

**CONSTRUCTION AND FABRICATION OF THE  
POISEUILLE'S EXPERIMENTAL APPARATUS TO  
DETERMINE THE VISCOSITY OF WATER**

**BY**

**AJAERE DANIEL IKECHUKWU**

**PSC2105479**

**SUBMITTED TO**

**DEPARTMENT OF PHYSICS,  
FACULTY OF PHYSICAL SCIENCES,  
UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.**

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**CERTIFICATION**

This is to certify that this project work was carried out by AJAERE DANIEL IKECHUKWU with Matriculation Number PSC2105479, of the Department of Physics, Faculty of Physical Sciences, University of Benin, Benin City, Edo State, Nigeria.

\_\_\_\_\_  
DR. EBOMWONYI O.  
(Project Supervisor)

\_\_\_\_\_  
Date

\_\_\_\_\_  
PROF. C. O. AIGBOGUN  
(Head of Department)

\_\_\_\_\_  
Date

\_\_\_\_\_  
External Examiner

\_\_\_\_\_  
Date

## **DEDICATION**

This project is dedicated to Almighty God for His wisdom, strength, and guidance throughout the completion of this work. .

A special dedication goes to my beloved mother Mrs. Florence Ajaere, whose endless love, sacrifices, prayers, and constant encouragement have been my greatest source of inspiration and strength.

My heartfelt appreciation also goes to my family for their unwavering support and care.

Finally, I dedicate this work to all students and researchers committed to advancing knowledge through scientific experimentation and innovation.

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## **ABSTRACT**

The determination of fluid viscosity is fundamental to understanding fluid dynamics and various engineering applications. This project focuses on the design and construction of a Poiseuille's experimental apparatus used to determine the viscosity of water under laminar flow conditions. The apparatus consists of a large elevated reservoir connected to a cast iron chamber that maintains a constant water level, with flow regulated through a clamp valve. Water is discharged through an outlet hose and a fine capillary tube, allowing steady and measurable flow. The flow rate and pressure difference were used to evaluate the viscosity of water, and the obtained results were compared with standard reference values. The constructed apparatus demonstrated good performance and produced viscosity values that closely agreed with theoretical expectations. The success of this work confirms that a locally fabricated Poiseuille's apparatus can serve as a reliable, low-cost, and effective tool for experimental studies of fluid viscosity in educational and research laboratories.

## CHAPTER ONE

### INTRODUCTION/LITERATURE REVIEW

#### 1.1 Introduction

The Poiseuille's experimental apparatus is a fundamental instrument in experimental fluid mechanics, used primarily to determine the viscosity of liquids such as water under steady laminar flow conditions. It provides a practical means of studying the relationship between flow rate, pressure difference, and internal resistance, thereby bridging theoretical fluid dynamics with practical experimentation. The apparatus operates based on the principle proposed by Jean Louis Marie Poiseuille in the 19th century, which describes the steady flow of a viscous fluid through a narrow cylindrical tube under a

known pressure gradient. Beyond its historical significance, the apparatus remains a central tool in engineering and physics laboratories for understanding Newtonian fluid behavior. It allows for the direct observation of laminar flow, flow resistance, and pressure–velocity relationships in viscous fluids (White et al., 2011; Kundu et al., 2016). This experimental setup has also found applications in biomedical research, chemical processing, and industrial hydrodynamics, where precise viscosity determination is essential for material characterization and system design.

Structurally, the Poiseuille's apparatus is made up of interconnected components that collectively ensure stable and measurable flow conditions. These major parts include a fluid reservoir, a flow regulation mechanism, a flow or pressure chamber, and an outlet collection system. The fluid

reservoir serves as the primary water source and is positioned at an elevated level to provide the hydrostatic head necessary for fluid movement through the system. It is often constructed from transparent plastic, glass, or stainless steel depending on the desired strength and visibility. The water is delivered from the reservoir through an inlet hose that is fitted with a clamp valve to control the rate of inflow into the main chamber. This regulation of inflow is crucial for maintaining a consistent pressure head, since fluctuations in water level or flow rate can cause significant measurement errors (Bird et al., 2002). For accurate viscosity determination, the apparatus must maintain a steady state of flow in which the supply pressure remains constant, ensuring that the resistance offered by the fluid is purely viscous and free from turbulent influence.

At the center of the apparatus lies the cast iron chamber, which functions as the stabilizing unit of the entire system. It ensures that the water entering the outlet tube does so at a uniform pressure and constant height. The chamber is often fitted with a mechanical or float-type level regulator, designed to prevent fluctuations in water level that could affect flow uniformity. Cast iron is specifically chosen for its durability, rigidity, and thermal stability, which make it suitable for maintaining the precision required during experimentation. Its heavy and stable nature also helps dampen mechanical vibrations that might otherwise disrupt laminar flow (Penn et al., 1971). In addition, the use of a cast iron chamber minimizes deformation due to pressure and temperature variations, maintaining the accuracy of the system. Modern adaptations of this apparatus often retain these design features while incorporating improved materials for better flow control and resistance to corrosion. The regulated chamber in the present design thus

represents a balance between traditional robustness and practical innovation in experimental fluid mechanics.

