Laboratory Manual

Fluid Mechanics Lab

(CEN 012130)

Department of Civil Engineering
Central University of Jharkhand

General Instructions

1. Each student has to submit a formal report (as per given Format) for each experiment conducted in the laboratory.

2. Reports are due at the date of the next laboratory turn.

3. The formal report must contain the observations data sheet signed by the instructor in the Appendix.

4. No bags allowed in the laboratory. Only carry your pen, notebook and a calculator.

5. It is recommended to wear full covering shoes in the laboratory.

6. Follow the general safety precautions.

Appendix

Following are to be given in the appendix:

1. Original date sheet (Get your data sheet signed by the instructor at the end of each experiment).
2. Show how data were used by a sample calculation.
3. Calibration curves of instrument, which was used in the performance of the experiment.
4. Include manufacturer of the instrument, model and serial numbers. The instructor will usually supply calibration curves. Alternatively, calibration may be a part of the experiment.
5. Bibliography listing of all references used.

Graphs Preparation

In many instances, it is necessary to compose a plot in order to graphically present results. Graphs must be drawn neatly following a specific format. There are many computer software packages that have graphing capabilities. Following are the features of note for preparation of graphs as listed below:

1. Border is drawn around the entire graph.
2. Axis labels defined with symbols and units.
3. Grid drawn using major axis divisions.
4. Each trend to be identified using a legend.
5. Data points to be identified with symbols.
6. The line representing the theoretical results has to have no data points represented.
7. Nothing to be drawn freehand.
8. Figure number to be given accordingly and Figure caption has to be reasonably descriptive.

TABLE OF CONTENTS

EXPERIMENT-1

VERIFICATION OF BERNOULLI'S THEOREM

1.1 Objectives

The objective is to validate Bernoulli's assumptions and theorem by experimentally proving that the sum of the terms in the Bernoulli equation along a streamline always remains a constant.

1.2 Equipment Required

The experimental set up consists of a horizontal Perspex duct of smooth variable cross section of convergent and divergent type. The piezometer pressure P at the locations of pressure tapping are measured by means of piezometer tubes installed at an equal distance along the length of conduit. The duct is connected with supply tanks at its entrance and exit end. A collecting tank is used to find the actual discharge.

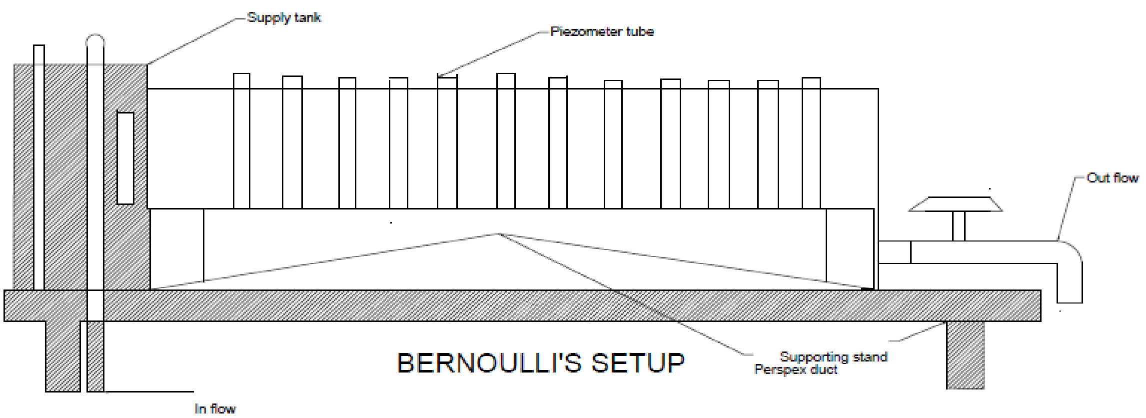

Figure 1.1 Apparatus for verification of Bernoulli's theorem

1.3 Theory

The Bernoulli theorem is an approximate relation between pressure, velocity, and elevation, and is valid in regions of steady, incompressible flow where net frictional forces are negligible. The key approximation in the derivation of Bernoulli's equation is that viscous effects are negligibly small compared to inertial, gravitational, and pressure effects. We can write the theorem as,

Pressure head ($\frac{P}{\rho g}$) + Velocity head ($\frac{V^2}{2g}$) + Elevation (Z) = a constant

where, *P = the pressure, (N/m²)*

ρ *= density of the fluid, (kg/m³)*

V = velocity of flow, (m/s)

g = acceleration due to gravity, (m/s²)

Z = elevation from datum line, (m)

The discharge through the test section can be determined using the collecting tank and stopwatch setup.

Actual discharge, $Q_{ac} = \frac{axH}{t}$, (m^3/s)

where, *a = area of the collecting tank, (m^2)*

H = height difference of the water column in the piezometer, (m)

t = time taken to rise H meters, (sec)

The velocity of flow at the cross section A_1 is, $V_1 = \frac{Q_{ac}}{A_1}$

Then the velocity head, $H_{v1} = \frac{V_1^2}{2g}$.

Assuming that the pipe line has negligible frictional losses in the flow and the elevation is constant everywhere, Bernoulli's equation for the horizontal pipe at cross section A_1 can be verified as,

Pressure head (H_{p1}) + Velocity head (H_{v1}) = Const:

1.4 Procedure

Note down the dimensions of the convergent-divergent duct of the apparatus. Also measure the collecting tank cross sectional area. Open the inlet valve to the supply tank and allow water to fill up to a high level. Open the outlet valve and regulate both the inlet and outlet valves so that the head in the supply tank remains constant. Note the time to collect water for a specific rise in the collecting tank and thus find the discharge through the duct. Also, note down all the piezometer readings at different locations A_1, A_2, ...up-to A_{11}.Repeat the experiment for atleast four different values of discharge. Plot the curves showing the variation of H_p, H_v and H_t with position and tabulate the readings.

1.5 Observations and calculations

Area of the collecting tank , *a* = ... cm

No.	Head, H (m)	Time for collecting V m^3 of water in tank, t (sec)	Discharge, Q_{ac} (m^3/sec)	Duct No.	Area, A (m^2)	Velocity, V (m/s)	Velocity Head, $H_v = V^2/2g$ (m)	Pressure Head, H_p (m)
1.				1				
				2				
				..				
				..				
				11				
2.				1				
				2				
				..				
				..				
				11				
3.				1				
				2				
				..				
				..				
				11				
4.				1				
				2				
				..				
				..				
				11				

1.6 Results and Inferences

The Bernoulli's theorem is verified and the variation in total head is due to frictional losses.

1.7 Precautions

2 Apparatus should be in levelled condition.

3 Readings must be taken in steady condition of water.

4 Unbalanced mass should be measured by taking care that water disturbance should be minimum.

5 Readings should be noted that water level in the inlet supply tank must be constant.

6 There should not be any air bubble in the piezometer.

7 Apparatus must be free from dirt and kept clean.

EXPERIMENT-2

REYNOLDS APPARATUS

2.1 Objective

To Study laminar-turbulent transition for flow in a transparent tube.

2.2 Equipment Required

The apparatus consists of a storage and supply tank, which has the provision for supplying colour dye through a jet. A Perspex tube is provided to visualize the flow condition within the tube. The entry of water in the Perspex tube is through an elliptical bell mouth to ensure smooth flow at the entry. A regulating value is provided downstream to regulate the volumetric flow. Vary the discharge gradually to prevent flow disturbances, particularly in the transition range of Reynolds numbers. A collecting tank is used to measure discharge of water through the tube.

