LABORATORY MANUAL

FLUID MACHINERY LAB

SUBJECT CODE: BME 351

B.TECH. (ME) SEMESTER -III

Academic Session: 2023-24, ODD Semester

Dronacharya Group of Institutions
Plot No. 27, Knowledge Park-3, Greater Noida, Uttar Pradesh 201308
Affiliated to

Dr. A P J Abdul Kalam Technical University
Lucknow, Uttar Pradesh 226031

List of Experiments mapped with COs

S. No	Aim of the Experiment	COs
1.	To determine the coefficient of impact for vanes	CO4
2.	To determine coefficient of discharge of an orifice meter.	CO2
3.	To determine the coefficient of discharge of Notch (V, Rectangular and Trapezoidal types).	CO3
4.	To determine the friction factor for the pipes. (Major Losses).	CO3
5.	To determine the coefficient of discharge of Venturimeter.	CO1
6.	To determine the coefficient of discharge, contraction & velocity of an Orifice.	CO1
7.	To verify the Bernoulli's theorem.	CO5
8.	To find critical Reynolds number for a pipe flow	CO2
9.	To determine the Meta-centric height of a floating body.	CO3

EXPERIMENT NO. 1

Aim: To determine the co efficient of impact for vanes

Apparatus: Collecting tank, Nozzle of given diameter, Vanes of different shape (flat, inclined or curved).

Theory: Momentum equation is based on Newton's second law of motion which states that the algebraic sum of external forces applied to control volume of fluid in any direction is equal to the rate of change of momentum in that direction. The external forces include the component of the weight of the fluid & of the forces exerted externally upon the boundary surface of the control volume. If a vertical water jet moving with velocity is made to strike a target, which is free to move in the vertical direction then a force will be exerted on the target by the impact of jet, according to momentum equation this force (which is also equal to the force required to bring back the target in its original position) must be equal to the rate of change of momentum of the jet flow in that direction.

Formula Used:

$F=\rho\ Q\ v(1-\cos\beta)$

$F=\rho\ Q2\ (1-\cos\beta)/A$ as $v=Q/A$

Where,

F =force (calculated)

ρ = density of water

β=angle of vane
V =velocity of jet
Q =discharge
A =area of nozzle (π /4d2)

(i) for flat vane β=90o

$$F' = \rho Q2/A$$

(ii) for hemispherical vane β=180o

for % error =F- F'/ F'x100

$$F' = 2\ \rho Q2/A$$

F = Force (due to putting of weight)

(iii) for inclined vane

$$F'=\rho\ Q\ v(1-\cos\beta)$$

$$F'=\rho\ Q2\ (1-\cos\beta)/A$$

Procedure:

1. Note down the relevant dimension or area of collecting tank, diameter of nozzle, and density of water.

2. Install any type of vane i.e., flat, inclined or curved.

3. Note down the position of upper disk, when jet is not running.

4. Note down the reading of height of water in the collecting tank.

5. As the jet strike the vane, position of upper disk is changed, note the reading in the scale to which vane is raised.

6. Put the weight of various values one by one to bring the vane to its initial position.

7. At this position finds out the discharge also.

8. The procedure is repeated for each value of flow rate by reducing the water supply.

9. This procedure can be repeated for different type of vanes and nozzle.

Observations & Calculations:

Dia of nozzle =

Mass density of water ρ =

Area of collecting tank =

Area of nozzle =

Horizontal flat vane

When jet is not running, position of upper disk is at =

S.No.	Discharge measurement				Balancing		Theoretical Force F'= ρQ2/A	Error in % = F-F'/F'
	Initial (cm)	Final (cm)	Time (sec)	Discharge (cm3/sec) Q	Mass W (gm)	Force F		

Inclined vane

When jet is not running, position of upper disk is at =

Angle of inclination $\beta = 45^o$

S. No.	Discharge measurement				Balancing		Theoretical Force F'= ρQ2(1-cosβ)/A (dyne)	Error in % = F-F'/F'
	Initial (cm)	Final (cm)	Time (sec)	Discharge (cm3/sec) Q	Mass W (gm)	Force F		

