

Vision of the Institute

“To become a leading institute of providing professionally competent and socially responsive technocrats with high moral values.”

Mission of the Institute

- ⇒ To create an eco-system for the dissemination of technical knowledge, to achieve academic excellence.
- ⇒ To develop technocrats with creative skills and leadership qualities, to solve local and global challenges.
- ⇒ To impart human values and ethics in students, to make them socially and Eco-friendly responsible.

LAB MANUAL OF FLUID MECHANICS LAB

[BCE 353]

B. TECH, 2nd Year, 3rd Sem



**Dr. A.P.J. Abdul Kalam Tech. University
Uttar Pradesh**

2025-26

Department of Civil Engineering

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BABU BANARASI DAS INSTITUTE OF TECHNOLOGY & MANAGEMENT

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MANUAL CONTENTS

This manual is intended for the 2nd year students of Civil Engineering in the subject of Fluid Mechanics Lab. This manual typically contains practical/lab sessions related Fluid Mechanics covering various aspects related to the subject of enhanced understanding.

Students are advised to thoroughly go through this manual rather than only topics mentioned in the syllabus as practical aspects are the key to understanding and conceptual visualization of theoretical aspects covered in the books.

Good Luck for your Enjoyable Laboratory Sessions.

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PREFACE

This practical manual will be helpful for students of Civil Engineering for understanding the course from the point of view of applied aspects. Though all the efforts have been made to make this manual error free, yet some errors might have crept in inadvertently. Suggestions from the readers for the improvement of the manual are most welcomed.

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VISION OF THE DEPARTMENT

To impart academic excellence in Civil Engineering field with emphasis on holistic development of the professional, while inculcating ethics, socially and professionally responsive technocrats.

MISSION OF THE DEPARTMENT

Mission-1. To provide a comprehensive platform for the academic expertise and proficiency.

Mission-2. To develop Civil Engineering professionals with creative skills and leadership qualities in order to face regional and global challenges.

Mission-3. To develop ethics in students in order to promote socially responsible environmental awareness with innovative thinking.



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Program Educational Objectives (PEOs) of Department

The following are PEOs of the department:

PEO 1: To enhance skill and expertise in field of Civil Engineering with aim of boosting employability and entrepreneurship.

PEO 2: To develop multidisciplinary approach of Civil Engineering system with lifelong learning solutions.

PEO 3: To develop the potential to pursue higher education and research in field of Civil Engineering.



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Program Outcomes:(PO)

Graduates will be able to achieve

PO 1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering Fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.



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PO 10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear

PO 11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

Program Specific Outcomes (PSOs) of the Department

PSO 1: Graduates shall be able to apply critical thinking in research, design, analysis and implementation of Civil Engineering problems.

PSO 2: Graduates shall be able to inculcate the idea of sustainability in engineering solution to meet real world challenges.

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Course Evaluation Scheme

Sr No	Subject Code	Subject Name	Periods			Evaluation Scheme				Total	Credit
			L	T	P	Sessional Assessment			PE		
						CT	TA	PS			
1.	BCE353	Fluid Mechanics lab	0	0	2	-	-	50	50	100	1

Course Objectives:

The main objectives of this lab course are:

1. **To understand fundamental principles of fluid mechanics** through practical experiments such as flow measurement, Bernoulli’s theorem, and momentum equation.
2. **To develop experimental skills** in measuring fluid properties like discharge, velocity, pressure, and head loss using laboratory instruments.
3. **To verify theoretical concepts** such as conservation of mass, momentum, and energy using real-life setups.
4. **To analyze fluid flow behavior** including laminar and turbulent flow, boundary layer development, and pipe flow characteristics.
5. **To calibrate flow measuring devices** such as orifice meter, venturi meter, and bend meter and study their performance.
6. **To interpret and analyze experimental data**, including plotting graphs and calculating coefficients (Cd, Cv, friction factor, etc.).
7. **To develop problem-solving and engineering application skills** in hydraulics and fluid systems.

Pre- requisite:

- i) Basic fluid mechanics theory
- ii) Knowledge of Bernoulli equation and Reynolds number
- iii) Basic mathematics and measurement techniques

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Course Outcomes (COs)

Course Outcomes: The students should be able to:		Bloom's Level
CO1	Conduct fluid mechanics experiments and record flow parameters.	L4
CO2	Analyze experimental data to determine flow coefficients and characteristics.	L4
CO3	Verify fundamental fluid mechanics laws through experimentation.	L5
CO4	Use modern fluid mechanics instruments and lab equipment.	L5
CO5	Interpret fluid flow behavior for basic engineering applications.	L4

CO-PO-PSO Mapping

	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	2	-	1	1	-	-	-	2	2	-	1	2	1
CO2	3	2	2	1	1	-	-	-	2	2	-	1	2	-
CO3	2	2	-	1	1	-	-	-	2	2	-	1	2	-
CO4	2	2	-	-	3	-	-	-	2	2	-	2	2	-
CO5	3	2	-	-	1	-	-	-	2	2	-	1	1	-
Avg.	2.40	2.00	2.00	1.00	1.40	-	-	-	2.00	2.00	-	1.20	1.80	1.00

The extent of mapping is as follows: 1 for low, 2 for moderate, 3 for high &“-” for No correlation between CO & PO.

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List of Experiments

S. No.	Experiment
1	To verify the momentum equation using the experimental set-up on impact of jet.
2	To determine the coefficient of discharge of an orifice of a given shape. Also to determine the coefficient of velocity and the coefficient of contraction of the orifice mouth piece.
3	To calibrate an orifice meter and study the variation of the co-efficient of discharge with the Reynolds number.
4	To calibrate a Venturi meter and study the variation of the co-efficient of discharge with the Reynolds number.
5	To calibrate a bend meter and study the variation of the co-efficient of discharge with the Reynolds number.
6	Verification of Bernoulli's Theorem
7	To study the transition from laminar to turbulent flow and to determine the lower critical Reynolds number.
8	To determine Meta-centric height of a given ship model.
9	To determine the head loss for a sudden enlargement, sudden contraction and losses in bend.
10	Flow Visualization -Ideal Flow

Beyond the Syllabus

1	To determine Head-Discharge (H-Q) curve, Power-Discharge (P-Q) curve and Efficiency-Discharge (η -Q) curve of a centrifugal pump.
2	To analyze the flow distribution in series and parallel pipe systems and determine the head losses occurring due to friction in pipes and fittings.



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INDEX

S.No.	Name of the Experiment	CO	BTL	Lab Conduction Date	Remark/ Grade/ Marks	Faculty Signature with Date
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

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Do's (What You Should Do)

1. Read the experiment carefully before performing it and understand the aim, apparatus, and procedure.
2. Check all connections and fittings (pipes, valves, manometers) before starting the setup.
3. Take accurate readings of discharge, pressure, and time using proper instruments.
4. Ensure steady flow conditions before recording observations.
5. Note readings properly in observation table without overwriting.
6. Use measuring instruments carefully, such as manometers, stopwatch, and scale.
7. Plot graphs neatly (if required), such as discharge vs head or Reynolds number vs coefficient.
8. Follow safety instructions given by the lab instructor.
9. Keep the lab clean and dry, especially near electrical equipment.
10. Switch off the pump and equipment after completing the experiment.

Dont's (What You Should Avoid)

1. Do not start the pump without water supply, as it may damage the system.
2. Do not touch rotating or moving parts of the apparatus while it is running.
3. Do not take readings in unsteady conditions (fluctuating flow).
4. Do not ignore leakage in pipes or fittings.
5. Do not handle electrical switches with wet hands.
6. Do not apply excessive force on valves or instruments.
7. Do not disturb the setup of other experiments.
8. Do not record false or assumed readings.
9. Do not leave the experiment unattended while running.
10. Do not forget to close valves and drain water after use.