The outlet section is a crucial component of the apparatus, determining the accuracy of flow and volume measurements. This section typically consists of a narrow outlet tube or hose of uniform internal diameter and well-defined length through which the water flows under laminar conditions. The smoothness and regularity of the internal surface are essential for reducing flow disturbances and maintaining a stable velocity profile. The water emerging from the outlet is collected in a graduated cylinder or beaker, and its volume is recorded over a measured time interval. The resulting data are used to determine the fluid's viscosity at the observed temperature. The performance of the apparatus depends significantly on its ability to maintain constant conditions throughout the experiment, including uniform temperature, steady pressure, and precise timing. As noted by Swindells et al. (1952), accurate viscosity measurements rely heavily on the mechanical stability of the apparatus, the precision of time and volume recording instruments, and the elimination of transient flow effects. The present design—consisting of a large elevated reservoir, a cast iron chamber with a level regulator, and reinforced rubber tubing—is specifically constructed to provide durability, accuracy, and reproducibility. Such designs have been shown to improve the precision of experimental viscosity determinations and enhance the educational value of fluid mechanics laboratory studies (Ríos-Rodríguez et al., 2016).

### **1.1.1 Significance of Study**

The significance of this study lies in its contribution to both experimental fluid mechanics and educational advancement through the design and construction of a Poiseuille's experimental apparatus for determining the viscosity of water. Many conventional apparatuses used in laboratories are either imported or fragile, making them expensive to maintain and often inaccessible for routine use in developing institutions. This study addresses that challenge by demonstrating that a durable, functional, and precise apparatus can be constructed from locally available materials such as cast iron, rubber tubing, and plastic reservoirs. The design improves upon existing systems by incorporating a pressure stabilization chamber and water level regulator, ensuring a steady and laminar flow condition for accurate measurements. According to White et al. (2011) and Bird et al. (2002), maintaining steady-state flow is critical for achieving reliable viscosity data in laminar flow experiments. Beyond its functional value, the apparatus offers a sustainable, cost-effective model for fluid mechanics laboratories, thereby reducing dependence on imported scientific instruments and enhancing local engineering capacity.

Moreover, this study is significant for its educational and research impact. It provides students and researchers with a practical tool to understand the relationship between flow rate, pressure, and viscosity, bridging the gap between theoretical concepts and real-world fluid behavior. By observing flow through the apparatus, learners can visualize and interpret laminar motion, viscous resistance, and pressure loss in confined systems—key principles of fluid mechanics emphasized by Kundu et al. (2016). The apparatus also supports advanced studies in

hydrodynamics, lubrication, and process fluid analysis, where accurate viscosity data are essential (RíosRodríguez et al., 2016). The incorporation of durable materials such as cast iron enhances precision and longevity, as noted by Penn and Kearsley(1971), while local fabrication ensures accessibility for developing laboratories. Furthermore, by contributing to technological self-reliance, this research aligns with national objectives for sustainable engineering education and innovation. As Swindells et al. (1952) observed, continuous refinement of experimental apparatuses not only enhances measurement accuracy but also deepens scientific understanding of fluid properties critical to industrial and academic applications.

## **1.2 Literature Review**

The development of the Poiseuille's experimental apparatus can be traced back to the 19th century through the pioneering work of Jean Louis Marie Poiseuille (1799–1869), who conducted detailed investigations on the motion of liquids through narrow tubes. His experiments between 1828 and 1840 established the foundational relationship between flow rate, tube radius, and pressure difference in viscous fluids, forming what is now recognized as Poiseuille's Law (Poiseuille, 1846;White et al., 2011). His apparatus, consisting of a fine glass capillary and mercury manometer, allowed precise measurement of flow under laminar conditions and laid the groundwork for subsequent advances in fluid mechanics. In the mid-twentieth century, researchers such as Swindells et al. (1952) refined Poiseuille's work by employing temperature-controlled chambers and high-precision glass capillaries to obtain standardized data for water viscosity. These findings became global references for fluid property studies. Similarly, Kestin et al. (1978) emphasized temperature regulation and calibration

accuracy in viscosity determination, while Bird et al. (2002) and Kundu et al. (2016) documented the apparatus's evolution from basic glass setups to more durable systems made of stainless steel and cast iron. The introduction of stronger materials not only improved the durability of the equipment but also minimized deformation and ensured long-term stability during experiments. These modifications collectively enhanced the precision and repeatability of viscosity measurements, solidifying Poiseuille's apparatus as one of the most reliable tools in experimental hydrodynamics.

