

THE DEMONSTRATION CORNER

Bernoulli's Principle – Under Pressure

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In this demonstration, we utilize simple everyday household items to test Bernoulli's principle and verify the apparent counterintuitive nature of its predictions.

Bernoulli's principle, after the Swiss scientist Daniel Bernoulli (1700-1782), relates the pressure P , flow speed v , and the elevation of a fluid. The equation that expresses this principle quantitatively (assuming the fluid does not change elevation) is

$$P + \frac{1}{2} \rho v^2 = \text{constant},$$

where ρ is the density.

A major prediction of Bernoulli's principle emerges from this equation: where the velocity of a fluid is relatively high, the associated fluid pressure is relatively low, and vice versa.

This demonstration requires a blower (a shop vac, electric leaf-blower or air mattress pump can be used), large cork stopper with small hole (~ 0.5 cm diameter), and a metal disc (bristol board disc can be substituted) with a small nail stuck to the surface.

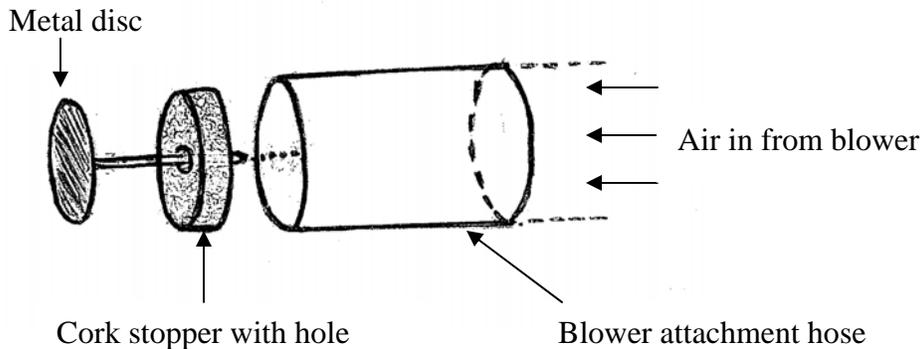


Figure 1. Equipment setup for demonstration.

Figure 1 illustrates the equipment: the cork stopper is fitted into the blower attachment hose and held in place so that air from the blower is forced through the small hole at the centre of the stopper, at high velocity. Before moving the metal disc towards the hole in the stopper, I usually ask the class to predict the outcome and also to confirm that the blower is indeed blowing air outwards and not in vacuum mode, i.e., not sucking air in. (A quick blast of air at a few students

confirms this.) Most students predict that the disc would be blown away due to the high pressure generated as a result of the high velocity of air issuing from the hole in the stopper, with the logic of their prediction (based on experience) being that a rapidly moving fluid has a high pressure.

When the disc is brought close to the hole it is clear that it is attracted to, and remains suspended close to, the cork stopper (Fig. 2). This counterintuitive result is a consequence of Bernoulli's equation. Because the air speed is very high as the air moves through the narrow gap between the cork and the disc, the pressure is low. Consequently, the air pressure above the disc is less than the atmospheric air pressure beneath the disc, resulting in a net upward air-force on the disc, which balances the downward weight of the disc.

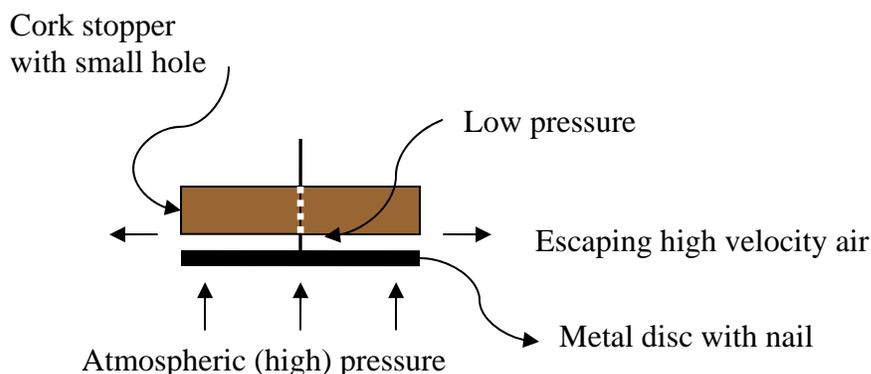


Figure 2. With the metal disc close to the cork stopper the pressure difference across the disc causes it to be attracted toward the stopper and remain suspended below the small hole through which high-velocity air is escaping. The small nail stuck to the disc surface and inserted into the hole in the stopper prevents lateral movement of the disc.

A useful explanation for students as to why their prediction — that high fluid velocities give rise to high pressure — is incorrect, and to clarify any misconceptions, is the example of a person being hit and knocked over by fast-moving water out of a fire-hose. The force that knocks you over is indeed due to fluid pressure, and you would justifiably conclude that the pressure was high. However the pressure is not high until you slow down the water by getting in its way. The rapidly moving water in the jet is approximately at atmospheric pressure before it hits you, but as you stop the water, its pressure increases dramatically.

Bernoulli's principle explains many other common phenomena such as the (perfume) spray atomizer, the dynamic lift experienced by aircraft wings and the motion of "curve balls" in baseball.

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Submissions describing demonstrations will be gladly received by the column editor.
