Flight

Worksheet 7

A worksheet produced by the Native Access to Engineering Programme
Concordia University, Montreal

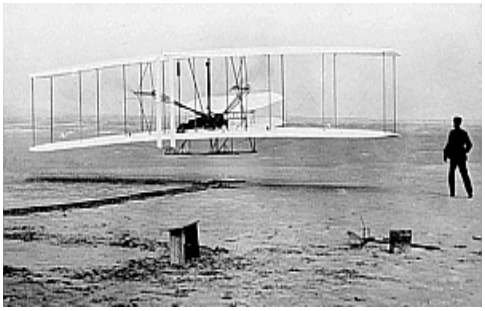
What is flight?

The Webster Dictionary defines flight as
The act of flying; a passing through the air by the help of wings; volitation; mode or style of flying.

Birds fly, insects fly, even some dinosaurs flew. Although people had been studying flight for several hundred years, and had actually taken to the air in hot air balloons, we couldn't actually fly until less than 100 years ago!

Orville and Wilbur Wright conducted the world's first successful flight at Kittyhawk, North Carolina on December 17, 1903. Orville flew the plane they had built a distance of 120 feet in 12 seconds.

How fast was the plane going in km/h?



Source: National Aviation Museum
http://www.aviation.nmstc.ca

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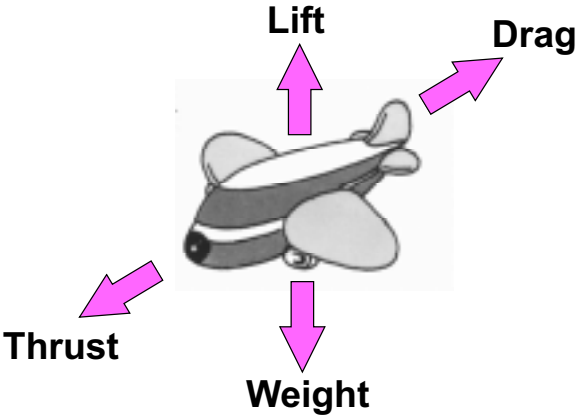
The first successful flight of an airplane in Canada occurred in Baddeck Bay, Nova Scotia on February 23, 1909. The *Silver Dart*, as the plane was called, had been designed and built by 4 young engineers and Alexander Graham Bell.

Alexander Graham Bell had another major accomplishment.
Do you know what it was?

How does an airplane fly?

In order to understand how an airplane flies, you have to look at the forces which act on the plane. There are two forces which work to slow a plane down and keep it on the ground. These are drag and weight. Drag is a backwards force caused by air flowing over the body of the plane. Weight is a downwards force caused by the Earth's gravity acting on the mass of the plane.



How do you think these forces are overcome?

In order to get into the air you need to create forces which are pushing forward and up more than drag and weight are pulling backward and down. These forces are thrust and lift. Thrust is a forward force created by engines or propellers. Lift is an upwards force caused by the effect of air moving over the plane's wings.

Daniel Bernoulli and the key to lift

Equal pressure

No motion

If you have the same amount of pressure on every side of an object, it won't move. But if there is more pressure on one side of the object than the others it might move (provided there's enough pressure to overcome friction and any other forces acting on it).

Unequal pressure

Motion

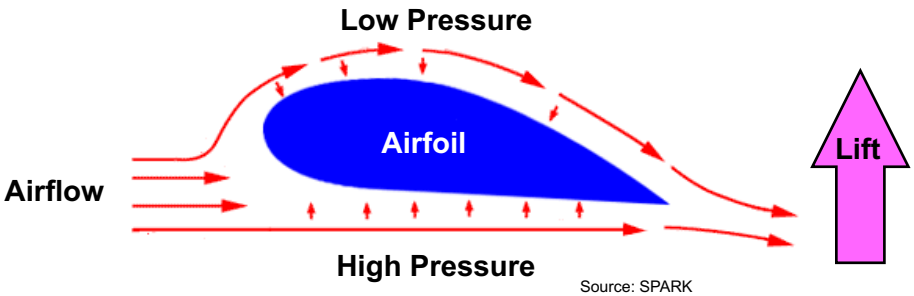
Nearly 300 years ago, a Swiss mathematician named Daniel Bernoulli discovered that fast moving fluids, including air, exert less pressure on an object than slow moving fluids. (Air is a fluid because it flows.)

How do you think this knowledge helped in achieving flight?

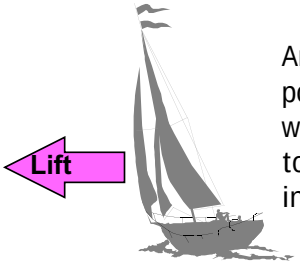
Birds' wings and airfoils

People who were studying flight looked to the birds for inspiration. They realized that the shape of a bird's wings is one of the key factors in its flying ability. A bird's wing is curved along the top and flatter on the bottom. This shape is called an airfoil.

