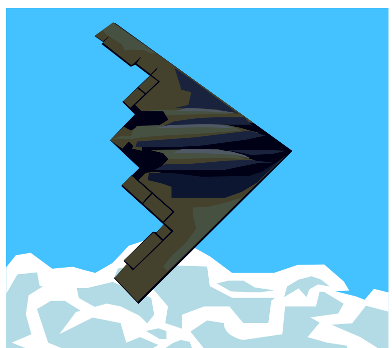
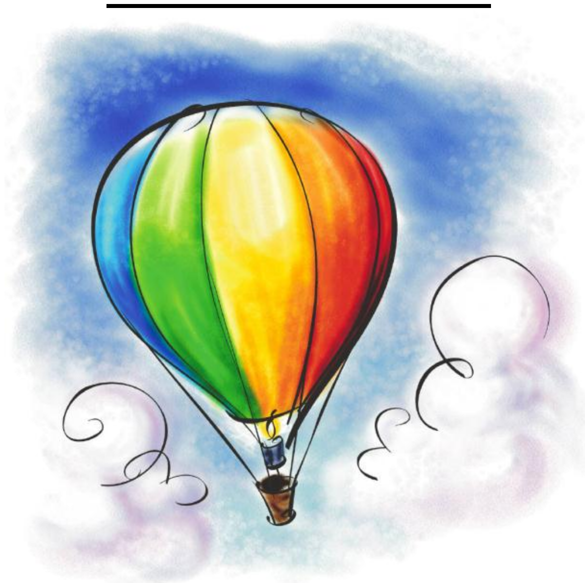
Air and Aerodynamics
Flight
Note Pack





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Essential Questions of Aerodynamics

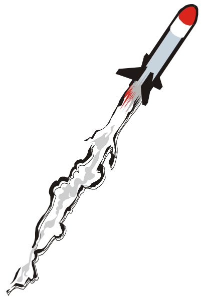
The students should be able to answer the following questions:

1. Why does air exert pressure on objects in our atmosphere?
2. What forces can change the amount of pressure being exerted on an object?
3. What is the main difference between gasses and liquids that allows gasses to be compressed?
4. What design changes are needed to reduce the drag force on a flying device?
5. How can you prove the existence of air?
6. What experiments can be performed to show evidence of the different gasses in our atmosphere?
7. What are the four flying forces that aircraft designers have to consider?
8. How does Newton's Law – "for every action, there is an equal and opposite reaction"- apply to flying things (birds, airplanes, insects, flying mammals)?

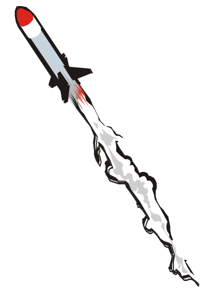
Essential Questions for Flight

The students should be able to answer the following questions:

1. What factors influence the flight of an airplane from travelling in a straight line?
2. What are the three main axis of rotation of an airplane?
3. What controls the flight path of an airplane along the three axis of rotation?
4. Why do hot air balloons float (using air pressure and mass in your explanation)?
5. What are the advantages and disadvantages of propellers of different sizes?
6. How do jet engines achieve greater thrust than propellers?



Aerodynamics and Flight Study Guide



A-1 Background Info

Flight is the ability to move with direction through the air. This ability comes naturally to many animals, but humans can only fly in machines that they have invented. As early as the 16th century, Leonardo da Vinci was sketching devices that resemble the modern helicopter, but he did not yet understand the aerodynamic forces involved in flight. **Aerodynamics** is the study of the flow of air and other gases and the forces acting on bodies moving through gases. Through an increasing understanding of aerodynamics, humans are learning new ways to fly.

There are two kinds of machines that carry people into the air:

- One kind is the lighter-than-air vehicles, which contain gas that is more buoyant than air (hydrogen or helium), or which contain heated air that is lighter than cool air (hot air balloons).
- The other kind is heavier-than-air vehicles. These are aircraft, helicopters, rockets and gliders. In order for these machines to fly, they must be able to overcome the force of gravity and lift into the air.

