NATIONAL INSTITUTE OF TECHNOLOGY, AGARTALA

राष्ट्रीय प्रौद्योगिकी संस्थान अगरतला
NATIONAL INSTITUTE OF TECHNOLOGY AGARTALA
ज्ञानम परम बलम

GOVT. OF INDIA

Department of ...Mechanical............... Engineering

Submitted by

Name : ....Ridham Banik.......................................

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Subject : Fluid Mechanics and Fluid Machines Lab.......

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Experiment - 1

Aim:- To study and verify Bernoulli's Equation

Theory:- Bernoulli's principle states that as the speed of a moving fluid increases, the pressure within the fluid decreases. Bernoulli's theorem states that "in a steady and continuous flow of a frictionless incompressible fluid the summation of potential head, the pressure head and the kinetic head is same at all the point."

so, for two different sections of a pipe flow—

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 = \text{Constant}$$

where v = velocity, p = pressure, z = potential head.

Apparatus required:

i) Water supply from pump.

ii) A convergent - divergent duct of width 3.75cm and different sections with piezometer tubes filled vertically at regular intervals.

iii) A discharging measuring tank

iv) Stop watch.

Procedure :-

i) Open the inlet valve slowly and allow the water to flow from pump.

ii) Now adjust the flow to get a constant head in the supply tank to make flow in the outflow equal.

iii) Under this condition, the pressure head will become constant in the piezometer tubes.

iv) Note down the quantity of water collected in the measuring tank for a given interval of time

v) Compute the area of cross-section under the piezometer tube

vi) Compute the area of cross-section under the tube.

vii) Take atleast three readings as described in the above steps.

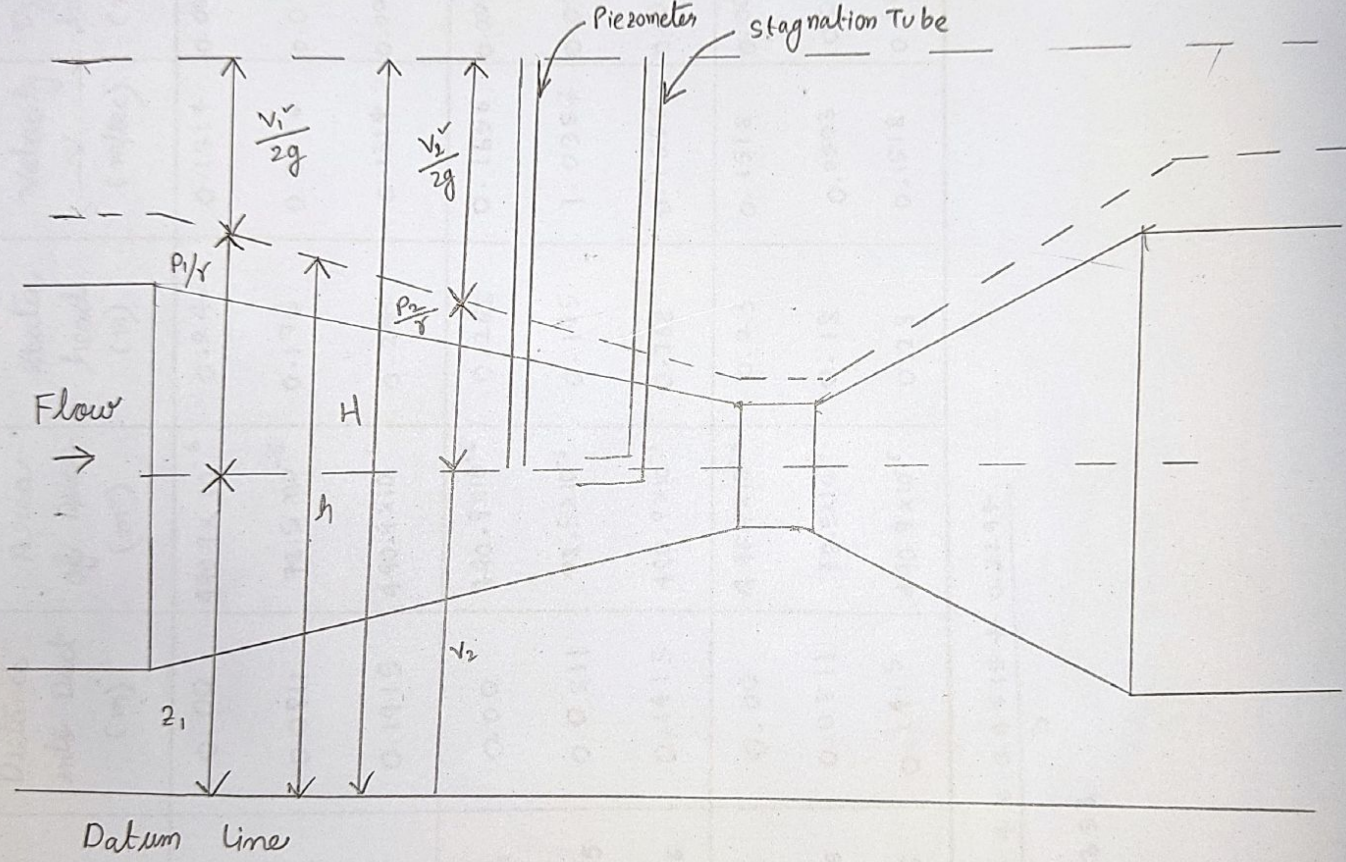
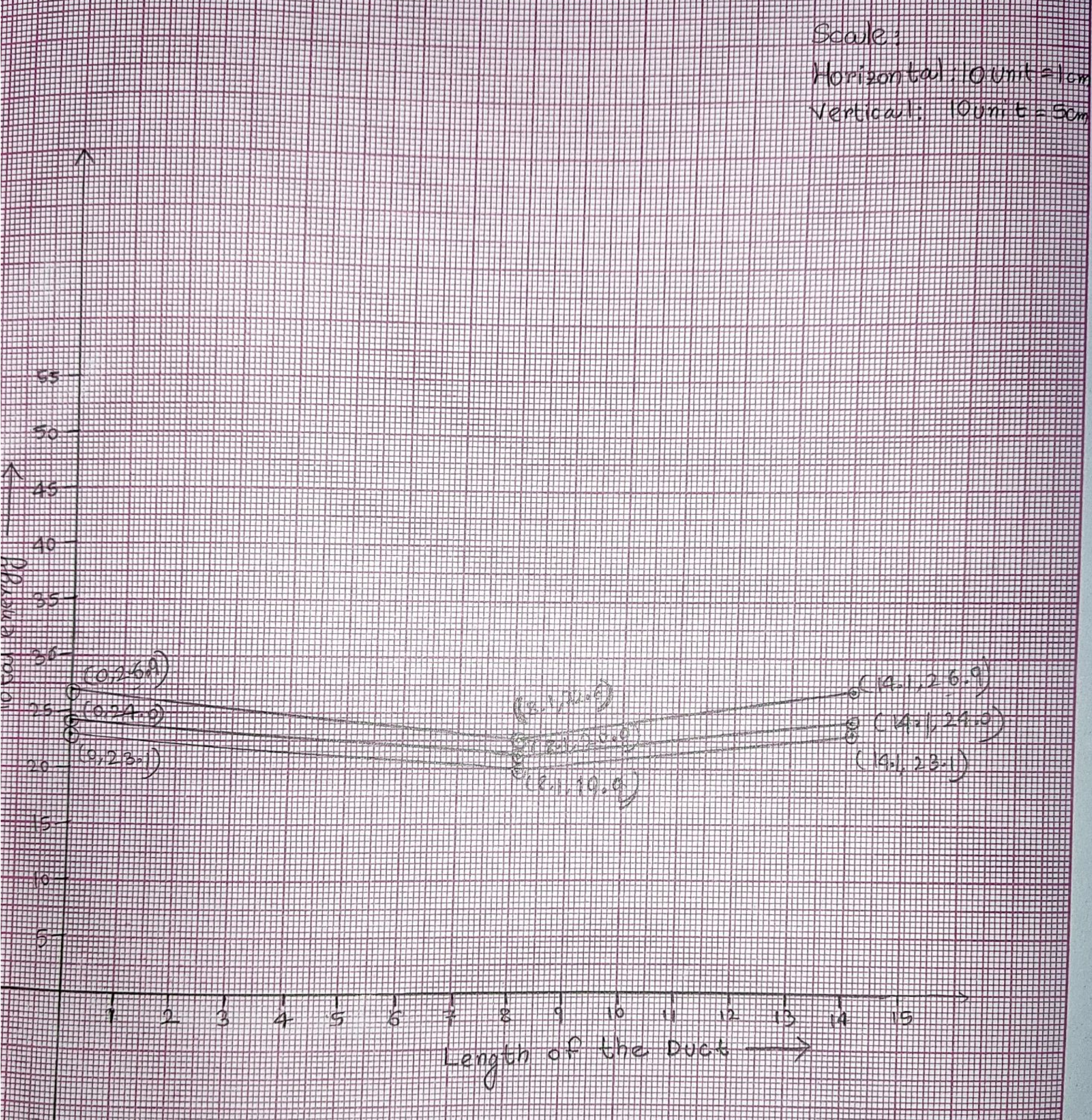


