Experiment No. 01

MEASUREMENT OF CAPPILARY RISE

Aim

To measure capillary rise produced in capillary tubes of different sizes and compare it with the estimated values.

Apparatus

Glass capillary tubes of different diameters, measuring scale and given liquid.

Theory

The liquid has greater adhesion than cohesion, thus it wets the solid surface with which it is in contact and also tends to rise at the point of contact with the result that the liquid surface is concave upward and angle of contact θ is less than 90°.The phenomenon of rise or fall of liquid surface relative to the adjacent general level of liquid is known as capillarity. The capillary rise can be determined by considering the condition of equilibrium in a circular tube of small diameter inserted in a liquid

Capillary Rise is given by, $h = 4\sigma / \rho g d$

where, h is the height of rise, σ is the surface tension, ρ is the density of the liquid and d is the diameter of tube.

Procedure

i. Capillary tubes are well cleaned.
ii. Place the panel in the receiver with a certain level of water
iii. Place a cardboard between the capillary tubes.
iv. Mark the cardboard at the height of capillary rising in each tube.
v. Measure the capillary rise “H” in each tube

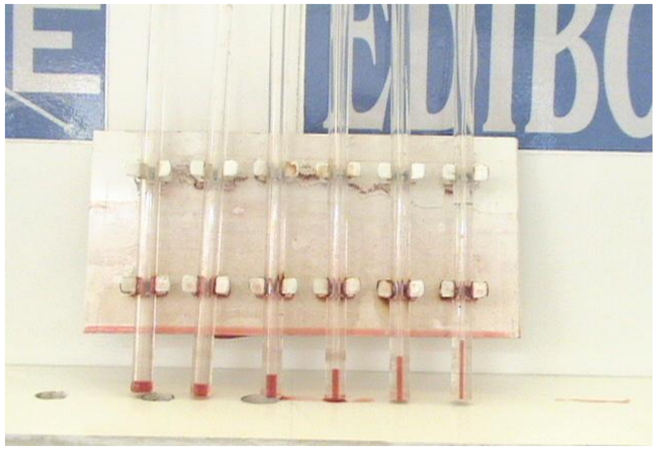


Fig. 1 Capillary rise in tubes of different diameter

Sample Calculation

Observation Table

S. No.	**Tube diameter (mm)**	**Capillary Rise h (mm)**	
		Observed	**Calculated**
1			
2			
3			
4			
5			
6			

Results and Discussion

Experiment No. 02

DETERMINATION OF THE METACENTRIC HEIGHT

Aim

To determine the metacentric height of a typical float.

Apparatus

Metacentric height instrument, measuring scale etc.

Theory

Metacentre is the point, where the line of buoyant force and the perpendicular passing through the centre of gravity intersect.

The metacentric height , **GM = w x/W tanθ**

where, GM = metacentric height in mm, w is the mass of the slider in kg, x is the distance to the movable weight from the central position in mm, W is the mass of the trough and the slider in kg, θ is the angle of inclination

The distance between the buoyancy and the metacentre, **BM = I/V**

where, V is the volume in the displaced water, I is the moment of inertia of the plane of water respect to the longitudinal axis = $lb^3 / 12$

Hence, the metacentric height, **GM = BM – BG**

Procedure

1) Weigh the adjustable transversal mass as well as the floating prismatic base and assembly.
2) Displace the sliding mass up to upper part of the mass in such a way that the gravity center be in the upper part of the floating assembly
3) Fill the volumetric tank with water.
4) Move the adjustable mass to the right of the center in 10mm steps of x, until the end of the scale, recording the angular displacement for every position.

Observations

Mass of movable slider w = 0.302

Mass of trough W’= 1.649

Mass of slider and trough W = 1.951

OBSERVATION TABLE

Distance from the movable mass to the right of the center, X(cm)	Position of vertical slider Y (cm)	Inclination angle θ	$\tan\theta$	Metacentric height GM(cm)
2				
4				
6				
8				
-2				
-4				
-6				
-8				

Sample Calculation

Results and Discussion

Experiment No. 03

FRICTION FACTOR

Aim

To find the friction factor for the given pipes of different sizes and materials in different ranges of Reynolds number.

Equipment

Pipe friction apparatus

Theory

The major factor contributing to the energy loss in any pipe flow is through the boundary shear. In cases of steady flow through the pipe, a constant pressure gradient is to be maintained to overcome the frictional losses due to the boundary shear. Estimation of frictional losses is important from engineering point of view as the design of pipe mains carrying water from any reservoir to the township over a long distance mainly depends upon the friction factors. Booster pumps at places are to be provided to add additional energy needed to maintain the required quantity of flow.

In steady, uniform turbulent incompressible flow in conduits of constant cross section, the wall shear stress 'τ_0 varies about proportional to the square of the average velocity.

$$\tau_0 = \frac{1}{2}\lambda\rho V^2 \tag{1}$$

in which λ is a dimensionless coefficient, ρ is the mass density of the fluid flowing and V is the mean velocity of the flow.

In Fig.1 a steady uniform flow is indicated in either a closed conduit. For closed conduit flow, energy for flow could be supplied by the potential energy drop, as well as by a drop in pressure, P_1-P_2. With flow vertically downward in a pipe, P_2 could increase in the flow direction but potential energy drop Z_1- Z_2 would have to be greater than (p1-p2)/γ to supply energy to overcome the wall shear stress.

