EXPERIMENT 1

Flow Through a Variable Duct Area—Bernoulli's Experiment

OBJECTIVE

To verify the Bernoulli's theorem.

THEORY

The Bernoulli's theorem is based on the principle of law of conservation of energy. According to this theorem, for an ideal (inviscid, incompressible, irrotational) and steady fluid flow along a streamline, the total energy per unit weight of the flowing fluid is constant. The total energy consists of kinetic energy, pressure energy and potential energy. Further, the energy per unit weight has the dimensions of length and, therefore, each type of the energies is also known as the head. Thus, according to Bernoulli's theorem,

$$\frac{p}{\rho g} + \frac{V^2}{2g} + y = \text{constant}$$

where $p/\rho g$ is known as the pressure head (also called static head), $V^2/2g$ is known as the velocity head (also called the kinetic head or dynamic head), and y is called the elevation head (also called the potential head or datum head).

However, for real fluid flow, there always occurs a loss of energy in the direction of flow as some energy of the flowing fluid is converted into heat energy due to viscous and turbulent shear. Therefore, for real fluids flow, Bernoulli's equation between two points can be written as

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + y_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + y_2 + h_L$$

where h_L is the loss of energy per unit weight or the head loss between two points under consideration.

The sum of the pressure head, velocity head and datum head is known as the total head and the sum of the pressure head and datum head is known as the piezometric head. The simplest way of measuring the pressure head at a point is by using a piezometer and the line joining the levels of liquid columns of different piezometers installed along the direction of flow is called the hydraulic gradient line (HGL). The line joining the levels of total head is known as the total energy line (TEL).

EXPERIMENTAL SET-UP

The set-up consists of a horizontal converging-diverging duct having constant width but varying depth (Figure 1.1). The duct is made of transparent perspex sheets, which are joined together to form duct of required shape. A number of piezometers are fitted on the duct at equal intervals for measuring the pressure heads at different gauge points. The duct is connected to two tanks, one at the upstream end (inlet tank) and the other at the downstream end (outlet tank). The inlet tank is fitted with a piezometer for indicating the water level in the tank. The outlet tank is provided with an outlet valve for controlling the outflow. The set-up is placed on a hydraulic bench. Water is supplied to the inlet tank by a supply pipeline provided with an inlet valve (supply valve) and connected to a constant overhead water tank.

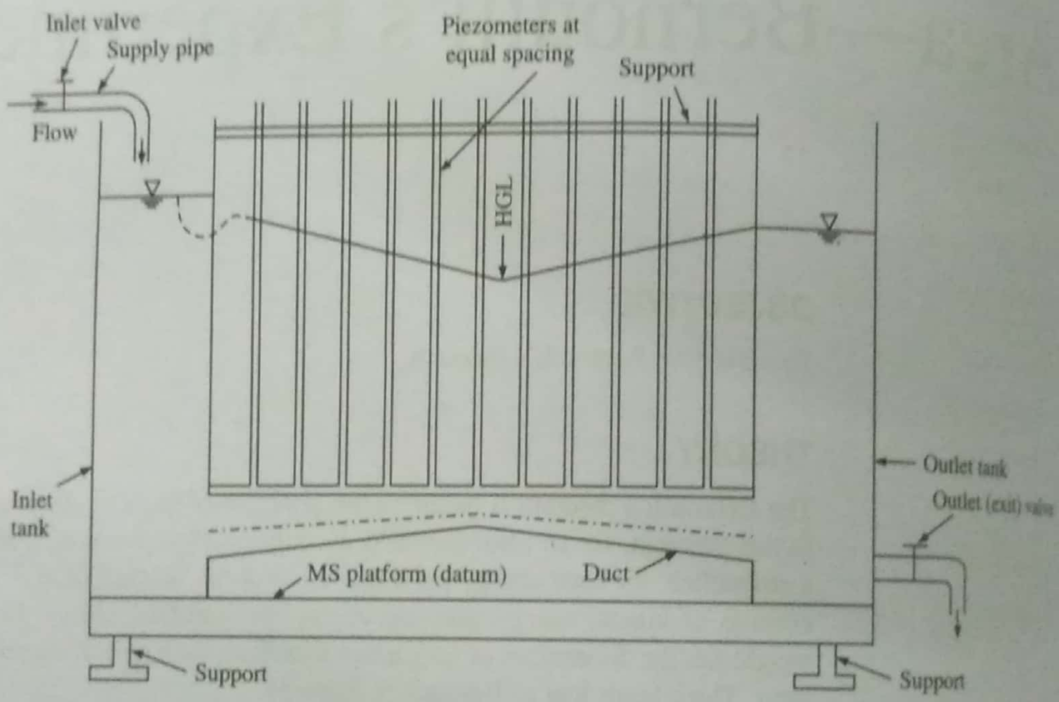


Figure 1.1 Bernoulli's apparatus.

PROCEDURE

1. Open the inlet valve gradually to fill the inlet tank. The water level will start rising in various piezometers. Remove the air bubbles in the piezometers, if any. Open the exit valve and adjust the inflow and the outflow so that the water level in the piezometers is constant, i.e. let the flow becomes steady.
2. Measure the levels of water in various piezometers with respect to an arbitrary selected suitable horizontal plane as datum i.e., MS platform.
3. Measure the discharge, in the discharge measurement tank.
4. Repeat the above steps for one more run by regulating the supply valve.
5. Calculate the areas of the duct at various gauge points using similar triangles or any other method.

OBSERVATIONS AND CALCULATIONS

Dimensions of the duct at the inlet and outlet sections = 4 x 4 cm²

Dimensions of the duct at the throat section = 4 x 2 cm²

Length of the duct, L = 90 cm

Width of the duct, B = 4 cm

Distance between the two piezometers = 7.5 cm

Calculation of areas at different gauge points of the duct

Piezometer No., i	1	2	3	4	5	6	7	8	9	10	11
Distance from inlet section, X_i	7.5	1.5	22.5	30	37.5	45	50.5	60	67.5	75	62.5
Area of duct, a_i	14.8	13.6	12.6	11.2	10.2	8	10.2	11.2	12.6	13.6	14.8

Computation of total head

Run No. 1

Discharge, Q = 1103.26 cm³/s

Mean velocity, $V_i = Q/a_i$	74.3	31.17	37.56	98.5	108.16	137.9	108.16	98.5	87.56	81.12	74.59
Velocity head, $V_i^2/2g$	2.83	3.1	3.9	4.95	5.9	9.7	5.9	4.95	3.9	3.35	2.83
Piezometric head = $(p_i/\rho g + y)$	35	32.3	31.5	30.1	29.4	26.5	29.1	29.9	30.9	31.2	32.1
Total head, $H = (p_i/\rho g + V_i^2/2g + y)$	35.25	35.3	35.4	35.05	35.5	36.2	35	34.85	34.81	34.55	34.9

