Bernoulli's Principle

Bernoulli's Principle

Has this ever happened to you? You've just turned on the shower. Upon stepping into the water stream, you decide that the water pressure is not strong enough. You turn the faucet to provide more water, and all of a sudden the bottom edge of the shower curtain starts swirling around your legs. What's going on? It might surprise you that the explanation for this unusual occurrence also explains how wings help birds and planes fly and how pitchers throw curve balls.

Fluid Pressure Decreases as Speed Increases

The strange reaction of the shower curtain is caused by a property of moving fluids that was first described in the eighteenth century by Daniel Bernoulli (buhr NOO lee), a Swiss mathematician. **Bernoulli's principle** states that as the speed of a moving fluid increases, its pressure decreases. In the case of the shower curtain, the faster the water moves, the less pressure it exerts. This creates an imbalance between the pressure inside the shower curtain and the pressure outside it. Because the pressure outside is now greater than the pressure inside, the shower curtain is pushed toward the water stream.

Science in a Sink You can see Bernoulli's principle at work in **Figure 14.** A table-tennis ball is attached to a string and swung gently into a moving stream of water. Instead of being pushed back out, the ball is actually held in the moving water when the string is given a tug. Why does the ball do that? The water is moving, so it has a lower pressure than the surrounding air. The higher air pressure then pushes the ball into the area of lower pressure—the water stream. Try this at home to see for yourself!

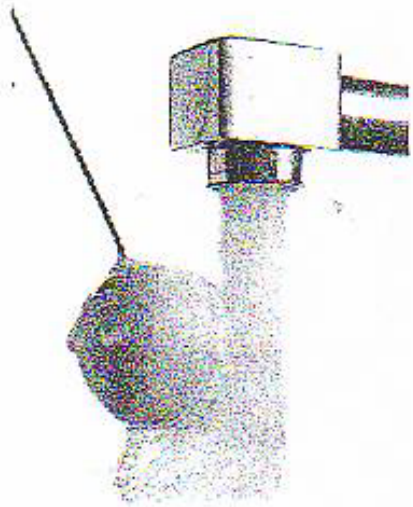


Figure 14 *This ball is pushed by the higher pressure of the air into an area of reduced pressure—the water stream.*

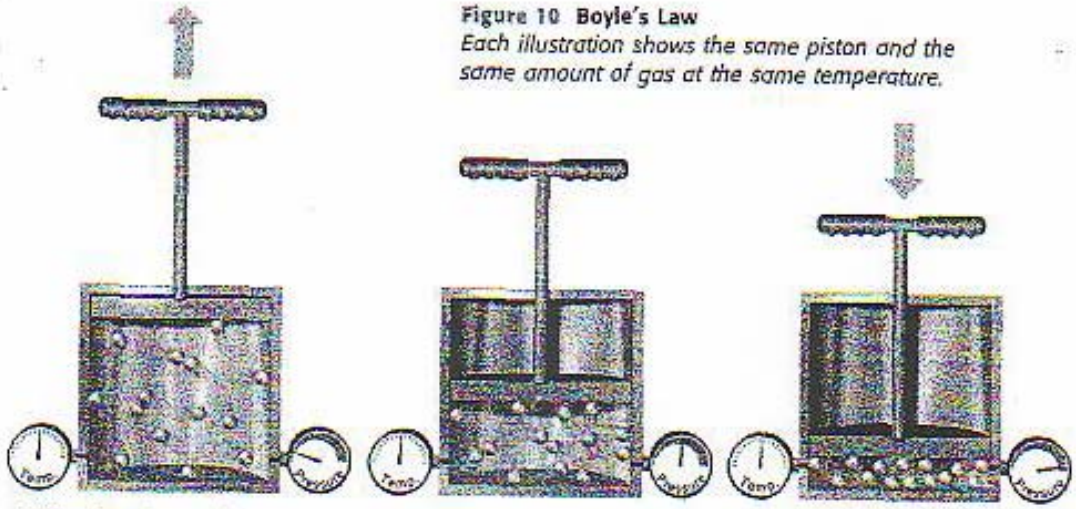
Taken from – Holt Science & Technology, *Physical Science*, 2001

Boyle's Law

$$V_1 \times P_1 = V_2 \times P_2$$

Boyle's Law Imagine a diver at a depth of 10 m blowing a bubble of air. As the bubble rises, its volume increases. By the time the bubble reaches the surface, its original volume will have doubled due to the decrease in pressure. The relationship between the volume and pressure of a gas is known as Boyle's law because it was first described by Robert Boyle, a seventeenth-century Irish chemist. **Boyle's law** states that for a fixed amount of gas at a constant temperature, the volume of a gas increases as its pressure decreases. Likewise, the volume of a gas decreases as its pressure increases. Boyle's law is illustrated by the model in **Figure 10**.