Fig:- For verifying Bernoulli's theorem

Volume collected V (m³)	Time to collect t (sec)	Flow rate Q (m³/sec)		Distance into Duct (m)	Area of Duct (m²)	Static head (m)	Velocity V (m/sec)	Dynamic head (m)	Total head (m)	Average head (m)
			h_1	0.00	490.9×10^{-6}	0.24	0.1314	0.0008801	0.2408801	
0.001	15.5	6.45×10^{-5}	h_5	0.0811	78.5×10^{-6}	0.175	0.8216	0.0344	0.2094	0.2304
			h_6	0.1415	490.9×10^{-6}	0.24	0.1314	0.0008801	0.2408801	
			h_1	0.00	490.9×10^{-6}	0.268	0.1656	0.0013978	0.2[illegible]3978	
0.001	12.3	8.13×10^{-5}	h_5	0.0811	78.5×10^{-6}	0.195	1.0357	0.05467	0.19967	0.24615
			h_6	0.1415	490.9×10^{-6}	0.268	0.1656	0.0013978	0.2693978	
			h_1	0.00	490.9×10^{-6}	0.23	0.1518	0.001174	0.231174	
0.001	13.4	7.46×10^{-5}	h_5	0.0811	78.5×10^{-6}	0.18	0.9503	0.046	0.226	0.2294
			h_6	0.1415	490.9×10^{-6}	0.23	0.1518	0.001174	0.231174	

$$\text{Total head} = \frac{0.2304 + 0.24615 + 0.2294}{3}$$

$$= 0.2353$$


Scale:
Horizontal: 10 unit = 1cm
Vertical: 10 unit = 50cm
55
50
45
40
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Length of the Duct
(0,26.9)
(0,24.0)
(0,23.1)
(14.1,26.9)
(14.1,24.0)
(14.1,23.1)

CM DIVISION

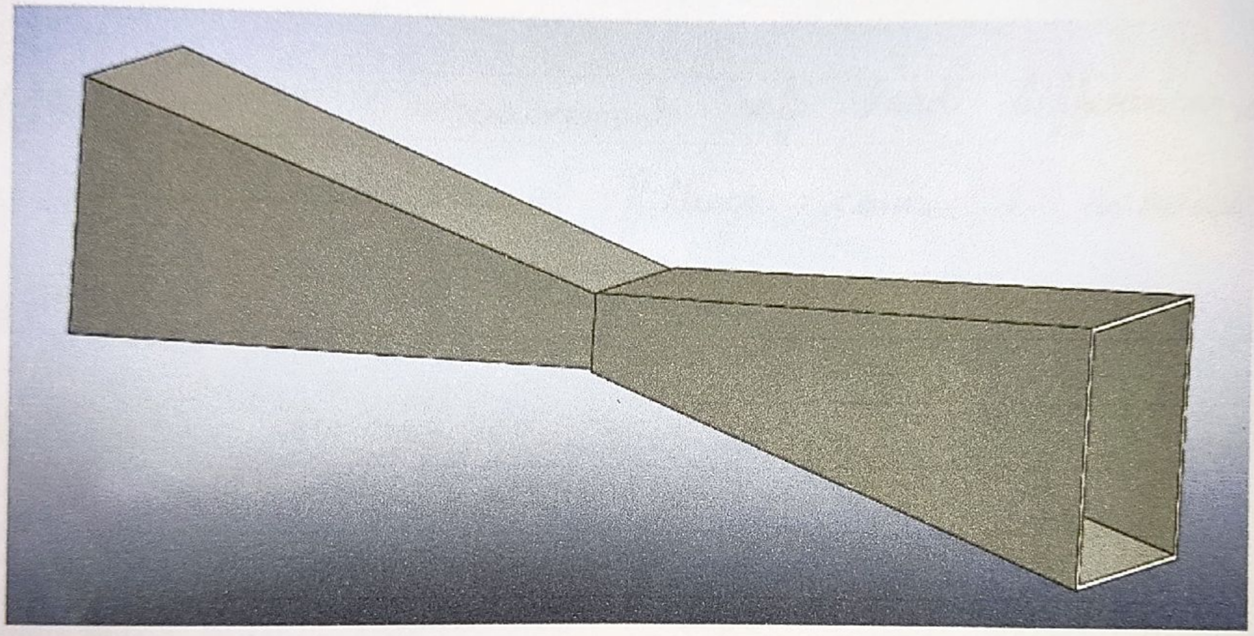


Fig:- Bernoulli's duct

Experiment - 2

Objective :- To determine the loss factors for the flow through a range of pipe fittings including bends, a contraction, an enlargement and a gate-valve.

Method :- By measurement of head difference across each of a number of fittings connected in series, over a range of steady flows.

Equipments :- In order to complete the demonstration we need a number of pieces of equipment:

a) The F-10 hydraulic bench which allows us to measure by timed volume collection.

b) The F1-22 energy losses in bends and fittings apparatus.

c) A stopwatch to allow us to determine the flow rate of water (not supplied)

d) Clamps for pressuring tapping connection tubes

e) Spirit level (not supplied)