Run No. 2

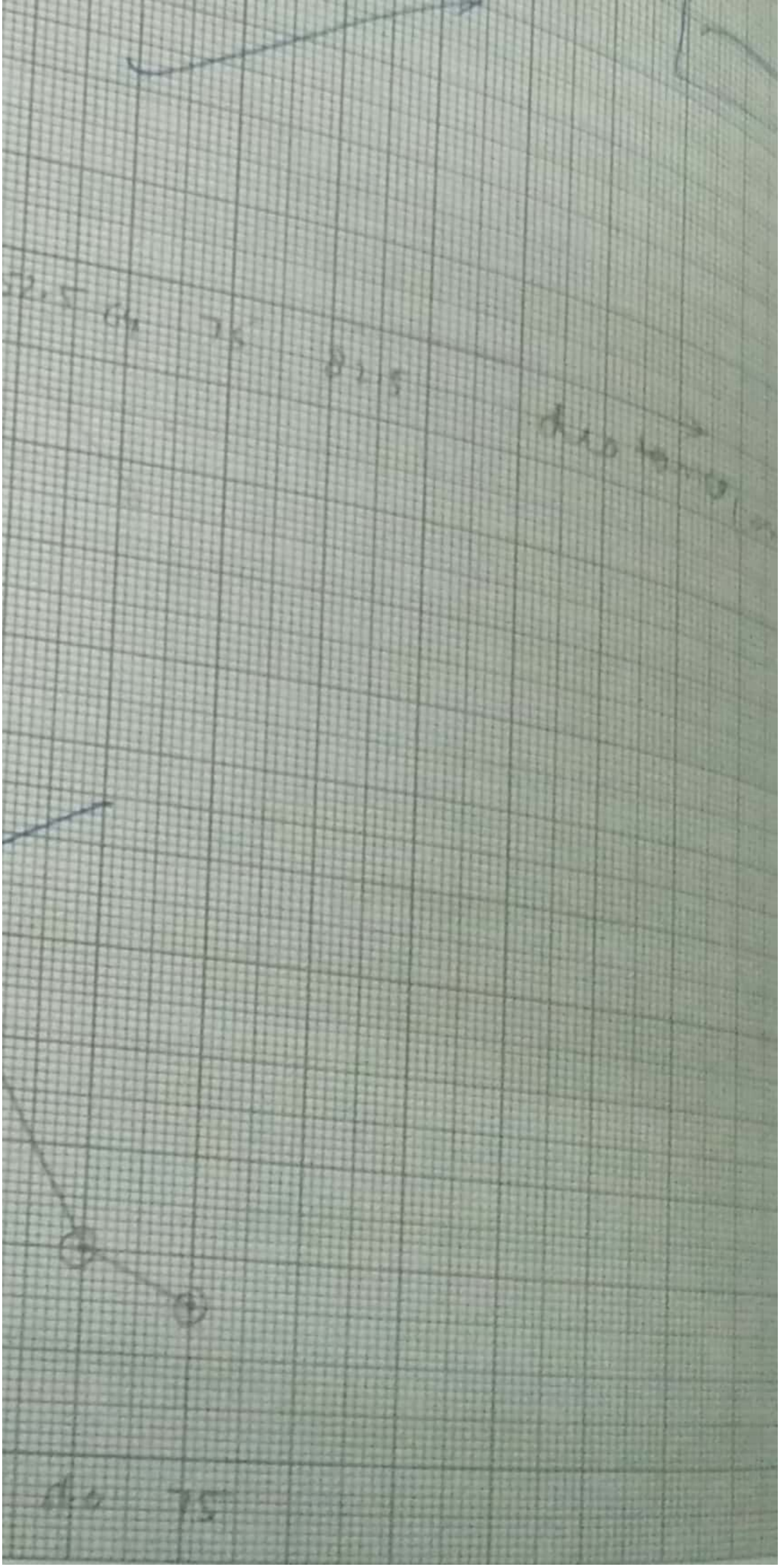
Discharge, Q = 1055.98 cm³/s

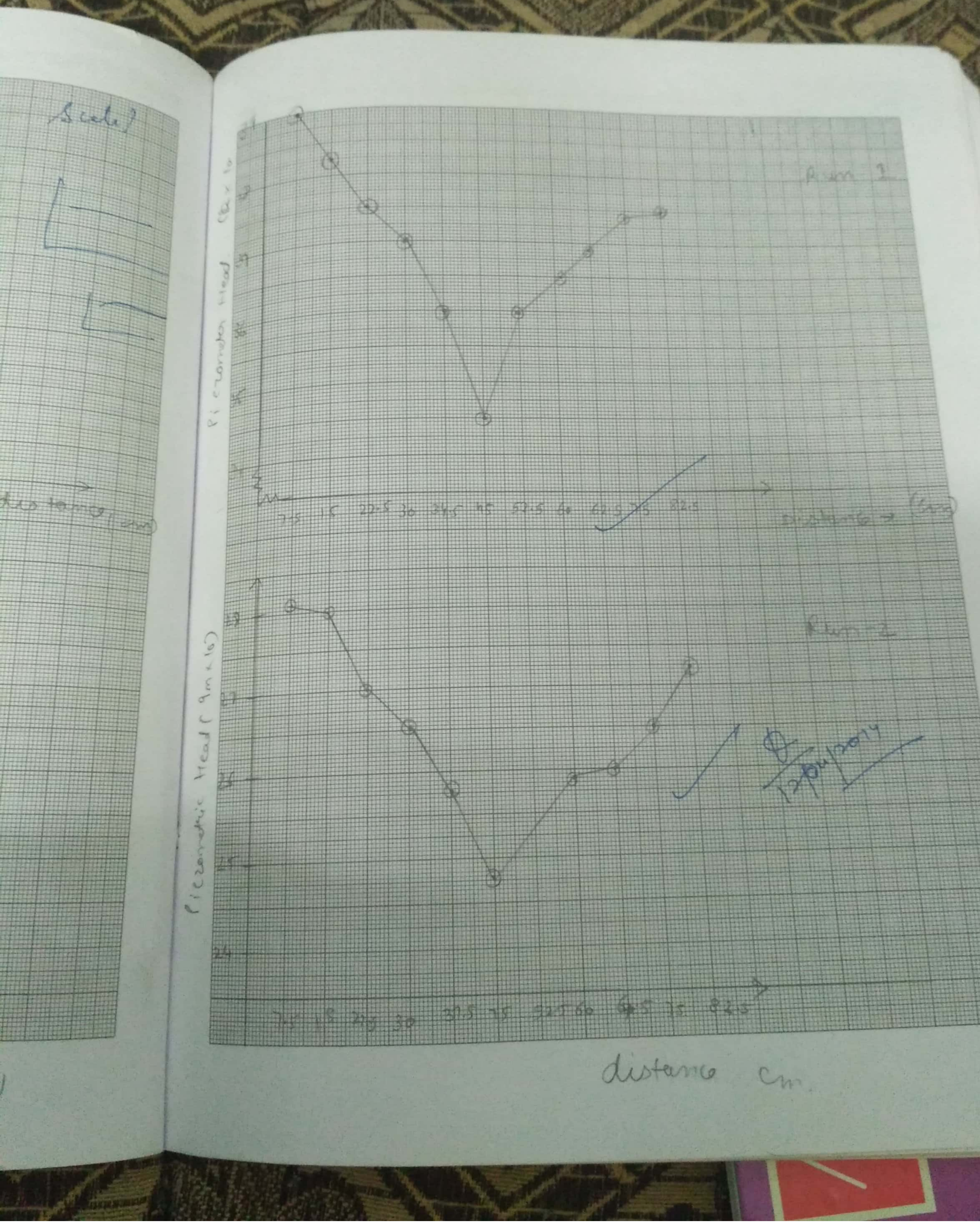
Mean velocity, $V_i = Q/a_i$	72.36	77.64	83.8	94.28	103.5	132	103.5	94.28	83.8	77.64	71.35
Velocity head, $V_i^2/2g$	2.66	3.07	3.58	4.58	5.46	8.8	5.46	4.53	3.58	3.07	2.6
Piezometric head = $(p_i/\rho g + y)$	21.6	20.9	19.6	18.8	17.3	15.5	17	17.8	18.5	19.1	19.5
Total head, $H = (p_i/\rho g + V_i^2/2g + y)$	24.2	23.9	23.2	23.3	22.7	24.3	22.46	22.3	22	22.17	22.1