Figure 10 Boyle's Law
Each illustration shows the same piston and the same amount of gas at the same temperature.



Lifting the plunger decreases the pressure of the gas. The particles of gas spread farther apart. The volume of the gas increases as the pressure decreases.

Releasing the plunger allows the gas to change to an intermediate volume and pressure.

Pushing the plunger increases the pressure of the gas. The particles of gas are forced closer together. The volume of the gas decreases as the pressure increases.

Taken from – Holt Science & Technology, *Physical Science*, 2001

Archimedes' Principle

Buoyant Force

Why does a rubber duck float on water? Why doesn't it sink to the bottom of your bathtub? Even if you pushed the rubber duck to the bottom, it would pop back to the surface when you released it. Some force pushes the rubber duck to the top of the water. That force is **buoyant force,** the upward force that fluids exert on all matter.

Air is a fluid, so it exerts a buoyant force. But why don't you ever see rubber ducks floating in air? Read on to find out!

Buoyant Force Is Caused by Differences in Fluid Pressure

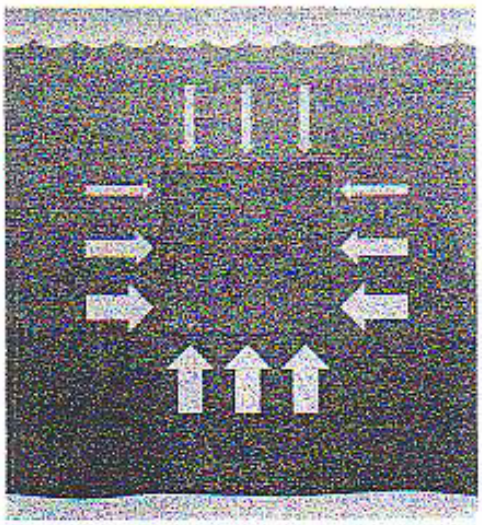


Figure 9 *There is more fluid pressure on the bottom of an object because pressure increases with depth. This results in an upward force on the object—buoyant force.*

Look at **Figure 9.** Water exerts fluid pressure on all sides of an object. The pressure exerted horizontally on one side of the object is equal to the pressure exerted horizontally on the opposite side. These equal pressures cancel one another. Thus, the only fluid pressures affecting the object are at the top and at the bottom. Because pressure increases with depth, the pressure on the bottom of the object is greater than the pressure at the top, as shown by the width of the arrows. Therefore, the water exerts a net upward force on the object. This upward force is buoyant force.

Determining Buoyant Force Archimedes (ahr kuh MEE deez), a Greek mathematician who lived in the third century B.C., discovered how to determine buoyant force. **Archimedes' principle** states that the buoyant force on an object in a fluid is an upward force equal to the weight of the volume of fluid that the object displaces. (*Displace* means "to take the place of.") For example, suppose the object in Figure 9 displaces 250 mL of water. The weight of that volume of displaced water is about 2.5 N. Therefore, the buoyant force on the object is 2.5 N. Notice that the weight of the object has nothing to do with the buoyant force. Only the weight of the displaced fluid determines the buoyant force on an object.

Taken from – Holt Science & Technology, *Physical Science*, 2001

Pascal's Principle

Pascal's Principle

Imagine that the water-pumping station in your town can now increase the water pressure by 20 Pa. Will the water pressure be increased more at a supermarket two blocks away or at a home 2 km away?

Believe it or not, the increase in water pressure will be transmitted through all of the water and will be the same—20 Pa—at both locations. This is explained by Pascal's principle, named for Blaise Pascal, the seventeenth-century French scientist who discovered it. **Pascal's principle** states that a change in pressure at any point in an enclosed fluid will be transmitted equally to all parts of that fluid.

