WOW STARTERS Paper Aeroplanes

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 2c about friction, including air resistance, as a force that slows moving objects
SC4 2e .... identify the direction in which forces act.

These are teachers' notes for the Paper Aeroplanes Wow Starter in which children are encouraged to make and test paper aeroplanes. Experiments with paper aeroplanes are great for exploring:

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

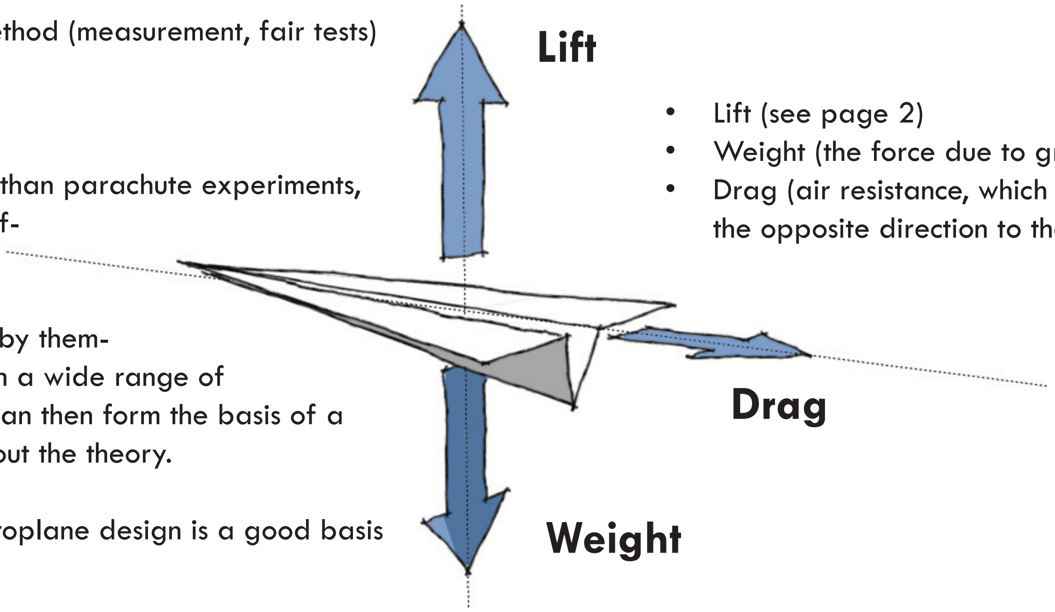
Though less focused than parachute experiments, paper aeroplanes offer more scope for creativity. Children can get a long way by themselves. They can gain a wide range of experiences, which can then form the basis of a group discussion about the theory.

The basic paper aeroplane design is a good basis for a range of tests:

- How does the thickness of paper affect flight?
- How does the addition of wing-flaps (or up-turned corners) affect flight?
- How does wing surface area affect flight?
- How does the size of the plane affect flight? (What are the largest and smallest paper planes that fly and what factors determine the limits?)

How do paper aeroplanes fly?

Three forces act on gliders:

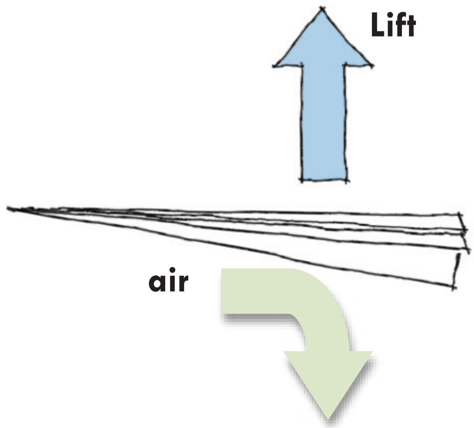


- Lift (see page 2)
- Weight (the force due to gravity)
- Drag (air resistance, which acts in the opposite direction to the motion)

Powered aeroplanes have an additional force: thrust, which is created by propellers or jets pushing air backwards. Paper aeroplanes get an initial push but once they leave your hand there is no more thrust.

Lift

'Lift' is is a force. It is the combination of all the forces that act upwards (against gravity). In a paper aero-plane lift is created by the air.



As a paper aeroplane moves forward, its wings push air down and this is what creates lift. By Newon's third law of motion (which states that every action has a re-action that is opposite and equal) pushing the air down has the effect of pushing the plane up.