When air hits the leading edge of an airfoil, some goes over the curved surface and some goes under the flatter surface. The air flowing over the curved surface wing moves faster (see why on the next page) than the air flowing over the flat surface, and so there is less pressure on the curved surface than on the flatter one. It is the imbalance of pressure on the two sides of the airfoil - higher pressure under the wing, lower pressure on top - which causes an airplane's wing to lift up!



Source: SPARK
http://nasaui.ited.uidaho.edu/nasaspark/default.html



An airfoil's lift is always created in the direction of the curved surface, and that surface can point in any direction. The sails on sail boats are airfoils, they allow boats to sail into the wind. Racing cars also have airfoils. In their case the curved surface of the airfoil faces down towards the track and "lift" actually helps make sure the car doesn't fly off the ground and into the air!

What airfoils can you identify?

Why does air speed up over the top of wing?

Air flows much like water flows - at least at relatively low speeds. When air hits a solid object, it cannot go through it, it must go around it. But why does it speed up?

The easiest way to understand why air speeds up over an object is to picture a tube full of water where the amount of water moving through the tube at any point in time is always the same.

If the water encounters an object in the pipe, its path becomes narrower. Essentially it has less volume in which to flow.

In order to maintain a constant rate of flow, one of two things could happen: (1) the water molecules could squish together (compress) so that the same amount of water passes through the narrower path; or, (2) the flow could speed up so that water moves over the object faster than it moves through the rest of the tube. Since water cannot be compressed into a smaller volume (liquids cannot be compressed), it must flow faster over the object.

Gases, like air, are more compressible than liquids, like water, but, at the speeds which most airplanes fly, freely flowing air acts very much like water - in other words it is incompressible. When air encounters the airfoil of an airplane wing, it is almost as if its flow path has narrowed and so the air speeds up over the curved surface of the airfoil.

Wing design and lift

Wings with lots of surface area (long or wide wings) get more lift than wings with less surface area (short or stubby wings). And faster moving planes generate more lift than slower moving planes. Generally, the slower a plane moves or the heavier it is, the larger its wings should be.

For instance, a 747-400 which carries 416 passengers and weighs more than 362,000 kilograms at take off has a wing span of 64.4m.

Source: Rolls Royce
http://www.rolls-royce.com

A Cessna Skyhawk, on the other hand, can carry only 4 passengers and is much, much lighter; it has a wing span of just over 10m.

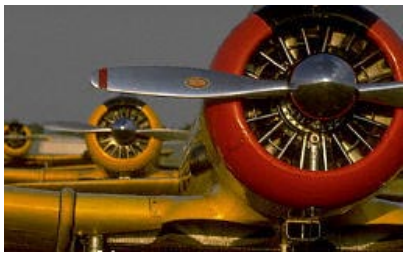
Source: Cessna
http://www.cessna.com

Fast planes, like military fighter jets tend to have short stubby wings, can you figure out why?

Thrust

Birds provide both lift and thrust for flight by flapping their wings. The thrust or forward motion of an airplane comes from its propellers or engines.

Propellers: Propellers actually work a lot like wings. The cross section of each blade in a propeller has the shape of an airfoil. By spinning quickly through the air a difference in air pressure is created between the front and back surfaces of the blade resulting in thrust.



Source: Corbis
http://www.corbis.com

Which side of the propellers is the low pressure side?

Propellers are used to generate both lift and thrust on a certain type of aircraft, what is it?

Source: Rolls Royce
http://www.rolls-royce.com

Jet Engines: Jet engines are used in commercial, heavy transport and military airplanes. In the engines combustion chamber fuel is mixed with oxygen and then ignited. The resulting hot, expanding exhaust gasses pass through a nozzle at the rear of the jet producing thrust.

One of Newton's Laws explains why pushing hot gas out the back of a jet will move an airplane forward. Do you know which one it is?

A (very) little about flight in Canada

Aircraft have been very instrumental in the development of Canada and the opening up of the country.

Source: National Aviation Museum
http://www.aviation.nmstc.ca

In the 1920s pilots who had been trained to fly during World War I came home and began connecting people both East-West and North-South. In bush planes like the HS-2L they started the first forestry patrols, timber surveys, aerial mapping and scheduled mail services.

Planes were designed to work in remote regions with difficult terrain and specific needs. Some were designed with a high-lift wing for carrying heavy loads of cargo to remote communities. Others were designed with special features like wings which could fold back for storage; these planes could be easily covered and protected from snow falls in the North. Today, planes are still designed specifically for Canadian conditions and needs.

Can you think of needs which might be specific to Canada?

