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ज्ञानम् आत्म प्रदीपाय

Fluid Mechanics and Fluid Power
Practical Manual
Course Code: ESC-205
2021

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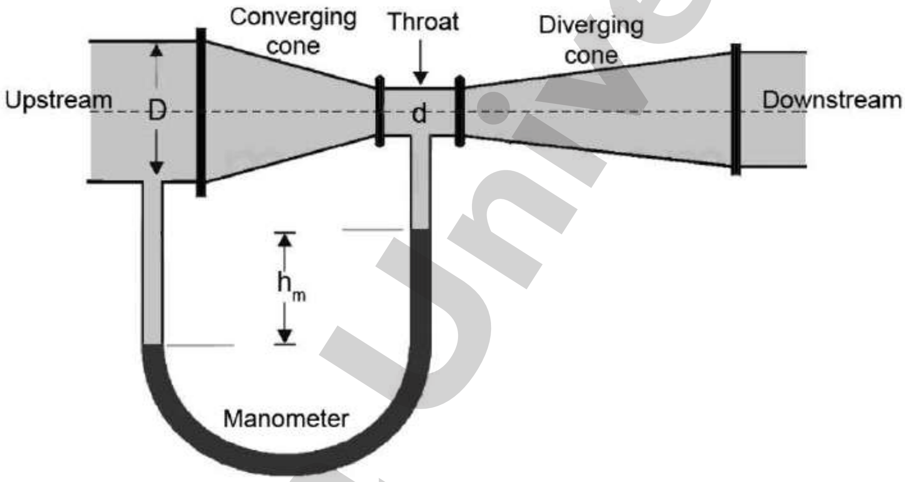
CONTENTS

MANDATORY INSTRUCTIONS

1. Students should report to the labs concerned as per the timetable.
2. Record should be updated from time to time and the previous experiment must be signed by the faculty in charge concerned before attending the lab.
3. Students who turn up late to the labs will in no case be permitted to perform the experiment scheduled for the day.
4. After completion of the experiment, certification of the staff in-charge concerned in the observation book is necessary.
5. Students should bring a notebook of about 100 pages and should enter the readings/observations/results into the notebook while performing the experiment.
6. The record of observations along with the detailed experimental procedure of the experiment performed in the immediate previous session should be submitted and certified by the staff member in-charge.
7. Not more than FIVE students in a group are permitted to perform the experiment on a set up.
8. The group-wise division made in the beginning should be adhered to, and no mix up of student among different groups will be permitted later.
9. The components required pertaining to the experiment should be collected from Lab-in-charge after duly filling in the requisition form.
10. When the experiment is completed, students should disconnect the setup made by them, and should return all the components/instruments taken for the purpose.
11. Any damage of the equipment or burnout of components will be viewed seriously either by putting penalty or by dismissing the total group of students from the lab for the semester/year.
12. Students should be present in the labs for the total scheduled duration.
13. Students are expected to prepare thoroughly to perform the experiment before coming to Laboratory.
14. Procedure sheets/data sheets provided to the students groups should be maintained neatly and are to be returned after the experiment.
15. **DRESS CODE:**
    - Boys - Formal dress with tuck in and shoes.
    - Girls - Formal dress

1. **Experiment No.: ESC-205/01**
2. **Experiment Name: Fluid flow measurements**
3. **Objectives:** Determination of coefficient of discharge for Venturimeter
4. **Principle:**

   A Venturimeter is a device used to measure the rate of flow of a liquid in a pipe line. It consists of a converging cone, throat section (cylindrical) and a diverging cone. The principle (Bernoulli's theorem) used is to measure the difference of head between two sections and computing the average flow velocity from which the discharge is computed using discharge continuity equation. Coefficient of discharge (C_d) is the ratio of actual discharge to the corresponding theoretical discharge.



The theoretical discharge through Venturimeter is given by

$$Q_t = \frac{a_1 a_2}{\sqrt{a_1{}^2 - a_2{}^2}}\sqrt{2gh}$$

Where,

a_1 = Cross-section area of inlet of Venturimeter

a_2 = Cross-section area of throat of Venturimeter

h = Equivalent water head = $x\left[\frac{s_m}{s} - 1\right]$

s_m = Specific gravity of manometric fluid i.e. mercury = 13.60

s = Specific gravity of flowing fluid i.e. water =1

x = Difference in levels of manometric fluid in the two limbs of manometer.

Coefficient of discharge, $C_d = \frac{Q_a}{Q_t}$

Actual discharge, $Q_a = \frac{A \times r}{t}$

Where,

a = Area of measuring tank;

r = Rise of water level in the measuring tank, and

t = Time for ______ cm rise in measuring.

5. Apparatus:

1. Venturimeter with pressure tapings at the entrance and the throat installed in a horizontal pipeline.
2. U-tube manometer to measure the difference across the tapings.
3. A constant steady supply of water with a means of varying discharge.
4. Measuring tank and stop watch to measure the actual discharge.

6. Procedure:

1. Select a Venturimeter set-up.
2. Note down diameter of the pipe.
3. Connect the two limbs of manometer to inlet and throat of the Venturimeter.
4. Allow the water to flow in the pipe by opening the gate valve.
5. Vent the manometer by removing the air bubbles in the tube.
6. Note down the manometer readings4ifference in elevation of manometric fluid in left and right limbs
7. Note down the time required to collect a known height of water in collecting tank.
8. Repeat Steps 6 to 7 for various discharges by varying the gate valve for four more trails.