f) Thermometer

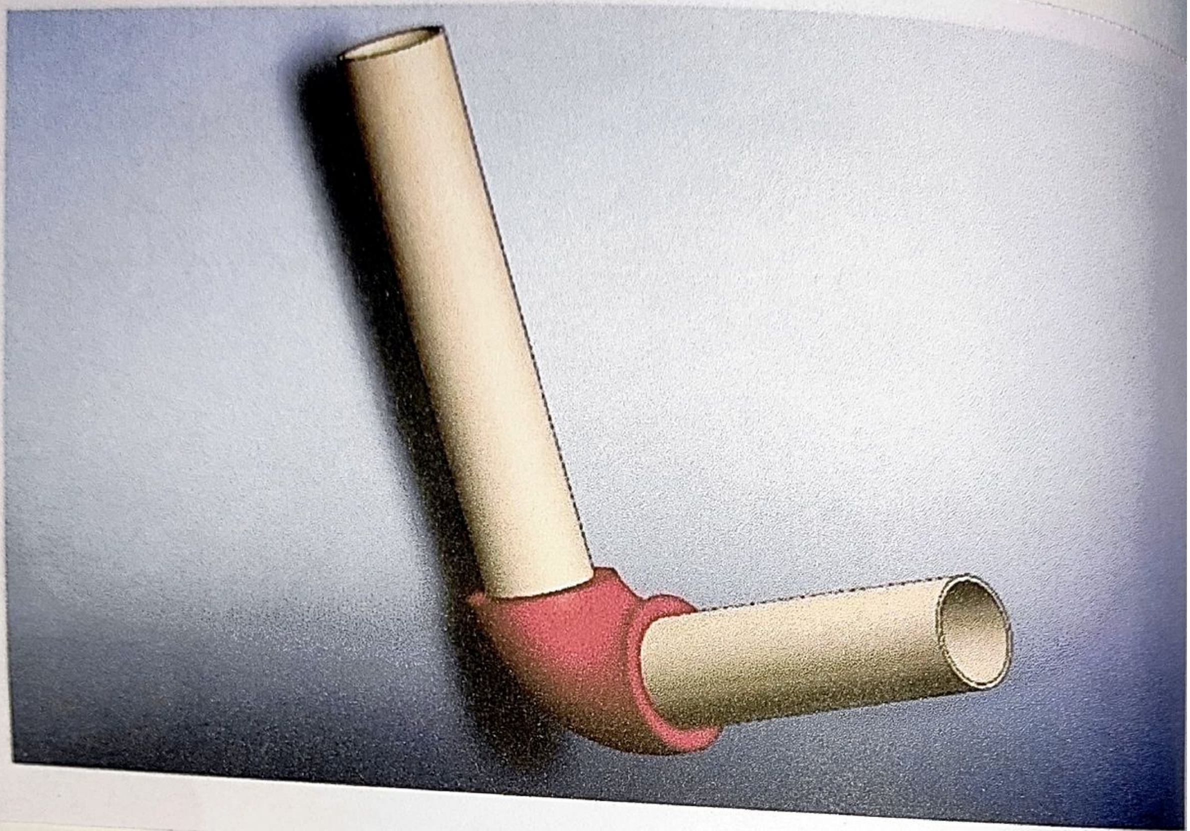


Fig :- short bend

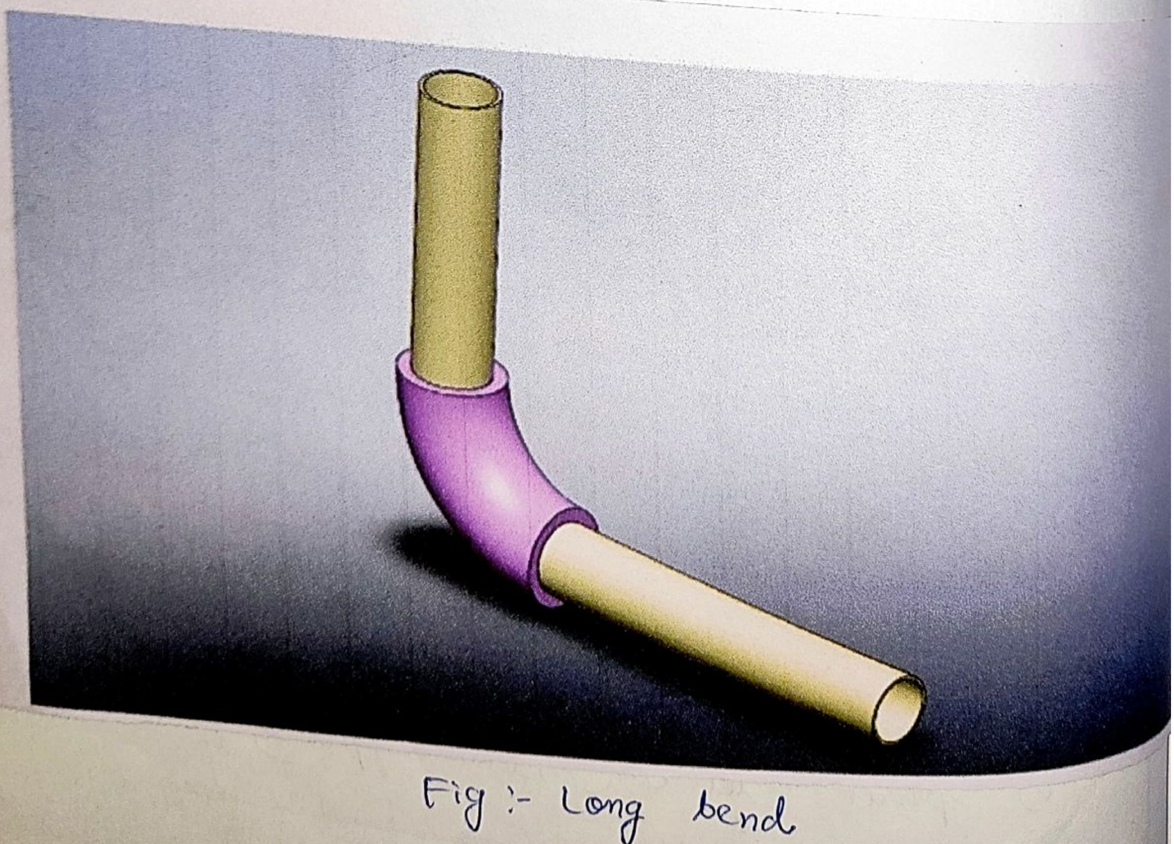


Fig :- Long bend

Technical Data :- The following dimensions from the equipment are used in the appropriate calculation. If required these values may be checked as part of the experimental procedure and replaced with our own measurement.

Internal diameter of pipe-work

$d = 0.0183 m$

Internal diameter at enlargement outlet and contraction inlet

$d = 0.0240 m$

Theory :- The energy loss which occurs in a pipe fitting (so-called secondary loss) is commonly expressed in terms of a head loss (h) in the form,

$$\Delta h = \frac{K v^2}{2g}$$

Due to change in pipe cross-sectional area through the enlargement and contraction, the system experience an additional change in static pressure. This change can be calculated as

$$\frac{V_1^2}{2g} - \frac{V_2^2}{2g}$$

To eliminiate this effect of change of the area change on the measured head losses, this value should be added to the head loss regarding reading for the enlargement and the contraction. Note that $(h_1 - h_2)$ will be -ve for the enlargement and $\frac{V_1^2}{2g} - \frac{V_2^2}{2g}$ will be given for the contraction

For the gate valve experiment, measure difference between the gap, i.e. before and after the gate is measured directly using a pressure gauge. This then be converted to an equivalent head loss using the equation,

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

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

Procedure - Equipment Setup :- Set up the losses apparatus on the hydraulic bench so that its base is horizontal. Connect the test ring inlet to the bench flow supply and run the outlet extension tube to the volumetric tank and secure it in place.

Open the bench valve, the gate valve and the flow control valve and start the pump to fill the test rig with water. In order to bleed screw and remove the cup from the adjacent air valve. Connect a length of small bore tubing from the air valve to the volumetric tank. Now, a part the bench valve follow flow through the manometer to purge all air from them; then tighten the air bleed screw and partly open both the bench valve and the test rig flow control valve. Next, open the air bleed screw slightly to allow air to enter the top of the manometers, re-tighten the screw when the manometer levels reach to a convenient height.

Check that all manometers levels are on scale at the maximum volume flow rate required approximately 17 liter/minute. These levels can be adjusted further by using the air bleed screw and the hand pump supplied.

Procedure (taking a set of result):- The gate should be kept fully open. The flow is adjusted from the bench control valve and at a given flow rate, height readings from all the manometer are taken after the level have studied. In order to measure the volume flow rate, we should carry out a timed volume collection using volumetric tank. This is achieved by closing the ball valve and measuring (with a stop watch) time taken to accumulate a known volume of fluid in the tank which is read from a sight glass. The procedure is repeatable for at least 5 sets of measurement over a flow range.

Observation Table :-

Fitting	Manometer h_1 (m)	Manometer h_2 (m)	Head Loss $h_1 - h_2$ (m)	Volume m^3	Time (sec)	Flow rate Q (m^3/sec)	Velocity V	$V^2/2g$	K
Elbow	0.217	0.200	0.017	0.001	31.09	3.22×10^{-5}	0.1224	7.64×10^{-4}	22.2513
	0.262	0.246	0.016		29.11	3.44×10^{-5}	0.1308	8.72×10^{-4}	18.3486
	0.334	0.326	0.008		22.96	4.35×10^{-5}	0.1654	1.39×10^{-3}	5.7554
Short Bend	0.217	0.217	0	0.001	31.09	3.22×10^{-5}	0.1224	7.64×10^{-4}	0
	0.263	0.263	0		29.11	3.44×10^{-5}	0.1308	8.72×10^{-4}	0
	0.341	0.340	0.001		22.96	4.35×10^{-5}	0.1654	1.39×10^{3}	0.7194
Enlargement	0.218	0.218	0.000	0.001	31.09	3.22×10^{-5}	0.07124	2.59×10^{-4}	0
	0.262	0.262	0.000		29.11	3.44×10^{-5}	0.07611	2.95×10^{-4}	0
	0.343	0.343	0.000		22.96	4.35×10^{-5}	0.09624	4.72×10^{-4}	0
Contraction	0.217	0.218	0.001	0.001	31.09	3.22×10^{-5}	0.1224	7.64×10^{-4}	1.3089
	0.262	0.264	0.002		29.11	3.44×10^{-5}	0.07611	8.72×10^{-4}	2.2936
	0.343	0.340	0.003		22.96	4.35×10^{-5}	0.09624	1.39×10^{-3}	2.1583
Long	0.216	0.217	0.001	0.001	31.09	3.22×10^{-5}	0.1224	7.64×10^{-4}	1.3089
	0.262	0.262	0.000		29.11	3.44×10^{-5}	0.07611	8.72×10^{-4}	0
	0.343	0.341	0.002		22.96	4.35×10^{-5}	0.09624	1.39×10^{-3}	1.4388

