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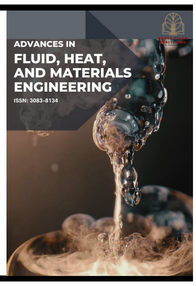

Analysis of Velocity for Different Density Using Different Height

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ABSTRACT

This study investigates the relationship between velocity, density, and height in various fluid systems, providing a comprehensive analysis of how these factors interact under different conditions. The experiment involved measuring the velocity of fluids with varying densities as they flowed through channels of differing heights. Key principles such as fluid mechanics, Bernoulli's equation, and the continuity equation were applied to water bottles with three different height holes and interpreted the results. It was observed that greater water heights resulted in higher velocities due to increased gravitational potential energy, while variations in density, simulated by adding solutes, provided additional insights into flow characteristics. This analysis highlights the relevance of height and density in fluid flow applications, offering a clear understanding of fundamental fluid mechanics concepts through an accessible experimental setup. The experimental setup consisted of water bottles with different heights which are 0.055 m, 0.150 m and 0.225 m. Variations in fluid density were introduced by dissolving different solutes such as water, salted water and wasted oil to simulate changes in the physical properties of the fluid. Results indicated that the initial height of the fluid significantly influenced its velocity, with taller columns of water producing higher exit velocities due to increased gravitational potential energy. Hole C have higher velocity compared to hole A and B meanwhile hole A have lower velocity compared to hole B and C for each liquid. Additionally, fluids with higher densities exhibited slower velocities under similar conditions, demonstrating the inverse relationship between density and flow rate when other factors remain constant. The study demonstrates the importance of easily accessible experimental instruments, such as water bottles with holes, in the teaching and analysis of fluid mechanics by highlighting the significance of height and density as crucial variables in regulating flow behavior. Based on the result, if position of the hole from the surface of the liquid is higher, the velocity of the flow will increase for each liquid.

1. Introduction

A fundamental idea in fluid dynamics, Bernoulli's Principle explains the complex interplay between pressure, velocity, and elevation in a moving fluid. This theory, which was first proposed by Daniel Bernoulli in the 18th century, offers a deep comprehension of the behavior of fluids under many circumstances and serves as the basis for several natural phenomena and technical

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applications. Fundamentally, Bernoulli's Principle states that a fluid's velocity increases when its pressure decreases and inversely. Bernoulli's Equation, which is based on the conservation of energy in a fluid flow system, provides a mathematical expression for this relationship [1-3].

This study uses a simple setup using a plastic water bottle to examine how density and height affect fluid velocity. To let fluid out, the side of the bottle has been drilled with three tiny holes of varying sizes and heights. To investigate how changes in fluid density and height affect velocity, the bottle is then filled with a variety of fluids such as water, saltwater, and wasted oil [4]. By measuring the velocity at each hole and comparing it to the fluid's depth above the hole, the flow of each fluid is examined. The study shows that the velocity is directly related to the fluid column's height since higher height results in higher gravitational potential energy and, consequently, a higher exit velocity [5-7].

The study's findings demonstrate how height, density, and velocity interact. According to Bernoulli's Principle, the velocity of water is highest at the bottom hole and gradually decreases at the middle and top holes. On the other hand, because saltwater and oil have higher densities, their overall velocities are lower and the differences across the three holes are less significant. This illustrates that while examining fluid dynamics, density and height must be taken into consideration because they together define the system's energy distribution [8,9].

This analysis offers important new perspectives on how Bernoulli's Principle is applied in practical situations. For instance, knowing how pressure, velocity, and fluid density relate to one another is crucial for maximizing flow rates and reducing energy loss in hydraulic systems and water supply networks [10]. The results highlight the significance of density in the design of effective transport systems in organizations that handle several fluids with different densities, such as gas and oil. By concentrating on these variables, the research provides a comprehensive understanding of the elements influencing fluid flow behavior and connects theoretical fluid dynamics with real-world applications [11,12].

The experimental setting also shows how easy it is to use basic instruments to investigate complicated fluid dynamics issues. A water bottle that has been slightly altered might be a useful tool for measuring and visualizing basic concepts. Because they allow students to see firsthand how height and density affect velocity, these experiments are extremely useful in educational settings and help students become more engaged with the material. The study's scope can be increased to include more complex studies by making further changes, such as changing the size of the holes or employing fluids with a wider range of densities [13,14].