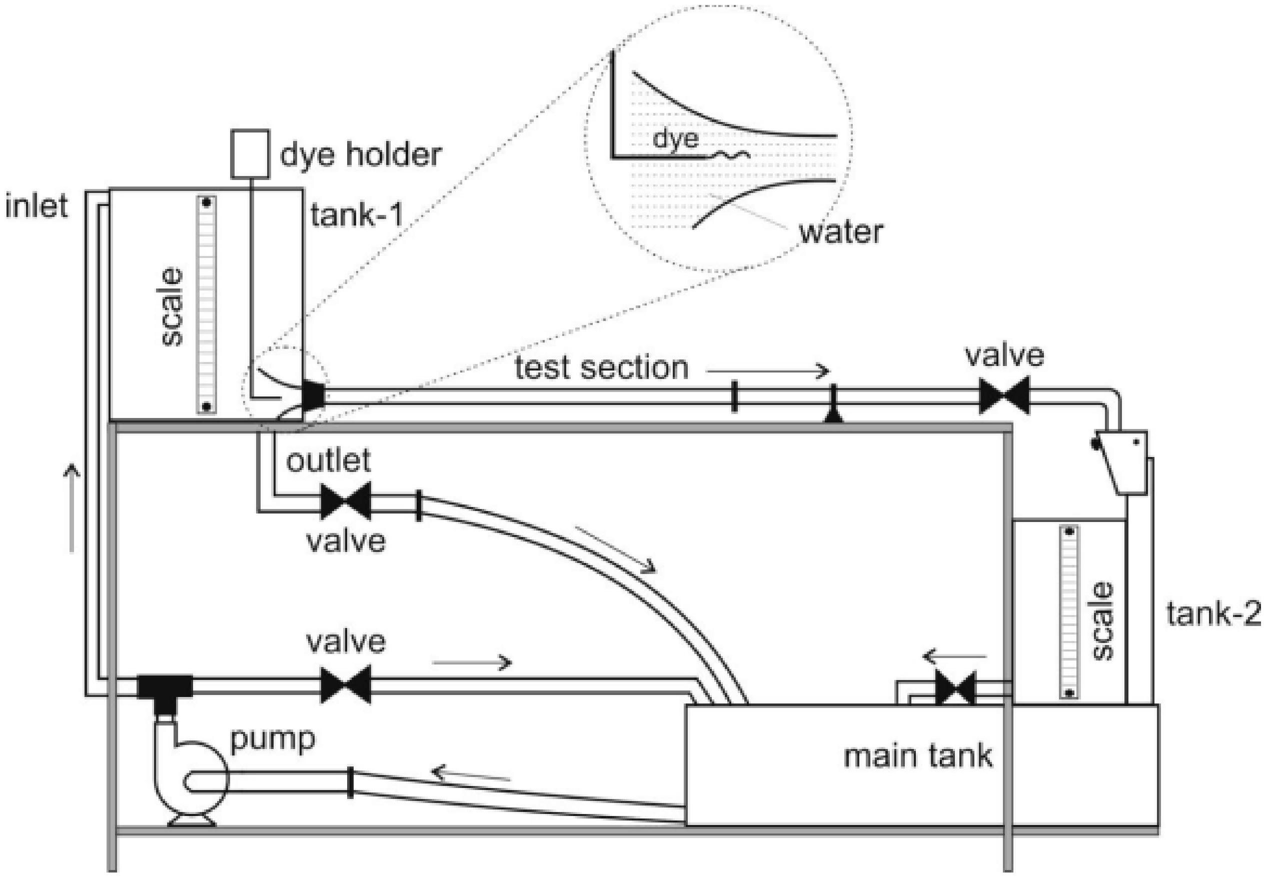

Figure 2.1 Reynolds Apparatus for demonstration of laminar and turbulent flow

2.3 Theory

Laminar flow in a tube is known to undergo transition to become turbulent with increasing values of Reynolds number. The two states of flow can be distinguished by introducing a color dye along the axis of the tube. In laminar flow, the dye remains undisturbed and moves along the tube axis. In turbulent flow, the velocity field reveals time dependent oscillations which lead to stronger mixing of the dye with the surrounding fluid.

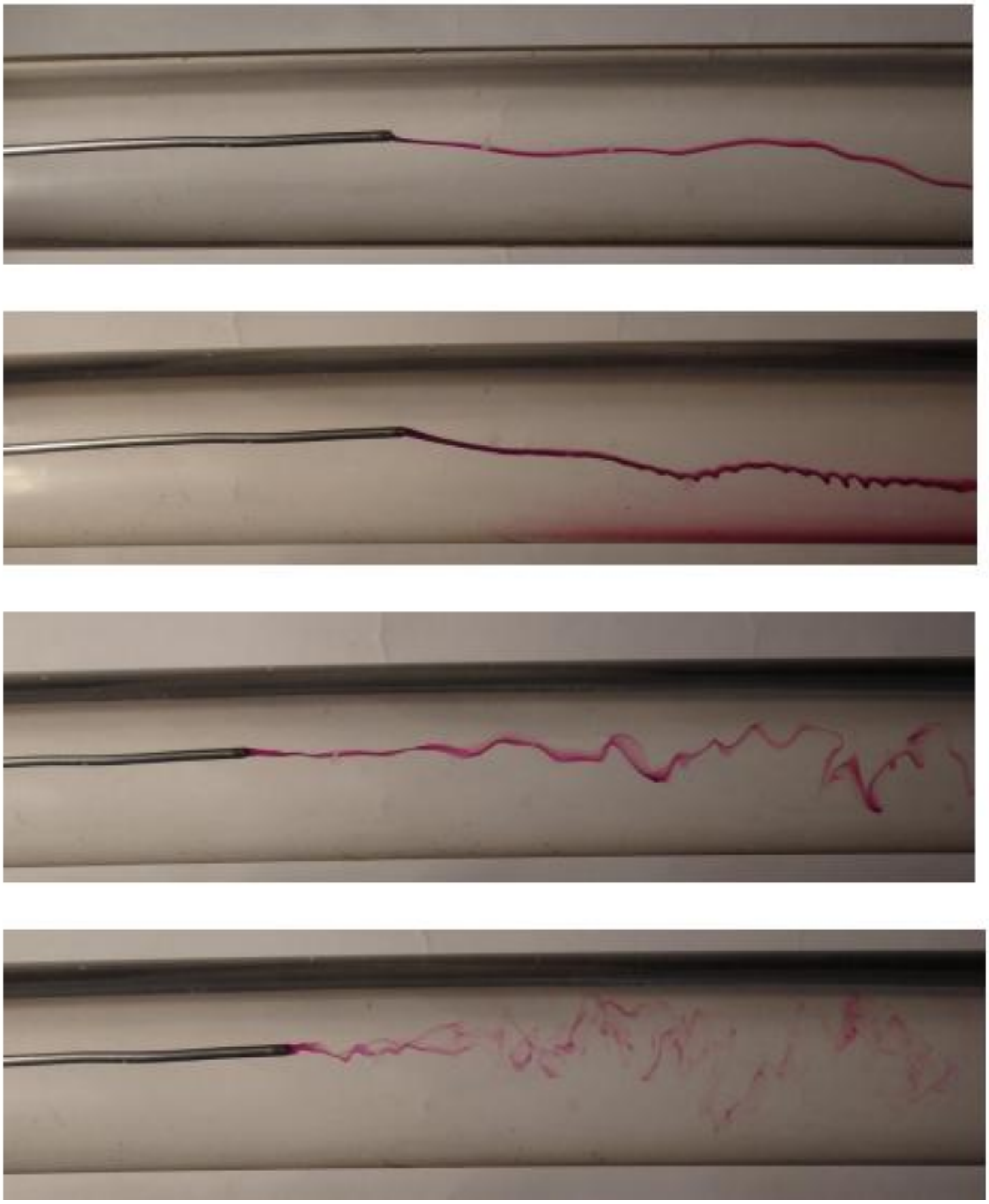

Figure 2.2 Visualisation of changes in flow with different Reynolds Number from Laminar to Turbulent

2.4 Procedure

Adjust the supply valve and wait for the flow to get stable. Measure the dimensions of the collecting tank and note the head of water in the piezometer attached to the collecting tank in a certain time interval. Measure the discharge at this setting of the supply valve.

Repeat the same procedure for the other openings of valve for different discharges. Carefully estimate the critical Reynolds number below which flow is laminar and above which it is turbulent. Once the flow is set in a particular Reynolds number, visualize dye mixing for flow in a tube under laminar and turbulent conditions.

2.5 Observations and Calculations

Area of the collecting tank, A =

Diameter of the tube, d =

S. No.	Head difference in Peizometer (m)	Time (s)	Discharge, Q (m^3/s)	Velocity in tube, V (m/s)	Re = $\rho Vd/\mu$	Type of Flow (Laminar/Transition/Turbulent)
1.						
2.						
3.						
4.						
5.						

2.6 Results and Inference

2.7 Precautions

- Apparatus should be in levelled condition.
- Readings must be taken in steady condition of water.
- Unbalanced mass should be measured by taking care that water disturbance should be minimum.
- Readings should be noted that water level in the inlet supply tank must be constant.
- There should not be any air bubble in the piezometer.
- Apparatus must be free from dirt and kept clean.

EXPERIMENT-3

METACENTRIC HEIGHT OF FLOATING BODIES

3.1Objective

To determine the metacentric height of a flat-bottomed pontoon.

3.2Equipment Required

The experimental set consists of a pontoon (flat bottomed vessel) which is allowed to float in a MS tank having a transparent side. Removable steel strips are placed in the model for the purpose of changing the weight of the vessel. By means of a pendulum (consisting of a weight suspended to a long pointer), the angle of tilt Ø can be measured on a graduated arc. For tilting the ship model a cross bar with two movable hangers is fixed on the model. Pendulum and graduated arc are suitably fixed at the center of the cross bar.

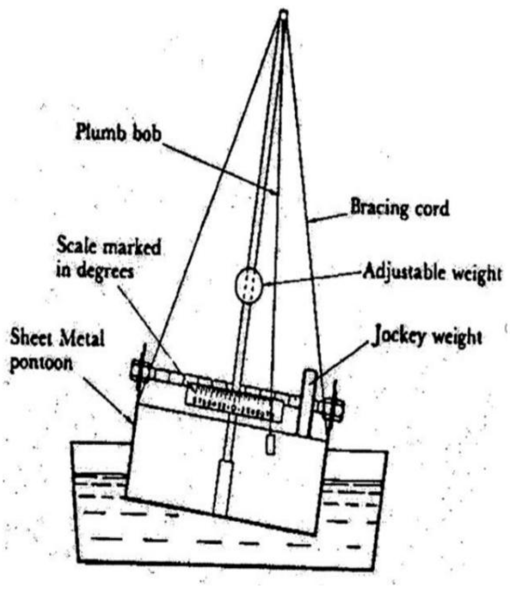

Figure 3.1. A floating flat-bottomed pontton

3.3 Theory

A body floating in a fluid is subjected to the following system of forces:

1. The downward force of gravity acting on each particle that goes to make up the weight of body, *W*c acting through center of gravity, *G*.

2. The upward buoyant force of the fluid acting on the various elements of the submerged surface of the floating body F_B, acting through

For a body to be in equilibrium on the liquid surface, the two forces *W*c and F_B must lie in the same vertical line i.e, these two forces must be collinear, equal and opposite.

