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Fluid Mechanics-I
Laboratory Manual

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LIST OF EXPERIMENTS

1. Verification of Bernoulli's equation
2. Calibration of V –notch
3. Calibration of rectangular notch
4. Calibration of trapezoidal –notch
5. Determination of metacentric height
6. Determination of coefficients of an orifice (C_d, C_C, C_v)
7. Calibration of venturimeter
8. Calibration of orifice plate
9. Determination of surface tension of liquids
10. To study the vortex flow properties

EXPERIMENT NO - 1

OBJECTIVE: Verification of Bernoulli's equation.

EQUIPMENT USED:

Inlet supply tank with overflow arrangement, outlet supply tank with means of varying flow rate, Perspex duct of varying cross-section and a series of piezometric tubes installed along its length.

INTRODUCTION AND THEORY:

Considering friction less flow along a variable are duct, the law of conservation of energy states "for and Inviscid, incompressible, Irrotational and steady flow along a stream line the total energy (or Head) remains the same". This is called Bernoulli's equation. The total head of flowing fluid consist of a pressure head, velocity head and elevation head, then

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+Z_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+Z_2$$

where P, V and Z refer to the pressure, velocity and position of the relative to some datum at any section.

EXPERIMENTAL SET UP:

The experimental set up consist up consist of a horizontal duct of smooth variable cross-section of convergent and divergent type. The section of the pipe is 40 mm at the entrance and the exit and 20 mm at middle. The total length of duct is 90 cm. The piezometric pressure P at the location of pressure tapings is measured by means if 11 piezometer tubes installed at an equal distance of 7.5 cm along the length of conduit, the duct is connected with supply tanks at its entrance and exit end with flow rate. A collection tank is used to find the actual discharge.

EXPERIMENTAL PROCEDURE:

1. Note down the piezometer distance from inlet section of the Perspex duct.
2. Note down the cross section area of perspex duct at each of the piezometer tapping points.
3. The datum head is treated as constant throughout the duct.

4. By maintaining suitable amount of steady head or nearby steady head condition in the supply tanks, three establishes a steady no uniform flow in the conduit.
5. The discharge flowing in the conduit is recorded together with the water levels in each piezometer tubes.
6. This procedure is repeated for other value of discharge.

OBSERVATION:

If V is the velocity of flow at a particular section of the duct and Q is the discharge, then by continuity equation

$$V = \frac{Q}{Area\ of\ Section}$$

OBSERVATION AND COMPUTATION SHEET:

Area of collecting tank (cm) =

Increase in depth =

Time (sec)

Discharge (cm^3/sec) =

Tube No.	1	2	3	4	5	6	7	8	9	10	11
Distance Form inlet Section (cm)											
Area of C/S of conduit a (cm^2)											
Velocity of Flow (cm/sec) V=(Q/A)											
$V^2/2g$ (cm)											
$(P/\rho g) + z$ (cm)											
$(P/\rho g) + z + V^2/2g$											

GRAPH TO PLOT:

Plot piezometric head (P/w +z), velocity head ($v^2/2g$) and total head (P/w + z + $v^2/2g$) v/s Distance of piezometric tubes from same reference point.

COMMENT:

Since the conduit is horizontal, the total energy at any section with reference to the datum line of the conduit is the sum of p/w and $v^2/2g$ (here w is the weight density of the fluid and g is acceleration due to gravity). One can compare the value of the total energy at different sections and comment about the constancy of energy in converging and diverging conduit.

PRECAUTION:

1. Reading must be taken in steady or nearby steady conditions. And it should be noted that water level in the inlet supply tank should reach the overflow condition.
2. There should not be any air bubble in the piezometer and in the perspex duct.
3. By closing the regulating value, open the control value slightly such that the water level in the inlet supply tank reaches the overflow conditions. At this stage check that pressure head in each piezometer tube is equal. If not adjust the piezometers to b ring it equal.

EXPERIMENT NO - 2

OBJECTIVE: Calibration of V -notch.

EQUIPMENT USED: A constant steady water supply tank (Notch tank) with baffles wall, pointer gauge, collecting tank, trapezoidal -notch.

INTRODUCTION AND THEORY:- Different type of models are available to find discharge in an open channel as notch, weir etc. for calibration of either rectangular notch, trapezoidal notch or V notch some flow is allowed in the flume,. Once the flow becomes steady and uniform discharge coefficients can be determine for any models.

In general, sharp crested notch are preferred where highly accurate discharge measurement are required, for example in hydraulic laboratories, industry and irrigation pilot schemes, which do not carry debris and sediments.

Notches are those overflow structure whose length of crest in the direction of low is accurately shaped. There may be rectangular, trapezoidal, V notch etc. the V-notch is one of the most precise discharge and head over the weir can be developed by making the following assumptions as to the flow behavior.

a. Upstream of the weir, the flow is uniform and the pressure varies with depth according to the hydrostatic equation $p=\rho gh$.
b. The face surface remains horizontal as far as plane of the weir, and all particles passing over the weir move horizontally.
c. The pressure throughout the sheet of liquid or nappe, which passes over the crest of the weir, is atmospheric.
d. The effect of viscosity and surface tension are negligible.
e. The velocity in the approach channel is negligible.

