FLEET ARC CENTRE OF EXCELLENCE IN FUTURE LOW-ENERGY ELECTRONICS TECHNOLOGIES

# Home Science Activity: Under pressure: Heat, airplanes & Bernouli

What does heat and a dude called Bernouli have to do with deciding when it is too dangerous to fly a plane. Be prepared to do some quiz questions.

The experiments in this activity relate to what enables a plane to get off the ground and what can make it come crashing down again. And about 150 years before the Wright Brothers built the first ever airplane in 1903, there was Daniel Bernouli, a Dutch mathematician who worked out that the faster a fluid flows the lower its pressure. This discovery is known as the Bernouli Principle and it is the reason we can get airplanes to lift off the ground. The fluid we will play with in the following experiments is air because air flows just like a fluid with the same effect.

**Learning Intentions**
Students will begin to understand the forces involved in flight: Gravity, lift and Bernouli's Principle (how the rate of fluid flow affects fluid pressure).

**Materials**
Experiment one

- ping pong ball (or a small plastic inflatable ball)
- hair dryer
- toilet roll (optional)

| Teacher Notes | Teaching Notes: Running the activity |
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| **What is happening:**<br>Bernouli's principle<br>The faster a fluid flows (the fluid in this case being air) the lower its pressure. Air will flow just like a fluid with the same effect. Air will flow from a region of high pressure to one with lower pressure. This is the force keeping the ball in the airstream from the hair dryer. See Figure 1. The ball is oscillating left and right, in and out of the vertical airstream. As it moves left or right out of the air stream, air will flow faster over the side of the ball still in the air stream. This will create an area of lower pressure on that side of the ball. The force on the side of the ball with higher air pressure will push the ball back into the centre of the air stream. Hence the ball will remain suspended in the airstream. See Figure 1(a) and (b) below.<br><br>Tilting the hair dryer<br>When you tilt the hair dryer, Bernouli's principle is still working. See Figure 2. When the hair dryer is tilted, the oscillations of the ball will be up and down rather than left or right. When the ball begins to fall down out of the airstream, the lift created by the faster air travelling over the top of the ball that is still in the air stream will push the ball back up into the middle of the airstream again until gravity pulls it back down again, and Bernouli kicks in and pushes it up again…..and so on.<br>The toilet roll | **Method**<br>1. Turn off the heat on the hair dryer so that it blows cool air.<br>2. Turn the hair dryer on and point it straight up.<br>3. Place a ping pong ball into the stream of air (Try place two balls).<br>4. The ball should start floating in mid-air.<br>5. Slowly bend the hair dryer to the side. How far can you bend it before the ball falls?<br>6. Place and hold a toilet roll on top of the hair dryer and repeat the experiment. What do you notice?<br>7. With the hair dryer on an angle and the ball still staying aloft, turn the heat to high. What happens to the ball?<br><br>Variation<br>**Go big.** Play around with different size balls and bigger air blowing machines. Got a leaf blower handy?<br><br>**Results**<br>You should see the ball suspended in and spinning around in the airstream above the hair dryer. You can draw some pictures on your ball to see this easier. The ball floats at the point where the force from the air flowing up out of the hair dryer and the |

Air pressure keeps the ball in the stream of air when you tilt the hair dryer because fast air rushes past the ball, keeping it in place. When you use a toilet roll, the air is being pushed through a smaller space. This causes the air to move faster, the ball to float higher, or you can tilt the hair dryer a bit more. This is why planes with a heavier load must travel faster along the runway to generate sufficient lift to get off the ground. That is, they need to generate a faster flow of air over the wings to generate greater lift.

Adding heat
When the hair dryer was tilted, what happened to the ball when you turned the heat on the hair dryer up high? The ball should fall to the ground. This is because warmer air has a lower density. The warmer the air the more the air particles get excited and bounce around more and spread out. Or in other words they are not packed together as tightly as in colder air, meaning there is effectively less air molecules in hot air than cold air. That means there are less air molecules to push back on the wing and provide lift. Hot air (with lower density) has lower (barometric) pressure than cooler air. Hence, when we blow hot air across the ball, there is already low air pressure underneath the ball because the air is hot. The difference between the low air pressure underneath the ball and the now only slightly lower air pressure above the ball is not great enough to provide the lift required to keep the ball from falling.

This also why planes can't go really high altitudes or into space. At such altitudes there is not much air (really low air pressure). In space there is no air – and no air pressure – and therefore no lift.