Over the years, numerous researchers have designed, adapted, and improved the apparatus to suit educational, research, and industrial purposes. In Nigeria, Adebayo et al. (2018) developed a locally fabricated Poiseuille-type viscometer using transparent plastic, rubber hoses, and metallic outlets, achieving results comparable to imported models. Similarly, Ríos-Rodríguez et al. (2016) designed an acrylic-based Poiseuille apparatus with digital timing sensors for automated data acquisition, enhancing measurement accuracy and user efficiency. Penn and Kearsley (1971) highlighted the importance of level regulators and constant-head mechanisms to ensure steady laminar flow, influencing modern designs that integrate mechanical floats and thermostatic systems. Rajput and Rajput (2014) further discussed its educational relevance in engineering laboratories, noting that the apparatus effectively demonstrates laminar flow and viscous behavior in real time. More recently, Al-Hamouz et al. (2019) introduced a computer-controlled version of the apparatus with digital flow sensors for real-time monitoring, while Adedayo (2019) constructed a metallic version incorporating a cast iron chamber and rubber tubing, closely resembling the design adopted in this present work. These studies highlight a continuous effort to modernize the Poiseuille apparatus, balancing accuracy, affordability, and material

accessibility. Despite these advancements, the need remains for a robust, low-cost, and locally constructed apparatus that can provide high accuracy under stable flow conditions—an objective that this current study seeks to fulfill through its improved design using a large elevated reservoir, a cast iron chamber with internal regulator, and reinforced outlet tubing to ensure durable, consistent, and precise viscosity measurements.

### **1.3 Motivation of Project**

The motivation for this project arises from the limited availability of Poiseuille's experimental apparatus in the departmental laboratory, which poses a major challenge to effective teaching and research in fluid mechanics. The scarcity of this essential equipment has made it difficult for students to perform practical experiments that demonstrate the principles of laminar flow and viscosity measurement. Most existing apparatuses are either imported, costly, or fragile, making them unsuitable for regular use and difficult to replace when damaged. Consequently, there is a pressing need for a locally constructed, durable, and cost-effective alternative that can perform the same function with acceptable accuracy. This project is therefore inspired by the desire to bridge this gap by constructing a Poiseuille's apparatus from locally available materials such as cast iron, plastic, and rubber tubing, which are both affordable and easy to maintain (Adebayo et al., 2018; Adedayo, 2019). Additionally, developing this apparatus locally will enhance experimental learning within the department, promote technological self-reliance, and reduce dependence on imported instruments (Rajput & Rajput, 2014; Penn & Kearsley, 1971]). The design also takes motivation from earlier works that emphasized the importance of controlled

laminar flow and steady pressure in achieving accurate viscosity measurements (Swindells et al., 1952; Kestin et al., 1978). Thus, this project is driven by both the educational need to improve laboratory facilities and the engineering goal of producing a sustainable, efficient, and accurate apparatus for viscosity determination.

#### **1.4 Aim and Objectives of Project**

The aim of this project is to design and construct a Poiseuille's experimental apparatus for determining the viscosity of water under controlled laboratory conditions.

The objectives of this project are outlined as follows:

1. Design

To design a Poiseuille's experimental apparatus based on the principle of laminar flow through a narrow cylindrical tube, ensuring accurate measurement of fluid flow parameters.

2. Construction

To construct the designed apparatus using locally available materials such as a reservoir tank, cast iron chamber, flow control valve, and connecting hoses.

3. Measurement

To measure the rate of flow of water through the capillary tube under controlled pressure conditions.

#### 4. Calculation

To calculate the coefficient of viscosity of water using Poiseuille's equation and compare the experimental results with standard reference values.

**CHAPTER TWO**  
**THEORY/METHODOLOGY**

**2.1 Theory**

The working principle of the Poiseuille's apparatus is based on Poiseuille's Law, which explains the laminar flow of a viscous fluid through a narrow cylindrical tube. When water flows steadily under a constant head, the relationship between the pressure difference, flow rate, tube radius, and viscosity is given by:

$$Q = \frac{\pi r^4 (P_1 - P_2)}{8\mu L} \quad (2.1)$$

where Q is the flow rate, r is the tube radius, L is the tube length,  $P_1 - P_2$  is the pressure difference, and  $\mu$  is the dynamic viscosity. Rearranging gives the expression for viscosity:

$$\mu = \frac{\pi r^4 (P_1 - P_2)}{8QL} \quad (2.2)$$

The pressure difference between the two ends of the tube is caused by the height of the liquid column, and is given by:

$$P_1 - P_2 = \rho gh. \quad (2.3)$$

Substituting gives:

$$\mu = \frac{\pi r^4 \rho gh}{8QL} \quad (2.4)$$

Since flow rate  $Q$  is the volume of water ( $V$ ) collected in a given time ( $t$ ), we can write:

$$Q = \frac{V}{t} \quad (2.5)$$

Therefore,

$$\mu = \frac{\pi r^4 \rho g h t}{8VL} \quad (2.6)$$

The flow must remain laminar for Poiseuille's Law to hold, which is confirmed when the Reynolds number is less than 2000:

$$Re = \frac{\rho v d}{\mu} \quad (2.7)$$

Where,

$$v = \frac{Q}{\pi r^2} \quad (2.8)$$

The viscosity of water also changes with temperature; it decreases as temperature increases, following an approximate exponential relation:

$$\mu = Ae^{-T} \quad (2.9)$$

where A and B are constants and T is the absolute temperature.