A v-notch is having a V-shaped opening provided in its body so that water is discharged through this opening. This line which bisects the angle of notch should be vertical and the same distance from both sides of the channel. The discharge coefficient cd of a v-notch may be determined by formula.

Where Q is the discharge over triangular notch.

EXPERIMENT SETUP:

The experiment set up consists of a tank whose inlet section is provided with 2 nos. of baffles for stream line flow. While at the downstream portion of he tank one can fit rectangular notch, trapezoidal notch, V notch. A tank hook gauge is used to measure the head of water over the model. A collecting is used to find the actual discharge through the notch.

EXPERIMENT PROCEDURE:

1. The notch under test is positioned at the end of the tank, in a vertical plane and with the sharp edge on the upstream side.
2. The tank is filled with water up to crest level and subsequently note down the crest level of the notch by the help of a point gauge.
3. The flow regulating valve is adjusted to give the maximum possible discharge without flooding the notch.
4. Conditions are allowed to steady before the rate of discharge and head H were recorded.
5. The flow rate is reduced in stages and the reading of discharge and H were taken.
6. The procedure is repeated for other type of notch.

OBSERVATION AND COMPUTATION SHEET:

Apex angle of Notch = θ

Crest Level of trapezoidal notch H_1 **=**

Area of collecting tank, a=

S. No.	Discharge Measurement				Final Reading of water level above the notch H_2	Head over notch $H = H_2 - H_1$ (cm)	C_d =
	Initial (cm)h_1	Final (cm)h_2	Vol. (cm^3)	Vol. (cm^3/sec) Q=vol/t			

EXPERIMENT NO. - 3

OBJECTIVE: Calibration of rectangular notch.

EQUIPMENT USED: A constant steady water supply tank (Notch tank) with baffles wall, pointer gauge, collecting tank, and models.

INTRODUCTION AND *THEORY*: Different types of models are available to find discharge in an open channel as notch, venturimeter notch etc. for calibration of either rectangular notch, trapezoidal notch some flow is allowed in the flume. Once the flow becomes steady and uniform discharge coefficients can be for any model.

In general, sharp crested notches are preferred where highly accurate discharge measurement is required, for example in hydraulic laboratories, industries and irrigation pilot schemes, which do not carry debris and sediments. Notches are those overflow structure whose length of crest in the direction of flow is accurately shaped. There may be rectangular, trapezoidal, V notch etc. the relationship between discharge and head over the notch can be developed by making the following assumptions as to the flow behavior.

a. Upstream of the notch, the flow is uniform and the pressure varies with depth according to the hydrostatic equation $P=\rho gh$.

b. The free surface remains horizontal as far as the plane of the notch, and all particles passing over the notch move horizontally.

c. The pressure throughout the sheet of liquid which passes over the crest of the notch is atmospheric.

d. The effect of viscosity and surface tension are negligible.

e. The velocity in the approach channel is negligible.

A rectangular notch, symmetrically located in a vertical thin plate, which is placed perpendicular to the side and bottom of a straight channel, is defined as a rectangular sharp-crested notch. The discharge coefficient C_d of a rectangular notch my be determined by applying formula

$$Q=\frac{2}{3}C_d\sqrt{2g}\,BH^{\frac{3}{2}}$$

Where Q is the discharge over a rectangular notch, B is the width of notch, H is the head over the crest of the notch and g is acceleration due to gravity.

EXPERIMENTAL SET-UP: The experiment setup consists of a tank whose inlet section is provided with –2 nos. of baffles for stream line flow. While at the downstream portion of the tank one can fix a notch of rectangular notch, trapezoidal notch or V-notch. A hook gauge is used to measure the head of water over the model. A collecting tank is used to find the actual discharge through the notch.

EXPERIMENTAL PROCEDURE: The notch under test is positioned at the end of the tank, in a vertical plane, and with the sharp edge on the upstream side.

1. The tank is filled with water up to crest level and subsequently note down the crest levels of the notch by the help of a point down.
2. The flow regulating value is adjusted to give the maximum possible discharge without flooding the notch.
3. Conditions are allowed to steady before the rate of discharge and head H were recorded.
4. The flow rate is reduced is stage and the reading of discharge and head H were taken.
5. The procedure is repeated for other type of notch.

OBSERVATION AND COMPUTATION SHEET-

Width of notch, B =

Crest level of notch H_1 =

Area of collecting tank, a =

Sr. No.	Discharge measurement			Discharge (cm^3/sec) Q	Final reading of water level above the notch H2	Head over notch H= H_2-H_1 (cm)	$C_d = \dfrac{Q}{\frac{2}{3}\sqrt{2g}\,BH^{\frac{3}{2}}}$
	Initial h1 (cm) h_1	Final h_2	Time (sec)				

Average C_d=

EXPERIMENT NO - 4

OBJECTIVE: Calibration of trapezoidal -notch

EQUIPMENT USED: A constant steady water supply tank (Notch tank) with baffles wall, pointer gauge, collecting tank, models, trapezoidal -notch.

