Calculating Gravity in the Universe

Key Stage 4

Topics covered: Gravity, weight, mass

Watch the video "What is gravity?"
https://vimeo.com/323700167

Introduction

Gravity is everywhere in the Universe. It is what keeps the planets orbiting around the Sun and makes sure your feet land back on the ground when you jump on Earth – not letting you drift off into space!

This resource is aimed at KS4 and will explore how weight and mass are linked to each other. We will be starting off with a few teacher notes to give you an outline of the activities included. You will then find printable activity sheets and answer sheets.

Teacher's Notes:

We recommend that you start off by showing your students our video 'What is Gravity?'. The video is available on our website (https://www.rmg.co.uk/discover/teacher-resources/what-is-gravity) and on our Vimeo page (https://vimeo.com/323700167).

There are two activities included in this resource for your students to try. Activity 2 follows on from activity 1 so doing both activities together is recommended. Each activity includes written instructions for the students. We recommend printing the activities on A4 sheets of paper.

In "**Weight and mass in the Solar System**" (pages 3 - 4), students are given a table of information and by using the equation relating weight and mass, students solve some mathematical problems to work out the weight of an object on different bodies on the Solar System.

The second activity "**Weight of a supermassive black hole**" (page 5), students use the gravity equation to determine the strength of gravity of the supermassive black hole lying at the centre of the Milky Way galaxy and in turn work out how much the object from the previous task would weight at the black hole.

Activity 1: Weight and mass in the Solar System

The force of gravity changes depending on where you are. Astronauts far away from the Earth working on the International Space Station experience far weaker gravity than humans on Earth. This is why we see them floating around the station!

Mass is a measurement of how much material an object is made of – it is unaffected by gravity and doesn't change (unless you happen to lose an arm or a leg)!

Weight is how heavy an object is due to the force of gravity.

The **strength of gravity** is measured at the surface of an object or for a gaseous object, where the pressure of the atmosphere is equal to 1 atm – the same pressure as the Earth's atmosphere at sea level.

Object	Gravity, g (m/s^2)	Weight of Cat, w (N)	Relative gravity	Mass, m (kg)
Sun	274			1.99×10^{30}
Mercury	3.7			3.30×10^{23}
Venus	8.87			4.87×10^{24}
Earth	9.81	29.43	1	5.97×10^{24}
Moon	1.62		0.17	7.34×10^{22}
Mars	3.72			6.42×10^{23}
Jupiter	24.79			1.90×10^{27}
Saturn	10.44			5.68×10^{26}
Uranus	8.69			8.68×10^{25}
Neptune	11.15			1.02×10^{26}

$$w = mg$$

Weight (N) = Mass (kg) x Gravity (m/s^2)

Mass is measured in kg and weight is measured in Newtons (N) which is a force.

Ant

Cat

Elephant

Our cosmic cat has been hopping on to different planets and we want to know how much he weighed on each!

1. Using the values in the table for the Earth, work out the mass of our cat.

Mass of cat, m = ______________ kg

2. Now that you know the mass of the cat, in fill in table with the weight of the cat on the Moon, Sun and all the other planets.

3. Often it is easier to compare the relative gravity. We use Earth as the basis for this so 1g = 9.81 m/s^2. With this information can you fill in the table to show the relative gravity of each of the objects in the table to show how strong their gravity is compared to the Earths. The Moon has been done for you.

   E.g. $\text{relative gravity} = \dfrac{\text{gravity of Moon}}{\text{gravity of Earth}} = \dfrac{1.62}{9.81} = 0.17$

4. Now take a look at the mass of each of our Solar System objects – what is the trend / pattern between an object's mass and its gravity?