Curved hemispherical vane

When jet is not running, position of upper disk is at =

S.No.	Discharge measurement				Balancing		Theoretical Force F'= 2ρQ2/A	Error in % = F-F'/F'
	Initial (cm)	Final (cm)	Time (sec)	Discharge (cm3/sec) Q	Mass W (gm)	Force F		

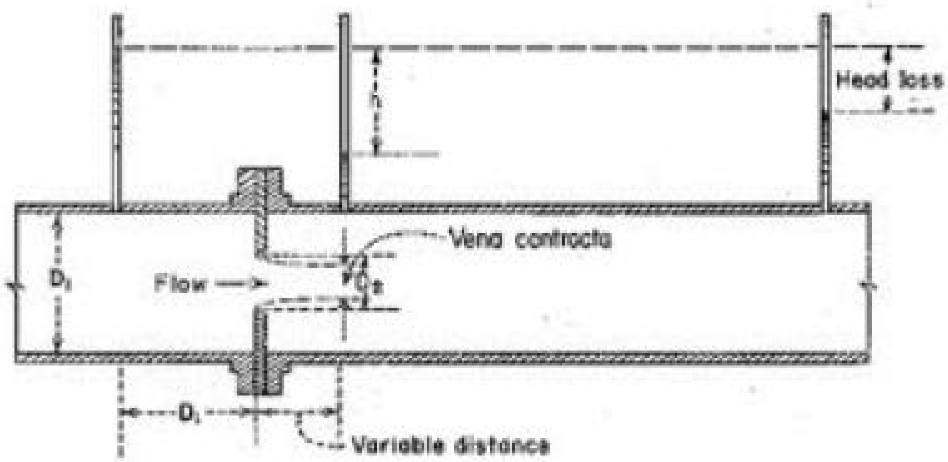
Conclusion: Hence the co efficient of impact for vanes is determined.

EXPERIMENT NO. 2

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

Apparatus: Orifice meter, installed on different pipes, arrangement of varying flow rate, U-tube manometer, collecting tank.

Theory: Orifice meter are depending on Bernoulli's equation. Orifice meter is a device used for measuring the rate of fluid flowing through a pipe



Formula Used:

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

Where

A = Cross section area of inlet
a = Cross section area of outlet
Δh = Head difference in manometer
Q = Discharge
Cd = Coefficient of discharge
g = Acceleration due to gravity

Coefficient of discharge of orifice meter will be less than 1, but smaller than Cd value of venturimeter.

Where

A = Cross section area of inlet
a = Cross section area of outlet
Δh = Head difference in manometer
Q = Discharge
Cd = Coefficient of discharge
g = Acceleration due to gravity

Coefficient of discharge of orifice meter will be less than 1, but smaller than Cd value of venturimeter.

Procedure:

1. Set the manometer pressure to the atmospheric pressure by opening the upper valve.
2. Now start the supply at water controlled by the stop valve.
3. One of the valves of any one of the pipe open and close all other of three.
4. Take the discharge reading for the particular flow.
5. Take the reading for the pressure head on from the u-tube manometer for corresponding reading of discharge.
6. Now take three readings for this pipe and calculate the Cd for that instrument using formula.
7. Now close the valve and open valve of other diameter pipe and take the three reading for this.
8. Similarly take the reading for all other diameter pipe and calculate Cd for each.

Observations & Calculations:

Diameter of Orifice meter =
Area of cross section =
Area of collecting tank =

Discharge					Manometer Reading				Cd= $\frac{Q\sqrt{A^2 - a^2}}{Aa\sqrt{2g\Delta h}}$
Initial reading	Final reading	Difference	Time (sec)	Q	h1	h2	h2-h1	Δh= 13.6(h2-h1)	

Conclusion: Hence the coefficient of discharge of Orifice meter is __________.

EXPERIMENT NO:3

Aim: To determine the coefficient of discharge of Notch (V, Rectangular and Trapezoidal types).