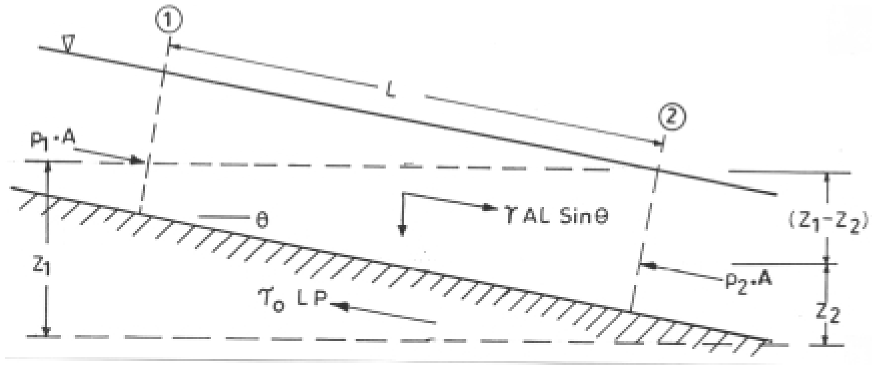


Fig. 1 Axial Forces on Control Volume of Fluid Flowing

The linear momentum equation applied between sections 1 and 2 in the direction of flow yields.

$$F_1 = 0 = (p_1 - p_2)A + \gamma ALSin\theta - \tau_0 LP \tag{2}$$

in which P is the wetted perimeter of the conduit, that is the portion of the perimeter where the wall is in contact with the fluid, A is the area of cross section of flow, L is the distance between the two sections, γ is the specific weight of the liquid flowing and θ is the inclination of the bed of the channel in the section 1 and 2 yields.

$$\left(\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1\right) = \left(\frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2\right) + h_f \tag{3}$$

where hf is the head loss between sections 1 and 2. Since the velocity head is same i.e.

$\frac{V_1^2}{2g} = \frac{V_2^2}{2g}$, we have,

$$h_f = \frac{P_1 - P_2}{\gamma} + \left(Z_1 - Z_2\right) \tag{4}$$

since $L\ Sin\theta$ = (Z1-Z2), from Eq.2, it can be written as

$$\frac{P_1 - P_2}{\gamma} + \left(Z_1 - Z_2\right) = \frac{LP}{\gamma A} \tag{5}$$

From Eq. 4 and 5

$$h_f = \frac{\tau_0 LP}{\gamma A} = \frac{1}{2}\rho V^2 \lambda \frac{LP}{\gamma A} \tag{6}$$

$$h_f = \lambda \frac{L}{R} \frac{V^2}{2g} \tag{7}$$

where R is the hydraulic radius= A/P. For circular pipes, R=D/4. The unit of h_f is meter-Newton/Newton. After solving for V, we have

$$V = \sqrt{\frac{2g}{\lambda}} \sqrt{RS} = C\sqrt{RS} \tag{8}$$

For pipes, λ =f/4 and R= D/4, then

$$h_f = f \frac{LV^2}{2gD} \tag{9}$$

Eq. 9 is known as Darcy-Weisbach pipe friction equation, f is known as the Darcy-Weisbach pipe friction factor.

Procedure:

1. Gradually open the inlet valve of the set-up to let water into the pipes and connecting tubes. Disconnect the pressure tapping from the manometer, allow the water to flow freely thorough the flexible tubes connected to the pressure tapping to remove air bubbles if any. After ensuring that there are no air bubbles, connect the flexible tubes back to the manometer.
2. Record the size of the pipes, the distances of the pressure tapping which are to be used as lengths-of pipes and temperature of water flowing.
3. Allow the discharge to come to steady state and note the difference in pressure between the tappings.
4. For the same discharge, close the outlet valve of the collecting tank. Allow the water level in the collecting tank to rise by a certain amount. Note the time taken for this rise in water level and the area of the collecting tank. The discharge is equal to the volume of water collected divided by the time taken.
5. Repeat the procedure for different values of different discharges and different pipes. Maintain different tabular forms for different pipes.

Observation Table

Length of the pipe, or the distance between the pressure tappings, L=

Diameter of the pipe, D=

Temperature of water =

S.No.	Volume of water collected in the tank	Time taken (mm)	Discharge Q	Velocity of flow, V=Q/A	(V2/2g)	Differential manometer reading	Friction factor, f	Reynolds number
1								
2								
3								
4								
5								
6								

Plot the friction factor f verses the Reynolds number of flow

Sample Calculation

Result

Experiment No. 04

IMPACT OF A JET

OBJECTIVE:

To measure the force exerted by a jet on a flat plate normal to the Jet

APPARATUS

Impact of Jet Apparatus

Theory

A jet of fluid emerging from a nozzle has some velocity and hence it possesses a certain amount of kinetic energy. If this jet strikes an obstruction placed in its path, it will exert a force on the obstruction. This impressed force is known as impact of the jet. Since, a dynamic force is involved by virtue of fluid motion; it always involves a change of momentum.

Flat plate normal to the jet: Let a jet of diameter d and velocity V is issued from a nozzle and strikes a flat plate as shown in Fig 1. The plate is held stationary and perpendicular to the centre line of the jet. The jet after striking the plate will leave it tangentially i.e. the jet will get deflected through 90^0.

The quantity of fluid striking the plate Q= $(\pi d^2/4) \times V$ **=** a V**,** where a is the area of cross section of the jet. Thus, the mass of fluid issued by the jet per second is m = ρ Q = ρaV; where ρ represents the mass density of the fluid. Since ρ = $\frac{w}{g}$ (w/g), where w is the specific weight of the fluid, the mass m may also be expressed as m = $\frac{waV}{g}$

After striking the plate since the jet gets deflected through 90^0, the component of the velocity of the jet leaving the plate, in the original direction of the striking jet will be zero. Therefore, by applying impulse-momentum equation, the force F exerted by the stationary plate on the jet of fluid in the direction normal to the plate may be determined as

$$- F = \frac{waV}{g}(0 - V)$$

$$F = \frac{waV^2}{g} \qquad \text{---- (i)}$$

The sign for the force F has been considered as negative because the force exerted by the plate on the jet is in the negative x-direction. Further the force which the jet exerts on the plate is equal and opposite to the force exerted by the plate on the jet, hence it is equal to F acting in the positive x-direction and its magnitude is given by equation (i)