INTRODUCTION AND THEORY:-Different type of models are available to find discharge in an open channel as notch, Venturiflume, weir etc. for calibration of either rectangular notch, trapezoidal notch or V notch some flow is allowed in the flume,. Once the flow becomes steady and uniform discharge coefficients can be determine for any models.

In general, sharp crested notch are preferred where highly accurate discharge measurement are required, for example in hydraulic laboratories, industry and irrigation pilot schemes, which do not carry debris and sediments.

Notches are those overflow structure whose length of crest in the direction of low is accurately shaped. There may be rectangular, trapezoidal, V notch etc. the V-notch is one of the most precise discharge and head over the weir can be developed by making the following assumptions as to the flow behavior.

a. Upstream of the weir, the flow is uniform and the pressure varies with depth according to the hydrostatic equation p= ρ gh
b. The face surface remains horizontal as far as plane of the weir, and all particles passing over the weir move horizontally.
c. The pressure through out the sheet of liquid which passes over the crest of the weir is atmospheric.
d. The effect of viscosity and surface tension are negligible.
e. The velocity in the approach channel is negligible.

A trapezoidal watch is combination of a rectangular and triangular notch. Thus, the total discharge will be equal to the slum of discharge through a rectangular notch & discharge through a triangular notch. If discharge coefficient for the whole of the trapezoidal notch is assumed to be c_d, then the expression for discharge coefficient can be determined by applying formula.

$$Q = C_d\sqrt{2g}\,H^{\frac{3}{2}}\left[\frac{2}{3L} + \frac{8}{15}H\tan\frac{\theta}{2}\right]$$

Where Q is the discharge of a trapezoidal notch θ is angle of notch and H is the head over the crest of the notch.

EXPERIMENT SETUP:

The experimental set up consists of a tank whose inlet section is provided with 2 nos. of baffles for stream line flow. While at the downstream portion of the tank one can fit rectangular notch, trapezoidal notch, V notch. A tank hook gauge is used to measure the head of water over the model. A collecting is used to find the actual discharge through the notch.

EXPERIMENT PROCEDURE:

1. The notch under test is positioned at the end of the tank, in a vertical plane and with the sharp edge on the upstream side.
2. The tank is filled with water up to crest level and subsequently note down the crest level of the notch by the help of a point gauge.
3. The flow regulating valve is adjusted to give the maximum possible discharge without flooding the notch.
4. Conditions are allowed to steady before the rate of discharge and head H were recorded.
5. The flow rate is reduced in stages and the reading of discharge and H were taken.
6. The procedure is repeated for other type of notch.

OBSERVATION AND COMPUTATION SHEET:

Trapezoidal -notch.

Apex angle of Notch $\frac{\theta}{2} = 45^0$

Crest Level of trapezoidal notch H_1=

Area of collecting tank, a=

L= length of the crest of the notch =

S. No.	Discharge Measurement				Final Reading of water level above the notch H_2	Head over notch $H = H_2 - H_1$ (cm)	C_d =
	Initial (cm)h_1	Final (cm)h_2	Vol. (cm^3)	Vol. (cm^3/sec) Q=vol/t			

EXPERIMENT NO - 5

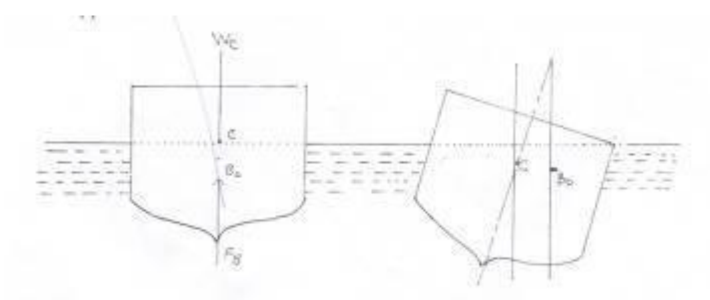
OBJECTIVE: Determination of metacentric height

EQUIPMENT USED: A pontoon floating in a tank. Removable strips, graduated arc with pointer, movable, hangers, set of weight.

INTRODUCTION AND THEORY: A body floating in a fluid is subjected to the following system of force.

1. The downward force of gravity acting on each particle that goes to make up the weight of body, we 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 center of buoyancy B.