Apparatus: Arrangement for finding the coefficient of discharge inclusive of supply tank, collecting tank, pointer, scale & different type of notches

Theory: Notches are overflow structure where length of crest along the flow of water is accurately shaped to calculate discharge.

Formula Used:-

For V notch the discharge coefficient

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

For Rectangular notch

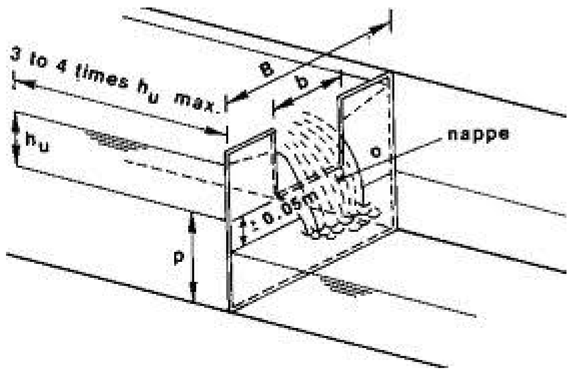
$$C_d = \frac{Q}{\frac{2}{3}\sqrt{2g}\;B\,H^{\frac{3}{2}}}$$

For Trapezoidal notch

$$C_d = \frac{Q}{\frac{2}{3}\sqrt{2g}\,H^{\frac{3}{2}}\,(\mathrm{B} + \tan\frac{\theta}{2})}$$

Where

Q = Discharge
H = Height above crest level
θ = Angle of notch
B = Width of notch



Procedure:

1. The notch under test is positioned at the end of tank with vertical sharp edge on the upstream side.
2. Open the inlet valve and fill water until the crest of notch.
3. Note down the height of crest level by pointer gauge.
4. Change the inlet supply and note the height of this level in the tank.
5. Note the volume of water collected in collecting tank for a particular time and find out the discharge.
6. Height and discharge readings for different flow rate are noted.

Observations & Calculations:

Breath of tank =
Length of tank =
Height of water to crest level for rectangular notch is =
Height of water to crest level for V notch =
Height of water to crest level for Trapezoidal notch =
Angle of V notch =
Width of Rectangular notch =

Type Of notch	Discharge					Final height reading above width	Head above crest level	Cd
	Initial height Of tank	Final height Of tank	Difference In height	Volume	Q			

Conclusion:

Hence

The coefficient of discharge of V Notch is ______________.

The coefficient of discharge of Rectangular Notch is ______________.

The coefficient of discharge of Trapezoidal Notch is ______________.

EXPERIMENT NO:4

Aim: To determine the friction factor for the pipes.(Major Losses).

Apparatus: A flow circuit of G. I. pipes of different diameters, U-tube differential manometer, collecting tank.

Theory:

Friction factor in pipes or Major losses:-

A pipe is a closed conduit through which fluid flows under the pressure. When in the pipe, fluid flows, some of potential energy is lost to overcome hydraulic resistance which is classified as follows:

1. The viscous friction effect associated with fluid flow.
2. The local resistance which result from flow disturbances caused by
   a. Sudden expansion and contraction in pipe
   b. Obstruction in the form of valves, elbows and other pipe fittings.
   c. Curves and bend in the pipe.
   d. Entrance and exit losses

The viscous friction loss or major loss in head potential energy due to friction is given by

$$h_f = \frac{4flV^2}{2gd}$$

Where

hf = Major head loss
l = Length of pipe
4f = Friction factor
V = Inlet velocity
g = Acceleration due to gravity
d = Diameter of pipe

Procedure:

1. Note down the relevant dimensions as diameter and length of pipe between the pressure tapping, area of collecting tank etc.
2. Pressure tapping of a pipe is kept open while for other pipe is closed.
3. The flow rate was adjusted to its maximum value. By maintaining suitable amount of steady flow in the pipe.
4. The discharge flowing in the circuit is recorded together with the water level in the left and right limbs of manometer tube.
5. The flow rate is reduced in stages by means of flow control valve and the discharge & reading of manometer are recorded.
6. This procedure is repeated by closing the pressure tapping of this pipe, together with other pipes and for opening of another pipe.