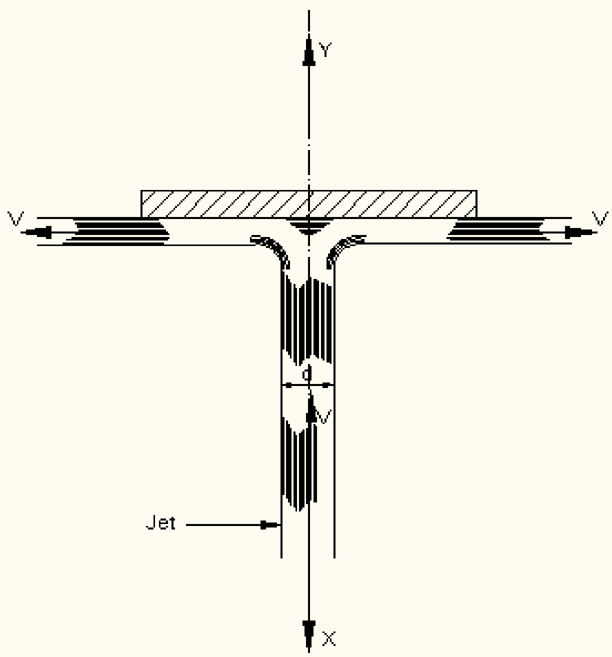


Fig. 1 Fluid jet striking stationary flat plate

PROCEDURE:

1. Fill up clean water in the sump tank up to the mark
2. Fix the flat plate to the fixing rod. Fix the nozzle in perspex box at centre and close the top covers.
3. Adjust the balance weight. Locking bolt is provided so that the vane fixing rod is in horizontal position.
4. Connect the electric supply and hose pipe connection to inlet of the nozzle.
5. Fully open the bypass valve. Start the pump.
6. Slowly close bypass valve. The jet strikes the vane.
7. Now, the vane fixing rod gets unbalanced. Put the sliding weight over the rod and adjust it's distance such that vane fixing rod is in balanced position.
8. Note down the balance weight and it's distance from the centre of the pivot.
9. Close the discharge valve of the measuring tank. Turn the funnel towards the measuring tank so that the water gets collected in the measuring tank. Start stop watch at -0 Lit and measure the time required for 10 Lit.
10. For next reading use same procedure.
11. After completion of experiment drain all the water and tighten the drain plug.

OBSERVATION TABLE

Sl no.	**Time for 10 litre discharge t (sec)**	**Weight added m (kg)**	**Distance of sliding weight, l (m)**	**F_{Theo} (kg)**	**F_{exp} (kg)**
01		0.1			
02		0.1			
03		0.1			

CALCULATIONS:

Diameter of the nozzle = 8 mm

Diameter of jet: d = 8×10^{-3} m

Cross sectional area of jet, a = 5.02 x 10^{-5} m^2

Let the time required for 10 litre level rise in measuring tank be t sec

Discharge = $\frac{0.01}{t}$ m^3/ sec

Velocity of jet = $\frac{Q}{a}$ m/sec

Force exerted by the flat vane (deflection of jet is 90^0)

F_{Theo} = paV^2 kg

Where ρ = Density of water = 1000 kg/ m^3

Experimentally, taking moments about the fulcrum,

Distance of vane from fulcrum is 0.135 mtr. (along the beam)

F_{exp} x 0.135 = m x g x l

F_{exp} = (m x g x l) / 0.135

Where, m = Mass of sliding weight in kg

l = Distance of sliding weight from fulcrum, m

g = Gravitational acceleration = 9.81 m/ sec^2

RESULT

Experiment No. 05

VERIFICATION OF BERNOULLI'S THEOREM

Aim: Verification of Bernoulli's Theorem

Theory: Bernoulli's law indicates that, if an in viscid fluid is flowing along a pipe of varying cross section, then the pressure is lower at constrictions where the velocity is higher, and higher where the pipe opens out and the fluid stagnates. The well-known Bernoulli equation is derived under the following assumptions:

1. fluid is incompressible (density □ is constant);
2. flow is steady: $\frac{\partial}{\partial t} = 0$
3. flow is frictionless ($\tau = 0$);
4. along a streamline;

Then, it is expressed with the following equation:

$$\frac{P}{\rho g} + \frac{v^2}{2g} + z = h^* = const$$

Where (in SI units):

p = fluid static pressure at the cross section in N/m^2.

□ = density of the flowing fluid in kg/m^3

g = acceleration due to gravity in m/s^2 (its value is $9.81\ m/s^2 = 9810\ mm/s^2$)

v = mean velocity of fluid flow at the cross section in m/s

z = elevation head of the center of the cross section with respect to a datum $z=0$

h^* = total (stagnation) head in m

The terms on the left-hand-side of the above equation represent the pressure head *(h)*, velocity head *(h_v)*, and elevation head *(z)*, respectively. The sum of these terms is known as the total head *(h^*)*. According to the Bernoulli's theorem of fluid flow through a pipe, the total head h^* at any cross section is constant (based on the assumptions given above). In a real flow due to friction and other imperfections, as well as measurement uncertainties, the results will deviate from the theoretical ones.

In our experimental setup, the centerline of all the cross sections we are considering lie on the same horizontal plane (which we may choose as the datum, $z=0$), and thus, all the *'z'* values are zeros so that the above equation reduces to:

$$\frac{P}{\rho g} + \frac{v^2}{2g} + z = h^* = const \qquad \text{(This is the total head at a cross section).}$$

For our experiment, we denote the pressure head as h_i and the total head as h^*_i, where '*i*' represents the cross section we are referring to.

Procedure:

1. Open the inlet valve slowly and allow the water to flow from the supply tank.
2. Now adjust the flow to get a constant head in the supply tank to make flow in and out flow equal.
3. Under this condition the pressure head will become constant in the piezometer tubes.
4. Measure the height of water level "h" (above the arbitrarily selected plane) in different piezometric tubes.
5. Compute the area of cross-section under the piezometer tubes.
6. Note down the quantity of water collected in the measuring tank for a given interval of time.
7. Change the inlet and outlet supply and note the reading.
8. Take at least two reading as described in the above steps.

