Air and flight

Introduction

This topic lends itself to a number of curriculum ideas. Problem-solving skills; appreciation of technology and its impact on society; the history of science/technology; career paths; language development; and flow chart design could all be covered in a unit on air and flight.

Although the flight activities in this topic can be used for all levels of primary school, older students tend to get more out of these activities, as they are able to discuss the concepts at a deeper level. None of these activities can be explained without an understanding that flight is occurring through air. The idea of air is thus a prerequisite to understanding flight.

Key concepts of air and flight

The activities in this topic are designed to explore the following key concepts:

Early years

- Air is all around us.
- Wind is moving air.
- Air fills up spaces if allowed.
- Air can push or cause pressure on things.
- Air slows down falling objects such as paper, balls and parachutes.
- The shape and size of an object affects the nature of airflow around it, hence the air resistance.
- Planes and other flying things are held up by the force of air on their wings.

Middle years

- Air in the atmosphere exerts a pressure in all directions.
- The atmosphere can exert a surprisingly strong force on objects.
- ‘Sucking’ reduces pressure, causing a force imbalance towards the low-pressure region.
- The pressure of air is used in many applications (tyres, hoists, etc.).
- Air pressure differences tend to equalise.
- A moving stream of air has reduced pressure.
- Air has weight.

- Air expands on heating, causing a pressure increase if it is contained.
- Hot air is less dense (or more spread out) than cold air, and rises.
- Air consists of a mixture of gases, one of which (O_2, dioxide) is necessary for burning.
- Objects can be shaped to either minimise or maximise the force of air on them.
- A flat object such as a plane wing, a boomerang or a paper tube can be supported by forces that arise due to differences in airflow across the top and bottom surfaces.
- To every action there is an equal and opposite reaction: a stream of air (or water) forced from a balloon or rocket will cause a force back on the balloon or rocket to propel it.
- The force from air on a moving object depends on the surface area, and the shape of the object.
- Wind is moving air.

Students’ alternative conceptions of air

Research into students’ ideas about this topic has identified the following non-scientific conceptions:

- Younger children often only associate air with wind, which is moving air. Presumably this stems from a view that only directly observable entities are real. Thus, they are most likely to interpret ‘air is everywhere’ as meaning that air is only outside.
- Young children will think that air moves unaccountably into or out of enclosed spaces, to explain why there might or might not be air in upturned glasses, containers or cupboards.
- The wind is caused by trees swaying.
- Fans and moving objects create air (rather than simply set air in motion).
- Students can attribute the causes of these ‘air taking up space’ or ‘air pressure’ activities to their own action (‘the water comes out because we lifted our finger’, or ‘the tissue remains dry because we were careful’) or use explanations based on analogy rather than identify causal mechanism (‘the air was trapped’). Thus students can have an ‘alternative’ view of the nature of scientific explanation.
- Suction involves creating a vacuum, which causes a negative, pulling force on objects. In fact ‘suction’ is often not thought of so specifically but rather is a term used to describe a class of phenomena. In this sense the use of the terms ‘suction effect’, ‘suction cap’ or even ‘suction force’ can be quite helpful in locating causes for movement or identifying the nature of a phenomenon. It is the identification of the term with air ‘pulling’ that is incorrect.
- Pressure only operates in a downward direction.
- Air exerts a force only when it moves.
- Air has no weight or negative weight.
- Hot air has negative weight, which causes it to rise.

Activities

The presence of air

Young children find the assertion that ‘air is everywhere’ difficult to accept. Studies have shown that they tend to associate the presence of air mainly with open spaces, breezes and breathing, and will think, for instance, that a jar will contain no air. Some of the activities in this section are meant to reinforce the idea of air as a tangible presence that takes up space and resists compression.

These activities focusing on the presence of air are most useful for early years classes, but could also be productively used in the introductory exploration section of middle years sequences.

ACTIVITY: WHERE IS AIR?

Teaching note: By the age of eight or so, most students will have a confident idea about air taking up space and will be able to talk reasonably about some of these activities in terms of air movement, or air being ‘squashed’.

It is instructive to talk with Years 1 and 2 students about where air might be found: in a cupboard or a jar, or underneath a table. Students can be challenged to collect air in plastic bags from places of their choice, trapping it by tying the top. Some comments might include: ‘I had no idea there would be air across the hall even though this door was shut tight’; ‘I even found air in the toilet bowl with the door shut!’.

Older students might explore whether there is air in soil, or in cork, by putting these things underwater and watching for bubbles. They can also measure their lung capacity by bubbling air into an upturned bottle held full of water in a bucket.

Key idea: Air is everywhere.

You will need:

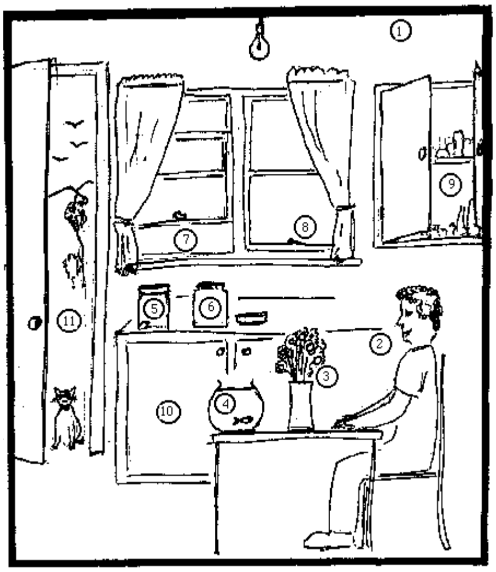
- **a class set of the figure below.**

Hand out and/or discuss the following probe with the students.

WHERE IS AIR? NAME:

Tick ✓ Where you think there is air.

1. All round the room?
2. Where Mark is sitting?
3. Where the flowers are?
4. In the fishbowl?
5. In the jar with the lid on?
6. In the jar with the lid off?
7. By the open window?
8. By the closed window?
9. In the open cupboard?
10. In the closed cupboard?
11. Outside?



ACTIVITY: COLLECTING AIR

You will need:

- **plastic bags.**

Give students a plastic bag each and ask them to collect as much air as they can in the bag any way they like. Some children will blow the bag up; others will run around the room with the bag open collecting air. Ask the children if there is anywhere that we can't collect air like this (hint: in outer space).