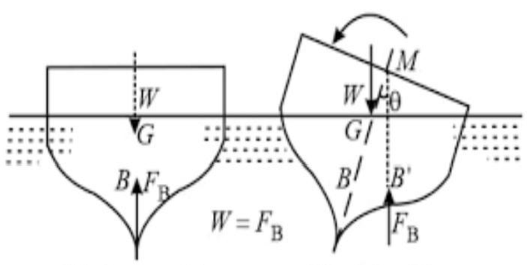

Figure 3.2. Metacentric height of a floating body

When the vessel has been tilted through an angle Ø, the center of gravity C of the body G, is usually remains unchanged in its position, but B i.e. center of buoyancy will generally change its position. Thus *W*c and F_B form a couple. The line of action of F_B in distance *CM* is called the metacentric height. The metacentric height is a measure of the static stability of the floating bodies.

The metacentric height can be obtained by equating the righting couple and the applied moment as:

$$\frac{W_m \ X_c}{(W_c+W_m)tan\emptyset}$$

where, *W*c is the weight of the vessel, W_m the weight of unbalanced mass causing moment on the body, X_d is the distance of the unbalanced mass from the center of the cross bar.

3.4 Procedure

Step1: Note down the relevant dimensions as area of collecting tank, mass density of water, etc.

Step2: Note down the water level in the tank when the pontoon is not in the tank.

Step3: Pontoon is allowed to float in the tank. Note down the reading of water level in the tank. Mass of pontoon can be obtained by the help of Archmide's principle

Step4: Position of unbalanced mass, weight of unbalanced mass and the angle of heel can be noted down. Calculate the metacentric height of the pontoon.

Step5: The procedure is repeated for other positions and values of unbalanced mass.

Step6: Also the above procedure is repeated while changing the weight of the pontoon by changing the number of strips in the pontoon.

3.5 Observations and Calculation

Area of tank, A (cm^2). =

Water level (without pontoon), Y_1, (cm) =

Density of displaced Water, ρ =

S. No.	Reading on Tank with Pontoon Y_2 (cm)	Mass of Pontoon, Wc = (Y_2-Y_1) $A\rho$ (gm)	Unbalanced mass, Wm (gm)	Angle of heel, $\emptyset$ (degrees)	Distance of Unbalanced mass, X_d (cm)	Metacentric Height (cm) $\frac{W_m X_d}{(W_c+W_m)tan\emptyset}$	Average (cm)

3.6 Results and Inferences

3.7 Precautions

- Apparatus should be in levelled condition.
- Readings must be taken in steady condition of water.
- Unbalanced mass should be measured by taking care that water disturbance should be minimum.
- Readings should be noted that water level in the inlet supply tank must be constant.
- There should not be any air bubble in the piezometer.
- Apparatus must be free from dirt and kept clean.

EXPERIMENT - 4

FLOW OVER NOTCHES

4.1 Objective

To observe characteristics of flow over a V-notch and to determine the coefficient of discharge.

4.2 Equipment required

- The Hydraulics Bench: It allows to measure flow by timed volume collection. The hydraulics bench consists of a sump tank which supports bench top incorporating a flow channel and volumetric measuring tank.
- The Stilling baffle: It locates into slots in the walls of the channel. It promotes a smooth flow condition in the channel.
- The V Notche: Weirs to be tested are clamped to the weir carrier in the channel by thumb nuts.
- Vernier Height Gauge: It is mounted on an instrument carrier which is located on the side channels of the moulded top.
- Stop Watch

Figure 4.1 V-Notch

4.3 Theory

Because the depth of the flow above the base of a notch is related to the volume flow rate through it, the notch forms a useful flow measurement device. The classical results for flow over notches are obtained by an application of the Bernoulli equation, from a point well up-stream to a point just above the notch. This approach requires a number of very substantial assumptions and it yields the following results:

For a V notch

$$Q_t = C_d \, \frac{8}{15} \tan\frac{\theta}{2} \sqrt{2g} \, H^{\frac{5}{2}}$$

where

Q_t = volume flow rate;

H = height above notch base;

B = width of rectangular notch;

θ = angle of the Vee in the triangular notch;

C_d = the discharge coefficient, which has to be determined by experiment.

(The coefficient C_d is required to accommodate the effects of the simplifying assumptions in the theory). These can be rearranged to give:

for a Vee notch.

$$C_d = \frac{15\, Q_t}{8\ \tan\frac{\theta}{2}\, \sqrt{2g}\, H^{\frac{5}{2}}}$$

4.4 Procedure

Experimental setup: Ensure that the hydraulic bench is positioned so that its surface is horizontal (necessary because flow over notch is driven by gravity). Mount the rectangular notch plate into the flow channel. In order to measure the datum height (with the height gauge) of the base of the notch, position the instrument carrier as shown in the diagram. Then carefully lower the gauge until the point is just above the notch base and lock the coarse adjustment screw. Then, using the fine adjustment, adjust the gauge until the point just touches the notch bottom and take a reading; be careful not to damage the notch. Mount the instrument carrier as shown in the diagram and locate it approximately half way between the stilling baffle and the notch plate. Open the bench control valve and admit water to the channel; adjust the valve to give approximately 10mm depth above the notch base. To help achieve this, you may find it useful to pre-set the height gauge position to give a rough guide.

Taking Set of Results: Observe and record the general features of the flow. To take an accurate height reading, use the fine adjustment to lower the gauge until the point just touches its reflection on the surface; (to achieve this, you will need to have your eye level just above the surface). Ensure that the flow rate is large enough to prevent the outflow from the notch “clinging” to the notch plate; it should project clear of the plate. Determine the volume flow rate by measuring the time required to collect a known volume in the volumetric tank. This is done by using the ball valve to close the tank outflow and then determine the volume collected from the sight-glass. This measurement should be repeated twice, to check for consistency. Remember to open the valve again at the end of the measurement.

Repeat this procedure having opened the bench valve further, to produce an increase in depth of approximately 10mm; check that the level has stabilized before taking readings. Continue to take readings (atleast six) with increasing flow rate until the level reaches the top of the notch; take care not to allow spillage to occur over the plate top adjacent to the notch. Before starting this test, check that there is sufficient water in the bench main tank, to allow the pump to operate without drawing in air at the maximum flow rate (i.e., maximum height above notch).

Replace the rectangular notch plate with the Vee-notch plate and repeat the above procedure. Note, however, that for this notch you will need to work with height increments of 5-6 mm.

4.5 Observations and calculations

Width of the notch, B (cm) = .. cm

Crest level of the notch, H_1 = .. cm

Area of collecting tank (a) = ..cm x …cm

S.No.	Discharge Readings				Final reading of water level H_2 (cm)	Head, $H=H_1-H_2$ (cm)	C_d
	Initial (cm)	Final (cm)	Time (sec)	Discharge (cm^3/sec)			

4.6 Results and Inferences

4.7 Precautions

1. Apparatus should be in leveled condition.
2. Reading must be taken in steady or nearby steady conditions. And it should be noted that water level in the inlet supply tank must be constant.
3. There should not be any air bubble in the piezometer.
4. The equioment must be free from dirt and kept clean.

EXPERIMENT - 5

ORIFICE AND MOUTHPIECES

5.1 Objective

To determine the coefficient of discharge C_d, velocity C_v, and contraction C_c of various types of orifices and mouthpieces.

5.2 Equipment Required

The experimental set up consists of a supply tank with overflow arrangement and a gauge glass tube for water level measurement is the tank. There is also provision for fixing the various orifices and mouthpieces (interchangeable) installed in the vertical plane of the tank side. A set of orifice consisting of 10 mm dia and 15 mm dia orifice is provided with the apparatus. Further a set of mouthpiece is also provided which consists of (1) 10 mm dia and 25 mm length, (ii) 10 mm dia and 40 mm length (iii) 10 mm x 25 mm x 25 mm long divergent and (iv) 25 mm x 10 mm x 25 mm long convergent mouthpiece. Arrangement is made such that the water passes only through this attached opening. Water comes out of the opening in the form of jet.

A horizontal scale on which is mounted a vertical scale with a hook gauge is attached to the supply tank. Thus hook gauge can be moved horizontally as well as vertically in *x* and *y* direction and its corresponding movement can be read on horizontal and vertical scales respectively. A collecting tank is used to find the actual discharge of water through the jet.

5.3 Theory

An orifice is an opening in the wall of a tank, while a mouthpiece is a short pipe fitted in the same opening. A mouthpiece will be running flu if its length does not exceed two to three times the diameter. Both orifice and mouthpiece are used for discharge measurement. The jet approaching the orifice continues to converge beyond the orifice till the streamlines become parallel. This section of the jet is then a section of minimum area and is known as vena contracta.

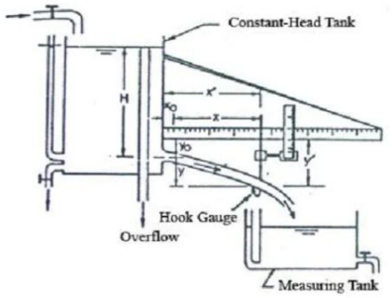

Figure 5.1. A mouthpiece discharging water

If V_c the true horizontal velocity at the vena contracta, then the properties of jet trajectory give the following relationship:

$$y = \frac{g}{2V_c^2}x^2$$

$$V_c = \left\{\frac{gx^2}{2y}\right\}^{1/2}$$

The theoretical velocity in the plane of the vena contracta V_o is given by $\left(\frac{V_o^2}{2g} = \mathrm{h}\right)$ i.e., $V_o = (2gh)^{1/2}$. Now coefficient of velocity C_v = actual velocity/ theoretical velocity.

$$C_v = \frac{x}{2\sqrt{yh}}$$

In which *h* is the constant head in the supply tank and *x* & *y* are coordinates of the jet with respect to the centre of opening.