Experiment No. 6
ORIFICE

OBJECTIVE

To determine the value of coefficient of contraction, coefficient of velocity and coefficient of discharge for the given orifice.

Theory

The coefficient of contraction, C_c, is defined as the ration of the cross-section of the vena-contracta, a_c, to the cross-section of the orifice, a_0 i.e.

$$C_c = a_c / a_0 \quad \text{---} \quad (i)$$

Because of the energy loss which takes place as the water passes down the tank and through the orifice, the actual velocity v_c in the plane of vena-contracta will be less than the theoretical velocity, v_o.

The ratio of the actual velocity v_c and the ideal velocity v_0, if often referred to as the coefficient of velocity, C_v of the orifice,i.e.

$$C_v = v_c / v_0 \quad \text{----} \quad (ii)$$

The theoretical velocity in the plane of the vena-contracta, v_0, can be calculated from the equation.

$$v_0^2 / 2g = h_0 \quad \text{i.e. } v_0 = \sqrt{2gh_0} \qquad \text{----} \quad (iii)$$

The actual velocity in the plane of the vena-contracta, v_c, is given by the equation

$$v_c = \sqrt{\frac{gx^2}{2y}} \quad \text{----------} \quad (iv)$$

where x and y (measured positive downward) represent the horizontal and vertical coordinates of a point on the trajectory of the jet (origin being taken at the lowest point of the jet at vena-contracta. Substituting the values v_c and v_0 in Eq. (ii), we get

$C_v = \sqrt{\frac{x^2}{4yh_0}}$ --------- (v)

Finally the coefficient of discharge, C_d, is defined as the ratio of the actual discharge to that which would take place if the jet is discharged at the ideal velocity without reduction of area. The actual discharge, Q, given by

$Q = v_c a_c$ ----------- (vi)

and can be measured with the help of measuring tank. And if the jet is discharged at the ideal velocity v_0 over the orifice area, a_0, the discharge Q_0 would be

$Q_0 = v_0 a_0$

$= \sqrt{2gh_0}\, a_0$ ----- (vii)

Thus, the coefficient of discharge is given by

$C_d = \frac{Q}{Q_0} = \frac{v_c}{v_0}\frac{a_c}{a_0} = C_c C_V$ ----- (ix)

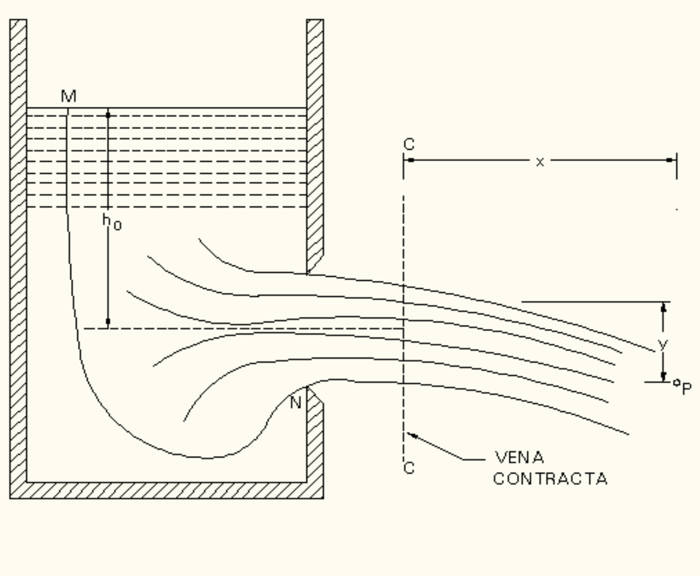


Fig. 1 Flow through an orifice

Description of the Apparatus:

An orifice is an opening made in the side or bottom of tank, having a closed perimeter, through which the fluid may be discharged. Orifice is used to measure the co-efficient of discharge.

The apparatus consists of a supply tank, at the side of which a universal fixture for mounting orifice or mouthpiece is attached. A centrifugal pump supplies the water to supply tank. Head over orifice/ mouthpiece is controlled by a bypass valve provided at pump discharge. A measuring tank is provided to measure the discharge. A gauge for measuring X and Y co-ordinates of jet from the orifice is provided, which is used to calculate C_v of orifice.

PROCEDURE:

1. Fill up sufficient water in sup tank & supply tank, up to level of orifice fixture
2. Fit the required orifice to the tank.
3. Start the pump. Adjust the supply valve. Wait for some time till the water level in the supply tank becomes steady.
4. When water level becomes steady, note down the time required for 10 litres level rise in measuring tank.
5. Measure X and Y co-ordinates of two points in jet, one of which should be closer to orifice and the other away from the orifice.
6. Repeat the procedure for different heads and for other orifice.

OBSERVATIONS

Sl No.	Head (m)	Time for 10 litres level rise in measuring tank, t (sec)	X_1 (cm)	Y_1 (cm)	X_2 (cm)	Y_2 (cm)
01						
02						
03						
04						

CALCULATIONS

1) Dia. of orifice= m

   Area of orifice, a_0= m^2

   Head over orifice, h_0 = m

   Theoretical discharge, $Q_0 = \sqrt{2gh_0}\ a_0\ m^3/sec$

2) Actual discharge,

$$Q = 0.01/t\ (m^3 / sec)$$

3) Coefficient of discharge

$$C_d = Q/Q_{th}$$

4) Co-efficient of velocity

   Let, $x = X_2 - X_1$ m

   $y = Y_2 - Y_1$ m

Then

$$C_v = \sqrt{\frac{x^2}{4yh_0}}$$

Where h_0 is the head over orifice, m

5) Coefficient of contraction

   $C_c = C_d / C_v$

Experiment No. 07

Free and Forced vortex

OBJECTIVE

To determine the surface profile of a vortex apparatus.

Theory

When a liquid contained in a cylindrical vessel is given the rotation either due to rotation of the vessel about vertical axis or due to tangential velocity of water, surface of water no longer remains horizontal but it depresses at the center and rises near the walls of the vessel. A rotating mass of fluid is called vortex and motion of rotating mass of fluid is called vortex motion. Vortices are of two types viz. forced vortex and free vortex. When a cylinder is in rotation then the vortex is called forced vortex. If water enters a stationary cylinder then a vortex is called a free vortex.

