

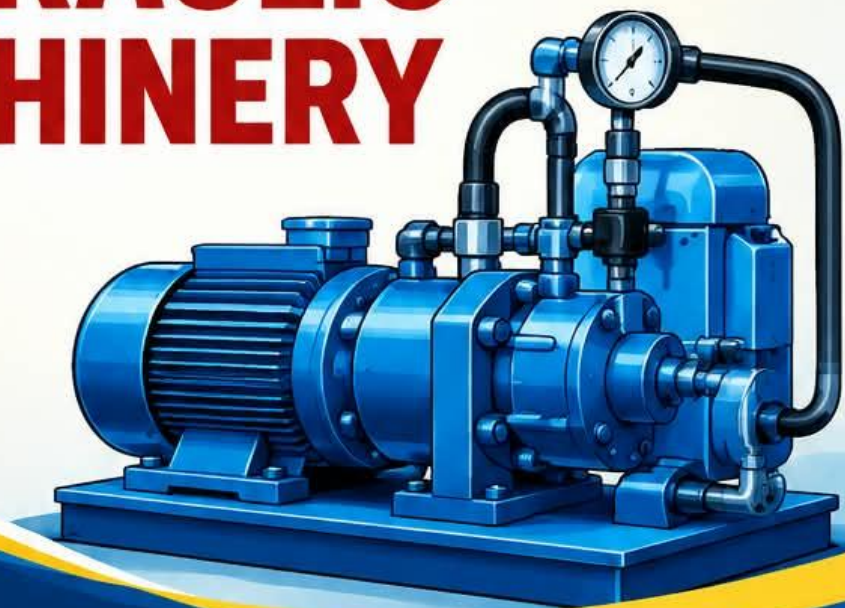
K. N. S. Government Polytechnic

Samastipur

Department of Mechanical Engg.

LAB. MANUAL :-

FLUID MECHANICS & HYDRAULIC MACHINERY



Sem : - 4th (Mechanical Engg.)

2026



FLUID MECHANICS & HYDRAULIC MACHINES

LABORATORY – PRACTICALS



K) Suggested Laboratory (Practical) Session Outcomes (LSOs) and List of Practical: P2425402

S.No.	Practical/Lab Session Outcomes (LSOs)	S.No.	Laboratory Experiment/Practical Titles	Relevant COs (Number(s))	
1. VISCOSITY & FLUID PROPERTIES (ISO 1.1 – 1.8)					
S0 1.1	Determine viscosity of given liquid.	1.	Use viscometer to determine the viscosity of a given liquid.	C01	
S0 1.2	Measure the rise of liquid level.	2.	Measure the rise of liquid level using capillary action in capillary tube.	C01	
S0 1.3	Measure specific gravity of any given fluid.	3.	Determine the specific gravity of any given fluid.	C01	
S0 1.4	Measure the pressure of the given fluid.	4.	Use manometer/ incline manometer to measure the pressure of the given fluid.	C01	
S0 1.5	Measure meta-centric height of ship model.	5.	Determine the meta-centric height of ship model.	C01	
S0 2.1	Measure discharge through a pipe using Venturi meter.	6.	Determine Coefficient of Discharge of Venturi meter.	C02	
S0 2.2	Measure discharge through a pipe using Orifice meter.	7.	Determine Coefficient of Discharge, coefficient of contraction and coefficient of velocity of Orifice meter.	C02	
S0 2.3	Determine the coefficient of friction of flow through pipes.	8.	Determine coefficient of friction of flow through pipes.	C02	
S0 2.4	Measure static pressure.	9.	Experimentally justify Bernoulli's theorem for a viscous and incompressible fluid.	C02	
S0 2.5	Measure pressure energy, kinetic energy and datum energy of a given flowing fluid.	10.	Determine the pressure energy, kinetic energy and datum energy of a given flowing fluid.	C02	
S0 3.1	Measure discharge through given pipe.	11.	Determine discharge through a given pipe using orifice meter, pitot tube and venturi meter.	C03	
S0 3.2	Determine Cc, Cd, Cv for different types of orifices.	12.	Determine Cc, Cd, Cv for different types of orifices.	C03	
S0 3.3	Determine head loss.	13.	Determine loss of head due to A. Sudden enlargement B. Sudden contraction C. Friction in pipes	C03	
2. FLOW MEASUREMENT (ISO 2.1 – 2.4)					
S0 3.4	Determine the different types of flow Patterns.	14.	Determine the different types of flow Patterns by Reynolds's experiment	C03	
S0 3.5	Measure the flow characteristic.	15.	Measure the flow characteristic of given flowing fluids	C03	
3. FLOW THROUGH PIPES (ISO 3.1 – 3.5)					
S0 3.6	Calculate the minor losses of flow through pipes.	16.	Determination of minor losses of flow through pipes.	C03	
S0 4.1	Calculate the overall efficiency of the given turbine.	17.	Determine overall efficiency using Pelton turbine.	C04	
S0 4.1	Calculate the overall efficiency of the given turbine.	18.	Determine overall efficiency using Francis/Kaplan turbine.	C04	
S0 4.2	Determine the reaction force produced by the impact of a jet of water on to various target vanes.	19.	Investigate the reaction force produced by the impact of a jet of water on to various target vanes.	C04	
S0 4.3	Plot characteristics curve of the given turbine.	20.	Plot the characteristic curves of • Pelton wheel • Francis turbine • Kaplan turbine	C04	
4. HYDRAULIC TURBINES (ISO 4.1 – 4.3)					
	S0 5.1	Calculate overall efficiency of the given pump.	21.	Determine overall efficiency using Centrifugal pump.	C05
	S0 5.2	Determine overall efficiency of the given pump.	22.	Determine overall efficiency using Reciprocating pump.	C05
	S0 5.2	Determine the performance characteristics and power required for the given pump.	23.	Determine the power required to drive the given reciprocating pump.	C05
	S0 5.2	Determine the performance characteristics of the given pump.	24.	Determine the performance characteristics of • Centrifugal pump • Reciprocating pump	C05



———— Better Practice → Better Performance ————



Experiment No: - 01

Name of Experiment –

Use viscometer to determine the viscosity of a given liquid.

Apparatus and Materials Required

- Ostwald viscometer
- Stopwatch
- Specific gravity bottle (density bottle)
- Pipette
- Thermometer
- Distilled water
- Given test liquid



THEORY: -

Viscosity is the property of a fluid by virtue of which it resists the relative motion between its different layers. It is caused by the internal friction between the layers of the fluid.

A viscometer is an instrument used to determine the viscosity of a liquid by measuring the time required by the liquid to flow through a specified portion of the instrument.

For a comparative measurement using a standard liquid:

$$\frac{\eta_1}{\eta_2} = \frac{\rho_1 t_1}{\rho_2 t_2}$$

Therefore,

$$\eta_1 = \frac{\rho_1 t_1}{\rho_2 t_2} \times \eta_2$$

Where:-

η_1 = Viscosity of the given liquid

η_2 = Viscosity of the standard liquid

ρ_1 = Density of the given liquid

ρ_2 = Density of the standard liquid

t_1 = Flow time of the given liquid

t_2 = Flow time of the standard liquid

PROCEDURE -

1. Clean the viscometer thoroughly and make sure that it is completely dry.
2. Fix the viscometer vertically on a suitable stand.
3. Fill the viscometer with the given liquid up to the required level.
4. Note the temperature of the liquid using a thermometer.
5. Allow the liquid to attain a uniform temperature.
6. Allow the liquid to flow through the viscometer.
7. Start the stopwatch when the liquid passes the first reference mark.
8. Stop the stopwatch when the liquid reaches the second reference mark.
9. Record the flow time.
10. Repeat the observation at least three times and calculate the average flow time.
11. Repeat the same procedure for the standard liquid.
12. Use the observed values in the formula to calculate the viscosity of the given liquid.

OBSERVATION TABLE -

For the Given Liquid

S.N.	Temperature (°C)	Flow Time (s)
1.		
2.		
3.		

Mean Flow Time, $t_1 = \underline{\hspace{2cm}}$ s

For the Standard Liquid

S.N.	Temperature (°C)	Flow Time (s)
1.		
2.		
3.		

