COLLEGE OF ENGINEERING & TECHNOLOGY

LABORATORY MANUAL

FLUID MECHANICS AND HYDRAULICS

SUBJECT CODE: 3140611

CIVIL ENGINEERING DEPARTMENT

B.E. 2ND YEAR

NAME:______________________________

ENROLLMENT NO: ______________________________

BATCH NO: ______________________________

YEAR: ______________________________

Amiraj College of Engineering and Technology,
Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

Amiraj College of Engineering and Technology,
Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

CERTIFICATE

This is to certify that Mr. / Ms. ____ Of class___________________ Enrolment No __________________________has Satisfactorily completed the course in __________________________________as by the Gujarat Technological University for ____ Year (B.E.) semester___ of Civil Engineering in the Academic year____________.

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List Of Experiments

Sr. No.	Title	Date of Performance	Date of submission	Sign	Remark
1.					
2					
3					
4					
5					

EXPERIMENT NO. 1

Measurement of Viscosity

Aim:- To measure of viscosity

Theory:-

Viscosity measuring device:-

1. Capillary tube

2. Viscometer.

Capillary tube:- Poiseiulle showed that the volume (v) of a liquid or gas flowing per second through a horizontal capillary tube of a given radius length (L) under a constant difference of pressure (ΔP) between two ends is inversely proportional to the viscosity of fluid. The volume of fluid through the f tube in t is given by

The lesser the volume of flowing fluid through the tube per unit time, the larger the viscosity.

Viscometer:- It is an instrument to measure the viscosity. It measures some quantity which is a function of viscosity. The quantity measured is usually time taken to pass certain volume of the liquid through an orifice fluid at the bottom of the viscometer. The temperature of liquid, while it is being passed through the orifice should be maintained constant. Some viscometer is used are say bolt universally, redwood, Engler viscometer which has a vertical tube. The times in second to pass 60cc of fluid liquid for the determination of viscosity is “say bolt second”.

The following empirical relations are used to determine kinematics viscosity in stokes:-

A) Say bolt universal viscometer

B) Red wood viscometer

C) Engler viscometer

Velocity measuring device:- Rota Meter.

Construction:- A Rota meter is a device to find the velocity of a flow in a pipe with the aid of rotating free float. It is essentially an orifice meter with fixed pressure drop and variable orifice area. Fluid is allowed to flow vertically upward through a tapered transparent tube placed vertically with a large end at the top. The float is freely suspended upside the tube. The maximum diameter of float is slightly less then the minimum bore. There are two L-bend lies on the inlet and outlet of the tube. Guide wire for float is calibrated at the centre of the tapered tube. The outlet portion for fluid generally less then the inlet portion. The tapered tube is generally having the glass covering on the part of taking the reading of the float

Working:- When there is no flow, float rests at bottom, but fluid when some velocity float has rises upward to make way for fluid motion. The float rises to such a position that the pressure loss across the amuler orifice just balances to the weight of the float mechanism which is attached to it. The float therefore attains a state of equilibrium and the distance from the stop to float is a measure of the discharge in liter/second. The float is provided with slantwise slots to enable it to occupy a stable position at the center of tube.

Pressure measuring device:-

A) Dead weight piston gauge

B) Mechanical gauge

A) Dead weight piston gauge:- This is the direct method for precise determination to of a piston steady pressure measurement. The instrument consists of a piston & a cylinder of known area connected to a fluid pressure on the piston equal to the pressure times the piston area. This force can be balanced by weight fitted on the top of the vertical piston. This is the most accurate device and used for precision and for calibrating other pressure gauge. The pressure of liquid is balanced by known weight. Pressure in Kgf/cm2 or KN/m2

B) Mechanical gauge:- By the help of spring or dead weight balanced the liquid column whose pressure is to be measured. In gauge are the liquid exert the force on a movable diaphragm or piston, which is the resisted by a spring of known valve. The intensity of pressure then would be equal to the force F divided by the area

a of the diaphragm or piston P =F/a

They are suited for the measurement of high pressure when it is more then to atmospheres. The most accurate and reliable region on the scale of mechanical gauge in between 40% & 70% of the maximum may give direct pressure reading, portability and wider operating gauge. They can fairly accurate reading if properly calibrated.