GRAPHS

1. Plot the piezometric head, $(p_i/\rho g + y)$ versus distance with piezometric head as ordinate X_i, on an ordinary graph paper for both runs.
2. Plot the total head H versus distance X_i with the total head as ordinate on an ordinary graph paper for both runs.

DISCUSSION




Scale)
Run 1
Run-2
7.5 15 22.5 30 37.5 45 52.5 60 67.5 75 82.5
distance cm.

Date:

ROUGH OBSERVATION SHEET

Dimensions of the duct at the inlet and outlet sections = 40 mm
Dimensions of the duct at the throat section = 20 mm
Length of the duct, L = 900 mm
Width of the duct, B = 40 mm
Distance between the two piezometers = 75 mm
Plan area of the measuring tank, A_m = 397 × 397

Discharge Measurement (Q)

Run No.	*Initial level, H_1*	*Final level, H_2*	*Rise, ΔH*	*Time, t*	$Q = A_m \times \Delta H/t$
1.	3	10	7	10	840 cm³/s
2.	10	16.7	6.7	10	804 cm³/s

Run No. 1

Piezometer No., i	1	2	3	4	5	6	7	8	9	10	11

EXPERIMENT 2

Calibration of Venturimeter

OBJECTIVE

To calibrate a venturimeter and to study the variation of the coefficient of discharge with the Reynolds number.

THEORY

Venturimeter is the most commonly used device for the measurement of discharge of fluid through a pipe. The other devices used for measuring the discharge through pipes are orifice meter, bend meter, rotameter, etc. The basic principle on which a venturimeter works is that by reducing the cross-sectional area of the flow passage, a pressure difference is created and by measuring this pressure difference, discharge through the pipe can be determined.

A venturimeter consists of an inlet section, a converging pipe, a cylindrical throat and a diverging pipe as shown in Figure 2.1. The inlet section of the venturimeter is of the same diameter as that of the pipe. Two pressure tappings are provided, one at the inlet section just upstream of the converging pipe and the other at the throat section so that for a given discharge, Equation (i) can be expressed as

$$Q = C_d C\sqrt{\Delta h} = K\sqrt{\Delta h} \tag{ii}$$

where $K = C_d C$ and $C = \dfrac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}}\sqrt{2g}$ and is called the venturimeter constant.

The value of the differential head (Δh) can be found by writing the gauge equation between the inlet and throat sections and is given by the following expression,

$$\Delta h = \Delta x\left(\frac{S_m}{S_p} - 1\right) \tag{iii}$$

where Δx is the difference of levels in the monometric liquid, S_m is the specific gravity of manometric liquid, and S_p is the specific gravity of the liquid in the pipe.

For mercury–water column manometer, $S_m = S_{Hg} = 13.6$ and $S_p = S_w = 1.0$, then from Eq. (iii), we get

$$\Delta h = 12.6 \times \Delta x \tag{iv}$$

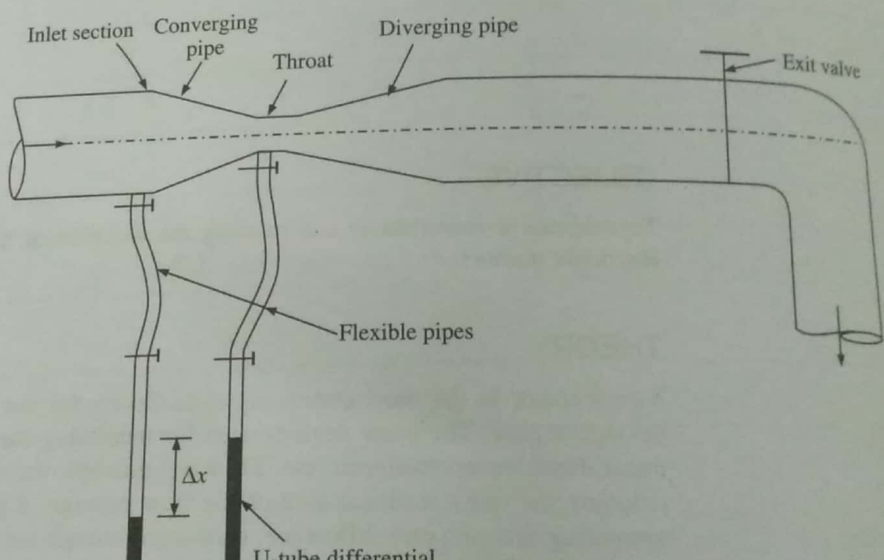


Figure 2.1 Venturimeter apparatus.

PROCEDURE

1. Open the pressure tappings of the venturimeter (keeping the pressure tappings of the orificemeter in the closed position).
2. Remove air in the manometer. For this, the following steps are carried out:
   - Open the inlet and exit valves slightly so that water starts flowing through the venturimeter.
   - Open the pressure tappings of the manometer simultaneously and then adjust the inlet and outlet valves till there is a free flow of water from the plastic tubes.
3. Open the inlet valve fully and wait for sometimes so that the flow becomes steady.
4. Note the difference of levels, Δx in the manometer.
5. Measure the discharge, in the discharge measurement tank.
6. Repeat steps (4) and (5) for more runs by regulating the flow using exit valve.
7. Note the temperature of water used in the experiment.