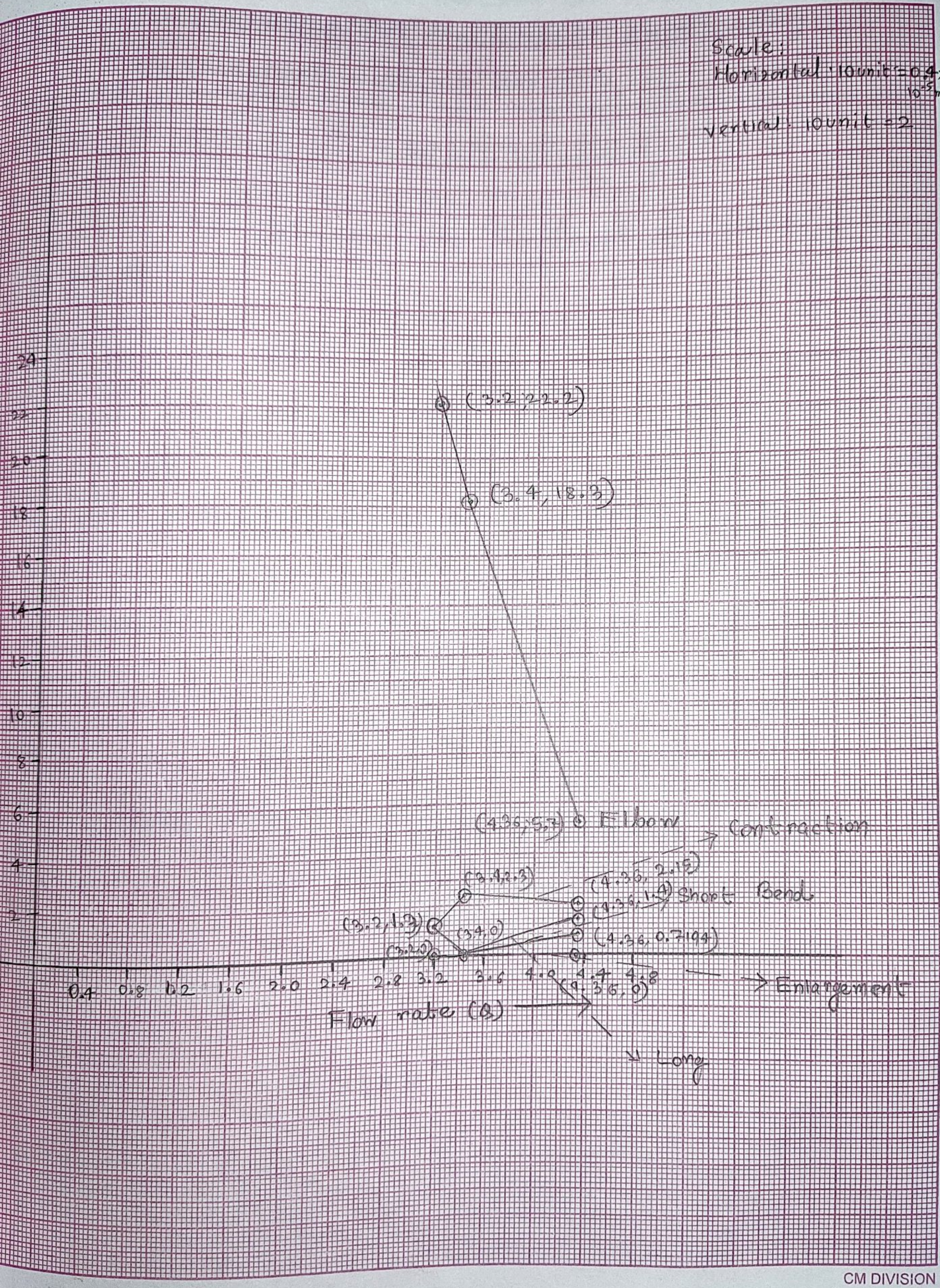
For contraction

diameter, $d = 0.0183 m$ area, $A = 2.62\times10^{-4} m^2$

For enlargement, longbend, elbow, short bend

diameter, $d = 0.0240 m$ area, $A = 4.52\times10^{-4}$

Conclusion: Thus by following process we are able to determine the loss factor for flow through different section.



Scale:
Horizontal: 10unit = 0.4 x 10^-5 m³/s
Vertical: 10unit = 2
(3.2, 22.2)
(3.4, 18.3)
(4.36, 5.7) Elbow
Contraction
(3.4, 2.3)
(4.36, 2.15)
(4.36, 1.4) Short Bend
(3.2, 1.3)
(3.4, 0)
(3.2, 0)
(4.36, 0.7194)
(4.36, 0)
Enlargement
Long
Flow rate (Q)
0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0 4.4 4.8
24 22 20 18 16 14 12 10 8 6 4 2

Experiment No. - 3

Aim :- To determine the coefficient of discharge of triangular notch.

Theory :- A notch is a device used for measuring the rate of flow of liquid through a small element or a tank. It may defined as an opening in the side of a tank for a small channel in such a way that the fluid / liquid surface in the tank or channel is below the top edge of the opening.

Discharge over a triangular notch is given by

$$Q = (8/15) \times C_d \times \tan(\theta/2) \times \sqrt{2g} \times H^{5/2}$$

where,
C_d = Coefficient of discharge
θ = Angle of notch
H = Head of liquid above the notch

So, $Q = C_d \times \left\{ \frac{8}{15} \times \tan\left(\frac{\theta}{2}\right) \times \sqrt{2g} \right\} \times H^{5/2}$

$= C_d \times K \times H^{5/2}$

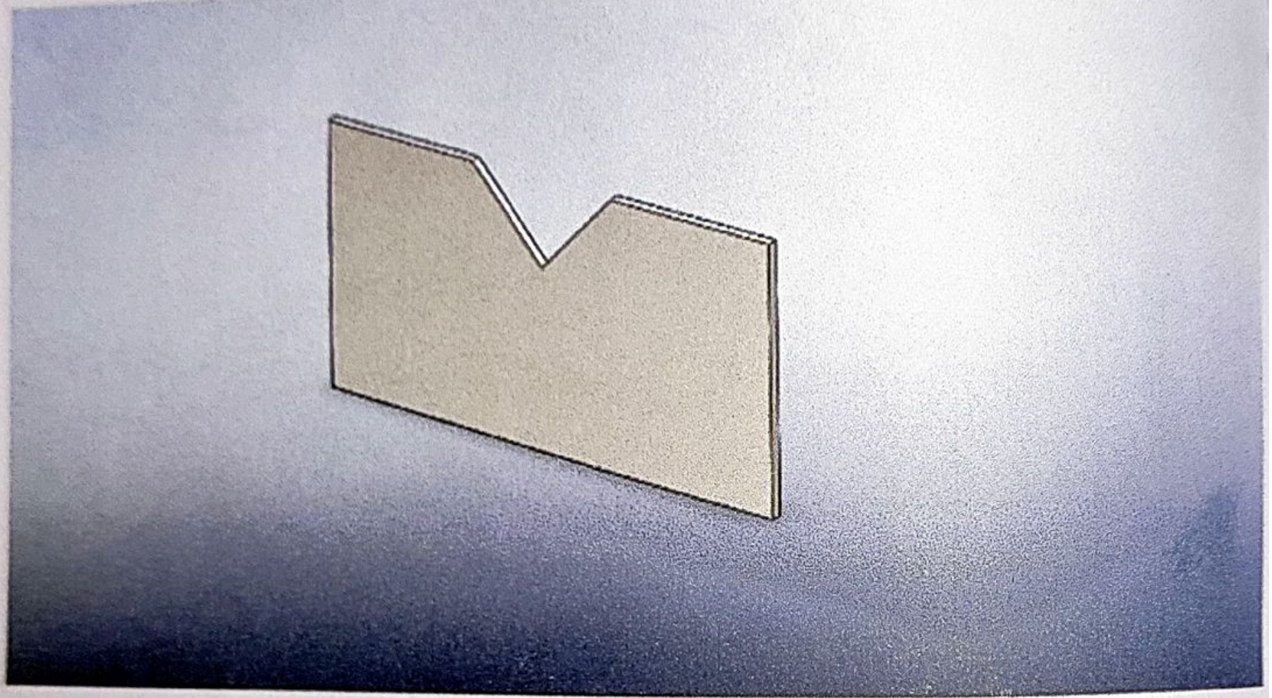


Fig :- Triangular notch

Apparatus Required :-

1) A notch fitted flume with two walls to reduce the velocity of approach.

2) Scale and stop-watch.

