Fluid Mechanics Lab

Rotation of flexible arm

MEP2010: Fluid Mechanics Lab

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1 | Introduction

The phenomenon of flow-induced vibrations is of significant interest in engineering and fluid dynamics. Understanding how a liquid jet exiting an L-shaped tube can cause the tube to oscillate at different flow rates is crucial for various applications, including piping systems, heat exchangers, and aerospace structures. This report presents the methodology and required apparatus for conducting an experiment to investigate this phenomenon.

2 | Objectives

Our objective is to experimentally study the impact of a liquid jet on an L-shaped tube and analyze the resulting tube oscillations. We will compare experimental data with theoretical predictions to validate our understanding.

3 | Equipment Required

1. L-Shaped Tube (we are using Plastic Pipe of 20mm diameter)
2. Pump or pressurized reservoir
3. Calibrated valves
4. Mounting mechanism
5. High-speed camera
6. Data collection
7. Calibration equipment

4 | Methodology

1. First we join the two pipes with the help of an angle.
2. Then we hinge the L-shaped tube with the help of a needle.
3. Then we measure different flow rate by filling the jar and counting the seconds it takes to fill the jar as the unit of Q is (V/s).
4. After that we flow the water through the L-shaped tube and let the pipe move or oscillate.
5. Test different flow rates by adjusting the water flow using a control valve or pump to observe how the L-shaped tube responds to varying flow conditions.
6. Take the reading and calculate rotation velocity with the help of formula

5 | Reading

We use a gauge to collect the volume output from the L-shaped tube to calculate the flow rate and velocity of the flow within the tube.

We measure time using a timer.

Table 5.1: A table without vertical lines.

S.N.	Time(sec.)	Volume(ml)
1	10	2800
2	12	2000
3	15	3000
4	34	1500

(a) image a

(b) image b

(c) image c

Figure 5.1: Three images

6 | Used Formula

used simple fluid mechanics formula

Continuity eqn

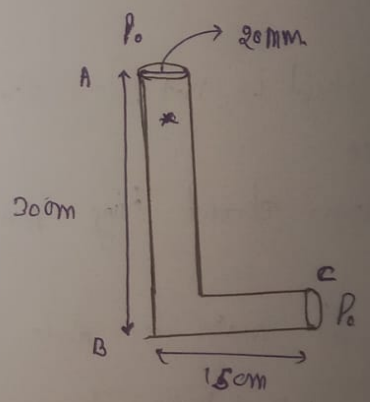
$$A_1V_1 = A_2V_2$$

B. eq

$$P_1 + \frac{1}{2}\rho V_1^2 + \rho g z_1 = P_2 + \frac{1}{2}\rho V_2^2 + \rho g z_2$$

momentum eqn / Newton second law

$$\boxed{\Sigma F = \frac{dP}{dt}}$$



area of L-shape tube is constant through all flow so velocity is also constant

$$\boxed{\begin{aligned} V_A &= V_B = V_C \\ A_A &= A_B = A_C \end{aligned}}$$

$P_A = P_0$

$P_C = P_0$

$P_B = ?$

diameter of tube = 20mm

Pressure calculation at B

(using B. eqn) between A & B

$$P_A + \frac{1}{2}\rho V_A^2 + \rho g z_A = P_B + \frac{1}{2}\rho V_B^2 + \rho g z_B$$

$$\boxed{V_A = V_B}$$

$$P_B = P_A + \rho g z_A$$

$$\boxed{P_B = P_0 + \rho g (0.30)} = 101{,}325 + 997 \times 9.8 \times 0.30 = \underline{104256.10 \text{ Pa}}$$

2931.12

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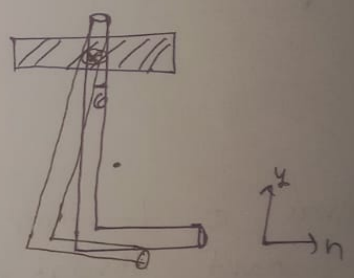
when fluid is not flow then tube is balance.

momentum about hing point is zero



center of mass of Rode (Combine body center of mass

$$\boxed{C.M. = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}} \qquad \boxed{m_1 = \frac{m_2}{2}}$$

