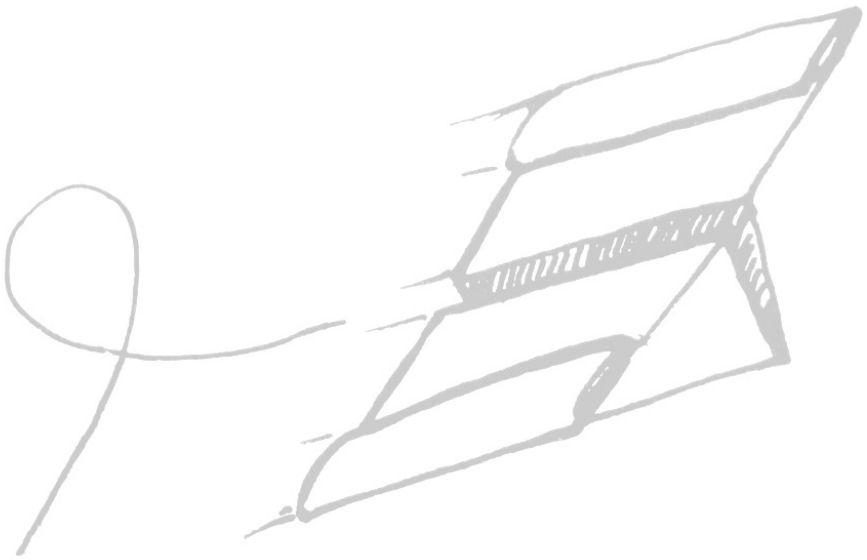
Let's Do Science

Grade Six

Air and Aerodynamics



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Air and Aerodynamics

Before You Begin

Air is a mixture of gases that are essential to life on Earth, and yet we often take the air around us for granted. This unit focuses on helping students understand the attributes of air and how air interacts with objects in flight. By studying birds and airplanes, they learn about a variety of adaptations and designs that make flight possible and provide for propulsion and control. The concepts learned here will be important building blocks for the grade 6 unit Flight.

Topic A: Air and Aerodynamics

(Suggested time: 4-6 weeks)

This unit can be done any time of the year, but should precede the grade 6 Flight unit, as it covers underlying concepts such as the properties of air and Bernoulli's principle.

Send letters home informing parents of the unit and listing materials that may be needed during the unit. Perhaps a parent has a reverse-flow vacuum cleaner that can be borrowed or a mounted bird of some sort for looking at feathers and wings. Field study and guest speaker bookings should be made early.

Background Information

In order to fly, the downward force of gravity must be overcome. Period. This holds equally true for balloons, birds, bullets, bats, insects, kites, planes and spacecraft.

There are several ways to overcome gravity. Hot-air and helium balloons depend on the fact that they are lighter than the air they displace so they float upward, much like a cork floats to the surface when immersed in water. Spacecraft use the immense power of rockets to thrust them skyward against the pull of gravity. This unit examines the unique nature of *air in motion* that allows animals and airplanes to fly using wings.

First, let's consider what air is—an invisible mixture of several gases. If asked to name one of these gases, oxygen is usually the first that springs to mind. There are clues all around us pointing to the presence of oxygen in the atmosphere: animals, humans included, use it in the respiratory process, it's the element that combines with iron atoms to form rust and it's the essential ingredient that sustains combustion. But oxygen is not the most abundant gas present in air. It makes up roughly one-fifth of the mixture. Nitrogen is the gas that accounts for nearly the entire remaining four-fifths, and extremely small amounts of other gases, such as carbon dioxide, helium, methane and water vapour, fill out the roster. Although less readily detectable than oxygen, their presence can be inferred if you consider the following. If air were composed primarily of oxygen, even the smallest spark could set off a planet-wide firestorm!

As a gas, air possesses two qualities vital to the mechanics of flight. First, it behaves like a fluid that can flow around surfaces. As we will see shortly, certain aspects of fluid dynamics account for the force that counteracts gravity during winged flight. Second, air, like other gases, occupies a set volume of space at a given temperature and pressure and, although it can be compressed into a smaller volume under the right conditions, it generally resists, exerting a pressure known as *air resistance*.