Description of the Apparatus:

The apparatus consists of a Perspex cylinder with drain at centre of bottom. The cylinder is fixed over a rotating platform which can be rotated with the help of a D.C. motor at different speeds. A tangential water supply pipe is provided with flow control valve. The whole unit is mounted over the sump tank. Water is supplied by a centrifugal pump.

PROCEDURE:

A. Forced Vortex

1. Close the drain valve of the cylindrical vessel. Fill up some water (say 4-5 cm height from bottom) in the vessel.
2. Switch "ON" the supply and slowly increase the motor speed. Do not start the pump.

3. Keep motor speed constant and wait till the vortex formed in the cylinder stabilizes. Once the vortex is stabilized note down the co-ordinates of the vortex and completes the observation table.
4. With the surface speed attachment of the tachometer, measure the outside rotational speed of vessel and note down in the observation table.

B. Free Vortex

1. Open the bypass valve and start the pump.
2. Slowly close the water bypass valve & drain valve of the cylinder. Water is now getting admitted through the tangential entry pipe to the cylinder.
3. Properly adjust the bottom drain valve so that a stable vortex is formed.
4. Note down the co-ordinates of the vortex. Also measure the time required for 10 lit. level rise in the measuring tank and complete the observation table.

OBSERVATIONS

A. Forced Vortex

Sl No.	Radius r (x co-ordinate) cm	Height (z) (y co-ordinate) cm	Rotational speed (rpm)

B. Free Vortex

Discharge (m^3/sec)	Radius (x co-ordinate) r cm	Height (y co-ordinate) z cm	C
Q_1	r_1	z_1	
	r_2	z_2	
	r_3	z_3	
	r_4	z_4	
	r_5	z_5	
	r_6	z_6	
Q_2	r_1	z_1	
	r_2	z_2	
	r_3	z_3	
	r_4	z_4	
	r_5	z_5	
	r_6	z_6	
Q_3	r_1	z_1	
	r_2	z_2	
	r_3	z_3	
	r_4	z_4	
	r_5	z_5	
	r_6	z_6	

Inner diameter of the cylinder= 300mm

Length of the cylinder= 145 mm

Calculations:

A) Forced Vortex

Rotational speed = rpm

Angular velocity, $\omega = \frac{2\pi N}{60}$ rad/ sec

For forced vortex,

$$Z = \frac{\omega^2 . r^2}{2g}$$

$$Z_1 = \frac{\omega^2 . r_1^{\ 2}}{2g}$$

$$Z_2 = \frac{\omega^2 . r_2^{\ 2}}{2g} \text{ etc.}$$

B) Free Vortex

Discharge $Q = \frac{0.01}{t}$ m^3/ sec

For free vortex

$vr = C$

And $z_2 - z_1 = C^2 / 2g\ (1/r_1^2 - 1/r_2^2)$

Similarly calculate values of z at different r.

PRECAUTIONS:

1. While making the experiment of forced vortex, see that water does not spill away from the vessel. Do not increase the speed of rotation excessively.
2. Do not start the pump for forced vortex equipment.

Experiment No. 08

FLOW ANALYSIS USING REYNOLD'S NUMBER

Aim

Study of different types of flow using Reynold's apparatus

Apparatus

TecQuipment H215 Reynolds number and Transitional Flow Demonstration Flow Apparatus

Theory

Consider the case of the fluid along a fixed surface such as the wall of a pipe. At some distance y from the surface the fluid has a velocity *(u)* relative to the surface. The relative movement causes a shear stress *(τ)* which tends to slow down the motion so that the velocity close to the wall reduced below u. It can be shown that the shear stress produces a velocity gradient *(∂u/∂y)* which is proportional to the applied stress. The constant of the proportionality is the coefficient of viscosity and the equation is given by,

$$\tau = \mu \frac{\partial u}{\partial y}$$

The inertia force *(F_i)* is directly proportional to density *(p)*, square of the diameter of the pipe *(d^2)* and the velocity.

$$F_i \infty \rho d^2 u^2$$

Viscous forces (F_v) are given by shear stress multiplied by area,

$$F_v \infty \mu \frac{d^2 u}{dy^2}$$

Reynolds number is given by the ratio of inertia forces to the viscous forces

$R_e = \dfrac{\rho u d}{\mu} = \dfrac{ud}{\nu}$, in which ν is the kinematic viscosity.

Procedure

1) Set the apparatus, turn on the water supply and partially open the discharge valve at the base of the apparatus.
2) Adjust the water supply until the level in the constant head is just above the overflow pipe and is maintained at this level by a small flow down the overflow pipe.

3) Open and adjust the dye injector valve to obtain a fine filament of dye in the flow down the glass tube. A laminar condition should be achieved in which the filament of dye passes down the complete length of the tube without disturbance.
4) Slowly increase the flow rate by opening the discharge valve until disturbances of the dye filament are noted. This is regarded as the starting point of the transition to turbulent flow. Increase the water supply as required maintaining the constant head conditions.
5) Record the temperature of the water using the thermometer then measure the flow rate by timing the collection of the known quantity of water from the discharge pipe.
6) Further increase the flow rate as described above until the disturbances increase such that the dye filament becomes rapidly diffused. Small eddies will be noted just above the point where dye filament completely breaks down. This is regarded as the onset of fully turbulent flow. Record the temperature and flow rate.
7) Now decreases the flow slowly until the dye returns to a steady filament laminar flow and again record the temperature and flow rate.

Observation Table

Room temperature =

Diameter of the pipe, d= 12 mm

Sl. No.	Time (s)	u (m/s)	$\boldsymbol{v}$ $* 10^{-6}$ m^2/s	R_e	Condition
1.					
2.					
3.					
4.					
5.					