Observations & Calculations:

Diameter of pipe d =

Length of pipe between pressure tapping l =

Area of collecting tank =

SNo	Manometer Reading			Discharge Measurement				F = $\pi^2 g d^5 / 8 l Q^2$ hf
	Left limb h1 (cm)	Right limb H2 (cm)	Difference of head in terms of water hf =13.6(h1-h2)	Initial (cm)	Final (cm)	Time (sec)	Discharge Q (cm^3/sec)	
1.								
2.								
3.								

$$F = 4f = \frac{\pi^2 g d^5}{8lQ^2\, h_f}$$

Conclusion: Hence the friction factor for the pipes is F =_________.

EXPERIMENT NO:5

Aim: To determine the coefficient of discharge of Venturimeter.

Apparatus: Venturimeter, installed on different diameter pipes, arrangement of varying flow rate, U- tube manometer, collecting tube tank.

Theory: Venturimeters are depending on Bernoulli's equation. Venturimeter is a device used for measuring the rate of fluid flowing through a pipe. The consist of three parts in short

1. Converging area part
2. Throat
3. Diverging part

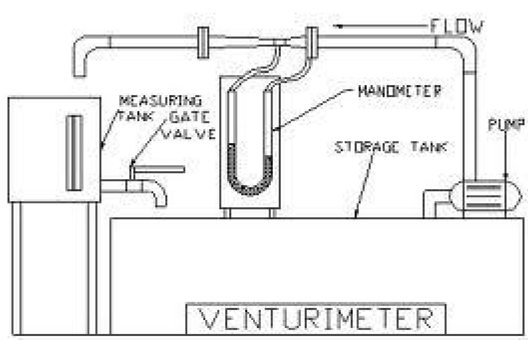
Formula Used:

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

Where

A = Cross section area of inlet
a = Cross section area of outlet
Δh = Head difference in manometer
Q = Discharge
Cd = Coefficient of discharge
g = Acceleration due to gravity

Coefficient of discharge value of Venturimeter is closer to 1.



Procedure:

1. Set the manometer pressure to the atmospheric pressure by opening the upper valve.
2. Now start the supply at water controlled by the stop valve.
3. One of the valves of any one of the pipe open and close all other of three.
4. Take the discharge reading for the particular flow.
5. Take the reading for the pressure head on from the u-tube manometer for corresponding reading of discharge.
6. Now take three readings for this pipe and calculate the Cd for that instrument using formula.
7. Now close the valve and open valve of other diameter pipe and take the three reading for this.
8. Similarly take the reading for all other diameter pipe and calculate Cd for each.

Observations & Calculations:

Diameter of Venturimeter =

Area of cross section =

Area of collecting tank =

Discharge					Manometer Reading				$Cd = \frac{Q\sqrt{(A^2 - a^2)}}{Aa\sqrt{(2g\Delta h)}}$
Initial reading	Final reading	Difference	Time (sec)	Q	h_1	h_2	h_2-h_1	$\Delta h = 13.6(h2-h1)$	

Conclusion: Hence the coefficient of discharge of Venturimeter is __________.

EXPERIMENT NO:6

Aim: To determine the coefficient of discharge, contraction & velocity of an Orifice.

Apparatus:

Supply tank with overflow arrangement, Orifice plate of different diameter, hook gauge, collecting tank, piezometric tube.

Theory:

A mouthpiece is a short length of pipe which is two or three times its diameter in length. If there pipe is filled externally to the orifices, the mouthpiece is called external cylindrical mouthpiece and discharge through orifice increase is a small opening of any cross-section on the side of bottom of the tank, through which the fluid is flowing orifice coefficient of velocity is defined as the ratio of two actual discharge to orifice ratio of the actual velocity of the jet at vena- contracta to the coefficient of theoretical velocity of the jet coefficient of contraction of defined as ratio of the actual velocity of jet at vena- contracta.

Vena- Contracta:

The fluid out is in form of jet goes on contracting form orifice up to dispute of about ½ the orifice dia. after the expend this least relation.