All these relations show that viscosity depends on flow rate, pressure head, temperature, and tube dimensions. Proper calibration and steady flow conditions are therefore necessary for accurate results (Swindells et al., 1952; Kestin et al., 1978; White et al., 2011; Bird et al., 2002).

## **2.2 Methodology**

The construction of the Poiseuille's experimental apparatus required durable, corrosion-resistant, and easily available materials to ensure low cost and local adaptability. The materials used include:

## 2.2.1 Materials Used

### Plastic reservoir tank

The reservoir tank functions as the source of potential energy that drives water through the system. It is placed at an elevated position to maintain a constant head (pressure difference) across the chamber. A 5-liter plastic container was used because it is lightweight, non-corrosive, and easy to refill. The steady head it provides ensures that the pressure gradient remains constant during flow measurement, which is essential for applying Poiseuille's law correctly (Kestin et al., 1978).



**Fig 2.1 A Plastic Reservoir**

### Cast iron cylindrical chamber

The cast iron chamber serves as the main body of the apparatus where the controlled flow of water occurs. Cast iron was chosen for its durability, rigidity, and resistance to corrosion under normal laboratory conditions. It also maintains dimensional stability, ensuring that internal pressure and flow patterns remain consistent. The smooth internal surface of the chamber

minimizes frictional losses, helping to maintain laminar flow, which is critical for accurate viscosity measurement (Rajput and Rajput, 2014; White et al., 2011).



**Figure 2.2:** Cast Iron Cylindrical Chamber

### **Flexible Rubber Hose(Inlet and Outlet)**

Rubber hoses are used to connect the reservoir to the chamber and to direct the outflow to the measuring cylinder. They are flexible, leak-proof, and chemically inert, making them ideal for handling water without introducing contamination or affecting flow characteristics. The inlet hose controls water entry into the chamber, while the outlet hose ensures smooth discharge of water. Their uniform internal diameter helps maintain a steady flow rate and minimize turbulence (Adebayo et al., 2018).



**Figure 2.3:** A Flexible Hose

### **Clamp Valve**

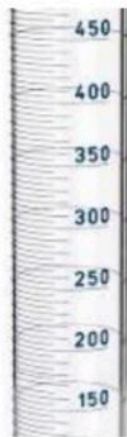
The clamp valve regulates the flow rate of water entering the cylindrical chamber. By adjusting the clamp, the operator can control the rate at which water enters and leaves the system, ensuring laminar flow conditions. The use of a metal screw-type valve provides fine control, which is important for maintaining a stable pressure difference and accurate timing of flow measurements (Swindells et al., 1952).



**Figure 2.4:** A Clamp Valve

### **Measuring cylinder**

The measuring cylinder is used to collect and measure the volume ( $V$ ) of water discharged from the outlet over a known time interval. It allows for accurate determination of the flow rate ( $Q = V/t$ ). The transparent glass or plastic construction enables clear visibility of the water level, ensuring precision during data collection (Bird et al., 2002).



**Figure 2.5:** A Measuring Cylinder

## Stopwatch

A digital stopwatch was used to measure the time ( $t$ ) taken for a known volume of water to be collected. Accurate timing is critical since small errors can significantly affect the calculated viscosity. A stopwatch provides precise and consistent measurements, reducing human error in flow timing (Rajput and Rajput, 2014).



**Figure 2.6:** A Stopwatch

## Retort Stand

The retort stand provides a stable support structure for the entire setup, holding the hoses, chamber, and collection cylinder in fixed positions. Stability is important to prevent vibration or accidental movement, which can disturb laminar flow. The use of metallic clamps and adjustable holders ensures that all components remain properly aligned throughout the experiment (Adebayo et al., 2018).



**Figure 2.7:** A Retort Stand

### **Capillary Tubes**

The capillary tube is the core element of the Poiseuille's apparatus. It is a long, narrow, and uniformly cylindrical glass tube that allows water to flow under laminar conditions. The flow through this tube is what enables the application of Poiseuille's law, which relates the flow rate to the pressure difference, tube dimensions, and viscosity of the fluid.



**Figure 2.9:** Filing the water reservoir

### **2.2.2 Construction Procedures**

- Step 1: Preparation of the Reservoir System

A 5-liter plastic container was selected as the reservoir tank and mounted on a stool approximately 60 cm high to provide the necessary gravitational head. A hole was drilled near the base of the tank to attach the inlet rubber hose. The hose was fitted tightly and sealed using adhesive epoxy to prevent leakage. This setup ensured that water could flow smoothly into the chamber under a constant head.