CALCULATION -

$$\eta_2 = \text{_____ Pa}\cdot\text{s}$$

$$\rho_1 = \text{_____ kg/m}^3$$

$$\rho_2 = \text{_____ kg/m}^3$$

$$t_1 = \text{_____ s}$$

Using,

$$t_2 = \text{_____ s}$$

$$\eta_1 = \frac{\rho_1 t_1}{\rho_2 t_2} \times \eta_2$$

Substituting the values:-

$$\eta_1 = \text{_____ Pa}\cdot\text{s}$$

Therefore,

$$\text{Viscosity of the given liquid} = \text{_____ Pa}\cdot\text{s}$$

RESULT

The viscosity of the given liquid was determined using a viscometer and was found to be _____ Pa·s.

PRECAUTIONS

(During the Experiment)

- 1** The viscometer should be clean and completely dry before use. 
- 2** The viscometer must be kept vertical during the experiment. 
- 3** The temperature of the liquid should remain constant. 
- 4** The liquid should be free from dust and air bubbles. 
- 5** The stopwatch should be operated carefully. 
- 6** The readings should be taken at eye level. 
- 7** Each observation should be repeated to obtain an accurate mean value. 
- 8** The viscometer should be cleaned properly after the experiment. 

Follow these precautions for safe and accurate results!



Viscometer

EXPERIMENT NO - 02

NAME OF THE EXPERIMENT -

To measure the rise of liquid level using capillary action in a capillary tube.

APPARATUS REQUIRED

1. Capillary tube
2. Beaker
3. Given liquid (e.g., water)
4. Measuring scale / Vernier scale
5. Stand and clamp
6. Thermometer
7. Tissue paper for cleaning

THEORY

Capillary action is the phenomenon in which a liquid rises or falls in a narrow tube due to the combined effects of adhesion between the liquid and the tube wall and cohesion between the liquid molecules.

The height of rise of a liquid in a capillary tube is given by

$$h = \frac{2T \cos \theta}{\rho g r}$$

h = height of rise of liquid (m)

T = surface tension of the liquid (N/m)

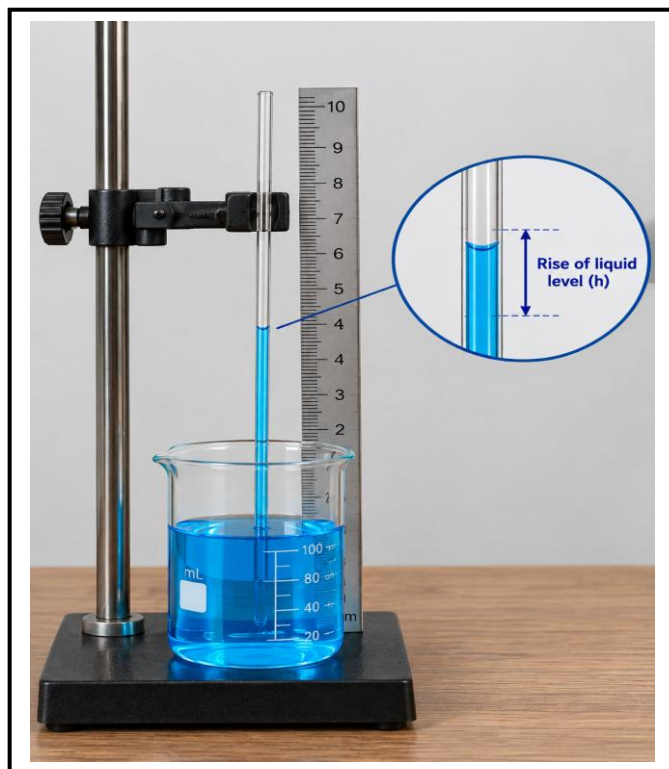
θ = angle of contact

ρ = density of liquid (kg/m³)

g = acceleration due to gravity (m/s²)

r = radius of capillary tube (m)

For water in a clean glass capillary tube, the angle of contact is approximately zero, so $\cos \theta \approx 1$.



PROCEDURE

1. Clean the capillary tube thoroughly and make it completely dry.
2. Fill a clean beaker with the given liquid.
3. Fix the capillary tube vertically with the help of a stand and clamp.
4. Dip the lower end of the capillary tube into the liquid.
5. Allow sufficient time for the liquid to reach a stable level inside the capillary tube.
6. Measure the level of the liquid in the beaker.
7. Measure the level of the liquid inside the capillary tube.
8. The difference between these two levels gives the height of rise (h) of the liquid.
9. Repeat the observation for different capillary tubes, if provided.
10. Take at least three readings and calculate the average height of rise.
11. Record all observations carefully in the observation table.

OBSERVATION TABLE -

S.N.	Radius of Capillary Tube (mm)	Liquid Level in Breaker (cm)	Liquid Level in Capillary Tube(cm)	Height of Rise, h (cm)
1.				
2.				
3.				

Average height of rise, h = _____ cm

CALCULATION

Height of rise,

$$h = \text{Liquid level in capillary tube} - \text{Liquid level in beaker}$$

For the observation:

$$h = \text{.....} - \text{.....}$$

$$h = \text{..... cm}$$

Average height of rise -

$$\bar{h} = \frac{h_1 + h_2 + h_3}{3}$$

$$\bar{h} = \underline{\hspace{2cm}} \text{ cm}$$

RESULT -

The rise of liquid level in the capillary tube due to capillary action was measured and found to be cm.

PRECAUTIONS

1. The capillary tube should be clean and completely dry.
2. The capillary tube must be kept vertical during the experiment.
3. The liquid should be free from dust and impurities.
4. Air bubbles should not be present inside the capillary tube.
5. The reading should be taken at eye level.
6. The capillary tube should not be touched with bare hands near the measuring region.
7. The liquid should be allowed to attain a stable level before taking the reading.
8. The experiment should be repeated to obtain accurate results.

CONCLUSION

The height of rise of the given liquid in a capillary tube was successfully measured using the principle of capillary action.

EXPERIMENT NO - 03

NAME OF THE EXPERIMENT -

To determine the specific gravity of the given fluid using a specific gravity bottle.

APPARATUS REQUIRED

1. Specific gravity bottle
2. Given fluid
3. Weighing balance
4. Distilled water
5. Beaker
6. Tissue paper
7. Funnel



THEORY -

Specific gravity is defined as the ratio of the density of a fluid to the density of water at the same temperature.

$$\text{Specific Gravity} = \frac{\text{Density of given fluid}}{\text{Density of water}}$$

Using a specific gravity bottle, the specific gravity can be determined from the masses of equal volumes of the given fluid and water.

Let:

- W_1 = Mass of empty specific gravity bottle
- W_2 = Mass of bottle filled with water
- W_3 = Mass of bottle filled with given fluid

Then,

$$\text{Mass of water} = W_2 - W_1$$

$$\text{Mass of given fluid} = W_3 - W_1$$

Therefore,

$$SG = \frac{W_3 - W_1}{W_2 - W_1}$$

PROCEDURE

1. Clean and dry the specific gravity bottle thoroughly.
2. Weigh the empty bottle with its stopper and note the mass as W_1 .
3. Fill the bottle completely with distilled water.
4. Insert the stopper carefully and remove any excess water from the outside.
5. Weigh the bottle filled with water and record the mass as W_2 .
6. Empty the bottle and clean it properly.
7. Fill the bottle completely with the given fluid.
8. Insert the stopper and wipe the outside of the bottle carefully.
9. Weigh the bottle filled with the given fluid and record the mass as W_3 .
10. Calculate the mass of water and the mass of the given fluid
10. Use the formula to calculate the specific gravity of the given fluid.

OBSERVATION TABLE -

S. No.	Observation	Symbol	Value
1	Mass of empty bottle	W_1	_____ g
2	Mass of bottle + water	W_2	_____ g
3	Mass of bottle + given fluid	W_3	_____ g
4	Mass of water	$W_2 - W_1$	_____ g
5	Mass of given fluid	$W_3 - W_1$	_____ g

CALCULATION -

Mass of water -

$$W_w = W_2 - W_1$$

$$\begin{aligned} W_w &= \text{_____} - \text{_____} \\ &= \text{_____} \text{g} \end{aligned}$$

Mass of given fluid-

$$W_f = W_3 - W_1$$

$$W_f = \underline{\hspace{2cm}} - \underline{\hspace{2cm}}$$
$$= \underline{\hspace{2cm}} \text{ g}$$

Specific gravity:-

$$SG = \frac{W_f}{W_w}$$

$$SG = \frac{W_3 - W_1}{W_2 - W_1}$$

$$SG = \underline{\hspace{2cm}}$$

RESULT -

The specific gravity of the given fluid was determined and found to be _____.

