at this point.*	Pupils could be placed in mixed ability groups, for peer support. Alternatively, different groups could complete different experiments based on their achievement. Pupils could then compare to see if different methods gave the same results.
32-36 mins Determine anomalous readings	Pupils identify and delete anomalous readings.	9	*Depending on which practical activity your pupils have followed, they may need to identify and delete anomalous readings. This will be especially important if they have completed a data logging or freefall timing activity.*	Pupils could decide within groups which are the anomalous readings. Alternatively pupils could take copies of the results and analyse them individually.

36-40 mins Reflect on practical	Pupils review their findings and methodology.	10	*Pupils bring together their results, to form a class average. The first three questions on slide 10 provide pupils with a structure to evaluate their results and their methodology.* *The fourth question has been specifically included if you have completed a freefall practical and have used differing masses of similar sizes. In this case, acceleration results should be independent of mass (depending on quality of results) and some pupils may be able to discern this.*	If you have completed a freefall practical and used differing masses of similar sizes, some higher achieving pupils may be able to recognise that acceleration of fall is independent of mass (depending on the quality of pupils' results).
40-42 mins Consider a popular misconception: that heavy objects fall quicker than lighter objects	Test prior knowledge of misconception.	11	*If pupils concluded that freefall acceleration is independent of mass in the above practical, this can be linked to the activity below.* *Ask pupils to consider a hammer and a feather. Which one has the largest weight force? Which one will hit the ground first when dropped?* *Why?* *The hammer will have the largest weight (shown by the larger force arrow). On Earth, the hammer will fall to the ground quickest, but this is **not** because it is heavier.*	Pupils could vote on the correct answer, maybe using voting cards, or mini-whiteboards. Higher achieving pupils could be asked to explain why the hammer falls to Earth quicker, to better assess prior knowledge.

42-46 mins Address misconception that heavy objects fall quicker than lighter objects	Show evidence contradicting misconception.	12	In 1971, during the Apollo 15 mission on the Moon, Commander David Scott dropped a 1.3 kilogram hammer and a 3 gram feather from the same height. *Click the link to watch this video on YouTube. The quality is not great due to the 1970s recording technology. Hopefully it can be seen that both objects hit the Moon's surface at the same time.* *It's possible to complete this as a demonstration in the classroom, with a 'guinea and feather tube' and a vacuum pump*[1].	Pupils could be asked to predict what will happen. Higher achieving pupils could be asked to rationalise their choice, lower achieving pupils could vote on a number of multiple choice options.
	Pupils re-examine evidence based on new knowledge.	13	*Ask pupils to re-evaluate everyday experience, with new understanding.* *The only reason that a feather falls slower than a hammer on the Earth is that **air resistance** has much more of an effect on the feather. The Moon on the other hand is a vacuum. Since it has no atmosphere, there is no air resistance slowing the feather's descent.*	Some pupils may be able to answer this question directly. Others may require further support, such as a list of differences between the Moon and Earth. Pupils could answer in groups, or think-pair-share.
46-50 mins Review of Part 1	Assess whether learning objectives have been met.	14	*To assess the learning objectives of part 1, pupils can answer the six questions presented on slide 14.* *See Answers to the Part 1 Review for the answers.*	Pupils could peer assess their answers and suggest improvements where necessary.

[1] An example of this experiment being done can be found at https://www.youtube.com/watch?v=clom4DdnFfM

Part 2: Big Telescopes

Learning Objectives

All	• Set 'Part 3: Gravity in Space' in a real-world, global context • Understand that science is ongoing and new scientific projects are underway • Inspire pupils with the scale and scope of scientific enquiry
Most	• Comprehend that visible light is not the only sort of wave that travels through space and that other waves show different things
Some	• List the advantages of building big telescopes

Suggested timeline of activities (times dependent on group)

Time & Activity	Activity details	Slide	Teaching notes	Differentiation
0-2 mins Introduce Part 2	Introduce idea that astronomers need to collect data. Introduce learning objectives if required.	15	In order for astronomers to study gravity in space, they need to make observations of planets and stars with telescopes. But why do astronomers need to study gravity?	N/A
2-4 mins Current gravity research	Introduce concept that science research is ongoing and there is still a lot we don't know.	16	There is still a lot we don't know about gravity in space. For example, we don't know if our current theories of gravity are completely correct, or what happens when gravity is very strong, or very weak[2]. Looking at the effects of gravity can also tell us about the universe and help us answer questions, such as, "What is Dark Matter?" We need telescopes to look into space to answer these questions (and many more!).	N/A

[2] Seven mysteries about gravity: http://www.newscientist.com/special/seven-things-that-dont-make-sense-about-gravity