ACTIVITY: FANS

You will need:

- **pieces of paper.**

Fan a student's cheek with a piece of paper. Ask the student what they feel. Where does the breeze come from? How did it get there? (Note: young children will claim that the paper creates the wind!)

ACTIVITY: BLOW UP A BALLOON

You will need:

- **balloons.**

Blow up a balloon. Release the air slowly and feel it coming out of the balloon. Discuss what this means. What is being felt? What was the sequence of events in terms of the presence of air?

Air takes up space

These activities are suitable for Years Prep to 4 students but could also be used in the middle years as initial exploratory activities.

ACTIVITY: PUSHING A PLASTIC BAG INTO A JAR

Teaching note: You can try this also using a balloon, with its neck over a soft-drink bottle. A variation on this involves using a pin to prick a hole in the plastic bottle and seeing if it makes a difference having a finger over the hole or not. In practical terms, students will see the challenge as one of forcing the bag inwards, and will break the seal trying this. It is a productive exercise to challenge them to then open the bag out again; this proves difficult unless air can be reintroduced to the bag.

Key idea: Air takes up space.

You will need:

- **a glass or plastic jar**
- **a small plastic bag**
- **sticky tape or a strong rubber band.**

Open out a plastic bag by blowing in it or waving it around to catch some air.

Fix the plastic bag over the top of an open jar. Attach it firmly with rubber bands and tape, so that it is airtight. Push the plastic bag into the jar (without causing any air leaks).

What do you think will happen? Try it!

What did you discover? Was it easy?

Could you make the plastic bag open out more by gently pulling? Try it!

ACTIVITY: TISSUE IN A GLASS

Key ideas: Air takes up space. Air can push on water.

You will need:

- **a trough or plastic container of water at least 10 cm deep**
- **a transparent glass or cup**
- **tissue paper.**

Push some dry tissue paper into the bottom of a glass, so that it won't fall out when the glass is upside down. Push the glass, upside down, underneath the water in the trough or plastic container.

Do you think the paper will get very wet? Try it.

Take the glass out and feel the paper. Can you explain what you find?

ACTIVITY: SAILING A BOAT UNDERWATER

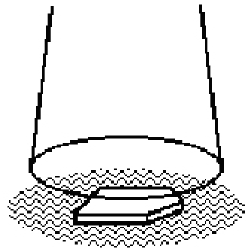
Teaching note: A plastic bottle top works well as a boat. The activity is really impressive with a large perspex container over a toy boat or floating duck. Students will find all sorts of reasons involving air in some strange situations to explain why the tissue remains dry or the boat is pushed down. It is interesting to ask the question 'Is the boat floating?' to probe what students' conception of floating is.

Key ideas: Air takes up space. Air pushes on water surfaces.

You will need:

- **a trough or plastic container of water at least 10 cm deep**
- **a transparent glass or cup**
- **a small plastic bottle top or wooden boat small enough to float under the cup.**

Let your little toy boat float in the trough or container of water. What do you think will happen if you put the plastic container upside down over the boat and push it down to the bottom? Will the boat sink? Try it.



Draw a picture to show what happened. Why did this happen?

ACTIVITY: PLASTIC BAG CUSHION

Key idea: Air exerts a force to hold up objects.

You will need:

- **a plastic bag.**

Fill a plastic bag with air. Twist the opening up and hold it tightly, to make a cushion out of the bag.

How much will the cushion hold up? Will it hold a book? Will it hold you? Try sitting on it!

Air is incompressible

The following activities are suitable for middle years classes. They involve the idea of air under pressure, exerting a force.

ACTIVITY: BALLOON TURTLE

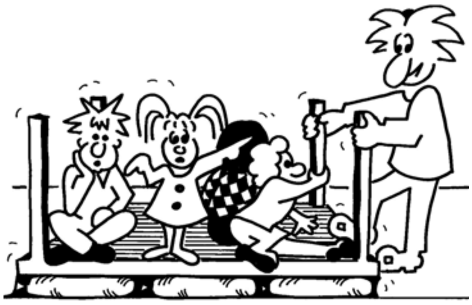
Key ideas: Air can support heavy objects. Air is relatively incompressible.

You will need:

- **a table that can be upturned (make sure the table is held steady)**
- **a clean, swept floor area**
- **six to ten round balloons.**

Blow up a number of balloons (not too tightly) and place them evenly over an expanse of floor (sweep the floor clean of dust). Upturn a table and place it gently on top of the balloons (ensuring that the balloons are equally distributed under the table). Ask the students to climb on top of the upturned table. How many students do you think can fit on top of the table before the balloons burst?

Have students draw what is happening, with an explanation. What is holding the table up? What does this tell us about air?

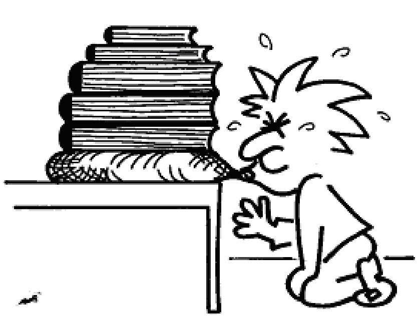


ACTIVITY: HOW MANY BOOKS?

You will need:

- **a plastic bag or balloon**
- **books.**

Blow up a plastic bag or balloon, and then steady it while books are carefully placed on it. Alternatively, lift a stack of books by blowing into a plastic bag. Can you think of some common applications of this principle?



ACTIVITY: BICYCLE PUMP

You will need:

- **a bicycle pump.**

Feel the compression and heat generated as you pump a bicycle pump with your thumb over the end. (Note: part of the charm of this activity is that it gives very tactile evidence of the presence of air and its relative incompressibility.)

Air has weight

ACTIVITY: BALLOON SCALE

You will need:

- **two identical balloons**
- **a wire coathanger**
- **string.**

Blow up two balloons to an identical size and tie them to either end of a wire coathanger. Hang the coathanger so that the balloons are free of any impediments. Gently put a small hole in the top of one of the balloons, near where it is attached to the coathanger. As air escapes from the punctured balloon the full balloon will pull the coathanger down on that side.