(same material cut length is half)

$$c_x = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$$

$$c_x = \frac{\frac{m}{2}\frac{x_1}{2} + m(0)}{m + \frac{m}{2}}$$

$$c_x = \frac{x_1/2}{3/2} = \frac{x_1}{3 \cdot 2} = \frac{x_1}{6}$$

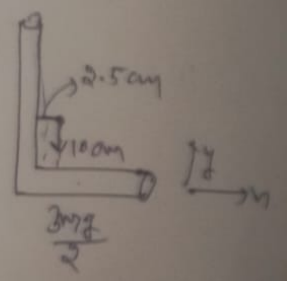
$$\boxed{c_x = \frac{15}{3 \cdot 2}}$$

$$\boxed{c_x = \frac{15}{6}\,cm} = 2.5\,cm$$

$$y = \frac{m_1 y_1 + m_2 y_2}{m_1 + m_2}$$

$$c_y = \frac{\frac{m}{2}(0) + m\left(\frac{y}{2}\right)}{\frac{3m}{2}} = \frac{y}{3}$$

$$\boxed{c_y = 10\,cm}$$



(Not Balance so it is rotate

momentum about (X) point is zero

$$mg\sin\theta \times c_y = mg\cos\theta\, x$$

$$\tan\theta = \frac{c_x}{c_y}$$

$$\theta = \tan^{-1}\left(\frac{c_x}{c_y}\right)$$

$$\theta = \tan^{-1}\left(\frac{2.5}{10}\right)$$

$$\boxed{\theta = 14^\circ}$$

when Stand is not flow then it is balance at θ = 14° from Vertical

calculation of force

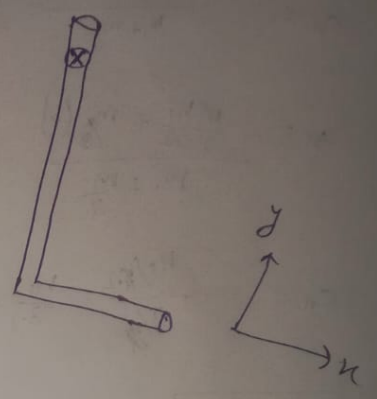
Force in x direction.

$$\boxed{\Sigma F_x = \frac{dP_x}{dt}}$$

$$\boxed{F_x = -P_2 A_2 + \rho Q V_2}$$

$$\boxed{F_x = m\omega^2 R}$$

$$\boxed{m\omega^2 l = P_2 A_2 + \rho Q V_2}$$



$v = \frac{Q}{A}$

$$\omega = \sqrt{\frac{P_2 A_2 + \rho Q V_2}{\rho Q l}}$$

$\rho \rightarrow$ density

$A_2 =$ area.