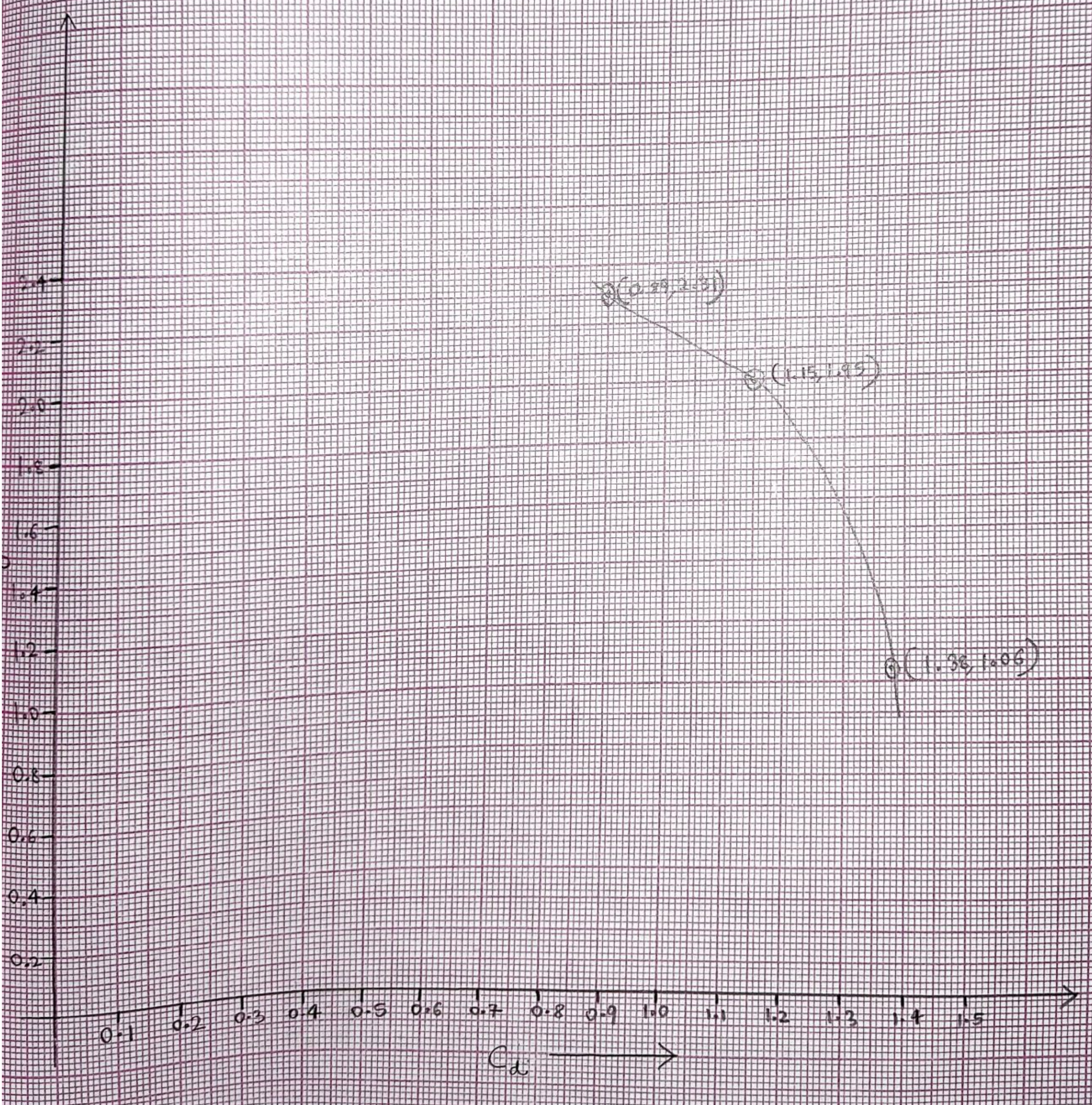
3) A discharge measuring tank.

Table for Computation :-

Angle of V- notch (θ) = 90°

Datum Height h_0 (m)	Volume collected V (m^3)	Time for collection t (sec)	Volume flow rate, Q (m^3/sec)	Height above notch, H (m)	$H^{5/2}$ Vee notch	Vee notch discharge coefficient, C_d
12.8	0.001	9.44	1.06×10^{-4}	1.6	3.2382	1.3856×10^{-7}
12.8	0.001	5.14	1.95×10^{-4}	2.2	7.1789	1.498×10^{-5}
12.8	0.001	4.33	2.31×10^{-4}	2.6	10.9002	8.9707×10^{-6}

Scale:
Horizontal: 10 unit = 0.1
Vertical: 10 unit = 0.2×10^{-4} m^3/sec



Experiment - 4

Aim :- To determine coefficient of discharge for a rectangular notch.

Theory :- A notch is a device used for measuring the rate of flow of a liquid through a small channel or a tank. It may defined as an opening in the side of a tank or a small channel in such a way that the liquid surface edge of the opening.

Considering a rectangular notch provided in channel or tank carrying water.

Let H = head of water of still or crest

b = width of Notch

For finding the discharge of water flowing over notch, we consider an elementary horizontal strip of water of thickness 'dh' and length surface of water.

The area of strip $= b \times dh$

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

Discharge through strip

$dQ = C_d \times$ area of strip $\times V_{th}$

where, C_d = coefficient of discharge

$\therefore$ The total discharge, $Q = \int_0^H C_d\, b \sqrt{2g} \sqrt{h} \times dh$

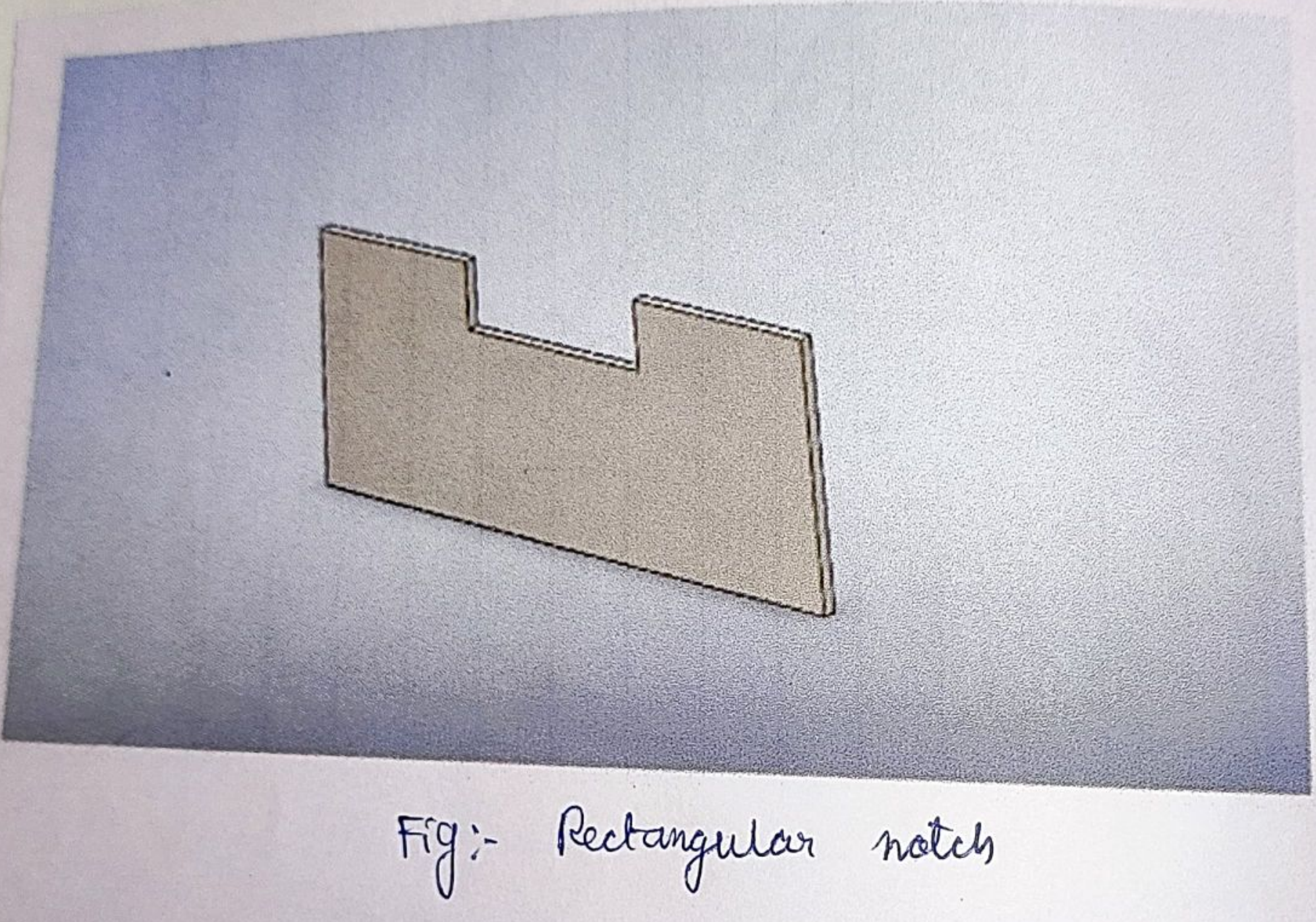


Fig:- Rectangular notch

$$Q = C_d\, b \sqrt{2g} \int_0^H \sqrt{h}\, dh$$

$$Q = C_d\, b \sqrt{2g} \frac{(H)^{3/2}}{\frac{3}{2}}$$

$$Q_{th} = \frac{2}{3} b \sqrt{2g}\, (H)^{3/2}$$

Procedure :-

i) The tank dimensions were measured.

ii) The flow in the channel having rectangular notch was started.

iii) The flow was kept constant.

iv) The head of water in piezometer of constant time interval for collecting tank was noted.

v) Open slightly the value without increase the rotation suddenly after fixed time interval.

vi) Also note the head over the still after each interval.