Atmospheric pressure

Teaching note: These activities are suitable for middle years classes. For younger students the concept of atmospheric pressure is very difficult to comprehend. These activities involve the interaction of air and water, and you may find that younger students will interpret them as being about ‘water’ rather than ‘air’, which is less noticeable and thus probably less exciting for them.

The idea that air takes up space, and competes for space with water, can be used to effectively explain most of these experiments. The more powerful concept of air pressure is more difficult, but accessible in restricted form, for younger students, who tend to talk of the ‘strength’ of air, or of air ‘pushing’.

Students tend to call up a range of conceptions to account for their observations of these activities, many of them quite useful over a range of phenomena. The idea of ‘suction’, for instance, while not acceptable as a scientific explanation, is more accessible to students (and adults) than the more powerful idea of competing pressures that underlies many of these activities.

In planning a sequence of activities on air pressure it would be a good idea to start with an activity such as *Magic finger*, which works nicely as a probe and allows students to vary the conditions (i.e. opening and closing the hole, or shaking, or increasing the hole size) to explore what is causing the water to be trapped.

The idea of atmospheric pressure is counter-intuitive for two reasons. Firstly, students do not have a confident idea of the gas state because they do not associate matter with an insubstantial, invisible presence—‘If you can’t see it or feel it, then forget about it!’. The other reason is that the effects of atmospheric pressure are mainly masked by the fact that air is everywhere; we do not collapse under the weight of the atmosphere because every part of our bodies is composed of air or water or other substances, which are at atmospheric pressure and resist the effect of the atmosphere.

Another, more technical, difficulty sometimes encountered is that if students accept that the weight of the atmosphere above us is bearing down on us, they imagine the force due to this must be downwards also, and not applied in all directions, as is evident from the upturned glass or magic finger.

For all these reasons, we recommend saving a serious discussion of these concepts until the middle years level. That being said, some of these activities work well as challenges with lower year levels. Don’t be surprised, though, if students revert to simpler ideas even after you’ve discussed the principles thoroughly.

You will also find that students will use a variety of explanations for these activities, and will hold onto naive ideas for some of them despite considerable discussion. Learning is a slow process, and it’s important to monitor what students are thinking about each activity.

ACTIVITY: MAGIC FINGER

Teaching note: The 'magic finger' is really a double trick. The original version had the magic finger on the hand not holding the container! Every time the finger points, the water comes out because, unknown to the audience, the finger on top of the (secret) hole rolls slightly to let air in. Classes have been kept going on this by challenging others to see if their fingers are magic. They're always delighted to learn the trick and talk about it.

Even quite young students can get some sense of this activity. The easiest way to explain it is in terms of air needing to be let into the top hole to take up the space the escaping water will leave. Some students are attracted to a 'trapped/released' image and claim that the finger allows water to escape at the bottom and air to escape out the top! The air pressure explanation involves the outside pressure pushing on the water at the holes (again, you can see the effect of surface tension as the water forms half-drops) and keeping it up, provided the air inside is not at atmospheric pressure also.

Key ideas: The atmosphere exerts a pressure. Air will fill up space if allowed.

You will need:

- **a plastic soft-drink bottle with cap**
- **a hot nail**
- **tongs**
- **a bucket**
- **water.**

Take a plastic soft-drink bottle and make two or three small holes in the bottom and one in the lid (use a hot nail held in some tongs to make the holes). Fill the container about two-thirds full of water and replace the lid. Place your finger over the hole in the lid and lift the container up. As you remove your finger from the hole, water will pour out of the holes in the bottom. Replace your finger and the water will stop flowing. To make a performance of this, you can point to the container with your other hand and command the water to flow or stop (while moving your finger on the hole in the lid accordingly). To debunk the magic finger idea, allow students to experiment with their own containers over bowls of water.

ACTIVITY: UPTURNED GLASS

Key idea: The atmosphere exerts a pressure in all directions.

You will need:

- **a glass**
- **water**
- **a container to catch spilt water**
- **a piece of card or stiff paper or plastic sheet**
- **drinking straws**
- **optional items: oil, sparkling mineral water, detergent, plastic tubing of various diameters.**

Fill the glass with water, to the top, and put the piece of white card on top. Hold the card while you turn the glass upside down. Make sure you do this over the tray, so it won't matter if it spills.

What do you think will happen if you take your finger off the card?

Does it make any difference to what happens if the glass is only half full of water?

What holds the card on? (Textbooks give the standard answer: 'atmospheric pressure'.) Does air inside the glass play a role? Will it work for a very tall glass? Does it work with different liquids? Sparkling mineral water? Oil?

Is the card really needed? Lift water with a straw by putting your finger on the top of the straw. Try it with different size straws or with some plastic tubing.

Does surface tension play a role? Try it with some detergent in the water.

Explanatory note: Most of the tricks in this section, involving water being supported counter-intuitively, are related to the same principle. The *Upturned glass* is a case in point, but we have never seen an explanation of this that is satisfactory. This activity has now been run with many students and adults, and the following questions come up:

- How come it works with air inside? Doesn't the air pressure from inside push back?
- Why is the card necessary? Why doesn't it work with just the water?
- How big a surface will the trick work with? Would it work with a bucket?
- How tall a glass would it work with? Surely there must be some limit?
- Isn't it suction? When we try to do it with no air inside, there's an air bubble that always goes up to the top, sucked up just like the card.

The questions and extra challenges in the activity are meant to address some of these.

The reason the card stays on is because of the outside air pressure acting upwards. The complication of the air inside can be explained thus: when the glass is upturned, the water level and card drop very slightly, increasing the volume of the enclosed air. This drops the pressure, and the card settles when the upward pressure exactly matches the downward weight of the water and card, and the downwards but reduced pressure from the air inside.

If the card is relatively rigid you will be able to see it drops just a bit so there's a slight gap between the card and glass rim, filled with water. The surface tension of the water allows this to happen by maintaining the surface and even providing a small adhesive force. The trick works even if the water is taken out, provided the card is wet! We've found a piece of thin plastic works better than paper since it doesn't soak, but it's also been done with table napkins and glasses of wine, when pushed! You need to be careful that the card or napkin is not too big so that it droops and breaks the water seal.