Coefficient of velocity:

It is a ratio of actual velocity jet at vena-contracta to theoretical velocity.

Formula Used:-

$$C_d = \frac{Q_{actual}}{Q_{theoretical}}$$

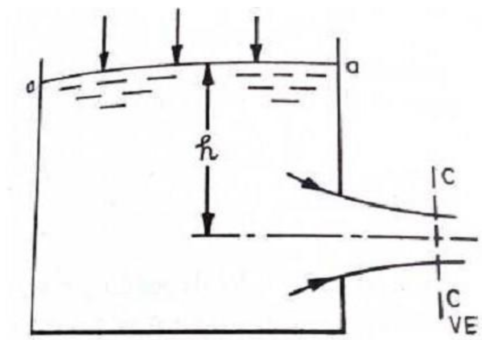
$Q_{theoretical}$ = Theoretical velocity x Theoretical area = $\sqrt{2gh}\,.\,a$

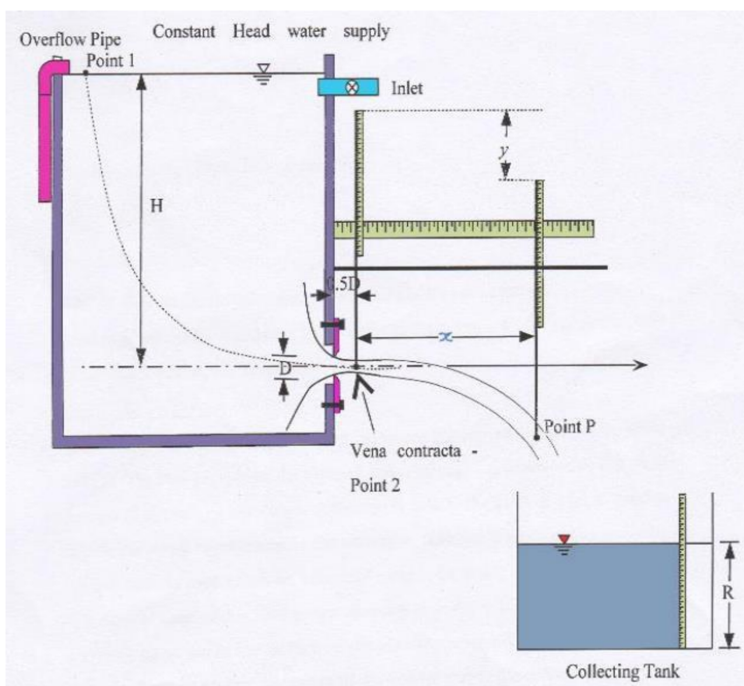
$$C_d = \frac{Q}{a.\sqrt{2gh}}$$

$$C_v = \frac{Actual\ velocity\ of\ jet\ at\ Vena\ contracta}{Theoretical\ Velocity}$$

$$Coefficient\ of\ Contraction = \frac{Area\ of\ jet\ at\ Vena\ contracta}{Area\ of\ Orifice}$$

$$C_c = \frac{a_c}{a}$$





Procedure:-

1. Set the mouthpiece of orifice of which the Cc, Cu, Cd are to be determined.
2. Note the initial height of water in the steady flow tank and the height of datum from the bottom of orifice and mouthpiece. These remains constant for a particular mouthpiece or orifice.
3. By using the stop valve, set a particular flow in tank and tank height of water in tank.
4. Take the reading of discharge on this particular flow.
5. Using hook gauge, find the volume of Xo Y for mouthpiece.
6. Take three readings using hook gauge for one particular orifice.
7. Using the formula get value of Cd, Cu, and Cc for a particular orifice and mouthpiece.