The investigation of velocity for fluids with different densities leaving from different heights is the main emphasis of this study. It illustrates that density and height play a crucial role in determining velocity, which has consequences for both theoretical comprehension and real-world implementation [15]. The work emphasizes the significance of these factors in fluid mechanics and promotes more research into more complex systems by demonstrating the dynamics of fluid flow using a straightforward but efficient experiment [16,17]. The objective of this study is to investigate the effect of fluid density and height on the velocity, analyze the relationship between these parameters, and validate the application of relevant physical laws such as Bernoulli’s principle.

2. Methodology

2.1 Geometry of the Water Bottle

A water A water bottle with three different holes labeled A, B, and C, each at different heights: A at 5.5 cm, B at 15 cm, and C at 22.5 cm from surface liquid as shown in Figure 1.

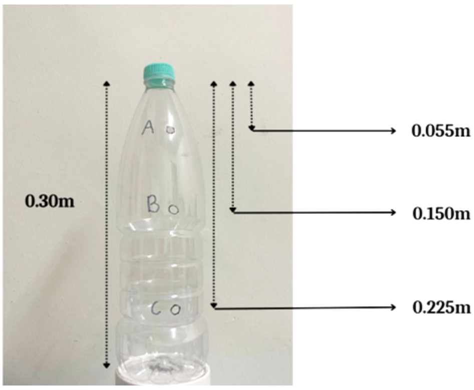

Fig. 1. Water bottle with three different heights of holes

2.2 The Experimental Setup

Three water bottles were prepared successfully with three holes drilled at different heights and labelled A, B, and C as in Figure 2. By using the paper tape, role the paper tape and fill the paper tape with the pieces of wood until it fits and close each hole of the bottle using it. Double check if all holes already fit. Fill the first bottle with water and double check if the hole still fits and the water or oil did not spill. Measurement tools including measuring tape and stopwatch were tested and calibrated for accuracy. Repeat step first until forth for saltwater and wasted oil.

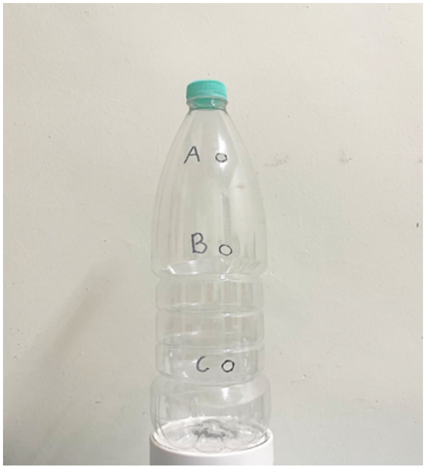

Fig. 2. Three holes at a water bottle was successfully drilled and label A, B and C

2.3 Analysis of Velocity Using Bernoulli Equation

A methodical technique to analysing how fluid dynamics change with changing densities and hole placements is part of the experimental methodology for assessing the velocity of water flow from a bottle with three distinct hole heights. A transparent water bottle with three uniformly placed holes at varying heights (top, middle, and bottom) is prepared before the experiment starts. Liquids having different densities such as water, saltwater, and wasted oil bare put into the bottle. The velocity is determined by either measuring the horizontal distance travelled by the liquid as it exits each hole or by timing the flow rate with a stopwatch and collecting the liquid. Since velocity is dependent on both the density of the liquid and the height of the liquid column above the hole, the Bernoulli equation offers theoretical justification.

$$\frac{P_1}{\rho g}+\frac{v_1^2}{2g}+z_1=\frac{P_2}{\rho g}+\frac{v_2^2}{2g}+z_2 \tag{1}$$

which is P representing pressure (Pa), ρ is a density of fluid (kg/m³), v is a velocity (m/s), g is a gravitational acceleration and lastly z represent height (m).

The theoretical framework is based on Bernoulli's equation, which states that the square root of the height of the liquid column above the hole determines the velocity of the liquid exiting the hole. Because of the larger height of the liquid column, lower holes show higher pressure and greater velocity, while higher holes correspond to lower pressure and reduced velocity. The experiment can be repeated with various liquids to examine how density affects flow velocity. To examine the link between density, height and fluid velocity as predicted by Bernoulli's Principle using a straightforward water bottle setup with three holes at different height, and to compare the flow characteristics of water, salted water and wasted oil, this experiment provides a clear and useful understanding of fluid mechanics concepts.