7. Tabular Column:

S. No.	Manometer reading $x = (x_1 - x_2)$ (m)	Equivalent water head h=12.6 X x (m)	Time taken for ------ cm Rise in collecting tank (s)	$Q_a = \frac{A \times r}{t}$ m³/s	Q_t m³/s	$C_d = \frac{Q_a}{Q_t}$
1						
2						
3						
4						
5						

8. Calculation

$Q_a = \frac{A \times r}{t}$ = …………………; A = ……………… × ………………… = …………….. m^2;

$Q_a = \frac{(\qquad\qquad)}{(\qquad)}$ = …………………….. m^3/s

$Q_t = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$ = ……………… m^3/s

$h = x\left[\frac{s_m}{s} - 1\right]$ = ………………….. ; $x = (x_1 - x_2)$ m; g = 9.81 (m/s^2)

$a_1 = \frac{\pi d_1^2}{4}$ = ……………….. m^2 d_1 = diameter of the pipe

$a_2 = \frac{\pi d_2^2}{4}$ = ……………….. m^2 d_2 = diameter of the pipe

GRAPHS:

Draw the graph of $\log Q_a$ vs $\log h$

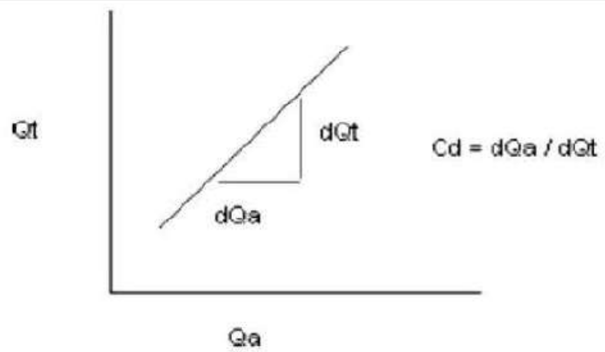
$$Q_a = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh^n} = Kh^n$$

Where, $K = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2g}$

$\log Q_a = \log K + n \log h$, at $h = 1$: $Q_a = k$

Hence, $C_d = \frac{K}{\left(\frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}}\right)\sqrt{2g}}$

General values of Venturimeter coefficient ranges from C_d 0.95 to 0.98



Draw Q_a Vs Q_t .

Find C_d value from the graph and compare it with calculated C_d value from table

9. Result

1. The coefficient of discharge of Venturimeter = ……………. From Calculation
2. The coefficient of discharge of Venturimeter = ……………. From Graph1

10. Precautions:

1. The Venturimeter should be fixed in the pipeline such that the pipe, on both Sides, is long enough and does not affect the flow in Venturimeter.
2. Sufficient time should be given for the flow to become steady-uniform.
3. The air bubbles should be completely removed in the pipe connecting the Manometer. This should be achieved only by opening the valves provided at the top of the manometers simultaneously. If they are opened separately, the manometric fluid (usually mercury, which is very costly) will spill out of.

11. Possible Errors

1. The manometric reading (head) for the flow through the pipe before and after taking readings of volumetric measurements (actual discharge) should be the same. If they are not same, take the average of the two readings for volumetric readings.
2. Reading errors may occur at manometer and volumetric piezometer scale by not recording the readings at the eye level.
3. Synchronize stopwatch operations for volumetric measurements.

PRE-LAB QUESTIONS

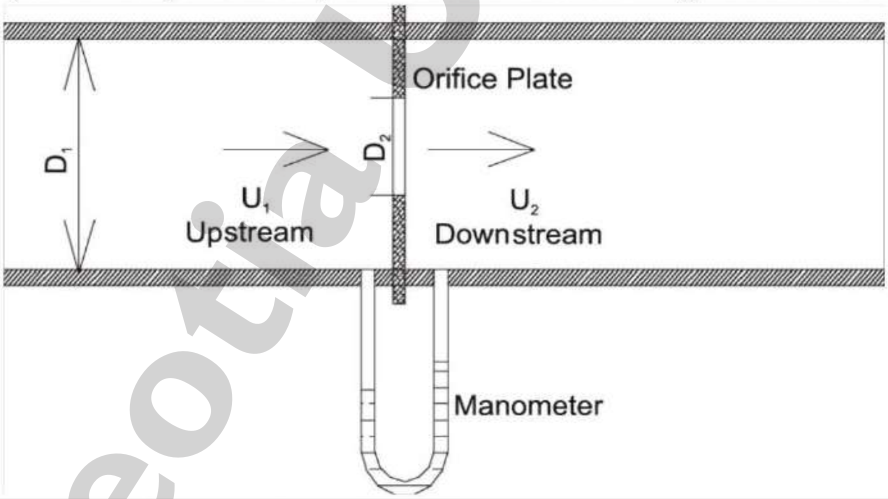
1. Write continuity equation for incompressible flow?
2. What is meant by flow rate?
3. What is the use of orifice meter?
4. What is the energy equation used in orifice meter?
5. List out the various energy involved in pipe flow.

POST-LAB QUESTIONS

1. How do you find actual discharge?
2. How do you find theoretical discharge?
3. What do you meant by co-efficient of discharge?
4. Define vena-contracta?
5. List out the Bernoulli's applications.

1. **Experiment No.: ESC-205/02**
2. **Experiment Name: Fluid flow measurements**
3. **Objectives:** Determination of coefficient of discharge for Orifice meter
4. **Principle:**

An orifice plate is a device used for measuring the volumetric flow rate. It uses the same principle as a Venturi nozzle, namely Bernoulli's principle which states that there is a relationship between the pressure of the fluid and the velocity of the fluid. When the velocity increases, the pressure decreases and vice versa. An orifice plate is a thin plate with a hole in the middle. It is usually placed in a pipe in which fluid flows. When the fluid reaches the orifice plate, with the hole in the middle, the fluid is forced to converge to go through the small hole; the point of maximum convergence actually occurs shortly downstream of the physical orifice, at the so-called *vena contracta* point. As it does so, the velocity and the pressure changes. Beyond the *vena contracta*, the fluid expands and the velocity and pressure change once again. By measuring the difference in fluid pressure between the normal pipe section and at the *vena contracta*, the volumetric and mass flow rates can be obtained from Bernoulli's equation. Orifice plates are most commonly used for continuous measurement of fluid flow in pipes. This experiment is process of calibration of the given orifice meter.