1 Bourdon tube pressure

gauge 2 Diaphragm pressure

gauge

3 Dead weight pressure gauge

Viva Questions:-

1 Define and explain the Newton‟s law of viscosity?

2 Define construction of bourdon tube pressure gauge?

3 Define construction of Rotameter?

4 What is meant by calibration?

5 Which type of fluid is used in bourdon tube pressure gauge?

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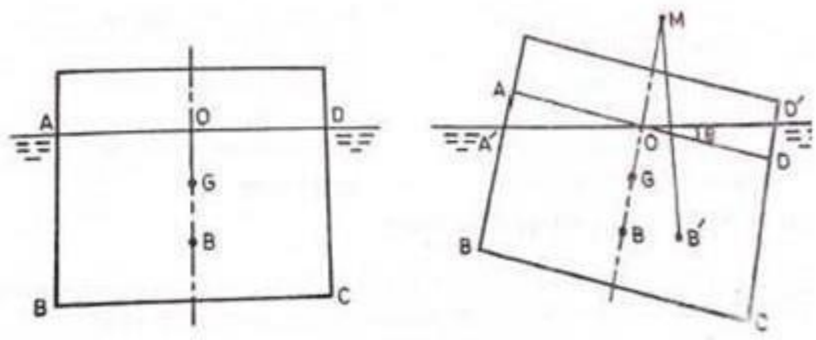
Experiment No: 2
Stability of Floating Body

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=

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Height of water in tank with pontoon X2	Difference in height X=X2-X1	Weight of pontoon Wc=XAρ	Unbalanced massWm 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.

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

Viva Questions:-

1. Define Buoyancy?
2. Define Meta-centre?
3. Define Meta- centric height?
4. With respect to the position of metacentre, state the condition of equilibrium for a floating body?

EXPERIMENT NO. 3

Study Characteristics of Laminar and Turbulent Flows (Reynolds Experiment)

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

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

Formula Used:- Reynolds No = Inertia force/Viscous force

Theory:-

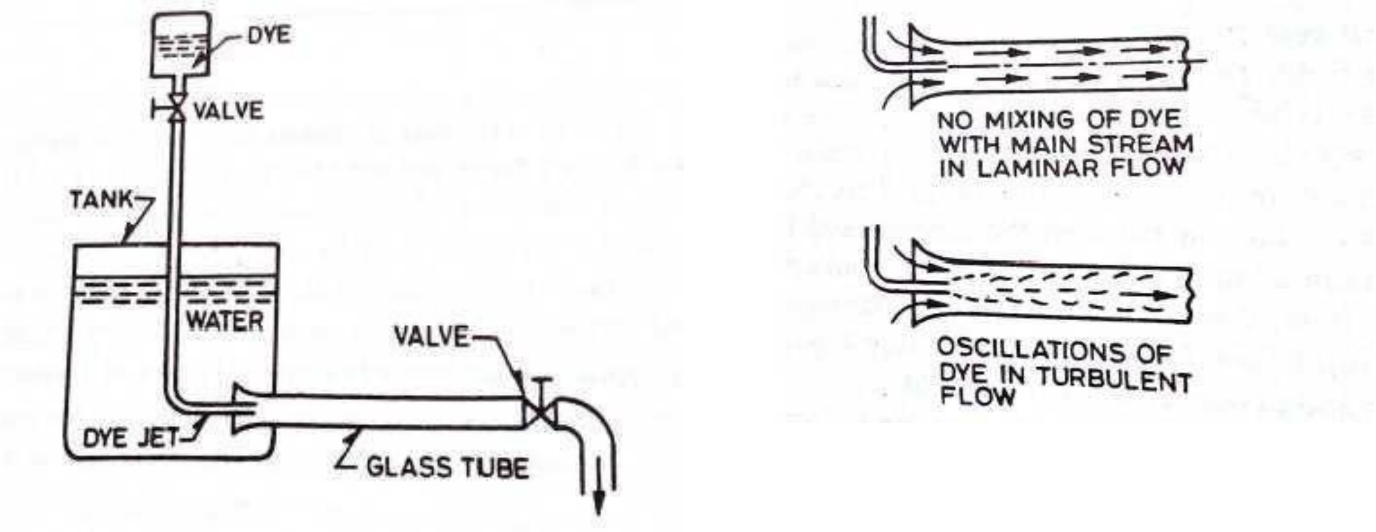


Figure: Reynold No. apparatus

Reynolds Number:- It is defined as ratio of inertia force of a flowing fluid and the viscous force of the fluid. The expression for
Reynolds number is obtained as:-

Inertia force (Fi) = mass . acceleration of flowing
= δ. Volume. Velocity/ time
= δ. $\frac{voSuNe}{tiNe}$Velocity
= δ.area .Velocity . Velocity
= δ.A .V^2

Viscous force (Fv) = Shear stress . area
= τ. A
= μ. du/dy . A
= VA/τ

By definition Reynolds number:-
Re= Fi/Fu
= δAV2/μ/t.A

`

= V.L /μ/s

= V.L /v { v = μ/ ρis kinematics viscosity of the fluid }

In case of pipe flow, the linear dimension L is taken as dia (d) hence Reynolds number for pipe flow is :-

Re = V .d /v

or Re = ρVd /v

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.