Air resistance affects a moving object in two ways: it generates drag acting in the direction opposite to the direction of motion and it also lifts the object perpendicular to the direction of motion. This effect is experienced when you launch a kite. As you run with the face of the kite vertical behind you, you can feel the *drag* exerted on the kite and watch as it soars upward due to *lift* (see Fig. 1).

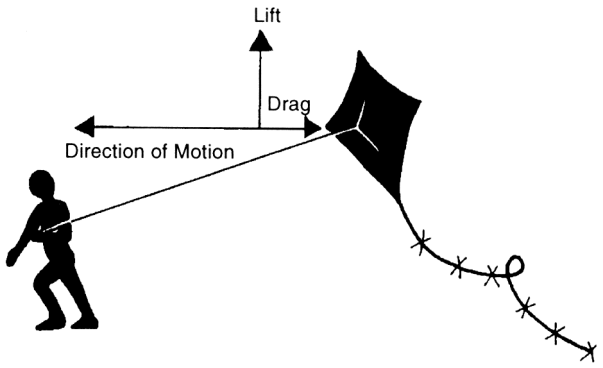

Figure 1.
Aerodynamic forces.

The *aerodynamic forces* (for example, the amount of drag and lift) created in a stream of air depend on:

- air density—forces vary in direct proportion to air density;
- airspeed—forces increase as the square of the airspeed; and
- the shape, angle and area of the surface meeting the air.

This last set of factors—shape, angle of attack and surface area—provides us with the greatest amount of aircraft design flexibility. The goal is to come up with a form that minimizes the drag attributable to these factors (for example, to *streamline* the form) while maximizing lift.

Wings are streamlined forms known as *airfoils* that make use of a phenomenon called *Bernoulli's principle* to maximize upward lift. According to Bernoulli's principle, as the velocity of a fluid increases, the pressure it exerts decreases. (Remember, air in motion behaves like a fluid.) Because air moves over the curved upper surface of a wing faster than it moves along the underside of a wing, there is less air pressure above the wing, more below and lift is created (see Fig. 2). The same principle is behind the design of golf balls: the tiny dimples act as individual airfoils that accelerate air flow over the ball's surface and create lift. You can also apply Bernoulli's principle to generate a downward force by making the airfoil's lower surface curved (longer) and upper surface flat (shorter). Race cars use this reverse airfoil design to gain increased traction on the road (see Fig. 3).

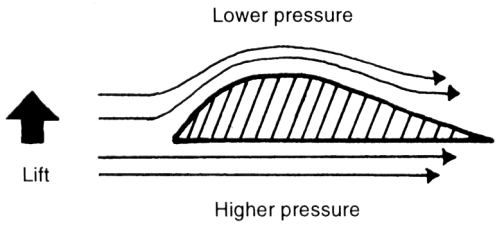

Figure 2.
Normal airfoil.

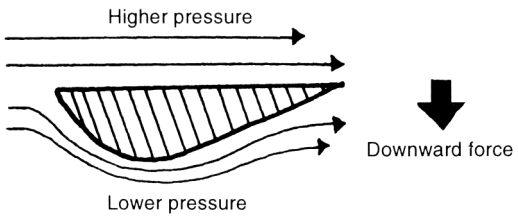

Figure 3.
Reversed airfoil.

In general, for an airplane or an animal to sustain straight, forward flight at a constant speed and altitude, forward thrust provided by the propulsion must be greater than the backward drag (see Fig. 4). To achieve flight, the upward lift must be greater than the downward force of gravity, and additional thrust is needed. If thrust balances drag, and lift balances the

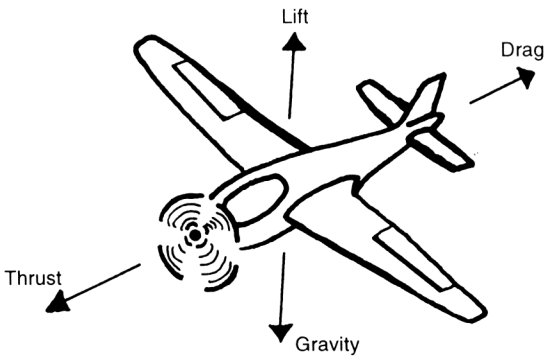

Figure 4.
Forces on an aircraft.

downward force of gravity, the plane or animal will *hover*.