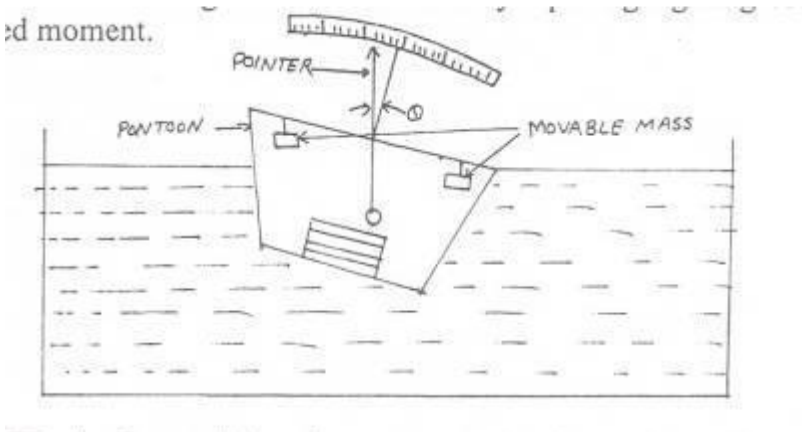
   For a body to be in equilibrium on the liquid surface, the two forces Wc and FB must lie in the same vertical line i.e. these must be collinear, equal and opposite.



CENTRE OF BUOYANCY AND METACENTRE

When the pontoon has been titled through an angle, the center of gravity of body G, usually remain unchanged in its position, but B i.e. center of buoyancy will generally change its position, thus Wc and Fb in the new position cuts the axis of the body at M, which is called the metacentre and the distance GM 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 righting couple and applied moment.



Here Wc is the weight of pontoon, W_M the weight of unbalanced mass causing moment on the body, Xd is the distance of the unbalanced mass from the center of the cross bar

EXPERIMENTAL SET UP :

The experimental setup consists of a pontoon which is allowed to float in a M.S. tank having a transparent side. Removable steel strips are placed in the model for the purpose of changing the weight of the model. By means of pendulum (Consisting of a suspended to a long pointer) the angle of tilt can be measured on a graduated arc. For titling the ship model a cross bar with two movable hangers is fixed on the model. Pendulum and graduleds are arc suitably fixed at the center of cross bar.

EXPERIMENTAL PROCEDURE:

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

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

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

4. Position of unbalanced mass, weight of unbalanced mass, and the angle of heel can be noted down. Calculate the Metacentric height of the pontoon.

5. The procedure is repeated for other position and value of unbalanced mass. Also the procedure is repeated while changing the number of strips in the pontoon.

OBSERVATIONS AND COMPUTATION SHEET:

Area of tank

Water level (without pontoon) Y_1=

Unit weight of water ρ =

Reading on tank with pontoon Y_2 (cm)	Mass of pontoon (gm) $W_c=(Y_2-Y_1)A\rho$	Unbalanced Mass (gm) W_m	Angle of Heel (degree) θ	Distance of unbalanced Mass X_d (cm)	Meta centric height (cm) $W_mX_d/(W_c+W_m)\tan\theta$	Average (cm)

PRECAUTION:

1. Apparatus should be in leveled condition.
2. Reading must be taken in steady condition of water.
3. Unbalanced mass should be distributed by taking care that water should be disturbed at minimum.

EXPERIMENT NO - 6

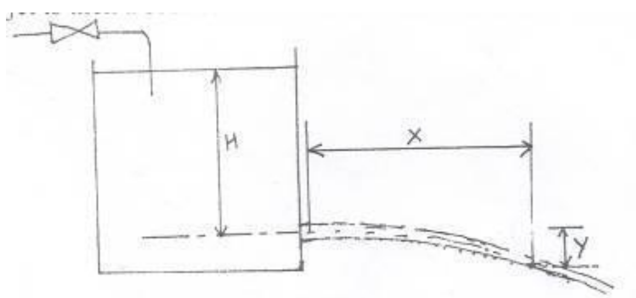
OBJECTIVE: **Determination of coefficients of an orifice (C_d, C_C, C_V)**

EQUIPMENT USED:

Supply tank with overflow arrangement and provision of fitting of orifice or mouth piece installed in the vertical plane of the tank side, scale and sliding apparatus with hook gauge, orifice 10 mm dia.

INTRODUCTION AND THEORY:

An orifice is an opening in the wall of the tank, while a mouth is a short pipe fitted in the same opening. Orifice is used for discharge measurement. The jet approaching the orifice continues beyond the orifice till the streamline becomes parallel. This section is the jet approaching the orifice, continue to coverage beyond parallel. This section of the jet approaching the orifice continue to coverage beyond the orifice till the streamlines become parallel. This section of jet is then a section of minimum area and is known as vena contracta.



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

$$Y = \frac{g}{2V_c^2} X^2$$

$$V_c = \left[\frac{gX^2}{2Y}\right]^{\frac{1}{2}}$$

The theoretical velocity in the plane of the vena contracta V_o is given by

$$\frac{V_c^2}{2g} = h \qquad \text{i.e. } V_o = \sqrt{2gh}$$

Now co-efficiency of velocity $C_v = \frac{X}{2\sqrt{Yh}}$

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

The actual discharge Q when divided by $a\sqrt{2gh}$ yields the coefficient of discharge C_d. Here a is the area of cross section if the orifice and g is the acceleration due to gravity.