PRECAUTIONS

1. The specific gravity bottle should be clean and completely dry before use.
2. The bottle should be filled completely without air bubbles.
3. The stopper should be properly fitted during weighing.
4. Excess fluid should be removed from the outside of the bottle before weighing.
5. The weighing balance should be properly calibrated and set to zero.
6. The temperature of the water and given fluid should be approximately the same.
7. The bottle should be handled carefully to avoid loss of fluid.

CONCLUSION -

The specific gravity of the given fluid was successfully determined by comparing its mass with the mass of an equal volume of water.

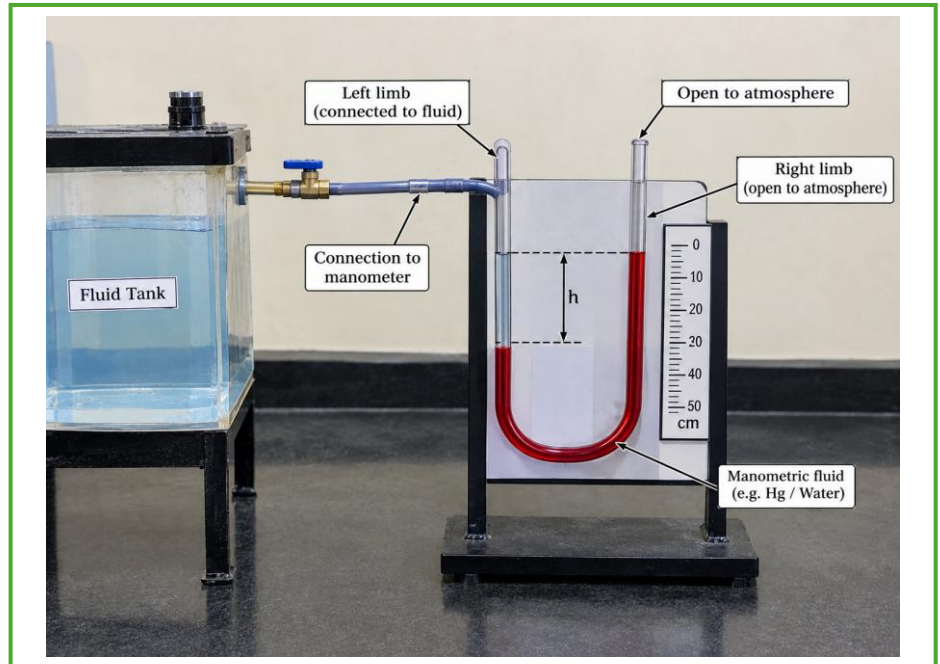
EXPERIMENT NO - 04

Name of Experiment:-

To measure the pressure of the given fluid using a manometer / inclined manometer

Apparatus Required -

1. Manometer / Inclined manometer
2. Fluid tank
3. Connecting tube
4. Control valve
5. Manometric fluid
6. Measuring scale
7. Given fluid



Theory -

A manometer is a pressure-measuring device that works on the principle of hydrostatic pressure. The pressure of the given fluid causes a difference in the levels of the manometric fluid.

For a simple manometer:

$$P = \rho_m g h$$

Where:

- P = pressure of the given fluid
- ρ_m = density of manometric fluid
- g = acceleration due to gravity
- h = difference in the levels of manometric fluid

For an inclined manometer, the vertical head is obtained from the inclined length:

$$h = L \sin \theta$$

Therefore,

$$P = \rho_m g L \sin \theta$$

Procedure -

1. Place the manometer on a firm and level surface.
2. Fill the manometer with the appropriate manometric fluid, ensuring that there are no air bubbles.
3. Connect one end of the manometer to the pressure point of the given fluid using a connecting tube.
4. Keep the other limb open to the atmosphere, if an open manometer is being used.
5. Open the control valve slowly and allow the pressure to stabilize.
6. Observe the levels of the manometric fluid in both limbs.
7. Note the difference in liquid levels h .
8. For an inclined manometer, note the length L along the inclined tube and the inclination angle θ .
9. Calculate the vertical head using:

$$h = L \sin \theta$$

10. Calculate the pressure using the appropriate manometer equation.

Observation Table –

S.N.	Manometric fluid	Difference in level $h(\text{m})$	Inclined length $L(\text{m})$	Angle θ	Pressure $P(\text{Pa})$
01					

Calculation -

For a vertical manometer:

$$P = \rho_m g h$$

For an inclined manometer:

$$h = L \sin \theta$$

Hence,

$$P = \rho_m g L \sin \theta$$

Substitute the observed values to obtain the pressure of the given fluid.

Result -

The pressure of the given fluid is found to be:

$$P = \text{_____ Pa}$$

Precautions -

1. Ensure that the manometer is properly connected and free from leakage.
2. Remove air bubbles from the connecting tube.
3. Take the readings only after the liquid levels become steady.
4. Read the liquid level at eye level to avoid parallax error.
5. Do not open the control valve suddenly.
6. Keep the manometer properly positioned during the experiment.
7. Use the correct density of the manometric fluid in calculations.

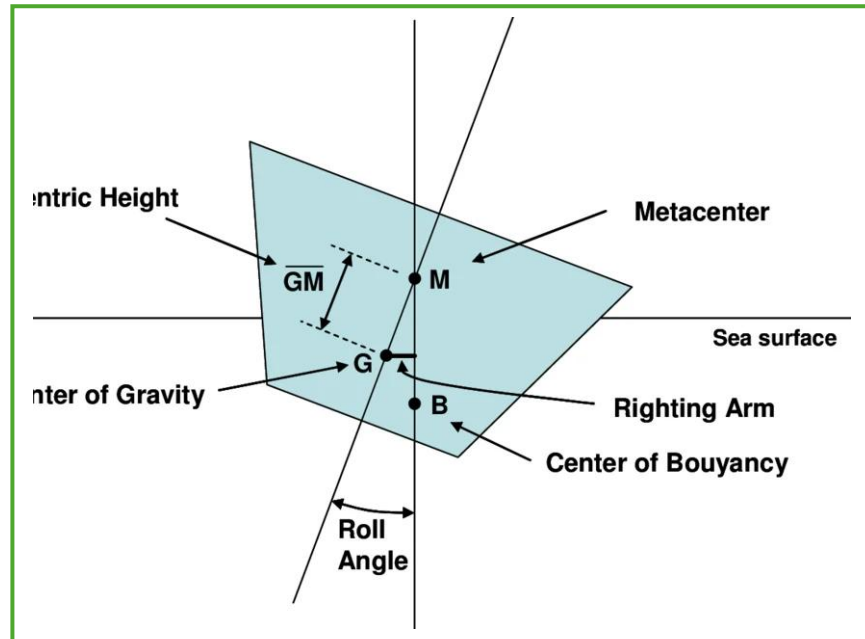
EXPERIMENT NO - 05

Name of Experiment –

To determine the metacentric height of a ship model

Apparatus Required -

1. Ship model
2. Metacentric height apparatus
3. Plumb bob and pointer
4. Horizontal movable weight
5. Vertical movable weight
6. Measuring scale
7. Water tank
8. Spirit level
9. Weights and weight hanger



Theory -

The metacentric height (GM) is the vertical distance between the centre of gravity (G) and the metacentre (M) of a floating body. The metacentric height is an important parameter for determining the stability of a floating body. When a weight was moved transversely through a distance x , the ship model inclines through an angle θ .