The actual discharge *Q* when divided by $a\sqrt{(2gh)}$ yield the coefficient of discharge C_d, here *a* is the area of cross section of the orifice (or the mouthpiece) and *g* is the acceleration due to gravity.

Once C_d and C_v are known, the coefficient of contraction C_c can be obtained by dividing C_d with C_v.

$$C_c = \frac{C_d}{C_v}$$

5.4 Procedure

Step 1: Note down the relevant dimensions as area of collecting tank and supply tank.

Step 2: Attach an orifice/mouthpiece and note down its diameter.

Step 3: The water supply was admitted to the supply tank and conditions were allowed to steady to give a constant head. The lowest point of the orifice/mouthpiece is used as the datum for the measurement of h and y.

Step 4: The discharge flowing through the jet is recorded together with the water level in the supply tank.

Step 5: A series of readings of dimensions x and y was taken along the trajectory of the jet.

Step 6: The above procedure is repeated by means of flow control valve.

Step 7: The above procedure is repeated for other types of orifice/mouthpiece.

5.5 Observations and Calculations

Size and shape of the mouth piece/orifice =

Area of cross section of mouth piece/orifice, a, cm^2 =

Area of cross section of collecting tank, cm^2 =

Area of cross section of supply tank, A, cm^2 =

Reading on the piezometer at the level on the centre of mouth piece/orifice, h_o =

(A) CONSTATN HEAD METHOD

(i) Determination of C_d

Run No.	Reading on the Piezometer a_1 (cm)	Value of $h = h_o$ cm	Discharge measurement				$C_d = \frac{Q}{a\sqrt{2gh}}$
			Initial	Final	Time	Discharge,	

			(cm)	(cm)	(sec)	Q (cm^3/sec)	

Average C_d =

(ii) Determination of C_v

Reading of horizontal scale at exit of orifice/mouthpiece, X_o =

Reading of vertical scale at exit of orifice / mouthpiece, Y_o =

Run No.	h (cm)	x_1, cm	y_2, cm	X= x_1-x_o cm	Y= y_2-y_o cm	$C_v = \frac{X}{2\sqrt{yh}}$

Average C_v =

Therefore,

$$C_c = \frac{C_d}{C_v}$$

5.6 Results and Inferences

5.7 Precautions

1. Apparatus should be in levelled condition.
2. Reading must be taken in steady or nearby steady conditions. And it should be noted that water level in the inlet supply tank must be constant.
3. There should not be any air bubble in the piezometer.
4. Orifice must be free from dirt and kept clean.

EXPERIMENT - 6

ENERGY LOSSES IN PIPE FITTINGS

6.1 Objective

To determine the energy loss for flow through a range of pipe fittings which include a long bend, a short bend, mitre, elbow, sudden contraction and enlargement.

6.2 Equipments required

Apparatus required to perform the experiment are as follows-

1. Hydraulic bench fitted with energy loss apparatus: It is a pipe with several fittings and also valve to control discharge.

Figure 4.1 Energy loss apparatus

2. Piezometers (a type of manometer) are connected to the pipe upstream and downstream of each fitting to measure the pressure in the pipe at those locations.
3. Collecting tank to find out discharge passing through pipes fitted with ball arrangement.
4. Stop watch for time measurement.

The experimental set up consists of pipe circuit of 20mm diameter fitted with following fittings.

- Large bend
- Mitre
- Sudden enlargement
- Small bend

- Sudden contraction

Pressure tappings are provided on up-stream and down-stream ends of these fittings to enable the measurement of pressure head difference across the fittings. The pressure tappings are connected to several piezometers. Also a collecting tank is provided to find the actual discharge.

6.3 Theory

In long pipes, the major loss of energy in pipe flow is due to friction while the minor losses are those, which are caused on account of the change in cross-section, bends, valves and fittings .In short pipes, above losses may sometimes outweigh the friction losses.

The minor energy head lose h_L in terms of velocity head can be expressed as

$$h_L = \frac{kV^2}{2g}$$

where, k = loss coefficient, which is practically constant at high Reynold's number for particular flow geometry,

V = velocity of flow in the pipe and

g = acceleration due to gravity.

However, for sudden enlargement of the section, the simultaneous application of continuity, Bernoulli's and momentum shows that

$$h_L = \frac{k(V^2 - V_1^2)}{2g}$$ can be treated as $$h_L = \frac{kV^2}{2g}$$ also.

where, V and V_1 are velocities of flow in the smaller and larger diameter respectively.

Due to change in pipe c/s area through the enlargement and contraction, the system experiences an additional change in static pressure. The change can be calculated as

$$\Delta h = \frac{V^2}{2g} - \frac{V_1^2}{2g},$$

This value should be added in head loss due to enlargement and subtracted from the head loss due to contraction.

6.4 Procedure

It is not possible to make measurements on all fittings simultaneously and therefore, it is necessary to run two separate tests.

Exercise – A

This measures losses across all pipe fittings except the gate valve, which should be kept fully open. Adjust the flow from the bench control valve and, at a given flow rate, take height readings from all of the manometers after the levels become steady. Using the volumetric tank carry out a timed volume collection to determine the volume flow rate. This is achieved by closing the ball valve and measuring (with a stopwatch) time taken to accumulate a known volume of fluid in the tank, which is read from the sight glass. Collect fluid for at least one minute to minimize timing errors. Repeat this procedure to give a total of at least five sets of measurements over a flow range from approximately 8 – 17 liters per minute. The outflow water temperature at the lowest flow rate together with the table detailing the kinematic viscosity of water at Atmospheric Pressure is used to determine the Reynolds number.

Exercise - B

This measures losses across the gate valve only. Clamp off the connecting tubes to the mitre bend pressure tapings (to prevent air being drawn into the system). Start with gate valve closed and open fully both the bench valve and the test rig flow control valve. Now open the gate valve by approximately 50% of one turn (after taking up any backlash). For each flow rates measure pressure drop across the valve from the pressure gauge, adjust the flow rate by use of the test rig flow control valve. Once measurements have started, do not adjust the gate valve. Determine the volume flow rate by timed collection. Take at least five set of readings by varying the control valve. Repeat this procedure for the gate valve opened by approximately 70% of one turn and then approximately 80% of one turn (Total there should be 3 sets with five readings in each).

Pressure difference before and after the gate is measured directly using a pressure gauge. This can then be converted to an equivalent head loss using the equation

$$1 \text{ bar} = 10.2 \text{ m water}$$

The loss coefficient can then be calculated as above for the gate valve.

6.5 Observations and Calculations

Diameter of the pipe (D) in m =

Diameter of the pipe (D) in m at enlargement =

$$k = \frac{(h_L \pm \Delta h)2g}{V^2}$$

Exercise A

Type of fitting: Mitre

S. No.	Piezometer Readings			Discharge Measurements			$V=Q/A$	k
	Left (mm)	Right (mm)	h_L (mm)	Vol. (Lit)	T (sec)	Q (m^3/s)		

Type of fitting: Elbow

S. No.	Piezometer Readings			Discharge Measurements			$V=Q/A$	k
	Left (mm)	Right (mm)	h_L (mm)	Vol (Lt)	t (sec)	Q (m^3/s)		

Type of fitting: Short bend

S. No.	Piezometer Readings	Discharge Measurements		

	Left (mm)	Right (mm)	h_L (mm)	Vol. (Lt)	t (sec)	Q (m^3/s)	$V=Q/A$	k

Type of fitting: Long bend

S. No.	Piezometer Readings			Discharge Measurements			$V=Q/A$	k
	Left (mm)	Right (mm)	h_L (mm)	Vol. (Lt)	t (sec)	Q (m^3/s)		

Type of fitting: Sudden enlargement

S. No.	Piezometer Readings			Discharge Measurements			$V_1 = Q/A$	$V_2 = Q/A$	Δh	k
	Left (mm)	Right (mm)	h_L (mm)	Vol (Lit)	t (sec)	Q (m^3/s)				

Type of fitting: Sudden Contraction

Sl no.	Piezometer Readings	Discharge				

				Measurements			$V_1 = Q/A$	$V_2 = Q/A$	Δh	k
	Left (mm)	Right (mm)	h_L (mm)	Vol (Lit)	t (sec)	Q (m^3/s)				

Exercise –B- Gate valve

S. No.	Discharge Measurements			$V = Q/A$	Δh (Gauge reading)	k
	Vol (Lt)	t (sec)	Q (m^3/s)			

For exercise-A: Plot graphs of :

i. k against volume flow rate $Q_{t.}$

For exercise-B: Plot graphs of :

i. k against volume flow rate $Q_{t.}$

6.5 Results and Inferences

6.6 Precautions

1. Apparatus should be in levelled condition.

2. Reading must be taken in steady or nearby steady conditions. And it should be noted that water level in the inlet supply tank must be constant.
3. There should not be any air bubble in the piezometer.
4. The equipment must be free from dirt and kept clean.