The Theoretical discharge through orifice meter,

$$Q_t = \frac{a_1 a_2}{\sqrt{a_1^{\,2} - a_2^{\,2}}}\sqrt{2gh}$$

H = Differential head of manometer in m of water = $12.6 \times h_m \times 10^{-2}$ (m)

g = Acceleration due to gravity ($9.81 m/sec^2$)

Inlet Area of orifice meter in m^2, $a_1 = d_1^2/4$

Area of the throat or orifice in m^2, $a_2 = d_2^2/4$

Take inlet diameter of pipe = d_1 = 40 mm and Orifice diameter = d_2 = 25 mm

Coefficient of discharge, $C_d = \frac{Q_a}{Q_t}$

Actual discharge, $Q_a = \frac{A \times r}{t}$

Where,

a = Area of measuring tank;

r = Rise of water level in the measuring tank, and

t = Time for ______ cm rise in measuring.

5. Apparatus:

1. Orifice meter with pressure tapings at the entrance and the throat installed in a horizontal pipeline.
2. U-tube manometer to measure the difference across the tapings.
3. A constant steady supply of water with a means of varying discharge.
4. Measuring tank and stop watch to measure the actual discharge.

6. Procedure:

1. Select a Orifice meter set-up.
2. Note down diameter of the pipe.
3. Connect the two limbs of manometer to inlet and throat of the Orifice meter.
4. Allow the water to flow in the pipe by opening the gate valve.
5. Vent the manometer by removing the air bubbles in the tube.
6. Note down the manometer readings4ifference in elevation of manometric fluid in left and right limbs
7. Note down the time required to collect a known height of water in collecting tank.
8. Repeat Steps 6 to 7 for various discharges by varying the gate valve for four more trails.

7. Tabular Column:

S. No.	Manometer reading $x = (x_1 - x_2)$ (m)	Equivalent water head h=12.6 X x (m)	Time taken for ------ cm Rise in collecting tank (s)	$Q_a = \frac{A \times r}{t}$ m^3/s	Q_t m^3/s	$C_d = \frac{Q_a}{Q_t}$
1						
2						
3						
4						
5						

8. Calculation

$Q_a = \frac{A \times r}{t} =$ ………………….; A = ……………… × …………………. = ……………… m^2;

$Q_a = \frac{(\qquad)}{(\qquad)} =$ ……………………… m^3/s

$Q_t = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh} =$ ……………… m^3/s

$h = x \left[\frac{s_m}{s} - 1\right] =$ ………………….. ; $x = (x_1 - x_2)$ m; g = 9.81 (m/s^2)

$a_1 = \frac{\pi d_1^2}{4} =$ ……………….. m^2 d_1= diameter of the pipe

$a_2 = \frac{\pi d_2^2}{4} =$ ……………….. m^2 d_2= diameter of the pipe

GRAPHS:

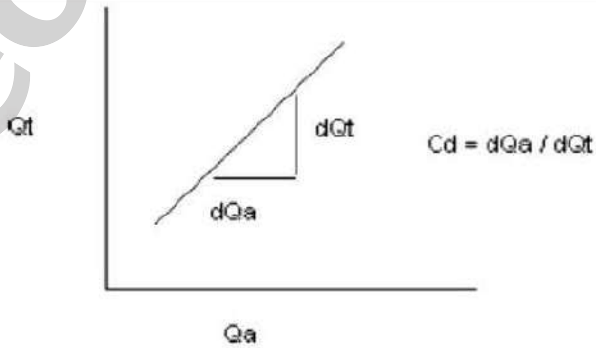
Draw the graph of $log\ Q_a$ vs $log\ h$

$Q_a = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh^n} = Kh^n$

Where, $K = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2g}$

$log\ Q_a = logK + n \log h$, at $h = 1$: $Q_a = k$

Hence, $C_d = \frac{K}{\left(\frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}}\right)\sqrt{2g}}$



Draw Q_a Vs Q_t .

Find C_d value from the graph and compare it with calculated C_d value from table

9. Result

1. The coefficient of discharge of Orifice meter = …………… From Calculation
2. The coefficient of discharge of Orifice meter = …………… From Graph1

10. Precautions:

1. The Orifice meter should be fixed in the pipeline such that the pipe, on both Sides, is long enough and does not affect the flow in Orifice meter r.
2. Sufficient time should be given for the flow to become steady-uniform.
3. The air bubbles should be completely removed in the pipe connecting the Manometer. This should be achieved only by opening the valves provided at the top of the manometers simultaneously. If they are opened separately, the manometric fluid (usually mercury, which is very costly) will spill out of.

11. Possible Errors

1. The manometric reading (head) for the flow through the pipe before and after taking readings of volumetric measurements (actual discharge) should be the same. If they are not same, take the average of the two readings for volumetric readings.
2. Reading errors may occur at manometer and volumetric piezometer scale by not recording the readings at the eye level.
3. Synchronize stopwatch operations for volumetric measurements.

PRE-LAB QUESTIONS

1. Write continuity equation for incompressible flow?
2. What is meant by flow rate?
3. What is the use of orifice meter?
4. What is the energy equation used in orifice meter?
5. List out the various energy involved in pipe flow.

POST-LAB QUESTIONS

1. How do you find actual discharge?
2. How do you find theoretical discharge?
3. What do you meant by co-efficient of discharge?
4. Define vena-contracta?
5. List out the Bernoulli's applications.

1. **Experiment No.: ESC-205/03**
2. **Experiment Name: Fluid flow measurements**
3. **Objectives:** Determining coefficient of discharge for wires
4. **Principle:**

A notch or sharp crested weir is a device used to measure the discharge flowing through the open channel. The general types of notches according to their geometric shapes are rectangular, triangular and trapezoidal.

