Flight

Worksheet 7

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

Teacher's Guide

This guide contains some suggestions for how you can work with worksheet 7, "Flight."

1. Do the students understand the definition of flight? You might ask them if they can guess what language the word "volitation" comes from: it comes from the French word for flight, "vol."

2. The dinosaurs which flew were called pterodactyls. Scientists can't be absolutely sure that pterodactyls flew because they are extinct. Fossil remains seem to indicate that there were similarities (such as bone structure)between pterodactyls and animals which we know can fly, like birds.

3. Hot air balloons don't actually fly; because they are filled with gas which is lighter than air, they float on air much like a boat floats on water.

4. This is an exercise in unit conversion.

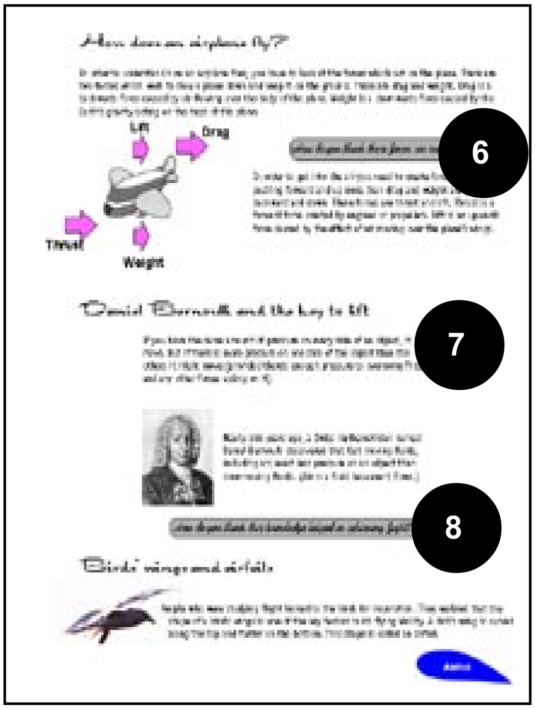
Convert feet to kilometers

$$\frac{120\ ft}{12s} \times \frac{1m}{3.28ft} \times \frac{1km}{1000m} = \frac{120}{39\ 360} = 0.00305\ km/s$$

Convert seconds to hours

$$\frac{0.00305\ km}{s} \times \frac{60s}{1\ min} \times \frac{60\ min}{1\ hr} = 10.98\ km/h$$

5. Alexander Graham Bell invented the telephone.



6. Perhaps it would help the students to think about this question by telling them about one of the laws of motion formulated by Isaac Newton.

   Newtons' First Law says that any object which is at rest or moving at a constant rate will keep on being at rest or moving at a constant rate unless some force is applied to the object. So in order to get an object to change what it is doing, you have to exert a force on it. Exerting a force is exactly what has to be done to get an airplane off the ground. But what kind of force is needed?

   Since we want the plane to be going up and forwards, we need forces in those directions which are greater than the forces of weight and drag acting on the plane.

7. If the larger arrows in the picture represent greater pressure, the ball would move up towards the top of the page.

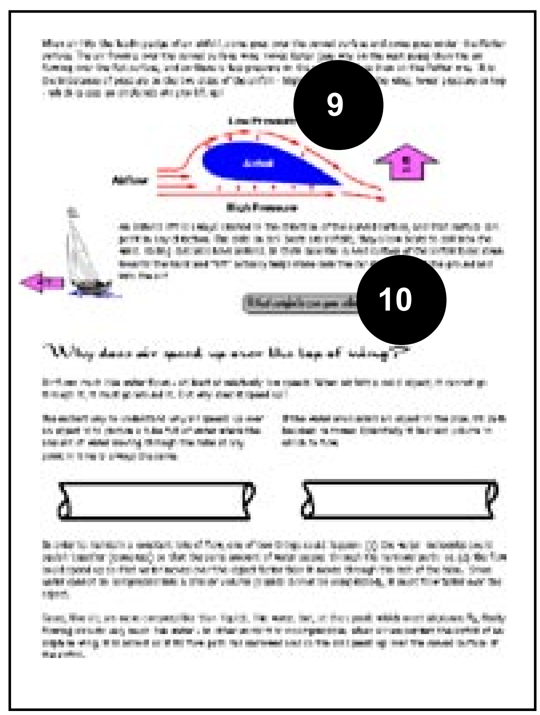
8. The answer to this question is given in the text which follows it. Perhaps before moving on to it the students could brainstorm about how Bernoulli's discovery helped people achieve flight. Why would it be important to know that faster moving fluids exert less pressure on an object than slower moving ones? Are there any ways in which they could apply this knowledge, or make use of it ?