Bill Nye Video "Fluids"

While watching the video, list three or more BIG IDEAS discussed in the movie. Like, why are we watching a movie on fluids, when out topic is on Aerodynamics?

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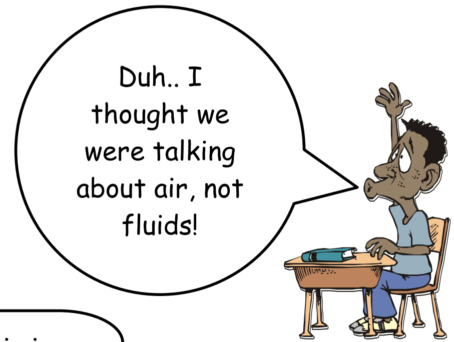
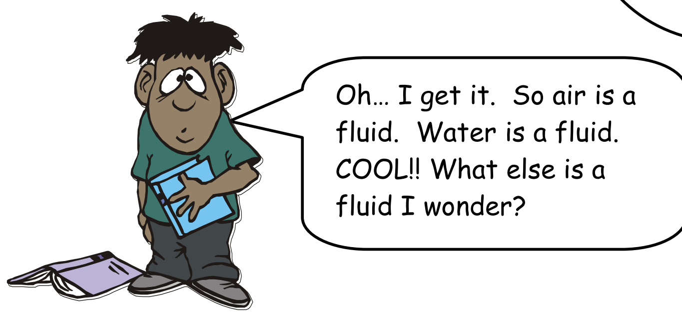
A-2 Fluid Dynamics

Fluid dynamics → the study of the forces on solid objects as they pass through a fluid.

Fluid → Any substance that flows, takes the shape of its container, and can be either a liquid or a gas.





A-3 Properties of Air

To understand anything about flight, you must first understand certain important properties of air. Air is the gas that is all around us. It makes up our atmosphere that surround the earth like a huge ocean. (☺fluid connection☺) Although we cannot see or feel air since it is a gas, we know that it is all around us, that it has weight and it takes up space. It acts almost exactly the same as a fluid and objects in flight are governed by the same dynamics as objects floating or swimming in water. There are four main properties of air that are important to flight:

- **The gas we call our air is made up mainly of nitrogen (approximately 80%) and oxygen (approximately 20%).** There are also very small amount of other gasses, and water vapor. The main reason oxygen is important to flight is that it burns, and jet engines take advantage of this property during flight.
- **Air takes up space.** When we swing a bag though the air, it fills with something. Even though it is invisible, it is taking up space and nothing else can exist in that space at the same time. Air is able to hold up planes in much the same way as water hold you up in a pool.

Parachutes work because of this property. Most parachutes today are rectangular in shape and when they are opened, they capture air and trap it temporarily. In much the same way as an air mattress will hold you up in water, the air trapped in the parachute will keep you from falling down through the atmosphere as fast. Whatever the parachute brings down safely is called the payload. Parachutes are use for escape mechanisms, breaking systems, delivery systems and sports.

- **Air has weight and therefore exerts pressure.** We are so use to the air pressure around us that we do not even notice it and we thing of air as being weightless. The air in our classroom weighs approximately 120 kilograms, which is more than an adult human! Another reason we don't notice it is because the pressure is directed in all directions and is balance by pressure inside our bodies (our own blood pressure). In fact, if we suddenly took air pressure away, we would explode in much the same way that a marshmallow does in a vacuum chamber! That is why astronauts must wear special pressurized suits when they venture into space where there is no air. There are a few characteristics of air pressure that are important for flight:

  - **The lower in the atmosphere you are, the more pressure there is.** This is because air has weight and the more weight there is, the more pressure you feel. You can feel this kind of fluid pressure when you swim to the bottom of the deep end of the pool. You can feel the water pressing much more on you than on the surface of the water. Air acts in the same way. The atmospheric pressure is greatest where the air meets the ground, and it gets progressively weaker as you go up. The compressed air at the surface of the earth is much warmer than the less compressed air higher up in the atmosphere. Any material that is compressed tends to heat up.
  - **Moving air has less pressure than air that is still.** The faster air moves, the less pressure it has. Therefore, whenever you have air moving faster, slower moving (higher pressure) air will be pushing on it. This is just the opposite of what you would expect since you think of fast moving air (wind) as exerting

more force than air standing still. However, that sensation is a result of drag (an important flight force to be discussed later), not air pressure.