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EXPERIMENT NO.: 01

Objective: -

To verify the momentum equation using the experimental set-up on impact of jet.

Apparatus Used: -

Collecting tank, transparent cylinder, two nozzles of dia 10 mm & 12mm, Vane of different shape (flat, inclined or curved).

Principle: -

Momentum equation is based on Newton’s second law of motion which states that the algebraic sum of external forces applied to control volume of fluid in any direction is equal to the rate of change of momentum in that direction. The external forces include the component of the weight of the fluid & of the forces exerted externally upon the boundary surface of the control volume. If a vertical water jet moving with velocity is made to strike a target, which is free to move in the vertical direction then a force will be exerted on the target by the impact of jet, according to momentum equation this force (which is also equal to the force required to bring back the target in its original position) must be equal to the rate of change of momentum of the jet flow in that direction.

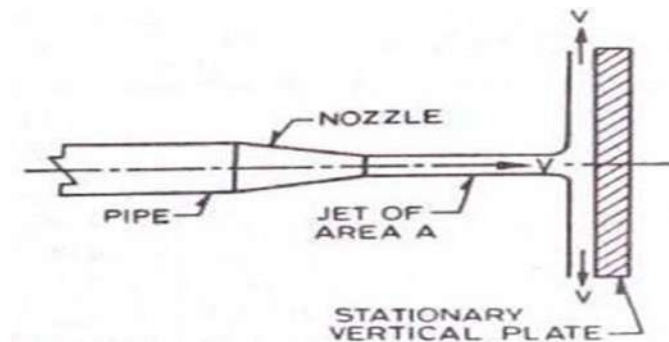


Figure: Impact of jet

Formula Used: -

$$F' = \rho Q v(1 - \cos\beta)$$

$$F' = \rho Q^2(1 - \cos\beta) \text{ as } v = Q/a$$

Where F' =force (calculated)

ρ = density of water

β =angle of difference vane

V =velocity of jet angle

Q =discharge

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A =area of nozzle ($\pi/4d^2$)

(i) for flat vane $\beta=90$ $F = \rho Q^2/a$

(ii) for hemispherical vane $\beta=180$ for % error = $F - F'/F' \times 100$ $F = 2 \rho Q^2/a$
 $F =$ Force (due to putting of weight)

iii) for inclined vane

$F' = \rho Q v(1 - \cos\beta)$

$F = \rho Q^2(1 - \cos\beta)$

Procedure: -

1. Note down the relevant dimension or area of collecting tank, dia of nozzle, and density of water.
2. Install any type of vane i.e. flat, inclined or curved.
3. Install any size of nozzle i.e. 10mm or 12mm dia.
4. Note down the position of upper disk, when jet is not running.
5. Note down the reading of height of water in the collecting tank.
6. As the jet strike the vane, position of upper disk is changed, note the reading in the scale to which vane is raised.
7. Put the weight of various values one by one to bring the vane to its initial position.
8. At this position finds out the discharge also.
9. The procedure is repeated for each value of flow rate by reducing the water supply.
10. This procedure can be repeated for different type of vanes and nozzle.

Observations: -

Dia of nozzle =

Mass density of water $\rho =$

Area of collecting tank =

Area of nozzle =

Horizontal flat vane:

When jet is not running, position of upper disk is at =

Sr. No.	Discharge measurement				Balancing		Theoretical force $F' = \rho Q^2/a$	Error in % $= (F - F')/F'$
	Initial (cm.)	Final (cm.)	Time (sec)	Discharge Q (cm ³ /sec)	Mass (gm)	Force F (dyne)		
1.								
2.								
3.								

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Inclined vane:

When jet is not running, position of upper disk is at =

Angle of inclination $\beta = 45^\circ$

Sr. No.	Discharge measurement				Balancing		Theoretical force $F' = \rho Q^2(1 - \cos\beta)/a$	Error in% $=(F-F')/F'$
	Initial (cm.)	Final (cm.)	Time (sec)	Discharge Q (cm ³ /sec)	Mass (gm)	Force F(dyne)		
1.								
2.								
3.								

Result: - The value of impact of jet from the given table is=

Safety Precautions: -

1. Water flow should be steady and uniform.
2. The reading on the scale should be taken without any error.
3. The weight should be put slowly & one by one.
4. After changing the vane, the flask should be closed tightly.

EXPERIMENT NO.: 02**Objective: -**

To determine the coefficient of discharge of an orifice of a given shape. Also to determine the coefficient of velocity and the coefficient of contraction of the orifice mouth piece.

Apparatus Used: -

Supply tank with overflow arrangement, Orifice plate of different diameter, hook gauge, collecting tank, piezometric tube.

Principle: -

A mouthpiece is a short length of pipe which is two or three times its diameter in length. If there pipe is filled externally to the orifices, the mouthpiece is called external cylindrical mouthpiece and discharge through orifice increase is a small opening of any cross-section on the side of bottom of the tank, through which the fluid is flowing orifice coefficient of velocity is defined as the ratio of two actual discharge to orifice ratio of the actual velocity of the jet at vena- contracta to the coefficient of theoretical velocity of the jet coefficient of contraction of defined as ratio of the actual velocity of jet at vena- contracta.

Vena- Contracta: - The fluid out is in form of jet goes on contracting form orifice up to dispuete of about $\frac{1}{2}$ the orifice dia. After the expend this least relation.

Coefficient of velocity: - It is a ratio of actual velocity jet at vena-contracta to theoretical velocity.

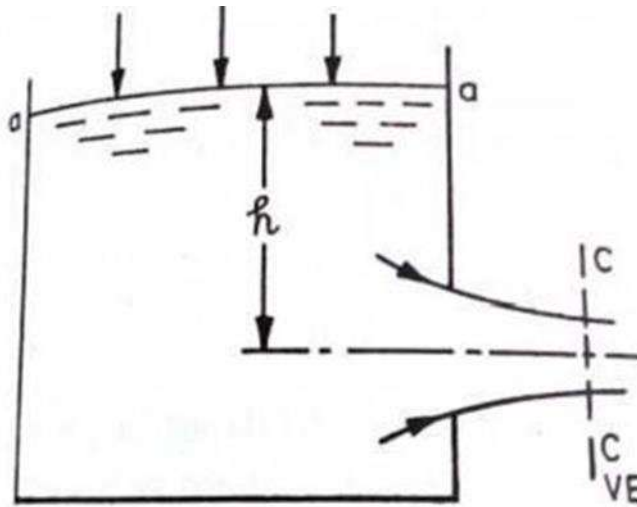


Figure: Flow through Orifice

Procedure: -

1. Set the mouthpiece of orifice of which the C_c , C_u , C_d are to be determined.
2. Note the initial height of water in the steady flow tank and the height of datum from the bottom of orifice and mouthpiece. These remains constant for a particular mouthpiece or orifice.
3. By using the stop valve, set a particular flow in tank and tank height of water in tank.
4. Take the reading of discharge on this particular flow.
5. Using hook gauge, find the volume of X or Y for mouthpiece.
6. Take three readings using hook gauge for one particular orifice.
7. Using the formula get value of C_d , C_u , and C_c for a particular orifice and mouthpiece.

