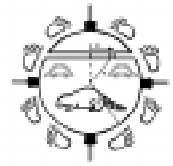




# Flight

## Worksheet 7

*A worksheet produced by the Native Access to Engineering Programme*



## 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.

The worksheet preview shows the following sections:

- 1:** A quote: "The British Dictionary defines flight as 'The act of flying - a journey through the air by the action of sustaining one's own wings.'" Next to it is an illustration of a pterodactyl.
- 2:** A section titled "What is flight?" with a small image of a bird.
- 3:** A section titled "The first flight" with an image of a hot air balloon.
- 4:** A section titled "The first airplane" with an image of an early airplane.
- 5:** A section titled "Alexander Graham Bell and the telephone" with an image of a telephone.

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.

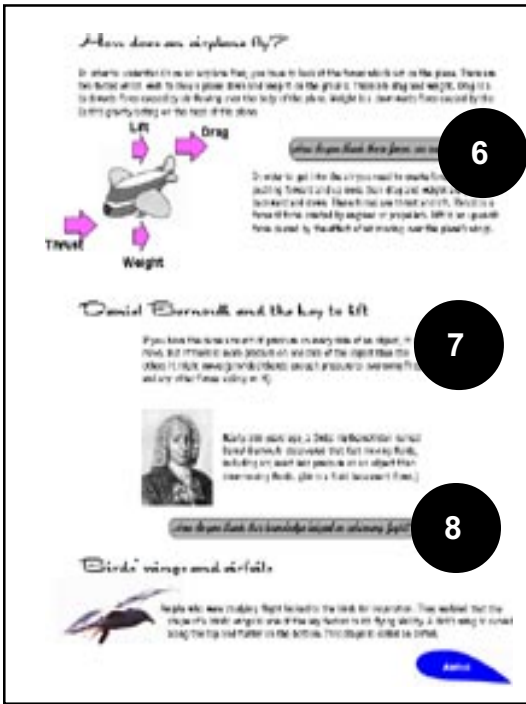
Convert feet to kilometers

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

Convert seconds to hours

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

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://nasau.i.ted.uidaho.edu/nasaspark/default.htm>.)

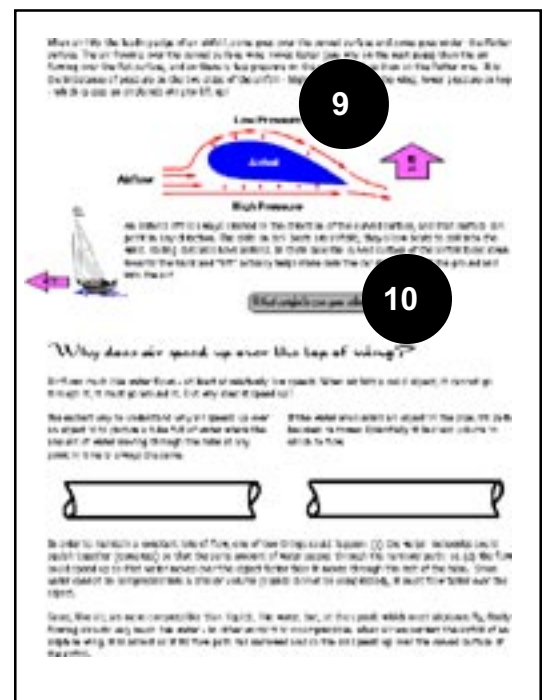
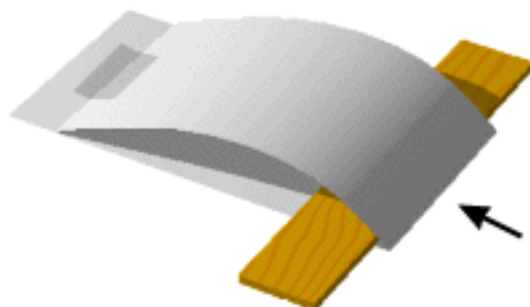
**a. Paper Wing Design**

You need:

- 1/2 a sheet of typing paper (cut lengthwise)
- ruler
- tape

Activity:

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

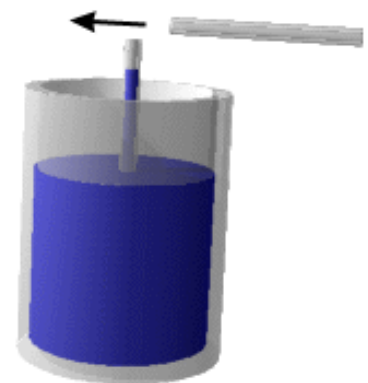
2 drinking straws

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.