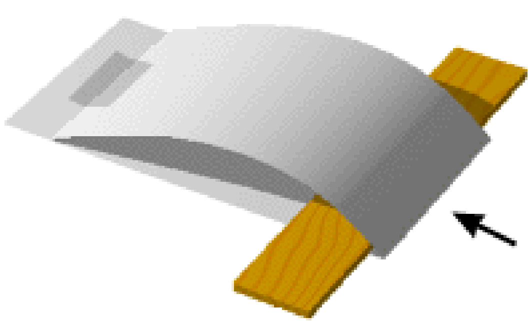
9. There are a number of easy demonstrations/activities which demonstrate lift. (The following activities are available in a number of science books; these were taken from the SPARK Project Website at http://nasaui.ited.uidaho.edu/nasaspark/default.htm.)

   a. Paper Wing Design

   <u>You need:</u>
   1/2 a sheet of typing paper (cut lengthwise)
   ruler
   tape

   <u>Activity:</u>
   Begin by folding the piece of paper in half widthwise. Next, tape the top edge of the paper so that it is about 1/2" from the bottom edge; this will make the top half of the paper curved like the top of a wing. This is your model wing. Slide the wing over the ruler so that the curved side is facing up and the folded seam is facing you. Holding the ruler in front of you with the wing hanging down, blow straight at the folded seam. The wing will lift up from its hanging, "at-rest" position.





Explanation:
Because there is a curve over the top of the wing, the air passing over the top of the wing has a greater distance to travel than the air going under the wing. As a result, the air going over the top must travel at a greater velocity than the air traveling under the wing. The increased air speed over the top of the wing also lowers the air pressure (Bernoulli's Principle). The wing is therefore lifted by the higher pressure underneath the wing.

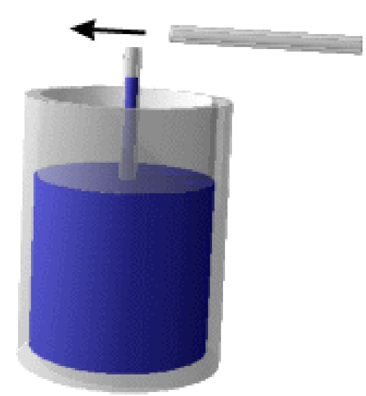
b. The Ball and Funnel Challenge

You need:
ping-pong balls
a few funnels large enough to hold the ping pong balls

Activity:
Let the students know that it is time to have a little contest—you are going to see who can blow a ping-pong ball out of a funnel the easiest. All you must do is give a ball and funnel to each participating student, have them place the ball in the funnel, and then try to blow the ball out as far as they can. The ball won't move! In order to blow the ping-pong ball out of the funnel, you must blow across the top of the funnel. This activity can also be done by hooking a blower hose to the end of the funnel in order to provide a constant blowing air supply. The funnel can then be held upside down, swung around, etc., and the ball still will not fly out!

Explanation:
This activity is explained by Bernoulli's Principle. When a person blows through the funnel, the air coming directly underneath the ping-pong ball is moving more quickly than the air over the top of the ball. As Bernoulli's Principle tells us, this faster moving air results in a decrease in air pressure under the ball, causing the ball to be pushed into the funnel by the higher air pressure coming through the top of the funnel. If a person blows over the top of the funnel, this creates an increase in air speed over the top of the ball and thus decreases the pressure in that area. Thus, the ball is pushed out of the funnel by the higher air pressure coming from underneath.