OBSERVATIONS AND CALCULATIONS

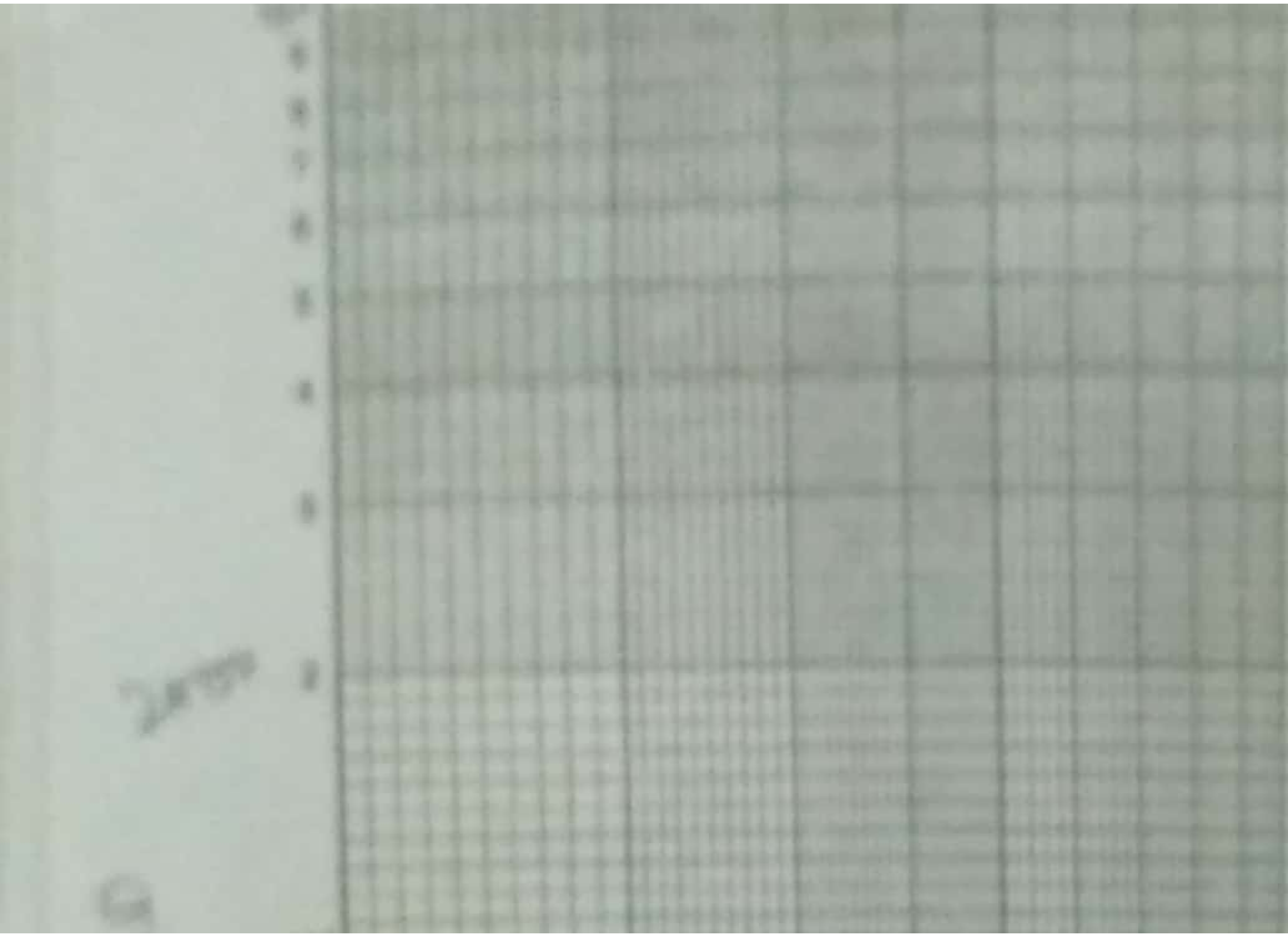
Area of an inlet section, A_1 = 506.71 mm^2 = 5.0671 cm^2
Area of the throat section, A_2 = 170.714 mm^2 = 1.70714 cm^2
Venturimeter constant C = 83.5 cm^3/s
Diameter of throat section, D_2 = 1.5
Temperature of water, T°C = 18°C
Kinematic viscosity of water, v at T°C = 1.12×10^{-6} m^2/s
= 1.12×10^{-2} cm^2/s

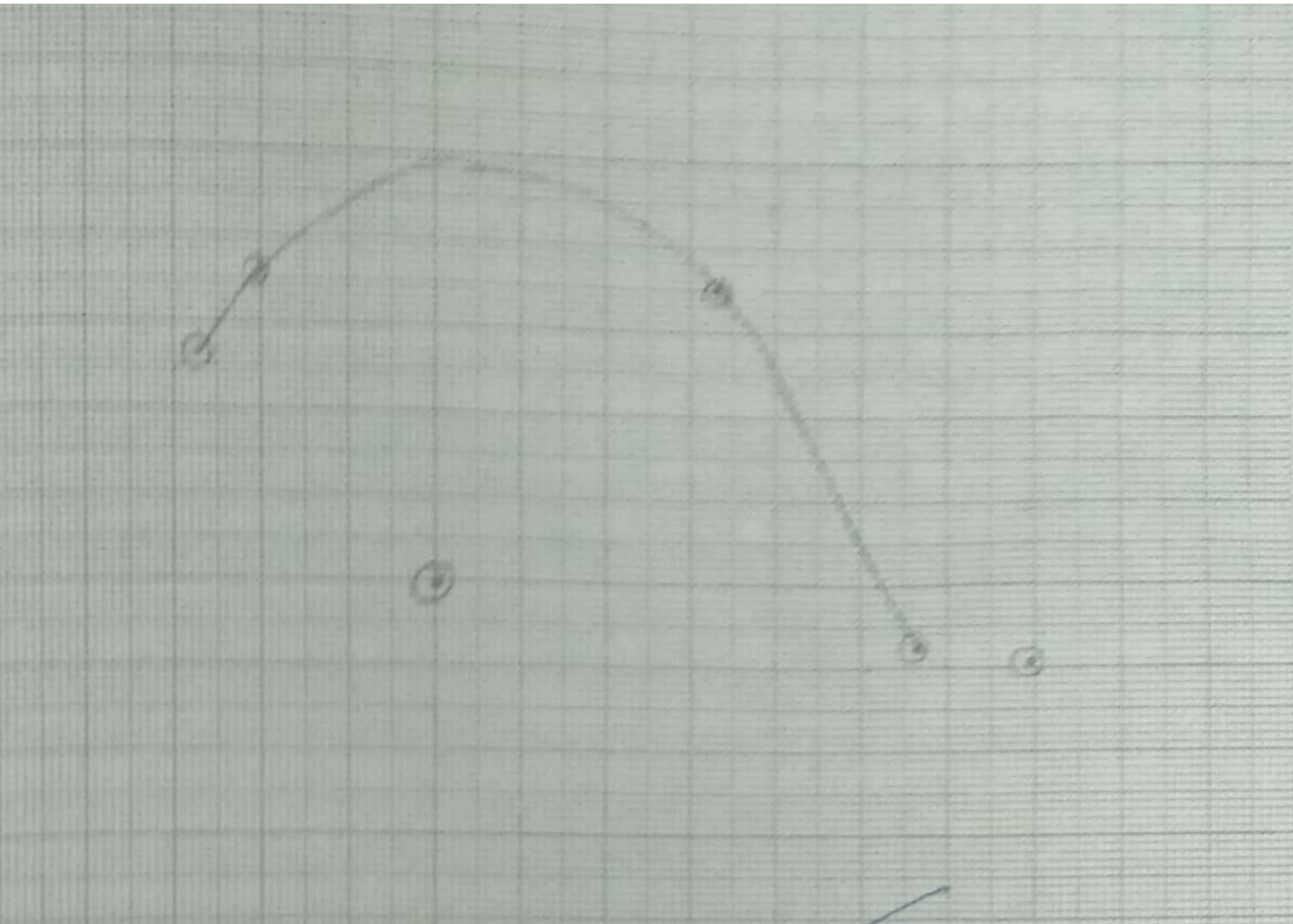
Run No.	1	2	3	4	5	6	7
Discharge, Q	2.88	3.2	4.64	4.56	7.12	8.4	9.12
Δx	1.5	1.8	4.2	4.8	9	14.3	17
$\Delta h = 12.6 \times \Delta x$ [Using Eq. (iv)]	18.9	22.68	52.92	60.48	113.4	130.18	214.2
$C_d = Q/(C\sqrt{\Delta h})$ [Using Eq. (ii)]	7.973	8.087	7.616	7.057	8.047	7.531	7.502×10
Reynolds No., $\mathrm{Re} = \dfrac{Q \cdot D_2}{A_2 v}$	2.192	2.435	3.53	3.471	5.418	6.392	6.940