End contraction: Due to the constriction of flow as it flows through the weir, the actual flow decreases. In case of rectangular weir, the flow through the weir including end contraction is given by

$$Q = \frac{2}{3} C_d \sqrt{2g} (L - 0.2h) h^{\frac{3}{2}} = \frac{2}{3} C_d \sqrt{2g}\, L h^{\frac{3}{2}} - \frac{2}{15} C_d \sqrt{2g}\, h^{\frac{5}{2}}$$

As can be seen reduction in flow is triangular portion

$$\frac{8}{15} \times \frac{1}{4}\, C_d \sqrt{2g}\, h^{\frac{5}{2}} = \frac{8}{15}\, C_d \sqrt{2g} \tan\theta\ h^{\frac{5}{2}}$$

C_d = Coefficient of discharge

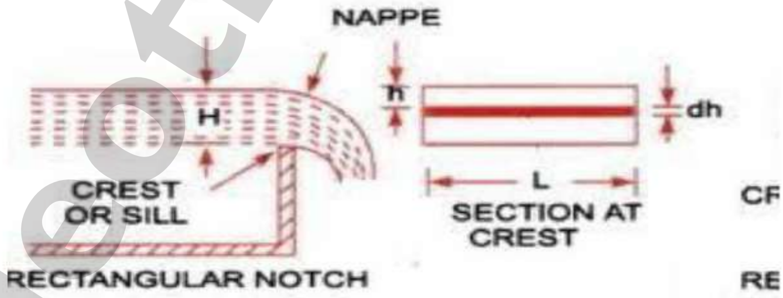
L= Crest length of rectangular notch=..............................

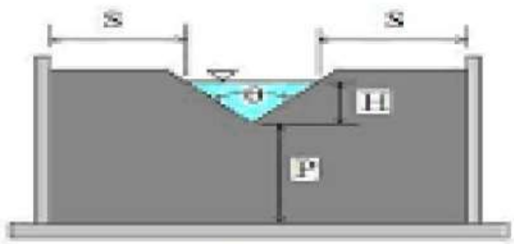
θ = Half-angle of the triangular portion=..............................

h= difference between crest reading to gauge reading (head of water over the notch)

g= 9.81 m/s^2

$\tan\theta = 1/4$





V Notch Weir

5. **Apparatus:**
   1. The apparatus consists of the following notches made of SS 304 material.
      i. Rectangular Notch

ii. V – Notches.

2. A separate Notch tank is provided to simulate the channel flow with quick interchangeable facilities for changing the Notches.
3. A measuring tank is provided to measure the flow rate.
4. Piezometer is provided to measure the height of the water collected in the measuring tank.
5. A Monobloc Centrifugal Pump
6. The whole arrangement is mounted on an Aesthetically designed sturdy frame made of MS angle with all the provisions for holding the tanks and accessories..

6. Procedure:

1. Fix the notch plate under test at the end of the approach channel in a vertical plane with the sharp edge on the upstream side.
2. Fill the channel with water upto the crest level and adjust the hook gauge reading to zero.
3. Adjust the by-pass valve to give maximum possible discharge without flooding the notch.
4. Note the final hook gauge reading. This gives the head over the notch 'H'.
5. Collect the water discharging from the notch in the measuring tank of known dimension and measure the rise of water level 'R' in the measuring tank for a known time 't' sec.
6. Conditions are allowed to steady before the head and rise of water level are recorded.
7. Lower the water level in the approach channel in stages by adjusting the flow control valve and record the series of readings 'H', 'R' and 't' at each stage.

7. Tabular Column:

Triangular Notch

S. No.	Head over Notch	Time for____mm rise in tank	$Q_a = \frac{A \times r}{t}$	Q_t	$C_d = \frac{Q_a}{Q_t}$
	M	S	m^3/s	m^3/s	
1					
2					
3					
4					
5					

8. Calculation

Crest reading = ………………………………m

$Q_a = \frac{A\times r}{t}$=……………… A=…………………………×…………………=……………………………m^2

$Q_t = \frac{8}{15} C_d\sqrt{2g}\ \tan\theta\ \ h^{\frac{5}{2}}$ m^3/s

g=9.81 m/s^2 $\theta = 30^0$ or 45^0

Q_t =………………………

$C_d = \frac{Q_a}{Q_t}$ =…………………………

Graphs:

Draw the graph of $log\ Q_a\ vs\ log\ h$

Rectangular weir and Cipoletti weir

$$Q_a = \frac{2}{3} C_d\sqrt{2g}\ L\ h^n = Kh^n$$

$$K = \frac{2}{3}\ C_d\sqrt{2g}$$

Where,

$Log\ Q_a = log\ K + n\ log\ h$ $at\ \ h=1;\ \ Q_a = K$

Hence $C_d = \frac{k}{\frac{2}{3}\sqrt{2g}\ L}$ and n is the slope of the line

Triangular weir

$$Q_t = \frac{8}{15}\ C_d\sqrt{2g}\ \tan\theta\ \ h^{\frac{5}{2}} = Kh^n$$

$$K = \frac{8}{15}\ C_d \tan\theta\ \sqrt{2g}$$

Where,

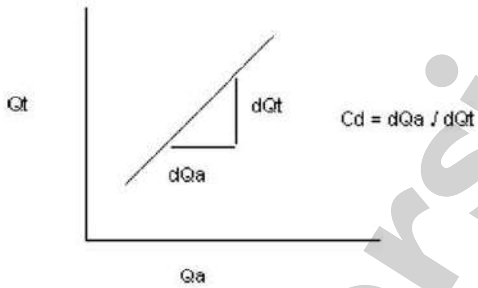
$Log\ Q_a = log\ K + n\ log\ h$ at h =1; $Q_a = K$

Hence,

$C_d = \frac{k}{\frac{8}{15}\tan\theta\ \sqrt{2g}}$ And n is the slope of the line

General values of the C_d varies in between 0.60 to 0.62 depending on the type of notch

Normal graph



9. Result :

10. Precautions:

1. The weir / notch should be fixed exactly in the vertical plane perpendicular to the flow axis.
2. 2. The weir should be fixed in a position such that it is symmetrical over vertical axis.
3. 3. Sufficient time should be given foe the flow to become steady-uniform.
4. 4. Gauge readings should be measured only in peizometre attached to the channel and not on the free surface

11. Possible Errors

1. Head should be constant in the head tank and the point gauge measurements before and after taking the readings of volumetric measurements (actual discharge) should be the same. If the measurements are not the same, take the average of the two readings.
2. Reading error may occur at gauge and volumetric peizometre scale by not recording the readings at the eye level.
3. Synchronize the stop watch operations for volumetric measurement

PRE-LAB QUESTIONS

1. Derive expression for theoretical discharge?
2. Sketch and explain flow through notch apparatus?
3. What are the applications of square notch?
4. What is the application of flow through notch?
5. What are the units of discharge?