The trick doesn't work with lemonade because the bubbles increase the pressure inside the glass. It works without a card provided the surface is small enough to maintain the surface through cohesion, as with a straw used for transferring water by the action of the thumb at the top (identical in principle to the *Magic finger* activity).

ACTIVITY:
TRICKY CUP

Key ideas: The atmosphere exerts a pressure on water surfaces. Air will fill up space if allowed.

You will need:

- **a clear plastic cup**
- **a heated needle**
- **a container of water.**

Make a tiny hole in the bottom of a clear plastic cup with a heated needle. Hold the cup underwater, full of water. Pull it slowly out of the water, upside-down, with your finger on the hole.

Can you explain why the water stays in the cup?

What will happen if you take your finger off the hole?

ACTIVITY:
TRICKY STRAW

Key idea: Pressure imbalance causes a force.

You will need:

- **a glass of water**
- **drinking straws**
- **a needle.**

Can some people suck faster than others? Have a drinking race. Who will win?

Do some straws work better than others? Can you explain the differences?

Prick one of the straws with a pin so it has lots of tiny holes! Why does that make a difference?

ACTIVITY:
BIRD FEEDER

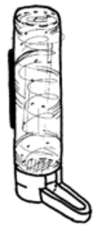
Key ideas: The atmosphere exerts a pressure on water surfaces. Air will fill up space if allowed.

You will need:

- **a bird feeder**
- **a drinking straw.**

Fill the bird feeder with water and put the feeding tray on. Why doesn't the water come out?

What do you think will happen if you suck some water out with a straw? Try it.

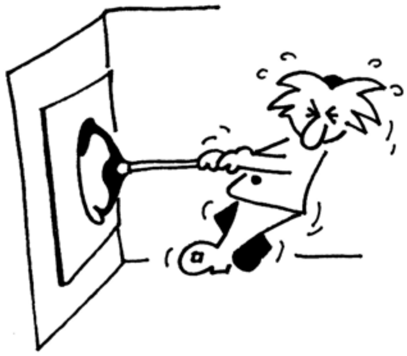


ACTIVITY: STICKY DART

Key idea: The atmosphere exerts a pressure.

You will need:

- **a dart with a suction cup at the end**
- **a tile or tiled surface.**



Press the dart against the tile, and make it stick. Try to pull it off. What makes it stick? Why doesn't it pull off?

Work out the best way of getting the dart unstuck. What is happening now?

Explanatory note: The *Tricky cup* activity is just like the *Upturned glass* activity except that the outside pressure is acting down on the water surface and is transferred through the water to keep the cup full. The hole lets air in to take the place of the dropping water.

The holes in the straws in the *Tricky straw* activity stop the air pressure being reduced to below atmospheric pressure, and you end up sucking up air instead. Some students swear that it works because water is sucked up but leaks out of the holes, despite observational evidence to the contrary!

The *Bird feeder* activity illustrates the same principle as the *Tricky cup* activity. If the water in the tray of the bird feeder drops below the rim it allows air to enter the device and push out (or replace) the water as the level drops until the tray lip is covered again.

The *Sticky dart* activity tends to invite 'suction' explanations, for obvious reasons. What actually happens is that the action of pushing the dart down forces air out. The rubber springs back, opening up the volume underneath slightly and reducing the pressure. Any attempt to pull it off only reduces the pressure underneath more, so that the difference from the atmosphere acting on the top more than makes up for the pull force. The way to get these off? Lift the edge with a fingernail to let air in at normal pressure underneath.

Flight

Some curriculum links for flight

The history of flight is a study that is ideally suited for study by primary school students.

In less than an average human lifetime we have progressed from the first powered flight of 37 m into the air to landing on the Moon. The Wright brothers achieved a sustained flight with a powered aircraft for 12 seconds in 1903. In 1969 Neil Armstrong stepped onto the surface of the Moon after a journey of approximately 370 000 kilometres in just under four days. In 1981 the space shuttle *Columbia* established reuseable spacecraft as a means of extraterrestrial travel.

Grandparents can provide anecdotal data to enliven reading, and the major space events (*Apollo* missions) have been televised and are readily available for viewing (also hot air balloons, airships, etc.).

Students can easily build models of the early gliders and kites that provided much of the early knowledge that led to advances in flight. Equal emphasis should be placed upon historical research and the discussion of findings from model building and flying. For example, what effect has powered flight had on communications, jobs, lifestyle?

What other things fly, apart from planes? How do they do it?

Students could explore other ways of natural flight. For example, they could look at bird skeletons, feathers, dandelion seeds (for parachutes), etc.

The first few activities are suitable for all year levels, but for middle years students they are likely to be the prelude to more sophisticated explorations and further challenges.

ACTIVITY:
PAPER DROP

Teaching note: In this activity, most students will arrive at a conclusion that the air resists the A4 paper but that dropping it held vertically minimises the surface that is pushing through the air and hence it will drop quickly (at least initially, until it skews off course). Younger students will often say that the crumpled paper drops more quickly than the A4 sheet because it is heavier. Density, or compactness, is often confused with weight, and this is a good opportunity to have that discussion. The book falls more quickly, of course. This is because it has greater weight to overcome the action of air on its surface.

The real purpose of the activity, however, is the surprise and challenge offered by the fact that the paper falls along with the book. The reason is that the book is pushing the air that would be resisting the paper on its own. It is not needing to force through air, and effectively falls as it would in a vacuum. This is similar to the experiment conducted by Neil Armstrong on the moon, when he dropped a hammer and a feather to find they fell at identical rates in the absence of an atmosphere … as argued by Galileo. Some people argue that the paper is in the book’s slipstream, which is in fact the same explanation if you think about it. The argument that air comes around the back of the book because of turbulence, and holds the paper on, is unnecessarily complicated and I think incorrect, although there is *some* turbulence.

One five-year-old child explained this counter-intuitive result very quickly and convincingly by pointing out that the paper acted just like another page in the book, and so would be expected to fall with it!

Dropping the paper and book from a greater height can productively extend this activity—students are often convinced it would separate if given enough time—

or by dropping it with the paper partly projecting out from the book. You can get some interesting turbulence/vortex effects by projecting it out a long way.

Key idea: Air offers resistance to falling objects.