Observation:-

Type	Time	Discharge				$Q=m^3/3$	$R_e=4Q/\pi\Delta V$
		initial	Final	Difference	Volume		

Precaution:-

1. Take reading of discharge accurately.
2. Set the discharge value accurately for each flow.

Result:-

Viva Questions:-

1. Reynolds number importance?
2. Describe the Reynolds number experiments to demonstrate the two type of flow?
3. Define laminar flow, transition flow and turbulent flow?

`

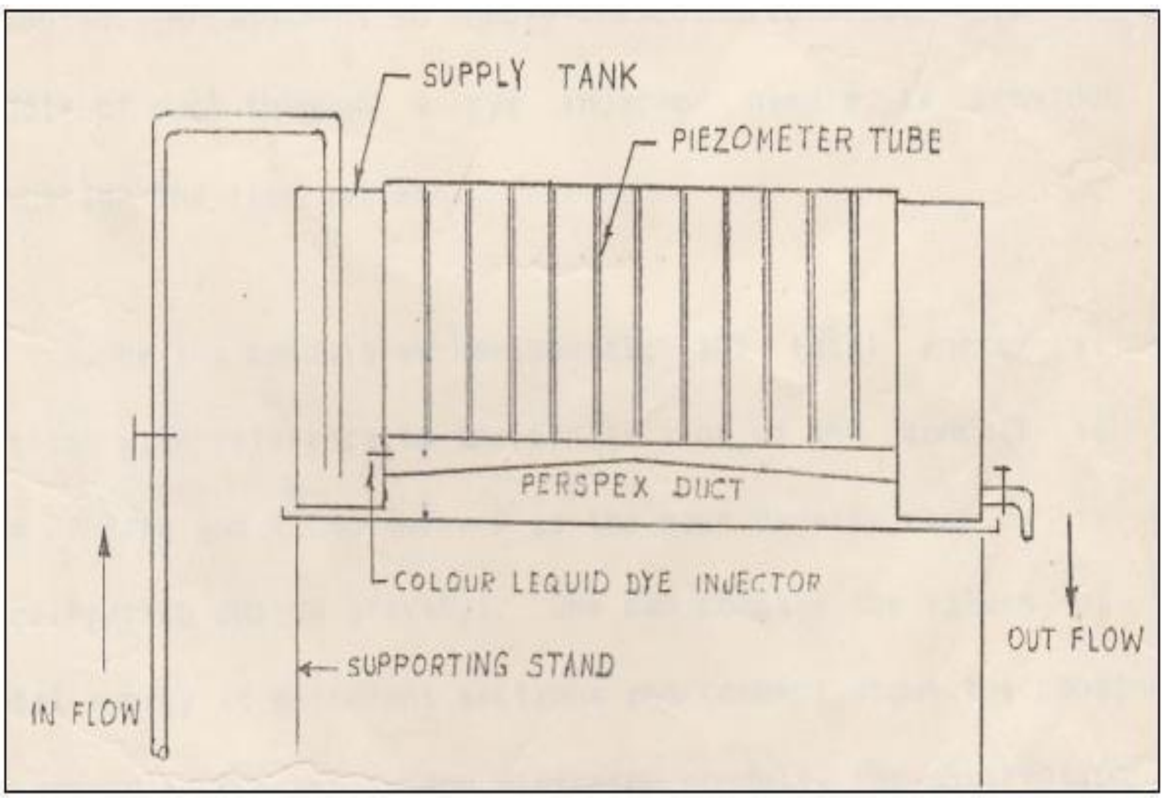
Experiment No: 4

Verify the Bernoulli's Theorem

Aim:- To verify the Bernoulli"s theorem.

Apparatus Used:- A supply tank of water, a tapered inclined pipe fitted with no. of piezometer tubes point, measuring 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.



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Formula Used:-

— —

H = Total Head

Z= Potential

head

P/ g = Pressure head

$V^2/2g$ =Velocity head

P = intensity of

pressure S = density

of water

g = acceleration due to

gravity V = velocity of

flowing water

H1 = H2 = H3 = H (Total Head)

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.