The heeling moment is -

$$W \times x$$

The restoring moment is:

$$W \times GM \times \tan \theta$$

Therefore,

$$wx = W(GM) \tan \theta$$

Hence,

$$GM = \frac{wx}{W \tan \theta}$$

Where:

- GM = metacentric height
- w = weight moved transversely
- x = transverse distance through which the weight is moved
- W = total weight of the ship model
- θ = angle of heel

Procedure

1. Place the ship model gently in the water tank.
2. Ensure that the model is floating freely and is not touching the sides or bottom of the tank.
3. Check that the model is initially in an approximately upright position.
4. Determine the total weight W of the ship model.
5. Attach a known weight w to the transverse movable arrangement.
6. Move the weight through a known transverse distance x .
7. Observe the inclination of the ship model using the plumb bob and pointer arrangement.
8. Measure the displacement of the pointer or plumb bob.
9. Determine the angle of heel θ .
10. Repeat the experiment for different positions of the movable weight.
11. Calculate the metacentric height using:

$$GM = \frac{wx}{W \tan \theta}$$

16. Take the mean value of GM from the observations.

Observation Table -

S. No. Total weight W (N) Movable weight w (N) Distance moved x (m) Angle of heel θ GM (m)

1	_____	_____	_____	_____	_____
2	_____	_____	_____	_____	_____
3	_____	_____	_____	_____	_____

Calculation -

Using -

$$GM = \frac{wx}{W \tan \theta}$$

Substitute the observed values-

$$GM = \frac{(\quad)(\quad)}{(\quad)\tan(\quad)}$$

$$\boxed{GM = \quad \text{m}}$$

Result

The metacentric height of the given ship model is -

$$\boxed{GM = \quad \text{m}}$$

Precautions

1. The ship model should float freely without touching the tank.
2. The movable weight should be shifted slowly and accurately.
3. The model should be allowed to come to rest before taking the reading.
4. Avoid sudden movement or disturbance of the water.
5. Read the scale carefully to avoid parallax error.
6. Ensure that the plumb bob and pointer are properly aligned.
7. Take multiple readings and use their mean value for greater accuracy.

EXPERIMENT NO - 06

Name of Experiment –

To determine the co-efficient of discharge of the given Venturi meter.

Theory -

Venturimeter has two sections. One divergent area and the other throat area. The former is represented as a_1 and the later is a_2 water or any other liquid flows through the venturimeter and it passes to the throat area the value of discharge is same at a_1 and a_2

Apparatus Required -

1. Venturimeter
2. Differential U tube
3. Collecting tank
4. Stop watch
5. Scale

Procedure -

1. Measure the length and breadth of the collecting tank

$$L = \quad \text{m} ,$$

$$B = \quad \text{m}$$

2. Open the respective valve in the pipeline and close all the valves. Adjust the flow suitably.
3. Note the limb reading (h_1) m and the right limb reading (h_2) m of the manometer.
4. Close the drain valve of the collecting tank.
5. Find the time taken for 10 cm (t) rise of water level in the collecting tank.
6. Repeat the experiment for the different flow rates and through different flow meters.

Calculation -

$$Q_{\text{act}} = \frac{A \times R}{t} \quad (\text{m}^3 / \text{sec})$$

Where ,

A = area of collecting tank in m^2 ($A = L \times B \text{ m}^2$)

R = Height of collected water in tank = 10 cm (0.1m)

t = time taken for 10 cm rise of water

Theoretical Discharge -

$$Q_{\text{the}} = K \sqrt{h} \quad \text{m}^3 / \text{sec}$$

Where,

$$K = \frac{a_1 \times a_2 \sqrt{2g}}{\sqrt{a_1^2 - a_2^2}}$$

a_1 = area of inlet pipe in m^2

$$a_1 = \frac{\pi}{4} \times d_1^2$$

a_2 = area of the throat in m^2

$$a_2 = \frac{\pi}{4} \times d_2^2$$

g = specific gravity in m/sec^2

$h = (h_1 - h_2) / (S_m / S_{2-1})$ m of water column

h_1 = Manometric head in the first limbs (m)

h_2 = Manometric head in the second limbs (m)

S_m = Specific Gravity of Mercury (13.06)

Co- Efficient of Discharge -

$$C_d = \frac{Q_{\text{act}}}{Q_{\text{the}}} \quad , \text{ (no unit)}$$

HEAD VS ACTUAL DISCHARGE (Q_{act})

The difference of head is increased when Q_{act} is increasing.

Q_{act} VS Q_{the}

The Q_{the} is increased when Q_{act} is increasing

C_d VS Q_{act}

C_d is increased when Q_{act} is increasing

- The coefficient of discharge through venture meter is
- Thus the coefficient of discharge of the given venture meter is found using the tabulation calculation and graph

EXPERIMENT NO - 07

Name of Experiment –

Determine Coefficient of Discharge, coefficient of contraction and coefficient of velocity of Orifice meter.

Apparatus Required –

1. Orifice tank
2. Orifice plate
3. Measuring tank
4. Measuring cylinder
5. Pressure head arrangement
6. Stopwatch
7. Scale
8. Vernier caliper
9. Water supply arrangement

Theory -

When water flows through an orifice, the jet contracts after passing through the orifice. The minimum cross-sectional area of the jet is called the vena contracta.

The three important coefficients are:

1. Coefficient of Discharge (C_d) -

$$C_d = \frac{Q_{actual}}{Q_{theoretical}}$$

2. Coefficient of Contraction (C_c) -

$$C_c = \frac{A_c}{A_o}$$

Where,

A_c = Area of jet at vena contracta

A_o = Area of orifice

3. Coefficient of Velocity (C_v)

$$C_v = \frac{V_{actual}}{V_{theoretical}}$$

$$C_d = C_c \times C_v$$

Procedure -

1. Measure the diameter of the orifice accurately using a vernier caliper.
2. Fill the orifice tank with water.
3. Allow water to flow through the orifice and obtain a steady head of water.
4. Measure the head of water above the centre of the orifice.
5. Collect the discharged water in the measuring tank for a known time.
6. Measure the volume of water collected.
7. Determine the actual discharge -

$$Q_{\text{actual}} = \frac{v}{t}$$

8. Measure the dimensions of the jet at the vena contracta to determine its area.
9. Calculate the theoretical velocity

$$V_{\text{velocity}} = \sqrt{2gH}$$

10. Calculate C_d , C_c , and C_v using the above equations.

Observation Table-

S.N.	Head $H(\text{m})$	Volume $V(\text{m}^3)$	Time $t(\text{s})$	Actual Discharge $Q(\text{m}^3/\text{s})$	Jet Area $A_c(\text{m}^2)$
01					
02					
03					

Calculations

Theoretical velocity -

$$V_{\text{th}} = \sqrt{2gH}$$

Actual discharge

$$Q_{\text{act}} = \frac{V}{t}$$

Theoretical discharge –

$$Q_{th} = A_0 \sqrt{2gH}$$

Therefore,

$$C_d = \frac{Q_{actual}}{Q_{theoretical}}$$

$$C_c = \frac{A_c}{A_o}$$

$$C_v = \frac{V_{actual}}{V_{theoretical}}$$

Result

The coefficients of the given orifice are determined as

$C_d =$ _____

$C_c =$ _____

$C_v =$ _____

Precautions

1. Maintain a constant head during the experiment.
2. Ensure that there is no leakage from the apparatus.
3. Take accurate measurements of the orifice and jet diameter.
4. Start and stop the stopwatch carefully.
5. Avoid air bubbles in the water flow.
6. Take multiple observations and use their average value.

Experiment – 08

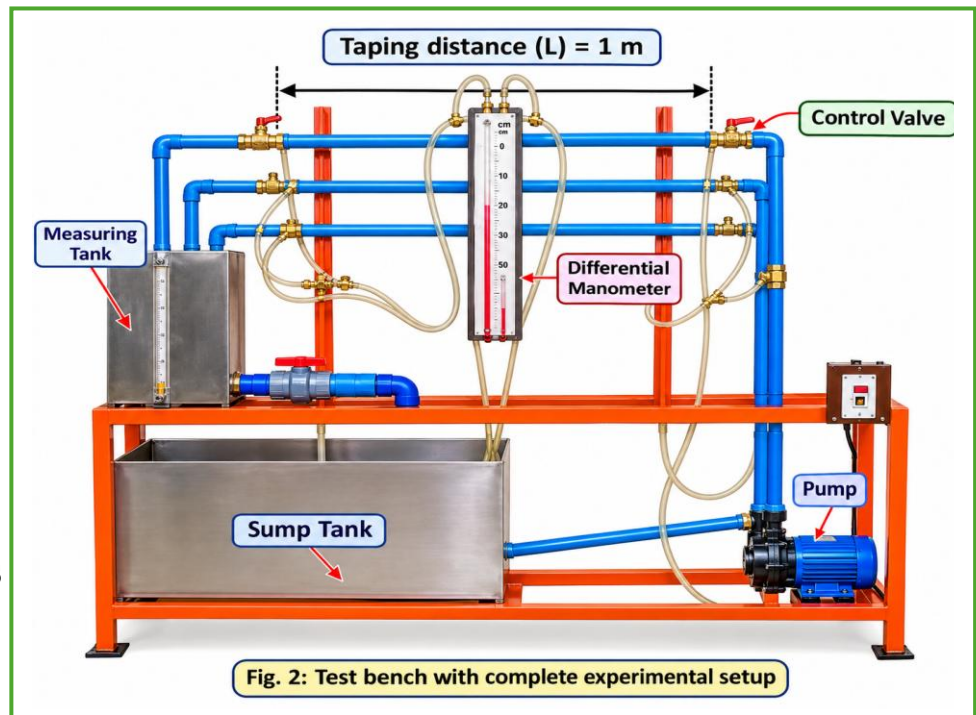
Name of Experiment –

Determine Coefficient of Friction of Flow Through Pipes

Apparatus Required

1. Pipe friction apparatus
2. Differential manometer
3. Measuring tank
4. Stopwatch
5. Measuring cylinder
6. Scale
7. Connecting pipes and valves

Theory:-



When a fluid flows through a pipe, friction between the fluid and the pipe wall causes a loss of pressure or head. This loss is known as frictional head loss.

