Physics Laboratory Exercise: The Bernoulli Effect

Background Information

The Bernoulli Equation states that for a fluid with very low viscosity flowing in a pipe,

\[ p_1 + \rho g h_1 + \frac{1}{2} \rho v_1^2 = p_2 + \rho g h_2 + \frac{1}{2} \rho v_2^2 \]

For fluids flowing out of a large container, in your report you need to show that the velocity at the exit point is given by a special form of the Bernoulli Equation:

\[ v = \sqrt{2gh} \]

And in your report you also need to show that the flow rate is given by:

\[ R = \frac{V}{t} = A \sqrt{2gh} \]

In an ideal case where we can assume the velocity of exiting fluid is constant, the time to empty a given volume is:

\[ t = \frac{V}{A \sqrt{2gh}} \]

Materials

In addition to the usual paper, pencil, and calculator, this lab requires the following materials:

- 5 gallon bucket with a small ¼-inch hole drilled in the bottom, and a stopper for that hole
- About 5 gallons of tap water
- Bottle with volume marks
- Ruler
- Stopwatch
Step 1: Setup

Set up the provided equipment as illustrated then fill the bucket with water.

![Initial setup of lab exercise equipment](image)

The bucket has a hole at the bottom that was created with a $\frac{1}{4}''$ drill bit. That’s $\frac{1}{4}''$ in diameter. When calculating area of the hole, assume a $\frac{1}{4}''$ diameter.

Step 2: Experiment

Place the small bottle with volume marks beneath the opening in the bucket then remove the stopper. Start the stopwatch. When the volume in the small bottle reaches **16 ounces**, stop the stopwatch and **replace the stopper**. Record the time elapsed. Repeat for a total of six tests. – While the fluid is flowing, use your cellphone camera (or any other camera) to **take a close-up picture** of the fluid stream as it exits the bucket.

**Volume emptied** = 16 ounces  
**Height of water (h)** = 3 inches

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Step 3: Calculate

Calculate the theoretical amount of time it will take to empty 16 ounces from the bucket of water.

Volume emptied (V) = 16 ounces ÷ 998.83 ounces/ft³ = __________

Area of drain hole (A) = πr² = __________

Acceleration due to gravity (g) = 32 ft/s²

Height of water (h) = 3 inches = ________ ft

\[ t_{theoretical} = \frac{V}{A\sqrt{2gh}} \]

Theoretical time to empty volume (t_{theoretical})

Step 4: Analyze

Calculate the error between \( t_{theoretical} \) and \( t_{actual} \) for all test runs.

\[ Error = 1 - \frac{t_{theoretical}}{t_{actual}} \]

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Assume the hole made by the \( \frac{1}{4} \)“ drill bit isn’t an accurate \( \frac{1}{4} \)“. What is the actual diameter? To solve, rearrange the time-to-drain equation to solve for the diameter of the hole.

\[ t = \frac{V}{A\sqrt{2gh}} \]

Calculated diameter (inches)

What was the percent error in the hole’s diameter?

Write the equation you use here:

\[ Error = \]

| Given diameter (inches) |          |         |         |         |         |
| Calculated diameter (inches) |          |         |         |         |         |
| Error                  |          |         |         |         |         |

By analyzing the shape of the stream leaving the bucket, find the approximate outflow speed, and include this in your report.

[Hint: Use both the Equation of Continuity and Bernoulli’s Equation.]