4-6 mins Telescope example	Introduce VLT (Very Large Telescope) as example of current big telescope.	17	Telescopes can be thought of as giant eyes which have been built to collect more light and see objects better. This is the VLT (Very Large Telescope) and a picture of the Sombrero Galaxy taken by it. It is owned and run by ESO (the European Southern Observatory). There are 15 countries involved in ESO, including the UK. The VLT is made up of 4 telescopes, each 8 m across. Each telescope uses a curved mirror to collect light and focus it on to a detector. The 4 telescopes can work individually or all together to boost their seeing power. The VLT is 2.6 km high, on a mountain in Chile where the air is very thin. This means it has an extremely clear view of the sky. It also uses a laser to measure distortions in the air (this is called Adaptive Optics). This means it can take even better quality images[3].	For higher achieving pupils, this could be extended into a research task. Pupils could look up this and/or other big telescopes around the world and present their findings to the rest of the class[4].

[3] More information on the VLT can be found here: http://www.eso.org/public/teles-instr/vlt/
[4] A list of the ten biggest telescopes in the world can be found here: http://www.space.com/14075-10-biggest-telescopes-earth-comparison.html

6-7 mins Astronomy at other wavelengths	Introduce telescopes that observe other forms of (electro-magnetic) radiation.	18	Light is a form of (electro-magnetic) radiation, but there are many others. Astronomers don't just use telescopes that look at light, they also use telescopes designed to pick up these other forms of radiation. Here are three examples: The SOHO (SOlar and Heliospheric Observatory) satellite a joint mission by the European Space Agency and NASA. Launched in 1995, SOHO observes the Sun in light and ultra-violet rays. SOHO is orbiting in space 1.5 million kilometres from Earth[5]. NASA's James Webb space telescope is due for launch in 2018. It will observe cool objects in the universe by detecting infrared radiation. It will look for the first galaxies after the Big Bang and see how stars and planets form in massive clouds of gas and dust[6]. The Lovell telescope at Jodrell Bank in Cheshire is part of the University of Manchester. It was built between 1952 and 1957 and it picks up radio waves from objects like exploding stars, dead stars and galaxies out in space. Its dish is 76 metres across, which makes it the third largest steerable telescope in the world[7].	Some pupils may be familiar with some other forms of radiation, especially infrared radiation (which can be felt as heat). This is the same radiation that is picked up by heat and night vision cameras. *This content links in to most Key Stage 4 specifications on the electro-magnetic spectrum.*
7-8 mins Example of observations	Example of an observation in another form of radiation.	19	This is an image of the Sun as it appears to our eyes, in visible light (*warning: never look directly at the Sun!*). By looking with ultra-violet rays however, we can see many more features that we couldn't before. This image was taken by the SOHO satellite. By looking with other forms of radiation, astronomers see things that would be completely invisible in ordinary light. Other forms of radiation reveal a hidden universe!	N/A

[5] More on SOHO at: http://sohowww.nascom.nasa.gov/
[6] More on James Webb Space Telescope here: http://jwst.nasa.gov/index.html
[7] More on the Lovell telescope at: http://www.jb.man.ac.uk/aboutus/lovell/

8-9 mins Advantages of big telescopes	List the advantages of big telescopes.	20	Right now scientists and engineers around the world are building new, bigger and better telescopes. Big telescopes see better than smaller ones, but why? Firstly, big telescopes collect more light, so can see fainter objects (like eyes widening in the dark). Big telescopes also create better quality (sharper) images[8].	Some pupils may be able to predict that big telescopes can collect more light, especially if prompted to consider the eye as an analogy. Pupils could think-pair-share their ideas.
9-10 mins Example of future telescope	Example of a future science and engineering development.	21	With modern technology (e.g. supercomputers and fibre-optic data networks) it is preferable to build many linked smaller telescopes, rather than single large ones. The Square Kilometre Array (SKA) will be the largest radio telescope in the world, built of over 3000 smaller dishes, spread across the deserts of Australia and South Africa[9]. It will act like one giant telescope thousands of kilometres wide. A telescope that size would be impossible to build as one giant dish! The SKA will be so powerful it will be able to detect organic molecules in space. The SKA is being built by a global partnership of ten countries: Australia, Canada, China, Germany, Italy, New Zealand, South Africa, Sweden, the Netherlands and the United Kingdom (India is also an Associate Member).	N/A

[8] The explanation for this is A-level physics, so it is not addressed here, but it can be found at http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/cirapp.html
[9] More information on SKA can be found at http://www.skatelescope.org/

Part 3: Gravity in Space

Learning Objectives

All	• To comprehend the terms star, galaxy and universe
Most	• Use a 3D model of gravity to address the misconception that there is no gravity in space
Some	• Evaluate a 3D model of gravity