Work Problem



Origin	Destination	Distance (km)
Yellowknife	Whitehorse	1181
Whitehorse	Saskatoon	1109
Saskatoon	Thunder Bay	1193
Thunder Bay	Ottawa	1082
Ottawa	Montreal	164
Montreal	Toronto	927
Toronto	Winnipeg	709
Winnipeg	Edmonton	489
Edmonton	Prince Rupert	1110
Prince Rupert	Whitehorse	766
Whitehorse	Churchill	1007
Churchill	Yellowknife	1002

1. You are a charter pilot for Yellowknife. The next business today you are going to a conference in Montreal and you have questions to attend to in the States. The only problem is that most of your planes are broken. The plane you have left has to be refueled every 1200 km. As you start to plan your route to Montreal, you find that you can't fly to Prince Rupert, Whitehorse to Montreal, or Yellowknife to Montreal.

2. You are currently in Yellowknife and want to see which routes of the plane you have managed to create. You are going to draw a map of the routes. The cities you will be connecting will be Yellowknife, Whitehorse, Prince Rupert, Edmonton, Saskatoon, Thunder Bay, Winnipeg, Toronto, Ottawa, and Montreal. The map should show the routes of the plane and the distances between the cities. You should also show the direction of travel on each route. The finished map should look something like the following.



# 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:

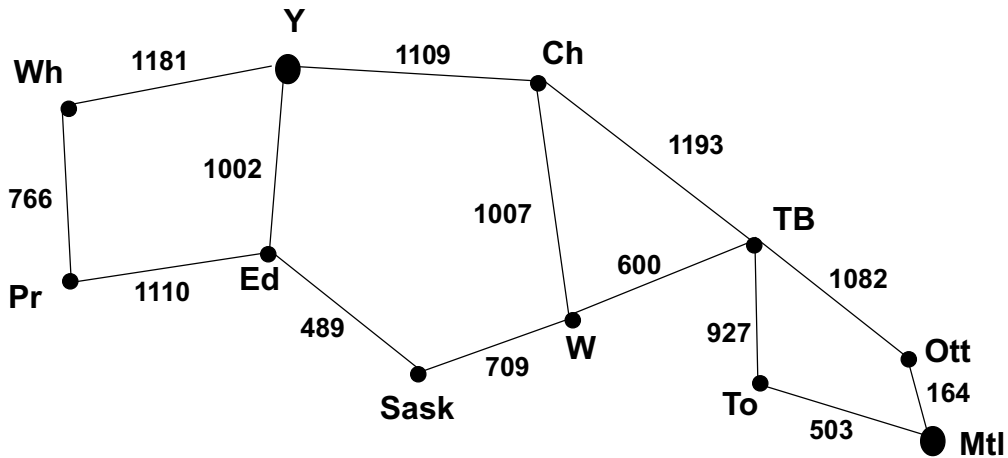
Yellowknife to Montreal, Whitehorse to Saskatoon, Whitehorse to Winnipeg, Whitehorse-Thunder Bay, Whitehorse to Edmonton, Whitehorse to Vancouver, Saskatoon to Thunder Bay, Winnipeg to Toronto, and Thunder Bay to Montreal.