You will need:

- **a number of A4 sheets of paper**
- **an A4-sized book.**

An air-resistance predict–observe-explain (POE) sequence, worked in pairs:

Hold two sheets of A4 paper at an equal height above the floor. Hold one parallel to the floor and the other perpendicular. Drop the two at the same time. Which do you think will hit the ground first?

Screw up one of the sheets of A4 paper and repeat the above experiment. Which one will reach the floor first this time?

Take one A4 sheet of paper and an A4-sized book. Hold both parallel to the floor at the same height and drop them simultaneously. Which one will land first?

Now, put the A4 sheet of paper UNDER the book and drop them together. What will happen?

Put the A4 sheet of paper ON TOP of the book and drop them together. What do you think will happen here?

ACTIVITY: PARACHUTE

Teaching note: This probe, because of the length and multiple challenges, will inevitably become a learning activity. How well it works as a probe depends on the questioning that takes place, focusing on students' ideas of air resistance, surface and weight. Some questions to consider:

- what principles govern the operation of the parachute?
- what would one hope students would be able to say about parachutes, after such an activity?

Key ideas: Air resistance causes an upward force on falling objects. The size and shape of an object affect the force.

You will need:

- **a freezer bag or larger plastic bag**
- **a reel of cotton**
- **plasticine**
- **scissors.**

Construct a parachute using a freezer bag, or even a larger plastic bag, using cotton attached at the corners, with a plasticine model figure. Construct a parachute that will drop as slowly and steadily to the ground as possible.

Predict what will make a difference to the effectiveness of the parachute.

Try out your ideas—compare different parachutes and figure sizes and methods of attachment. It is a good idea to keep comparing your changes with a standard model.

Investigate the effect of cutting a hole in the canopy. How big a hole can be cut without ruining the parachute? What is the effect of the hole on:

- **the dropping speed?**
- **the smoothness of fall?**

Explanatory note: A parachute involves the action of air resistance, as the canopy pushes down through the air, in opposition to the weight force mainly from the plasticine figure. Getting a slow drop requires the lift force to be maximised by opening out the bag to provide a large canopy, and the weight to be minimised by having a very small person. The right balance makes a very slow drop.

It is surprising how well a parachute with a large hole in the canopy works. It will be marginally slower than without a hole, but the net resistance must be pretty much dependent on the total canopy area, hole or not. What is attractive about the holed parachute is that the flow of air is smoother, and it does not rock from side to side as air spills out from around the canopy. Recreational parachutes have holes in them.

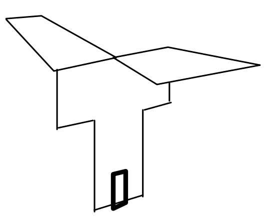
ACTIVITY: WHIRLYBIRDS

Teaching note: As well as conceptual engagement, this activity provides the opportunity for the development of students' knowledge of investigations: hypothesising, fair testing, measuring, recording and reporting. Try varying the number of paperclips, and the wing length, separately. Timing the fall is difficult, and comparing different designs two at a time is probably the most productive thing to do if you don't have access to a stopwatch and a balcony from which to drop the whirlybirds. To keep track of what is happening, students should modify one aspect at a time, and preferably retain each modified design to keep track of what is happening.

Key ideas: Flight involves the force of air on wings. The fall of an object involves the balance between downward weight and upward lift.

You will need:

- **sheets of A4 paper (possibly photocopied with four whirlybird patterns on them)**
- **scissors**
- **paperclips.**



Trace and cut out the whirlybird design shown in the figure *Whirlybird design*. Fold it to match the figure at left.

What do you think will happen when you drop the whirlybird? Try it.

Can you modify your whirlybird to make it spin the other way?

Design a whirlybird that takes as long as possible to reach the ground when dropped from head height. (You might consider varying size, number of clips, wing span.)

Design a whirlybird that spins as fast as possible. Thinking about your learning:

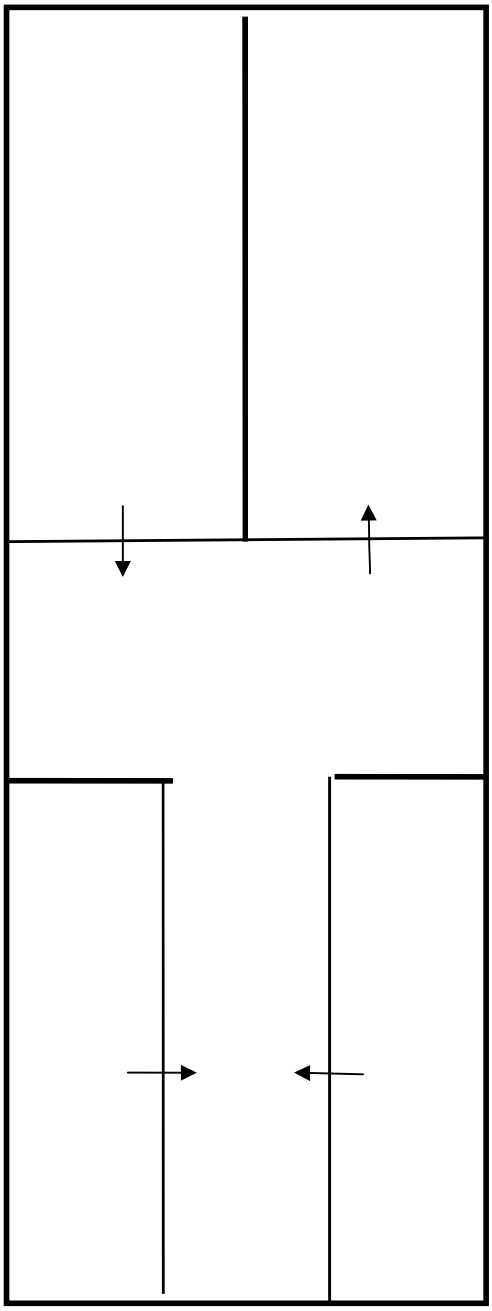
- **What have you learnt about airflow and forces and flying, in modifying your whirlybirds?**
- **Develop a list of useful bits of technology based on this principle (hint: windmill).**

FIGURE: WHIRLYBIRD DESIGN

Cut along the solid lines. Fold along the dotted lines in the direction of the arrows.