According to Darcy–Weisbach equation:

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

Therefore,

$$f = \frac{2gh_f D}{LV^2}$$

Where,

f = coefficient of friction

h_f = frictional head loss (m)

L = length of pipe (m)

D = diameter of pipe (m)

V = mean velocity of flow (m/s)

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

Discharge is -

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

and velocity -

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

For a circular pipe -

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

Procedure -

1. Fill the supply tank with water and remove air from the system.
2. Open the inlet and outlet valves gradually.
3. Allow water to flow steadily through the test pipe.
4. Note the differential head from the manometer.
5. Collect a known quantity of water in the measuring tank.
6. Note the time required to collect the water.
7. Calculate discharge (Q) and velocity (V).
8. Calculate the frictional head loss (h_f).
9. Use the Darcy–Weisbach equation to determine the coefficient of friction.
10. Repeat the experiment for different flow rates and calculate the average value.

Observation Table -

S.N.	Head Difference $h_f(m)$	Volume V (m^3)	Times t sec	Discharge Q (m^3/s)	Velocity V (m/s)	Coefficient f
01						
02						
03						
04						

Result –

The coefficient of friction of flow through the given pipe is

Precautions -

- 1. Ensure that there is no air trapped in the manometer tubes.**
- 2. Maintain steady flow during observations.**
- 3. Open the valves gradually.**
- 4. Take accurate readings of head difference and discharge.**
- 5. Avoid leakage from pipe joints.**
- 6. Take the average of repeated observations for better accuracy**

Experiment – 09

Name of Experiment –

To verify the Bernoulli's theorem

Apparatus Required

1. Supply tank of water
2. Tapered inclined pipe fitted with no. of piezometer tubes point
3. Measuring tank
4. Scale
5. Stop Watch

Theory:-

Bernoulli's theorem states that when there is a continuous connection between the particle of flowing mass liquid, the total energy of any sector of flow will remain same provided there is no reduction or addition at any point Formula Used :-

$$\frac{P}{\rho g} + \frac{V^2}{2g} + z = \text{Constant}$$

Where,

P = Pressure head

$\frac{V^2}{2g}$ = Velocity head

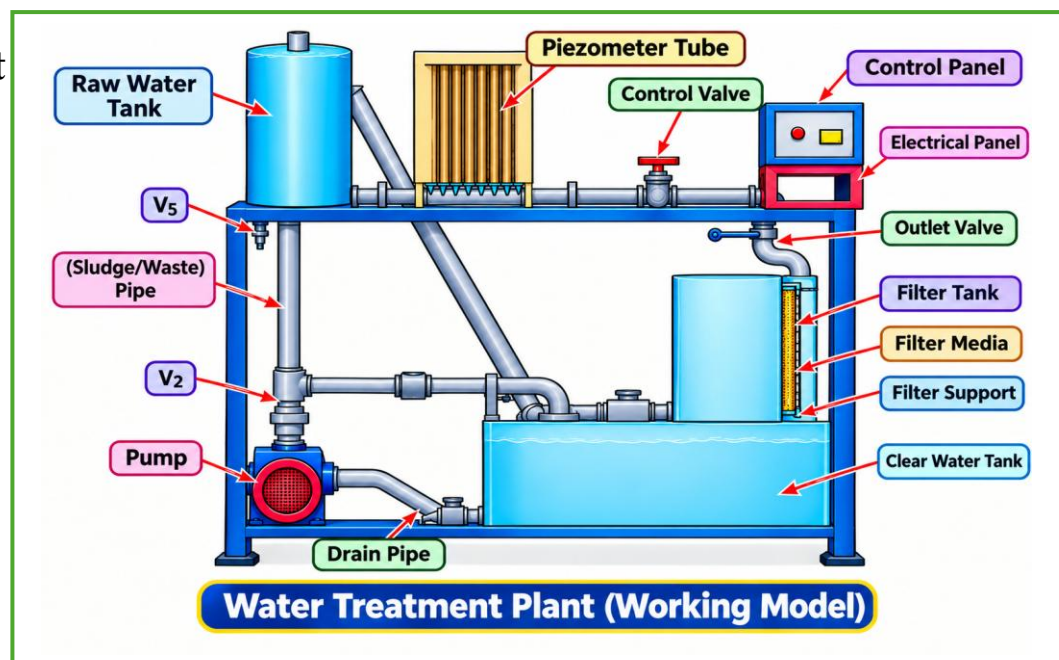
Z = Datum head

P = Pressure of fluid

ρ = Density of fluid

V = Velocity of fluid

g = Acceleration due to gravity



Therefore,

Total Head = Pressure Head + Velocity Head + Datum Head

Procedure

1. Fill the supply tank with water and remove air bubbles from the system.
2. Allow water to flow through the Bernoulli apparatus.
3. Adjust the control valve to obtain a steady flow.

4. Note the water levels in all piezometer tubes.
5. Collect a known quantity of water in the measuring tank.
6. Record the time required to collect the water.
7. Calculate the discharge $Q = \frac{V}{t}$
8. Calculate the velocity at each section $V = \frac{Q}{A}$
9. Calculate the velocity head $\frac{V^2}{2g}$
10. Calculate the total head at each section

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

11. Compare the total head at different sections.

Observation Table –

S.N.	Area (A)	Piezometer Head (P/ρg)	Velocity (V)	Velocity Head ($\frac{V^2}{2g}$)	Datum Head (Z)	Total Head
01						
02						
03						
04						

Result-

The total head at different sections of the pipe is found to be approximately constant. Hence, Bernoulli's theorem is verified experimentally.

Precautions -

1. The flow should be steady.
2. Air bubbles should be removed from the piezometer tubes.
3. Readings should be taken at eye level.
4. The discharge should be measured accurately.
5. Sudden changes in flow should be avoided.

Experiment – 10

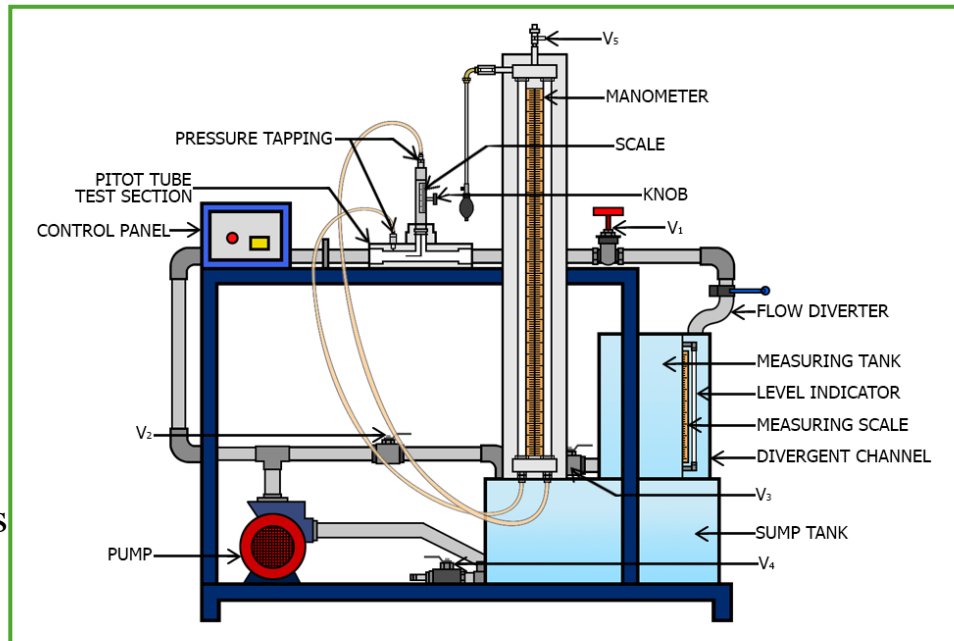
Name of Experiment-

Determine Discharge Through a Given Pipe Using Orifice Meter, Pitot Tube and Venturi Meter

Apparatus Required

- Orifice meter
- Pitot tube
- Venturi meter
- Pressure gauges/manometer
- Measuring tank
- Stopwatch
- Water supply arrangement
- Connecting pipes and valves

Theory -



The discharge through a pipe is given by

$$Q = A \times V$$

Where,

Q = Discharge (m^3/s)

A = Cross-sectional area of pipe (m^2)

V = Mean velocity of flow (m/s)

1. Orifice Meter

The theoretical discharge is:

$$Q_{th} = \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh}$$

Actual discharge

$$Q = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh}$$

Where C_d is the coefficient of discharge.