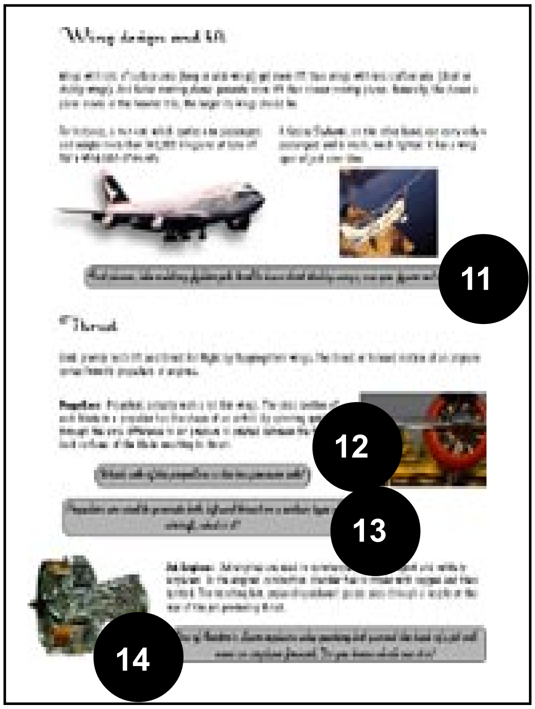
c. Water Up a Straw



You need:
a tall glass of water
2 drinking straws

Experiment:
Place one straw into the glass of water, holding it upright and keeping the bottom of the straw just off the bottom of the glass. Next, blow a short, hard blast of air through the second straw, holding it so that it is perpendicular to the first straw and their ends are touching. Water will come spraying out of the first straw into the air.

Explanation:
By blowing over the top of the first straw you decrease the pressure in that area (due to the increased air velocity). This causes the water to be pushed out of the top of the straw by the higher pressure at its base.



10. Airfoils are used on many vehicles - cars, trucks etc... - to help make the vehicles more aerodynamic and stable. A good example of an airfoil - believe it or not - is an Olympic ski jumper. When the jumper is in the air he will try to mimic the shape of an airfoil. It will help him to jump further by providing a little bit of lift which keeps him in the air longer.

11. Military aircraft - particularly fighter planes - move very fast, sometimes faster than sound. By moving so fast they generate a lot of lift, so their wings don't have to be very big. They also have stubby wings because planes which travel near or faster than the speed of sound build up shock waves at certain points on their structure; the shorter wings reduce this effect.

12. The low pressure side of the propeller should be the side facing away from the plane.

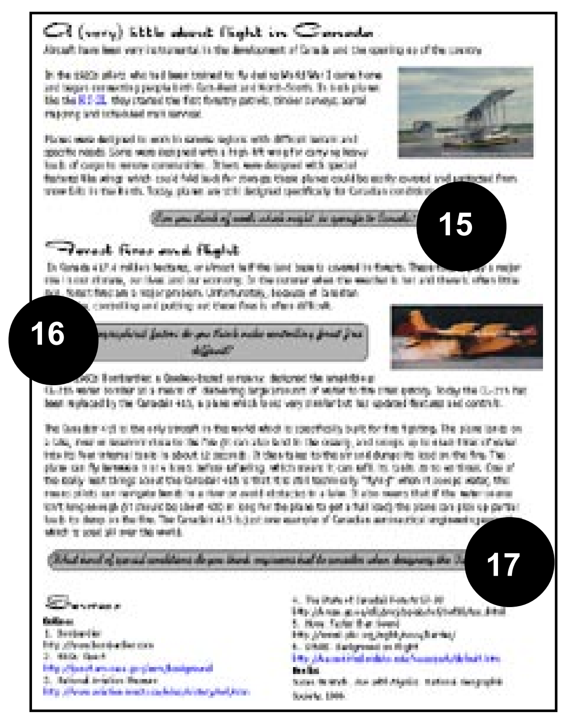
13. A helicopter.