`

Observation table:-

	1	2	3	4	5	6	7	8	9	10	11
Reading of piezometric tubes											
Area Of cross section under the foot of each point											
Velocity of water under foot of each point											
$V^2/2g$											
p/ρ											
$V^2/2g + p/\rho$											

Sample calculation:

Dimensions of measuring tank

L = and B =

Area of measuring tank, (A) = (L×B)=

Rise in water level in the measuring tank, (x)=

Time taken for the water rise in the tank (t) =

Actual Discharge (Q) =

Area of cross section of the duct (a) =

velocity (v) = Q/a

velocity head = $V^2/2g$ (g = 9.81m/s)

`

Precautions:-

1. When fluid is flowing, there is a fluctuation inthe height of piezometer tubes, notethe mean position carefully.
2. Carefully keep some level of fluid in inlet and outlet supply tank.

Result:-

Viva Questions:-

1. Briefly explain the various terms involved in Bernoulli‟s equation?
2. Assumption made to get Bernoulli‟s equation from Euler‟s equation by made?

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EXPERIMENT NO. 5

Determine Hydraulic Coefficient of a small circular Orifice

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

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

Formula Used:-

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

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

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

$$C_v = \frac{\text{actual velocity of jet at vena contracta}}{\text{theoretical velocity}}$$

$$\text{coefficient of contraction} = \frac{\text{area of jet at vena contracta}}{\text{area of orifice}}$$

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

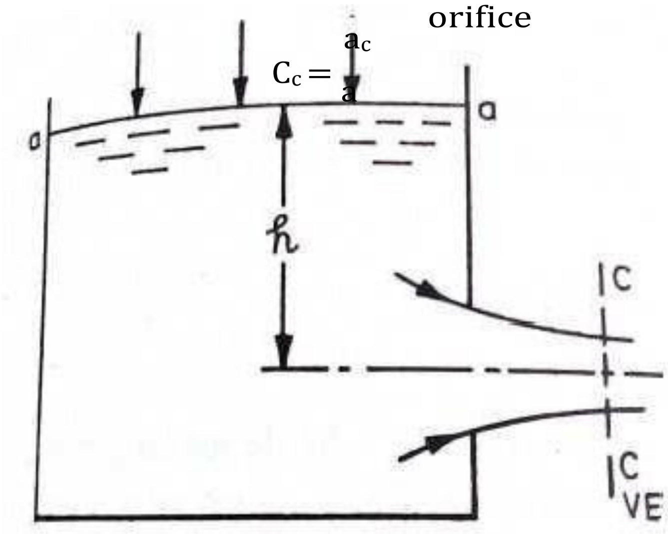

Figure: Flow through Orifice

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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 todispute 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. Coefficient of contraction:-

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

$$\text{coefficient of contraction} = \frac{\text{areaofjet atvena}}{\text{contracta area of orifice}}$$

Coefficient of discharge:-

$$C_d = \frac{Q_{actuaS}}{Q_{theoreticaS}}$$

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:- x' + y' are reading on horizontal/vertical scale

a_o	$h=\mu a_o$	x‘‘	y‘‘	X=x‘‘-x_oy	Y=y‘‘-y_o	C_u=x/2gh	Average

h = Reading on piezometer
a0 = Reading on piezometer at level on centre of
mouthpiece y0 = Reading on vertical scale at exit of orifice
x0 = Reading on horizontal scale at exit of orifice

Sr. No.	X	ZP	FR	volume	time	Q=V	C_d=Q/2gh	Average

`

Precautions:-

1. Take the reading of discharge accurately.
2. Take value of h without any parallax error.
3. Set the orifice and mouthpiece.
4. Height of water in the steady flow.
5. Take reading from hook gauge carefully.

Result:

Viva Questions:-

1. Define Orifice?
2. Define Mouth piece?
3. Define vena contracta?
4. Define co efficient of velocity?

Experiment No. 6

Calibration of Floe Measuring Devices (Venturimeter, Orificemeter, Rectangular and V-notch

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

Apparatus Used:- 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

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

For Rectangular notch

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

For Trapezoidal notch

$$C_d = \frac{Q}{\frac{2}{3}\sqrt{2g}\left(B + \frac{8}{15}\tan\frac{\theta}{2}\right) H^{\frac{3}{2}}}$$

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

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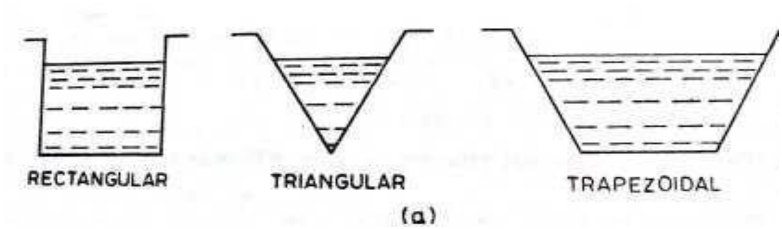

