Acceleration due to Gravity

Key Stage 4

Topics covered: force, mass, acceleration, gravitational field strength, impact forces.

Watch the video "Newton's Laws of Motion", https://vimeo.com/159043081

Your weight is a force, F (N), caused by the effect of gravity. It depends on your mass, m (kg), but also on the acceleration, a (m/s^2), due to the gravity of the object that is pulling you towards it.

$$F = ma \qquad (1)$$

We can estimate the acceleration due to the gravity on the surface of the Earth using mechanics. If we ignore the effects of atmospheric drag and measure the time, t (s), for an object to fall from a height, d (m), then the acceleration due to the Earth's gravity can be calculated using the equation below:

$$a = \frac{2d}{t^2} \qquad (2)$$

ROYAL OBSERVATORY GREENWICH

Activity 1 - Calculating the acceleration due to gravity on Earth

Equipment: marble, 2 metre rulers + blue-tack, balance and stop clock

a) Measure the mass of the marble using the balance and record the result.
Mass = ___________ kg

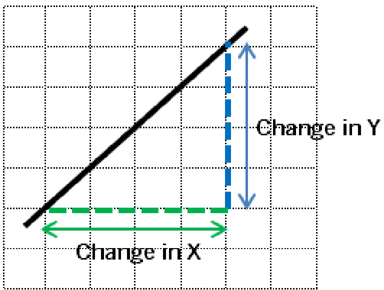
b) Stick the rulers vertically against a flat wall with one touching the ground and the other directly above it.

c) Choose 5 different heights to drop your marble from and time how long it takes to reach the ground. Fill in the table below as you collect your results. You may want to repeat and average your results if you have time.

Height, d (m)	Time, t (s)	2d (m)	t^2 (s^2)

d) Plot a graph of 2d against t^2 and draw a line of best fit through your results.

e) Calculate the gradient of this line (equation 2) which will give you the acceleration due to the gravity of the Earth at its surface.



$$Gradient = \frac{Change\ in\ Y}{Change\ in\ X}$$

Calculated acceleration due to gravity ________________ units: _______

Extension

Because the Earth is not a perfect sphere (it bulges out more at the equator), the acceleration due to gravity is slightly less at the equator compared to the poles. Find your latitude by visiting: http://www.sensorsone.com/local-gravity-calculator/#latitude to see how close your calculated value is to your local acceleration due to gravity.

Activity 2 – Parachutes and impact forces

When scientists design probes to land on other planets, they have to take into account the acceleration due to gravity on those planets to ensure the impact force on the probe is low enough to limit any damage caused to it.

1. Combine equations (1) and (2) to find the impact force in terms of distance, time and mass:

$$F =$$

Equipment: marble, sellotape, thread, 4 paperclips, some plastic bags, 2 metre rulers and a stop clock.

a) Cut squares of different areas out of the black bags.
E.g. 20 cm x 20 cm, 30 cm x 30 cm etc.

b) Stick the rulers vertically against a flat wall with one touching the ground and the other directly above it.

c) Cut 4 lengths of thread and tie them together at one end. Stick this end to the marble. Tie each of the other ends of the threads to a paperclip which can be attached to the 4 corners of the plastic bag parachute.




d) Using the ***same*** marble and ***same*** drop height (e.g.1.5 m), time how long it takes for each of the different sized parachutes to fall. Record your results in the table below and then calculate the impact force. You may want to repeat and average your results if you have time.

Mass of marble, m = _______________ kg
Drop height, d = _______________ m

Size of parachute	Time t, (s)	Impact force F, (N)
No parachute		
20 cm x 20 cm		
30 cm x 30 cm		
40 cm x 40 cm		
50 cm x 50 cm		

2. Why is it important that parachutes are used during the descent of landing space probes?

3. How else could the landing force of a probe be reduced? (Watch the "Newton's Laws of Motion" video for ideas)!

4. What other factors might scientists think about when designing a parachute to help land a space probe safely on another planet or moon?

Acceleration due to Gravity: ANSWERS

Key Stage 4

Activity 1

Acceleration due to gravity: **9.8** (or close to this value)
Units: **kg m/s²**

Activity 2

1. $$F = \frac{2dm}{t^2}$$

2. Parachutes increase the time taken to fall and so help reduce the impact force experienced by a space probe. The larger the parachute, the smaller the impact force and so the lower the risk of damage to the probe.

3. • Small thrusters can be used as the probe gets close to the surface. They exert a downwards force which by Newton's third law results in an upward force and this acts to help decelerate the falling probe.

   • Air bags around the probe (must withstand puncture from rocks).

4. This list is not exhaustive:
   - Material – resistance to heat, chemical resistance, weight, strength (needs to withstand great deceleration), permeability (whether it's tightly woven or not i.e. more holes)
   - Cost of manufacture and launch (extra load)
   - Shape (and area)
   - Length of shroud/ rigging lines / how they detach
   - Does the planet have an atmosphere to provide atmospheric drag / help slow down the probe?
   - Surface the probe will be landing on - is the terrain soft, hilly or does it have a liquid surface?