WOW STARTERS

Parachutes

National Curriculum references:

SC1 Planning: 2a, 2b, 2c, 2d
SC1 Obtaining and presenting evidence: 2e, 2f, 2g, 2h
SC1 Considering evidence and evaluating: 2i, 2j, 2k, 2l, 2m

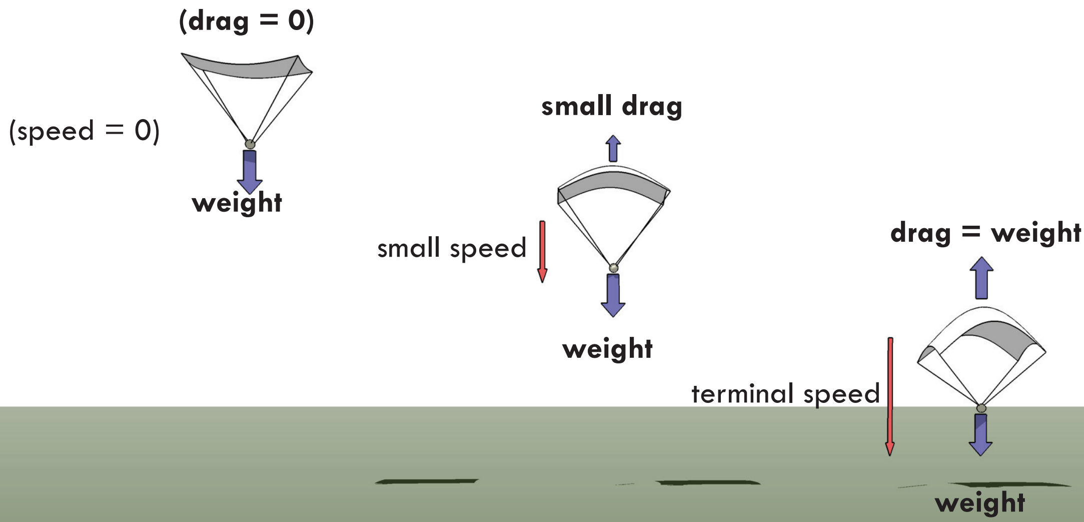
SC4 2b that objects are pulled downwards because of the gravitational attraction between them and the earth.
SC4 2c about friction, including air resistance, as a force that slows moving objects and may prevent objects from starting to move.
SC4 2e …. identify the direction in which forces act.

These are teachers' notes for the Parachutes Wow Starter (see page 6) in which children are encouraged to conduct experiments with easily constructed parachutes.

Children can get a long way by themselves. They can gain a wide range of experiences, which can then form the basis of a group discussion about the theory.

Experiments with parachutes are great for exploring:

- Experimental method (measurement, fair tests)
- Variables
- Forces
- Gravity



1. Starting Off
Before the parachute and plasticine are released, there is no drag – only weight. When released they start falling with an acceleration of 9.8 metres per second per second.

2. Speeding Up
As the parachute and plasticine speed up, drag increases and this reduces the effect of the weight (the force due to gravity). The plasticine is still accelerating, but at a slower rate.

3. Steady descent
Eventually, the parachute reaches a speed at which the weight is balanced by the drag. Because there is no longer any (total) force, the parachute continues falling at this speed – it doesn't get any faster.

How do parachutes work?

There are two main forces on a falling object: weight (the force due to gravity) and drag (also known as air resistance). Without drag a falling object would get faster and faster as it falls (see Acceleration section, page 4). The size of the drag force depends on speed. When a falling object begins to fall the size of the drag force is zero (because the speed is zero). As the falling object speeds up, the size of the drag force increases until it matches the weight (the force due to gravity). When drag and weight are the same size the total force is zero, so the falling object stops accelerating and carries on at the speed it is going.

What is drag?

Drag, also known as 'air resistance', is a force caused by having to push air molecules out of the way. Drag pulls an object in the opposite direction to the one it is moving – it resists the movement.