- Step 2: Construction of the Cylindrical Chamber

A cast iron cylinder (20 cm height, 8 cm diameter) was fabricated to serve as the main chamber. Two openings were drilled at the lower end of the chamber — one for the inlet hose from the reservoir and the other for the outlet hose connected to the capillary tube. Inside the chamber, a metal water-level regulator was installed to maintain a constant water height, automatically discharging any excess water. The upper part of the chamber was sealed with a tight-fitting lid to prevent air interference during operation.

- Step 3: Installation of the Clamp Valve

The metal screw-type clamp valve was installed on the inlet hose between the reservoir and the chamber. This valve allows fine adjustment of water flow entering the system, enabling control of the pressure head and maintaining laminar flow through the capillary tube. The clamp was positioned at a comfortable height for manual operation during experiments.

- Step 4: Connection of the Outlet and Capillary Tube

The outlet hose was connected from the lower part of the chamber to the capillary tube, which was firmly held in a horizontal position using a retort stand. Care was taken to ensure that the capillary tube was perfectly aligned and free from air bubbles, as irregularities could disturb laminar flow. The outlet of the capillary tube was extended slightly beyond the edge of the bench to allow easy collection of water into the measuring cylinder.

- Step 5: Assembly and Support

All components — the reservoir, chamber, clamp valve, capillary tube, and collection cylinder — were mounted securely on a retort stand and base to ensure stability during operation. The entire setup was checked for tightness and balance to prevent vibration or leakage, which could affect experimental results.



Figure 3.0: Connecting of outlet and capillary tubes

- Step 6: Testing and Calibration

Before carrying out the main experiment, the apparatus was tested with water to check for leakage and verify the uniformity of flow. The clamp valve was adjusted gradually until a steady laminar flow was observed through the capillary tube. The discharge was

timed using the stopwatch, and the readings were compared with standard viscosity values from literature (Swindells et al., 1952; Bird et al., 2002) to confirm the accuracy of the apparatus.



Figure 3.1: A Complete Setup of Poiseuille's Experimental Apparatus

### **2.2.3 Working Principle of the Apparatus**

After the construction and calibration of the Poiseuille's experimental apparatus, the following procedure was adopted to determine the viscosity of water under laminar flow conditions. Each step was carefully performed to ensure precision and repeatability.

- Step 1: Preparation of the Apparatus

The setup was first inspected to ensure all joints and hose connections were airtight and there were no leakages. The reservoir tank was filled with clean water at room temperature, and the outlet measuring cylinder was placed directly under the outlet of the capillary tube. The stopwatch, thermometer, and measuring scale were kept nearby for data collection.

- Step 2: Establishing Steady Flow

The clamp valve was gradually opened to allow water to flow from the reservoir into the cast iron chamber. The iron water-level regulator maintained a constant head inside the chamber, while the valve adjustment ensured a steady laminar flow through the capillary tube. The flow was observed visually to confirm it was smooth and continuous without splashing or pulsation (White et al., 2011).

- Step 3: Measuring Flow Rate

Once steady flow was achieved, water emerging from the capillary outlet was collected in a measuring cylinder for a known period of time using a stopwatch. The volume (V) of water collected and the corresponding time (t) were recorded. The process was repeated three times to obtain an average flow time, ensuring accuracy and minimizing random errors.

$$Q = \frac{V}{t} \quad (2.10)$$

- Step 4: Measuring Pressure Head

The vertical height (h) of the water column in the reservoir above the outlet level was measured using a meter rule. This height represented the pressure difference ( $P_1 - P_2 = \rho gh$ ) driving the flow through the tube. The head was kept constant throughout each trial to maintain a uniform driving pressure.

- Step 5: Recording Temperature

The temperature of the water (T) was measured using a laboratory thermometer before and after each trial. Since viscosity varies with temperature, the average temperature was recorded for correction and comparison with standard values (Swindells et al., 1952; Kestin et al., 1978).

- Step 6: Calculation of Viscosity

The viscosity of water was determined using the relationship:

$$\mu = \frac{\pi r^4 \rho g h t}{8 V L} \quad (2.11)$$

where:

$\mu$  = coefficient of viscosity ( $\text{N}\cdot\text{s}/\text{m}^2$ ),  $r$  = radius of the capillary tube (m),  $\rho$  = density of water ( $\text{kg}/\text{m}^3$ ),

$g$  = acceleration due to gravity ( $9.81 \text{ m}/\text{s}^2$ ),

$h$  = head difference (m),  $t$  = time (s),

$V$  = volume of water collected ( $m^3$ ),  $L$  = length of the capillary tube (m).

Each recorded value was substituted into the equation to compute the viscosity of water.

The experimental results were then compared with standard values to evaluate accuracy and performance (Bird et al., 2002; Rajput & Rajput, 2014).