Observation: -

$x' + y'$ are reading on horizontal/vertical scale

a_0	$h = \mu a_0$	x'	y'	$X = x' - x_0$	$Y = y' - y_0$	$C_u = x/2gh$	Average

h = Reading on piezometer

a_0 = Reading on piezometer at level on centre of mouthpiece

y_0 = Reading on vertical scale at exit of orifice

x_0 = Reading on horizontal scale at exit of orifice.

Result: -

Precautions: -

1. Take the reading of discharge accurately.
2. Take value of h without any parallax error.
3. Set the orifice and mouthpiece.
4. Height of water in the steady flow.
5. Take reading from hook gauge carefully.

EXPERIMENT NO.: 03**Objective: -**

To calibrate an orifice meter and study the variation of the co-efficient of discharge with the Reynolds number.

Apparatus Used: -

Orifice meter, installed on different pipes, arrangement of varying flow rate, U- tube manometer, collecting tube tank, vernier calipers tube etc.

Theory: -

Orifice meter is depending on Bernoulli's equation. Orifice meter is a device used for measuring the rate of fluid flowing through a pipe. It is a cheaper device than Venturi meter.

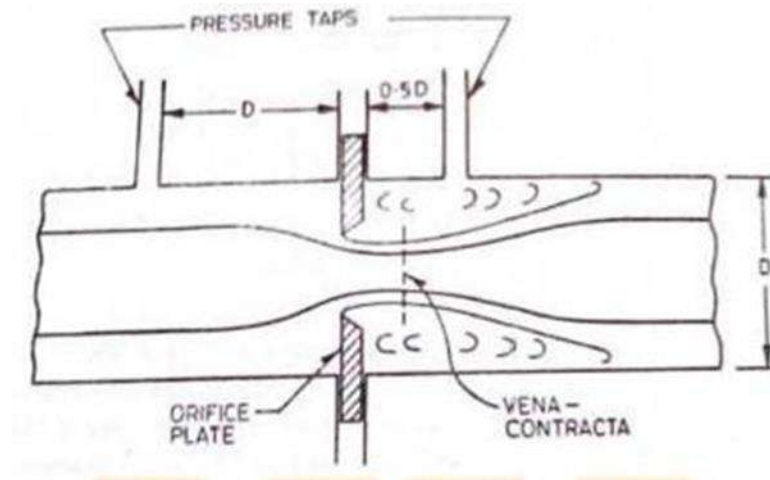


Figure: Orifice meter

Formula Used: -

$$Q = C_d a A \sqrt{2gh} / \sqrt{A^2 - a^2}$$

where

A = Cross section area of inlet a = Cross section area of outlet

h = Head difference in manometer Q = Discharge

Cd = Coefficient of discharge

g = Acceleration due to gravity

Procedure: -

1. Set the manometer pressure to the atmospheric pressure by opening the upper valve.
2. Now start the supply at water controlled by the stop valve.
3. One of the valves of any one of the pipe open and close all other of three.
4. Take the discharge reading for the particular flow.
5. Take the reading for the pressure head on from the u-tube manometer for corresponding reading of discharge.

6. Now take three readings for this pipe and calculate the Cd for that instrument using formula.
7. Now close the valve and open valve of other diameter pipe and take the three reading for this.
8. Similarly take the reading for all other diameter pipe and calculate Cd for each.

Observations: -

Diameter of Orifice meter =

Area of cross section =

Area of collecting tank=

Discharge					Manometer reading				= $\frac{V}{A \cdot \sqrt{2gh}}$ -
(cm.) Initial	(cm.) Final	Difference	(sec) Time	Discharge	H1	H2	H1 H2-	H1) h=13.6(H2-	
									$\frac{V}{A \cdot \sqrt{2gh}}$

Result: -

Precautions: -

1. Keep the other valve closed while taking reading through one pipe.
2. The initial error in the manometer should be subtracted final reading.
3. The parallax error should be avoided.
4. Maintain a constant discharge for each reading.
5. The parallax error should be avoided while taking reading the manometer.

EXPERIMENT NO.: 04

Objective: -

To calibrate a Venturi meter and study the variation of the co-efficient of discharge with the Reynolds number.

Apparatus Used: -

Venturi meter, installed on different diameter pipes, arrangement of varying flow rate, U- tube manometer, collecting tube tank, vernier caliper tube etc.

Theory: -

Venturi meter are depending on Bernoulli's equation. Venturi meter is a device used for measuring the rate of fluid flowing through a pipe. The consist of three parts in short

1. Converging area part
2. Throat
3. Diverging part

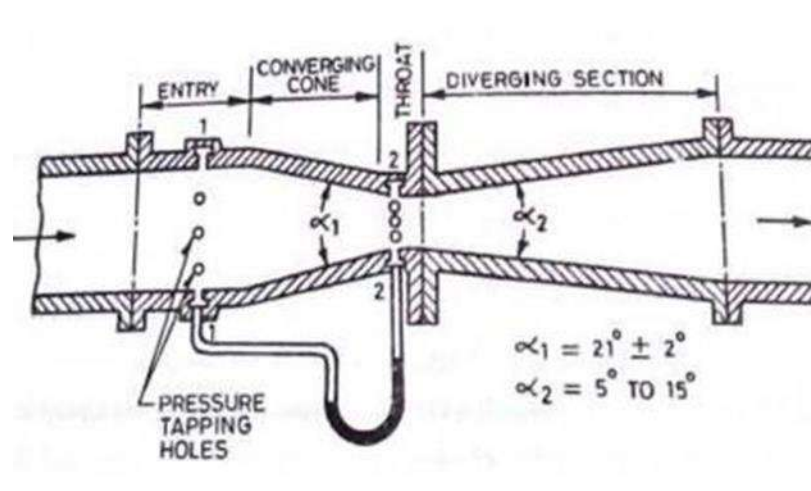


Figure: Venturimeter

Formula Used: -

$$Q = C_d a A \sqrt{2gh} / \sqrt{(A^2 - a^2)}$$

Where

A = Cross section area of inlet

a = Cross section area of outlet

h = Head difference in manometer

Q = Discharge

C_d = Coefficient of discharge

g = Acceleration due to gravity

Result: -

Precautions: -

1. Keep the other valve closed while taking reading through one pipe.
2. The initial error in the manometer should be subtracted final reading.
3. The parallax error should be avoided.
4. Maintain a constant discharge for each reading.
5. The parallax error should be avoided while taking reading the manometer.

EXPERIMENT NO.: 05

Objective: -

To calibrate a bend meter and study the variation of coefficient of discharge (Cd) with Reynolds number (Re).

Apparatus Used: -

- Bend meter setup (pipe with bend)
- Differential manometer
- Water supply system (pump)
- Measuring tank
- Stopwatch
- Scale / measuring device

Principle: -

When fluid flows through a **pipe bend**, a pressure difference develops between the inner and outer sides due to **centrifugal force**.

This pressure difference is used to determine discharge.

Coefficient of discharge:

$$C_d = Q_{\text{actual}} / Q_{\text{theoretical}}$$

Reynolds number:

$$Re = \frac{\rho V D}{\mu}$$

- At higher Reynolds number → flow becomes turbulent
- Cd varies slightly and tends to become nearly constant

Procedure: -

1. Start the pump and allow water to flow through the bend meter.
2. Adjust the valve to obtain steady flow.
3. Note the differential manometer reading (pressure difference).
4. Measure discharge by collecting water in measuring tank for a known time.
5. Calculate actual discharge (Q_{actual}).
6. Calculate theoretical discharge (Q_{theoretical}).
7. Determine Cd.
8. Calculate Reynolds number for each trial.
9. Repeat experiment for different flow rates.