14. Newton's third law says that for every action there is an equal and opposite reaction. The thrust created by a jet engine would do nothing if it didn't have something to push against; it is pushing against the air to move the plane forward.

15. Students can discuss aspects of Canada's geography and other things which might make special aircraft necessary. For instance:

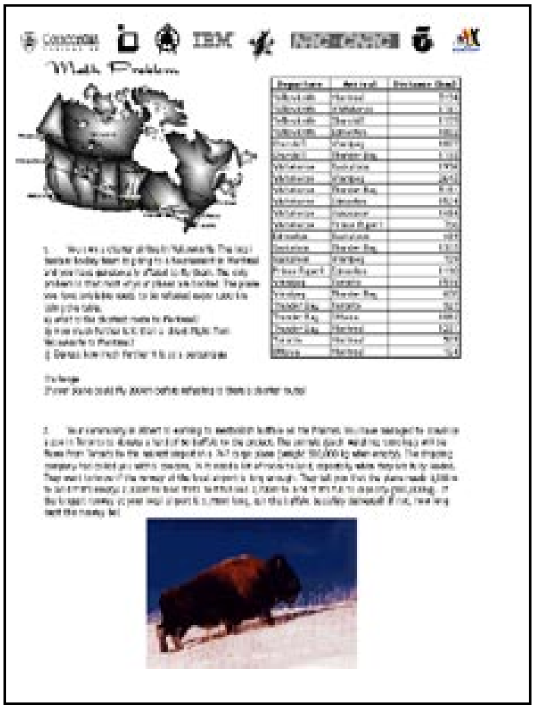
    In the early days of flying, many planes in Canada were equipped with skis or pontoons instead of wheels so that they could land on water or frozen surfaces. In those days, especially in the North or remote regions, there were very few airports, but Canada has many lakes and rivers which could become instant landing strips.

16. Much forested land is in remote regions which have few or no roads. In these cases it can become difficult to control and put out fires without air support.



17. Some of the following special conditions may have been considered in the Canadair 415 design.

    - High temperatures: engineers would have to consider both the materials used for building the plane and how the plane would perform in turbulent flying conditions.
    - Load: Water makes for very heavy loads, so the plane would have to be designed with a great deal of lift capacity.
    - Waves: in cases where the plane might fill its tanks from the ocean, engineers would have to figure out how stable the aircraft is in high waves.



Solutions

Question 1a.

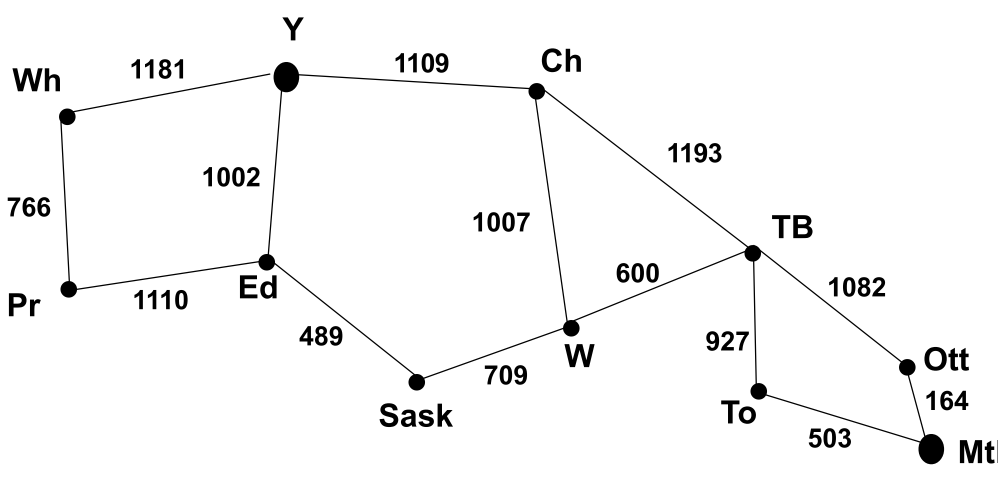
I. What do you know?
- The distances between each airport.
- The plane needs to be refueled every 1200 km.