- **Warm air is lighter than cool air.** Gasses are lighter when they warm up because the molecules move faster and expand. Since there are not as many molecules in one space, the gas becomes lighter in weight. This is how hot air balloons fly, and why they are considered a "lighter than air" craft.

What are the properties of air and give an example of an aircraft that takes advantage of this principle.

1.____

2.

3.

4.

5.

6.

Also Study Your Lab Results From the Centres.

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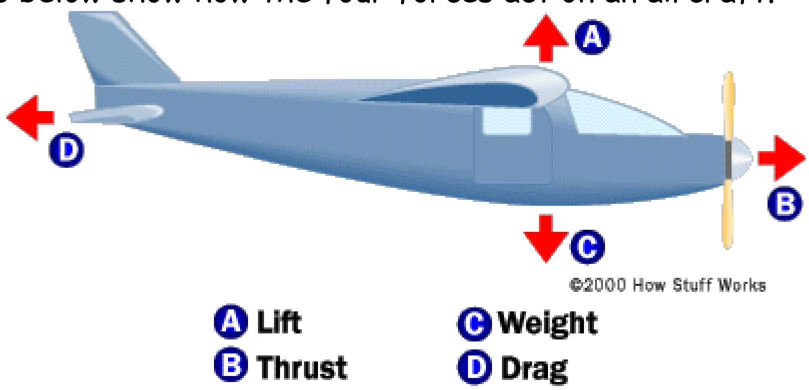
☺ **Aerodynamics Unit Test April 14th** on everything before this note!! ☺

Flight Section

F-1 Forces Acting on an Aircraft (incl. Rockets)

Four main forces act on an aircraft to keep it flying in a straight and level. These forces are lift, weight (gravity), thrust and drag. Thrust and drag act against each other and thrust must exceed drag in order to keep an aircraft flying. Lift and weight act against each other and lift must exceed weight in order to keep the aircraft from falling back to earth. The illustrations below show how the four forces act on an aircraft.



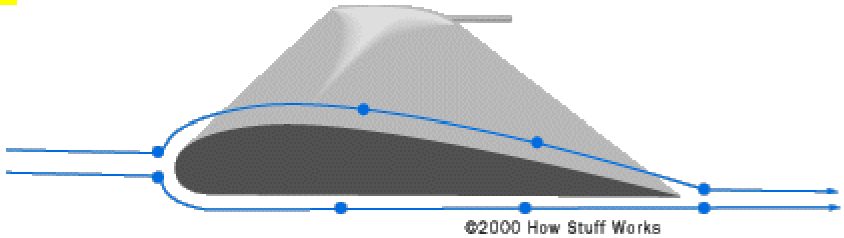
F-2 How an Aircraft Achieves Lift

NOTE: This is an incomplete explanation of how lift is created. We will cover other theories in class. However, this is the only theory that you will be tested on.

Probably the most amazing aspect of flight is how these huge objects can apparently defy the Laws of Gravity and stay in the air. This is due to the force called lift. This force was best explained by Daniel Bernoulli and is known as **Bernoulli's Law or Bernoulli's Principle**. It explains the lift, or upward force, that allows aircraft and many other things to fly. We have already learned that as the speed of air movement increases, the pressure it exerts decreases. An aircraft wing is designed to take advantage of this characteristic by being made in the shape of an aerofoil (shown below). The top of the wing is curved so that air traveling over it has further to go than air traveling below the wing. The top air must go faster to reach the back edge of the wing at the same time as the bottom air.

