Bernoulli's Principle Encyclopedia Article

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Bernoulli's Principle

Bernoulli's principle describes the relationship between the pressure and the velocity of a moving fluid (i.e., air or **water**). Bernoulli's principle states that as the velocity of fluid flow increases, the pressure exerted by that fluid decreases.

During the late eighteenth century, **Daniel Bernoulli** pioneered the basic tenet of kinetic theory, that molecules are in motion. He also knew that flowing fluids exerted less pressure, but he did not connect these ideas logically. In *Hydrodynamica*, Bernoulli's logic that flow reduced pressure was obscure, and his formula was awkward. Bernoulli's father Johann, amid controversy, improved his son's insight and presentation in *Hydraulica*. This research was centered in St. Petersburg where Leonard Euler, a colleague of Bernoulli and a student of Johann, generalized a rate-of-change dependence of pressure and density on speed of flow. Bernoulli's principle for liquids was then formulated in modern form for the first time.

In this same group of scientists was D'Alembert, who found paradoxically that fluids stopped ahead of obstacles, so frictionless flow did not push.

Progress then seems to have halted for about a century and a half until Ludwig Prandtl or one of his students solved Euler's equation for smooth streams of air in order to have a mathematical model of flowing air for designing wings. Here, speed lowers pressure more than it lowers density because expanding air cools, and the ratio of density times degrees-kelvin divided by pressure is constant for an ideal-gas.

More turbulent flow, as in atmospheric winds, requires an alternative solution of Euler's equation because mixing keeps air-temperature fixed.

Bernoulli's principle is regarded by many as a paradox because currents and winds upset things, but standing a stick in a stream of water helps to clarify the enigma. One can observe calm, smooth, level water ahead of the stick and a cavity of reduced pressure behind it. Calm water pushes the stick, as lower pressure downstream fails to balance the upsetting force.

Bernoulli's principle never acts alone; it also comes with molecular entrainment. Molecules in the lower pressure of faster flow aspirate and whisk away molecules from the higher pressure of slower flow. Solid obstacles such as airfoils carry a thin stagnant layer of air with them. A swift low-pressure airstream takes some molecules from this boundary layer and reduces molecular impacts on that surface of the wing across which the airstream moves faster.

See Also

Atmospheric Chemistry; Hydrostatic Pressure