Figure: Notches

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:-

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 =

Type of Notch	Discharge					Final height reading above width	Head above crest level	C_d
	Initial height in tank	Final height in tank	Difference in height	Volume	Q			

`

Width of Rectangular notch =

`

Precaution:-

1. Make the water level surface still, before takings the reading.
2. Reading noted should be free from parallax error.
3. The time of discharge is noted carefully.
4. Only the internal dimensions of collecting tank should be taken for consideration and calculations.

Result:

The value of C_d for V-notch……
The value of C_d for rectangular notch……
The value of C_d for trapezoidal notch ……

Viva Questions:-

1. Differentiate between :-
- Uniform and non uniform flow
- Steady and unsteady flow
2. Define notch?
3. What is coefficient of discharge?

`

Venturimeter:

Aim:- To determine the coefficient of discharge of Venturimeter.

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

Formula Used:-

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

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

Theory:- Venturimeter 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 part in short

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

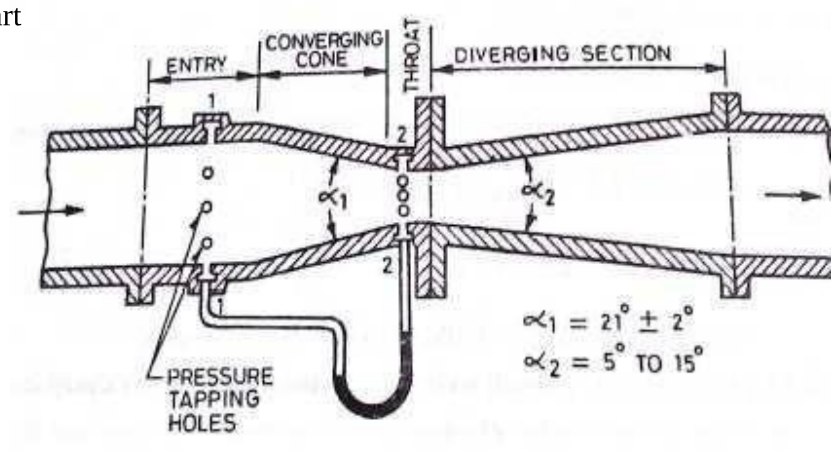

Figure: Venturimeter

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:-

Diameter of Venturimeter= Area of cross section = Venturimeter=
Area of collecting tank=

Discharge					Manometer reading				$C_d = \frac{Q.\sqrt{A^2 - a^2}}{A.a.\sqrt{2g\Delta h}}$
Initial (cm.)	Final (cm)	Difference	Time (sec)	Discharge	H_1	H_2	H_2-H_1	Δh=13.6(H_2-H_1)	

Result:-

Precautions:-

1.Keep the other valve closed while taking reading through one pipe.
2.The initial error in the manometer should be subtracted final reading.
3.The parallax error should be avoided.
4.Maintain a constant discharge for each reading.
5.The parallax error should be avoided while taking reading the manometer.

Viva Questions:-

1. Venturimeter are used for flow measuring. How?
2. Define co efficient of discharge?
3. Define parallax error?
4. Define converging area part?
5. Define throat?
6. Define diverging part?

EXPERIMENT NO. 7

Pipe Friction

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

Apparatus Used:- A flow circuit of G. I. pipes of different diameter viz. 15 mm, 25mm, 32 mm dia, U-tube differential manometer, collecting tank.

Theory:-

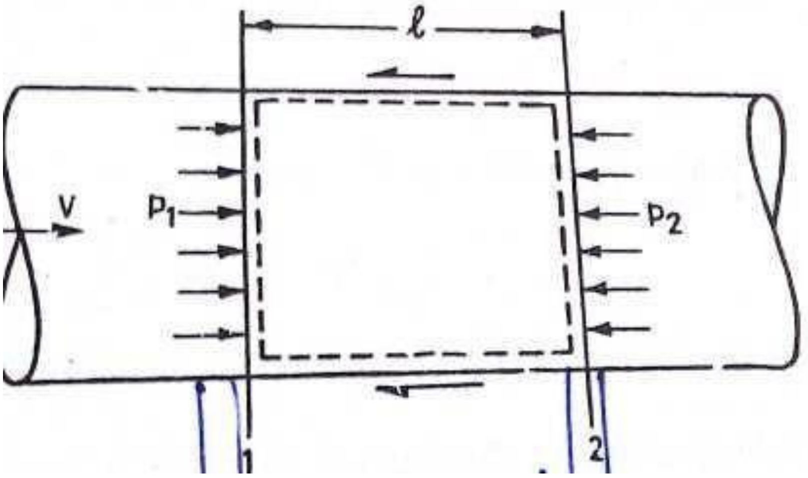

Figure: Losses in pipes during flow

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:-

1. The viscous friction effect associated with fluid flow.
2. The local resistance which result from flow disturbances caused by Sudden expansion and contraction in pipe