Observation:-

Datum height h_0 (m)	Volume collected V (m^3)	Time for collection t (sec)	Volume flow rate (m^3/sec)	Height above notch H (m)	$H^{3/2}$ Rectangular notch	Rectangular notch Discharge coefficient
0.0740	0.001	8.90	1.1236×10^{-4}	0.0235	3.6025×10^{-3}	0.3521
0.0740	0.001	6.90	1.4493×10^{-4}	0.035	6.5479×10^{-3}	0.2499
0.0740	0.001	2.90	3.4483×10^{-4}	0.059	1.4331×10^{-2}	0.2717

Calculation:-

Actual discharge, $Q_{ac} = \frac{V}{\Delta t}$

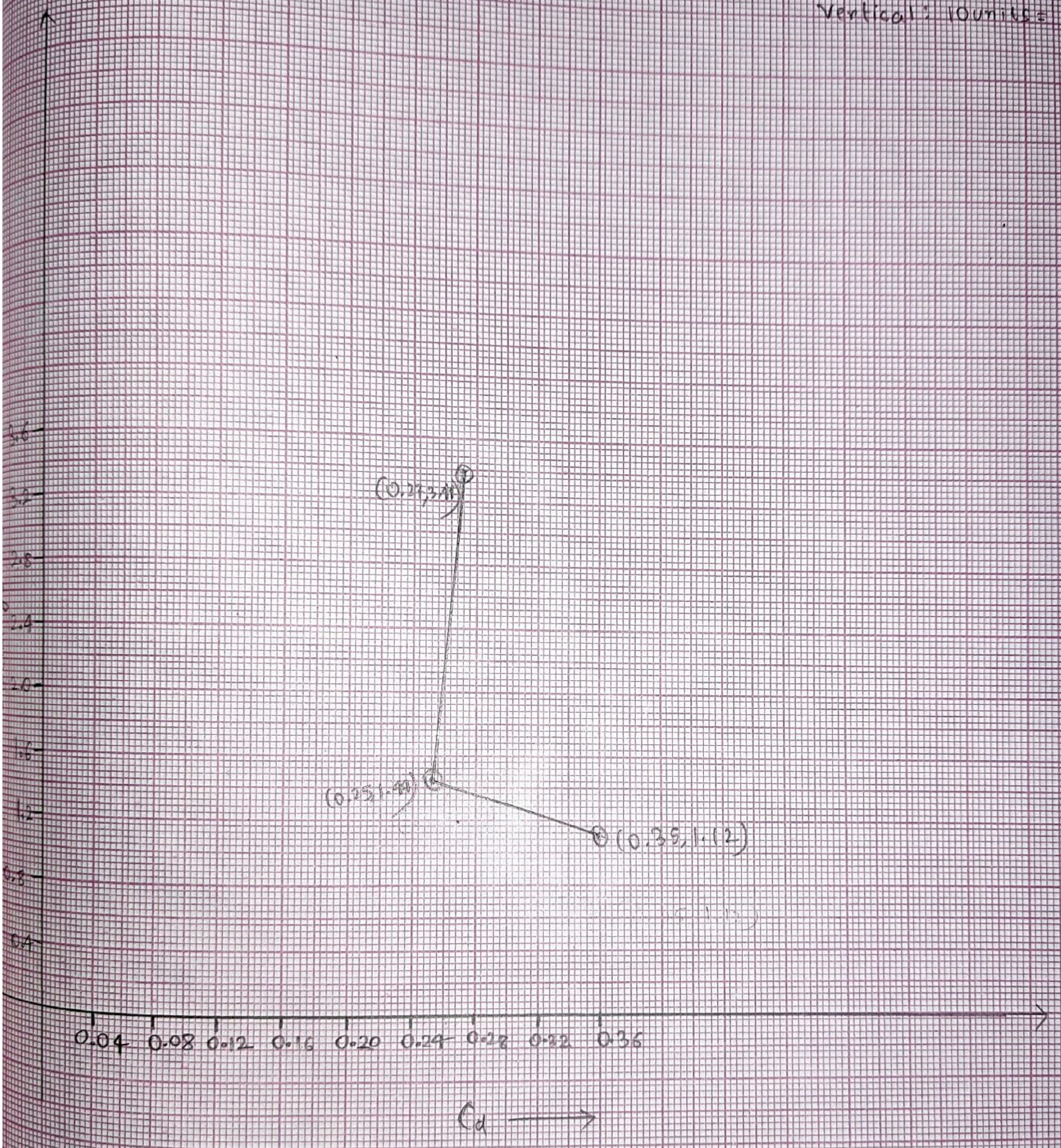
Theoretical discharge, $Q_{th} = \frac{2}{3} b \sqrt{2g}\, H^{3/2}$

Coefficient of discharge, $C_d = \frac{Q_{ac}}{Q_{th}}$

Mean coefficient of discharge, $C_{d_{mean}} = \frac{0.3521 + 0.2499 + 0.2717}{3}$

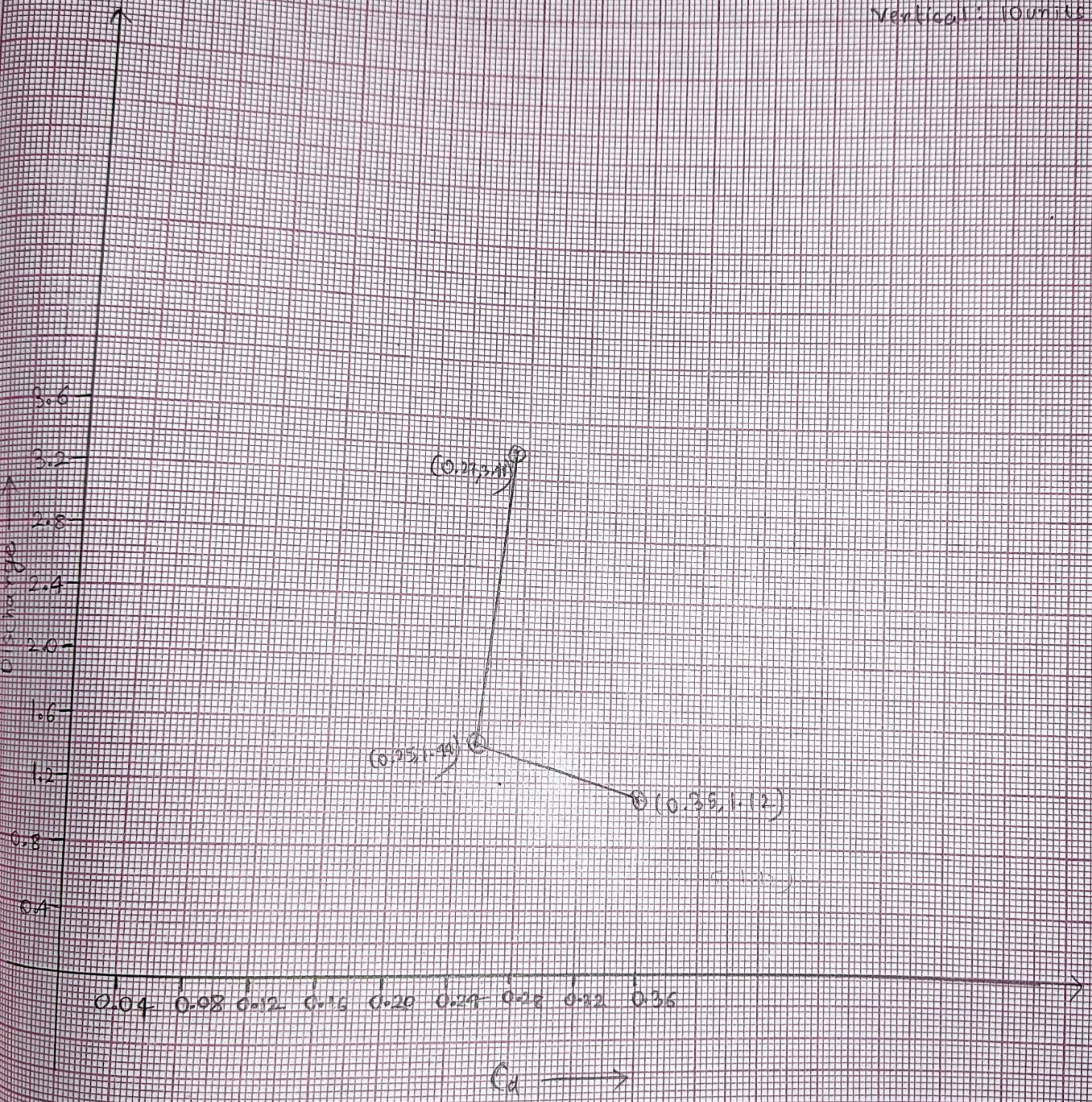
$= 0.2912$

Scale:
Horizontal: 10 units = 0.04
Vertical: 10 units = 0.4×10^{-4} m^3/sec



(4)

Scale:
Horizontal; 10 units = 0.04
Vertical: 10 units = 0.4×10^{-4} m³/sec



Experiment - 5

Aim:- To observe laminar, transitional and turbulent pipe flow.

Method:- Visualisation of flow behaviour by injection of a dye into a steady flow in a pipe. This is a classical experiment and was first performed by Osborne Reynolds in the late nineteenth century.

