BERNOULLI'S PRINCIPLE:

APPLIED AND IN THE REAL WORLD

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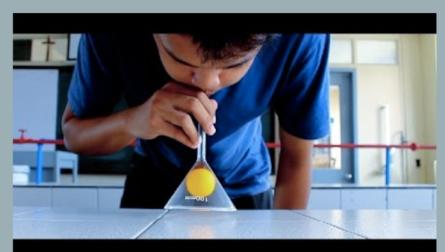
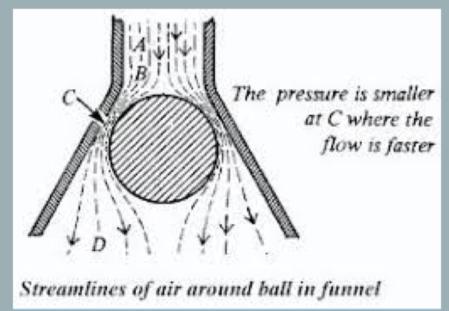
IN THE REAL WORLD



Practicalphysics.org

Here, air is blown into the base of a funnel. Intuition would suggest that the ball will be launched out of the funnel. The ball is instead held against the base of the funnel, even when the funnel is turned upside down.



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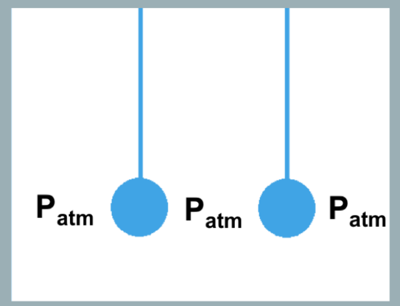
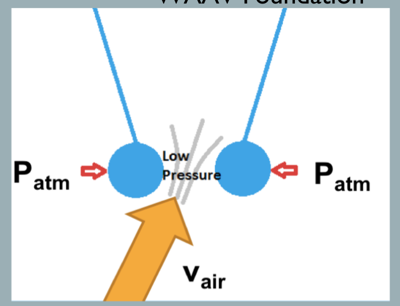
The strange behavior in this example is due to the Bernoulli principle. There is a small avenue of air between the sides of the funnel and the ball. At the wide portion of the funnel is atmospheric pressure,. But, at the constriction, the velocity of the air is high and pressure is low. This pressure differential hold the ball in the funnel with a force greater than gravity.

In high wind natural disasters, the roofs of houses are often torn off. The fast moving air (wind) is creating an area of low pressure. Inside the house, the pressure is atmospheric pressure. This pressure differential causes the roof to be lifted off the house entirely.

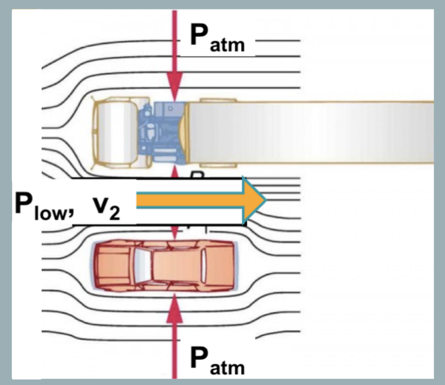
ABC News

WAAV Foundation





When high velocity air is blown between two suspended ping pong balls, the balls touch each other rather than blowing apart. This counterintuitive effect is due to Bernoulli's principle. High speed air between the balls is causing an area of low pressure. The pressure here is lower relative to the atmospheric pressure outside the balls, causing them to be pushed together another.

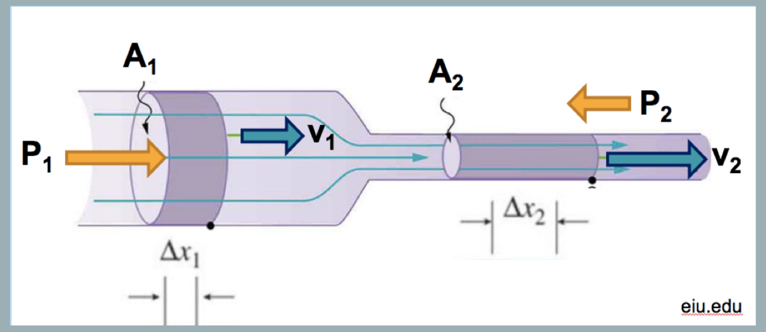


Cnx.org

A similar effect occurs when one car is passing another at high speed on the highway. The high-speed air at the constriction between the cars creates an area of low pressure relative to the atmospheric pressure, and the cars are pushed together by this higher atmospheric pressure.