Forest fires and flight

In Canada 417.6 million hectares, or almost half the land base is covered in forests. These forests play a major role in our climate, our lives and our economy. In the summer when the weather is hot and there is often little rain, forest fires are a major problem. Unfortunately, because of Canadian geography, controlling and putting out these fires is often difficult.

What geographical factors do you think make controlling forest fires difficult?

Source: Bombardier

In the 1960s Bombardier, a Quebec-based company, designed the amphibious CL-215 water bomber as a means of delivering large amounts of water to fire sites quickly. Today the CL-215 has been replaced by the Canadair 415, a plane which looks very similar but has updated features and controls.

The Canadair 415 is the only aircraft in the world which is specifically built for fire fighting. The plane lands on a lake, river or reservoir close to the fire (it can also land in the ocean), and scoops up to 6140 litres of water into its four internal tanks in about 12 seconds. It then takes to the air and dumps its load on the fire. The plane can fly between 3 or 4 hours before refueling, which means it can refill its tanks 20 to 40 times. One of the really neat things about the Canadair 415 is that it is still technically "flying" when it scoops water, this means pilots can navigate bends in a river or avoid obstacles in a lake. It also means that if the water source isn't long enough (it should be about 400 m long for the plane to get a full load) the plane can pick up partial loads to dump on the fire. The Canadair 415 is just one example of Canadian aeronautical engineering expertise which is used all over the world.

What kind of special conditions do you think engineers had to consider when designing the Canadair 415?

Sources

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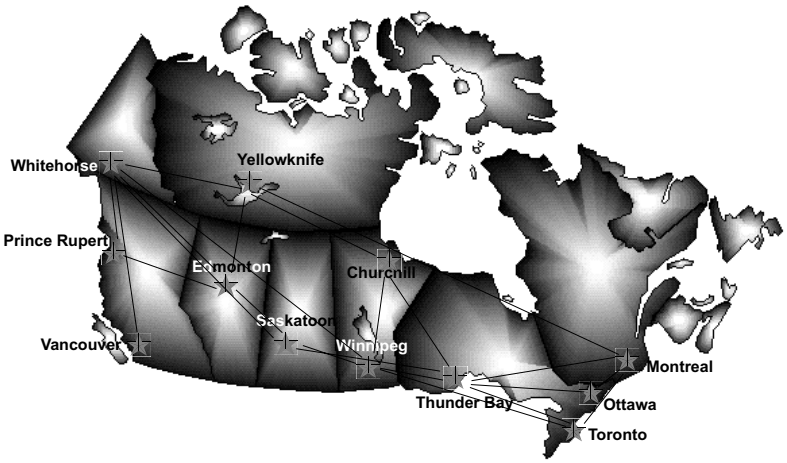
Math Problem



Departure	Arrival	Distance (km)
Yellowknife	Montreal	3194
Yellowknife	Whitehorse	1181
Yellowknife	Churchill	1109
Yellowknife	Edmonton	1002
Churchill	Winnipeg	1007
Churchill	Thunder Bay	1193
Whitehorse	Saskatoon	1976
Whitehorse	Winnipeg	2643
Whitehorse	Thunder Bay	3181
Whitehorse	Edmonton	1524
Whitehorse	Vancouver	1484
Whitehorse	Prince Rupert	766
Edmonton	Saskatoon	489
Saskatoon	Thunder Bay	1303
Saskatoon	Winnipeg	709
Prince Rupert	Edmonton	1110
Winnipeg	Toronto	1518
Winnipeg	Thunder Bay	600
Thunder Bay	Toronto	927
Thunder Bay	Ottawa	1082
Thunder Bay	Montreal	1231
Toronto	Montreal	503
Ottawa	Montreal	164

1. You own a charter airline in Yellowknife. The local bantam hockey team is going to a tournament in Montreal and you have generously offered to fly them. The only problem is that most of your planes are booked. The plane you have available needs to be refueled every 1200 km. Using the table,

a) what is the shortest route to Montreal?

b) How much further is it than a direct flight from Yellowknife to Montreal?

c) Express how much further it is as a percentage.

Challenge

If your plane could fly 2000km before refueling is there a shorter route?

2. Your community in Alberta is working to reestablish buffalo on the Prairies. You have managed to convince a zoo in Toronto to donate a herd of 50 buffalo to the project. The animals (each weighing 1000 kg.) will be flown from Toronto to the nearest airport in a 747 cargo plane (weight 300,000 kg when empty). The shipping company has called you with a concern, 747s need a lot of room to land, especially when they are fully loaded. They want to know if the runway at the local airport is long enough. They tell you that the plane needs 1,500m to land if it's empty; 2,100m to land if it's half full and 2,700m to land if it's full to capacity (500,000kg). If the longest runway at your local airport is 1,750m long, can the buffalo be safely delivered? If not, how long must the runway be?