Experiment Required:- In order to complete the demonstration we need a number of pieces of equipment,

1) The F1-10 hydraulics bench which allows us to measure flow by time volume collection.
2) The F1-20 Reynold's apperture.
3) A stop watch to allow us to determine the flow rate of water.
4) Thermometer

Theory:- A flow can behave in very difficult way, depending upon which forces predominate within it. Also, flows are dominated by viscous force, tend to be well ordered and predictable and are

There is an in-between stage, transitional flow, in which a dye stream will appear to wander about and will show intermiment bursts of mixing, followed by a more laminour behaviour.

The Reynold's no. Re provides a very useful method of characterising the flow, it is defined as

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

where ν is the kinematic viscosity. u is the mean velocity given in terms of the volume flow rate and d is the diameter of pipe.

It is common practice to take a Reynold's no. of 2000 as the value which divides - laminar from turbulent flow. However, this doesn't take account of the transition region and it maybe possible to keep a flow laminar for Reynold's number up to 10,000 or more. Also, pipe flows with Reynold's no. less than 1800 are inherently laminar.

described as laminar. In laminar pipe flow, the fluid behaves as it concentric layers (laminar) are sliding out each other with a maximum velocity on the axis, zero velocity at the tube wall and a parabolic velocity distribution. Dye imparted carefully at a point in a laminar pipe flow will be stretched out by the flow to form a clean well defined line. The only mixing that can occur is by molecular diffusion.

Increasing the flow rate substantially will alter the flow behaviour drastically as the inertia of the fluid (due to its density) becomes more significant then the viscous forces; this is then a turbulent flow. In turbulent pipe flow, dye injected at a point is rapidly mixed due to the substantial lateral motion in the flow and the dye behaviour appears chaotic. These motions appear random and arise from the growth of instabilities in the flow. Detailed behaviour is impossible to produce except in statistical terms.

Equipment set up:-

The Reynold's apparatus is positioned on a fixed, vibration free surface and ensure that the base is horizontal, ie. the test section is then vertical. The bell mouth entry is attached and marbles are added to that head tank carefully, placing them in by hand. The bell-mouth and marbles produce an inflow to the test section with a low level of disturbances.

The bench outflow is connected to the head tank inlet pipe. The head tank overflow is connected to the hydraulic bench volumetric tank. The outflow tube is attached to the apparatus flow control valve and the end of this tube is clamped at a fixed position above the volumetric tank, allowing enough space for insertion of the measuring cylinder.

Movement of the outflow tube end during a test will cause changes in volume flow rate, which is driven by the height difference between the head tank surface and the outflow point.

Procedure:-

With the apparatus flow control valve open slightly, and the bench valve adjusted to produce a slow trickle through the overflow pipe, the dye control valve is adjusted until a slow flow with clear dye indication is achieved.

In order to observe the velocity profile is laminar flow, the bench valve is closed and dye control valve is opened to deposit a drop of dye at the bell mouth entry. When the outlet control valve is opened, the dye is observed as it deforms to take up to a three dimensional parabolic profile. The volume flow rate is measured by timed collection and the outflow temperature table and the corresponding Reynold's no. of the flow is also calculated.

The flow rate is increased by opening the apparatus flow control valve and the injections are repeatable to visualise transitional flow and then, at the high flow rate, turbulent flow, as characterised by continuous and rapid mixing of the dye. As the test section flow is reduced, the bench valve is adjusted to keep the overflow rate at low level. At intermittent flows, it is possible to have a laminar characteristic in the upper part of the test section, which develops into transitional flow lower down. This upper section behaviour is described as an " inlet length flow" which means that the boundary layer has not yet extended across the pipe radius.

Observation :-

Pipe area = $7.854 \times 10^{-5} m^2$

$\therefore \frac{\pi}{4} d^2 = 7.854 \times 10^{-5}$ $\therefore d = 0.010003 m$

T = 30°C , Kinematic viscosity = 0.802

Volume collected (m^3)	Time to collect (s)	Temperature (°C)	Pipe Area (m^2)	Volume flow rate (m^3/sec)	Kinematic viscosity ($\times 10^{-6} m^2/s$)	Reynold's no.
0.0002	27.4	30	7.854×10^{-5}	7.2993×10^{-6}	0.802	1158.8199
0.0002	27.8	30	7.854×10^{-5}	7.1942×10^{-6}	0.802	1142.1395
0.0002	7.1	30	7.854×10^{-5}	2.8169×10^{-5}	0.802	4472.045
0.0002	4.9	30	7.854×10^{-5}	4.0816×10^{-5}	0.802	6979.8533
0.0002	3.5	30	7.854×10^{-5}	5.7143×10^{-5}	0.802	9071.8899
0.0002	3.1	30	7.854×10^{-5}	6.4516×10^{-5}	0.802	10242.4103

Conclusion :

The FI-20 apparatus allows the visualisation of flow patterns for laminar, transitional and turbulent flow.

Experiment - 6

Integral momentum equation :- Impact of a jet

Objective :- In this experiment, the force generated by a cylindrical water jet as it strikes a flat plate or a hemispherical cup is measured and compared with the force predicted using integral momentum equation.

Theory :- Mechanical work can be produced by allowing fluid under pressure to strike the vanes of turbine wheel. Rotational motion is then produced by the force generated on the jet strikes the vanes.

Let us consider a vane which is asymmetrical about the vertical (y) -axis. If a fluid jet exits a circular nozzle with velocity v_1 along the y - axis and strikes the vanes higher up, it is deflected by an angle β with respect to the horizontal direction. The fluid leaves the vane with velocity v_3 along the angle of deflection. Because the jet is exposed to the fluid exits the nozzle can be neglected. Using the momentum equation along y, we can calculate the force F_y exerted by the vane on the fluid by considering the control volume...