2. Venturi Meter

The discharge is ,

$$Q = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh}$$

Where:

A_1 = Area at inlet

A_2 = Area at throat

h = Differential pressure head

C_d = Coefficient of discharge

3. Pitot Tube

The velocity of flow is determined from:

$$V = C_v \sqrt{2gh}$$

Therefore,

$$Q = AV$$

Where C_v is the coefficient of velocity.

Procedure

1. Fill the water supply tank and start the pump.
2. Open the control valve and allow water to flow steadily through the pipe.
3. For the orifice meter, note the differential head from the manometer.
4. Measure the discharge by collecting a known volume of water in the measuring tank for a known time.
5. Repeat the procedure for different flow rates.
6. For the Venturi meter, note the pressure difference between the inlet and throat.
7. Calculate the velocity and discharge using the Venturi-meter equation.
8. For the Pitot tube, note the difference in pressure head.
9. Calculate the velocity using the Pitot-tube equation and hence determine discharge.
10. Compare the calculated discharge with the measured discharge.

Observation Table

S. No.	Instrument	Differential Head(h)	Time(t)	Collected Volume (V)	Discharge (Q)
1	Orifice Meter				
2	Venturi Meter				
3	Pitot Tube				

Experiment – 11

Name of Experiment -

To determine the coefficient of contraction (C_c), coefficient of discharge (C_d) and coefficient of velocity (C_v) for different types of orifices.

Apparatus Required -

1. Orifice tank
2. Different types of orifices
3. Measuring tank
4. Stopwatch
5. Hook gauge
6. Measuring scale
7. Water supply arrangement

Theory -

When water flows through an orifice, the jet contracts after passing through the orifice. The minimum cross-sectional area of the jet is called the vena contracta.

1. Coefficient of Contraction

$$C_c = \frac{A_c}{A_o}$$

Where:

A_c = Area of jet at vena contracta

A_o = Area of orifice

2. Coefficient of Velocity

$$C_v = \frac{V_{actual}}{V_{theoretical}}$$

The theoretical velocity is:

$$V_{th} = \sqrt{2gH}$$

Therefore,

$$C_v = \frac{V_{actual}}{\sqrt{2gH}}$$

3. Coefficient of Discharge

$$C_d = \frac{Q_{actual}}{Q_{theoretical}}$$

For an orifice:

$$Q_{theoretical} = A_o \sqrt{2gH}$$

Hence,

$$C_d = \frac{Q_{actual}}{A_o \sqrt{2gH}}$$

Also,

$$\boxed{C_d = C_c \times C_v}$$

Procedure

1. Fill the orifice tank with water.
2. Fix the required orifice in the tank.
3. Maintain a constant water head above the orifice.
4. Allow the water jet to discharge freely.
5. Locate the vena contracta and measure the dimensions of the contracted jet.
6. Measure the head H above the centre of the orifice.
7. Collect a known volume of water in the measuring tank.
8. Note the time required for collection.
9. Calculate the actual discharge:

$$Q_{actual} = \frac{V}{t}$$

10. Calculate C_c , C_v and C_d .
11. Repeat the experiment for different types of orifices and compare the values.

Observation Table

S. No.	Type of Orifice	Head H	Orifice Area A_o	Jet Area A_c	Actual Discharge Q	C_c	C_v	C_d
1								
2								
3								

Result -

The values of C_c , C_d and C_v are determined for the given different types of orifices.

Experiment – 12

Name of Experiment –

To determine the loss of head in a pipe due to

A. Sudden Enlargement

B. Sudden Contraction

C. Friction in Pipes

Apparatus Required

(i) Hydraulic bench

(ii) Test pipe arrangement

(iii) Pressure tapping points

(iv) Piezometer / Manometer

(v) Measuring tank

(vi) Stopwatch

(vii) Measuring scale

(viii) Valves and fittings

Theory

A. Loss of Head Due to Sudden Enlargement –

When the diameter of a pipe suddenly increases, the velocity of flow decreases and energy is lost due to eddies and turbulence.

$$h_e = \frac{(V_1 - V_2)^2}{2g}$$

Where -

h_e = Head loss due to sudden enlargement

V_1 = Velocity in the smaller pipe

V_2 = Velocity in the larger pipe

g = Acceleration due to gravity

B. Loss of Head Due to Sudden Contraction -

When the diameter of a pipe suddenly decreases, the flow contracts and then expands, resulting in energy loss.

$$h_e = \left(\frac{1}{C_c} - 1 \right)^2 \times \frac{V_2^2}{2g}$$

Where –

h_e = Head loss due to sudden contraction

C_c = Coefficient of contraction

V_2 = Velocity in the smaller pipe

g = Acceleration due to gravity

C. Loss of Head Due to Friction in Pipes -

When water flows through a pipe, friction between the fluid and the inner surface of the pipe causes loss of head.

According to Darcy-Weisbach equation:

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

Where -

h_f = Head loss due to friction

f = Friction factor

L = Length of pipe

D = Diameter of pipe

V = Mean velocity of flow

g = Acceleration due to gravity

Procedure -

1. Set up the hydraulic bench and experimental pipe arrangement.
2. Check all connections and valves for leakage.
3. Start the water supply and remove air bubbles from the system.
4. Allow the flow to become steady.
5. Note the pressure readings at the required tapping points.
6. Measure the discharge using the measuring tank and stopwatch.
7. For sudden enlargement, record the pressure difference across the enlarged section.

8. For sudden contraction, record the pressure difference across the contracted section.
9. For friction loss, record the pressure difference across a known length of straight pipe.
10. Repeat the experiment for different discharge rates.
11. Calculate the head loss for each condition and compare the experimental results with theoretical values.

Calculations

Discharge

$$Q = \frac{V_0}{t}$$

Velocity of flow

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

Head loss = Upstream head – Downstream head

Result -

The loss of head was determined experimentally due to

1. Sudden Enlargement
2. Sudden Contraction
3. Friction in Pipes

Precautions -

- (i) Ensure that there are no air bubbles in the pipeline.
- (ii) All pipe connections should be leak-proof.
- (iii) Take manometer readings at eye level.
- (iv) Maintain a steady flow during observations.
- (v) Record discharge and pressure readings carefully.
- (vi) Take repeated readings for better accuracy.