Obstruction in the form of valves, elbows and other pipe fittings. Curves and bend in the pipe.

Entrance and exit losses.

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

$$h_f = \frac{4 f l v^2}{2gd}$$

Hence the major head loss is friction loss

velocity______ $h_f = \frac{4 f l v^2}{2gd}$

Where,

hf =Major head loss l = Length of pipe 4f = Friction factor v = Inlet

`

-------- Darcy equation
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.

Observation:-

Diameter of pipe D =
Length of pipe between pressure tapping L =
Area of collecting tank =

Sr. No.	Manometer Reading			Discharge measurement				F $= n^2gD^5/8LQ^2h_f$
	Left limb H_1	Right limb H_2	Difference of head in terms of water $h_f = 13.6 (H_2-H_1)$	Initial cm.	Final cm.	Time sec	Discharge Q (cm^3/sec)	

Precautions:-

1. When fluid is flowing, there is a fluctuation in the height of piezometer tubes, note the mean position carefully.
2. There in some water in collecting tank.
3. Carefully keep some level of fluid in inlet and outlet supply tank.

Result:-

Viva Questions:-

1. Define major loss in pipe?
2. Define equilent pipe?
3. Define friction factor in the pipe?

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EXPERIMENT NO.8
Uniform Flow in Open Channel

Aim:- Uniform flow in open channel.

Theory:

The flow of liquid in a channel with free surface is known as open channel flow. The free surface is defined as a surface having constant pressure such as atmospheric pressure. Hence the flow of water through a passage under atmospheric pressure is called as flow in open channels. Flow in open channel takes place under the flow of gravity i.e. the flow takes place due to bed slope of channel.

Open channel flow is also classified as uniform or non-uniform depending upon the conditions of various parameters of the flow such as depth of flow, velocity of flow, discharge and cross sectional area.

The study of open channel flow is required for the following purposes:

- To estimate the discharge in river or canal
- To find out the area of submergence due to construction of dam or reservoir
- To design a canal
- To find the relationship between various flow parameters

UNIFORM FLOW IN AN OPEN CHANNEL:

For a flow to be Uniform, the following two main conditions must be satisfied:

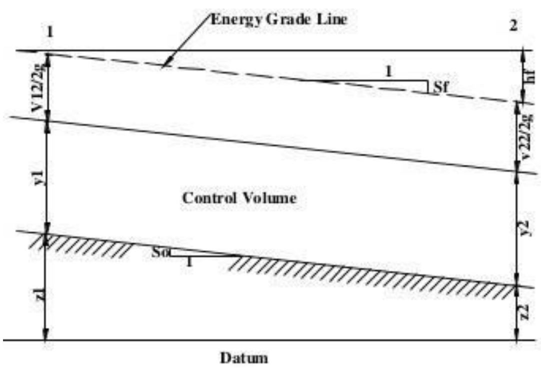
1. A flow is said to be uniform flow if flow characteristics such as depth of flow, velocity of flow and the flow rate at any cross section does not change along the entire length of channel.

$$\frac{\partial d}{\partial x} = 0 \quad \frac{\partial v}{\partial x} = 0$$

Where,

d= flow depth, v- velocity of flow and x=length of the channel section considered.

2. The slope of energy gradient line (S_e), Water surface slope (S_w) and Channel bedslope (S_o) must be same or equal.



Steady Uniform Flow in an Open Channel

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In order to carry water at uniform depth and cross section along their length, many artificial drainage and irrigation canals are designed in which flow can be consider as uniform. Uniform flow can occur only during steady flow conditions, which has been described in above Fig.1.

If the flow to is to beuniform, the cross section of the channel at section 1-1 and 2-2 as shown in fig. above must be same. Consequently flow depth and velocity of flow must also be same i.e.

$$V_1=V_2 \text{ and } d_1=d_2$$

The computation of the uniform flow can be carried out using velocity equation of Chezy‟s and Manning‟s and then multiplying it with the cross sectional area of channel. Fig.2 below shows the uniform flow in various channel sections such as circular, triangular, square, rectangle and trapezoidal.