Place a paperclip on the bottom.

Drop the whirlybird.



Explanatory note: The spinning effect is due to the action of air on the wings as it rushes past the dropping whirlybird. You can check this by holding the whirlybird and pushing up on one wing with your finger. The body moves back as the wing is forced up. Pushing up on the other wing has the opposite effect, and you can see that the net result is a spinning set of forces. Flipping the wings causes them to spin in the opposite direction.

The longer the wings, the slower the drop, because of the uplift on the greater wing area. The more paperclips, the faster the drop and spin, because of the greater weight.

The challenge of constructing a whirlybird that drops as slowly as possible is more difficult than constructing one that spins fast, although the measurement problem here is more challenging.

ACTIVITY: KITES

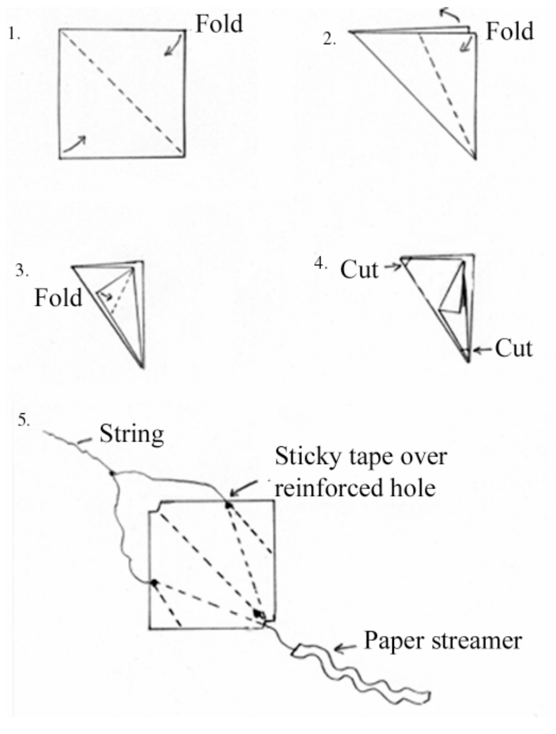
Key ideas: The force of air on surfaces can be controlled by carefully designing the shape of the surface. Stable flight involves the balance of forces.

You will need:

- **one square of paper or card, at least 16 cm × 16 cm (the larger the square, the sturdier the 'paper')**
- **enough string or strong wool to fly the kite (about 2 m)**
- **sticky tape**
- **glue**
- **a paper streamer for the tail (the length depends on the size of the kite and the strength of the wind on the day; alternatively, you can glue strips of paper end to end).**

Simple kites that are easy and fun to fly can be made. The figure *Making a kite* shows how to make a foolproof paper kite.

FIGURE: MAKING A KITE



Explanatory note: In the case of kites, the lift force is from moving air and will not be vertical, and there is the extra force of the string as well as that of gravity. Balance is important in a kite to maintain the right angle, and the tail is critical for providing stability.

ACTIVITY: PAPER PLANES

Key ideas: Air moving across wings can cause an uplift force. The shape of wings and balance of weight can be manipulated to control the flight. The shape of a flying object affects the air resistance on it.

You will need:

- **sheets of A4 paper**
- **paperclips.**

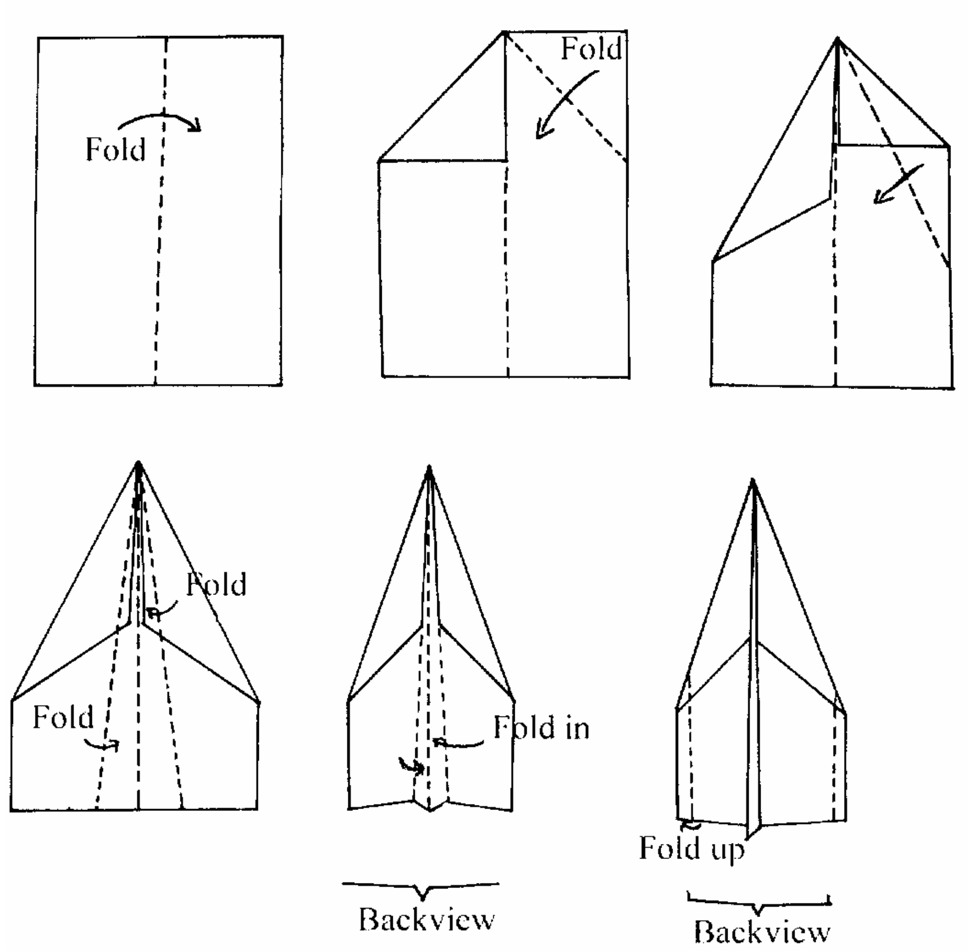
Using the basic pattern in the figure *Making a paper plane*, make a paper plane that:

- **stays as long as possible in the air**
- **does spectacular tricks.**

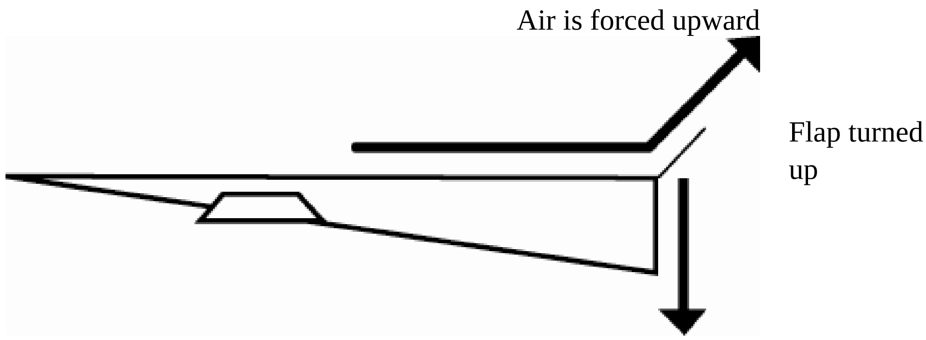
You may want to investigate the effect of paperclip weights, wing size, flaps, etc.

Try some different designs.

FIGURE: MAKING A PAPER PLANE



Explanatory note: The basic principle is that air rushing past the wings provides an uplift force that counteracts the downward pull of gravity. The plane flies with the wings slightly angled up, so that air rushes faster over the top surface of the wing compared to the bottom surface, causing a pressure difference. The question of balance of the plane is thus important, and paperclips can help with this (generally placed towards the front). The action of the flaps in causing the plane to soar, or dive, is similar in principle to the effect of air on the whirlybird wings as shown in the figure of a raised flap below.



The back of the plane is forced down as the airstream is forced up, thus causing the plane to lift.

ACTIVITY: FLYING LOOPS

Key ideas: The force of air on surfaces. Stability and balance depend on weight distribution.

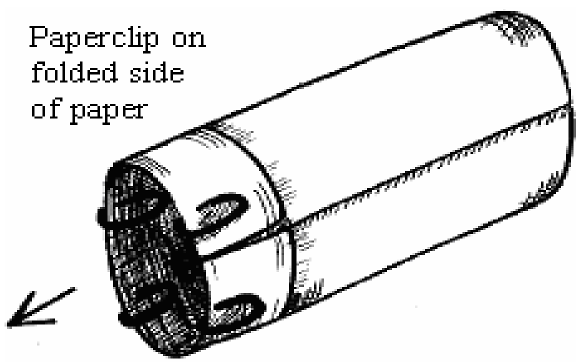
You will need:

- **sheets of A4 paper**
- **paperclips**
- **sticky tape**
- **a drinking straw.**

Make a flying loop by folding a sheet of A4 paper back about 3 cm along its long length, and then rolling it into a cylinder. Keep it together with four paperclips on the end with the fold.

Now throw the loop with the paperclips at the front. It will fly surprisingly smoothly.

What do you think the air is doing to keep the loop up?



Make a flying tube out of a plastic drinking straw and two loops of paper. What factors can be altered to improve its flight? (Hint: two paper loops stuck to a straw also fly smoothly if the straw is weighted with a paperclip.)

ACTIVITY: BALLOON ROCKET

Key idea: To every force there is an equal and opposite reaction force.

You will need:

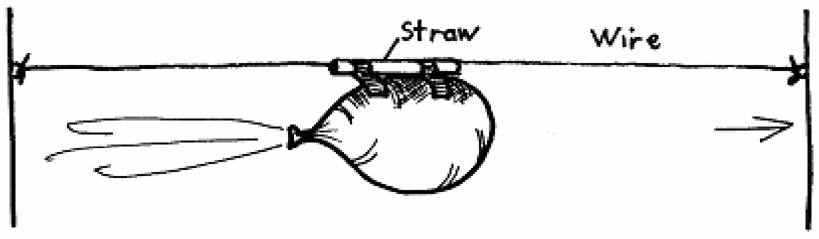
- **a length of fishing line or waxy string**
- **a means to attach the line or string to walls**
- **sticky tape**
- **a plastic soft-drink bottle**
- **plasticine**
- **Blu-Tack**
- **drinking straws**
- **long balloons**
- **paperclips.**

String a fishing line across the room with a straw attached so it can slide along the line. Use sticky tape to attach a balloon to the straw. Blow up the balloon and release it, pointing the balloon so it is propelled along the fishing line.

An interesting extension of this idea is to have the balloon inside a plastic soft-drink bottle that can be decorated. However, you can't blow the balloon up inside the bottle unless you prick a hole in the bottle. Why? The blowing up of the balloon and release of air can be done using a straw, with plasticine or Blu-Tack sealing the opening round the straw.

Design a wheeled cart (using recycled material) that is powered by a balloon. Adjust your design so that the cart can go as far as possible with one balloon deflation.

Explanatory note: The balloon rocket works on the principle of rocket propulsion. This is what is meant by 'to every action there is an equal and opposite reaction'. The balloon forces air out as it deflates, and itself experiences a force from the air in the opposite direction.



ACTIVITY: HOT AIR GARBAGE BAG

Key idea: Hot air rises.

You will need:

- **a garbage bag**
- **a hair dryer.**

Blow up a garbage bag using a hair dryer. Watch the bag inflate and attempt to rise.

ACTIVITY: TEA BAG ROCKET

You will need:

- **a tea bag**
- **matches.**

Remove the tag and the string from a tea bag, then undo and remove the staple. Unfold the tea bag and empty out the tea. Gently open the tube you are now left with, taking care not to tear it. Stand the tube vertically on end (I suggest you do it on a plate or non-flammable surface in case your rocket falls over). Ignite your rocket by lighting the TOP of the tea bag tube (not the base!) with a match and begin your countdown. The tube will burn almost all the way down and then shoot up.

Explanatory note: As we know, warm air rises because it is less dense than cooler air. The flames create a small pocket of warm air and, once combusted, the tea bag material is very light. Hence the warm, light, combusted tea bag rises to the roof. This works best in a coolish room.