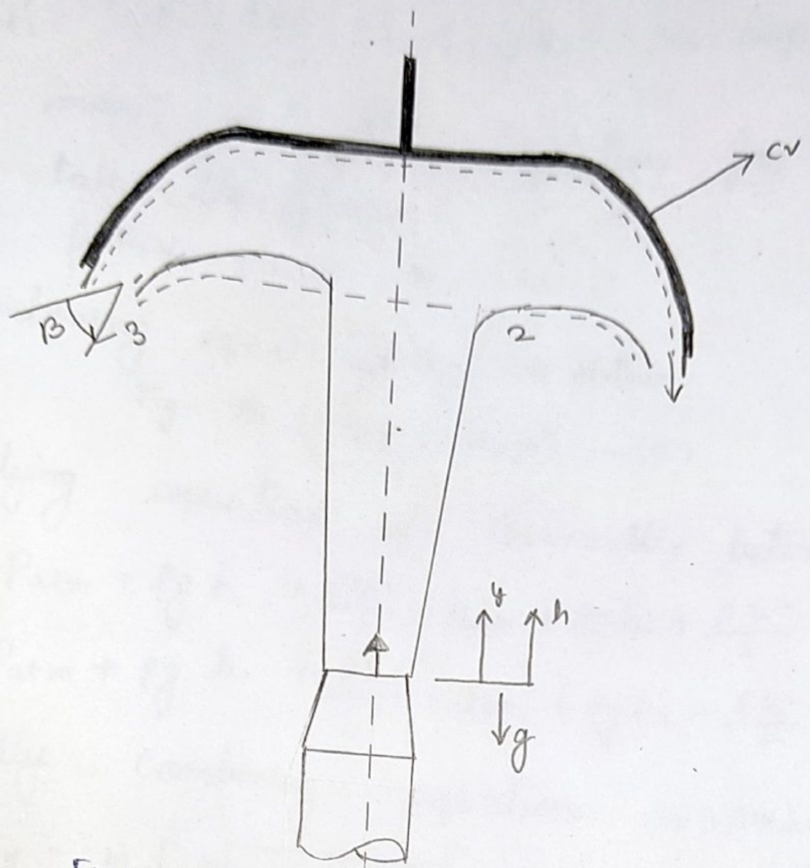


Fig:- Jet impingement detail showing the vane and the applied control volume

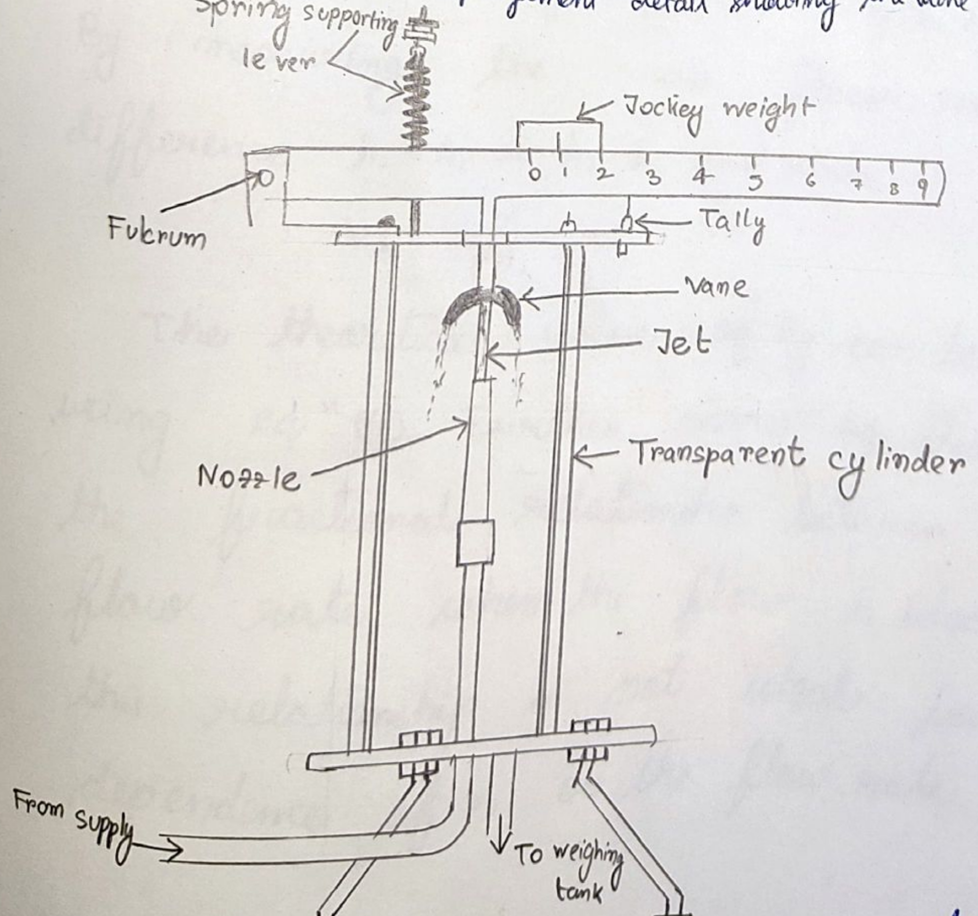


Fig 2:- Arrangement of jet impact apparatus

$$-F_y = \int_{ei} v\rho \vec{V}\vec{n}\, dA = V_2 \rho (-V_2) A_2 - V_3 \sin\beta \, \rho V_3 \quad \text{--- (i)}$$

The mass conservation equation for the same control volume takes the form

$$\rho A_2 V_2 = \rho A_3 V_3 = \dot{m} \quad \text{--- (ii)}$$

Combining eqn.(i) and (ii), we obtain

$$F_y = \dot{m}\,(V_2 + V_3 \sin\beta) \quad \text{--- (iii)}$$

Applying equation of Bernoulli's between points 1-2 & 1-3

$$P_{atm} + \rho g h_1 + \frac{\rho V_1^2}{2} = P_{atm} + \rho g h_2 + \frac{\rho V_2^2}{2} \quad \text{--- (iv)}$$

$$P_{atm} + \rho g h_1 + \frac{\rho V_1^2}{2} = P_{atm} + \rho g h_3 + \frac{\rho V_3^2}{2} \quad \text{--- (v)}$$

Finally, combining equations (iii), (iv) and (v) yields

$$F_y = \dot{m}\left[\sqrt{V_1^2 - 2g(h_2 - h_1)} + \sqrt{V_1^2 - 2g(h_3 - h_1)}\,(\sin\beta)\right] \quad \text{--- (vi)}$$

By measuring the mass flow rate and elevation difference $h_2 - h_1$ & $h_3 - h_1$ and since

$$V_1 = \frac{m}{\rho A_1}$$

The theoretical value of F_y can be determined using eq^n (vi). Further more equation (vi) represents the fractional relationship between F_y and the mass flow rate when the flow is ideal. Note that this relationship is not ideal because of the dependence of V_1 on the flow rate.

Apparatus :-

1) water pumping table with a weighing device to measure the mass flow rate of the jet.

2) A normal tapered nozzle used to form the vertical jet, which is deflected by either a flat plate or a hemispherical vane. The nozzle and vane are combined within a transparent cylinder.

3) A force measuring lever device for finding the resultant force on the vane.

4) stop watch

Measuring method :- As shown in fig., the vane is supported by a lever which carries a jockey weight. The lever can pivot around one end and is restrained by a vertically balanced by placing the jockey weight at its zero position, and then adjusting the nut above the spring. After the jet flow is turned on, the force generated by impact of jet causes the free end of the lever to move upward. The lever can be restored to its original balanced position by moving the jockey weight along the lever away from the spring. The impact force can then be measured using the analysis described

When the jet flow is absent and the lever is balanced, the jockey weight is at $x=0$. In this case, the forces acting on the lever include the spring force F_s and the jockey weight F_m. In addition, the weight W_1 of the lever is exerted at a distance l from the point of poivot. The applicable momentum equation is

$$F_s b = F_w a + W_1 l. \quad \text{— (vii)}$$

When the jet flow is not present, the lever balance is restored by moving jockey height at a distance x from its original position. The force exerted by the jet on the wall or plate or vane is depicted by F'_y. This force is equal and opposite to the force exerted by the plate vane on the fluid, i.e. $F'_y = -F_y$. The momentum equation takes the form

$$F_s b + F'_y a = F_w(a+x) + W_1 l \quad \text{— (viii)}$$

Combining equation (vii) & (viii), we obtained

$$F'_y = -F_y = F_w \cdot \frac{x}{a} = \frac{5.314}{0.1524} x = 35.09x \quad \text{(ix)}$$

with x in metres and F'_y in N. Thus measurement of x produces a values for the force exerted by the vane on the fluid. This force can be compared to the theoretical value obtained force can be compared to the theoretical value obtained from eqn. (vi)

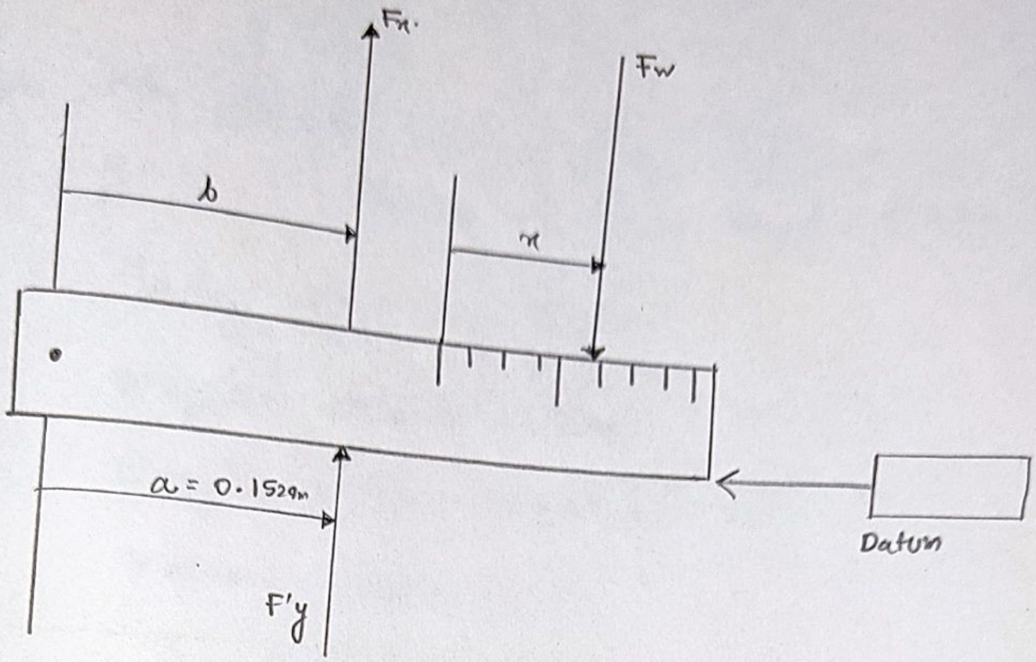


Fig -3:- Schematic diagram of the forces exerted on the lever

Procedure:-

1) The apparatus is first levelled by setting the lever to balanced position with the jockey placed at its zero position.

2) Using the bench value, the rate of flow of water is increased to its maximum, then the lever is restored to its balanced position by moving the jockey weight towards the force end of the lever.

3) By decreasing the rate of flow, the lever is balanced by repositioning the jockey weight. The procedure is repeated for a series of line different flow rate and the corresponding values x,

Observation

For hemispherical cup

$\beta = 90^\circ$, $h_2 - h_1 = 0.06m$, $h_3 - h_1 = 0.03m$

Jockey mass, $M = 0.6 kg$

Nozzle diameter $= 10mm$

Nozzle area $= 7.854 \times 10^{-5} m^2$

Volume $= 1 lit = 0.001 m^3$

Run	M (kg)	t (s)	$\dot{m}$ (kg/s)	V_1 (m/s)	F_y (N)	x (m)	F_y' (N)
1.	0.6	11.68	0.0369	1.090	0.0332	0.010	0.3504
2.	0.6	10.48	0.052	1.215	0.0823	0.040	1.4016
3.	0.6	3.65	0.1644	3.489	1.1098	0.100	3.504

Scale:

Horizontal: 10 unit = 0.01 kg/s

Vertical: 20 unit = 0.2 N