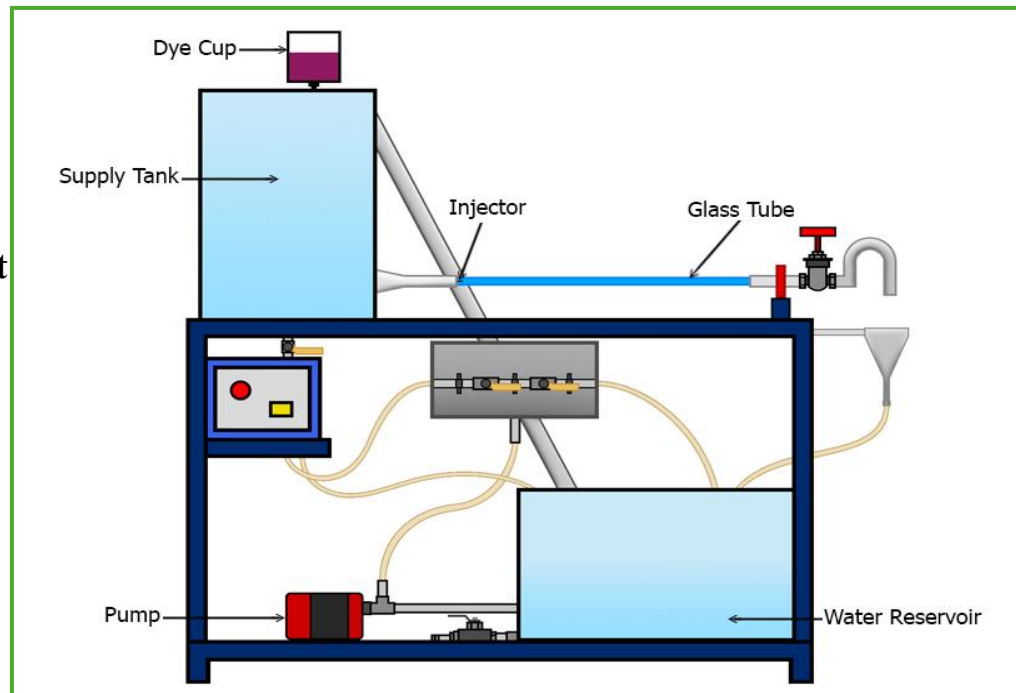
Experiment No – 13

Name of Experiment -

To determine the different types of flow patterns in a pipe using Reynolds' experiment and to determine the corresponding Reynolds number.

Apparatus Required -

- Reynolds apparatus
- Transparent glass tube
- Water supply tank
- Dye injection arrangement
- Dye solution
- Control valve
- Measuring cylinder
- Stopwatch
- Connecting pipes



Theory -

Reynolds number is a dimensionless number used to determine the nature of flow of a fluid.

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

Where -

Re = Reynolds number

ρ = Density of fluid

V = Mean velocity of flow

D = Diameter of pipe

μ = Dynamic viscosity

ν = Kinematic viscosity

Types of Flow

1. Laminar Flow -

When the dye filament flows in a straight and smooth line without mixing with the surrounding water, the flow is called laminar flow.

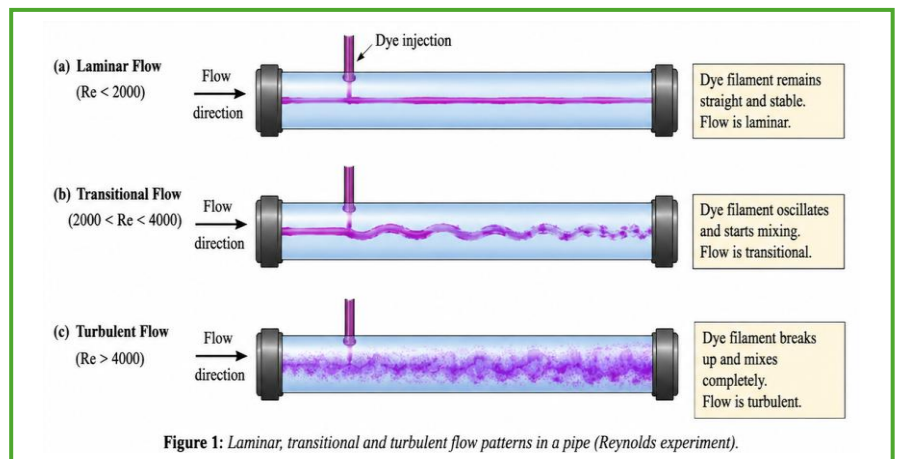


Figure 1: Laminar, transitional and turbulent flow patterns in a pipe (Reynolds experiment).

$$Re < 2000$$

2. Transitional Flow -

When the dye filament becomes unstable and starts wavering or mixing partially with the surrounding water, the flow is called transitional flow.

$$2000 < Re < 4000$$

3. Turbulent Flow -

When the dye mixes completely with the surrounding water and the flow becomes irregular, the flow is called turbulent flow.

$$Re > 4000$$

Procedure

1. Fill the supply tank with clean water.
2. Start the water supply and allow a steady flow through the transparent glass tube.
3. Fill the dye reservoir with a suitable dye solution.
4. Open the dye valve slightly so that a thin dye filament enters the flowing water.
5. Keep the flow rate low and observe the dye filament.
6. Measure the discharge for the selected flow condition.
7. Gradually increase the flow rate by opening the control valve.
8. Observe the change in the dye pattern.
9. Repeat the observations for different discharge rates.
10. Calculate the velocity and Reynolds number for each observation.
11. Identify the flow pattern as laminar, transitional, or turbulent.

Observation Table -

S.No.	Discharge Q	Area A	Velocity V	Reynolds No. Re	Flow Pattern
1					Laminar
2					Transitional
3					Turbulent

Calculation

Discharge:

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

Velocity:

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

Reynolds number:

$$Re = \frac{VD}{\nu}$$

Result -

The different types of flow patterns were determined by Reynolds' experiment:

- **Laminar Flow: $Re < 2000$**
- **Transitional Flow: $2000 < Re < 4000$**
- **Turbulent Flow: $Re > 4000$**

Precautions -

1. The water flow should be steady during observations.
2. The dye should be injected slowly and continuously.
3. The glass tube should be clean and free from air bubbles.
4. Avoid sudden changes in the flow rate.
5. Take accurate discharge and time measurements.
6. Observe the dye filament carefully.

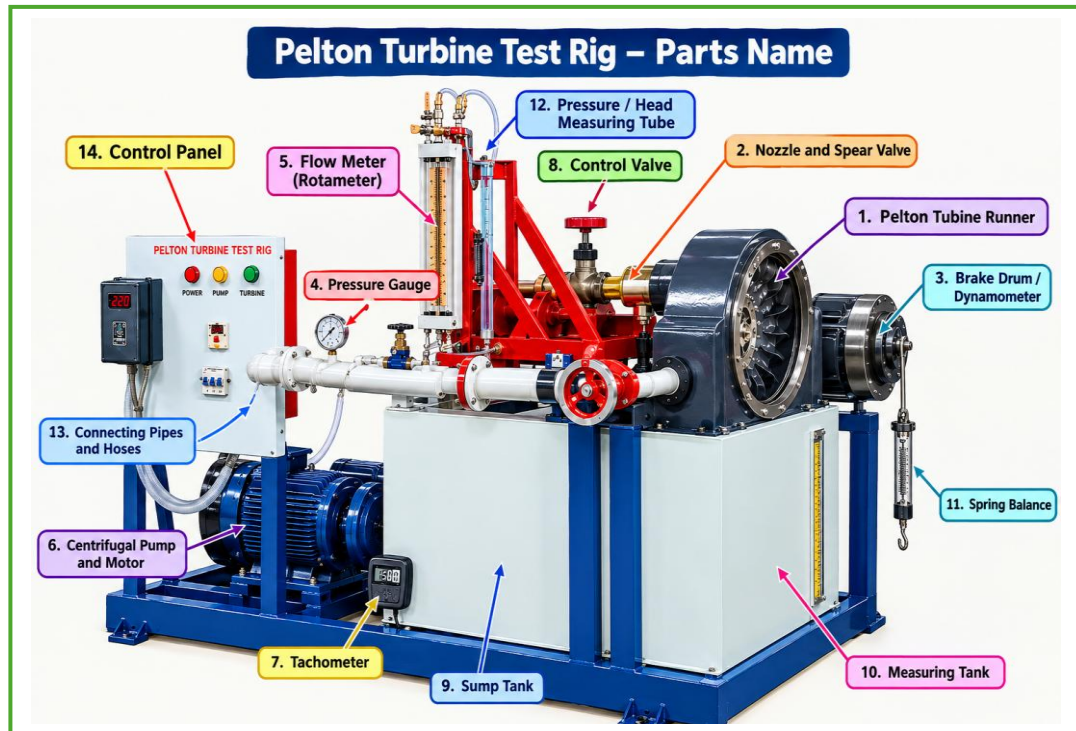
Experiment No – 14

Name of Experiment-

To conduct performance test on pelton turbine under various heads, speeds and loads and to plot the operating characteristics.

Apparatus Required -

- Pelton turbine test rig
- Water supply pump
- Pressure gauge
- Tachometer
- Brake drum or dynamometer
- Measuring tank
- Stopwatch
- Control valve
- Load arrangement



Theory –

A Pelton turbine is an impulse turbine that converts the kinetic energy of a high-velocity water jet into mechanical energy. Water from a nozzle strikes the buckets mounted on the runner, causing it to rotate.