Two main things affect the size of this force:

1. Area
2. Speed

A third thing can be important too:

3. Turbulence

Area: The important area so far as drag is concerned is the area of the object in the direction it is moving. An arrow has a fairly large overall surface area, but its surface area in its direction of travel is tiny, so it doesn't feel much drag.

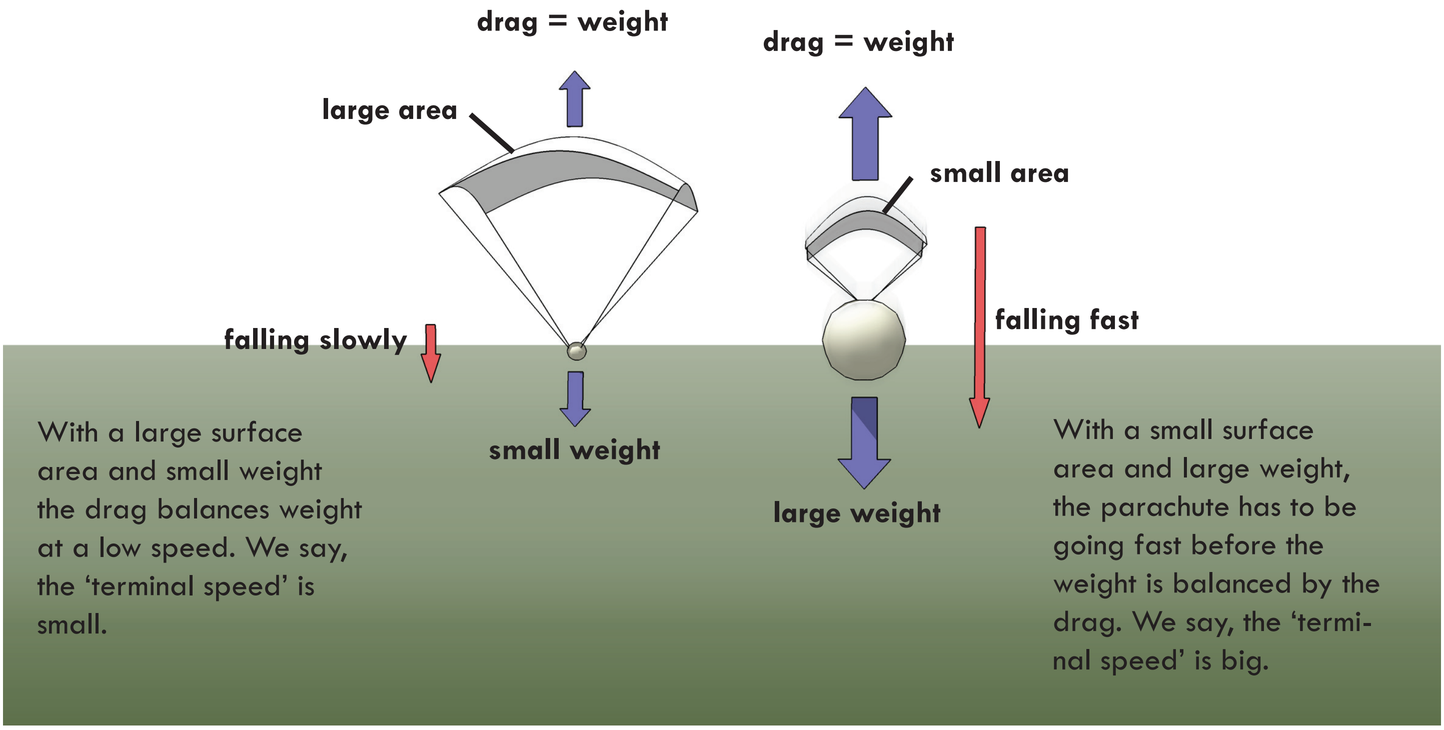
Speed: Until an object starts moving, it doesn't feel any drag. The faster it goes, the bigger the force. If you hold your hand still, there is no drag. If you run along with your hand out, you may feel a very slight push. If you hold your hand out of a moving car window then you will feel a very strong push.