### 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.

$$\text{TB-To-Mtl} = 927 \text{ km} + 503 \text{ km} = 1430 \text{ km}$$

$$\text{TB-Ott-Mtl} = 1082 \text{ km} + 164 \text{ km} = 1246 \text{ km}$$

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

$$1181 \text{ km} + 766 \text{ km} + 1110 \text{ km} + 489 \text{ km} + 709 \text{ km} + 600 \text{ km} + 1246 \text{ km} = 6601 \text{ km}$$

*Route 2:* Y-Ed-Sask-W-TB-Ott-Mtl

$$1002 \text{ km} + 489 \text{ km} + 709 \text{ km} + 600 \text{ km} + 1246 \text{ km} = 4046 \text{ km}$$

*Route 3:* Y-Ch-W-TB-Ott-Mtl

$$1109 \text{ km} + 1007 \text{ km} + 600 \text{ km} + 1246 \text{ km} = 3962 \text{ km}$$

*Route 4:* Y-Ch-TB-Ott-Mtl

$$1109 \text{ km} + 1193 \text{ km} + 1246 \text{ km} = 3548 \text{ km}$$

**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.

$$\text{Difference} = \text{Indirect route} - \text{direct route} = 3548 \text{ km} - 3194 \text{ km} = 354 \text{ km}$$

**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.

$$\begin{aligned} \text{Weight buffalo} &= \text{number of buffalo} \times \text{weight of each buffalo} &= 50 \times 1000 \text{ kg} \\ &= 50,000 \text{ kg} \end{aligned}$$

- III. Calculate how much the plane weighs loaded.

$$\begin{aligned} \text{Weight loaded plane} &= \text{weight empty plane} + \text{weight buffalo} = 300,000 \text{ kg} + 50,000 \text{ kg} \\ &= 350,000 \text{ kg} \end{aligned}$$

- IV. Calculate capacity load.

$$\begin{aligned} \text{Capacity load} &= \text{Total weight at capacity} - \text{weight empty plane} &= 500,000 \text{ kg} - 300,000 \text{ kg} \\ &= 200,000 \text{ kg} \end{aligned}$$

- V. Calculate half load.

$$\text{Half load} = \text{Capacity load} / 2 = 200,000 \text{ kg} / 2 = 100,000 \text{ kg}$$

- VI. Calculate total weight at half capacity.

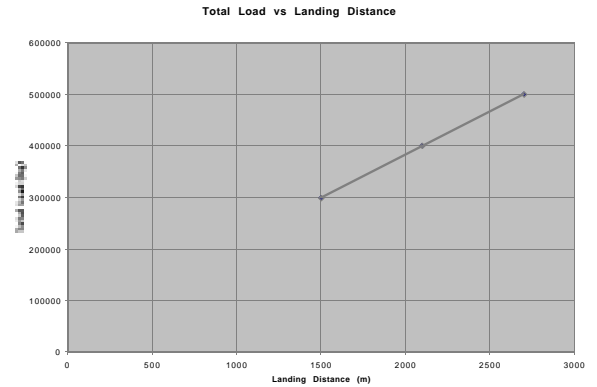
$$\begin{aligned} \text{Total weight half capacity} &= \text{weight of empty plane} + \text{half load} \\ &= 300,000 \text{ kg} + 100,000 \text{ kg} \\ &= 400,000 \text{ kg} \end{aligned}$$

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.

$$\begin{aligned}
 \text{Slope} &= \frac{y_1 - y_2}{x_1 - x_2} \\
 &= \frac{400,000 \text{ kg} - 300,000 \text{ kg}}{2,100 \text{ m} - 1,500 \text{ m}} \\
 &= \frac{100,000 \text{ kg}}{600 \text{ m}}
 \end{aligned}$$

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,

$$\begin{aligned}
 \frac{100,000 \text{ kg}}{600 \text{ m}} &= \frac{50,000 \text{ kg}}{x} \\
 x &= \frac{50,000 \text{ kg}}{100,000 \text{ kg}} \times \frac{600 \text{ m}}{1} = \frac{30,000,000 \text{ kg.m}}{100,000 \text{ kg}} = 300 \text{ m}
 \end{aligned}$$

The distance required for landing is then

$$1,500 \text{ m} + 300 \text{ m} = 1,800 \text{ m}$$

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