The amount of lift depends on how much air is being pushed down and so will be affected by the following factors:

- Forward speed
- Wing area
- Wing angle (angle of attack)

Note: this is a simplified explanation. The main prob-lem with it is that it doesn't give an intuitive sense of how the top of the wing also creates lift. You may want to talk about the wing 'squashing' the air – increasing pressure – rather than pushing the air away. A more complete explanation of how wings generate lift is here:

http://travel.howstuffworks.com/airplane8.htm

Weight

Discussing weight is a good way to reinforce the impor-tance of air in flight. The shape of a plane is impor-tant only because it interacts with air, and for no other reason.

The thing that makes paper aeroplanes fall is their weight. In general, the weight (the force due to grav-ity) will be a little bit bigger than the lift (the force produced by the wings pushing air down). If there were no lift or drag then the path a paper plane would take when it leaves your hand is the same as the path a stone would take. Lift and drag need air. If there were no air, like on the Moon, then planes would fly just like stones.

A discussion of weight might be an opportunity to consider the essential difference between rockets and aeroplanes. (Space rockets fly where there is no air so they only have weight and thrust – no lift or drag.)

Drag

Drag is a force caused by having to push air molecules out of the way. Drag pulls an object in the opposite di-rection 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 mov-ing 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 mov-ing smoothly past an object this is called 'laminar flow'. At a critical speed, which depends on the shape and surface of the object, flow changes from being laminar to being turbulent.

Why do paper aeroplanes fly straight?

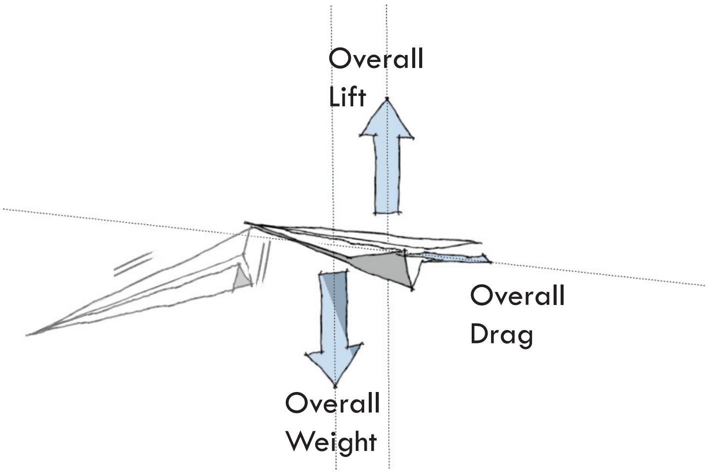
The shape of a paper aeroplane makes it much easier to push it through the air in one direction than any other. Try to push it sideways or backwards and the drag will be huge but when you push it forwards it slips through the air. Physicists might say something like: the shape of the plane breaks the symmetry and privileges one direction over all others.

In flight, the fact that the plane slips through the air easily in only one direction actually helps to steer it automatically. For instance, if the plane starts going to the left then the drag on the right will increase and pull it back to the centre.

Why do paper aeroplanes fly off-course?

When forces are not aligned (that is, not all acting on the same point) they create a 'turning force' (which, for some reason, physicists call a 'moment').

Many things can cause a plane to fly off-course. In general, if the three forces (weight, lift, drag) are not aligned then this can make the aeroplane turn (just like turning a steering wheel).



These are possible causes of unaligned forces:

- Weight is not distributed evenly (e.g. because one wing is bigger)
- Lift is greater from one wing than the other (e.g. because one wing is bigger)
- Drag is greater on one side than the other (e.g. because the wing is bent)

Controlling a paper aeroplane

One bit of a paper aeroplane you can modify easily is the wingtips. Bending the wingtips up can change the distribution of weight and change the amount of drag. Less intuitively, it can also change the amount of lift. It does this by changing the angle of attack of the wings because if air hits upturned wingtips, this can push the back of the plane down.

If a plane is flying to the left, try bending the right wingtip up. This will increase the drag on the right and help balance whatever forces were making it turn to the left.

If a plane is falling too fast, try bending both wingtips up. When air hits the wingtips it will push the back of the plane down and so increase the 'angle of attack' (the angle at which the wings fly into the air) which may increase the lift.

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 paper aeroplanes (and parachute experiments). 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.

Websites

All aspects of paper aeroplanes (including more links):

http://paperplane.org/

The World record for the length of time a paper aeroplane (launched from the ground) has stayed in the air is 27.6 seconds:

http://paperplane.org/Record/100898.htm

More teachers' notes about paper aeroplane experiments:

http://www.uga.edu/srel/kidsdoscience/kidsdoscience-airplanes.htm

A nice Java applet (web program) that simulates air passing over a wing:

http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html

Aerospace activities and lessons from NASA:

http://www.grc.nasa.gov/WWW/K-12/aeroact.htm

Explanation of lift:

http://travel.howstuffworks.com/airplane8.htm

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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