Observation Table: -

Trial	h (m)	Time (s)	Volume (ml)	Q _{actual}	Velocity	Re	Q _{theoretical}	Cd

Calculations: -

1. Actual discharge:
 $Q_{\text{actual}} = \text{Volume} / \text{Time}$
2. Velocity:
 $V = Q / \text{Area}$
3. Theoretical discharge:
 $Q_{\text{theoretical}} = A \times \sqrt{2gh}$
4. Coefficient of discharge:
 $Cd = Q_{\text{actual}} / Q_{\text{theoretical}}$
5. Reynolds number:
Use formula given above

Result: -

- Coefficient of discharge (Cd) is determined.
- It is observed that **Cd varies with Reynolds number** and becomes nearly constant at higher Reynolds number.

Precautions: -

1. Ensure steady flow before taking readings
2. Remove air bubbles from manometer
3. Avoid leakage in connections
4. Take accurate time and volume readings
5. Note readings carefully

EXPERIMENT NO.: 06

Objective: -

To verify Bernoulli's theorem by demonstrating that the total energy of flowing fluid remains constant along a streamline.

Apparatus Used: -

- Bernoulli's theorem apparatus (converging-diverging duct)
- Series of piezometer tubes
- Water supply system (pump)
- Measuring tank
- Stopwatch
- Scale

Principle: -

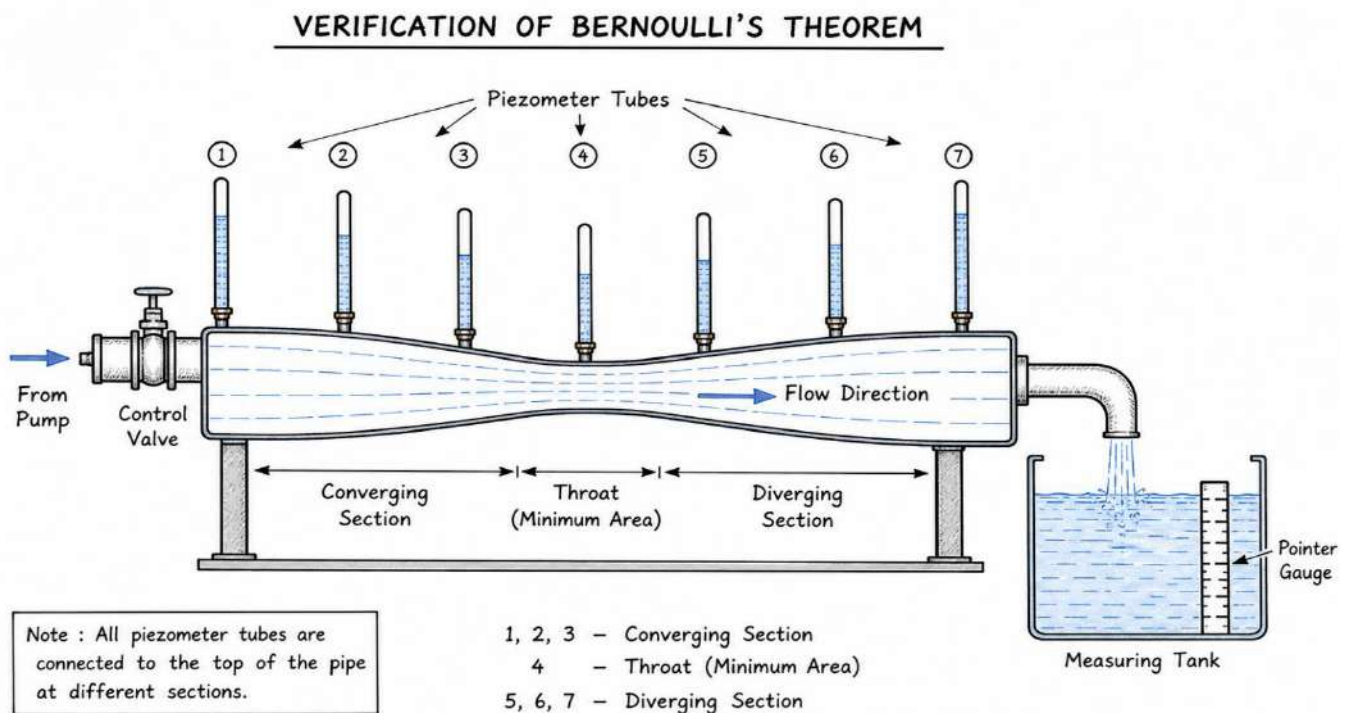
According to **Bernoulli's theorem**, for steady, incompressible, and frictionless flow:

$$\frac{P}{\gamma} + \frac{V^2}{2g} + Z = \text{Constant}$$

Where:

- $\frac{P}{\gamma}$ = Pressure head
- $\frac{V^2}{2g}$ = Velocity head
- Z = Datum head

As velocity increases \rightarrow pressure decreases, and vice versa.



Procedure: -

1. Start the pump and allow water to flow through the apparatus.
2. Adjust valve to obtain steady flow.
3. Note the readings of all piezometer tubes (pressure heads).
4. Measure discharge using measuring tank and stopwatch.
5. Calculate velocity at different sections using area and discharge.
6. Compute velocity head and total head at each section.
7. Compare total head values along the flow.

Observation Table: -

Section	Area (m ²)	Piezometer Head (m)	Velocity (m/s)	Velocity Head (m)	Datum Head (m)	Total Head (m)

Calculations: -**1. Discharge**

$$Q = \frac{\text{Volume}}{\text{Time}}$$

2. Velocity

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

3. Velocity Head

$$\frac{V^2}{2g}$$

4. Total Head

$$H = \frac{P}{\gamma} + \frac{V^2}{2g} + Z$$

Graph: -

- Plot **Total Head vs Distance along duct**
Graph should be approximately horizontal (constant energy)

Result: -

The total head at different sections is found to be approximately constant, hence Bernoulli's theorem is verified.

Precautions

1. Ensure steady and continuous flow
2. Remove air bubbles from piezometer tubes
3. Take readings carefully (avoid parallax error)
4. Ensure no leakage in the system
5. Maintain proper datum reference.

EXPERIMENT NO.: 07**Objective: -**

To study the transition from laminar to turbulent flow and to determine the lower critical Reynolds number.

Apparatus Used: -

Flow condition inlet supply, elliptical belt type arrangement for colored fluid with regulating tank

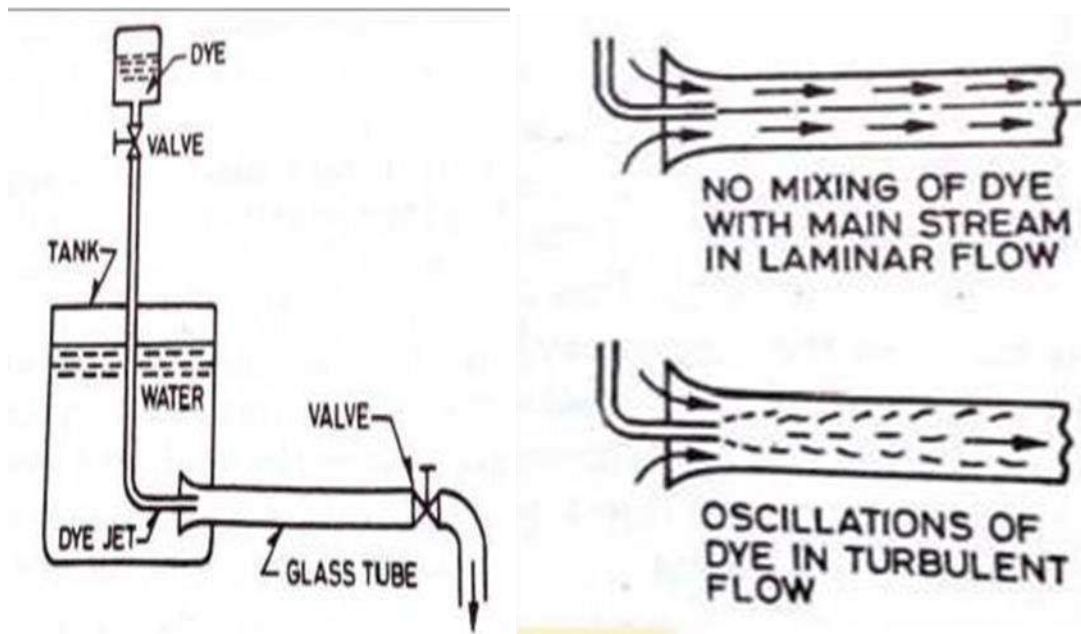


Figure: Reynold No. apparatus

Principle: -

Flow type depends on Reynolds number:

$$Re = \frac{\rho V D}{\mu}$$

- Laminar flow: $Re < 2000 \rightarrow$ smooth, parallel layers
- Transitional flow: $2000 < Re < 4000$
- Turbulent flow: $Re > 4000 \rightarrow$ irregular motion

In this experiment:

- Dye filament remains straight \rightarrow laminar flow
- Dye starts wavering \rightarrow transition begins
- Dye mixes completely \rightarrow turbulent flow

Procedure: -

1. Fill the tank and start water flow through the glass tube.
2. Allow flow to stabilize at low velocity.
3. Introduce dye gently at the centre of the tube.

4. Observe the dye pattern:
 - o Straight line → laminar
 - o Slight disturbance → transition
 - o Fully mixed → turbulent
5. Gradually increase flow rate using control valve.
6. Note the flow rate at which dye first becomes unstable (transition point).
7. Measure discharge by collecting water for a known time.
8. Calculate velocity and Reynolds number.
9. Repeat for accuracy.

Observation Table: -

Trial	Time (s)	Volume (m ³)	Discharge Q (m ³ /s)	Velocity V (m/s)	Temperature (°C)	Reynolds Number	Flow Type

Calculations: -

1. Discharge

$$Q = \frac{\text{Volume}}{\text{Time}}$$

2. Area of Pipe

$$A = \frac{\pi D^2}{4}$$

3. Velocity

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

4. Reynolds Number

$$Re = \frac{\rho V D}{\mu}$$

Graph: -

- Plot Reynolds Number vs Flow Type (qualitative)
- Mark region where transition occurs

Result: -

The transition from laminar to turbulent flow was observed.

The lower critical Reynolds number was found to be approximately 2000–2300.

Precautions: -

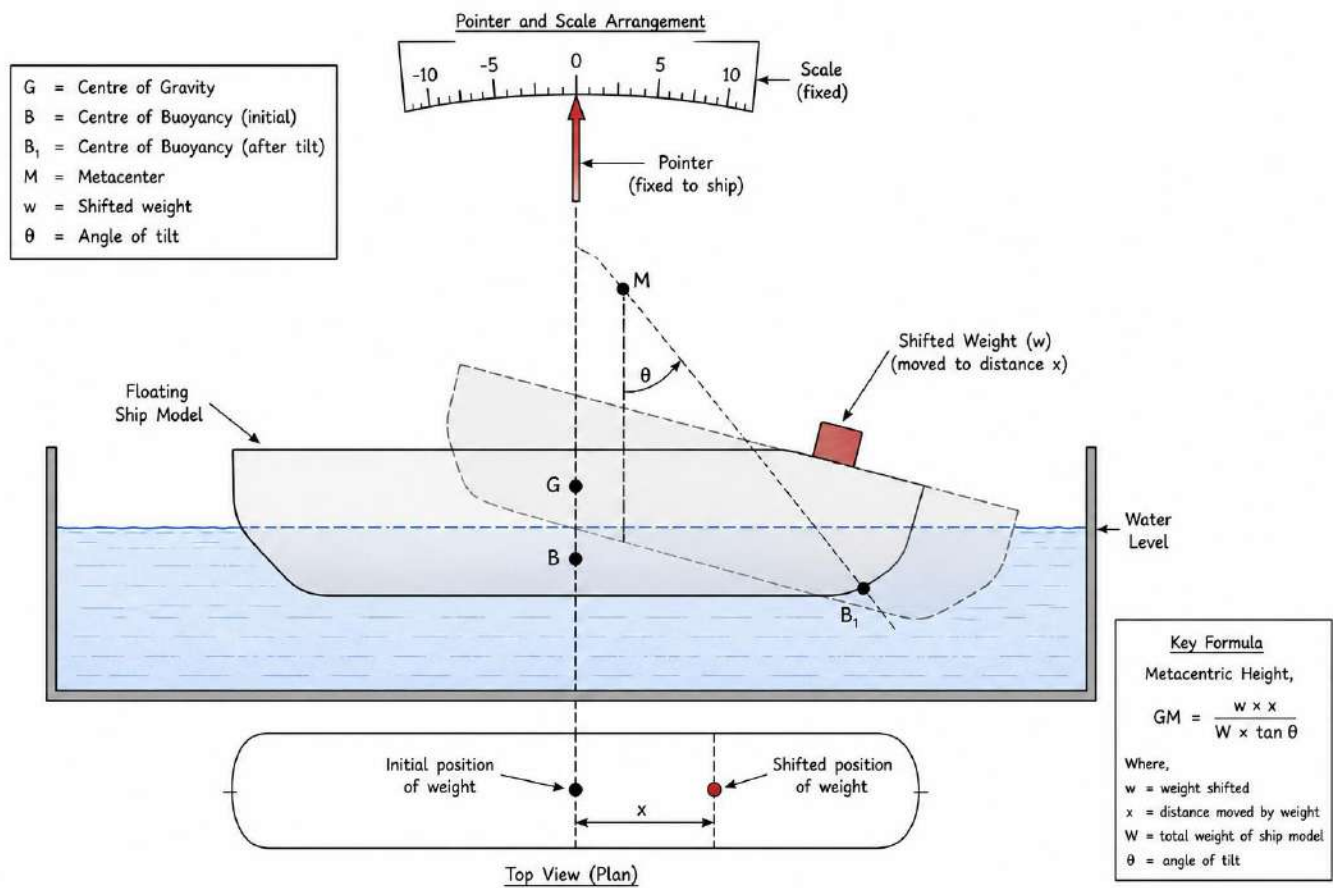
1. Introduce dye very gently to avoid disturbance
2. Ensure steady flow conditions
3. Avoid vibration in setup
4. Take accurate volume and time readings
5. Maintain constant temperature (viscosity depends on it)

EXPERIMENT NO.: 8**Objective: -**

To Determine the Metacentric Height of a Given Ship Model.

Apparatus Used: -

- Ship model (floating body)
- Water tank
- Sliding weight
- Scale for measuring displacement
- Spirit level
- Pointer and scale arrangement

**Principle: -**

When a floating body is tilted, the centre of buoyancy shifts and a point called the **Metacentre** is formed.