Turbulence: Pushing through air can cause air to move in chaotic patterns and swirl around. This is called turbulence, and it can increase drag. An object moving through air pushes the air forward at the front and leaves gaps in the back that the air behind rushes in to fill.

Smooth objects can slip through air without causing turbulence but rough surfaces and sharp edges can cause eddies (little swirls) to appear. When air is moving smoothly past an object this is called 'laminar flow'. At a critical speed, that depends on the shape and surface of the object, flow changes from being laminar to being turbulent.

Terminal velocity (terminal speed)

The speed at which the drag matches the weight is called the 'terminal velocity'. It depends on the area of the object in the direction of motion and on the weight of the object. (The bigger the area, the smaller the terminal velocity, the bigger the weight the bigger the terminal velocity)



What does 'aerodynamic' mean?

Children may have heard the term 'aerodynamic'. It is a useful term because it combines many of the aspects of forces and flow that are raised by parachute experiments (and paper aeroplanes). The question 'how can we make this more aerodynamic?' can bring a lot of ideas together.

The term 'aerodynamic' refers mainly to an object's shape. An object is aerodynamic if it slips though the air easily. (If it slips through water easily it is described as 'hydrodynamic'.) Qualities that make objects aerodynamic include:

- Small area in the direction of motion (resulting in long, elongated shapes such as darts and arrows)
- Polished surfaces (both to reduce the amount of air moved and to increase the critical speed at which laminar flow becomes turbulent)
- Smooth, gentle curves rather than sharp corners (to reduce the pressure differences between the air being pushed forward and the gap left behind, and so reduce turbulence).

Drag: things to try

Try experimenting with water. In water drag is greater than in air (because there is more stuff to move out of the way). This means that some effects are apparent at much lower speeds than in air. In addition, the effect of turbulence is directly visible in water, as is the transition from laminar to turbulent flow.

Area to weight ratio (or, why falling without a parachute is a bad idea if you're human but ok if you're a feather)

A person falling without a parachute has a fairly small area and a fairly large weight. This means that the force of drag does not balance the person's weight until they are going at roughly 55 metres per second (about 120 mph). We say, 'the terminal velocity of a falling person is 120 mph'. Note, however, that it's not falling that is the problem; it's the sudden deceleration when you reach the ground.

A mouse falling without a parachute has a smaller area than a human but it has a much, much smaller weight. The ratio between a mouse's surface area and its weight is much greater than a human. As a result, the terminal velocity it reaches (the speed when its weight is balanced by the force of drag) is much lower than human and a mouse will usually survive a fall (but it's best not to try this with a live mouse).

A feather has an enormous surface area to weight ratio (big surface area, tiny weight). This means the force of drag balances the weight almost as soon as you drop the feather and its terminal velocity is very small.

Other things to discuss

Modern parachutes have two additional features that make them more controllable than simple parachutes.

Some parachutes create thrust with holes at the back of the parachute from which air is forced out as the parachute falls. As air is pushed out the back, the parachute itself is pushed forward (as a consequence of Newton's Third Law of Motion: every action has a reaction that is equal and opposite). You can steer parachutes like this by changing the size of the holes on the left or right (and so changing the amount of thrust from each side).

Some parachutes have a shape that gives them lift (that is, the parachute is like a wing). The lift comes both from the way the parachute pushes air down as it moves forward and from the fact that the shape makes the air pressure above the wing less than the air pressure below the wing.

Gravity

One reason parachute experiments are a good basis for discussing gravity is that they explain why the subject can be confusing. There is much about gravity that is counterintuitive (e.g. the idea that light things fall at the same rate as heavy things) but our intuition is based on our experience, which generally involves air and drag.