Once Cd and C_v are know, the coefficient C_c can be obtained by dividing C_d by C_v,

$$C_c = C_d / C_v$$

EXPERIMENT SET-UP:

The experimental setup consists of a supply tank with overflow arrangement and gauge glass tube for water level measurement in the tank. There is also provision for fixing the various orifices and mouthpiece (interchangeable) installed in a vertical plane of the tank side. 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. This hook gauge can be moved as well as vertically in x and y direction and its corresponding movement can be read on horizontal and vertical scale respectively. A collecting tank is used to find the actual discharge of water through the jet.

EXPERIMENT PROCEDURE:

1. Note down the relevant dimensions as area of collecting tank and supply tank.
2. Attach an orifice and note down its diameter.

3. The apparatus is leveled.
4. The water supply was admitted to the supply tank and conditions are allowed to steady, to give a constant head.
5. The lowest point of the orifice is used as the datum for the measurement of h and y.
6. The discharge flowing through the jet was recorded together with the water level in the supply tank.
7. A series of reading of dimensions x and y was taken along the trajectory of the jet.
8. The procedure is repeated by means of flow control valve.

OBSERVATION AND COMPUTATION SHEET:

Area of cross section of collecting tank =
Size and shape of orifice =
Area of cross section of orifice, a =
Reading on the piezometer at the level on the center of orifice h_0 =

(i) Determination of C_d

Sr No.	Reading on the piezometer a_1	Value of $h=a_1-h_0$	Discharge measurement				$C_d = Q / a\sqrt{2gH}$
			Initial (cm)	Final(cm)	Time (sec.)	discharge (cm^3/Sec) q	

Average C_d=

(ii) Determination of C_v

Reading of horizontal scale at exit of orifice/mouthpiece x_0 =
Reading of vertical scale at exit of orifice/mouthpiece y_0 =

Sr. No.	H (cm)	Reading on Scale		$X= x'-x_0$	$Y=y'-y_0$	$C_v = \frac{x}{2\sqrt{yH}}$
		Horizontal x' (cm)	Vertical Y' (cm)			

Average C_v=

Therefore $C_c=C_d / C_v$

EXPERIMENT NO - 7

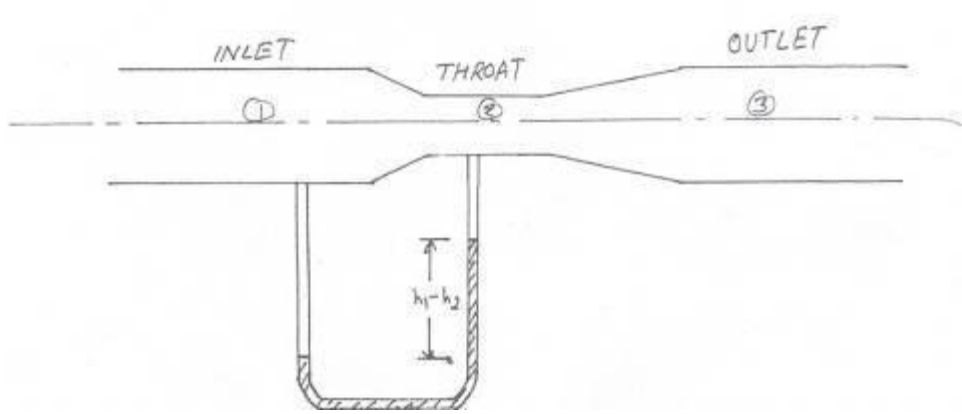
OBJECTIVE: Calibration of venturimeter.

EQUIPMENT USED:

Venturimeter fitted in a horizontal pipe line with means of varying flow rate, U tube different manometer.

INTRODUCTION AND THEORY:

The Venturimeter are devices used for measurement of rate of flow of fluid through a pipe. The basis principle on which a Venturimeter work is that by reducing the cross sectional area of flow passage, a pressure difference is created and the measurement of the pressure difference enables the determination of the discharge through the pipe.



A Venturimeter consists of (1) an inlet section followed by a convergent cone, (2) a cylindrical throat and (3) a gradually divergent cone. Since the cross-sectional area of the inlet section, the velocity of flow at the throat will become greater than that at the inlet section, according to continuity equation. The increase in the velocity of flow at the throat results in the decrease in the pressure at this section. A pressure difference is created between the inlet section and throat section which can be determined by connecting a different U-tube manometer between the pressure tapes provided at these sections.

Measurement of pressure difference between these sections enables the rate of flow of fluid (Q) to be calculated as

$$Q = \frac{C_d\, a\sqrt{2g\ \Delta h}}{\sqrt{1-\left[\frac{a}{A}\right]^2}}$$

Where a is the area of cross section of throat, A is the area of cross section of inlet section, g is the acceleration due to the gravity, h is the difference of head and Cd is the coefficient of discharge of Venturimeter.