Sample Calculation

Velocity =

Reynolds number =

RESULTS

Experiment No. 09

VENTURIMETER

Aim: To determine the coefficient of discharge of liquid flowing through venturimeter

Apparatus: Venturimeter, Stop watch, Collecting tank, Differential U-tube manometer, scale etc.

Description:

Venturimeter is a device consisting of a short length of gradual convergence and a long length of gradual divergence. Pressure tapping is provided at the location before the convergence commences and another pressure tapping is provided at the throat section of a Venturimeter. The difference in pressure head between the two tapping is measured by means of a U-tube manometer. On applying the Continuity equation & Bernoulli's equation between the two sections, the following relationship is obtained in terms of governing variables.

Theoretical Discharge $Q_{theo.} = a_1 a_2 \sqrt{\dfrac{2gH}{a_1^2 - a_2^2}}$ (m^3/sec)

Where, $H = (H_1 - H_2)(S_m/S_1 - 1)$

S_m and S_1 are Specific gravity of manometric fluid (mercury) and water flowing through pipeline system.

a_1= Area of inlet pipe in m^2 & a_2= Area of throat in m^2

Procedure:

The pipe is selected for conducting experiment.

The motor is switched on; as a result water flows through pipes.

The readings of H_1 and H_2 are noted.

The time taken for 10cm rise of water in collecting tank is noted.

The experiment is repeated for different discharges in the same pipe.

Coefficient of Discharge is calculated

Observations:

Volume of Collecting tank (Ah) =30 cm (L) * 30cm (W) * 10cm (h) =

a_1= Area of inlet pipe in m^2 = a_2= Area of throat in m^2 =

Actual Discharge: Q_{actual} = Ah/t (m^3/sec)

Theoretical Discharge Q $_{theo.}$ = $a_1 a_2 \sqrt{\frac{2gH}{a_1^2 - a_2^2}}$ (m^3/sec)

Where A= Area of collecting tank in m^2

h= Height of water collected in tank= 10cm

a_1= Area of inlet pipe in m^2, a_2= Area of throat in m^2

t=time taken for h cm rise of water

$H= (H_1-H_2)(S_m/S_1-1)$

Where H_1 and H_2 are Manomertic heads in first and second limbs

S_m and S_1 are Specific gravity of manometric fluid (mercury) and water flowing through pipeline system.

Coefficient of Discharge $C_d = Q_{actual} / Q_{theo}$

OBSERVATION TABLE

Diameter of the inlet pipe = 25 mm

Diameter of the throat = 12.5 mm

Sl. No.	**H_1 (m)**	**H_2 (m)**	**$H=(H_1- H_2)*12.6$ (m)**	**Time taken for 10cm rise of water (sec)**	**Q_{actual} (1) (m^3/sec)**	**$Q_{theo.}$ (2) (m^3/sec)**	**C_d=(1) /(2)**
1							
2							
3							
4							
5							

Mean Coefficient of Discharge =

Sample Calculation

Result and Discussion

Experiment No. 10

LOSSES IN PIPE FITTINGS

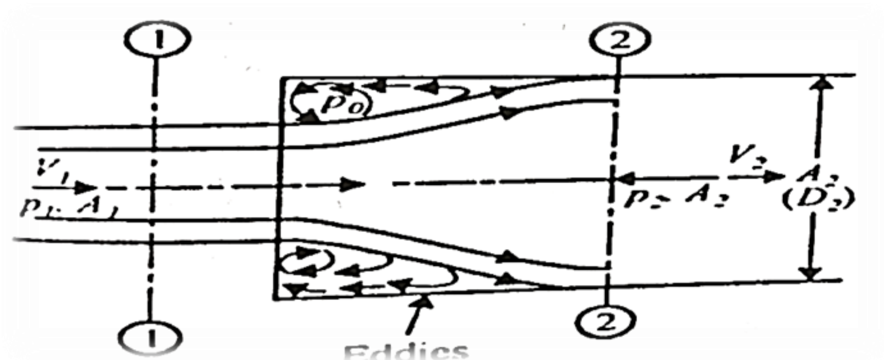
AIM: To determine different losses in pipe fittings.

OBJECTIVE: It comprises of the following items.

1. Test set up of the following
2. Stop watch
3. Accessories

INTRODUCTION AND THEORY:

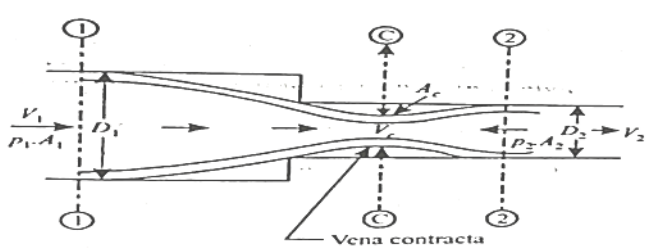
a. **Loss of head due to sudden enlargement:-**



Consider a liquid flowing through a pipe. Due to sudden enlargement in diameter from d_1 to d_2, the liquid flowing from smaller pipe is not able to follow the sudden change of boundary and turbulent eddies are generated as shown in the figure resulting in loss of head.

This head loss due to sudden enlargement is given by $h_e = (V_1 - V_2)^2/2g$

b. **Loss of head due to sudden contraction:-**



Water is flowing from large diameter pipe to smaller diameter pipe as shown in figure. The loss of head due to sudden contraction is actually due to sudden enlargement from vena-contracta to sec.2.