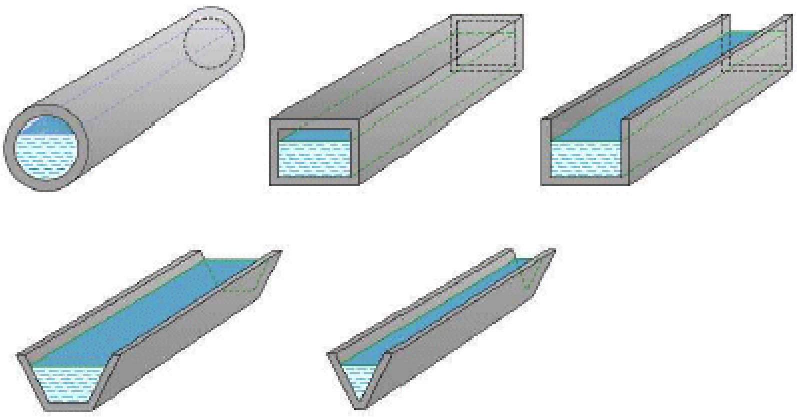

Fig. 2 Different Channel sections of uniform flow

EXPERIMENT NO. 9
Similitude and Model Studies

Introduction:

For predicting the performance of the hydraulic structure (such as dams, spillways etc.) or hydraulic machines (turbines, pumps) before actually constructing or manufacturing, models of the structures or machines are made and tests are performed on them to obtain the desired information.

Theory:

- The model is the small scale replica of the actual structure or machine. The actual structure or machine is called Prototype.
- It is not necessary the model should be smaller than the prototypes; they may be larger than the prototypes. The study of models of actual machines is called model analysis
- Model analysis is actually an experimental way of finding solutions of complex flow problems. Excet analytical solution is possible only for a limited numbers of flow problems.

Advantages:

- The performance of the hydraulic structure or hydraulic machine can be predicted, in advance, from the model.
- With the help of dimensional analysis, a relationship between the variables influencing a flow problem in terms of dimensionless parameters is obtained. This relationship helps inconducting tests on model.
- The merits of alternative designs can be predicted with help of model testing. Economical and safe design may be adopted.
- The tests performed on the models can be utilized for obtaining, in advance, useful information about the performance of the prototypes only if a complete similarity exists between the model and the prototype.

Similitude
Similitude is similarity of behavior for different systems with equal similarity parameters

Prototype	Model
(Real world)	(Physical/Analytical/Numerical….Experiments)

For similitude we require that the similarity parameters (SPs) (e.g. angles, length ratios, velocity ratios, etc) are equal for the model and the real world.

Similitude	Similarity parameters (SPs)
Geometric similitude	Length ratios, angles
Kinematic similitude	Displacement ratios, velocity ratios
Dynamic similitude	Force ratios, stress ratios, pressure ratios
⋮	
Internal constitution similitude	ρ, υ
Boundary conditions similitude	

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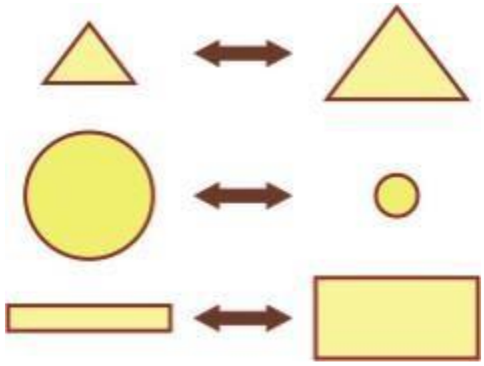
Similitude – Types of similarities

Similitude is defined as the similarity between the model and its prototype in every respect. Three types of similarities exist between model and prototype.

1. Geomatric similarity:

It concerns the length dimension {L} and must be ensured before any model testing can proceed. In general geometrical similarity is established when: A model and prototype are geometrically similar if and only if all body dimensions in all 3 coordinates have the same linear scale ratio. This means all the angles, flow directions, and the orientations of model and prototype with respect to surroundings must be identical.