$Q \rightarrow$ flow rate

$l \rightarrow$ length in y direction

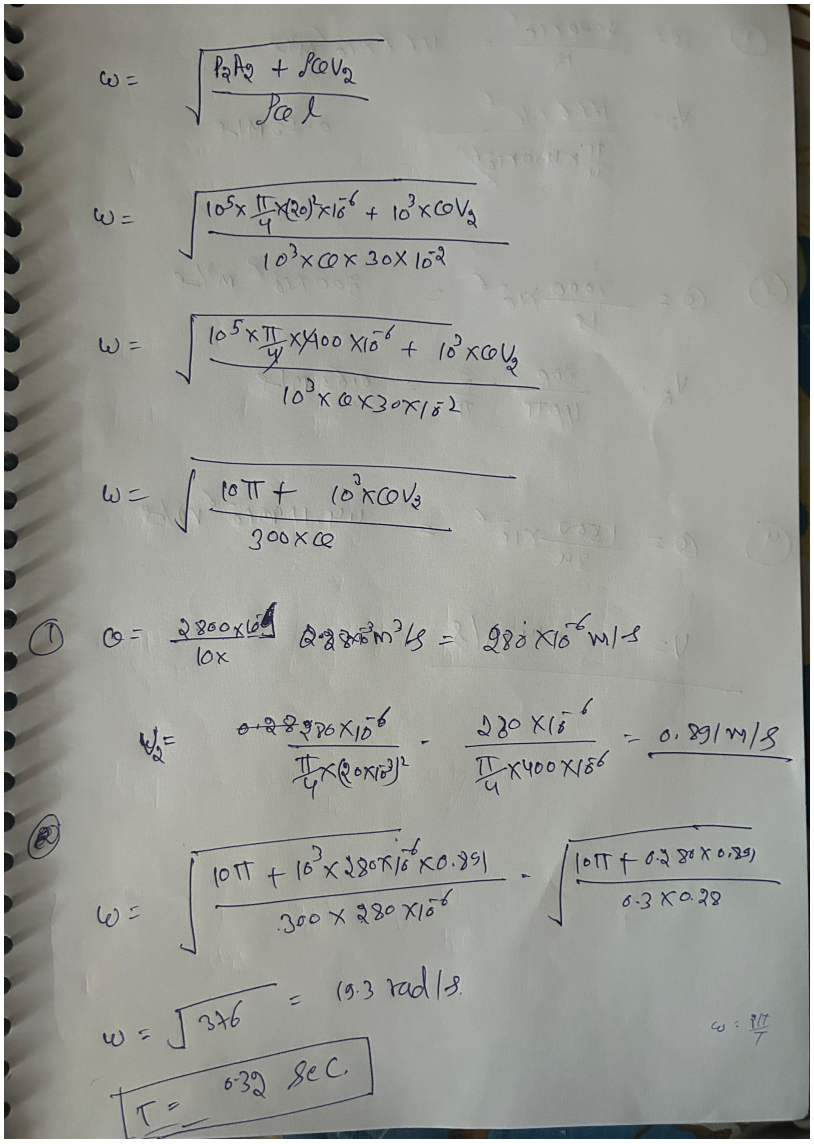
$$\boxed{l = 30 - 2 = 28 \text{ cm}}$$

$P_2 \rightarrow$ Pressure at point 2

(out let pressure)

y-direction force is balency by hing point

7 | Calculations and Analysis



$$\omega = \sqrt{\frac{P_2A_2 + \rho Q V_2}{\rho Q l}}$$

$$\omega = \sqrt{\frac{10^5 \times \frac{\pi}{4}(20)^2 \times 10^{-6} + 10^3 \times Q V_2}{10^3 \times Q \times 30 \times 10^{-2}}}$$

$$\omega = \sqrt{\frac{10^5 \times \frac{\pi}{4} \times 400 \times 10^{-6} + 10^3 \times Q V_2}{10^3 \times Q \times 30 \times 10^{-2}}}$$

$$\omega = \sqrt{\frac{10\pi + 10^3 \times Q V_2}{300 \times Q}}$$

(1) $Q = \frac{2800 \times 10^{-6}}{10 \times}$ $0.2800 m^3/s = 280 \times 10^{-6} m/s$

$$V_2 = \frac{280 \times 10^{-6}}{\frac{\pi}{4} \times (20 \times 10^{-3})^2} = \frac{280 \times 10^{-6}}{\frac{\pi}{4} \times 400 \times 10^{-6}} = 0.891 m/s$$

(2)

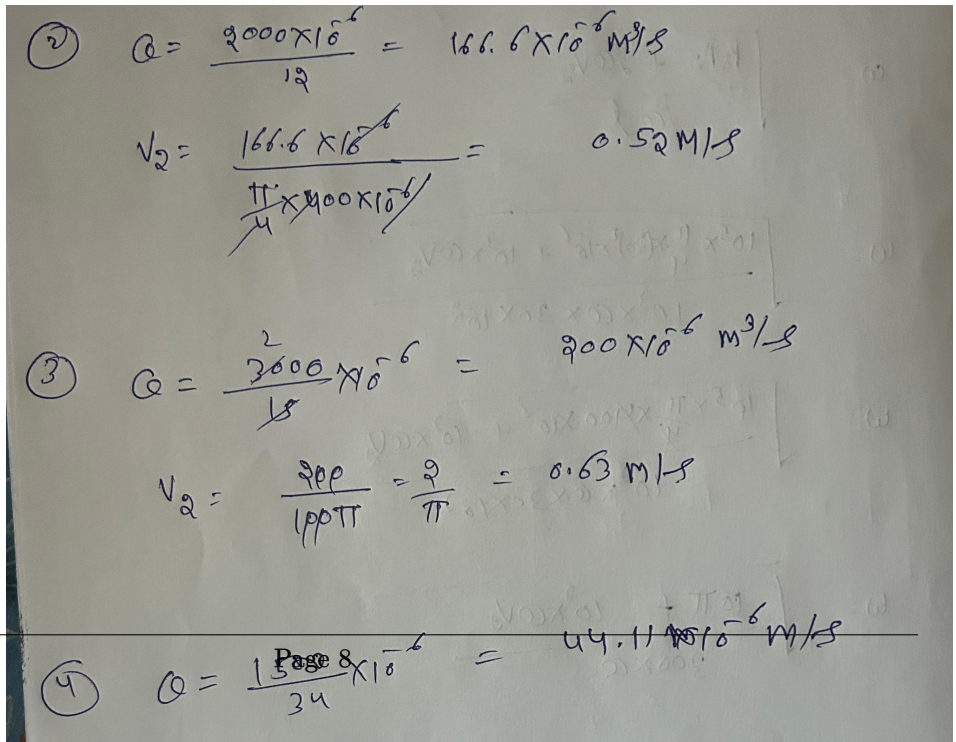
$$\omega = \sqrt{\frac{10\pi + 10^3 \times 280 \times 10^{-6} \times 0.891}{300 \times 280 \times 10^{-6}}} = \sqrt{\frac{10\pi + 0.280 \times 0.891}{0.3 \times 0.28}}$$