POST-LAB QUESTIONS

1. How do understand by theoretical discharge
2. Explain different types notches
3. Which one is maximum discharge in all Notches
4. How do you calculate the Co-efficient of Discharge

1. **Experiment No.: ESC-205/04**
2. **Experiment Name: Fluid flow measurements**
3. **Objectives:** To Study and Calibrate a Pitot Static Tube
4. **Principle:**

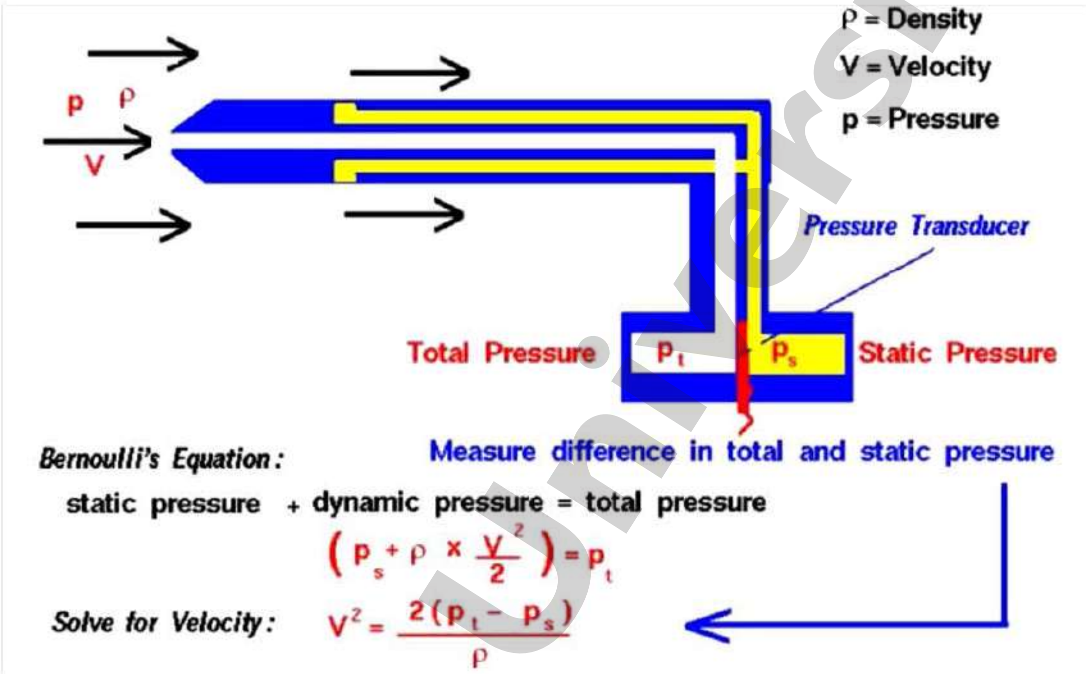


Figure 1 Pitot Static System

Fig.1 shows a schematic drawing of a pitot-static tube. Pitot-Static tubes, which are also called Prandtl tubes, are used on aircraft as speedometers. The actual tube on the aircraft is around 10 inches (25 centimeters) long with a 1/2 inch (1 centimeter) diameter. Several small holes are drilled around the outside of the tube and a center hole is drilled down the axis of the tube. The outside holes are connected to one side of a device called a pressure transducer. The center hole in the tube is kept separate from the outside holes and is connected to the other side of the transducer. The transducer measures the difference in pressure in the two groups of tubes by measuring the strain in a thin element using an electronic strain gauge. The pitot-static tube is mounted on the aircraft, or in a wind tunnel, so that the center tube is always pointed in the direction of the flow and the outside holes are perpendicular to the center tube. On some airplanes the pitot-static tube is put on a longer boom sticking out of the nose of the plane or the wing. Difference in Static and Total Pressure

Since the outside holes are perpendicular to the direction of flow, these tubes are pressurized by the local random component of the air velocity. The pressure in these tubes is the static pressure (SP) discussed in Bernoulli's equation. The center tube, however, is pointed in the direction of travel and is pressurized by both the random and the ordered air velocity. The pressure in this tube is the total pressure (T_P) discussed in Bernoulli's equation. The pressure transducer measures the difference in total and static pressure which is the dynamic pressure q.

$$Measurement = q = P_T - P_S$$

Solve for Velocity

With the difference in pressures measured and knowing the local value of air density from pressure and temperature measurements, we can use Bernoulli's equation to give us the velocity. Bernoulli's equation states that the static pressure plus one half the density times the velocity V squared is equal to the total pressure.

$$V = \sqrt{\frac{2(P_T - P_S)}{\rho}}$$

or

$$P_T - P_S = \frac{\rho V^2}{2}$$

5. Apparatus

1. Wind Tunnel
2. Manometer
3. Pitot Tube

6. Procedure

To calibrate a Pitot Tube

- Properly mount the pitot tube in the wind tunnel
- Connect the two tubes of the pitot tube to the manometer
- Start the wind tunnel
- Slowly increase the speed of the wind tunnel from 0 m/s to 18 m/s
- Record the values of differential pressure on the manometer against wind speed
- Plot the graph of differential pressure against wind speed in MATLAB/MS Excel
- Perform regression analysis and obtain a mathematical relationship between the independent and dependent variables.
- Ideally, you should get a second order polynomial relationship. ($P_T - P_S = \frac{\rho V^2}{2}$)
- Plot the ideal relationship assuming air density to be 1.225 kg/m^3
- Plot the experimentally obtained relationships onto the ideal relationship graph.
- Also plot the error plot i.e. the difference between the ideal and empirical results.
- What are the possible reasons for the error?

7. Tabulation

8. Calculation

9. Results

10. Precautions

1. If the velocity is low, the difference in pressures is very small and hard to accurately measure with the transducer. Errors in the instrument could be greater

than the measurement! So pitot-static tubes don't work very well for very low velocities.