Powered aircraft use a variety of propulsion devices to provide forward thrust. Fixed-wing aircraft rely on propellers or jet engines. These vehicles accelerate along a runway until the flow of air over the wing structure creates enough lift for take-off. They remain airborne by sustaining the airspeed required to maintain adequate lift with forward motion. Rotary-wing aircraft (such as helicopters) utilize airfoils as propeller blades. This allows them to achieve both thrust and lift as the blades turn. Some airplanes can take off vertically, then continue horizontally. Some helicopters can fly horizontally at very high speeds due to specific adaptations.

The wings of birds, bats and insects serve a similar dual function. They act as both the means of propulsion and as airfoils. Insect wings are often flat when at rest but take on the curved shape of an airfoil once they begin to beat against the air. Likewise, a bird's entire wing changes shape in the course of a wing stroke in order to maximize the lift and forward motion attained from the down stroke and minimize the drag encountered in the upstroke.

There are three important motions in addition to the bird's forward motion. They are flapping, twisting and folding. Twisting allows each part of the wing to keep the necessary angle relative to the airflow. The wings are flexible, so they twist automatically. Wing folding is not essential, but upstroke actually slows the bird down! By folding its wings a bird can reduce drag during the upstroke. Special feathers at the tip of the wing come together on the down stroke to form a solid structure that twists under at the end of the movement, imparting forward motion in much the same way we gain forward motion when swimming by cupping our hands. On the upstroke, these feathers spread apart, allowing air to pass with little resistance.

In addition to wings, insects and birds have evolved other features that help make them airworthy. Birds have compact, highly streamlined bodies that are perfect for flight. Their collar bones have fused into the familiar "wishbone" in order to provide a rigid skeletal frame that prevents the bird's body from being squashed when its powerful wing muscles contract. Their light, hollow bones provide maximum strength with minimum weight, and their eyesight is extremely sharp, rapidly delivering an enormous amount of information about the bird's three-dimensional environment to the brain for processing. Insects have evolved one or two sets of wings that are attached to their thorax (middle body section). Some insects, like a housefly, can take off backwards and sideways, because they can twist their wings.

Insects, in general, are small and lightweight. Like birds, they have specialized flight muscles to power their wings. However, with just a few

exceptions, most insects can fly only if the surrounding temperature is of the order of 25°C. Insects are *ectothermic* (their body temperature varies with the temperature of their immediate environment), so when it is cold outside, their body temperature is low as well. Their flight muscles need to be at a higher temperature in order to work efficiently.

Now that you know the basic principles of aerodynamics and how these are used to achieve flight, it's time to move on to the next unit and discover ways to control an object's movement through air.

Elementary Science Program of Studies

General and Specific Learner Expectations

The following general and specific learner expectations have been taken directly from the 1996 Elementary Science Program of Studies. The specific learner expectations (SLEs) are referred to by number in the second column of the activities table.

General Learner Expectation

Students will be able to:

Describe properties of air and the interactions of air with objects in flight.

Specific Learner Expectations

Students will be able to:

1. Provide evidence that air takes up space and exerts pressure; identify examples of these properties in everyday applications.
2. Provide evidence that air is a fluid and is capable of being compressed; identify examples of these properties in everyday applications.
3. Describe and demonstrate instances in which air movement across a surface results in lift—Bernoulli's principle.
4. Recognize that in order for devices or living things to fly, they must have sufficient lift to overcome the downward force of gravity.
5. Identify adaptations that enable birds and insects to fly.
6. Describe the means of propulsion for flying animals and for aircraft.
7. Recognize that streamlining reduces drag, and predict the effects of specific design changes on the drag of a model aircraft or aircraft components.
8. Recognize that air is composed of different gases, and identify evidence for different gases. Example evidence might include effects on flames, the "using up" of a particular gas by burning or rusting, and animal needs for air exchange.

Cross-curricular Connections

Mathematics

- Measure, chart and graph distances and time.

Art

- Draw or make models that compare the structures of birds, insects and aircraft.
- Integrate geometry with flight activities using *The Sky's the Limit* (Adair et al.).
- *Explorations in Science* will also offer integration suggestions.