II. Decide which routes absolutely can't be used.
The plane can only fly 1200 km without refueling, therefore any route which is more than 1200 kilometers can't be used. These routes should be highlighted or crossed out.

Routes which can't be used:
Yellowknife to Montreal, Whitehorse to Saskatoon, Whitehorse to Winnipeg, Whitehorse-Thunder Bay, Whitehorse to Edmonton, Whitehorse to Vancouver, Saskatoon to Thunder Bay, Winnipeg to Toronto, and Thunder Bay to Montreal.

III. Draw a map.
One of the easiest ways to keep all the routes straight and see which routes are connected is to draw an "airline network" map. Each city should be labelled represented by a dot (abbreviations can be used). The routes between cities should be represented by a line. Next to each route, the distance between cities should be marked. For this exercise, it may also be helpful to assume that the plane can only travel in the direction from departure city to arrival city as listed in the table; an arrow indicating the direction of travel can be placed on each route line. The finished maps should look something like the following.

Abbreviations
Ch: Churchill
Ed: Edmonton
Mtl: Montreal
Ott: Ottawa
Pr: Prince Rupert
Sask: Saskatoon
TB: Thunder Bay
To: Toronto
W: Winnipeg
Wh: Whitehorse
Y: Yellowknife



It does not matter if the maps are geographically accurate (i.e. Montreal is in the east and Prince Rupert is in the west) as long as the information is clearly presented.

IV. Figure out the distance for each route between Yellowknife and Montreal.
The first thing to notice is that all flights to Montreal have to pass through Thunder Bay. (In engineering terms, this is referred to as a XXXXX). By finding out whether the trip through Toronto or Ottawa is shorter, the students will cut down on the number of routes they need to calculate.

TB-To-Mtl = 927 km + 503 km = 1430 km
TB-Ott-Mtl = 1082 km + 164 km = 1246 km

The route through Ottawa is shorter, so from Thunder Bay that route should always be chosen.
Now calculate the distance of all the routes through Ottawa.

Route 1: Y-Wh-Pr-Ed-Sask-W-TB-Ott-Mtl
1181 km + 766 km + 1110 km + 489 km + 709 km + 600 km + 1246 km = 6601 km

Route 2: Y-Ed-Sask-W-TB-Ott-Mtl
1002 km + 489 km + 709 km + 600 km +1246 km = 4046 km

Route 3: Y-Ch-W-TB-Ott-Mtl
1109 km +1007 km + 600 km + 1246 km = 3962 km

Route 4: Y-Ch-TB-Ott-Mtl
1109 km + 1193 km + 1246 km = 3548 km

Answer:
The shortest route is 3548 km from
Yellowknife to Churchill to Thunder Bay to Ottawa to Montreal.

Question 1b

I. What do you know?
- Direct distance from Yellowknife to Montreal (from table): 3194 km
- Distance of shortest available route from Yellowknife to Montreal: 3548 km

II. Calculate how much further the indirect route is
This can be done by using simple subtraction.

Difference = Indirect route - direct route = 3548 km - 3194 km = 354 km

Answer:
The indirect route is 354 km longer than the direct route.

Question 1c

I. What do you know?
- Difference in distance: 354 km
- Direct distance from Yellowknife to Montreal (from table): 3194 km

II. Calculate % difference

$$\% \text{ difference} = \frac{\text{difference in distance}}{\text{direct distance}} \times 100 = \frac{354 \text{ km}}{3194 \text{ km}} \times 100 = 11.1\ \%$$

Answer:
The indirect route is 11.1% longer.

Challenge

The challenge can be solved in the same way as question 1a. There will be more routes to calculate as the plane can fly further.