The head loss is given by $h_c = \frac{v^2}{2g}\left(\frac{1}{C_c} - 1\right)^2$

If $C_c = 0.62$ then $h_c = 0.375\, V_2^2/2g$

If C_c is not given then use $h_c = 0.5\, V_2^2/2g$

c. Loss of head in bend:-

When there is any bend in a pipe, the velocity of flow changes, due to which separation of the flow from the boundary and also formation of eddies takes place. Thus the energy is lost. Loss of head in pipe due to bend is expressed as

$h_b = k\, V^2/2g$

k is the coefficient of bend and its value depends upon

1. Angle of bend
2. Radius of curvature
3. Diameter of the pipe

d. Loss of head in elbow:-

$h_{el} = k\, V^2/2g$

EXPERIMENTAL SET UP:

1. Sump Tank: 1210 x 410 x 410 mm^3
2. Measuring Tank: 410 x 330 x 410mm^3
3. Basic Piping
4. Pipe Fittings
    a. Sudden Enlargement
    b. Sudden Contraction
    c. Pipe Bend
    d. Pipe Elbow
    e. Flow Control Valve
    f. Differential Manometer

PROCEDURE:

1. Start the water.
2. Then fluid is allowed to flow through the pipe fittings like sudden enlargement, contraction, bend and elbow.
3. Take manometer difference of each of the pipe fittings.
4. Take the time required for 100 mm rise of water level in measuring tank
5. Above procedure is repeated for different reading.

OBSERVATIONS

1. Sump tank = ____________ mm^3
2. Measuring tank = (250 x600 x h)mm^3
3. Diameter of enlargement = 25 mm
4. Diameter of contraction = 12.5 mm
5. Diameter of bend = 25 mm
6. Diameter of elbow = 25 mm
7. Area of measuring tank = mm^2

OBSERVATION TABLE

Types of loss	S. No.	Manometer Reading		Difference X cm	Time required for 100 mm rise
		H_1 (cm)	H_2 (cm)		
Sudden Expansion	1				
	2				
Sudden Contraction	1				
	2				
Bend	1				

	2				
Elbow	1				
	2				

CALCULATIONS

1. **For Sudden Enlargement**

   d = mm = m

   i. Head Lost = x (S_h - 1) = mm of water
   ii. Discharge (Q) = Area of measuring Tank/time Required
   iii. Velocity (V) = $\frac{Q}{A}$
   iv. Head lost $h_e = (V_1 - V_2)^2/2g$

2. **For Sudden Contraction**

   i. Head Lost = x(S_h - 1) = mm of water
   ii. Discharge (Q) = Area of measuring Tank * 0.1/time Required
   iii. Velocity (v) = $\frac{Q}{A}$
   iv. Head loss $h_c = 0.375\ V_2^2/2g$

3. **For Bend**

   i. Head Lost = x(S_h - 1) = mm of water
   ii. Discharge (Q)= Area of measuring Tank * 0.1/time Required
   iii. Velocity (V) = $\frac{Q}{A}$
   iv. Head lost $h_b = kV^2/2g$ (assume k=1)

4. For Elbow

i. Head Lost = $x(S_h - 1)$ = mm of water

ii. Discharge (Q)= Area of measuring Tank * 0.1/time Required

iii. Velocity (V) = $\frac{Q}{A}$

iv. Head lost h_{el} = $kV^2/2g$ (assume k=1)

RESULT TABLE

Sl. No.	Type of loss	Head loss m of water
1	Sudden Expansion	
2	Sudden Contraction	
3	Bend	
4	Elbow	

Discussion

Experiment No. 11

FRICTION (MAJOR) LOSSES IN PIPES

OBJECTIVE:

To measure the friction factor for flow through different diameter of pipes over a wide range of Reynolds number and compare with corresponding theoretical value.

APPARATUS REQUIRED:

Flow losses in pipe apparatus with flow control device and manometer

Collecting tank = 30 cm (L)*30 cm (W)* h cm

Stop watch

THEORY:

Various fluids are transported through pipes. When the fluid flows through pipes, energy losses occur due to various reasons, among which friction loss is the predominant one. Darcy-Weisbach equation relates the head loss due to frictional or turbulent through a pipe to the velocity of the fluid and diameter of the pipe as

$$h_f = \frac{4flv^2}{2gD}$$

Where h_f = Loss of head due to friction

L=length of pipe between the sections used for measuring loss of head

D= Diameter of the pipe, 1”,3/4”,1/2”

f= Darcy coefficient of friction

DESCRIPTION:

The experiment is performed by using a number of long horizontal pipes of different diameters connected to water supply using a regulator valve for achieving different constant flow rates. Pressure tapings are provided on each pipe at suitable distances apart and connected to U-tube differential manometer. Manometer is filled with enough mercury to read the differential head ‘h_m’. Water is collected in the collecting tank for arriving actual discharge using stopwatch and the piezometric level attached to the collecting tank.

FORMULAE USED:

1). Darcy coefficient of friction (Friction factor)

$$f = \frac{2gDh_f}{4Lv^2}$$

Where $h_f = h_m * \left(\frac{\rho_m}{\rho} - 1 \right)$ h_m is differential level of manometer fluid measured in meters)

Q_{act} =Actual discharge measured from volumetric technique.

2).Reynolds number $Re_{D1} = \frac{\rho v D}{\mu}$ where μ is the coefficient of dynamic viscosity of flowing fluid. The viscosity of water is $8.90*10^{-4}$ Pa-s at 25^0 C. Viscosity of water at different temp is listed below:

Temperature(^{0}C)	10	20	30	40	50	60	70	80	90	100
Viscosity μ () Pa-s $*10^{-4}$	13.08	10.03	7.978	6.531	5.471	4.668	4.044	3.550	3.150	2.822

PROCEDURE:

1. Note the pipe diameter 'D', the density of the manometer fluid(mercury) 'ρ_m' =13600 kg/m^3 and the flowing fluid(water) 'ρ'=1000 kg/m^3.
2. Make sure only required water regulator valve and required valves at tapings connected to manometer are opened.
3. Start the pump and adjust the control valve to make pipe full laminar flow. Wait for some time so that flow is stabilized.
4. Measure the pressure difference 'h_m' across the orifice meter.
5. Note the piezometric reading 'Z_0' in the collecting tank while switch on the stopwatch.
6. Record the time taken 'T' and the piezometric reading 'Z_1' in the collecting tank after allowing sufficient quantity of water in the collecting tank.
7. Increase the flow rate by regulating the control valve and wait till flow is steady.
8. Repeat the steps 4 to 6 for different flows.