Acceleration

The force of gravity is what makes a falling object speed up. Force is related to acceleration by the following equation (Newton's Second Law of Motion):

$$F = ma$$

(Force = mass x acceleration)

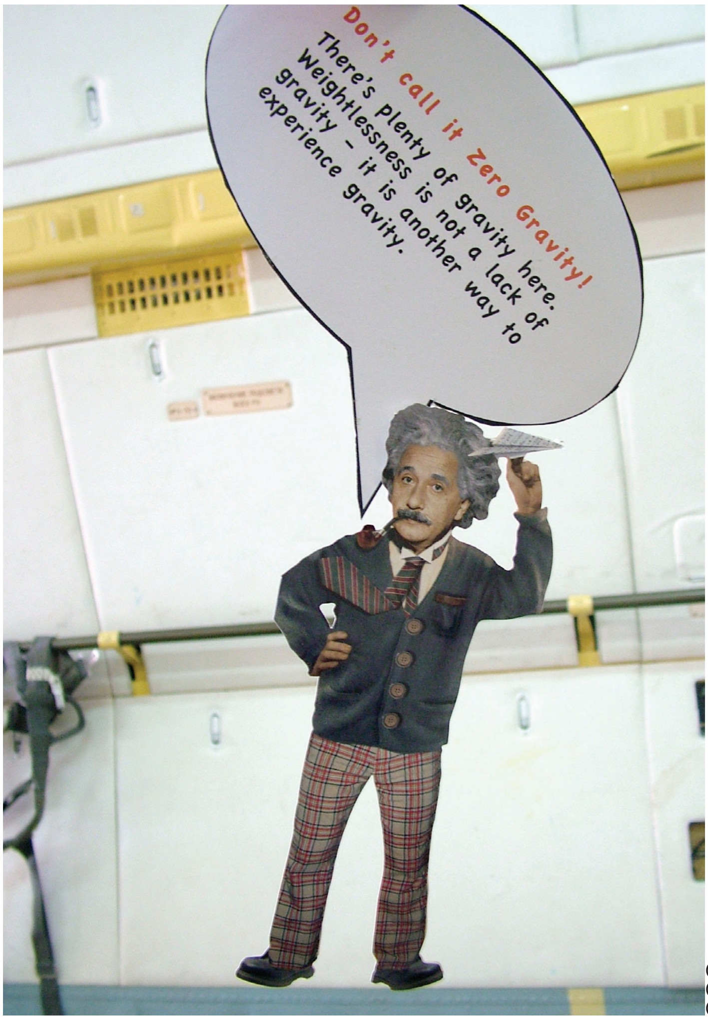
The units of force are Newtons, the units of mass are kilograms and the units of acceleration are metres per second per second.

Near to the Earth's surface, the Earth pulls on each kilogram of stuff with a force of 9.8 Newtons. This means that, if there are no other forces on an object, it will fall with an acceleration of 9.8 metres per second per second. After one second, it will be going at 9.8 metres per second; after two seconds it will be going at 19.6 metres per second; after 3 seconds it will be going at 29.4 metres per second; and so on.

Why don't heavy things fall faster than light things?

They do! If there is drag involved then heavy things will, in general, fall faster than light things. This is what leads to our intuition that heavy things fall faster. But, if the only force on falling objects is gravity then a heavy one will accelerate at exactly the same rate as a light one.

The force on the heavy object is greater than the force on the light object but this is balanced by the fact that it is harder to accelerate a heavy object (there is a bigger pull from gravity but there is more to be pulled).



In July 2008, Momentum's Luke Jerram travelled to Star City in Russia to make artwork in weightless conditions. A specially adapted aeroplane flew in a series of parabolas, which gave him brief periods of weightlessness (interspersed with periods during which he weighed twice as heavy as usual). He also had some messages from Adam Nieman with him, including this one.

News-flash: There IS gravity in space

A discussion of gravity would not be complete without a discussion of space. Many children (and some teachers) believe that there is no gravity in space. This is wrong, but it's easy to understand where the idea comes from. Video of astronauts shows them floating around and terms such as 'zero gravity' are used to describe what is going on. In fact, the strength of gravity in an orbiting spacecraft is almost as strong as it is on the surface of the Earth.