EXPERIMENT SET -UP:

The experimental set up consist of a circuit through which the fluid is circulated continuously having a venturimenter of 25 mm dia and having a d/ D = 0.6. The Venturimeter is provided with two tapping one each at upstream and at the throat section. A U tube mercury manometer with common manifold is provided to measure the pressure differences between two sections. A collecting tank is provided to find the actual discharge through the circuit.

EXPERIMENTAL PROCEDURE:

1. Note down the relevant dimensions as diameter of pipeline, throat dia of Venturimeter area of collecting tank, room temperature etc.
2. Pressure tapping Venturimeter is kept value.
3. The flow rate is adjusted to its maximum value.
4. By maintaining suitable amount of steady flow in the pipe circuit, there establishes a steady no uniform flow in the conduit. Time is allowed to stabilize the levels in the manometer tube.
5. The discharge flowing in the circuit is recorded together with the water levels in left and right limbs of manometer tube.
6. The flow rate is reduced in stage by means of flow control value and the discharge & reading of manometer are recorded.
7. This procedure is repeated by opening the pressure tapping of Venturimeter.

OBSERVATION AND COMPUTATION SHEET:

VENTURIMETER

Diagram of main pipe line, D =

The ratio d/D =

Area of cross diction of throat section a =

Are of cross section of inlet section A =

Area of collecting tank

Sr No.	Discharge Measurement				Manometer Reading			Q= $\frac{C_d\, a\sqrt{2g\Delta h}}{\sqrt{1-\left[\frac{a}{A}\right]^2}}$
	Initial (cm)	Final (cm)	Time (sec)	Discharge (cm^3/ sec) Q	Rise in left h_1(cm)	Rise in right limb h_2(cm)	Δh in terms of water head=12.6x(h_1- h_2)	

EXPERIMENT NO - 8

OBJECTIVE: Calibration of orifice plate

EQUIPMENT USED: Orifice meter fitted in a horizontal pipeline with means of varying flow rate, U tube differential manometer.

INTRODUCTION AND THEORY: The Orificemeter are devices used for measurement of rate of flow of fluid through a pipe. The basis principle, on which Orificemeter work is that by reducing the cross sectional area of passage, a pressure difference is created and the measurement of the pressure difference enables the determination of the discharge through the pipe.

An Orificemeter is a cheaper arrangement for measurement of discharge through pipes and its installation requires a smaller length as compared with venturi meter.

An Orificemeter 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 beveled at an angle lying between 30^0 and 45^0. The plate is clamped between the two pipe flanges with beveled surface facing downstream.

Two pressure tapes are provided, one on the upstream side of plate and other on the downstream side of the orifice plate. A pressure difference exists between two sections which can be measured by connecting a different manometer to the two pressure tape. The discharge coefficient can be calculated using following formula.

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

Where C_d is coefficient of orifice, a_0 is cross-sectional area of orifice, a_1 is cross sectional area of pipe, g is the acceleration due to gravity and Δh is the difference of head in terms of water.

EXPERIMENTAL SET-UP:

The experimental setup consists of a circuit through which the fluid is circulated continuously having a Orifice meter of 25 mm dia and having a d/D=0.6. The Orificemeter has two pressure tapings at upstream and downstream. A U tube mercury manometer with common manifold is pressure the pressure difference between two sections. A collecting tank is provided to find the actual discharge through the circuit.

EXPERIMENTAL PROCEDURE:

1. Note down the relevant dimensions as diameter of pipeline, dia of orifice, area of collecting tank, room temperature etc.
2. Pressure taping of Orificemeter is kept open.
3. The flow rate is adjusted to its maximum value.
4. By maintain suitable amount of steady flow in the pipe circuit, there establishes a steady no uniform flow in the conduit. Time is allowed to stabilize the levels in the manometer tube.
5. The discharge flowing in the circuit is recorded together with the water levels in left and right limbs of manometer tube.
6. The flow rate is reduces in steady by means of flow control value and the discharge & reading of manometer are recorded.
7. This procedure is repeated by closing the pressure taping of Orificemeter.

OBSERVATION AND COMPUTATION SHEET:

ORIFIC METER:

Diameter of main pipe line, D =

The ratio d/D = 0.6

Area of cross section of orifice a_0 =

Area of cross section of inlet section a_1 =

Area of collecting tank

Sr No.	Discharge Measurement				Manometer Reading			**C_d=** $\frac{Q\sqrt{a_1^2 - a_0^2}}{a_0 a_1 \sqrt{2g\Delta h}}$
	Initial (cm)	Final (cm)	Time (sec)	Discharge (cm^3/ sec) Q	Rise in left h_1(cm)	Rise in right limb h_2(cm)	Δh in terms of water head=12.6x(h_1-h_2)	

Average C_d =

Graph to plot: Plot a graph between Q vs Δ h.

EXPERIMENT NO - 9

OBJECTIVE: Determination of surface tension of liquids.