Suggested timeline of activities (times dependent on group)

Time & Activity	Activity details	Slide	Teaching notes	Differentiation
0-3 mins Introduce Part 3	Introduce gravity on a larger scale.	22	Now we will consider how gravity acts on larger scales; not only on the surfaces of planets, but further out. Gravity affects how all objects in space move, such as planets and stars. *As a starter: Pupils could guess what the picture on slide 22 shows. Pupils could write their guesses on mini-whiteboards or post-it notes.* The image shows an artist's impression, using real data from the European VLT telescope, of the stars which orbit the supermassive black-hole at the centre of our Milky Way galaxy and the cloud of gas which is falling into it. It's the force of gravity from the black-hole that is causing all this to happen.	Some pupils may not yet be familiar with the term galaxy.

3-5 mins Assess prior knowledge	Assess pupils' understanding of the direction of the force of gravity.	23	*Ask pupils which arrow correctly represents the force of gravity acting on the astronaut.* *Gravity will act between the centre of the astronaut and the centre of the Earth. Technically, gravity will act equally in both directions, but the effect of the force on the Earth from the astronaut is negligible (since the Earth is so massive) and so it can be ignored. The astronaut will be pulled towards the centre of the Earth.*	Pupils could vote on their choices using voting cards, or mini-whiteboards. For higher achieving pupils the options could be deleted and pupils could draw their answer on the board, if using an IWB. Alternatively side 23 could be printed out for pupils, to answer individually or in pairs/groups.
5-15 mins Practical activity 2	Introduce practical activity.	24	*See section Practical activity 2 for more information about the practical activity available at this point.*	High achieving pupils could be asked to design and construct their own models of gravity.
	Pupils use a 3D model of gravity.	25	*Slide 25 lists some examples of questions pupils could investigate using the equipment.*	Question 5 (what are the similarities and differences between this model and real life?) is aimed at high achieving pupils (see *Practical activity 2* for more information).
15-17 mins Identify examples in space where gravity acts	Example 1: Satellites	26	Gravity keeps satellites in orbit around the Earth. *A ball tethered to a piece of string and whirled overhead can be used to represent an orbit. The tension in the string represents the tug of gravity; preventing the ball/satellite from hurtling off into space.*	High achieving pupils could be asked to come up with a list of examples before being presented with slides 26-28. Other examples could include; keeping Moons in orbit around planets, the pull of black holes, galaxies interacting with each other, and so on.

<table>
<tr>
<td rowspan="2">17-21 mins

Identify further examples in space where gravity acts

Define terms star and galaxy</td>
<td>Example 2: planets</td>
<td>27</td>
<td>In exactly the same way, gravity keeps planets in orbit around the stars.

It is a common misconception that gravity drives the motion of the planets around the Sun. This is not the case. There is no force driving the planets around the Sun; the planets were formed in motion and there are no resistance forces in space to slow them down.</td>
<td>N/A</td>
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<tr>
<td>Example 3: Galaxies</td>
<td>28</td>
<td>Stars are grouped together in space in galaxies. On average a galaxy contains about 100 billion stars. Stars are held together in galaxies by the force of gravity between them.

This is a picture of galaxy NGC1300, taken by the Hubble Space Telescope. It is a barred spiral galaxy with two spiral arms (barred refers to the straight 'bar' of stars that runs through the central bulge of the galaxy). This is the same type of galaxy that we think our Milky Way galaxy is. We cannot take an image of our own galaxy like this, since we are inside it. Our Milky Way galaxy contains around 200 billion stars.

A popular analogy is that a galaxy is like a 'city' of stars; the stars being the individual houses in that city.</td>
<td>N/A</td>
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21-24 mins Define term universe	Consider image of Hubble Deep Field.	28	This is an image called the Hubble Ultra Deep Field, taken by the Hubble Space Telescope. The Hubble Space Telescope was pointed out into deep space to take this image. The image is of a tiny patch of sky, in which we can see almost to the edge of the observable universe. The image shows many galaxies, separated by vast distances of empty space. It is estimated that there are around 100 billion stars in the observable universe. The term universe refers to everything; all the matter and energy in existence.	Higher achieving pupils could estimate the number of stars in the observable universe; 100 billion stars per galaxy x 100 billion galaxies = 10^{24} stars. This number is larger than the total number of grains of sand on all the beaches of the Earth!
24-30 mins Review of Part 3	Assess whether learning objectives have been met.	29	*To assess the learning objectives of part 3, pupils can answer the eight questions presented on slide 29.* *See Answers to the Part 3 Review for the answers.*	Higher achieving pupils could be asked to review the 3D model of gravity used. That is: in what ways did the model successfully simulate the force of gravity? In what ways did it fail? How could the model be improved?