Observation:-

Area of measuring tank =
Dia. Of orifice d =
Area of Orifice =

Discharge Calculation:

Sl. No.	Tank Reading				Discharge(Q=Ah/t)
	Initial height h1	Final height h2	h=h2-h1	Time (t)	

Co-efficient Calculation:

Head (H)	X- axis			Y- axis			Qth = $\sqrt{\ }$	Cd= Qact/Qth	Cv= $\sqrt{\ }$	Cc= Cd/Cv
	X1	X2	X= X2-X1	Y1	Y2	Y=Y2-Y1				

Result:-

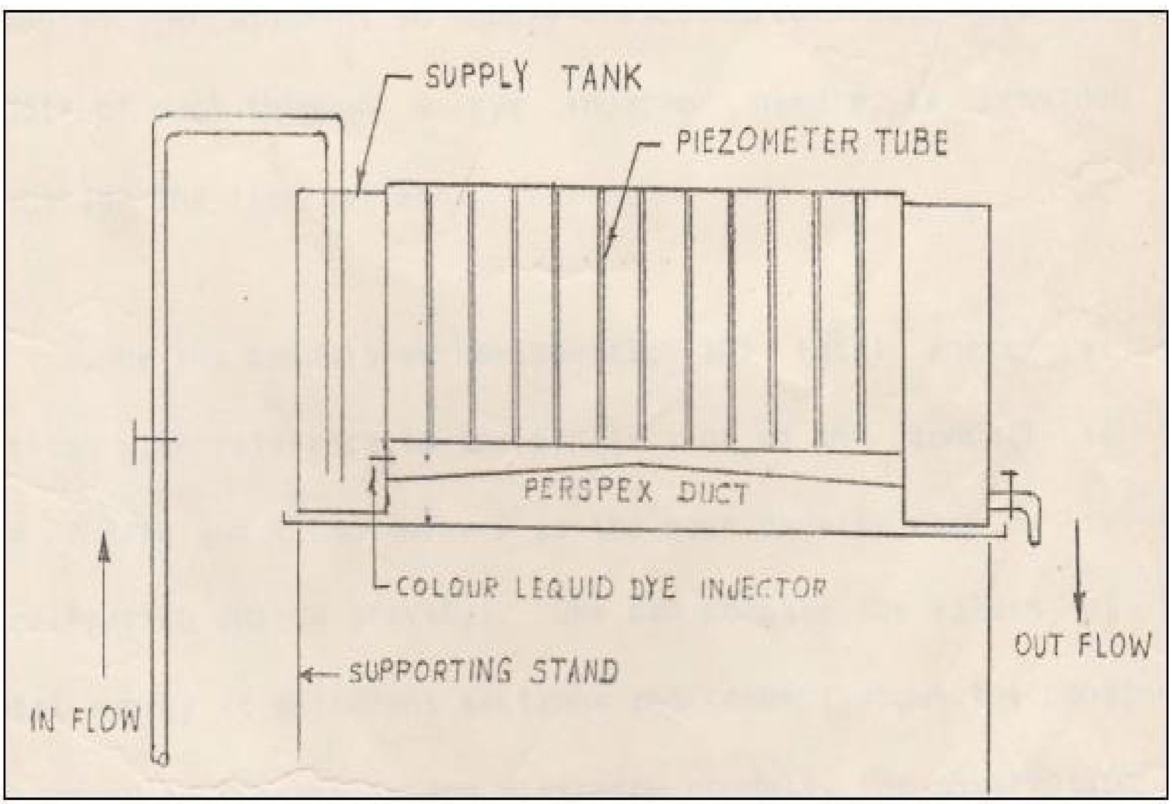
EXPERIMENT NO:7

Aim: To verify the Bernoulli's theorem.

Apparatus: A supply tank of water, a tapered inclined pipe fitted with no. of piezometer tubes point, measuri ng tank, scale, stop watch.

Theory:

Bernoulli's theorem states that when there is a continues connection between the particle of flowing mass liquid, the total energy of any sector of flow will remain same provided there is no reduction or addition at any point.



Formula Used:

H1 = Z1 + p1/w + V12/2g

H2 = Z2 + p2/w + V22/2g

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. Note down the quantity of water collected in the measuring tank for a given interval of time.
5. Compute the area of cross-section under the piezometer tube.
6. Compute the area of cross- section under the tube.
7. Change the inlet and outlet supply and note the reading.
8. Take at least three readings as described in the above steps.