EXPERIMENT - 7

FRICTION FACTOR OF COMMERCIAL PIPES

7.1 Objective

To study the variation of friction factor, *F*, for turbulent flow in smooth and rough commercial pipes.

7.2 Equipments Required

The set-up consists of two pipes. One of these pipes is hydro dynamically smooth and the other is hydro dynamically rough for the flow range in the set-up. The diameter of these pipes may range between 15mm and 25mm. These pipes may be about 5m long. The discharge is regulated by means of valve provided near the outlet end of each pipe. One common inlet valve for both pipes is also provided in the main supply line. For measuring the head loss h_f; two pressure taps, about 3m apart, are suitably located on each of these pipes. These pressure taps are connected to a manometer.

7.3 Theory

For steady uniform flow, in a pipe of diameter *D* and length *L*, Darcy and Weishbach obtained the following relationship by equating the pressure force exerted on the flow with the boundary shear force as,

$$h_f = f\,\frac{LV^2}{2gD}$$

This relation is known as Darey-Weishbach equation for the head loss due to friction in a pipe, here, h_f is the head loss on account of friction, *v* the mean velocity of flow, and *f* is the friction factor. The friction factor depends on Reynolds number, R_e(=VD/ν) and the relative roughness, *k*/*D*. Here, *k* is the equivalent sand grain roughness of the roughness projections on the surface of the pipe.

Nikuradse's experimental investigation on artificially roughened pipes demonstrated perfectly the same relationship among *f*, R_e and *k*/*D*. The results of his investigations have been summarized below:

1. For laminar flow, $R_e < 2000$ and $f = 64/R_e$. This means that the head loss in laminar flow is independent of the surface roughness and depends only on R_e.
2. For turbulent flow (i.e, $R_e > 3000$) there exists a curve f v/s R_e for different values of k/D.
3. Following are the equations for friction in turbulent flow. For hydro dynamically smooth turbulent flow in a pipe.

$$\frac{1}{\sqrt{f}} = 2\log Re\sqrt{f - 0.8}$$

And for hydro dynamically rough turbulent flow in a pipe,

$$\frac{1}{\sqrt{f}} = 2\log Re\frac{\mathrm{D}}{2\mathrm{K}} + 1.74$$

A surface is said to be hydro dynamically rough if $k/\delta' > 0.6$, if $k/\delta' > 0.25$ the surface is said to be hydro dynamically smooth. Here δ' is the thickness of laminar sub layer. For a hydro dynamically smooth pipe, the following equation, suggested by Blasius, is also in agreement with Nikuradse's data in the range $3000 < R_e < 10^5$.

$$f = \frac{0.316}{Re^{0.25}}$$

Since Nikuradse's experiments were conducted on the sand coated pipes, these results cannot be applied directly to the commercial pipes. However, Colebrook and white, starting from Nikuradse's equations, derived the following equation that can be used for obtaining friction factor values for the commercial pipes,

$$\frac{1}{\sqrt{f}} = -2\log\left[\frac{\mathrm{K/D}}{3.7} + \frac{2.51}{Re\sqrt{f}}\right]$$

This equation has been plotted by Moody in the manner shown in Fig. 7.1. Here, k is the equivalent sand grain roughness, defined as the diameter of such uniform sand grains which, when coated on a pipe wall, would yield the same limiting value (i.e., independent of R_e) of for rough conditions as that given by the pipe.

7.4 Procedure

1. Open the inlet valve and keep the outlet closed. Remove the air bubbles from the manometer tubes.
2. Open partially the outlet valve of one of the two pipes and keep the common inlet valve fully open.
3. Wait for some time os that the flow is stabileized. Take the manometer readings h_1 and h_2.
4. Measure the discharge.
5. Repeat steps (2) to (4) for different discharges.
6. Repeat steps (2) to (5) for other pipe also.

7.5 Observations and Calculation

	Pipe 1	**Pipe 2**
Area of cross section, *A*		
Distance between Pressure points, *L*		
Hydro dynamically Rough/Smooth		

Pipe No.	Run No.	Discharge Measurement				Manometer Readings		h_f	R_e
		Initial, cm	Final, cm	Difference, cm	Q	h_1	h_2		
1									
2									

7.6 Results and Inferences

Plot the computed values of f against the corresponding Reynolds numbers, R_e on Moody's diagram, Fig. 7.1. Use different symbols for the two sets of data. Check whether the hydro dynamically smooth pipe data are in agreement with the Blasius curve for smooth pipe. The data of hydro dynamically rough pipe should follow around one of the curves for hydro dynamically rough pipes shown in Fig.7.1, using the rough data and Moody's determine the value of k/D and thus compute pipe roughness.

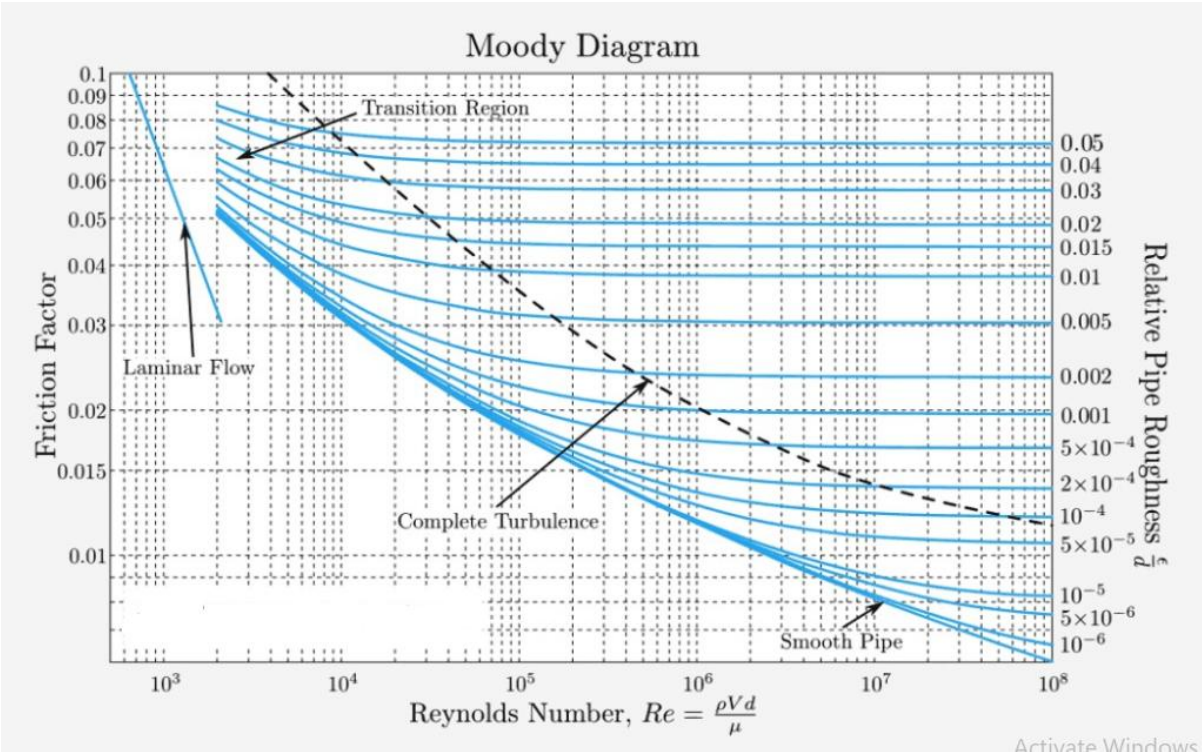

Figure 7.1 Variation of friction factor for commercial pipes (Moody’s Diagram).

7.7 Precautions

1. Apparatus should be in levelled condition.
2. Reading must be taken in steady or nearby steady conditions. There should not be any air bubble in the piezometer.
3. The equipment must be free from dirt and kept clean.

EXPERIMENT - 8

VENTURIMETER

8.1 Objectives

To calibrate the Venturimeter by establishing the relationship between flow rate and pressure difference and to find its coefficient of discharge.

8.2 Equipment Required

- A Venturimeter fitted in a horizontal pipe line with means of varying flow rate
- Stopwatch
- U-tube differential manometer

The experimental setup consists of a circuit through which the fluid is circulated continuously through a venturimeter of certain diameter and having a certain d/D ratio. The venturimeter is provided with two tappings one each at upstream and at the throat section. A U-tube mercury manometer with common manifold is provided to measure the pressure difference between two sections. A collecting tank is provided to find the actual discharge through the circuit.

8.3 Theory

Venturimeter is a device used for measurement of flow rate of fluids through pipes. The basic principle on which a venturimeter works is that by reducing the cross sectional area of passage, a pressure difference is created and the measurements of the pressure difference enables the determination of the discharge through the pipe.