GRAPHS

1. Plot Q versus Δx on a log-log graph, with Q as ordinate. Draw a best fit straight line to the data points for obtaining the calibration curve. From this graph, determine the slope, the value of constant K and the coefficient of discharge C_d.
2. Plot C_d versus Re with C_d as ordinate on an ordinary graph paper and draw a best fit curve to the data points.

DISCUSSION





ROUGH OBSERVATION SHEET

Date: 15/02

Diameter at an inlet section, D_1 = 25.4 mm
Diameter at the throat section, D_2 = 15 mm
Plan area of the measuring tank, A_m = 39.7 × 39.7
Temperature of water, T°C = 19
Kinematic viscosity of water, v at T°C = $1.12 \times 10^{-6}\ m^2/s = 1.12 \times 10^{-2}\ cm^2/s$

Run No.	Discharge (Q) measurement					Manometer readings		
	Initial level	Final level	Rise, ΔH	Time, t	$Q = A_m \times \Delta H/t$	x_1	x_2	Δx
1.	2.3	5.9	3.6	15	2.88×10^{-4}	19	20.5	1.5
2.	2	6	4	15	3.2×10^{-4}	18.8	20.6	1.8
3.	2	7.8	5.8	15	4.64×10^{-4}	17.5	21.7	4.2
4.	4	9.7	5.7	15	4.56×10^{-4}	17.3	22.1	4.8
5.	7	15.9	8.9	15	7.12×10^{-4}	14.3	25.3	11
6.	3	13.5	10.5	15	8.4×10^{-4}	12.5	26.8	14.3
7.	5	16.4	11.4	15	9.12×10^{-4}	11.2	28.2	17

1.	2.3	5.9	3.6	15	2.88×10^{-4}	19	20.5
2.	2	6	4	15	3.2×10^{-4}	18.8	20.6
3.	2	7.8	5.8	15	4.64×10^{-4}	17.5	21.7
4.	4	9.7	5.7	15	4.56×10^{-4}	17.3	22.1
5.	7	15.9	8.9	15	7.12×10^{-4}	14.3	25.3
6.	3	13.5	10.5	15	8.4×10^{-4}	12.5	26.8

EXPERIMENT 4

Determination of Friction Factor for Pipes of Different Materials

OBJECTIVE

To determine the friction factor for the pipes of different materials and to study its variation with

For the determination of h_f the value of the friction factor f_1 should be known. The value of the friction factor depends upon the Reynolds number of the flow and the type of the material of the pipe surface, i.e. rough or smooth. It also depends on the age and use of the pipe. The value of the friction factor is determined in the laboratory by using Eq. (i).

EXPERIMENTAL SET-UP

The set-up consists of four pipes of different materials, viz. galvanised iron (GI), cast iron (CI), aluminum (Al) and copper (Cu). GI and CI pipes are considered as rough pipes, whereas Al and Cu pipes are considered as smooth pipes. The pipes are connected through a common manifold. Water is supplied to the manifold through an inlet valve provided in the supply pipeline. A regulating valve is provided near the exit of each pipe (Figure 4.1). A multitube U-tube differential manometer containing mercury is connected between two pressure tappings of each pipe for measuring the pressure loss in the pipes and to compute the head loss due to the friction (h_f).

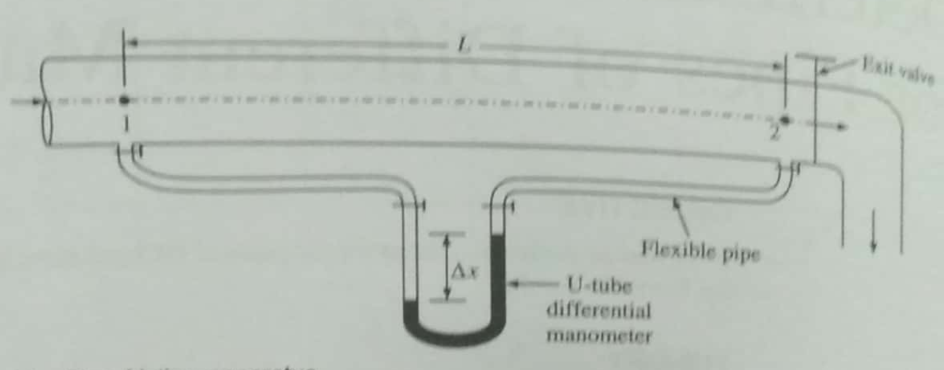


Figure 4.1 Pipe friction apparatus.