Observations & Calculations:

	1	2	3	4	5	6	7	8	9	10	11
Discharge Of piezometer Tube from inlet											
Area of Cross-section Under foot Of each point											
Velocity Of water Under foot Of each point											
V2/2g											
p/ρ											
p/ρ+ V2/2g											

Conclusion: Hence Bernoulli’s theorem is verified.

EXPERIMENT NO: 8

Aim: To find critical Reynolds number for a pipe flow.

Apparatus: Flow condition inlet supply, elliptical belt type arrangement for coloured fluid with regulating valve, collecting tank.

Theory: It is defined as the ratio of inertia force of a flowing fluid to the viscous force of the fluid.

Inertia force, F_i = Mass*Acceleration of the flowing fluid.

$$F_i = \rho A V^2$$

Since, Mass= density*volume; Acceleration=velocity/time; Discharge=Volume per unit time=A*V;

$$M = \rho * vol; acc = \frac{v}{t}; Q = \frac{vol}{sec} = AV$$

Viscous force F_v = Shear stress *Area

$$F_v = \tau * A$$

$$F_v = \left(\mu \frac{du}{dy}\right) * A$$

$$F_v = \mu * \frac{V}{L} * A$$

By definition Reynold's number, $R_e = \frac{F_i}{F_v}$

$$R_e = \frac{\rho A V^2}{\mu * \frac{V}{L} * A}$$

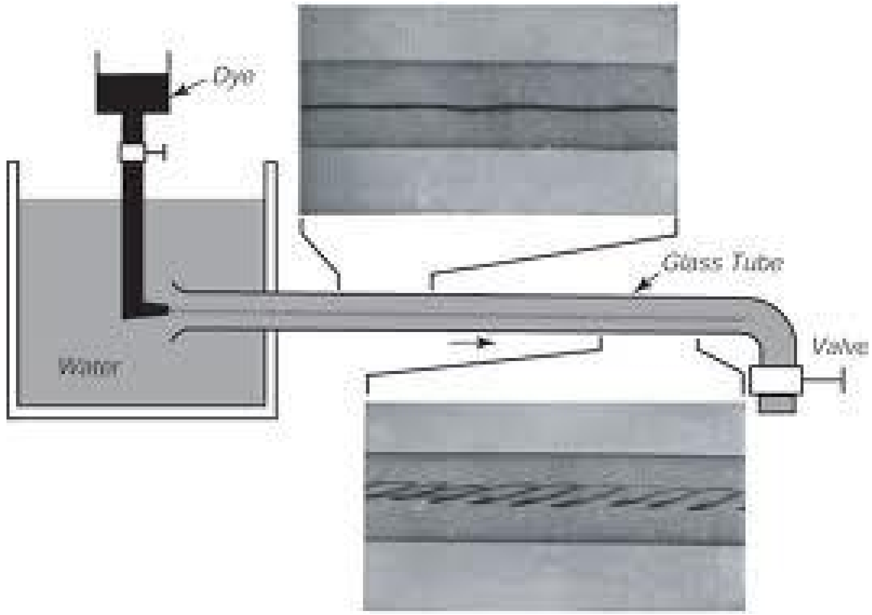
$$R_e = \frac{\rho V L}{\mu}$$

$$R_e = \frac{VL}{\left(\frac{\mu}{\rho}\right)}$$

$$R_e = \frac{VL}{\vartheta}; where\ \vartheta\ is\ kinematic\ viscocity$$

In case of the pipe flow, the linear dimension L is taken as diameter d,

$$R_e = \frac{Vd}{\vartheta}$$



Procedure:

1. Fill the supply tank some times before the experiment.
2. The calculated fluid is filled as container.
3. Now set the discharge by using the valve of that particular flow can be obtained.
4. The type of flow of rate is glass tube is made to be known by opening the valve of dye container.
5. Take the reading of discharge for particular flow.
6. Using the formula set the Reynolds no. for that particular flow, aspect the above procedure for all remaining flow.