L_m = Length of model D_m= Diameter of model V_m= Volume of Model b_m= Breath of model A_m= Area of model

L_p ,D_p,V_p,,b_p,A_p = Corresponding value of the prototype. Now, Similarity relations,

$$\frac{L_p}{L_m} = \frac{b_p}{b_m} = \frac{D_p}{D_m} = L_r$$

Where, L_r is called the scale ratio. Area and Volume ratio will be ,

$$\frac{A_p}{A_m} = \frac{L_p}{L_m} x \frac{b_p}{b_m} = L_r x L_r = L_r^2$$

$$\frac{V_p}{V_m} = \left(\frac{L_p}{L_m}\right)^3 = \left(\frac{b_p}{b_m}\right)^3 = \left(\frac{D_p}{D_m}\right)^3$$

2. Kinematic similarity:

Kinematic similarity refers to similarity of motion. Since motions are described by distance and time, it implies similarity of lengths (i.e., geometrical similarity) and, in addition, similarity of time intervals.

If the corresponding lengths in the two systems are in a fixed ratio, the velocities of corresponding particles must be in a fixed ratio of magnitude of corresponding time intervals.

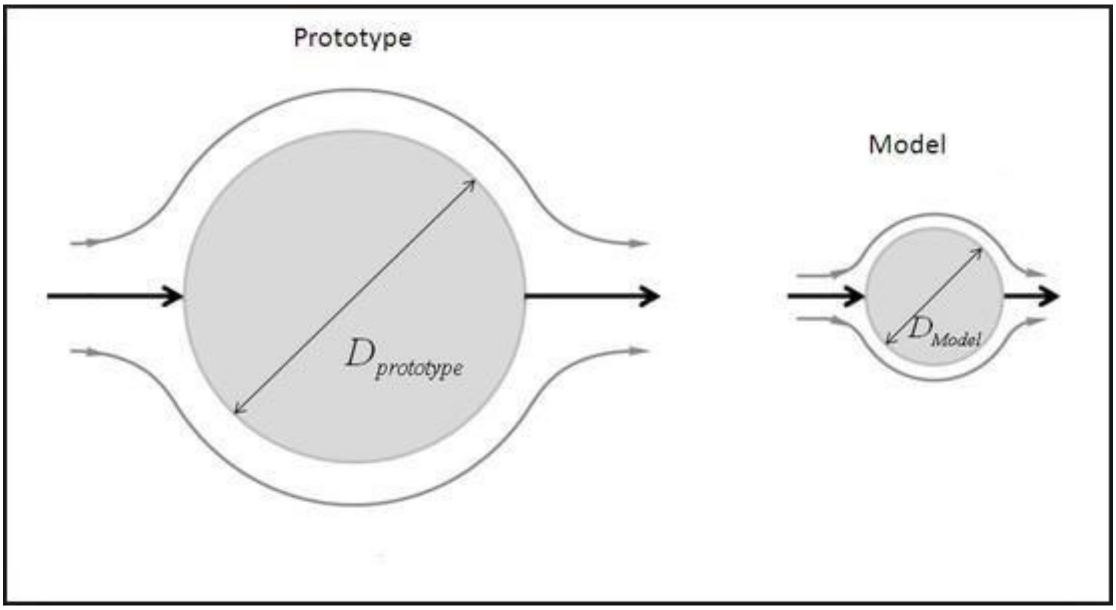


Figure 1: Kinematically Similar Low Speed Flows

For Kinematic similarity, we must have

$$\frac{V_{p_1}}{V_{m_1}} = \frac{V_{p_2}}{V_{m_2}} = V_r$$

V_r= Velocity ratio

For acceleration, we must have

$$\frac{a_{p_1}}{a_{m_1}} = \frac{a_{p_2}}{a_{m_2}} = a_r$$

a_r= acceleration ratio

3. Dynamic similarity:

Dynamic similarity is the similarity of forces. In dynamically similar systems, the magnitudes of forces at correspondingly similar points in each system are in a fixed ratio

In this regime forces at homologous points and times acting on homologous elements of fluid mass must be in the same ratio through the two systems. In addition, we therefore require geometric and kinematic similarity. Here forces are those of pressure, gravity, friction or viscosity, elasticity and surface tension. In addition, it should be known that, the physical properties involved are density, viscosity, elasticity, etc. As an example, expressing the force due to inertia by fi = ρV2l2 and that due to viscosity by fυ = μV l, and requiring that their ratio remains constant at all homologous points of model and the

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prototype, leads to:

Let,

$(F_i)_p$= Inertia force at a point in prototype $(F_v)_p$= Viscous force at a point in prototype $(F_g)_p$= Gravity force at a point in prototype

$(F_i)_m$, $(F_v)_m$, $(F_g)_m$= Corresponding values of forces at a corresponding point in model.

$$\frac{(F_i)_p}{(F_i)_m} = \frac{(F_v)_p}{(F_v)_m} = \frac{(F_g)_p}{(F_g)_m} = F_r$$