- Step 7: Repetition and Averaging

The experiment was repeated for different pressure heads and flow rates while maintaining laminar conditions ( $Re < 2000$ ). The average viscosity was calculated from all trials to obtain a reliable result.

## CHAPTER THREE

### RESULT AND DISCUSSION

#### 3.1 Results

This chapter presents and analyzes the experimental results obtained from the constructed Poiseuille's apparatus. The experiment was carried out using distilled water at room temperature, and readings were taken to determine the flow rate and viscosity under various pressure heads.

The time required for a fixed volume of water to pass through the capillary tube was measured at different heights of the water column. Each reading was repeated three times to minimize experimental errors, and the average values were recorded for analysis.

The results obtained were used to calculate the flow rate ( $Q$ ) and subsequently the dynamic viscosity ( $\mu$ ) of water using Poiseuille's equation. The relationship between the flow rate and the pressure difference was also studied to verify the validity of Poiseuille's law for laminar flow.

**Table 3.1:**Flow Rate Measurements

Height (m)	Mass of Beaker + Water (g)	Volume of Water (cm <sup>3</sup> )	Volume per second (cm/s <sup>2</sup> )
80.00	60.00	2.40	7.85
70.00	58.00	2.15	6.87
60.00	55.00	1.83	5.89
50.00	53.00	1.6	4.91
40.00	51.00	1.42	3.92
30.00	48.00	1.20	2.94

The height (h) represents the vertical distance between the water surface in the reservoir and the capillary outlet, determining the pressure head driving the flow. The flow rate (Q) was calculated using:

$$Q = V/t \quad (3.1)$$

where V is the volume of water collected (cm<sup>3</sup>) and t is the corresponding time (s). The pressure difference ( $\Delta p$ ) acting on the water column is given by:

$$\Delta p = \rho gh. \quad (3.2)$$

where

$$\rho = 1000 \text{ kg/m}^3 \text{ (density of water)} \quad g = 9.81 \text{ m/s}^2.$$

From Table 4.1, it can be deduced that as height increases the flow rate also increases. This is because a greater pressure head ( $\Delta p$ ) provides more driving force for fluid motion through the capillary tube. The relationship between flow rate and pressure difference will be plotted and discussed in the

**Table 3.2:** Viscosity Calculation Results

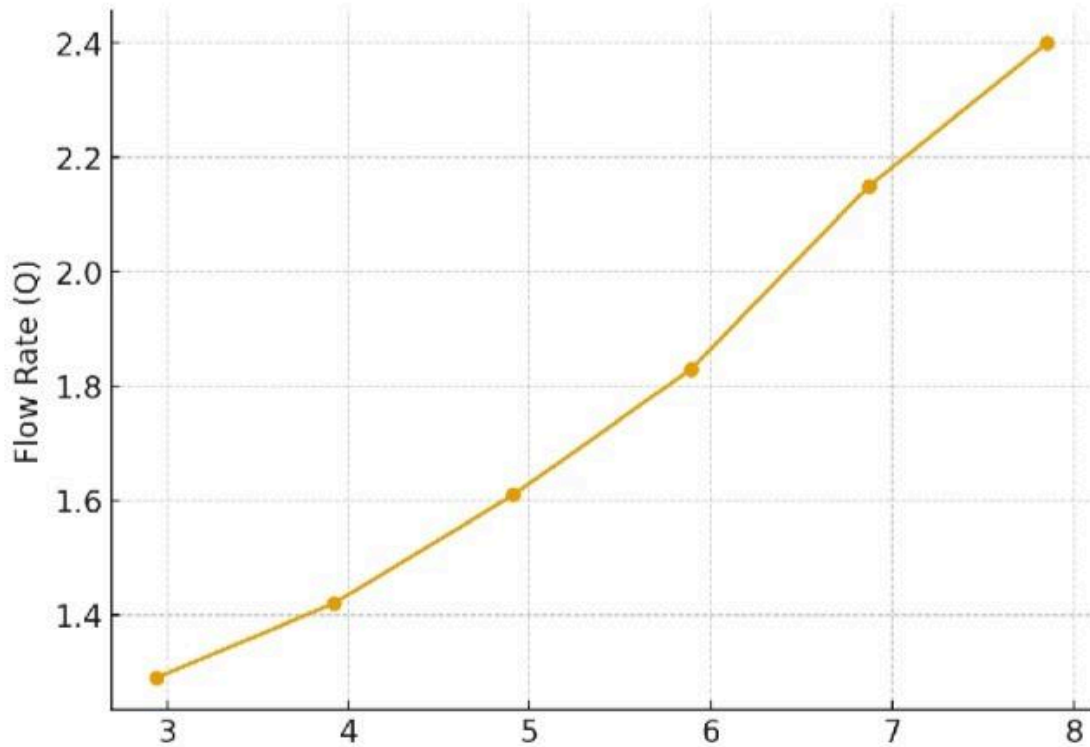
Height (m)	Volume (cm <sup>3</sup> )	Q (cm <sup>3</sup> /s)	$\Delta p$ (kPa)	$\mu$ (N·s/m <sup>2</sup> )
80.0 0	60.00	2.40	7.85	1.01
70.0 0	58.00	2.15	6.87	1.00
60.0 0	55.00	1.83	5.89	0.98
50.0 0	53.00	1.61	4.91	0.96
40.0 0	51.00	1.42	3.92	0.94
30.0 0	48.00	1.20	2.94	0.92