OBSERVATIONS AND CALCULATIONS

Kinematic viscosity of water, ν = 0.996 × 10⁻⁶ [illegible]
Diameter of the pipe, d = 1.58 cm
Area of the cross-section of the pipe, A = 1.76 cm²
Gauge length of the pipe (distance between pressure tappings), L = 160 cm

Pipe 1 (Material) Stainless Steel

Run No.	1	2	3	4	5	6
Discharge, Q	125.94	167.77	289.42	437.86	459.31	549.98
Δx	0.1	0.4	1.2	2.3	2.6	3.2
Head loss, $h_f = 12.6 \times \Delta x$	1.26	5.04	15.12	28.90	32.76	40.32
Mean velocity, $V = Q/A$	71.19	95.3	164.37	248.67	260.8	308.68
Friction factor, f_1 by Eq. (i)	17.31	16.3	16.4	13.8	14.1	12.4
Reynolds number, $Re = VD/\nu$	107.49	143.90	248.22	375.49	393.8	466.12

Pipe 2 (Material) Galvanised 1

Run No.	1	2	3	4	5	6
Discharge, Q	189.13	204.68	282.03	335.55	399.77	540.37
Δx	0.4	0.8	1.3	1.8	2.6	4.5
Head loss, $h_f = 12.6 \times \Delta x$	5.04	10.08	16.38	22.68	32.76	56.7
Velocity, $V = Q/A$	107.42	116.25	160.19	190.59	227.06	306.93
Friction factor, f_1 by Eq. (i)	22.3	21.9	18.78	18.38	18.7	17.7
Reynolds number, $Re = VD/\nu$	162.2	175.53	241.88	287.79	342.86	46[illegible]

ROUGH OBSERVATION SHEET

Date:

Temperature of water, T°C = 20.5°C

Kinematic viscosity of water at T°C, ν = 0.996×10^{-2} cm²/s

Plan area of the measuring tank, A_m = 39.7×39.7

Diameter of the pipe, D = 1.5

Gauge length of the pipe (distance between the pressure tappings), L = 100

Pipe 1 (Material) Stainless Steel

Run No.	Discharge Q measurement					Manometer readings		
	Initial level (cm)	Final level (cm)	Rise, ΔH (cm)	Time, t (s)	$Q = A_m \times \Delta H/t$ (cm³/s)	x_1	x_2	Δx
1.	5.4	15.5	10.1	127	125.34	20.5	20.6	0.1
2.	5.5	15.4	9.9	93	167.77	20.4	20.8	0.4
3.	5.5	15.6	10.1	55	281.42	20.0	21.2	1.2
4.	5.6	15.6	10.0	36	437.80	19.5	21.8	2.3
5.	5.5	15.7	10.2	35	459.31	19.3	21.9	2.6
6.	6.1	16.1	10.0	29	543.48	19	22.2	3.2

Pipe 2 (Material) Galvanised Iron.

Run No.	Discharge Q measurement					Manometer readings		
	Initial level (cm)	Final level (cm)	Rise, ΔH (cm)	Time, t (s)	$Q = A \times \Delta H/t$ (cm³/s)	x_1	x_2	Δx
1.	4.0	14.2	10.2	85	189.13	20.3	20.7	0.4
2.	5.0	15.2	10.0	77	204.68	20.1	20.9	0.8
3.	5.0	15.2	10.2	57	282.03	19.9	21.2	1.3
4.	5.1	15.0	9.9	46.55	335.55	19.7	21.5	1.8
5.	5.1	15.0	9.9	39.03	399.77	19.3	21.9	2.6
6.	15.0	15.2	10.2	29.75	540.37	18.4	22.9	4.5

Instructor's Signature

EXPERIMENT 6

Verification of Momentum Equation

OBJECTIVE

To determine the force exerted by a jet of water on a stationary vane and to verify the impulse-momentum equation.

THEORY

Vanes are the curved plates generally used in turbines. The force exerted by a jet of water on a vane is determined by using the impulse-momentum equation, which states that the resultant force acting on the fluid in a control volume in any direction is equal to the rate of change in momentum of fluid mass in the same direction.

Therefore, the net force acting on the fluid for the control volume in the x-direction [Figure 6.1(a)] is given by the expression,

$$F_x = \rho Q(V \cos \theta - V) \qquad \text{(i)}$$

where F_x is the force exerted on the fluid in the x-direction, ρ is the mass density of water, Q is the discharge through the nozzle, V is the velocity of the jet, and θ is the deflection angle (angle made by the deflecting jet with the initial direction of flow).

The force exerted by the fluid on the vane will be equal in magnitude, but opposite in direction, i.e.

$$F_x = \rho QV(1 - \cos \theta) \qquad \text{(ii)}$$

For a vertical water jet striking a vane, which is free to move in the vertical direction, a force will be exerted on the vane by the impact of jet. This force will also be equal to the force required to bring back the vane to its original position. Further, for the hemispherical vane, as used in the experimental set, $\theta = 180°$ and, therefore, the force (theoretical) exerted by the water jet on the vane is given by

$$F_t = 2\rho Q V$$

$$F_t = \frac{2\rho Q^2}{a}$$

where a is the area of the cross-section of the nozzle and F_t is the theoretical force.

Because of the losses, the actual force acting on the vane is less than the theoretical force. The ratio of the actual force to the theoretical force is known as the vane coefficient K.

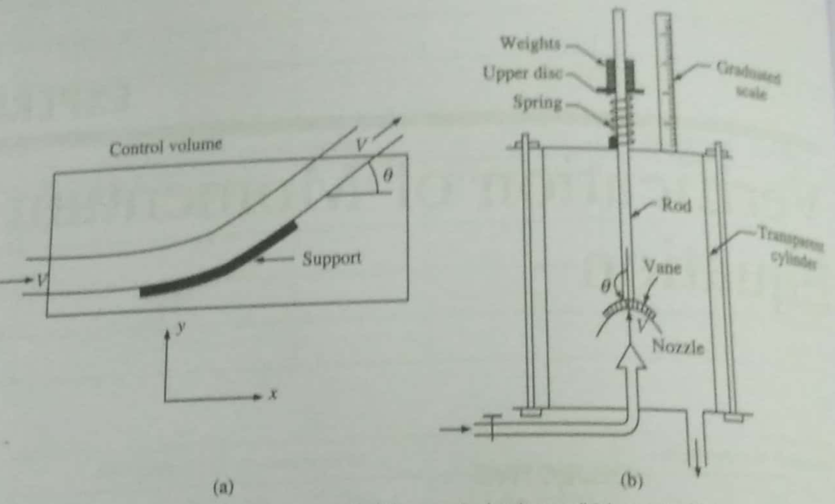


Figure 6.1 (a) Momentum equation as applied to a control volume, (b) Impact of jet apparatus.