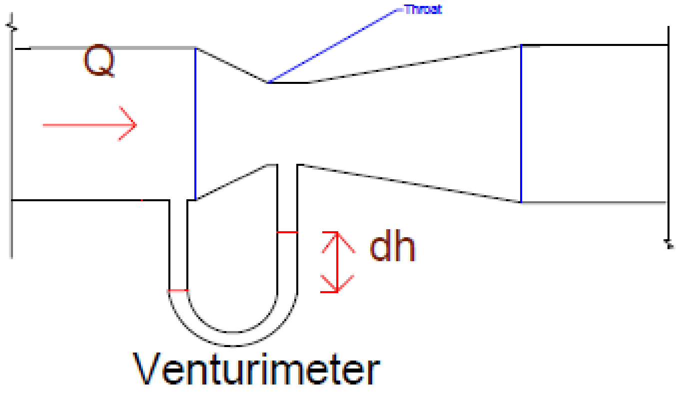

Figure 8.1 Venturimeter

A venturimeter consists of: (1) an inlet followed by a convergent cone, (2) a cylindrical throat and (3) a gradually divergent cone**.** According to Continuity equation, since the cross sectional area of the throat is smaller than the cross sectional area of the inlet section, the velocity of the flow at the throat will become greater than that at the inlet section. The increase in velocity of flow at the throat results in the decrease in the pressure at this section. A pressure difference is created between inlet and throat section which can be determined by connecting a differential U-tube manometer between the pressure taps provided at these sections. The measurement of pressure difference between these sections enable the rate of flow fluid (Q) to be calculated as

$$Q = C_d \frac{a\sqrt{2g\Delta h}}{\sqrt{1-(a/A)^2}}$$

where,

a = *area of the cross section of the throat,*

A = *area of the cross section of the inlet section,*

g = acceleration due to the gravity,

Δh = *difference of head and*

C_d = coefficient of discharge of venturimeter.

8.4 Procedure

Note down the relevant dimensions - diameter of pipeline, throat diameter of venturimeter and area of collecting tank, room temperature etc. Adjust the flow rate to its maximum value. By maintaining suitable amount of steady flow in the pipe circuit, establish a steady non-uniform flow in the conduit. Time is allowed to stabilize the levels in the manometer tube. Record the discharge flowing in the circuit together with the water levels in left and right limbs of manometer tube. Reduce the flow meter in stage by means of flow control value and record the discharge and readings of manometer. Repeat this procedure for other discharge values.

8.5 Observations and Calculations

Diameter of main pipe line, D =

The ratio d/D = 0.6

Area of cross section of throat section, a =

Area of cross section of inlet section, A =

Area of collecting tank =

S. No	Discharge measurement				Manometer reading			
	Initial (cm)	Final (cm)	Time (sec)	Discharge Q (cm^3/sec)	Left limb h_1 (cm)	Right limb h_2 (cm)	Difference of head of water $\Delta h = 12.6(h_1 - h_2)$	$C_d = \frac{Q\sqrt{1-(a/A)^2}}{a\sqrt{2g\Delta h}}$

Plot a graph between Q and Δh on a log log graph paper.

8.6 Results and Inferences

8.7 Precautions

1. Apparatus should be in levelled condition.
2. Reading must be taken in steady or nearby steady conditions. And it should be noted that water level in the inlet supply tank must be constant.
3. There should not be any air bubble in the piezometer.
4. The equipment must be free from dirt and kept clean.

EXPERIMENT - 9

ORIFICEMETER

9.1 Objectives

To calibrate the Orificemeter by establishing the relationship between flow rate and pressure difference and to find its coefficient of discharge.

9.2 Equipment Required

- An Orificemeter fitted in a horizontal pipe line with means of varying flow rate
- stopwatch
- U-tube differential manometer.

The experimental setup consists of a circuit through which the fluid is circulated continuously through an orificemeter of certain diameter and having a fixed d/D ratio. The orificemeter also has two pressures tapping at upstream and downstream. A U-tube mercury manometer with common manifold is provided to measure the pressure difference between two sections. A collecting tank is provided to find the actual discharge through the circuit.

9.3 Theory

An Orificemeter is a device used for measurement of flow rate of fluids through pipes. The basic principle on which an orificemeter works is that by reducing the cross sectional area of passage, a pressure difference is created and the measurements of the pressure difference enables the determination of the discharge through the pipe.

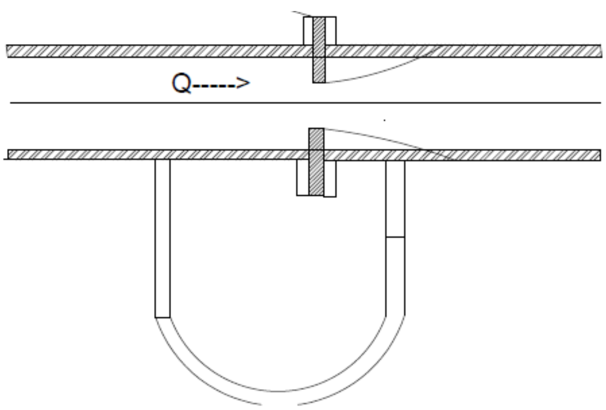

Figure 9.1 Orificemeter

An orificemeter is a cheaper arrangement for measurement of discharge through pipes and its installation requires a smaller length as compared with venturimeter. An orifice meter consists of a flat circular plate with a circular hole called orifice which is concentric with the pipe axis. The upstream face of the plate is bevelled at an angle lying between 30^o and 45^o. The plate is clamped between the two pipe flanges with bevelled surface facing downstream. Two pressure taps are provided, one on the upstream side of the plate and another on the downstream side of the orifice plate. Pressure differences exist between two sections which can be measured by connecting a differential manometer to the two pressure taps. The discharge coefficient can be calculated using following formula.

$$Q = C_d \frac{a_0 a_1 \sqrt{2g\Delta h}}{\sqrt{a_1^2 - a_0^2}}$$

where,

C_d= *Coefficient of orifice,*

a_o = *cross sectional area of orifice,*

a_1 = *cross section area of the pipe,*

g = *acceleration due to gravity and*

Δh = *difference in terms of water.*

9.4 Procedure

Note down the relevant dimensions - diameter of pipeline, diameter of orifice, area of collecting tank, room temperature etc. Adjust the flow rate to its maximum value. By maintaining suitable amount of steady flow in the pipe circuit, establish a steady non-uniform flow in the conduit. Time is allowed to stabilize the levels in the manometer tube. Record the discharge flowing in the circuit together with the water levels in left and right limbs of manometer tube. Reduce the flow meter in stage by means of flow control value and record the discharge and readings of manometer. Repeat this procedure for other discharges.

9.5 Observations and Calculations

Diameter of main pipe line, D =

The ratio d/D = 0.6

Area of cross section of throat section, a_o =

Area of cross section of inlet section, a_1 =

Area of collecting tank =

S. No	Discharge measurement				Manometer reading			$C_d = \frac{Q\sqrt{a_1^2 - a_O^2}}{a_O a_1 \sqrt{2g\Delta h}}$
	Initial (cm)	Final (cm)	Time (sec)	Discharge Q (cm^3/sec)	Left limb h_1 (cm)	Right limb h_2 (cm)	Difference of head of water $\Delta h = 12.6(h_1 - h_2)$	

Plot a graph between Q and Δh on a log log graph paper.

9.6 Results and Inferences

9.7 Precautions

1. Apparatus should be in levelled condition.
2. Reading must be taken in steady or nearby steady conditions. And it should be noted that water level in the inlet supply tank must be constant.
3. There should not be any air bubble in the piezometer.
4. The equipment must be free from dirt and kept clean.

EXPERIMENT 10
IMPACT OF JET APPARATUS

10.1 Objective

To experimentally verify the momentum equation.

10.2 Equipments required

Nozzle**,** Collection tank, transparent cylinder, hemispherical vane and a set of weights.

Figure 10.1 (a) Arrangement of nozzle, vane and cylinder containing power (b) Apparatus piezometer and control valve

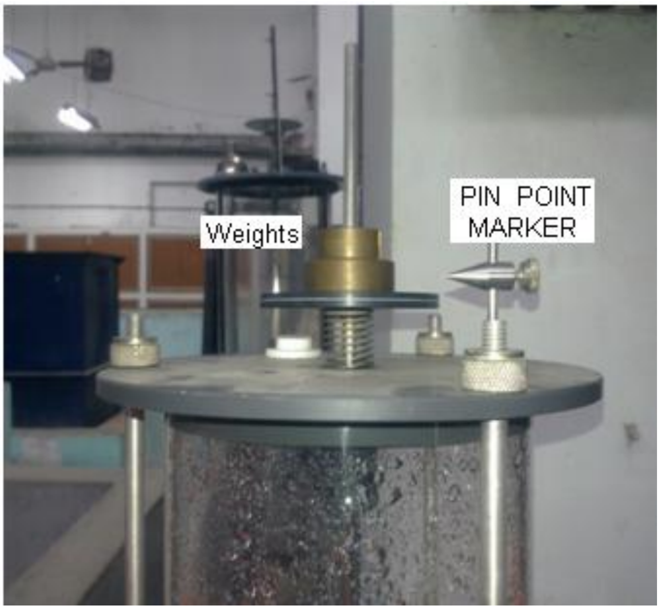

Figure 10.2 Position of weights and marker

10.3 Theory

Momentum Equation is based on Newton's second law of motion which states that the net force applied to a system in any direction is equal to the rate of change of momentum in that direction. The applied force is equal to the body force (e.g. the component of weight) and surface force (e.g. the pressure applied on the boundary of the system).