**Experiment two**
What is happening?
Again, Bernouli's principle applies. As you blow air across the top of the paper you are creating an area of lower pressure on the top of the paper. This creates an upward force on the paper pushing it up to the horizontal position. This lift is the force that get airplanes off the ground. The answer therefore is b) The paper will rise up to be horizontal.

Wing design and Bernouli
As an airplane speeds along the runway, the shape of the aircraft wing forces the air to move over the top of the wing faster than it moves below the wing. As with the tissue paper on the chin, the air pressure above the wing is lower than below the wing creating an upward force (Lift). The plane force from gravity are equal. But if you look really closely at the ball as it sits in the airstream you will notice that it oscillates back and forth. If you have the right camera, try take a close-up, slow motion video of ball in the airstream to see it happening. This is the Bernouli's principle on display.

Tilting the hair dryer
As you tilt the hair dryer the ball should continue to stay in the air stream – at least until you reach a specific angle where the force of gravity is greater than lift force generated by the difference in air pressure pushing the ball back into the air stream.

How far could you tilt the hair dryer before the ball fell to the floor?

Adding heat
Once you turn on the heat with the hair dryer tilted, the ball will fall from the air stream.

Why does heating the air make the ball fall?

What happens to air as it heats up? Do the air molecules like to get more active and move apart or come close together and not move much?

Will air molecules that are all bunched in tightly together have a higher or lower density than air where the molecules are far apart and flying around?

The density of the air affects the air pressure, which affects the force (Lift) that enables the ball to stay in the air stream when the hair dryer is tilted. Think about what this means for airplanes wanting to take off. More on this further on.

Going bigger: If you found an industrial-sized blower, you should be able to make a ball float higher and achieve a greater angle/tilt before the ball fell to the floor. Why do you think this happens? What is different about what a large blower such as a leaf blower compared to a hair dryer?

needs to travel fast enough to create a big enough pressure difference between the top and bottom of the wing to generate sufficient lift to get the plane off the ground. See Figure 3.

**Test your understanding**
When the air is hot as it was in Phoenix, Arizona the air pressure is already really low. In such conditions the planes are unable to get to a fast enough speed to generate enough of a difference in air pressure between the top and bottom of the wing and therefore generate sufficient lift to get the plane off the ground. The answer therefore is A), The air was too hot for the planes to take off.

Check the bbc news story the reported the incident.

And for a deeper look into the science and the implications of climate change check this Discover Magazine story.

**Experiment two**
All you need is a thin strip of tissue paper about 15cm long (or equally light paper that will naturally fold or droop down when you hold one end).

Method: Hold one end of the strip of paper against chin (just below lower lip) and blow across the paper.

What do you think will happen to the paper?
a. The paper will press down against your chin?
b. The paper will rise up to be horizontal?
c. The paper will stay where it is?

**Results**
The answer is b) The paper will rise up to be horizontal.

What is happening to the air pressure as you blow across the top of the paper? Think about what you learned about Bernouli's principle in the first experiment.

Think about what is happening here and apply it to an airplane wing.
Can you explain how an airplane gets off the ground by explaining what is happening with the tissue paper?

**Test your understanding**
In June 2017, more than 40 flights were cancelled in Phoenix Arizona when the temperature was forecast to hit 48 degrees. Why were the flights cancelled?

Based on what you have learned above, which of the following answers do you think is correct?
a. The air was too hot for the planes to take off
b. The planes' air-conditioning would overheat
c. The ashphalt runways had start to melt

Answer hint: Remember that warmer air has a lower density and therefore lower pressure than cooler air. Remember also what happened to the ball above the hair dryer when you turned the heat on. If the ball was a plane, it would not end well for the plane.

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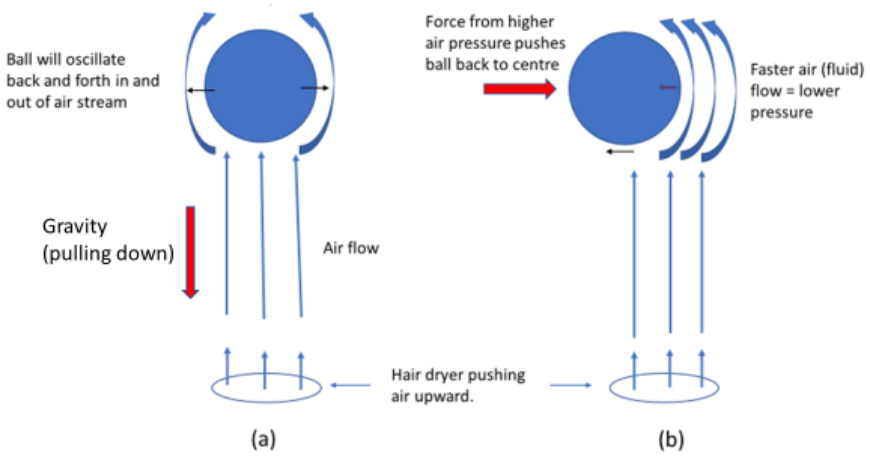
| | **A question to ponder**: Will climate change and the increase in extreme heat days we are expected to experience in Australia affect the number of days planes are not allowed to fly? |