Children's Alternative Frameworks

Children have the following misconceptions related to air.

- Blowing on something always makes it move away.
- Air neither has mass nor can it occupy space.
- Lift during animal flight (birds, insects) is produced entirely by flapping of the wings.
- Air has no weight.
- Scrunching up a piece of paper makes it heavier.

Activities

Classroom teachers have identified the following activities that may be done to address the Specific Learner Expectations (SLEs) in the Program of Studies. The list is not prescriptive and teachers may select activities that are most appropriate for their students.

Activities have been listed under two headings: Key Activities and Extension Activities. Key activities are supported by authorized resources and identify "powerful and practical" means for achieving learner expectations. Extension activities represent alternative ways of achieving or supporting learner expectations.

Key Activities

Key Activity	SLE	Print Resources	Essential Materials	Comments
Determining what students know about aerodynamics		*Explorations in Science, Level 6, Flights of Fantasy (Introducing Aerodynamics)*, p. 10	file cards, paper	This activity will provide the teacher with insight into students' prior knowledge. Students should first work independently in their journals and answer such questions as: What is air? What causes objects to fly? Does air weigh anything? How do birds fly? Then have them do the activity.
Determining that air takes up space (has volume)	1	*Explorations in Science, Level 6, It's in the Air (Where Is Air? and Extending the Activity)*, p. 10 *Explorations in Science, Level 6, It's in the Air (A Bizarre Jar)*, p. 15 *Innovations in Science, Level 6, Flight (Flightstorming)*, p. 6 *Innovations in Science, Level 6, Flight (Slow Down)*, p. 8 *Innovations in Science, Level 6, Flight (Up, Up and Away)*, p. 10 *Innovations in Science, Level 6, Flight (Full of Hot Air)*, p. 16 *Innovations in Science, Level 6, Flight (Fall Breakers)*, p. 25 *Innovations in Science, Level 6, Flight (Ready, Set, Thrust-Off!)*, p. 28 *Innovations in Science, Level 6, Flight (Flight Secrets)*, p. 31	large glass jar, funnel, modelling clay, plastic bags, pail or large container, drinking glasses	One or two of these activities could be combined with Key Activity 3 in a station approach. Also, one or more of the activities determining that air has mass could be included from Extension Activity 1.

Key Activity	SLE	Print Resources	Essential Materials	Comments
Determining that air takes up space (has volume)(cont'd)		*Innovations in Science, Level 6, Flight (Learner's Licence)*, p. 34 *Innovations in Science, Level 6, Flight (Sky Sleds)*, p. 37		
Recognizing and demonstrating that air exerts pressure	1	*Explorations in Science, Level 6, It's in the Air (Pressure and Paper)*, p. 12 *Explorations in Science, Level 6, It's in the Air (Lift with Your Lungs)*, p. 17	thin strips of soft wood, newspaper large and small plastic bags	The activity involving breaking a wood slat using air pressure can be dangerous if done incorrectly (the slat can fly up into a face if the newspaper is not kept flat to the table surface). For this reason, the activity should be done as a demonstration. Pressing the newspaper the night before helps ensure the newspaper remains flat during the activity. Two or three of these activities should be sufficient to effectively demonstrate that air exerts pressure.
Exploring Bernoulli's principle	3	*Explorations in Science, Level 6, Flights of Fantasy (Introducing Aerodynamics)*, p. 10 *Explorations in Science, Level 6, It's in the Air (Air in Motion)*, p. 21 *Innovations in Science, Level 6, Flight (Flight Secrets)*, p. 31 *Up, Up and Away: The Science of Flight* (Darling) *(Air on the Move* and *A Wind Tunnel)*, p. 10	file cards, paper Ping Pong balls, balloons, hair dryer rulers, index cards, pencils, tape, paper, empty pop cans, straws, balloons, hair dryer newspaper, old yardstick, thread spool, candle, index cards	These activities lend themselves to a station approach, where students can investigate Bernoulli's principle in a variety of situations. You can mix and match the activities to best suit your needs.
Investigating the compression of air	1, 2	*Explorations in Science, Level 6, It's in the Air (Squeezing the Air)*, p. 13	large plastic bags, inflation needles, basketballs or soccer balls	
Investigating the forces involved in flight	4	*Up, Up and Away: The Science of Flight* (Darling) *(Battle of Forces)*, p. 26 *Innovations in Science, Level 6, Flight (Up, Up and Away)*, p. 10 *Innovations in Science, Level 6, Flight (Full of Hot Air)*, p. 16	sausage-shaped balloons, straws, fishing line or strong thread, clear tape	This concept can be covered in class discussion after reading the materials.