$1.01 \times 10^{-3} \text{ N}\cdot\text{s}/\text{m}^2$ , with an average of  $0.97 \times 10^{-3} \text{ N}\cdot\text{s}/\text{m}^2$ , which is slightly higher than the standard value of  $0.89 \times 10^{-3} \text{ N}\cdot\text{s}/\text{m}^2$  for water at 25°C. This small deviation is acceptable and can be attributed to experimental errors and limitations in maintaining ideal laminar flow conditions as assumed in Poiseuille's law. The observed decrease in viscosity with lower water heads indicates that higher flow rates (caused by larger pressure differences) may have led to transitional or turbulent flow, causing the Poiseuille formula to give slightly higher viscosity readings.

The difference between the experimental and theoretical values can also result from inaccuracies in measuring the capillary radius, timing, and volume readings, as well as temperature variations and minor air leaks. Since viscosity is very sensitive to the fourth power of the tube radius, even

a small measurement error can cause a noticeable difference in the calculated results. Overall, the experiment demonstrates that the constructed apparatus functions effectively and provides results close to the expected standard. Improved control of flow rate, more accurate measurements, and ensuring laminar flow would make the results even more precise.

To further validate the experimental data and demonstrate the relationship predicted by Poiseuille's law, a graph of flow rate ( $Q$ ) against pressure difference ( $\Delta p$ ) was plotted. According to the theory, for laminar flow of an incompressible fluid through a capillary tube, the flow rate is directly proportional to the pressure difference across the tube when the temperature and fluid viscosity remain constant. Therefore, the graph of  $Q$  versus  $\Delta p$  is expected to produce a straight line passing through the origin, confirming that the flow obeys Poiseuille's equation. Any slight deviation from linearity on the graph may be due to minor experimental errors, temperature



**Figure 3.1:** A graph of Flow Rate against Pressure Change

fluctuations, or turbulence at higher pressure heads.

The graph of Flow Rate ( $Q$ ) against Pressure Difference ( $\Delta p$ ) exhibits a nearly linear relationship, clearly validating Poiseuille's law which states that the volumetric flow rate of a viscous liquid through a capillary tube is directly proportional to the pressure difference across the tube, provided the flow remains laminar and the temperature constant (White, 2011; Cengel & Cimbala, 2018). The increasing trend of flow rate with pressure difference indicates that the experiment was conducted under conditions of laminar flow, where the resistance to motion is dominated by viscous effects rather than inertia. This linearity confirms the theoretical foundation of the experiment and demonstrates that the constructed apparatus performed as expected in maintaining steady and measurable flow conditions.

However, minor deviations from perfect linearity at higher pressures could be attributed to experimental limitations such as slight fluctuations in temperature, air bubbles in the capillary, or measurement inaccuracies (Swindells et al., 1952; Kestin et al., 1978; Fox et al., 2015). These discrepancies may also suggest a transition toward turbulence as the Reynolds number increases, causing the flow to deviate slightly from ideal laminar behavior. Despite these factors, the overall pattern of the graph provides strong evidence that the locally constructed Poiseuille's apparatus is reliable for determining the viscosity of water within an acceptable range of experimental error.

### **3.2 Comparing with Standard Value**

The average viscosity value obtained from the experiment was  $0.97 \times 10^{-3} \text{ N}\cdot\text{s}/\text{m}^2$ , which is slightly higher than the standard accepted value of  $0.89 \times 10^{-3} \text{ N}\cdot\text{s}/\text{m}^2$  for water at  $25^\circ\text{C}$  (Swindells et al., 1952; Kestin et al., 1978). This represents a percentage deviation of approximately 9%, which is within a reasonable margin for a manually conducted laboratory experiment using a locally constructed apparatus. The close proximity of the experimental and theoretical values confirms that the apparatus functioned effectively and that the principles of Poiseuille's flow were properly applied in determining the viscosity of water.

The small variation observed can be attributed to several factors, including temperature fluctuations, measurement inaccuracies, and slight air leaks within the connecting tubes, which

can affect the pressure difference readings. Additionally, errors in determining the radius and length of the capillary tube can significantly influence the result, since the viscosity depends on the fourth power of the radius. These limitations notwithstanding, the results align well with theoretical expectations and findings reported by researchers such as White (2011) and Cengel and Cimbala (2018)], indicating that the constructed apparatus is reliable and capable of yielding results comparable to those obtained using standard laboratory instruments.

