Weight

Weight is the gravitational force that the Earth exerts on any object. The weight of an objects gives you an indication of how strongly the Earth attracts that body towards its centre. Weight is calculated as follows:

* Weight=*mg*
	+ where *m* = mass of the object (in kg)
	+ and *g* = the acceleration due to gravity (9,8*m*⋅s2)

For example, what is Sarah's weight if her mass is 50kg. Sarah's weight is calculated according to:

Weight=*mg=*(50kg)(9,8m⋅s2)=490kg⋅m⋅s2=490N



Weight is sometimes abbreviated as *Fg* which refers to the force of gravity. Do not use the abbreviation *W* for weight as it refers to `Work'.

Now, we have said that the value of *g* is approximately 9,8*m*⋅*s*2 on the surface of the Earth. The actual value varies slightly over the surface of the Earth. Each planet in our Solar System has its own value for *g*. These values are listed as multiples of *g* on Earth in [Table](http://cnx.org/contents/d85e3111-6378-49b7-b713-16ec667c7ef3%401/Gravity-and-mechanical-energy%3A#uid1)

|  |
| --- |
| A list of the gravitational accelerations at the surfaces of each of the planets in our solar system. Values are listed as multiples of *g* on Earth.**Note**: The "surface" is taken to mean the cloud tops of the gas giants (Jupiter, Saturn, Uranus and Neptune). |
| **Planet** | Gravitational Acceleration (multiples of *g* on Earth) |
| Mercury | 0,376 |
| Venus | 0,903 |
| Earth | 1 |
| Mars | 0,38 |
| Jupiter | 2,34 |
| Saturn | 1,16 |
| Uranus | 1,15 |
| Neptune | 1,19 |
| Pluto | 0,066 |

**Determining mass and weight on other planets**

Sarah's mass on Earth is 50kg. What is her mass and weight on Mars?

Differences between Mass and Weight

Mass is measured in kilograms (kg) and is the amount of matter in an object. An object's mass does not change unless matter is added or removed from the object.

The differences between mass and weight can be summarised in the following table:

|  |  |
| --- | --- |
| **Mass** | **Weight** |
| 1. is a measure of how much matter there is in an object. | 1. is the force with which the Earth attracts an object. |
| 2. is measured in kilograms. | 2. is measured in newtons |
| 3. is the same on any planet. | 3. is different on different planets. |
| 4. is a scalar. | 4. is a vector. |

Weight

1. A bag of sugar has a mass of 1kg. How much does it weigh:
	1. on Earth?
	2. on Jupiter?
	3. on Pluto?
2. Neil Armstrong was the first man to walk on the surface of the Moon. The gravitational acceleration on the Moon is 16 of the gravitational acceleration on Earth, and there is negligible gravitational acceleration in outer space. If Neil's mass was 90kg, what was his weight:
	1. on Earth?
	2. on the Moon?
	3. in outer space?
3. A monkey has a mass of 15kg on Earth. The monkey travels to Mars. What is his mass and weight on Mars?
4. Determine your mass by using a bathroom scale and calculate your weight for each planet in the Solar System, using the values given in [Table](http://cnx.org/contents/d85e3111-6378-49b7-b713-16ec667c7ef3%401/Gravity-and-mechanical-energy%3A#uid1)

Acceleration due to Gravity

Gravitational Fields

A *field* is a region of space in which a mass experiences a force. Therefore, a *gravitational* field is a region of space in which a mass experiences a gravitational force.

Free fall

Free fall is motion in the Earth's gravitational field when no other forces act on the object.

Free fall is the term used to describe a special kind of motion in the Earth's gravitational field. Free fall is motion in the Earth's gravitational field when no other forces act on the object. It is basically an ideal situation, since in reality, there is always some air friction which slows down the motion.

Experiment : Acceleration due to Gravity

**Aim:** Investigating the acceleration of two different objects during free fall.

**Apparatus:** Tennis ball and a sheet of paper.

**Method:**

1. Hold the tennis ball and sheet of paper (horizontally) the same distance from the ground. Which one would strike the ground first if both were dropped?
2. Drop both objects and observe. Explain your observations.
3. Now crumple the paper into a ball, more or less the same size as the tennis ball. Drop the paper and tennis ball again and observe. Explain your observations.
4. Why do you think the two situations are different?
5. Compare the value for the acceleration due to gravity of the tennis ball to the crumpled piece of paper.
6. Predict what will happen if an iron ball and a tennis ball of the same size are dropped from the same height. What will the values for their acceleration due to gravity be?

If a metal ball and tennis ball (of the same size) were dropped from the same height, both would reach the ground at the same time. It does not matter that the one ball is heavier than the other. The acceleration of an object due to gravity is independent of the mass of the object. It does not matter what the mass of the object is.

The shape of the object, however, is important. The sheet of paper took much longer to reach the ground than the tennis ball. This is because the effect of air friction on the paper was much greater than the air friction on the tennis ball.

If we lived in a world where there was no air resistance, the A4 sheet of paper and the tennis ball would reach the ground at the same time. This happens in outer space or in a vaccuum.