Because it is going faster, the top air has much less pressure to push down and the bottom air has more pressure to push up. This gives the plane its lift.

AEROFOIL



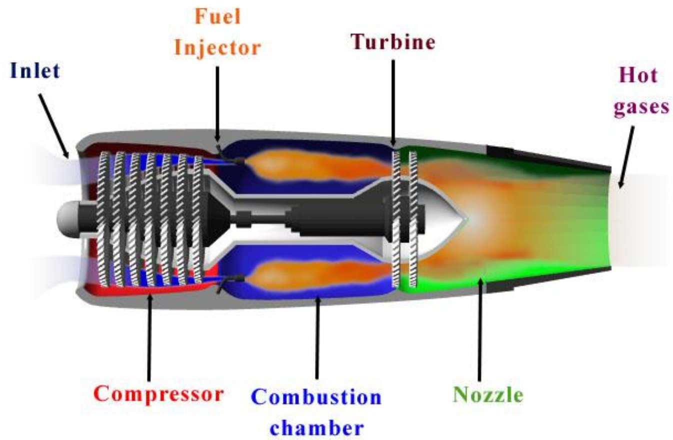
F-3 How Aircraft Achieve Thrust

As we already learned, thrust must exceed drag in order for a plane to fly. That is because for the aircraft to function, there must be air moving rapidly past it.

Streamlining is the easiest way to reduce drag. Wings of an aircraft are streamlined, and also curved more at the top giving them an airfoil shape, which enhances lift. Bodies of aircraft (fuselage) and, even more-so rockets, are also streamlined to reduce drag.

Mechanisms for providing thrust are varied, depending on the kind of plane. Fixed wing planes 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.

A propeller is actually a twisted wing designed so that when an engine rotates it, it produces a force like lift, but aimed in a forward direction. This force (thrust) pulls an aircraft through that air so that the wings can develop lift and hold the plane up. A propeller cuts through air. Propeller blades are also at an angle, so that as they cut the air, they push it backward. A spinning propeller creates a high-pressure area in front of it. This generates movement in the direction of the low pressure, moving the propeller and the plane attached to it forward. Because each blade of the propeller is an aerofoil, the rotating propeller also generates drag. Therefore, a constant source of energy – a motor – is required to keep the propeller turning. Increasing the number of rotor blades can increase thrust to a point, but if the plane is too heavy, you still have problems moving it.



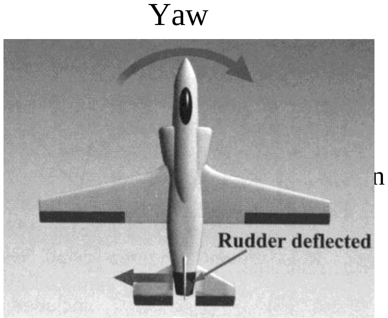
That is where jet propulsion engines come in. It can provide much greater thrust than propellers. A jet engine takes in surrounding air, compresses it, and then burns the oxygen in it. The air is combined with fuel in a combustion chamber to produce extremely hot gases that discharge out the rear of the jet engine. To visualize how this gives thrust, think of what happens to a balloon when you blow it up and then let it go. When you do this on the scale of a jet engine, you have enormous forward thrust, even at high speeds, where the efficiency of propellers drops off.

F-4 Directing an Aircraft

Unlike the balloonist who travels where the wind bids, the pilot of an aircraft has almost total control over the directional movement (with the exception of backwards in most cases, although some helicopters are even able to do this). This maneuverability is achieved by employing specially designed control surfaces that maintain the aircraft's stability and provide the means to reconfigure the shape of the aircraft in mid-flight.