5. Do you notice anything strange about one of these objects – why do you think this is the case?

Activity 2: Weight of a supermassive black hole

At the centre of our galaxy the Milky Way, there is a supermassive black hole called Sagittarius A*. Black holes are the densest objects in the Universe – let's find out how much our cosmic cat would weigh if it visited our black hole.

$$g = \frac{GM}{r^2}$$

$$\text{Gravity (m/s}^2\text{)} = \frac{\text{Gravitational constant (m}^3\text{/kg s}^2\text{) x Mass of object (kg)}}{\text{Radius of object}^2\text{ (m}^2\text{)}}$$

Sagittarius A*

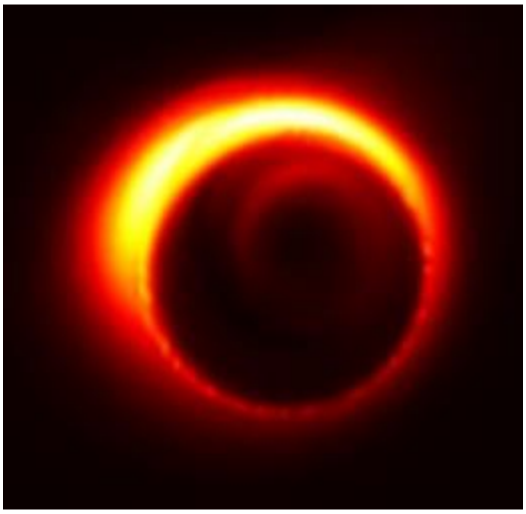
M = 5.17×10^{36} kg – this is the mass of the supermassive black hole

r = 22×10^{9} m – this is the radius of our supermassive black hole

G = 6.67×10^{-11} $m^3 kg^{-1} s^{-2}$ the gravitational constant – a number which never changes

1. Using the equation above, can you work out the strength of gravity, g, for the black hole?

2. Now work out the weight of the cat at the black hole and the relative gravity of the black hole compared to the Earth.



Calculating Gravity in the Universe: ANSWERS

Key Stage 4

Activity 1: Weight and mass in the Solar System

1. Mass (kg) = $\frac{\text{Weight (N)}}{\text{Gravity (m/s}^2\text{)}} = \frac{29.43}{9.81}$ = 3kg

2. See table below
   Use: Weight (N) = Mass (kg) x Gravity (m/s^2)
   Where Mass = 3kg in every case

3. See table below
   Use: relative gravity = $\frac{\text{gravity of object}}{\text{gravity of Earth}}$

Object	Gravity, g (m/s^2)	Weight of Cat, w (N)	Relative gravity	Mass, m (kg)
Sun	274	822	27.93	1.99 x 10^{30}
Mercury	3.7	11.10	0.38	3.30 x 10^{23}
Venus	8.87	26.61	0.90	4.87 x 10^{24}
Earth	9.81	29.43	1	5.97 x 10^{24}
Moon	1.62	4.86	0.17	7.34 x 10^{22}
Mars	3.72	11.16	0.38	6.42 x 10^{23}
Jupiter	24.79	74.37	2.53	1.90 x 10^{27}
Saturn	10.44	31.32	1.06	5.68 x 10^{26}
Uranus	8.69	26.07	0.89	8.68 x 10^{25}
Neptune	11.15	33.45	1.14	1.02 x 10^{26}

4. The more massive an object, the stronger gravity

5. Uranus has larger mass than Earth but lower gravity

   Uranus is a gas giant so it is not as dense as the Earth. The density of an object also affects its surface gravity. This is especially true with a gas planet as gas planets have no real surface like a terrestrial planet, the gravity measurement actually ignores much of Uranus as the surface gravity is measured when the pressure of the atmosphere is equal to 1 atm – the same as Earth's at sea level.

Activity 2: Weight of a supermassive black hole

1. $\text{Gravity (m/s}^2\text{)} = \dfrac{\text{Gravitational constant (m}^3\text{/kgs}^2\text{) x Mass of object (kg)}}{\text{Radius of object}^2\text{ (m}^2\text{)}}$

   $g = (6.67 \times 10^{-11} \times 5.17 \times 10^{36}) \div (22 \times 10^{9})^2 = 7.12 \times 10^5 \text{ m/s}^2$

2. Weight (N) = Mass (kg) x Gravity (m/s^2)

   $W = (3 \times 7.12 \times 10^5) = 21 \times 10^5 = 2{,}100{,}000 \text{ N}$

   $\text{relative gravity} = \dfrac{\text{gravity of supermassive black hole}}{\text{gravity of Earth}}$

   $\text{Relative } g = 7.12 \times 10^5 \div 9.81 = 72{,}628$

   At over 72,000 times heavier at the black hole, our cat might have a tough time moving. In fact, nothing can escape from a black hole if it gets too close – not even light which has no mass. Best not send any cats to Sagittarius A*!