EXPERIMENTAL SET-UP

The set-up consists of a closed circuit flow of water. A transparent cylinder is fixed on a mild steel stand. Two plates are fixed with holes at centre with the help of steel rods. One plate is kept at the top and the other at the bottom of the cylinder. A vertical rod which can move up and down is placed in a hole of the top plate. A spring is placed around the rod and kept on the top of cylinder [Figure 6.1(b)]. A disc is placed on the spring for placing the weights. A vertical scale is fixed to the cylinder for noting the initial position of the disc. A hemispherical vane is fixed at the lower end of the rod. A nozzle is placed through the hole in the bottom plate just below the vane so that the jet strikes at the centre of the vane. Water is supplied to the nozzle by using a centrifugal pump. The force exerted by the jet on the vane is determined by the placing weights on the disc to counteract the reaction of jet, i.e. the force required to bring back the vane to its original position.

A collecting tank and a discharge measuring tank are provided. A delivery valve is provided in the supply pipe for regulating flow. The water from the cylinder is discharged into the collecting tank from which it is recirculated again with the help of centrifugal pump.

PROCEDURE

1. Note the initial position of the disc on the graduated scale.
2. Close the delivery valve and start the pump.

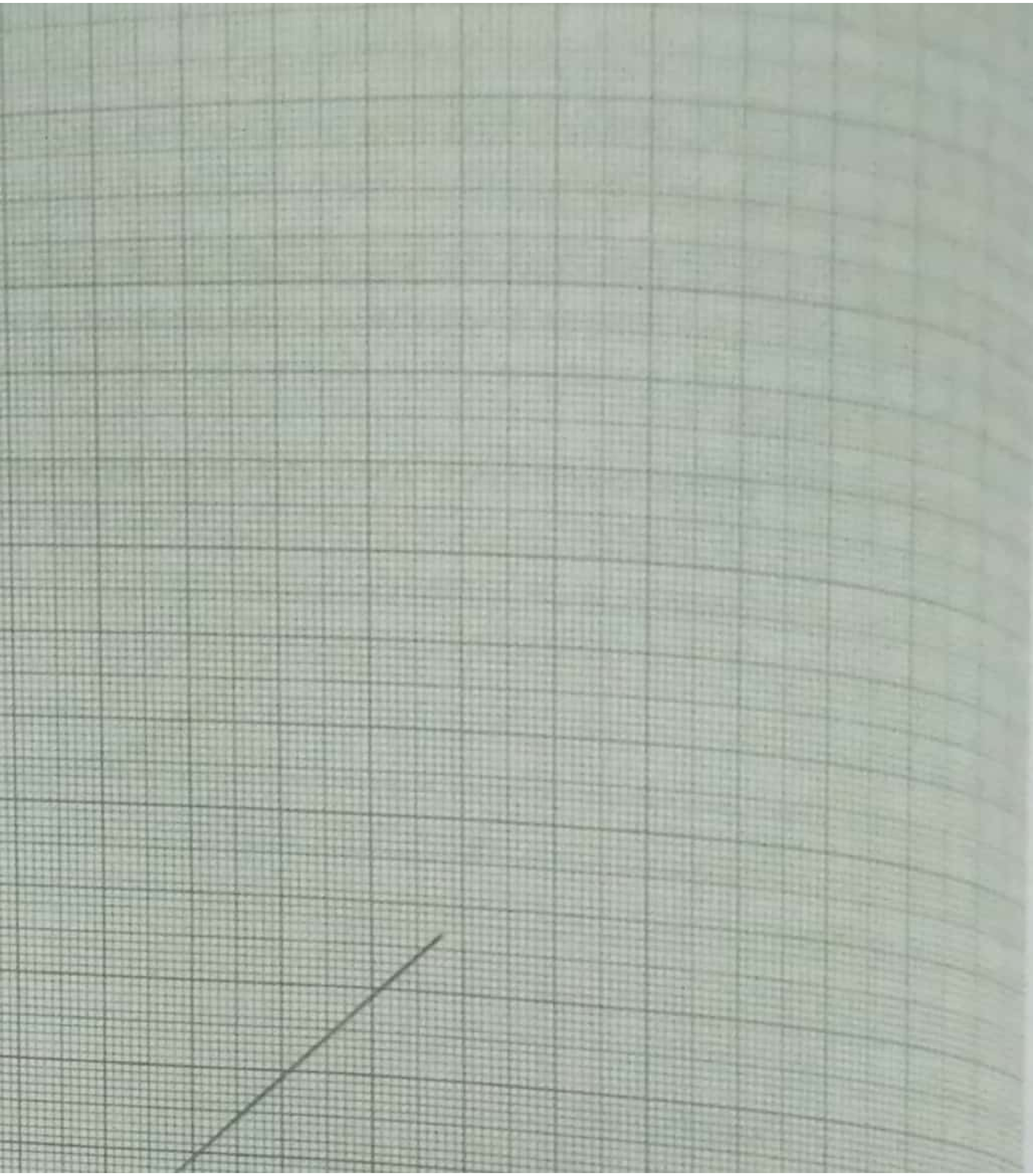
3. Open the delivery valve so that the water jet issuing from the nozzle strikes the hemispherical vane vertically.
4. Due to striking of the jet on the vane, the position of the upper disc is changed. Now place weights on the disc so as to bring the disc back to its original position. Adjust the inflow, if required.
5. Note down the weights placed on the upper disc.
6. Measure the discharge, in the discharge measurement tank.
7. Repeat steps (4) to (6) for other discharges by regulating the delivery valve.

OBSERVATIONS AND CALCULATIONS

Mass density of water, ρ = 1000 kg/m^3
Diameter of the nozzle, d = 0.01 m
Area of the nozzle, a = 0.12 m^2 ($\pi d^2/4$)

1 kg = 10N

Run No.	1	2	3	4	5	6
Discharge, Q (m^3/s) 10^{-4}	3.16	4.24	4.92	5.16	5.32	5.8
Balancing mass, M	0.200	0.400	0.500	0.600	0.700	0.800
Velocity of jet, $V = Q/a$ (m/s)	2.63×10^{-3}	3.53×10^{-3}	4.1×10^{-3}	4.3×10^{-3}	4.43×10^{-3}	4.83×10^{-3}
[illegible]	[illegible]	2.924	4.905	5.886	6.867	7.848



ROUGH OBSERVATION SHEET

Date:

Diameter of the nozzle, d = 0.01 m
Area of the nozzle, a $\pi d^2/4$ = 7.85×10^{-5}
Plan area of the measuring tank, A_m = 0.12 m^2

Run No.	Discharge (Q) measurement					Balancing mass, M
	Initial level m	*Final level* m	*Rise, ΔH* m	*Time, t* s	$Q = A_m \times \Delta H / t$ $\times 10^{-4}$ (m^3/s)	(kg)
1.	0.068	0.147	0.079	30	3.16	0.200
2.	0.072	0.178	0.106	30	4.24	0.400
3.	0.018	0.141	0.123	30	4.92	0.500
	0.039	0.168	0.129	30	5.16	0.600

EXPERIMENT 14

Transition of Flow—Reynolds Experiment

OBJECTIVE

To study the transition of flow from the laminar to turbulent using the Reynolds method.