EQUIPMENT: Shown in fig 2

THEORY:

The molecules of liquids attract each other by cohesive forces resulting into small distances between the molecules (on the order of 0.1 nm). Hence the compressibility of liquids is lower than that of gas, while the density is much higher. On the other hand, these cohesive forces are not strong enough to result into the fixed position of molecules that can be seen in solid matter. Liquids do not keep a fixed shape, but adapt the shape of a container. Attractive cohesive forces are short range forces which are based on the electronic interactions. They affect only molecules in their close vicinity (zone of molecular interaction). In the bulk of the liquid, each molecule is attracted equally in all directions by the neighbouring molecules, thus resulting in a total force of zero. However, the molecules at the surface do not have other like molecules on all sides of them and they are pulled inwards the liquid core by non-zero total force

Consequently, they cohere more strongly to those directly associated with them on the surface and form a surface "film". Nevertheless, these surface molecules are in the energetically unfavourable state, which makes liquid to minimize the surface area. The geometrical requirement of smallest surface area at the fixed volume is satisfied by the sphere. It is the reason why the free drops of water form spherical droplets.

Surface area increase, D*S*, is balanced out by the increase of energy, D*E*, where

$$dE = \sigma \times dS \qquad [1]$$

The coefficient σ defines the **surface tension** in the units of J/m2=N/m. Each liquid is characterized by its own surface tension, which decreases with an increasing temperature. The molecules of the liquid interact with the walls of the container through adhesive forces. The surface bends up (concave meniscus) when the adhesive intermolecular forces are stronger than the cohesive forces inside the liquid (e.g. water in a glass container shown on Figure), while it bends down (convex meniscus) when the adhesive forces are weaker (e.g. mercury in a glass container).

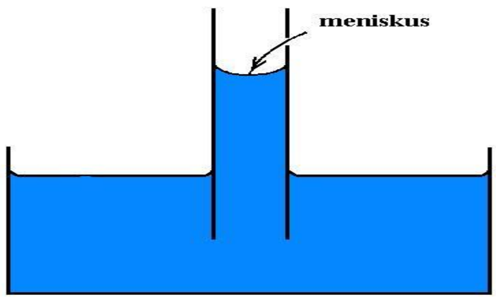


Fig 1: The glass capillary of a radius r immersed in water.

Capillary action is the result of interplay between the surface tension and adhesive forces. Water inside the capillary arises above the water level in the container (capillary elevation). Capillary pressure, p_k, that draws water into capillary is determined by the radius of capillary, r, and the surface tension of water, σ, as follows from

$$p_k = \frac{2\sigma}{r} \qquad [2]$$

Capillary pressure and capillary elevation is higher for narrower capillary.

In a contrary to water, capillary action in a case of mercury has an opposite direction. The mercury level inside the capillary is lower than that in the container (capillary depression). The capillary of radius *r* is immersed in the liquid of density r and surface tension σ, such that the bottom of capillary is at the depth of *h* bellow the water level .

We would need to apply pressure equivalent to the capillary pressure, p_k, to bring the liquid level in the capillary to the same level as that in the container. The additional pressure p_h is given by

$$p_h = h\, g\, \rho \qquad [3]$$

where *g* is a gravitational acceleration, would than cause water to be pushed out of the capillary completely. p_h is the hydrostatic pressure at a depth *h*, and it is a result of the weight of the liquid above this point. The pressure equal or greater than

$$p = p_k + p_h \qquad [4]$$

It is the equation that establishes the method of surface tension determination via pushing the bubbles through the capillary. Figure 2 describes the standard apparatus employed in such a measurement. The investigated liquid is contained in a beaker, with the capillary immersed in it. Water contained in a funnel A will create the desired pressure upon the opening of the knob C1. This pressure is measured by the manometer M, which consists of a U-shape glass tube filled with water. The water levels in the both arms of manometer are equivalent at the beginning of the experiment. However, pressure *p* will create a difference in water levels, *hv*, after opening the knob C1. This pressure is determined by

$$P = h_v \rho_v g \qquad [5]$$

where ρ_V is a density of water.

Therefore, surface tension is given by

$$\sigma = r/2 \, (h_v \rho_v - h\rho) \, g \qquad [6]$$

where the water density is r*V*=1 g/cm3=1000 kg/m3, and the density of the investigated liquid is marked on a beaker of stock solution. The capillary radius r can be determined from the control measurement in which we measure the known surface tension of water. The radius r is than expressed from equation [6] using the known parameters (σ*,* r*V* and r) and measured water levels *h* and *hv*.

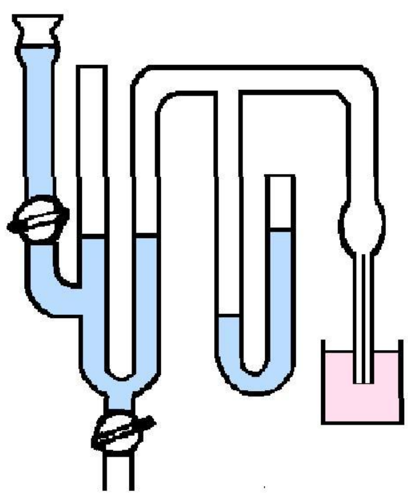


Figure 2: The apparatus for the determination of surface tension via pushing the bubbles through the capillary.