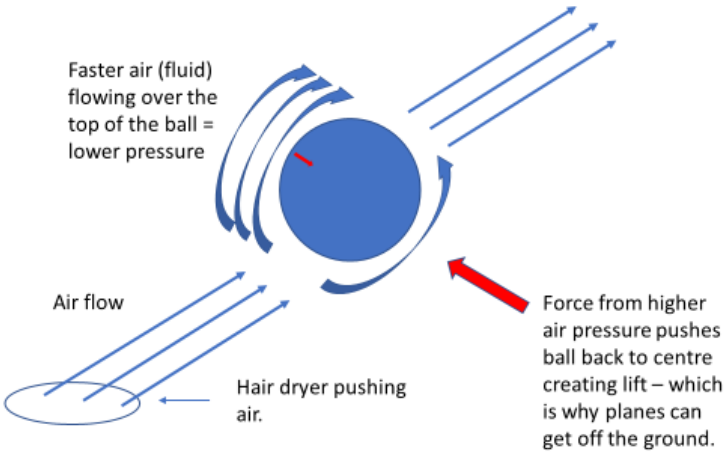



Figure 2. When the hair dryer is tilted the higher air pressure underneath the ball creates lift pushing the ball back into the centre of the air stream.

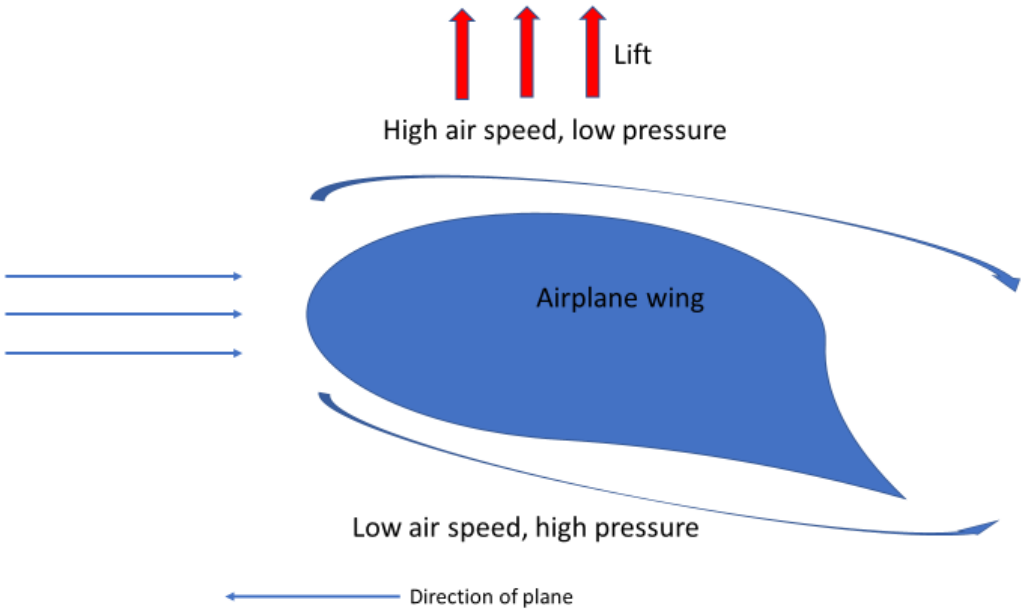



Figure 3. The shape of an airfoil (wing) forces air to travel over the top of the wing faster than it will travel below the wing. This creates a pressure difference between the top and bottom of the wing with the bottom of the wing being a region with higher pressure compared to the top of the wing. The faster the plane goes the greater the difference in air speed above and below the wing and therefore the greater the difference in air pressure. The greater the difference in air pressure, the greater the lift.