Observations & Calculations:

Type	Time	Discharge				Q	Re
		Initial	Final	Difference	Volume		

$$R_e = \frac{\rho Q L}{\frac{V}{L} * A * \mu}$$

$$R_e = \frac{\rho Q d}{\frac{V}{d}(\frac{\pi * d^2}{4})\mu}$$

$$R_e = \frac{4Q}{\pi d \vartheta}$$

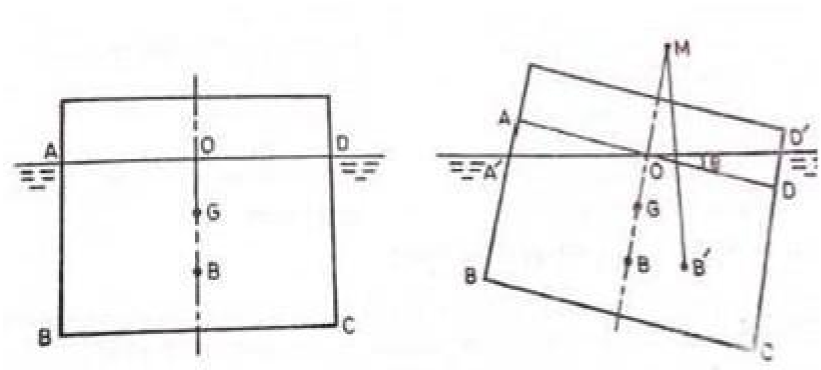
Conclusion: Reynolds number for a pipe flow=____________.

EXPERIMENT NO:9

Aim:- To determine the Meta-centric height of a floating body.

Apparatus Used:- Take tank 2/3 full of water, floating vessel or pontoon fitted with a pointed pointer moving on a graduated scale, with weights adjusted on a horizontal beam.

Theory: -



Consider a floating body which is partially immersed in the liquid, when such a body is tilted, the center of buoyancy shifts from its original position 'B' to 'B' (The point of application of buoyanant force or upward force is known as center of G which may be below or above the center of buoyancy remain same and couple acts on the body. Due to this couple the body remains stable. At rest both the points G and B also Fb x Wc act through the same vertical line but in opposite direction. For small change (θ) B shifted to B.

The point of intersection M of original vertical line through B and G with the new vertical, line passing through 'B' is known as metacentre. The dis tance between G and M is known as metacentre height which is measure of static stability.

Formula Used:

$$GM = \frac{W_m . X_d}{(W_c + W_m)\tan\theta}$$

Where: -

Wm is unbalanced mass or weight.

Wc is weight of pontoon or anybody.

Xd is the distance from the center of pointer to striper or unbalanced weight.

θ is angle of tilt or heel.

Procedure:

1. Note down the dimensions of the collecting tank, mass density of water.
2. Note down the water level when pontoon is outside the tank.
3. Note down the water level when pontoon is inside the tank and their difference.
4. Fix the strips at equal distance from the center.
5. Put the weight on one of the hanger which gives the unbalanced mass.
6. Take the reading of the distance from center and angle made by pointer on arc.
7. The procedure can be repeated for other positioned and values of unbalanced mass.

Observation Table:

Length of the tank =

Width of the tank =

Area of the tank =

Initial level of the water without pontoon X1 =

Final level of the water with pontoon (after adding unbalanced weight) X2 =

Difference in height of water (X) = X2–X1=

Height of water in tank with pontoon X2	Difference in height X=X2-X1	Weight of pontoon Wc=XAρ	Unbalanced mass (Wm) Kg	Xd (m)	Angle of turn(Θ)	GM=Metacentric Height (m)

Precautions: -

1. The reading taking carefully without parallax error.
2. Put the weight on the hanger one by one.
3. Wait for pontoon to be stable before taking readings.
4. Strips should be placed at equal distance from the centre.

Results: Meta centric height of the pontoon is measured with different positions and weights and value is…………

Mr. Deepak Kumar
Lab IN-charge

Dr. Shailesh Kumar Singh
Head of Department (ME)

Prof. (Dr.) Seema Shukla

Director