Metacentric height:

$$GM = \frac{w \cdot x}{W \cdot \tan \theta}$$

Where:

- w = weight shifted

- x = distance moved by weight
- W = total weight of model
- θ = angle of tilt

Interpretation:

- $GM > 0$ → Stable equilibrium
- $GM = 0$ → Neutral equilibrium
- $GM < 0$ → Unstable equilibrium

Procedure: -

1. Fill the tank with water and place the ship model in it.
2. Ensure the model floats freely and is in equilibrium.
3. Note initial reading of pointer (zero position).
4. Shift a known weight horizontally by a known distance.
5. Observe and record the deflection of pointer.
6. Calculate angle of tilt using geometry:

$$\tan \theta = \frac{\text{deflection}}{\text{length of pointer}}$$

7. Calculate metacentric height (GM).
8. Repeat for different weight positions.

Observation Table: -

S. No.	Weight shifted w (N)	Distance moved x (m)	Total weight W (N)	Pointer deflection (m)	Length of pointer (m)	tan θ	GM (m)

Calculations: -

1. Angle of Tilt

$$\tan \theta = \frac{y}{L}$$

Where:

- y = deflection
- L = length of pointer

2. Metacentric Height

$$GM = \frac{w \cdot x}{W \cdot \tan \theta}$$

Graph (Optional): -

- Plot ($w \times x$) vs $\tan\theta$
- Straight line graph

Result: -

The metacentric height of the given model is:

$$GM = \underline{\hspace{2cm}} \text{ m}$$

Since GM is positive/negative, the body is stable/unstable.

Precautions

1. Ensure model floats freely without touching tank walls
2. Shift weight gently to avoid oscillations
3. Take accurate pointer readings
4. Ensure proper levelling before experiment
5. Avoid external disturbances

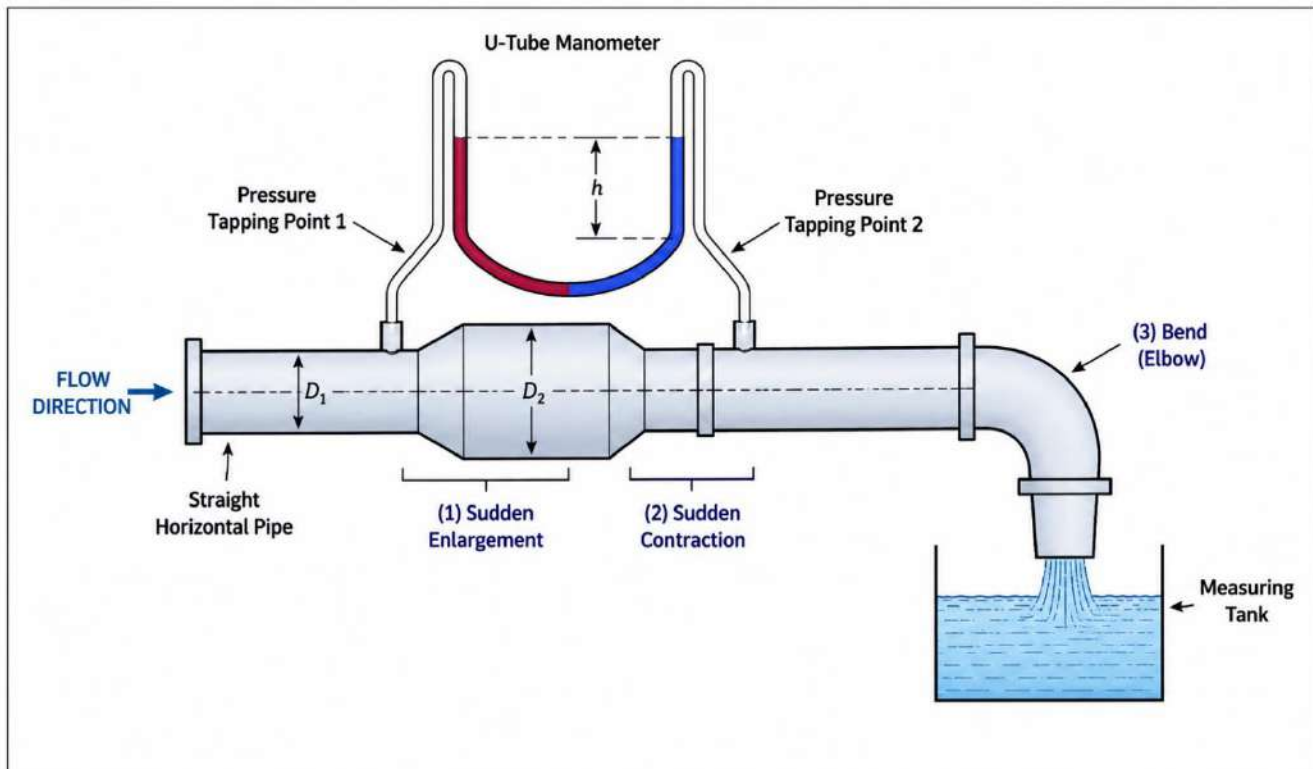
EXPERIMENT NO.: 9

Objective: -

- To determine **head loss** due to:
 - Sudden enlargement
 - Sudden contraction
 - Pipe bend
- To compare **experimental values** with **theoretical values**

Apparatus Used: -

- Pipe system with:
 - Sudden enlargement section
 - Sudden contraction section
 - Bend (elbow)
- Differential manometer
- Measuring tank
- Stopwatch
- Scale/measuring tape
- Control valve



Principle: -

When fluid flows through a pipe and encounters:

- **Sudden enlargement** → flow separates → energy loss due to eddies
- **Sudden contraction** → vena contracta forms → energy loss
- **Bend** → change in direction → turbulence and friction losses

Calculations: -

- Discharge:

$$Q = \frac{V}{t}$$

- Velocity:

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

- Head loss from manometer:

$$h = x \times (\text{specific gravity difference})$$

Result: -

- Head loss for:
 - Sudden enlargement = _____ m
 - Sudden contraction = _____ m
 - Bend = _____ m
- Experimental values are compared with theoretical values.

Precautions: -

- Ensure no air bubbles in manometer
- Take steady readings only
- Measure time accurately
- Keep flow uniform
- Check leakage in pipe system

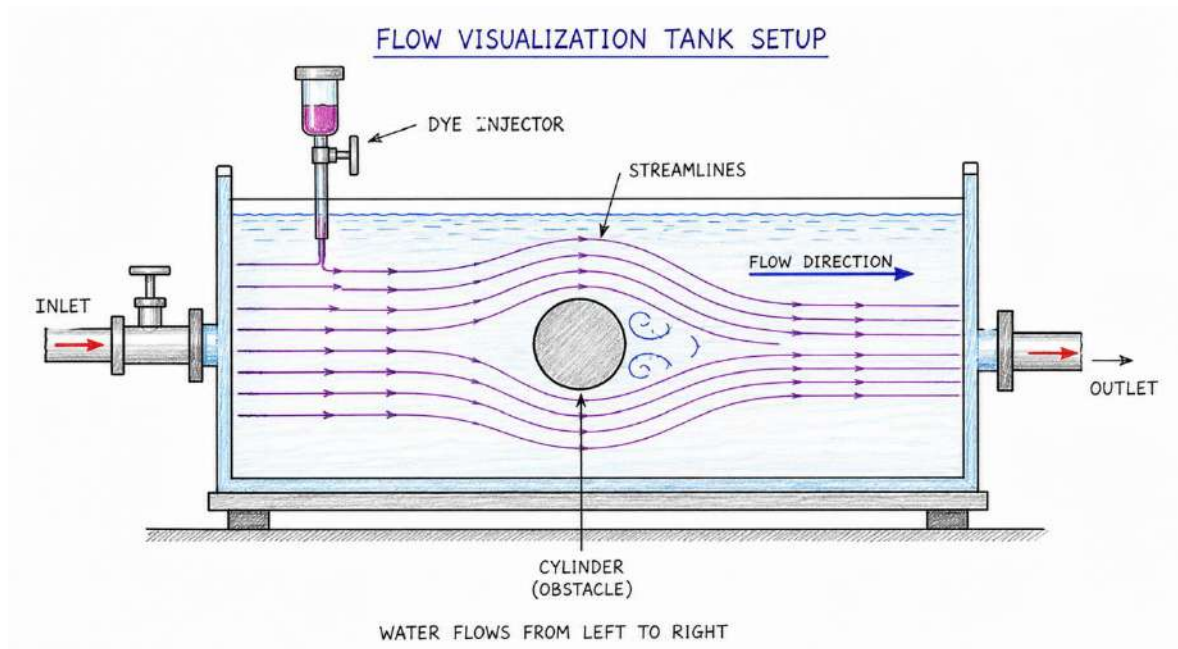
EXPERIMENT NO.: 10

Objective: -

- To visualize flow patterns of fluid under ideal conditions
- To study **streamlines**, **pathlines**, and **flow behavior**
- To understand characteristics of **Ideal Flow**

