Bernoulli Law

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Abstract. *We will present important laws in Physics verified trough simple experiments (Bernoulli's Law). The movement of a fluid is completely described only if the speed and pressure of the fluid is known in its every point. This means that we need to know the speed field ($\vec{v}$) and also the pressure field.*

If the fluid's speed is constant in different points of its movement path, we say that the fluid has a stationary at a permanent regime movement. A fluid moving due to the action of the Earth's gravitational field behaves similarly to an object thrown horizontally. The fluid's speed can also be considered as the speed of an object freely falling. The Bernoulli's Law is verified by obtaining identical results for the flowing speed of a fluid, considered as the speed of an object freely falling from a defined height (h), or as the speed of an object thrown horizontally.

Keywords. Bernoulli, Torricelli, Fluid, Vessel, Height, Pressure, Verification, Experiment.

1. Introduction

The idea to approach this issue started from two problems that we encountered in the book of Professors David Halladaz and Robert Resnick (Physics vol. I).

A liquid percolating through a hole in a large bowl, the hole being located at a distance below the water level by applying Bernoulli's equation of power lines joining points 1, 2 and 3 show that the flow velocity is $v = \sqrt{2gh}$. This relationship is known as the Torricelli's law (Figure 1).

Upper surface of the water from a reservoir is at a height above the horizontal period. What depth have been a vent than for shoot water out horizontally to hit the ground at a distance of the tank (Figure 2)?

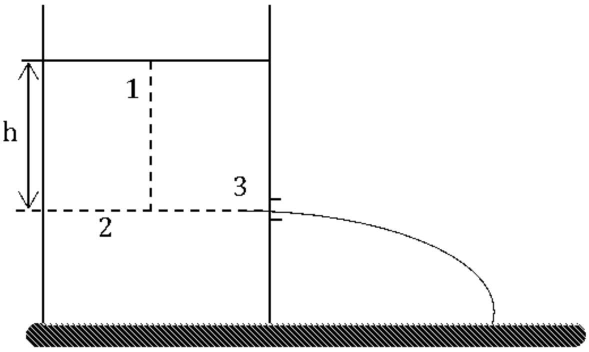

Figure 1. Torricelli's law

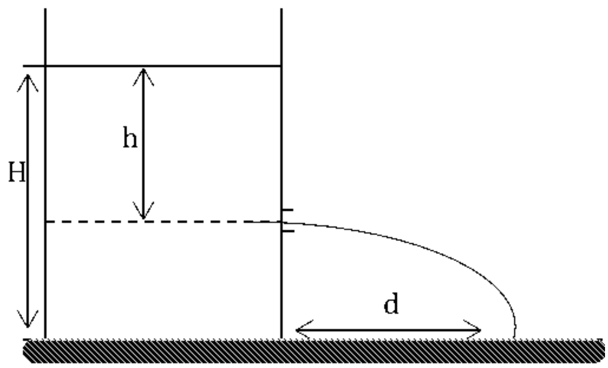

Figure 2. Interpretation of Torricelli's law

2. Necessary materials:

- a 2 liter plastic bottle in which we practice a unique opening at height *H/h* towards the bottom;
- graph paper glued on length glass;
- rule;
- horizontal tray to drain water.

3. Theory of experimental work:

The liquid flowing out through the inlet section is considered to be in steady flow. Applying Bernoulli's law for the tube current between sections *S* and *s* we get:

$$p_a + \frac{\rho v_2^2}{2} + \rho g h = p_a + \frac{\rho v^2}{2} \quad (1)$$

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where v_0 is the speed with which the liquid down in the vessel.

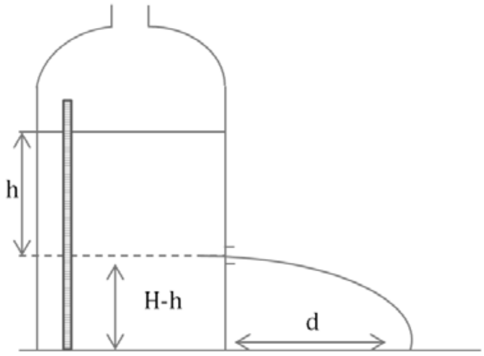


Figure 3. Theory of experimental work

If S sectional area is much larger than the section through which fluid flows ($S >> s$), based on the continuity equation can neglect the term $\frac{\rho v_0^2}{2}$ in equation (1) ($v_0^2 \to 0$).