$$\omega = \sqrt{376} = 19.3 \text{ rad/s}$$

$\omega = \frac{2\pi}{T}$

$$\boxed{T = 0.32 \text{ sec.}}$$

(a) image a



(2) $Q = \frac{2000 \times 10^{-6}}{12} = 166.6 \times 10^{-6} m^3/s$

$$V_2 = \frac{166.6 \times 10^{-6}}{\frac{\pi}{4} \times 400 \times 10^{-6}} = 0.52 m/s$$

(3) $Q = \frac{2000}{18} \times 10^{-6} = 200 \times 10^{-6} m^3/s$

$$V_2 = \frac{200}{100\pi} = \frac{2}{\pi} = 0.63 m/s$$

(4) $Q = \frac{150}{34} \times 10^{-6} = 44.11 \times 10^{-6} m/s$

8 | Results

tThe results obtained from the experimental analysis.
Use table (Table 8.1)

Table 8.1: A table without vertical lines.

S.N.	FLow Rate(m3/s))	velocity(m/s)	anguler velocity(rad/s)
1	280*10−6	0.89	19.3
2	200*10−6	0.63	18.4
3	166*10−6	0.52	17.9
4	44*10−6	0.14	17.1

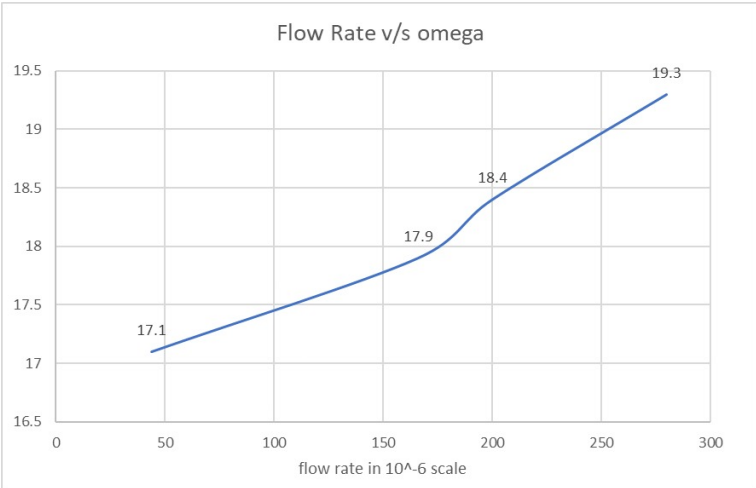


Figure 8.1: Single image at a random position

9 | Discussion

According to my experimental data and experimental setup, we observed that as we increase the flow rate, the velocity of the fluid also increases. This observation can be attributed to the constant diameter of the pipe in our setup. When the flow rate is increased, more fluid is pushed through the same cross-sectional area of the pipe per unit time. Therefore, in order to accommodate this increased flow rate, the fluid must move at a higher velocity. Additionally, the angular velocity may also increase, especially if the flow rate increase is due to an increase in the rotational speed of a L shape tube

10 | Innovative Ideas

1. We can use the same concept in windmill type of structure to generate electricity with the help of water.
2. Construct a system that harnesses energy from flowing water in pipes or channels using a flexible arm. The arm's rotation drives a hydraulic pump, which converts the mechanical energy into electrical energy for powering remote sensors or devices.
3. Design an irrigation system for agriculture that utilizes water flow to rotate flexible arms, distributing water evenly across fields. By controlling the flow rate, farmers can adjust the rotation speed of the arms to optimize water usage and crop yield.