Key Activity	SLE	Print Resources	Essential Materials	Comments
Investigating the forces involved in flight (cont'd)		*Innovations in Science, Level 6, Flight (Ready, Set, Thrust-Off!)*, p. 28		
		Innovations in Science, Level 6, Flight (Flight Secrets), p. 31		
		Innovations in Science, Level 6, Flight (Sky Sleds), p. 37		
Investigating adaptations of birds and insects that enable them to fly, and comparing them to aircraft	5, 6	*Up, Up and Away: The Science of Flight* (Darling) *(Looking at Feathers and Feather Power)*, p. 18	feathers, magnifying glasses or low-power microscopes	These references have readings and activities covering concepts. You may wish to have students further research the topic in the library. Check for allergies and local regulations before bringing birds into your classroom.
		Innovations in Science, Level 3, What's Up? (Flyers by Day), p. 17	student book (p. 49)	
		Innovations in Science, Level 3, What's Up? (Ready, Set, Thrust-Off!), p. 28		
		Explorations in Science, Level 6, High Fliers (It's a Plane, It's a Bird…), p. 10	flight log, mural paper, coloured pencils, crayons, paints, scissors	This activity involves taking the children on a bird-watching hike. Check field trip regulations in your school jurisdiction.
		Innovations in Science, Level 6, Flight (Flight Storming), p. 8		
Recognizing how streamlining reduces drag	7	*Explorations in Science, Level 6, It's in the Air (Falling Through Air)*, p. 19	sheets of paper and cardboard, old books (catalogues)	
		Innovations in Science, Level 6, Flight (Slow Down), p. 11	paper, stopwatch	
		Explorations in Science, Level 6, High Fliers (Floaters), p. 11	paper	
Looking for evidence that air is composed of different gases	8	*Explorations in Science, Level 6, It's in the Air (Burning the Air)*, p. 23	glass jars, candles, saucers, stopwatches	One or two of these activities will be sufficient to cover the concept. All of the activities involve an open flame and should be demonstrated only. Wood splints are available from most science suppliers. Check if use of fire and chemicals in the classroom has specific guidelines in your school district.
		Explorations in Science, Level 6, It's in the Air (A Different Gas), p. 27	glass bottles, balloons, vinegar, baking powder, matches, wood splints	
		Explorations in Science, Level 6, It's in the Air (Plants and Gases), p. 29	beakers, aquatic plants (may be collected from ponds or purchased), funnels, test tubes, wide-mouth jars, potted plants, calcium hydroxide, matches, wood splints	

Extension Activities

Extension Activity	SLE	Print Resources	Essential Materials	Comments
Building a hovercraft		*Explorations in Science, Level 6, It's in the Air (Build a Hovercraft)*, p. 31	old 45 rpm records, plastic container lids, thread spools	One of these activities could be added as extra support to ensure students understand that air is matter and has mass as well as volume.
Investigating lung capacity	1	*Innovations in Science, Level 6, Superkid! (Full of Fresh Air)*, p. 30	plastic tubs, plastic jugs, rubber or plastic hose, container for measuring liquid volume	
Making a vacuum	1	*Explorations in Science, Level 6, It's in the Air (Making a Vacuum)*, p. 25	flask, stopper, balloon, jar with lid, modelling clay, straws	

Assessment

For a broader discussion of science classroom assessment techniques see *Assessing Student Learning* in the introduction of this publication on p. 15. Good places to begin looking for the unit-related ideas are *Explorations in Science* assessment handbooks, *Innovations in Science* teaching notes, Unit tests and Portfolio ideas, Alberta Education sample tests at **www.education.gov.ab.ca** and Alberta Assessment Consortium at **www.aac.ab.ca**

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