3. Results and Discussion

3.1 Calculation for Velocity of Different Densities with Different Height

Derivation of velocity using Bernoulli's Principle using Eq. (1). For this experiment, $P_1 = P_2 = P_{atm} = 0$. Also, $z_2 = 0$ and $v_1 = 0$.

$$z_1=\frac{v_2^2}{2g} \tag{2}$$

$$v_2^2=z_1 2g \tag{3}$$

$$v_2=\sqrt{z_1 2g} \tag{4}$$

$$\therefore v=\sqrt{2gh} \tag{5}$$

where the velocity, v, gravitational acceleration, g, and height, z. Formula velocity for experimental value which is use a general formula of velocity:

$$v=\frac{d}{t} \tag{6}$$

where velocity, v in (m/s), distance, d in (m), and time, t in (s). Calculation theoretical value for hole A by using Eq. (5):

$$v=\sqrt{2(9.81)(0.055)}$$

$$v=1.04\ m/s$$

Calculation experimental value for hole A using water with density $1000\ kg/m^3$ by using Eq. (6):

$$v = \frac{0.13}{0.12}$$

$$v = 1.08\ m/s$$

The calculation above is specifically for Hole A. The same equation can be applied to calculate for Holes B and C for each liquid. There is a slight difference between the two sets of results after the theoretical velocity values are calculated using Bernoulli's equation and compared to the experimental values acquired by direct measurement. Numerous elements of the experimental design and assumptions of Bernoulli's equation contribute to this difference.

3.2 Data Collection from the Experimental Study

The theoretical result for this experiment is in Table 1 by using derivation of Bernoulli's equation with different height from surface liquid which are hole A is 0.055 m, hole B is 0.150 m and hole C is 0.225 m. After calculation, the value of velocity as in Table 1. The experimental result for this experiment is in Table 2 by using general formula which is distance divided by time to get a velocity for experiment with different height from liquid surface which are hole A is 0.055 m, hole B is 0.150 m, and hole C is 0.225 m. For density of fluid such as water is $1000\ kg/m^3$, wasted oil is $960\ kg/m^3$ and salted water is $1030\ kg/m^3$. The horizontal distance and time were recorded during the experiment as in Table 2.

Table 1
Theoretical data using Bernoulli's equation to get the velocity

Hole	Height from liquid surface (h) in m	Velocity, (v) in m/s
A	0.055	1.04
B	0.150	1.72
C	0.225	2.10

Table 2
Experimental data

Density of fluid	Hole	Height from liquid surface ($\boldsymbol{h}$) in m	Horizontal distance ($\boldsymbol{d}$) in m	Time ($\boldsymbol{t}$) in s	Velocity, ($\boldsymbol{v}$) in m/s
Water	A	0.055	0.13	0.12	1.08
($\boldsymbol{\rho = 1000\ kg/m^3}$)	B	0.150	0.17	0.15	1.13
	C	0.225	0.21	0.17	1.24
Wasted oil	A	0.055	0.10	0.11	0.91
($\boldsymbol{\rho = 960\ kg/m^3}$)	B	0.150	0.16	0.14	1.14
	C	0.225	0.19	0.16	1.19
Salted water	A	0.055	0.15	0.14	1.07
($\boldsymbol{\rho = 1030\ kg/m^3}$)	B	0.150	0.19	0.16	1.19
	C	0.225	0.25	0.19	1.32

3.3 Analysis Data

Based on the analysis, the velocities increase from condition A to condition C for all fluids. This indicates that the variable being changed, which might be height or pressure head, is exactly proportional to the velocity, which is according to ideas from Bernoulli's principle. The fact that salted water maintains the highest velocities indicates that it may be thicker than ordinary water, which causes a greater gravitational pull to affect the flow rate. Wasted oil has consistently lower velocity because wasted oil has a lower density than water and salted water. This study's findings support basic concepts in fluid mechanics, especially the relationship between velocity and height (pressure head) and fluid characteristics (density). On the other hand, Bernoulli's predictions are closely followed by water, wasted oil, and salted water. Small fluid losses or frictional effects in the setup may be the cause of the experimental velocities being slightly lower than theoretical values. The difference could be explained by variables like measurement errors or surface tension [18].

The graph clearly shows how fluid density, height, and velocity are related. Because water and salted water have lower viscosities than wasted oil, they move more quickly. The steady pattern observed in all three circumstances indicates that raising the height or lowering the restrictions improves velocity, supporting the theoretical ideas of fluid dynamics. This data can help guide future research on improving flow rates and designing efficient transport systems for fluids with different properties [19]. Three analysis graphs for experimental results were created. Based on the graph, hole C has a higher velocity compared to other holes and hole A has a lowest velocity compared to hole B and C in each liquid as in Figure 3, Figure 4, and Figure 5.