If a vertical water jet moving with a velocity 'v' strikes a vane, which is free to move in the vertical direction, a force is exerted on the vane. This force would be equal and opposite to a known force applied to the vane to bring it to its original position. According to the momentum equation this force will be equal to the rate of change of momentum of the jet in that direction. For a hemispherical cup the rate of change of momentum is given by

$$\Delta M = 2\rho Q v$$

where,

ρ = Mass density of fluid (water in this case)

Q = *Discharge Rate*

v = *Velocity of the jet (equal to Q/a)*

a = *cross section area of the nozzle*

10.4 Procedure

Note down the diameter of the nozzle and the position of the disc when the jet is not running. Adjust the flow rate to its maximum value and place weights on the upper disc to bring it back to its original position. Find the discharge from the collecting tank and note down the weight placed on the disc. Reduce the discharge and repeat this step for 10 discharge values. (It may be a good idea to put the weight first and then adjust the discharge to bring the disc to its original position, since the discharge can be more finely controlled.)

10.5 Observations and Calculations

Mass density of water, ρ =1000 kg/m^3

Diameter of nozzle = … m

Run No.	Initial Level (lit)	Final Level (lit)	Time (s)	Discharge (m^3/s)	Momentum M (N)	Weight F (N)	% Error 100(F-M)/M
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

10.6 Results and Inference

10.7 Precautions

1. Apparatus should be in levelled condition.
2. Reading must be taken in steady or nearby steady conditions. And it should be noted that water level in the inlet supply tank must be constant.
3. There should not be any air bubble in the piezometer.
4. The equipment must be free from dirt and kept clean.

EXPERIMENT 11
CENTRIFUGAL PUMP TEST

11.1 Objective

To obtain the efficiency of a centrifugal pump under varying speed.

11.2 Equipment Required

The apparatus consists of a pump connected with a D.C. motor. The suction pipe is provided with a vacuum gauge for measurement of suction head. While at the discharge side a pressure gauge is fitted for measurement of the delivery head. A variable speed motor drive is provided. A tachometer is provided for the measurement of the revolution of pump. A collecting tank is used to find the actual discharge through the pump.

11.3 Theory

Centrifugal pump is so named because the pressure head is generated by centrifugal action. The impeller is made up of a number of curve vanes, which are supported on both sides by plates known as shrouds. It rotates inside a casing or volute. Flow enters the pump through the centre or eye of the impeller. Energy is given to the liquid as the blades of the impeller transport it outwards in a radial direction.

The volute is usually shaped in the form of a spiral to form a gradual increase in flow area so that the velocity energy at exit from the impeller is converted to additional pressure energy.

The centrifugal pump is initially primed where in the suction pipe, casing of the pump and the portion of the delivery pipe up to the delivery valve are completely filled with the liquid to be pumped. With the delivery valve closed, the impeller is made to rotate. As a result a forced vortex is developed which imparts a centrifugal head to the liquid simultaneously, thereby leaving the vanes of the impeller at the outer circumference with high velocity and pressure. The high pressure of the liquid leaving the impeller enables the liquid to rise to a high level. This actions is a continuous process because the eye of the impeller is continuously supplied with replacement liquid from the pump as a result of the pressure gradient in the suction pipe (a partial vacuum exists at the eye of the impeller and the liquid in the sump is at atmospheric pressure). The high absolute velocity at the outlet of the vanes is converted to useful pressure energy by shaping the casing such that the liquid flows through a gradually expanding passage.

NOTE: In the supplied apparatus, a self priming pump does not require priming. In summary, it may be stated that a centrifugal pump lifts the liquid to a higher level as a result to a modification of the hydraulic gradient caused by centrifugal action and change in angular momentum. This is a contrast to a positive displacement pump where in lifting action is due to pushing in a confined space.

It may also be noted that the action of a centrifugal pump vis-s-vis a positive displacement pump is that its discharge capacity is much greater, it can be used to pump highly viscous liquids also, it can be operated at high speeds with less danger of separation and cavitations, and its maintenance requirement are low. However, it cannot built-up pressure as high as those that can be built up by reciprocation pumps.

The performance of a pump at a fixed/variable speed may be represented as follows:

1- Inlet pressure, m = p_1

2- Discharge pressure, m = p_2

3- Flow rate, m^3/sec = Q

4. Datum Head, m = Z_2

(Hence datum is the distance of the centre of the pressue gauge connected in the delivery line from the flange)

Total head across pump $H = (p_2 - p_1) + z_2$ m

Input Power P = (VXI) watts

Water Power $P_o = \rho g HQ$ watts

(where ρ is the mass density of the liquid being pumped).

$$Efficiency, \eta(\%) = \frac{\text{brake power}}{\text{input power}} \times 100$$

Flow measurement unit: Orifice meter

Diameter of inlet pipe, d_1 = 6.5 cm

Cross-sectional area of pipe, a_1 = 33.16 cm^2

Diameter of throat, d_2 = 3.9 cm

Cross-sectional area of throat, a_2 = 11.9 cm^2

11.4 Procedure

1. Note down the area of collecting tank position of delivery pressure gauge (Z_2) and arm distance of the spring from the centre of the shaft.
2. Priming the pump-set before starting. Priming means taking the air present in the suction volute casing by filling them with water, Ensure to close the air cock/priming adaptor as the air bubbles cease appearing and continuous stream of water come from air cock/priming adaptor.

NOTE: In the supplied apparatus, a self priming pump is used so the pump does not require priming

3. The speed control on the motor is set to a value and at the same time the flow control valve was adjusted to give the maximum possible discharge.
4. Conditions were allowed to steady before the rate of discharge *Q*, suction head, discharge head, load on the motor and r.p.s. value were recorded.
5. The flow rate is reduced in stages and the above procedure is repeated.

11.5 Observations and Calculations

Position of delivery pressure gauge (Datum head), Z_2, m =

ρg = 9810 N/m^3

Area of collecting tank 'a' = m^2

Run no.	Discharge measurement				Pump Speed (r.p.m) N	Suction head p_1, m	Delivery head p_2, m	Total Head (h) m	Voltmeter Reading, V	Ameter Reading, I	Water power, p_o (watt) ρg HQ	Input Power, p (watt) V*I	Efficiency, η %
	Initial h_1 (cm)	Final h_2 (cm)	Time (sec)	Q (m^3/s)									

11.6 Results and Inferences

11.7 Precautions

1. Apparatus should be in levelled condition.
2. Reading must be taken in steady or nearby steady conditions.

EXPERIMENT 12
PELTON WHEEL TURBINE

12.1 Objective

To study the Pelton Wheel Turbine and calculate the efficiency.

12.2 Equipment Required

The pelton wheel turbine assembly.

12.3 Theory

Electric power can be considered as the mother of automation. Jobs which are performed manually or which animal power as prime mover could be performed with most ease and development has always triggered means innovativeness leading to development of thermal/hydroelectric power plants, However server paucity of fossils fuels lead to development and intensive use of hydraulic power plants wherever possible.
At present the hydroelectric power plants are the most cheap and clean source of power.
In hydro electric power plant, the water is stored in a dam, where its level is raised to obtain a certain head water is then conveyed to the turbine via a head race the potential energy of water is converted to mechanical energy of rotation using a water Turbine. The electric alternators mounted on the turbine shaft the used to convert energy of rotation to electric power.

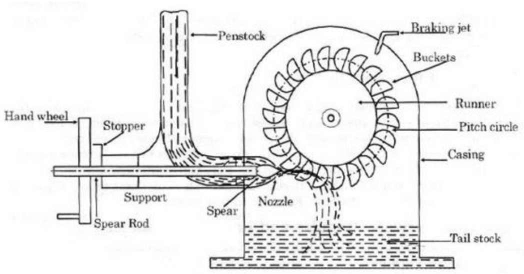

Fig. 12.1 Schematic diagram of a Pleton Wheel Turbine

The location of hydro electric power plants is the deciding factor for the harnessing the water power.
Generally a plant located in hilly terrain is characterized by a high head: which permits the

use of impulse turbine. While plants located in other areas can says; when water strikes the wheel it imparts energy to the wheel and wheel rotates. The main components of the turbine are:

1. Runner with buckets

The runner of the Pelton Wheel is circular metal disc on which the buckets are fixed. The disc material is usually steel.

Buckets - The buckets are the most important part of the Pelton Wheel as it is subjected to impact of water converting kinetic energy of water to mechanical energy of rotation. The buckets ate usually made of cast iron for medium power range and cast steel for higher power ranges.

The profile of bucket is typical having shape like two spoons joined together with a common dividing edge. The incoming jet of water meets the bucket at the common edge called splateer and gets divided in to two parts. After deflecting through 160 to 170 degree it leaves the bucket from lies in the fact that axial forces being equal neutralize each other. Hence the bearings supporting the wheel shaft are not subjected to axial thrust. The tip of the bucket is cut off. This is done to prevent the preceding bucket from interfering with the jet.

The number of buckets for Pelton Wheel is decided mainly on two principals these are:

1. Number of buckets should be as minimum jas possible so that loss dueto hydraulic friction is minimized.

2. Jet must be fully utilized so that volumetric losses are minimized.
The nozzle spear assembly is used to control the imput to the turbine. Theturbine usually operated under a constant head so to accommodate the load changesthe flow through the turbine rins always at maximum efficiency. In order to varythe flow the flow area shold be varied (as velocity is constant) this is achieved bymoving spear to and opening of by pass valve

2. Nozzle with regulating spear

The regulation of Pelton Wheel is done by spear rod assembly. Nozzle of Pelton Wheel is bolted to the supply pipe. The pipe is provided with a bend near the turbine. The nozzle is made of cast iron for small wheels and of cast steel for large Turbines. It is made of cast iron for small polished, The nozzle carried the journal for the regulating needle is in the form of spear. In the nozzle the cross-sectional area is reduced and velocity of water increased. The regulating needle regulated the flow of water through the turbine.