RESULTS AND DSICUSSION

OBSERVATION AND COMPUTATION-II DATE: ____________________

A) FOR PIPE NO. 1:

Diameter of pipe ‘D’= 0.0254 m Area of pipe ‘A’= m^2 Length of Pipe ‘L’= 1 m

Area of collecting tank A_{ct}= 0.09 m^2 Coefficient of dynamic viscosity at ^0C= Pa.s.

Density of the manometer liquid ρ_m= 13.6 x 1000 kg/m^3 Density of the flowing liquid ρ= 1000 kg/m^3

Tabulation 5.1- For pipe No. 1.

No.	Actual Measurement				Calculated values					f	Re No.	Log (Re)
	Time T (sec)	Z_1(m)	Z_0(m)	h_m(m)	Collecting tank h_{ct}(m) (3)-(4)	Volume(m^3) A_{ct}*h_{ct}	Discharge Q_{act} (7)/(2)	Velocity (8)/A	h_f(m) (5)*$\left(\frac{\rho_m}{\rho}-1\right)$	$f=\frac{2gDh_f}{4Lv^2}$	$\frac{\rho v D}{\mu}$	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

B)FOR PIPE NO. 2:

Diameter of pipe 'D'= 0.019 m Area of pipe 'A'= m^2 Length of Pipe 'L'= 1 m

Area of collecting tank A_{ct}=0.09 m^2 Coefficient of dynamic viscosity at ^0C= Pa.s.

Density of the manometer liquid ρ_m= 13.6 x 1000 kg/m^3 Density of the flowing liquid ρ=1000 kg/m^3

Tabulation 5.2- For pipe No. 2 .

No.	Actual Measurement				Calculated values					f	Re No.	Log(Re)
	Time T(sec)	Z_1(m)	Z_0(m)	h_m(m)	Collecting tank h_{ct}(m)	Volume(m^3) A_{ct}*h_{ct}	Discharge Q_{act}	Velocity (8)/A	h_f(m) (5)* $\left(\frac{\rho_m}{\rho}-1\right)$	$f=\frac{2gDh_f}{4Lv^2}$	$\frac{\rho vD}{\mu}$	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

C)FOR PIPE NO. 3:

Diameter of pipe 'D'= 0.0127 m Area of pipe 'A'= m^2 Length of Pipe 'L'= 1 m

Area of collecting tank A_{ct}= 0.09 m^2 Coefficient of dynamic viscosity at ^0C= Pa.s.

Density of the manometer liquid ρ_m = 13.6 x 1000 kg/m^3 Density of the flowing liquid ρ =1000 kg/m^3

Tabulation 5.3- For pipe No. 3 .

Sl. No	Actual Measurement				Calculated values					f	Re No.	Log (Re)
	Time T(sec)	Z_1(m)	Z_0(m)	h_m(m)	Collecting tank h_{ct}(m) (3)-(4)	Volume(m^3) $A_{ct}*h_{ct}$	Discharge Q_{act}	Velocity	h_f(m) $(5)*\left(\frac{\rho_m}{\rho}-1\right)$	$f=\frac{2gDh_f}{4Lv^2}$	$\frac{\rho vD}{\mu}$	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Experiment No. 12

ORIFICE METER

Aim: To determine the coefficient of discharge of orifice meter.

Apparatus: Orifice meter, Stop watch, Collecting tank, Differential U-tube manometer.

Description:

Orifice meter is a device used for measuring the rate of flow of a fluid through a pipe. Orificemeter works on the same principle as that of Venturimeter i.e. by reducing the area of flow passage a pressure difference is developed between the two sections and the measurement of pressure difference is used to find the discharge.

It consists of a flat circular plate which has a circular sharp edge hole called orifice, which is concentric with the pipe. The orifice diameter is kept generally 0.5 times the diameter of the pipe, though it may vary from 0.4 to 0.8 times the pipe diameter.

A mercury U-tube manometer is connected at section (1), which is at a distance of about 1.5 to 2.0 times the pipe diameter upstream from the orifice plate, and at section (2) which is at a distance of about half the diameter of the orifice on the downstream side from the orifice plate to know the pressure head between the two tappings.

Procedure:

The pipe is selected for conducting experiment.

The motor is switched on; as a result water flows through pipes.

The readings of $H_1$and H_2 are noted.

The time taken for 10cm rise of water in collecting tank is noted.

The experiment is repeated for different discharges in the same pipe.

Coefficient of Discharge is calculated

Formulae

Actual Discharge: $Q_{actual} = Ah/t$ (m^3/sec)

Theoretical Discharge $Q_{theo.} = a_1 a_2 \sqrt{\dfrac{2gH}{a_1^2 - a_2^2}}$ (m^3/sec)

Where A= Area of collecting tank in m^2

h= Height of water collected in tank = 10cm

a_1= Area of inlet pipe in m^2

a_2= Area of throat in m^2

t=time taken for h cm rise of water

$H= (H_1-H_2)(S_m/S_1-1)$

Where H_1 and H_2 are Manomertic heads in first and second limbs

S_m and S_1 are Specific gravity of manometric fluid (mercury) and water flowing through the pipeline system.

Density of the manometer liquid ρ_m= 13.6 x 1000 kg/m^3

Density of the flowing liquid ρ= 1000 kg/m^3

Coefficient of Discharge $C_d = Q_{actual} / Q_{theo}$

Volume of Collecting tank (Ah) =30cm (L) * 30cm (W) * 10cm (h) =

Diameter of the inlet pipe = 25 mm

Diameter of the throat = 12.5 mm

a_1= Area of inlet pipe in m^2 =

a_2= Area of throat in m^2 =

OBSERVATION TABLE

Sl. No.	**H_1 (m)**	**H_2 (m)**	**$H=(H_1H_2)$*12.6 (m)**	**Time taken for 10cm rise of water (sec)**	**Q_{actual} (1)**	**$Q_{theo.}$ (2)**	**C_d= (1)/(2)**
1							
2							
3							
4							
5							
6							

Mean Coefficient of Discharge =

Sample Calculation

Result and Discussion