2. If the velocity is very high (supersonic), we've violated the assumptions of Bernoulli's equation and the measurement is wrong again. At the front of the tube, a shock wave appears that will change the total pressure. There are corrections for the shock wave that can be applied to allow us to use pitot-static tubes for high speed aircraft.
3. If the tubes become clogged or pinched, the resulting pressures at the transducer are not the total and static pressures of the external flow. The transducer output is then used to calculate a velocity that is not the actual velocity of the flow. Several years ago, there were reports of icing problems occuring on airliner pitot-static probes. Output from the probes was used as part of the auto-pilot and flight control system. The solution to the icing problem was to install heaters on the probes to insure that the probe was not clogged by ice build-up.

1. **Experiment No.: ESC-205/05**
2. **Experiment Name: Experiment to verify Bernouli's theorem**
3. **Objectives:** To verify Bernouli's theorem
4. **Principle:**

The Bernoulli's theorem states that for steady, uniform and laminar flow of an incompressible fluid, the total energy unit weight or total head of each particle remains same along a stream line provided no energy is gained or lost.
Most of the hydraulic structures are based on the principle of Bernoulli's theorem. Verification of the above principle experimentally helps in better understanding of the principles of hydraulics.
Mathematically, Bernoulli's theorem can be expressed as
Total head (or) total energy per unit weight,

$$H_t = z + \frac{v^2}{2g} + \frac{p}{w} = constant$$

Where,

Z = datum head =position of conduit with respect to datum

$\frac{v^2}{2g}$ = Velocity head

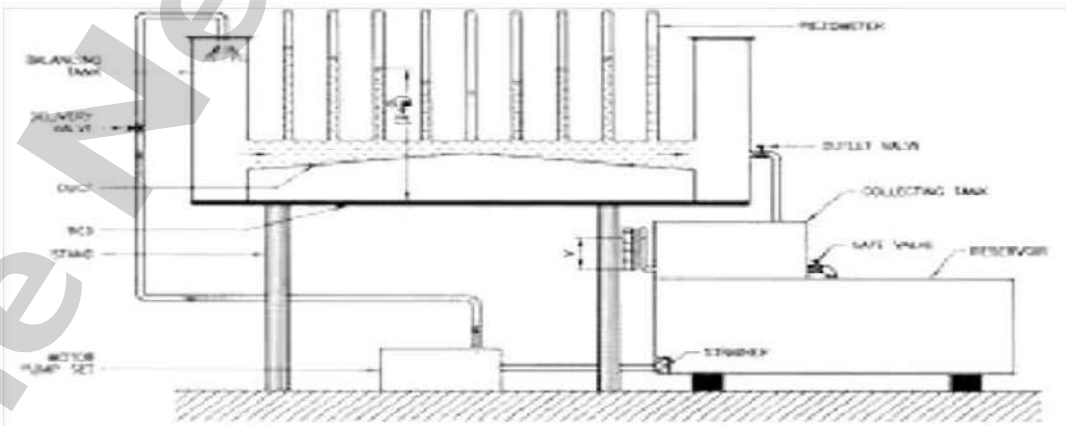
V= Velocity of flow $= \frac{Q}{A} = \frac{Actual\ discharge}{Cross\ sectional\ area}$

g = Acceleration due to gravity

$\frac{p}{w}$ = piezometric head or pressure head

W= Specific weight i.e., weight per unit volume $= \rho \times g = 9810\ N/m^3$

ρ = Mass density is the mass per unit volume of water.



Description of Equipment:

The experimental setup consists of a convergent- divergent passage of rectangular cross section made out of clear transparent sheet to facilitate visual observation of the flow. The passage walls are so made that the top of the wall is horizontal and the side walls are vertical and mutually parallel to each other. The lower wall is so constructed that it gives passage to the required convergence and divergence. The total length of test section of the passage is divided into number of equal lengths, where the peizometric tubes are fitted. Each of these peizometric tubes is provide with scale to measure the pressure energy or pressure heads.

At both the ends of the passage tanks are provided, which help to stabilize the flow. The calibrated scale is provided to measure the volume of water in the measuring tank based on the water level in the gauge glass.

The setup is provided with an arrangement for injecting a dye into the passage at its entrance through a fine nozzle with the help of which usual observation of the flow can be made.

5. Apparatus:

1. Bernoulli's apparatus
2. Collecting tank
3. Stop watch to measure the time of collection
4. Meter scale to measure the internal dimensions of the collecting tank

6. Procedure:

1. The experiment is conducted with datum line taken at the center line of the rectangular channel of varying cross sections and the same at all sections and considered 'zero' as its value.
2. Open the inlet valve to allow the flow from sully tank through the conduit. Also admit the dye into the passage.
3. Adjust the outlet valve of the apparatus, so that a constant head is maintained in the supply tank of apparatus.
4. Remove air bubbles in the peizometer tubes. Measure the pressure heads of various sections of the conduit with peizometers placed at each section.
5. Note the time 't' for collection of water to know rise 'H' of water level in the collecting tank.
6. Calculate the velocity and hence velocity head.
7. Tabulate the observations and calculate the total heads.

7. Tabulations

Observations and Tabulations										
Cross section		Time for H mm rise 't'in	Avg time 't'	Discharge Q= AH/t	Velocity V= Q/a	Velocity head V^2/2g	Pressure head h= P/W	Datum head z	Total head H
		s	S	mm^3/s	mm^3/s	mm/s	mm	mm	
No.	Area	Trail							
1	a1	1	2						
2	a2								
3	a3								
4	a4								
5	a5								
6	a6								
7	a7								