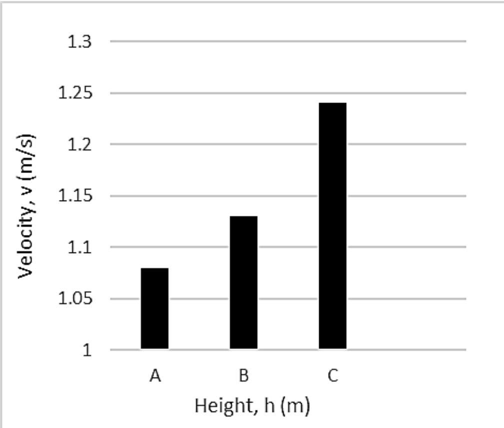

Fig. 4. Velocity versus height for water

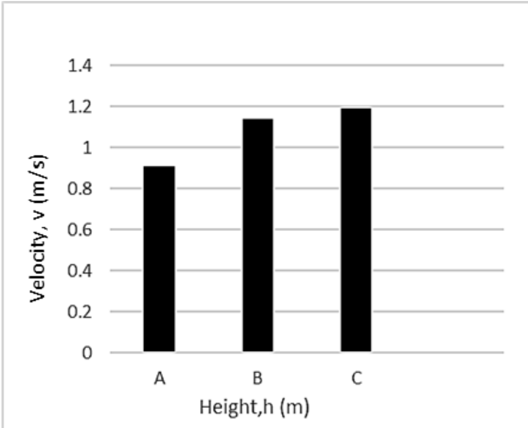

Fig. 5. Velocity versus height for wasted oil

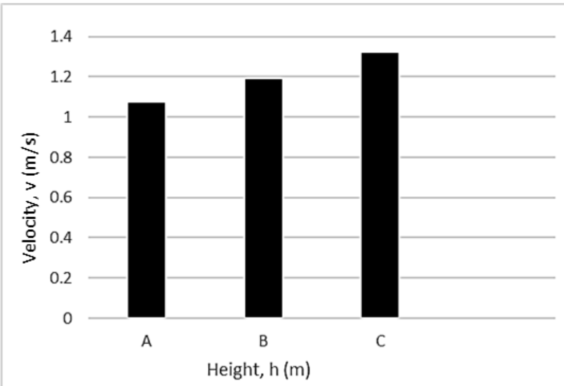

Fig. 6. Velocity versus height for salted water

3.4 Discussion

The relationship between liquid flow and several variables, such as liquid height, pressure, density, and the size and location of the hole, was clearly shown by this study. As anticipated, it was found that a larger flow rate and higher velocity was produced by increasing the liquid column's height. The finding that the increased liquid heights from the surface area cause the liquid to pass through the hole more quickly is proof of the impact of gravitational potential energy on fluid movement. Furthermore, the flow rate was significantly impacted by the hole's height. Liquid flowed more quickly through higher holes and more slowly through lower ones [20]. This result supports the hypothesis that the higher hole affects the rate of fluid outflow. The experiment showed that altering the hole's height can have a big impact on how liquid flows in following tests.

However, various sources of error, minor mistakes may be introduced by the measuring procedure itself, such as timing problems, irregular liquid heights, differences in hole diameter, liquid level readings, or differences in the way the stream's direction is captured and might have impacted the outcome's dependability. For example, turbulence and interaction with the surrounding air cause some energy to be lost as the liquid leaves the hole, lowering velocity in comparison to the theoretical predictions [21].

The fundamental ideas of fluid mechanics, such as how liquid height, pressure, density, and hole height and position affect liquid velocity, were all clearly demonstrated by this study. These results are consistent with established fluid mechanics theories and have applications in a variety of domains, such as water system design and leak prevention in engineering. In addition to improving theoretical knowledge, the experiment provides a practical understanding of the forces affecting fluid movement in ordinary circumstances such as drainage systems, liquid storage tanks, and agricultural irrigation installations [22].

4. Conclusions

Bernoulli's Principle is successfully demonstrated by this study, which shows how fluid velocity increases with density and pressure. The findings highlight the connection between pressure, density and velocity. Validate the theoretical computations and provide insights into fluid dynamics. The study reinforces important ideas in fluid physics and provides a useful method for illustrating Bernoulli's Principle. Although some variations were caused by measurement errors and water turbulence, the data collected indicates a respectable agreement between theoretical and experimental results. The facts support the theoretical derivations based on Bernoulli's Equation, which states that increased pressure at greater depths results in higher velocities.

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