It's not easy for ground-based creatures like us to appreciate the challenge of maintaining stability in the air. An aircraft must balance around three axes. Rotation around the longitudinal (nose-tail) axis is called **roll**. Motion around the lateral (wing tip to wing tip) axis is called **pitch**. Movement around the normal (top and bottom) axis is called **yaw.**

Yaw



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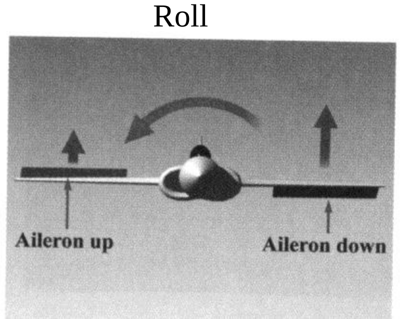
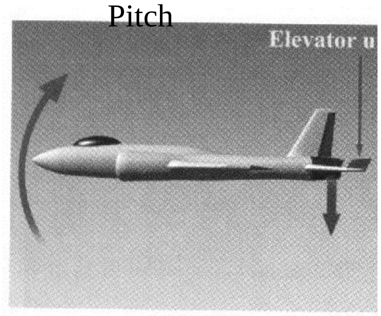
Roll



Pitch

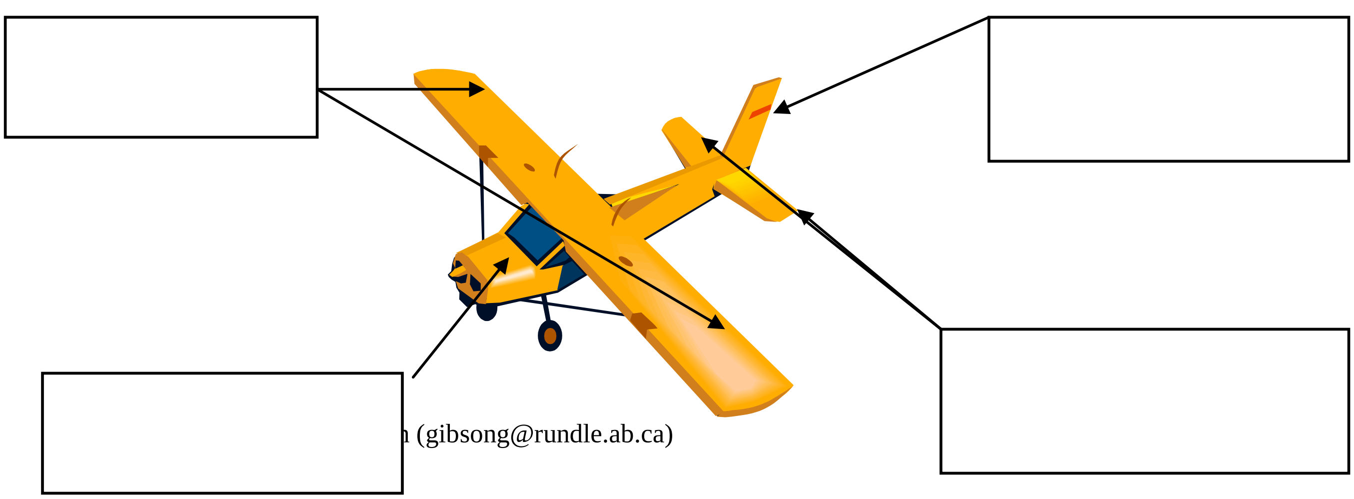


There are a number of primary control surfaces incorporated in fixed-wing aircraft design. These control surfaces enable an aircraft to change direction in mid-flight. There are shown in the illustration below and is discussed in the next section.

- **The fuselage** is the body of the aircraft to which the wings are attached. It serves to carry passengers and cargo, and it anchors the wings in place. It is as streamlined as possible to reduce drag.
- **The elevators** control the pitch of the plane. The elevators are located on the horizontal stabilizer, which is the small "wing like" structure near the tail of the plane. When the elevators are up, the nose of the plane (the pitch) goes up. When the elevators are down, the nose of the plane goes down.
- **The rudder** controls the yaw of the plane. The rudder is located on the vertical stabilizer that is the fin-like structure near the tail of the plane. When the rudder is turned to the left, the nose of the plane turns left. When the rudder is turned to the right, the nose of the plane turns right.
- **The ailerons** are moveable surfaces on the trailing edges of the wings. Lowering the left aileron and raising the right aileron will cause the plane's wings to roll to the right. This is called "banking." Lowering the right aileron and raising the left aileron will cause the plane's wings to roll to the left.