Bernoulli's law gets the following form:

$$p_a + \rho g h = p_a + \frac{\rho v^2}{2}$$

$$\rho g h = \frac{\rho v^2}{2} \quad \text{and} \quad v = \sqrt{2gh} \quad (2)$$

This law is called Torricelli's law and shows that the fluid flow velocity in this case coincides with the speed of a body falling freely from height.

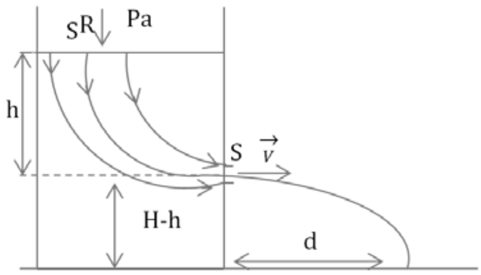


Figure 4. Bernoulli *vs.* Torricelli laws

Evaluation of fluid flow rate through the section can be made by measuring the distance that a jet crosses the horizontal stroke (d).

Fluid motion in gravitational field is similar to throwing horizontally so that the speed is given by:

$$v = d\sqrt{\frac{g}{2(H-h)}} \quad (3).$$

Verification of Torricelli's relationship just comparing flow velocity values obtained with relations (2) and (3).

As a work do the following:

- for determining speed of fluid flow and to chech Torricelli's law , is measured at different moments of time (close together) height using graph paper, using the rule that beating located near vessel;

- the data and the results are recorded in a table and compare the results.

$$\sqrt{2gh} = d\sqrt{\frac{g}{2(H-h)}}$$

$$d = 2\sqrt{H-h}\sqrt{h} \quad (4)$$

where $H-h$ is constant. Verification of relationship (4) can be done graphically representing $d = f(h)$. The slope of the line is $tg\alpha = 2\sqrt{(H-h)}$. Determine the height $(H-h)$ of slope chart ($H - h = \frac{tg^2\alpha}{4}$) and compared with experimentally determined value.

4. Calculation errors:

$\Delta v = \Delta g + \Delta h$

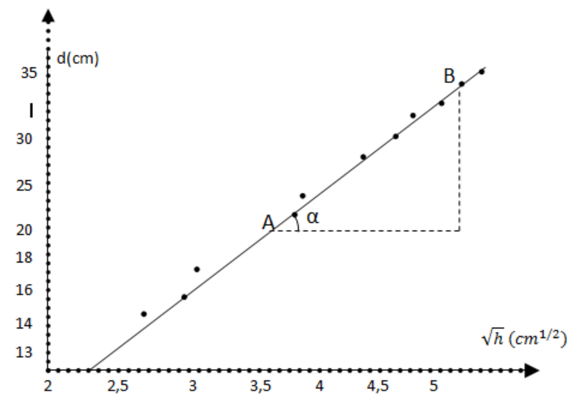
$\Delta v' = \Delta d + \frac{1}{2}\Delta(H-h) + \frac{1}{2}\Delta g$

if $g = 9{,}81\frac{m}{s^2}$, $\Delta g = 0{,}5 \cdot 10^{-2}\frac{m}{s^2}$

$\Delta(H-h) = \Delta d = \Delta h = 1mm$

5. Experimental data. Interpretation:

We present, for a number of determinations, the graphical representation of relationship $d = f(\sqrt{h})$.



$$tg\alpha = 6{,}387\ cm^{1/2}$$

Obtain $H_{calculat} = \frac{tg^2\alpha}{4} = 10{,}2\ cm$ in comparison with

$$H_{experimental} = 10\ cm$$

which means a relative error:

$$\Delta_h = \frac{H_{calculat} - H_{experimental}}{H_{calculat}} = 1{,}9\%$$

6. References (and Notes)

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