Bernoulli effect

Teaching note: The Bernoulli effect is fascinating, but counter-intuitive. It is quite difficult for younger students to grasp, since the concept of atmospheric air pressure itself is difficult and not readily established even by middle years students, and the activities also require some feeling for the possibility of unbalanced forces. These activities are generally not recommended for the early years except as intriguing phenomena. The links to the flight activities are difficult to make clear, but these activities do at least provide some rationale as to the way airflow is able to support a paper plane.

In each case with these tricks, a moving stream of air creates a low-pressure zone that the object moves towards. Some students will explain this by arguing: ‘We blew the air out of the way and so it doesn’t press as hard’—an interesting idea but not correct. The air is still there, but its pressure is lowered.

The Bernoulli effect is probably best explored at the lower secondary school level, although some of these activities would be productive for Years 5 and 6 students.

Key idea: Pressure is reduced in a moving stream of air.

In many science books one can find a range of activities designed to illustrate the Bernoulli effect; that pressure is reduced in a moving airstream. This is the principle on which aerofoils are based, although it is hard to relate it to paper planes with flat wings.

ACTIVITY: PAPER LIFT

Teaching note: This activity is a good candidate as a predict–observe–explain (POE) task.

You will need:

- **a thin strip of paper**

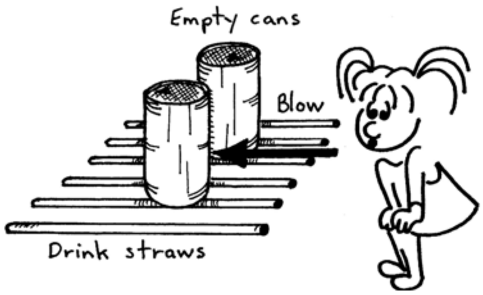
Take a thin strip of paper, hold it at one end close to your mouth, and blow across the top of it. The strip of paper rises!

ACTIVITY: FRIENDLY CANS

You will need:

- **two empty aluminium cans**
- **at least twelve drinking straws.**

Place two empty aluminium cans about 3 cm apart, on a set of plastic straws placed parallel so the cans can easily roll toward or away from each other. Blow gently between them. They come together because of the reduced pressure!



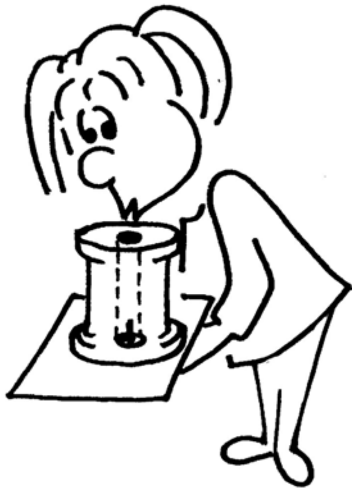
This trick can also be done with suspended balls if they are light enough.

ACTIVITY: FLOATING CARD

You will need:

- **a playing card**
- **a cotton reel**
- **a pin.**

Place a playing card against the end of a cotton reel and blow hard down through the hole in the reel. The card seems to stick to the reel because of the reduced pressure as the air flows past it. With a bit of practice the card can be suspended that way. A pin through the card, projecting into the reel, stops it slipping sideways.



Explanatory note: The floating card depends on the moving stream of air that is forced between the reel and card, and the same is true of air blown down through a funnel, forced past a ping-pong ball suspended underneath but the larger air pressure underneath.

ACTIVITY: BLOWING SUCKS!

You will need:

- **a ping-pong ball**
- **a pouring funnel.**

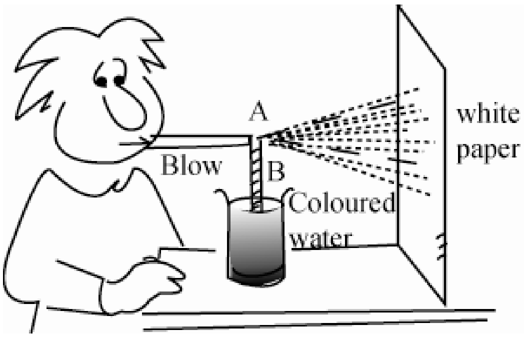
Hold a ping-pong ball inside a pouring funnel held upside down, and blow through the funnel. The ping-pong ball is suspended in the airstream!

ACTIVITY: WATER LIFT

You will need:

- **two drinking straws**
- **a glass of water.**

Cut a straw in two. Place one half in a glass of water (coloured water produces a more dramatic effect) as shown in the figure below and use the other straw to blow a stream of air across the top of the vertical straw. If you get it right, you will have quite an effective spray device!



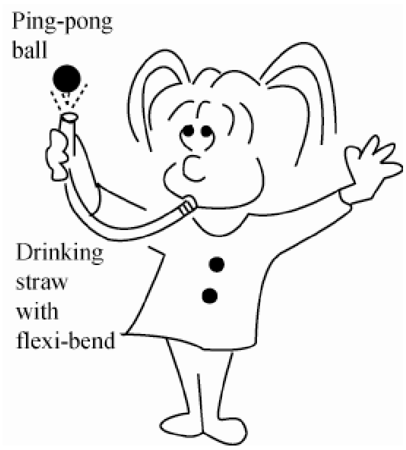
ACTIVITY: FLOATING BALL

You will need:

- **a drinking straw with a flexi-bend, or flexible tubing**
- **a ping-pong ball.**

Use a drinking straw with a flexi-bend. Angle the end of the straw up vertically, and place a ping-pong ball above the end of the vertical section. By blowing hard through the straw you should be able to balance the ping-pong ball on the stream of air.

If you practise, you will even be able to balance the ping-pong ball with an angle airstream.



A less stressful version of this trick can be done using a vacuum cleaner with an air exhaust. The vacuum tube, blowing out air, can be used to suspend a beach ball in mid-air.

Explanatory note: The ping-pong ball suspension, using a straw, is difficult to sustain unless you're a professional wind musician. To explain it fully: consider what happens if the ball slips slightly out of the stream. If it slips to the left, for instance, that creates a steady stream of air from the straw to the right, which reduces the pressure and brings the ball back to centre. There is thus a natural stabilising principle at work that cushions the ball in a moving stream of air.