8. Calculation:

Area of collecting tank $A = L \times B$ = mm^2

Discharge $Q = \frac{AH}{T}$ = mm^3

Velocity $V = \frac{Q}{a}$ = mm/s

Velocity head $\frac{v^2}{2g}$ = mm

Pressure head $h = \frac{p}{w}$ = mm

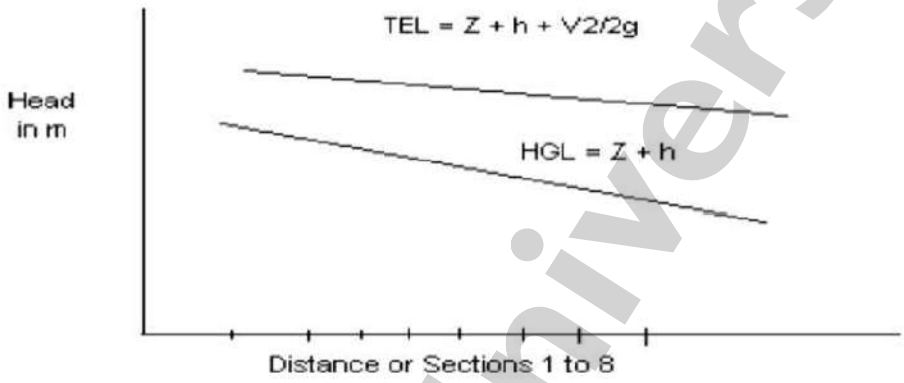
Datum head z = mm

Therefore total head at each station $H_t = z + \frac{v^2}{2g} + \frac{p}{w} =$ mm

$$H_t = z_1 + \frac{v_1^2}{2g} + \frac{p_1}{w} = z_2 + \frac{v_2^2}{2g} + \frac{p_2}{w} = constant$$

Graphs:

The graphs of pressure head, velocity head, and total head are drawn at various cross sections taking the cross section areas on x-axis.



9. Results:

Normal Graph:

9. Precautions:

5. The weir / notch should be fixed exactly in the vertical plane perpendicular to the flow axis.
6. 2. The weir should be fixed in a position such that it is symmetrical over vertical axis.
7. 3. Sufficient time should be given foe the flow to become steady-uniform.
8. 4. Gauge readings should be measured only in peizometre attached to the channel and not on the free surface

10. Possible Errors

4. Head should be constant in the head tank and the point gauge measurements before and after taking the readings of volumetric measurements (actual discharge) should be the same. If the measurements are not the same, take the average of the two readings.
5. Reading error may occur at gauge and volumetric peizometre scale by not recording the readings at the eye level.
6. Synchronize the stop watch operations for volumetric measurement

PRE-LAB QUESTIONS

1. State Bernoulli's theorem?
2. What is continuity equation?
3. What do you meant by potential head?
4. What do you meant by pressure head?
5. What do you meant by kinetic head?

POST-LAB QUESTIONS

4. What do you meant by velocity head?
5. What do you meant by HGL?
6. What do you meant by datum head?
7. What is the use of piezometer?

1. **Experiment No.: ESC-205/06**
2. **Experiment Name: Determination of metacentric height of a floating vessel**
3. **Objectives:** To Determine the metacentric height of a floating vessel
4. **Principle:**

The Stability of any vessel which is to float on water, such as a pontoon or ship, is of paramount importance. The theory behind the ability of this vessel to remain upright must be clearly understood at the design stage. Archimedes' principle states that the buoyant force has a magnitude equal to the weight of the fluid displaced by the body and is directed vertically upward. Buoyant force is a force that results from a floating or submerged body in a fluid which results from different pressures on the top and bottom of the object and acts through the centroid of the displaced volume.

This Laboratory experiment is an exercise in hydrostatics. It is designed to demonstrate the stability of a floating cylinder and to familiarize the student with the concept of buoyancy, metacenter, and metacentric height. It is also an experimental verification of the theory presented in the textbook.

The *center of the buoyancy* (C, the centroid of the displaced volume of fluid) of a floating body depends on the shape of the body and on the position in which it is floating. If the body is disturbed by a small angle of heel, the center of buoyancy changes because the shape of the submerged volume is changed. The point of intersection of the lines of action of the buoyancy force before and after heel is called the *metacenter* (M) and the distance between the *center of gravity* (G) and M, is called the *metacentric height* (GM, see Fig. 1).

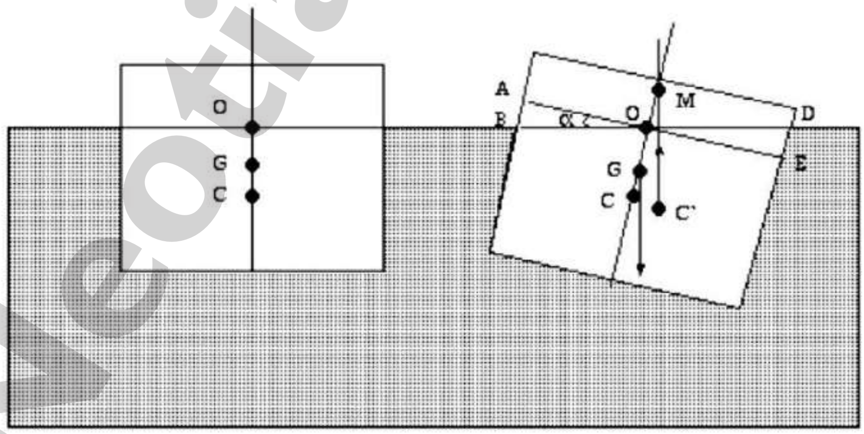


Fig. 1. Metacentric height of a floating body

The expression for the metacentric height GM is

$$GM = \frac{I_{oo}}{V} - CG$$

where I_{oo} is the moment of inertia of the waterline area about the axis of disturbance, and V is volume of the displaced liquid. For stability the metacentric height GM must be positive. Stability (restoring force) increases with increasing GM.

The objective of this experiment is to find the metacentric height and asses the stability of the several floating bodies.

5. Apparatus

There are three components of the experimental set-up:

1. Large vertically-standing cylinder containing fresh water
2. Small cylinder with a detachable cap at one end
3. Sand and a metric balance to weigh the cylinders

6. Procedures

1. Weigh the small cylinder and its cap together (*mc*)
2. Place the small empty cylinder into the large vertical cylinder containing fresh water and observe that it is unstable.
3. Pour a small amount of sand into the small cylinder (to give some ballast) and note if it is still unstable. Estimate how much of the cylinder is submerged, h, and then measure the height of sand, h_b.
4. Continue adding sand until the small cylinder remains vertical, i.e., stable. Measure the amount of cylinder that is submerged. Make sure that the open end of the small cylinder is capped when stability is reached.
5. Remove the small cylinder and measure its weight. Also measure the height of sand and record your results on the data sheet.