THEORY

Depending upon the relative magnitude of inertia and viscous forces, the flow of fluid in a pipe may be either laminar or turbulent. In laminar flow, viscous effects are more predominant than the inertial effects. But, when the velocity of flow is increased, the flow becomes turbulent after passing through transition state. A convenient measure of the two types of flow is the Reynolds number, may be denoted by Re. It is defined as the ratio of the inertia force to the viscous force and is given by the expression VD/ν, where V is the average velocity of flow, D diameter of the pipe, and ν is the kinematic viscosity of fluid. For flow in pipes, if Re < 2000, the flow is laminar and for Re > 4000, the flow is turbulent. For Re lying between 2000–4000, the flow is in transition state, which refers to the instability of laminar flow leading to turbulent flow. Further, the head loss due to friction h_f in the pipes is the proportional to V^n, where V is the mean velocity of the flow and n is an index. For laminar flow, $n = 1$ and for turbulent flow, $n = 1.72$ to 2. In order to determine the value of n, a log–log graph is plotted between h_f and V. Generally, to have a dimensionless plot, a log–log graph is plotted between h_f/L and VD/ν, where L is the length of pipe in which the head loss is h_f.

Osborne Reynolds was the first who demonstrated the existence of the two types of flow, viz. laminar and turbulent, experimentally. Reynolds injected dye as filament at the centre of a transparent tube and studied its behaviour. He observed that at low flow velocities, the dye remained in the form of straight and stable filament so steadily that it hardly seemed to be in motion. This corresponds to laminar flow conditions. With the increase in velocity of flow, a critical state was reached at which the filament of dye showed signs of irregularities and began to wavers. This shows that the flow is no longer laminar but in transitional state. With further increase in velocity of flow, the dye completely diffused over the cross-section of the tube and mixed with water. This corresponds to the turbulent flow conditions.

The velocity at which the flow changes from laminar to turbulent is called the upper critical velocity, and the corresponding Reynolds number as the upper critical Reynolds number. The velocity at which the flow changes back from turbulent to laminar is called the lower critical velocity, and the corresponding Reynolds number as the lower critical Reynolds number.

The upper critical Reynolds number is not a fixed quantity as it depends upon a number of factors such as initial disturbance to flow, the shape of entry to the tube, etc. On the other hand, the lower critical Reynolds number is well established and its value is usually about 2000.

EXPERIMENTAL SET-UP

The set-up consists of a constant head supply tank mounted on the steel plate and placed on the mid steel stand. A perspex tube is attached to the tank to visualize the different flow conditions. The tank has the provision for supplying dye through a needle at the centre of the tube in the form of a jet (Figure 14.1). The entry of water in the perspex tube is though an elliptical bell mouth entrance so as to have a smooth entry to the flow. Water is supplied to the tank through an inlet valve provided in the supply pipeline. A regulating valve is provided on the downstream side of the tube to regulate the flow gradually. A collecting tank is provided to measure the discharge. Alternatively, smaller discharges can be measured in the cylinder. The pressure head between two points is measured by using two piezometers.

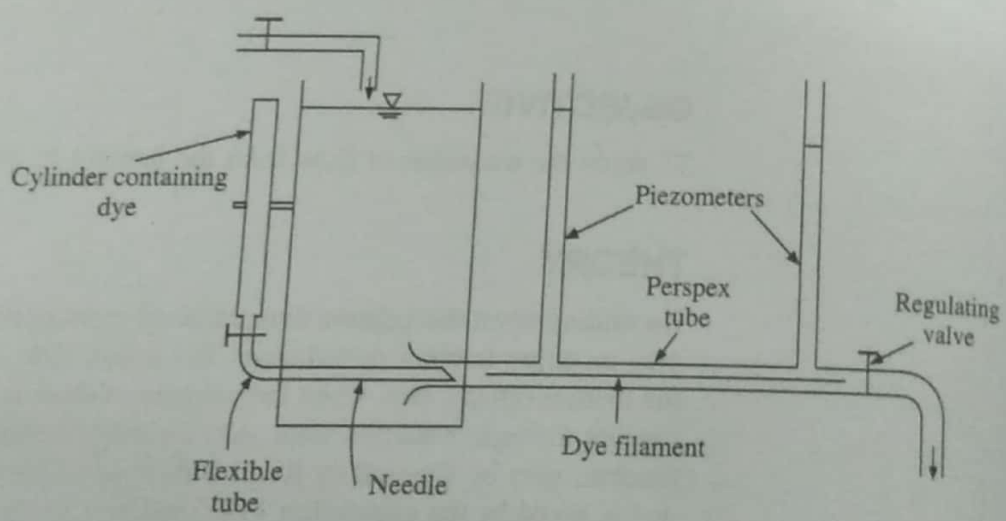


Figure 14.1 Reynolds apparatus.

OBSERVATIONS AND CALCULATIONS

Diameter of the perspex tube, D = 25.4 mm

Area of the conduit, A = 5.06 cm²

Gauge length of the tube, L = 80

Kinematic viscosity of water, ν = 0.996 × 10⁻⁶ m/s²

Increasing discharge

Run No.	Q	$V = \frac{Q}{A}$	$\frac{h_f}{L}$	$Re = \frac{VD}{\nu}$	Characteristic of dye	Type of flow
1	5.76	1.1373	2.27	2.06	straight	laminar
2	6.159	1.216	2.27	3.066	straight	laminar
3	6.896	1.361	2.27	3.432	zig-zag	transition
4	7.71	1.522	3.4	3.838	zig-zag	transition
5	8.104	1.6003	2.27	4.0359	Vanishes	turbulent
6	15.37	3.035	7.95	7.659	Vanishes	turbulent

Decreasing discharge

Run No.	Q	$V = \frac{Q}{A}$	$\frac{h_f}{L}$	$Re = \frac{VD}{\nu}$	Characteristic of dye	Type of flow
1	16.82	3.321	9.09	8.31892	Vanishes	turbulent

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Value of the upper critical Reynolds number = 8.3689
Value of the lower critical Reynolds number = 1860
Value of n for laminar flow = 1
Value of n for turbulent flow = 1.7-2

DISCUSSION

The graph of (h_f/L) Vs Re is an increasing curve with critical Reynold's number 8368.9 and lower critical Reynold's number is 1860.

Pressure head measurement			Characteristic of d...
$\frac{p_1}{\rho g}$	$\frac{p_2}{\rho g}$	$h_f = \left(\frac{p_1 - p_2}{\rho g}\right)$	
66.8	66.8		
66.4	66.4		
66.0	66.0		
65.0	65.0		
63.8	63.8		
62.8	62.8		