DERIVATION

BERNOULLI'S PRINCIPLE: *An **increase in velocity** of a stream of fluid results in a **decrease in pressure.***



eiu.edu

① The air is moving from one location to another, therefore work is being done.

$W = FD = \Delta x_1$

$F = PA$

$W_1 = (P_1A_1)\Delta x_1$

$W_2 = -(P_2A_2)\Delta x_2$

$W_{total} = W_1 + W_2$

$W_{total} = (P_1A_1)\Delta x_1 - (P_2A_2)\Delta x_2$

② Work-Energy Principle: The net work done on a system is equal to its change in kinetic energy

$W_{total} = (P_1A_1)\Delta x_1 - (P_2A_2)\Delta x_2$

$W_{total} = KE_2 - KE_1$

$KE = (½)(mv)^2$

$\Delta KE = (½)(mv_2)^2 - (½)(mv_1)^2$

$(P_1A_1)\Delta x_1 - (P_2A_2)\Delta x_2 = (½)(mv_2)^2 - (½)(mv_1)^2$

③ Use continuity and obtain density dependence

At any point, the flow rate is the same. (What goes in must come out)

volume flow in over $A_1 = A_1V_1\Delta t$ (v is velocity)

volume flow out over $A_2 = A_2V_2\Delta t$

mass in over $A = \rho A_1V_1\Delta t$

mass out over $A = \rho A_2V_2\Delta t$

So: $\rho A_1V_1 = \rho A_2V_2$

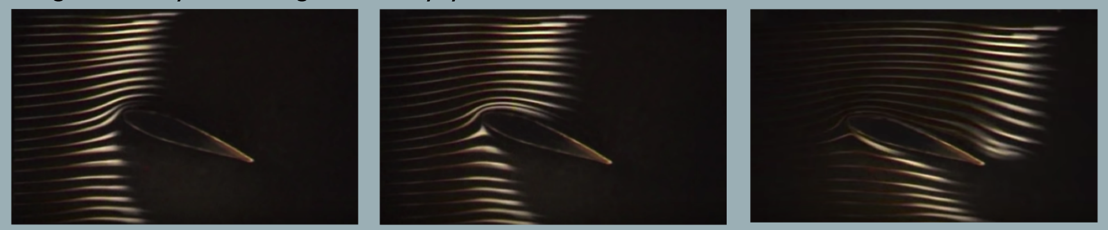
$½(\rho A_2\Delta x_2)v_2^2 - ½(\rho A_1\Delta x_1)v_1^2 = (P_1A_1\Delta x_1) - (P_2A_2\Delta x_2)$

$P_1 + ½\rho v_1^2 = P_2 + ½\rho v_2^2$

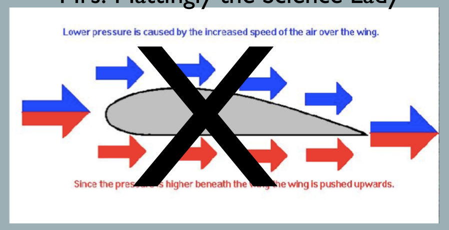
Bernoulli's Equation: $P_1 + ½\rho v_1^2 = P_2 + ½\rho v_2^2$

INCORRECT APPLICATIONS

Holger Babinsky, Cambridge University, youtube.com



Mrs. Mattingly the Science Lady



The classic explanation for airplane flight cites Bernoulli's Principle. While it is certainly applicable—there is indeed high velocity air over the top of the wing and a pressure differential that causes lift, the typical explanation relies on the assumption of equal transit time. This is the assumption that the air flow hitting the front of the airfoil (wing) must reunite at the other end. That incorrect explanation is shown in the figure on the far right. On the left are photos from a video of pulses of smoke in an airflow that are hitting an airfoil. As evident in these photos, the air over the top of the wing is indeed moving faster, but it reaches the end of the airfoil before the air underneath. This high velocity air, by Bernoulli's Principle, indicates the presence of a pressure differential and therefore lift, but the equal transit time explanation is incorrect. This common misapplication is an indication of the complexity of fluid dynamics and how weak our intuition for how fluids work really is.