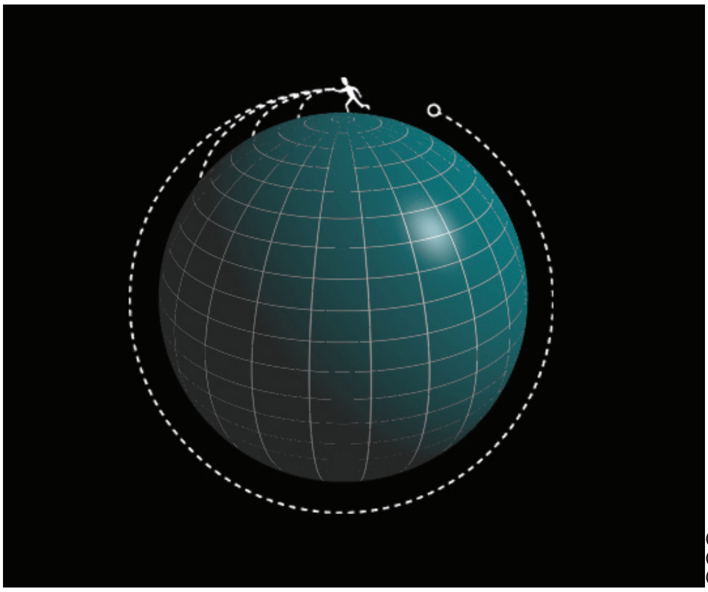
The difference is that there is no solid surface pushing back on the astronauts. The spacecraft and the astronauts are both moving round together. Floating in an orbiting spacecraft is exactly the same as being in a lift that is falling. Until the lift hits the ground, both the lift and people in it will be accelerating at the same rate. So the floor of the lift will not be pushing back on the people's feet and they will float.

Astronauts float because their spacecraft is falling through space with them – not because there is no gravity. 'Weightlessness' is a much better word to describe the experience of astronauts in orbit than 'zero gravity'.

The most remarkable aspect of gravity is that it extends across the entire universe – the Moon held in orbit around the Earth by gravity, the Earth and Moon are held in orbit around the Sun by gravity, the whole Solar System is held in orbit around the centre of the galaxy by gravity, our galaxy (the Milky Way) clings to neighbouring galaxies by gravity, and so on.

If there is gravity in space, why don't spacecraft fall to the ground?

If there were no gravity in space then spacecraft would just float off. But if the gravity is so strong, why doesn't the spacecraft fall back to Earth? If you just placed a spacecraft 300 km above the surface of the Earth then it would do just that – fall back to the ground. To prevent this from happening you have to give a spacecraft a sideways motion. It's still pulled towards the centre of the Earth but it is going sideways so fast that it keeps going round and round. This is a bit like swinging a rope around your head. You continue to pull on the rope but the end of the rope doesn't get any closer to you because it is going around so fast.



Being in orbit is a form of falling! It is what happens when you go sideways so fast that you don't hit the ground when you fall.

Websites

Some more teachers notes about parachute experiements:
http://www.seed.slb.com/en/scictr/lab/parachute/notes.htm

Wikipedia:
http://en.wikipedia.org/wiki/Parachute

Parachute jump – from 31 km up, with 99.2% of the atmosphere below:
http://www.youtube.com/watch?v=MQ7N6V-YKJ8&feature=related

News story about building a parachute to Leonardo DaVinci's design:
http://news.bbc.co.uk/1/hi/sci/tech/808246.stm

Weightlessness in Wikipedia:
http://en.wikipedia.org/wiki/Weightlessness

About Momentum

The Momentum Learning Network was formed in 2004 with support from Creative Partnerships. Teachers, creative practitioners and scientists meet regularly to discuss creativity and science. The aim is to support innovation and creativity in the classroom and beyond through collaborative cross-discipline debate, thinking and classroom based research. Wow Starters is one of the innovations to have emerged from Momentum.

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About Wow Starters

Wow Starters are short videos that introduce practical science activities at the beginning of a lesson. They are presented by children and encourage open-ended exploration of phenomena whilst also instilling the value of scientific experimental methods.

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