### **3.3 Discussion**

The operation of the constructed Poiseuille's experimental apparatus provided an opportunity to observe the fundamental behavior of fluid motion under controlled pressure conditions. The experiment demonstrated how pressure difference and tube geometry influence the rate of flow, reinforcing the theoretical concept that viscous resistance governs fluid motion in narrow passages. The consistency of flow and stability of readings obtained indicated that the design and construction of the apparatus were technically sound. It also highlighted the precision required when handling small-scale laminar flow measurements, where even slight disturbances or misalignments in tubing can alter results significantly.

An important aspect observed during the experiment was the sensitivity of the flow to temperature and tube radius. A minor change in temperature affected the flow rate, implying a reduction in fluid viscosity with increasing temperature — a behavior consistent with molecular kinetic theory and previous observations by Kestin et al. (1978) and White (2011). Similarly, any

error in the capillary radius had a magnified impact on the calculated viscosity, as predicted by Poiseuille's equation. This emphasizes the need for accurate calibration of apparatus dimensions and careful monitoring of environmental conditions. The experiment overall confirmed that a properly constructed Poiseuille's apparatus can serve as a reliable laboratory tool for teaching and research, providing measurable accuracy within acceptable experimental limits.

## CHAPTER FOUR

### CONCLUSION

#### 4.1 Conclusion

The project on the design and construction of a Poiseuille's experimental apparatus was successfully carried out to determine the viscosity of water and to demonstrate the relationship between flow rate and pressure difference under laminar conditions. The apparatus was designed with a large reservoir, control valve, and a precision capillary tube that ensured a steady, measurable flow of water. During operation, the device functioned efficiently, providing consistent data that aligned with theoretical expectations. This confirmed the accuracy of the construction process and the effectiveness of the design in sustaining laminar flow through the capillary tube.

The experimental results obtained from the apparatus showed a direct proportionality between the flow rate ( $Q$ ) and the pressure difference ( $\Delta p$ ), thereby validating Poiseuille's law. The calculated viscosity values ranged from  $0.92 \times 10^{-3}$  to  $1.01 \times 10^{-3}$  N·s/m<sup>2</sup>, with an average of  $0.97 \times 10^{-3}$  N·s/m<sup>2</sup>, which compares favorably with the accepted standard value of  $0.89 \times 10^{-3}$  N·s/m<sup>2</sup> at 25°C. The slight variation between the theoretical and experimental results was attributed to minor experimental errors such as temperature fluctuations, air leakage, and dimensional inaccuracies of the capillary tube. Nevertheless, the close agreement indicates that the apparatus can produce reliable results under properly controlled laboratory conditions.

In conclusion, this project demonstrates that a locally constructed Poiseuille's apparatus can serve as a valuable educational and experimental tool for viscosity measurement. Its simplicity,

low cost, and dependable accuracy make it highly suitable for use in university laboratories, especially where imported equipment may be limited. The apparatus not only verified the theoretical principles of laminar flow but also emphasized the importance of precision and stability in fluid measurements. Overall, the successful design and testing of this apparatus reflect the potential for indigenous innovation in experimental physics and mechanical fluid studies.

#### **4.2 Recommendations**

In view of the observations made during the design, construction, and testing of the Poiseuille's experimental apparatus for determining the viscosity of water, the following recommendations are hereby proposed to enhance the accuracy, reliability, and overall efficiency of the apparatus:

1. **Enhanced Flow Regulation:**

It is recommended that a precision flow control valve or needle valve be employed instead of the manual clamp valve. This will provide finer adjustment of the flow rate and minimize fluctuations during measurement.

2. **Temperature Stabilization:**

Since viscosity is strongly dependent on temperature, the incorporation of a thermostatically controlled water bath or digital temperature regulator is advised. This will ensure that the fluid temperature remains constant, thereby improving the reliability of the obtained data.

3. Improved Material Selection:

For long-term durability and to prevent corrosion or contamination, the use of stainless steel, glass, or chemically inert polymers for the chamber and tubing is recommended.

This will help maintain the purity of the working fluid and the stability of results.

4. Measurement Precision:

The integration of digital timing devices and flow sensors is recommended to eliminate manual errors associated with stopwatch readings and volumetric estimations, thus enhancing measurement accuracy.

5. Calibration and Standard Verification:

Periodic calibration of the apparatus using standard reference fluids with known viscosities should be conducted. This will ensure that the apparatus continues to yield dependable and reproducible results.

6. Automation and Data Logging:

The future model of this apparatus may include a data acquisition system interfaced with a microcontroller or computer. Such automation would enable continuous monitoring, real-time data analysis, and improved experimental repeatability.

#### 7. Pedagogical Application:

The apparatus, when refined, can serve as a valuable instructional tool in fluid mechanics and transport phenomena laboratories, offering students practical insight into laminar flow and viscosity

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