Galileo Galilei, an Italian scientist, studied the motion of objects. The following case study will tell you more about one of his investigations.

Case Study : Galileo Galilei

In the late sixteenth century, it was generally believed that heavier objects would fall faster than lighter objects. The Italian scientist Galileo Galilei thought differently. Galileo hypothesized that two objects would fall at the same rate regardless of their mass. Legend has it that in 1590, Galileo planned out an experiment. He climbed to the top of the Leaning Tower of Pisa and dropped several large objects to test his theory. He wanted to show that two different objects fall at the same rate (as long as we ignore air resistance). Galileo's experiment proved his hypothesis correct; the acceleration of a falling object is independent of the object's mass.

A few decades after Galileo, Sir Isaac Newton would show that acceleration depends upon both force and mass. While there is greater force acting on a larger object, this force is canceled out by the object's greater mass. Thus two objects will fall (actually they are pulled) to the earth at exactly the same rate.

**Questions:** Read the case study above and answer the following questions.

1. Divide into pairs and explain Galileo's experiment to your friend.
2. Write down an aim and a hypothesis for Galileo's experiment.
3. Write down the result and conclusion for Galileo's experiment.

Research Project : Experimental Design

Design an experiment similar to the one done by Galileo to prove that the acceleration due to gravity of an object is independent of the object's mass. The investigation must be such that you can perform it at home or at school. Bring your apparatus to school and perform the experiment. Write it up and hand it in for assessment.

Case Study : Determining the acceleration due to gravity 1

Study the set of photographs alongside showing the position of a ball being dropped from a height at constant time intervals. The distance of the ball from the starting point in each consecutive image is observed to be: *x*1=0 cm, *x*2=4,9 cm, *x*3=19,6 cm, *x*4=44,1 cm, *x*5=78,4 cm and *x*6=122,5 cm. Answer the following questions:

Determine the time between each picture if the frequency of the exposures were 10 Hz.

Calculate the velocity, *v*2, of the ball between positions 1 and 3.

$$v2=\frac{x3-x1}{t3-t1}$$

Calculate the velocity, *v*5, of the ball between positions 4 and 6.

$$v5=\frac{x6-x4}{t6-t4}$$

Calculate the acceleration the ball between positions 2 and 5.

$$a=\frac{v5-v2}{t5-t2}$$

Compare your answer to the value for the acceleration due to gravity (9,8*m*/s2).



The acceleration due to gravity is constant. This means we can use the equations of motion under constant acceleration that we derived in [motion in one dimension](http://cnx.org/contents/2e0149bb-32da-492e-9ab5-71d3699d1e34%404#cid10) to describe the motion of an object in free fall. The equations are repeated here for ease of use.

*vivfΔxtΔtg*=initial velocity(m/s)att=0s final velocity(m/s) at time(t) displacement(m) time(s)time interval(s)acceleration(m/s2)

*vf*=*vi*+*gt*

*Δx*=(*vi*+*vf*)2*t*

*Δx*=*vit*+12*gt*2

*v*2*f*=*v*2*i*+2*gΔx*

Experiment : Determining the acceleration due to gravity 2

Work in groups of at least two people.

**Aim:** To determine the acceleration of an object in freefall.

**Apparatus:** Large marble, two stopwatches, measuring tape.

**Method:**

1. Measure the height of a door, from the top of the door to the floor, exactly. Write down the measurement.
2. One person must hold the marble at the top of the door. Drop the marble to the floor at the same time as he/she starts the first stopwatch.
3. The second person watches the floor and starts his stopwatch when the marble hits the floor.
4. The two stopwatches are stopped together and the two times substracted. The difference in time will give the time taken for the marble to fall from the top of the door to the floor.
5. Design a table to show the results of your experiment. Choose appropriate headings and units.
6. Choose an appropriate equation of motion to calculate the acceleration of the marble. Remember that the marble starts from rest and that it's displacement was determined in the first step.
7. Write a conclusion for your investigation.
8. Answer the following questions:
	1. Why do you think two stopwatches were used in this investigation?
	2. Compare the value for acceleration obtained in your investigation with the value of acceleration due to gravity (9,8*m*⋅*s*2). Explain your answer.

**A freely falling ball**

A ball is dropped from the balcony of a tall building. The balcony is 15*m* above the ground. Assuming gravitational acceleration is 9,8*m*⋅*s*2, find:

1. the time required for the ball to hit the ground, and
2. the velocity with which it hits the ground.

By now you should have seen that free fall motion is just a special case of motion with constant acceleration, and we use the same equations as before. The only difference is that the value for the acceleration, *a*, is always equal to the value of gravitational acceleration, *g*. In the equations of motion we can replace *a* with *g*.

Gravitational Acceleration

1. A brick falls from the top of a 5*m* high building. Calculate the velocity with which the brick reaches the ground. How long does it take the brick to reach the ground?
2. A stone is dropped from a window. It takes the stone 1,5*s* to reach the ground. How high above the ground is the window?
3. An apple falls from a tree from a height of 1,8*m*. What is the velocity of the apple when it reaches the ground?