The performance of a Pelton turbine is evaluated by determining its discharge, input power, output power and efficiency under different operating conditions.

Important Formulae

Discharge –

$$Q = \frac{A_t R}{t}$$

Where:

A_t = area of measuring tank (m^2)

R = rise in water level (m)

t = time taken (s)

Input Power -

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

Output Power:

For a brake drum or rope brake-

$$P_{out} = \frac{2\pi NT}{60}$$

Where $T = (W - S)r$

N = turbine speed (rpm)

T = torque (N·m)

W = applied load (N)

S = spring balance reading (N)

r = effective radius of brake drum (m)

Efficiency-

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

Procedure -

1. Fill the sump tank with sufficient water and check all pipe connections.
2. Start the pump and allow water to flow through the Pelton turbine nozzle.
3. Adjust the control valve to obtain the required operating head.
4. Measure the water head using the pressure gauge.
5. Record the turbine speed using a tachometer.
6. Apply a small load to the brake drum or dynamometer.
7. Record the applied load and spring balance reading.
8. Measure the discharge using the measuring tank and stopwatch.
9. Repeat the observations for different loads while maintaining the selected head.
10. Change the operating head and repeat the test for different heads and speeds.
11. Calculate input power, output power and efficiency for each observation.
12. Plot the operating characteristics of the turbine.

Observation Table –

S.N.	Head, H (m)	Speed, N (rpm)	Load, W (N)	Spring balance, S(N)	Discharge, Q (m ³ /s)
01					
02					
03					
04					
05					

Calculation -

For each observation, calculate:

1. Discharge, (Q)
2. Input power, (P_{in})
3. Torque, (T)
4. Output power, (P_{out})
5. Efficiency, (η)

Operating Characteristics

Plot the following graphs using the experimental readings:

- Efficiency vs. Speed: Speed (rpm) on the X-axis and efficiency (%) on the Y-axis.
- Output Power vs. Speed: Speed (rpm) on the X-axis and output power (W) on the Y-axis.
- Torque vs. Speed: Speed (rpm) on the X-axis and torque (N·m) on the Y-axis.
- Efficiency vs. Load: Load (N) on the X-axis and efficiency (%) on the Y-axis.

Different operating heads should be represented by separate curves on the same graph for comparison.

Result -

The performance test of the Pelton turbine was conducted under various heads, speeds and loads. The input power, output power and efficiency were calculated, and the operating characteristics were plotted.

Precautions -

1. Check all water connections for leakage before starting the experiment.
2. Maintain a steady water head during each set of readings.
3. Apply the load gradually and uniformly.
4. Take speed readings only after the turbine reaches steady operation.
5. Ensure that the measuring tank is empty before starting each discharge measurement.
6. Do not exceed the maximum rated speed, head or load of the turbine test rig.

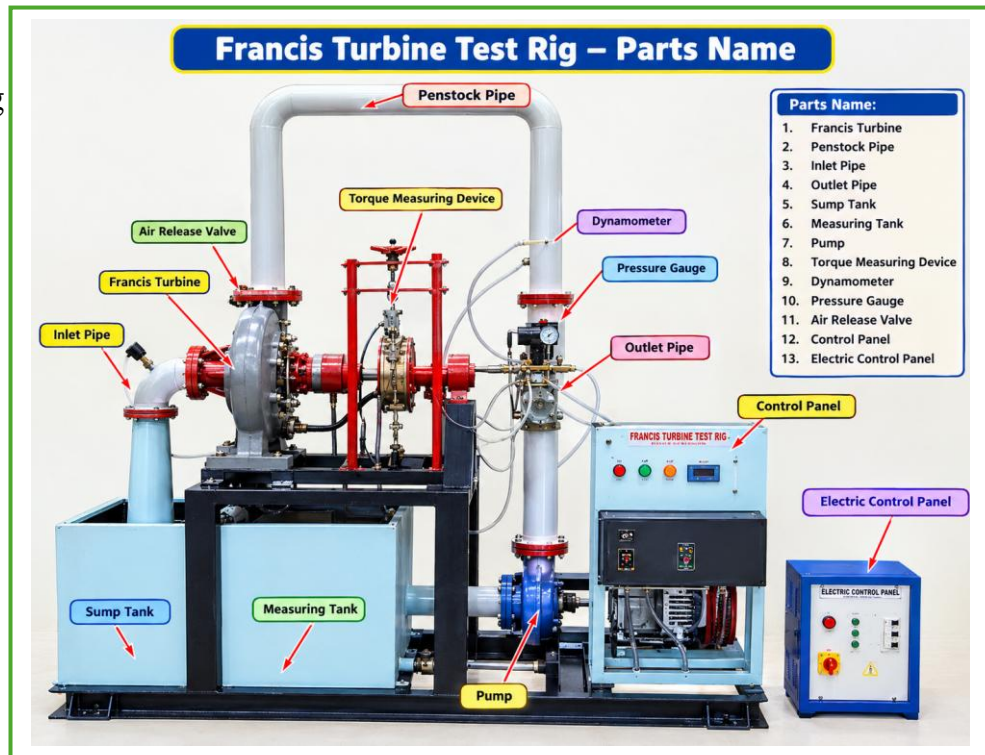
Experiment No – 15

Name of Experiment-

Determine overall efficiency using Francis/Kaplan turbine.

Apparatus Required -

1. Francis/Kaplan turbine test rig
2. Hydraulic pump
3. Pressure gauge
4. Tachometer
5. Brake drum or dynamometer
6. Measuring tank
7. Stopwatch
8. Control valve
9. Sump tank



Theory -

Francis and Kaplan turbines are reaction turbines that convert the hydraulic energy of water into mechanical energy.

Francis turbine:- A mixed-flow reaction turbine in which water enters the runner radially and leaves axially.

Kaplan turbine:- An axial-flow reaction turbine with adjustable runner blades, generally used for low-head and high-discharge conditions.

The overall efficiency is the ratio of the mechanical power produced by the turbine to the hydraulic power supplied to it.

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

η = overall efficiency (%)

P_{out} = mechanical output power (W)

P_{in} = hydraulic input power (W)

Important Formulae

1. Discharge-

$$Q = \frac{A_t R}{t}$$

Where:

A_t = area of measuring tank (m^2)

R = rise in water level (m)

t = time taken (s)

2. Hydraulic Input Power-

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

Where

ρ = density of water (1000 kg/m^3)

g = acceleration due to gravity (9.81 m/s^2)

Q = discharge (m^3/s)

H = net head supplied to the turbine (m)

3. Mechanical Output Power

For a brake drum or dynamometer:

$$P_{out} = \frac{2\pi NT}{60}$$

Where $T = (W - S)r$

N = turbine speed (rpm)

T = torque ($N \cdot m$)

W = applied load (N)

S = spring balance reading (N)

r = effective radius of brake drum (m)

Overall Efficiency –

$$P_{out} = \frac{2\pi NT}{60\rho g Q H} \times 100$$

Procedure -

1. Fill the sump tank with sufficient water and check all pipe connections.
2. Start the pump and allow water to flow through the turbine.
3. Adjust the control valve to obtain the required operating head.
4. Record the net head using the pressure gauge or head-measuring arrangement.
5. Measure the turbine speed using a tachometer.
6. Apply a suitable load to the brake drum or dynamometer.
7. Record the load and spring balance readings, if fitted.
8. Measure the discharge using the measuring tank and stopwatch.
9. Repeat the experiment for different loads while maintaining a steady head.
10. Calculate the input power, output power and overall efficiency for each observation.
11. Repeat the test at different heads, if required.

Observation Table -

S.N.	Head, H (m)	Speed, N (rpm)	Load, W (N)	Spring balance, S(N)	Discharge, Q (m ³ /s)
01					
02					
03					
04					
05					

Calculation -

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

η = overall efficiency (%)

P_{out} = mechanical output power (W)

P_{in} = hydraulic input power (W)

Result –

The overall efficiency of the given Francis/Kaplan turbine is determined experimentally and found to be _____ % at the specified operating head, speed and load.

Precautions -

1. Check all pipe connections for leakage before starting the experiment.
2. Maintain a steady water head during each observation.
3. Apply the load gradually and uniformly.
4. Take readings only after the turbine reaches steady operation.
5. Measure discharge and time accurately.
6. Do not exceed the rated head, speed or load of the turbine test rig.