Answer:
There is a shorter route. It is from Yellowknife to Churchill to Thunder Bay to Montreal.
Distance: 3533 km

Question 2

The quickest way to solve this problem is to tackle the second part first. If the distance needed to land safely is greater than 1,750 m, then the buffalo cannot be delivered safely; if it is the same or shorter then they can.

I. What do you know?
- Number of buffalo: 50
- Weight of each buffalo: 1000 kg
- Weight of empty plane: 300,000 kg
- Total weight at capacity: 500,000 kg
- Distance to land empty: 1500 m
- Distance to land half full: 2100 m
- Distance to land at capacity: 2700 m
- Longest runway 1750 m.

II. Calculate the total weight of buffalo.

Weight buffalo = number of buffalo x weight of each buffalo = 50 x 1000 kg
= 50,000 kg

III. Calculate how much the plane weighs loaded.

Weight loaded plane = weight empty plane + weight buffalo= 300,000 kg + 50,000 kg
= 350,000 kg

IV. Calculate capacity load.

Capacity load = Total weight at capacity - weight empty plane = 500,000 kg - 300,000 kg
= 200,000 kg

V. Calculate half load.

Half load = Capacity load/2 = 200,000 kg/2 = 100,000 kg

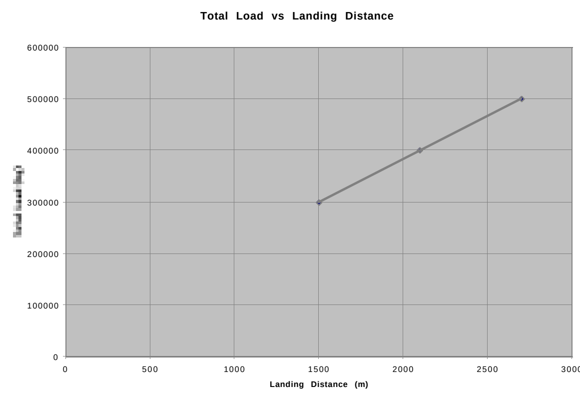
VI. Calculate total weight at half capacity.

Total weight half capacity = weight of empty plane + half load
= 300,000 kg + 100,000kg
= 400,000 kg

VII. Graph it

There is a relationship between the weight of the plane and the distance it needs to land safely. The planes needs 1,500 m to land if it is empty, 2,100 m if it is half full and 2,700 m to land when completely full. The weight of the plane in each of these conditions is either known or has been calculated.

1,500 m: 300,000 kg
2,100 m: 400,000 kg
2,700 m: 500,000 kg



To see the relationship between the weight and landing distance, draw a graph.

VIII. Determine distance required for landing.

Depending on how well the graph is drawn, the distance required for landing may be read directly off the graph by reading across from the 350,000 kg total load.

The other way to determine how much room is needed for landing is to calculate the relationship between weight and distance from the slope of the graph.

$$\text{Slope} = \frac{y1 - y2}{x1 - x2}$$

$$= \frac{400{,}000 \text{ kg} - 300{,}000 \text{ kg}}{2{,}100 \text{ m} - 1{,}500 \text{ m}}$$

$$= \frac{100{,}000 \text{ kg}}{600 \text{ m}}$$

This means that for every 100,000 kg of load above the actual weight of the plane, 600m of landing distance beyond the minimum 1,500 m are required.

The plane loaded with buffalo weighs 350,000kg. This is 50,000 kg more than the weight of the plane. Our graph shows a straight line, which means we have a constant slope, or a constant proportional relationship between weight and distance. So,

$$\frac{100{,}000 \text{ kg}}{600 \text{ m}} = \frac{50{,}000 \text{ kg}}{x}$$

$$x = \frac{50{,}000 \text{ kg}}{100{,}000 \text{ kg}} \times \underline{600 \text{ m}} = \frac{30{,}000{,}000 \text{ kg.m}}{100{,}000 \text{ kg}} = 300 \text{ m}$$

The distance required for landing is then

1,500 m + 300m = 1,800 m

Answer:
1,750 m is not enough for the plane to land safely.
It requires at least 1,800 m of runway.