PROCEDURE:

1. Fill the smaller beaker with the liquid of unknown surface tension and immerse the capillary into it.
2. Fill the funnel A with water, while the knobs C1 and C2 stay closed.
3. Slowly open the knob C1, thus create an additional pressure in the apparatus. Watch the bubbles that are being pushed through the capillary. The pressure *p* decreases as the water level in funnel A decreases, which results into the slow reduction in a rate of bubbling. Close the knob C1 right at the moment when the bubble formation stops. Read out the water levels *h* and h_V.
4. Open the knob C2 to release water form apparatus into the larger beaker.
5. Repeat the measurement (sections 3 and 4) 10 times and write the measured values into a table. Calculate the average values of h and hV.
6. Measure the room temperature t. Determine water surface tension at this temperature using the Table 1. Calculate the surface tension of the investigated liquids using the equation [6].

Tab. 1. The difference of water levels hV in manometer and the depth of capillary immersion h.

Measurement	Water		Liquid	
	h_V (m)	h (m)	h_V (m)	h (m)

EXPERIMENT NO - 10

OBJECTIVE: To study the vortex flow properties.

EQUIPMENT: As shown in the figure.

THEORY:

A **vortex** is a spinning, often turbulent, flow of fluid. Any spiral motion with closed streamlines is vortex flow. The motion of the fluid swirling rapidly around a center is called a vortex. The speed and rate of rotation of the fluid in a free (irrotational) vortex are greatest at the center, and decrease progressively with distance from the center, whereas the speed of a forced (rotational) vortex is zero at the center and increases proportional to the distance from the center. Both types of vortices exhibit a pressure minimum at the center, though the pressure minimum in a free vortex is much lower.

Forced (rotational) vortex

In a **forced vortex** the fluid rotates as a solid body (there is no shear). The motion can be realized by placing a dish of fluid on a turntable rotating at ω radian/s; the fluid has vorticity of 2ω everywhere, and the free surface (if present) is a paraboloid.

The tangential velocity is given by:

$v_\theta = \omega r$, where ω is the angular velocity and r is the radial distance from the center of the vortex.

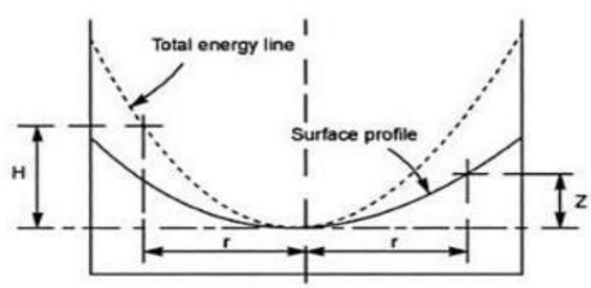


Figure: Forced Vortex: Total Energy Line and Surface Profile

The surface profile and total energy line are shown above in which the Z and H are measured at any radial distance r are measured at the horizontal datum passing through the lowest point of the surface profile. In which

$Z = \omega^2 r^2 / 2g$

$H = \omega^2 r^2 / g$

Both profiles are parabolic in nature and Z is one-half of

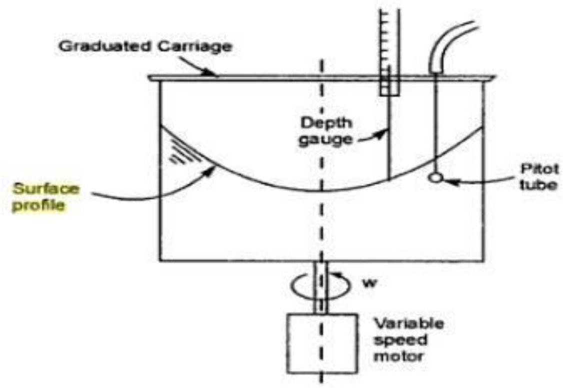


Figure: Apparatus for observation of the forced vortex

PROCEDURE:

1. Start the apparatus to start the rotation to form the vortex
2. Wait till the conditions becomes steady, i.e. depth of flow at a point doesn't change with time. Take the surface profile reading by the pointer along the radius of the cylinder on both sides. At r=0, i.e. the center of the vortex is taken as the datum for all the readings.
3. Repeat the same with different volume of water and different angular velocity of the water.

CALCULATIONS: Plot Z vs r and H vs r to obtain the surface profile and total energy line. Plot Z vs r^2 and H vs r^2 . Calculate the slope to obtain the values of $\omega^2/2g$ and ω^2/g respectively . Then calculate the values of ω and compared it with the observed ω.

r	Z