BIOMIMICRY

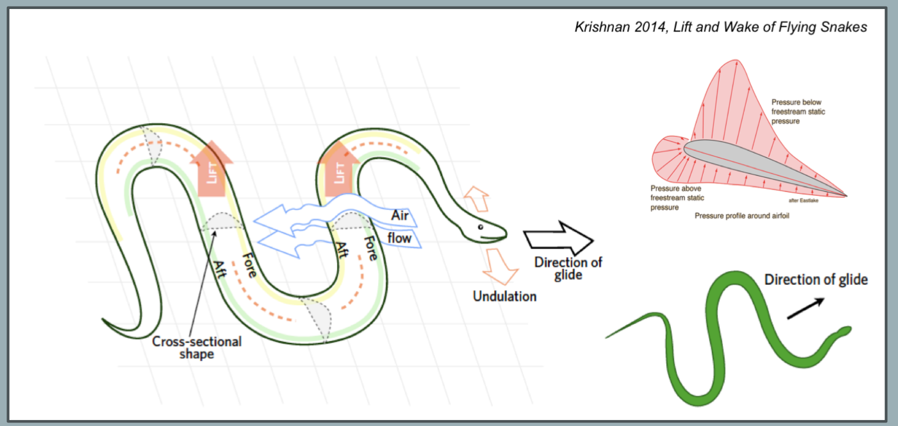
An important principle in design is rapid prototyping and iteration. Evolution is an iterative process that has been refining the design of nature for the age of the earth. Engineers study the highly sophisticated mechanisms of nature to create better designs. Above are two photos of products that are bioinspired. A coating inspired by the skin of shark is applied to airplanes made by AirBus to improve their aerodynamic efficiency by reducing friction with the air. Researchers at MIT studied the fur of beavers to create a wetsuit material that keeps athletes warm even when they are frequently in and out of the water, like beavers are. Although these examples are unrelated to Bernoulli's Principle, they show the value in taking natural phenomena such as flying snakes as a starting point in creating innovative technology.

FLYING SNAKES

Chrysopelea Paradisi, or the Paradise Flying Snake is a snake found in southeast Asia that is able to slither, climb, and fly, or rather, glide. What the snake really does is prolong, control, and direct its fall. Below is a series of photos depicting the movement of the snake in the air.

Krishnan 2014, Lift and Wake of Flying Snakes

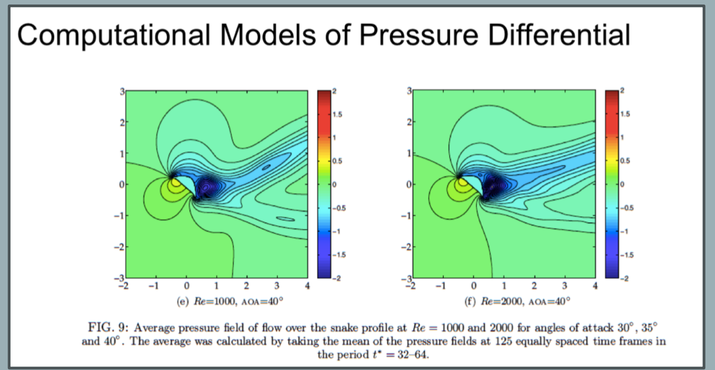
The snake does two things to prolong its airtime: 1) expand its ribs to flatten its body and 2) undulate in the air. With an impressive ability to control where it lands and in some cases double its airtime, the complex and effective motion of these snakes is the subject of physics and robotics research. With the support of an NSF grant and the REU program, I will be doing robotics research with a team at Oregon State University in collaboration with Virginia Tech. By studying the relationship between the geometry of the snake's body and the movement it achieves, robotics researchers hope to engineer a lightweight robotic system as versatile as the Paradise Flying Snake.



Krishnan 2014, Lift and Wake of Flying Snakes

When the snake flattens its body in the air, its shape approximates that of airfoil, as shown above. The S-shape of its body makes this airfoil-like cross section perpendicular to the air. As shown in the figures to the left which show pulses of smoke passing over an airfoil, the speed of the air above the airfoil is greater than the speed below. The figures above show a diagram of the snake's body acting as an airfoil. The photo on the right shows a picture of a real flying snake in the air. The flat shape of its body is apparent.

Computational Models of Pressure Differential



Socha 2015, How Animals Glide

Socha 2015, How Animals Glide

According to Bernoulli's principle, the resulting pressure differential causes lift. The figure above shows the outcome of a computational model of the pressure differential around the snake's body. The bluest areas are areas of low pressure, and the yellow and green areas are areas of high pressure. Below the cross section of the snake's body is higher pressure, which confirms the conclusion of Bernoulli's principle and explains a component of the snake's ability to produce lift.