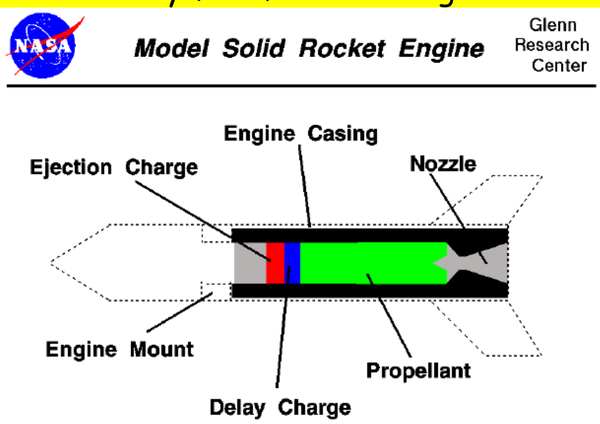
For any of these control surfaces to work, there must be rapidly moving air so the plane must keep its speed up.

Label the diagram below, include what each part is for.



F-5 Rockets and Space Flight

Remember that control surfaces won't work if air is not present, so how do rockets work? To launch a rocket (for lift to overcome gravity), you need incredibly powerful thrust. This is accomplished with a rocket engine. Rocket engines work on the same principle as jet engines (and as balloon rockets), but on a much larger scale. Also, there is no oxygen to burn in space so rockets need to carry fuel for their engines to work.



The rocket engines use in our model rockets work by igniting a solid fuel, creating super heated gasses that escape through the clay nozzle at the base. The force of this gas escaping is enough to lift the rocket off the ground.

Rockets need to be highly streamlined to minimize drag while traveling within the Earth's atmosphere, but not once in space, their aerodynamic surfaces serve no function since there is no air. Space is near vacuum, so spacecraft aren't slowed by drag. They can be any shape that suits their purpose, which is why you see such odd shaped satellites. As long as they are launched into orbit at a certain speed (approximately 8 km per second) they will be able to orbit indefinitely since centrifugal force (the tendency to fly out into space) is balanced by the pull of gravity.

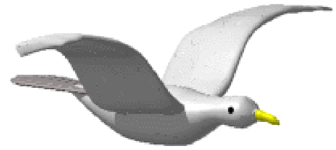
Spacecraft can be maneuvered with thruster jets. By firing a thruster on one side, the spacecraft moves the opposite way. Space shuttles must be more aerodynamic because they must maneuver through the Earth's atmosphere on their return to the ground. Other spacecraft usually land with the help of parachutes since they do not have other control surfaces.

F-6 Natural Flight

Bats, most birds, and many insects practice true natural flight. The motions of their wings produce the lift and thrust necessary to overcome weight and drag so that they can take off, fly and land. A number of other kinds of animals can glide for brief distances through the air.

The wings of birds and insects serve a similar dual function. They act as both the means of propulsion and as aerofoil. 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. 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 air-worthy. Birds have compact, highly streamlined bodies that are perfect for flight. Their collar bones have fused in 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. Many birds have the ability to soar. They can remain air-born by floating with out movement, supported by a rising column of air. For such birds as the eagle or condor, the little energy they expend in soaring may compensate for the very large amounts of energy needed for those birds to launch themselves.

Insects, in general, are small and lightweight. Like birds they have specialized flight muscles to power their wings which are made of cuticle (like your fingernails) material. Insect wings are often flat when at rest but take on the curved shape of an aerofoil once they begin to beat against the air.



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