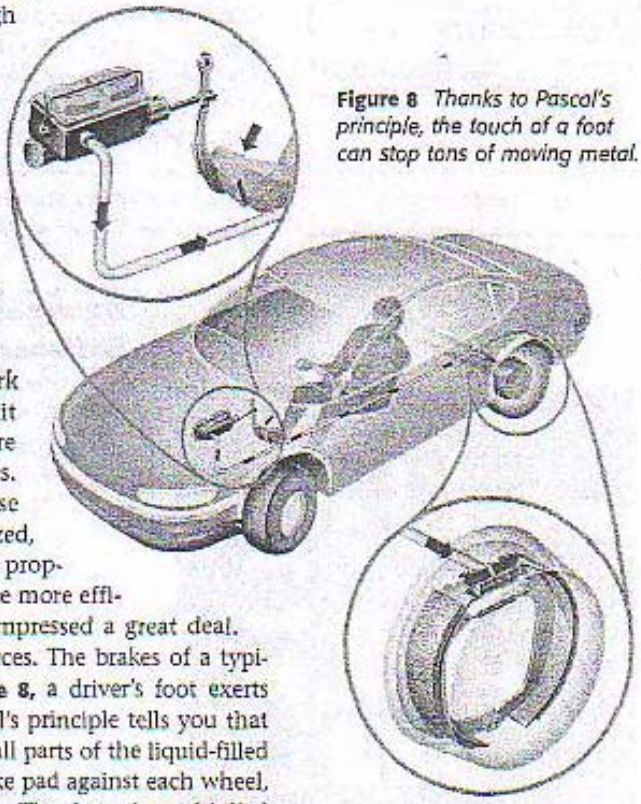


Figure 8 *Thanks to Pascal's principle, the touch of a foot can stop tons of moving metal.*

Putting Pascal's Principle to Work

Devices that use liquids to transmit pressure from one point to another are called *hydraulic* (hie DRAW lik) devices. Hydraulic devices use liquids because they cannot be compressed, or squeezed, into a smaller space very much. This property allows liquids to transmit pressure more efficiently than gases, which can be compressed a great deal.

Hydraulic devices can multiply forces. The brakes of a typical car are a good example. In **Figure 8,** a driver's foot exerts pressure on a cylinder of liquid. Pascal's principle tells you that this pressure is transmitted equally to all parts of the liquid-filled brake system. This liquid presses a brake pad against each wheel, and friction brings the car to a stop. The force is multiplied because the pistons that push the brake pads on each wheel are much larger than the piston that is pushed by the brake pedal.

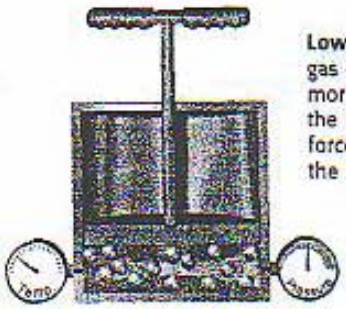
Taken from – Holt Science & Technology, *Physical Science*, 2001

Charles's Law

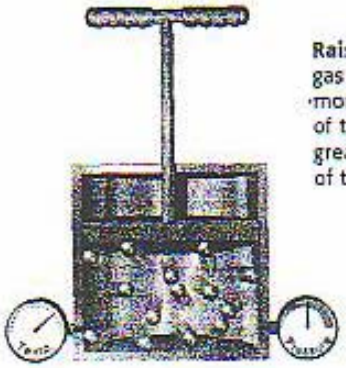
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Charles's Law An inflated balloon will also pop when it gets too hot, demonstrating another gas law—Charles's law. **Charles's law** states that for a fixed amount of gas at a constant pressure, the volume of the gas increases as its temperature increases. Likewise, the volume of the gas decreases as its temperature decreases. Charles's law is illustrated by the model in Figure 11. You can see Charles's law in action by putting an inflated balloon in the freezer. Wait about 10 minutes, and see what happens!

Figure 11 Charles's Law
Each illustration shows the same piston and the same amount of gas at the same pressure.



Lowering the temperature of the gas causes the particles to move more slowly. They hit the sides of the piston less often and with less force. As a result, the volume of the gas decreases.



Raising the temperature of the gas causes the particles to move more quickly. They hit the sides of the piston more often and with greater force. As a result, the volume of the gas increases.

Taken from – Holt Science & Technology, *Physical Science*, 2001