3. Casing

The casing of the Pelton Wheel has to carry housing for the bearing and it also has to support nozzle and pipe bend. The casing does not affect performance of the wheel. It's only function is to avoid the water from splashing outside & damping the vibration.

12.4 Procedure

1. Adjust the spring balances to give no load and make sure that they show 0 (zero).

2. Fully shut the spear valve (turn it fully clockwise).

4. Start the hydraulic bench and slowly open its control valve while opening the spear valve (turn it anticlockwise) until the bench flow is at maximum and the spear valve is fully open.
5. Use the Hydraulic Bench to measure the initial flow for reference. Note the inlet pressure.
6. Use the optical tachometer to measure the maximum (no-load) speed of the turbine. To do this, put the tachometer against the clear window at the back of the turbine and use it to detect the reflective sticker on the drum.

7. Slowly increase the load in steps to give at least six sets of results. At each step, record the turbine speed and the reading of each spring balance. Stop when the speed becomes unstable or the turbine stops rotating.

8. Repeat the test with the spear valve approximately half (50%) open and approximately quarter (25%) open.

The exact amount of spear valve opening is not important, as long as long they are different from each other to compare the effect.

12.5 Observations and Calculations

S. No.	Shaft Speed, N (RPM)	Net supply head, p_1 (m)	Discharge measurement				Break Weight, W_1 kg	Spring Balance, W_2 kg	Net Weight, $W = (W_2 - W_1)$
			h_1, cm	h_2, cm	$\Delta h = 12.6 (h_1 - h_2)$	Q (m^3/s)			

$$Efficiency, \eta(\%) \ = \frac{\text{brake power}}{\text{input power}} \times 100$$

Brake Power = 2πNT HP

where, T = Torque (Kg-m) = Net Weight, W×Re×4500

Re = effective ratio of brake drum, m

Input power = supply head (m)×Discharge (lpm)

Plot graphs of speed vs brake power and speed vs efficiency

12.6 Results and Inferences

12.7 Precautions

1. Apparatus should be in levelled condition.
2. Reading must be taken in steady or nearby steady conditions.

EXPERIMENT 13
FALL VELOCITY OF OBJECTS

13.1 Objective

To determine the coefficient of drag for objects of different shapes using the fall velocity method.

13.2 Equipments Required

- Glass jars
- Falling media such as Glycerin and oil
- Objects of different shapes and sizes
- Measuring scale
- Vernier calipers and
- Stop watch

13.3 Theory

When a heavier object falls freely in a fluid, its submerged weight becomes the driving force and the drag force resists the motion. If the object is dropped with no initial velocity, the drag force is zero and hence the object will accelerate under the action of the submerged weight. With increase in velocity, however, the drag force increases till it becomes equal and opposite to the submerged weight of the object. Under these conditions, the object attains a constant velocity, which is known as the terminal velocity, V_t. Since the drag force on the object is given by

$$F = C_D A \rho \frac{V^2}{2}$$

where,

F = Drag force, (N)

A = Projected area perpendicular to the flow direction,(m^2)

ρ = Mass density of the fluid,(kg/m^3)

V = Fall velocity, (m/s)

C_D = Coefficient of drag

The direction of the drag force is always opposite the direction of the body's velocity. The drag coefficient C_D is not constant. C_D depends upon the velocity of the body, viscosity of the medium, the shape of the body, and the roughness of the body's surface. An expression for C_D is given by-

$$C_D = \frac{2V_o(\gamma_o - \gamma_f)}{A\rho_f V_t^2}$$

where,

V_0 = Volume of the solid object, (m/s)

γ_0 = Specific weights of the object, (N/m)

γ_f = Specific weights of the fluid, (N/m)

V_t = Terminal velocity of the object, (m/s)

The Reynolds number has been found to be a useful dimensionless number that can characterize the drag coefficient's dependence upon the velocity. The Reynolds number is basically the ratio of the inertial force of the medium over its viscous force and is given by

$$\mathrm{Re} = \frac{L\rho v}{\eta}$$

where,

L = Characteristic length of the body along the direction of flow, (m)

η = Dynamic viscosity of the medium, (Ns/m^2)

ρ = Density of the medium, (kg/m^3)

v = Velocity of the body relative to the medium, (m/s)

13.4 Procedure

Measure the relevant dimensions of the object and drop it gently in the glass jar. Using a stop watch, find the time of fall through a preset distance. Follow similar procedure for diifferent objects and with the other liquids.Take atleast three sets of reading with each object in each fluid.

13.5 Observations and Calculations

Fluid	Sl No.	Object	Shape	Size	Distance (cm)	Time (sec)	Fall Velocity (m/s)	C_D	Re
Glycerine	1.								
	2.								
Oil	1.								
	2.								

13.6 Result and Inference

13.7 Precautions

1. The glass the should be kept closed when not in use to protect the liquid from dust and

other forgein materials.

2. The objects to be dropped in liquid should be properly cleaned before use.

EXPERIMENT 14
FLOW IN PIPE NETWORKS

14.1 Objective

A. To determine the characteristics of a pipe network consisting of three pipes of different sizes in series.
B. To determine the characteristics of a pipe flow network consisting of four pipes of various sizes in parallel.

14.2 Equipments Required

- Pipes of different diameters connected in series
- Manometer stand
- Probes
- Flow apparatus with pipes in parallel
- Stop watch
- Discharge measurement scale

14.3 Theory

A pipe line consisting of various diameter and lengths carrying a flow rate (Q) will have a total head loss (H_T) equal to the sum of head losses in all the sections and is given by :

$$H_T = H_{1-2} + H_{1-2} + H_{3-4}$$

The component head loss from each section is the summation of the pipes friction loss plus other losses arising from changes of section, junctions, bends and valves. Further the discharge through each pipe will be the same.

When pipes are connected in parallel, the incoming flow at the common inlet gets divided among all the pipes.

$$Q = Q_1 + Q_2 + Q_3 + Q_4$$

Except one, if all other pipes are closed in the network, the flow at the common junction inlet must be equal to the flow in the open pipe. Head change occurs during water travel through pipes, which is shown by a mercury manometer which has its ends connected to the entrance and exits of the pipe network. Flow in each pipe is measured individually by closing all other pipes. This process is repeated for all other pipes and then for the combined network. Calibration curves are prepared which would relate the head loss in a pipe with the flow in it.

14.4 Procedure

For Series set up :

After understanding the experimental procedure and getting connected the equipment, switch on the hydraulic bench pump. Connect the manometer probe at the control valve and at the outlet of the first pipe. Open the control valve slowly for nominal flow and using manometer note down the head loss in pipe section (H_{1-2}). Connect the probe between inlet and outlet of second pipe and using manometer note down the head loss in pipe section (H_{2-3}). Similarly repeat the procedure in pipe 3 and note down the readings between inlet and outlet of pipe (H_{3-4}) to represent the whole pipe network. Determine the volumetric flow rate using hydraulic bench measuring tank and stop watch. Repeat the procedure for increasing flow rate through the network. Verify the results that the total head loss across the series network (H_{1-4}) is equal to the sum of the 3 component head losses ($\Delta\sum_H = H_{1-2} + H_{2-3} + H_{3-4}$) for all flow rates. Calculate the theoretical head loss in any section for a given flow from knowledge of the pipe geometry and an estimated pipe friction factor. The values calculated should be compared to the experimentally measured values.

For Parallel set up :

After understanding the experimental procedure and getting connected the equipment, switch on the hydraulic bench pump and allow water to flow through the different pipes in the network. Further, for different flow values (Q), each time keep only one of the pipes open to allow flow through it while keep all others closed. Then, for this pipe, observe the difference in the level in the mercury manometer and note it down. Also, calculate the flow value with the help of the hydraulic bench measuring tank and stopwatch. Repeat the same procedure for at least four different flow values.

14.5 Observations and Calculations :

Series set up :

Diameter of 1st pipe D_1 = 13 mm, and Area A_1 =132.732 mm^2

Diameter of 2nd pipe D2 = 22mm, and Area A_2 = 240.528 mm^2

Diameter of 3rd pipe D_3 = 17.5mm, and Area A_3 = 380.132 mm^2

Discharge, Q = Volume collected / Time Taken

Three component head losses, $\sum\Delta_H = H_{1-2} + H_{2-3} + H_{3-4}$

Test No	Head Loss (H_{1-2}) (mm of	Head Loss (H_{2-3}) (mm of	Head Loss (H_{3-4}) (mm of	$\sum\Delta_H$ (mm of Hg)	Head Loss (H_{1-4})	Vol (m^3) $1*e^{-3}$	Time (Sec)	Flow Rate (m^3/s)	Error (%)

	Hg)	Hg)	Hg)		(mm of Hg)				
1									
2									
3									
4									

Parallel set up :

S. No.	Pipe diameter (mm)	Head Loss (mm)	Flow Volume (L)	Time (sec)	Flow(Q) (L/sec)
1	13				
2	13				
3	13				
1	17.5				
2	17.5				
3	17.5				
1	22				
2	22				
3	22				
1					
2	all open				
3					

Also, plot the calibration curve- Head loss vs discharge which can be used for further calculations.

14.6 Result and Inference

14.7 Precautions

1. The glass the should be kept closed when not in use to protect the liquid from dust and other forgein materials.
2. Apparatus should be in levelled condition.
3. Reading must be taken in steady or nearby steady conditions.