Apparatus Used: -

- Flow visualization tank (glass-sided)
- Water supply system
- Dye injector (coloured ink)
- Obstacles (cylinder, plate, aerofoil, etc.)
- Illumination system (light source)



Principle: -

In ideal flow:

- Fluid is **inviscid** (no viscosity)
- Flow is **irrotational**
- No energy loss occurs

Flow visualization helps observe:

- **Streamline**
- **Laminar Flow**
- **Flow Separation** (in practical cases)

Dye injection makes flow patterns visible.

Procedure: -

1. Fill the flow visualization tank with clean water.
2. Start the pump and allow steady flow conditions.
3. Adjust flow rate using control valve.

4. Inject dye slowly through the injector nozzle.
5. Observe formation of streamlines in the flow field.
6. Place an obstacle (cylinder/plate) in the path of flow.
7. Observe how streamlines change around the obstacle.
8. Repeat for different flow rates.

Observation Table: -

S. No.	Flow Condition	Dye Pattern Observed	Behavior of Streamlines	Remarks
1	Low flow rate	Smooth straight lines	Stable and uniform	Ideal flow behavior
2	Medium flow rate	Slight curvature near obstacle	Streamlines bend smoothly	No turbulence
3	High flow rate	More disturbance near object	Streamlines compress & expand	Flow separation begins

Calculations: -

(No numerical calculations are required in this experiment.)

However, theoretical relations used:

- Continuity equation:
 $A_1 V_1 = A_2 V_2$
- Bernoulli principle (ideal flow concept):
Pressure + Kinetic Energy + Potential Energy = Constant

Result: -

The flow patterns of fluid under ideal conditions were successfully visualized. Streamlines were observed to be smooth, continuous, and non-intersecting. The behavior of flow around obstacles was clearly studied, demonstrating characteristics of ideal flow.

Precautions: -

- Maintain steady flow throughout the experiment.
- Inject dye slowly for clear visualization.
- Avoid turbulence in water tank.
- Ensure obstacles are fixed firmly.
- Use clean water for better clarity of streamlines.
- Do not disturb the tank during observation.

BEYOND THE SYLLABUS

EXPERIMENT NO.: 01

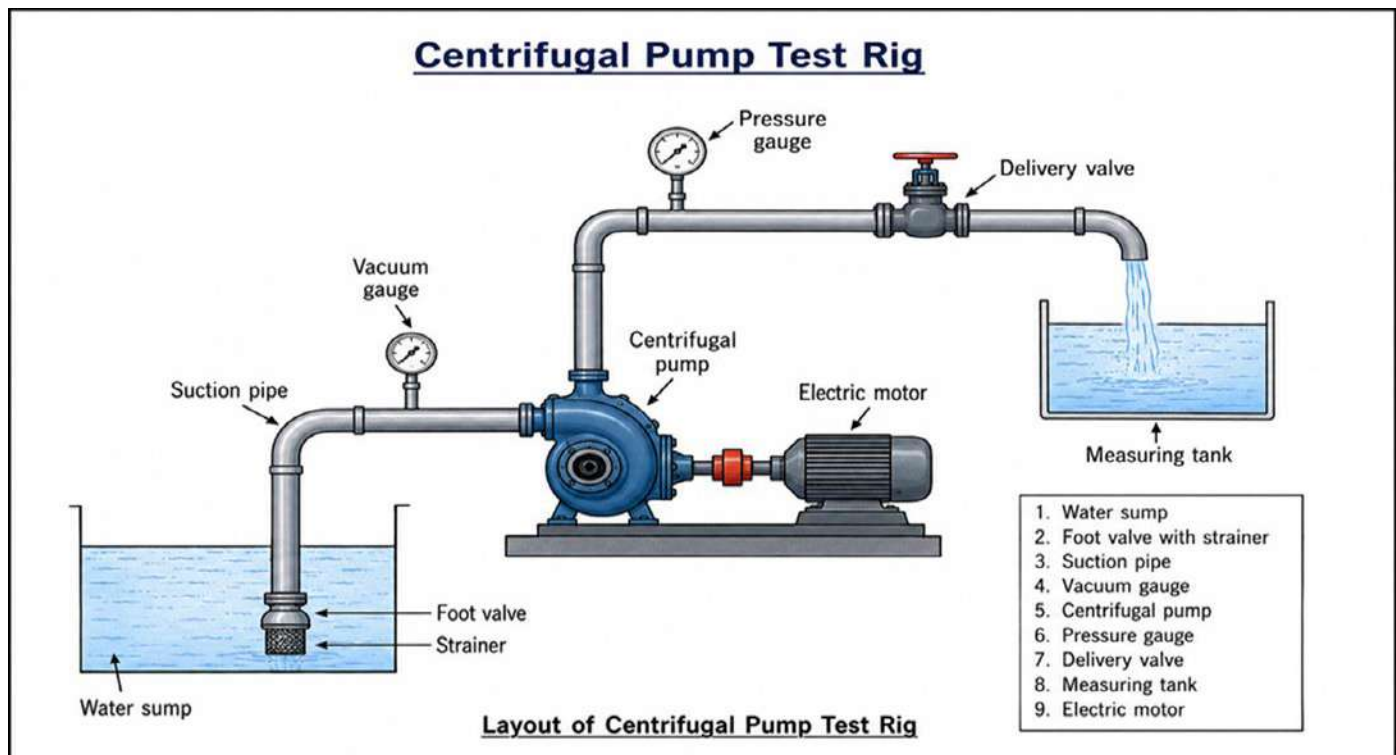
Objective: -

To determine:

1. Head–Discharge (H–Q) curve
2. Power–Discharge (P–Q) curve
3. Efficiency–Discharge (η –Q) curve of a centrifugal pump.

Apparatus Used: -

- Centrifugal Pump Test Rig
- Measuring tank
- Pressure gauges/vacuum gauges
- Wattmeter/Energy meter
- Stopwatch
- Delivery valve
- Tachometer



Theory

A centrifugal pump converts mechanical energy into hydraulic energy using centrifugal force.

Total Head Developed

$$H = \left(\frac{P_d}{\gamma} + \frac{V_d^2}{2g} + z_d \right) - \left(\frac{P_s}{\gamma} + \frac{V_s^2}{2g} + z_s \right)$$

Where:

- H = Total head (m)
- P_d, P_s = Delivery and suction pressures
- γ = Specific weight of water
- V_d, V_s = Velocities
- z_d, z_s = Datum heights

Discharge

$$Q = \frac{\text{Volume}}{\text{Time}}$$

Where:

- Q = Discharge (m^3/s)

Input Power

$$P_{in} = VI \cos \phi$$

Where:

- V = Voltage
- I = Current
- $\cos \phi$ = Power factor

Output Power (Water Power)

$$P_{out} = \rho g Q H$$

Efficiency of Pump

$$\eta = \frac{P_{out}}{P_{in}} \times 100$$

Procedure

1. Fill the sump tank with water.
2. Prime the centrifugal pump properly.
3. Start the motor with delivery valve closed.
4. Open the delivery valve gradually.
5. Measure discharge by collecting water in measuring tank for a known time.
6. Record:
 - Suction gauge reading
 - Delivery gauge reading
 - Time of collection
 - Voltage and current
7. Repeat the experiment for different valve openings.
8. Calculate:
 - Discharge
 - Head
 - Input power
 - Output power
 - Efficiency
9. Plot:
 - Head vs Discharge

- Power vs Discharge
- Efficiency vs Discharge

Observation Table

S. No.	Volume Collected (m ³)	Time (s)	Discharge Q (m ³ /s)	Suction Head hs (m)	Delivery Head hd (m)	Total Head H (m)	Voltage V (V)	Current I (A)	Input Power Pin (W)	Output Power Pout (W)	Efficiency η (%)

Graphs to be Drawn

1. Head (H) vs Discharge (Q)
2. Power (P) vs Discharge (Q)
3. Efficiency (η) vs Discharge (Q)

Precautions

1. Prime the pump before starting.
2. Never run the pump dry.
3. Open the delivery valve gradually.
4. Take readings only after steady flow is achieved.
5. Ensure there is no leakage in the pipe connections.
6. Avoid air entry into suction pipe.
7. Switch off the motor after completion of experiment.

Result

The performance characteristics of the centrifugal pump were studied successfully and the following curves were plotted:

1. Head vs Discharge curve
2. Power vs Discharge curve
3. Efficiency vs Discharge curve

The maximum efficiency of the pump was observed at _____ discharge.

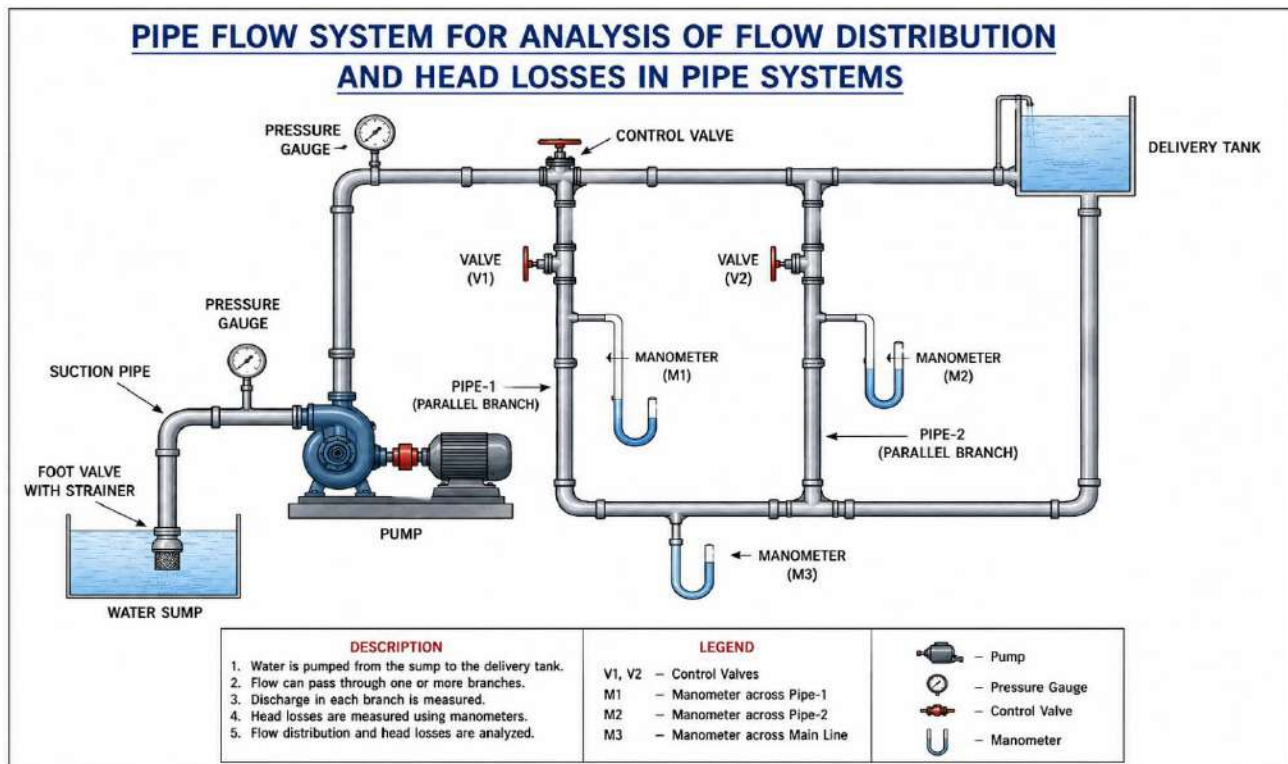
EXPERIMENT NO.: 02

Objective

1. To analyze the flow distribution in series and parallel pipe systems.
2. To determine the head losses occurring due to friction in pipes and fittings.
3. To verify the relationship between discharge and head loss in pipe networks.

Apparatus Used

1. Pipe Flow Network Test Rig
2. Centrifugal pump
3. Pipes of different diameters
4. Control valves
5. Pressure gauges / Manometers
6. Measuring tank
7. Stopwatch
8. Pipe fittings (elbows, bends, tees, reducers)
9. Flow control valves



Principle

When fluid flows through pipes, energy losses occur due to:

- Friction between fluid and pipe wall

- Sudden enlargement/contraction
- Bends and fittings

The total head loss in pipe systems depends on:

- Pipe length
- Diameter
- Flow velocity
- Surface roughness

For pipes connected:

- In **series**, discharge remains constant.
- In **parallel**, head loss remains same across branches.

Formulae

Darcy–Weisbach Equation

$$h_f = f \frac{L V^2}{D 2g}$$

Where:

- h_f = Head loss due to friction (m)
- f = Friction factor
- L = Length of pipe (m)
- D = Diameter of pipe (m)
- V = Velocity of flow (m/s)

Discharge

$$Q = AV$$

Where:

- Q = Discharge (m³/s)
- A = Area of pipe (m²)
- V = Velocity (m/s)

Procedure

1. Fill the sump tank with water.
2. Start the centrifugal pump.
3. Open the control valves gradually.
4. Allow water to flow through the pipe network.
5. Measure:
 - Pressure difference using manometers
 - Discharge through measuring tank
6. Record readings for:
 - Series pipe arrangement
 - Parallel pipe arrangement
7. Repeat observations for different flow rates.
8. Calculate:
 - Velocity
 - Head loss
 - Friction factor
9. Compare head losses in different pipe configurations.

Observation Table

S. No.	Pipe Diameter D (m)	Length L (m)	Discharge Q (m ³ /s)	Velocity V (m/s)	Pressure Difference (m)	Head Loss hf (m)

Precautions

1. Ensure there is no leakage in the pipe system.
2. Open valves gradually to avoid water hammer.
3. Remove air bubbles from manometer tubes.
4. Take readings only after steady flow is achieved.
5. Measure discharge accurately using stopwatch.
6. Ensure proper calibration of gauges.

Result

The flow distribution and head losses in series and parallel pipe systems were studied successfully. The variation of head loss with discharge was analyzed and verified experimentally.