7. Tabulation

According to procedures described above, measure the following quantities:

Case	Mass (gm)	h (cm)	h_b (cm)
Fresh(unstable)			
Fresh (stable)			

Data Analysis

Figure 2 shows a slender, hollow circular cylinder which has been made stable in the vertical position by means of ballast placed inside. The cylinder floats in a liquid of density, ρ, with a depth of immersion, h. The center of buoyancy is C, and G_c and G_b are the centers of gravity of the cylinder and ballast, respectively.

The center of gravity of the cylinder/ballast is G and its metacenter is M. Other dimensions are shown in the figure. The masses of the cylinder and ballast, *mc* and *mb*, will be measured during the experiment.

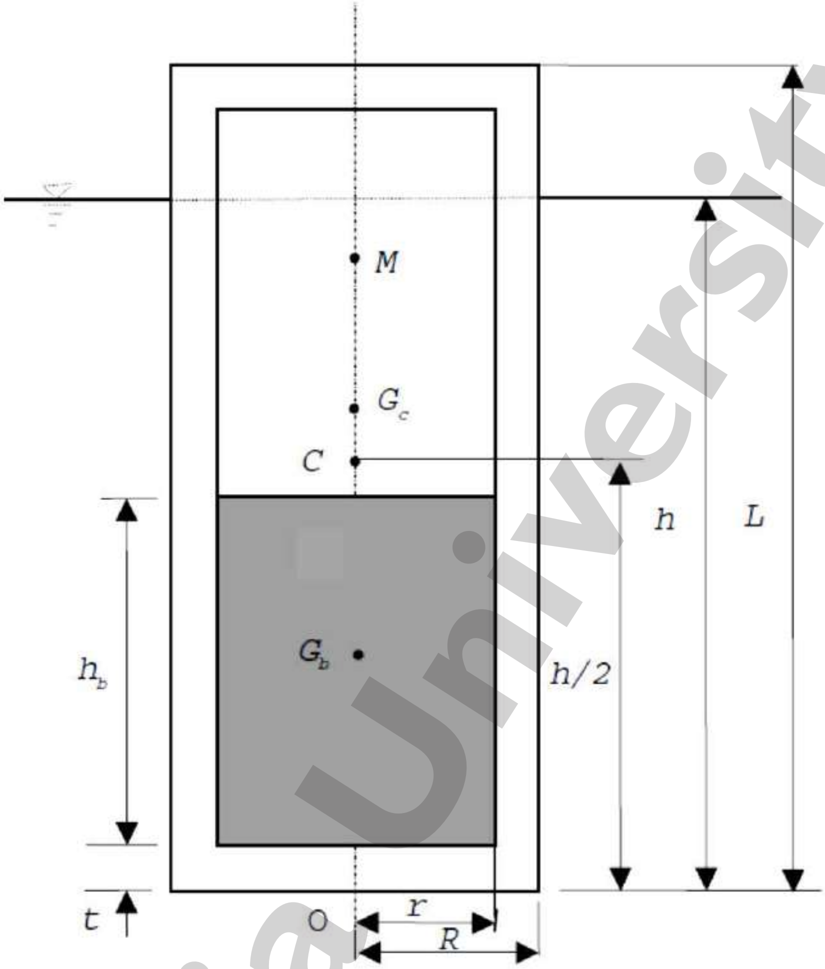


Fig. 2. Hollow cylinder with ballast.

Verify that:

1. The formula for h in terms of the cylinder radius, the density of the liquid ρ , and the masses, m_c and m_b,

$$h = \frac{(m_c + m_b)}{\pi R^2 \rho}$$

2. The formula for OG in terms of cylinder/ballast dimensions and the masses, m_c and m_b is

$$OG = \frac{OG_c m_c + OG_b m_b}{(m_c + m_b)} = \frac{m_c L/2 + m_b(h_b/2 + t)}{m_c + m_b}$$

3. The expression for the metacentric height, GM, is

$$GM = CM\text{-}CG = CM\text{-}(OG\text{-}OC) =$$
$$= \frac{I_{oo}}{V} - \frac{m_c L/2 + m_b(h_b/2 + t)}{m_c + m_b} + h/2$$
$$= \frac{R^2}{4h} - \frac{m_c L/2 + m_b(h_b/2 + t)}{m_c + m_b} + h/2$$

4. From the immersion, h, of the cylinders in the fresh water calculate the density of the fluid in gm/cm^3.
5. Calculate the metacentric height for the fresh in centimeters. Check the stability condition. Record all of your results in the following table.

	R (cm)	L (cm)	m_c	m_b	h (cm)	h_b (cm)	OG (cm)	GM (cm)
Result								

Further Considerations

1. Is there any other equilibrium position of the cylinder except the vertical position?
2. Consider a circular cylinder of homogeneous material of specific gravity, s = 0.5, length, L, and diameter, D, stable at the position shown in Fig. 3. Find the formulas for the immersion of the cylinder h at this position.

Fig. 3. Cylinder parallel to the water surface.

3. Consider a cylinder made with a plate thickness, $t = D/20$, but of a material such that the average value of s is still 0.5 shown in Figure 4. For L = 40cm and D = 4cm, find the position of stable equilibrium and the immersion, h.

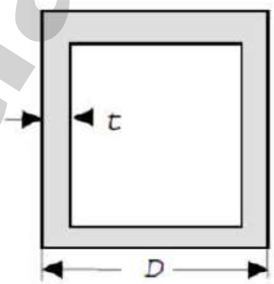


Fig. 4. Hollow cylinder

4. Determine the ranges of D/L for which the positions of the cylinders (vertical and horizontal) are stable.
5. What will happen if we change the density of the fluid, using brine, say, instead of fresh water?

8. Results

Name	R(cm)	L(cm)	m_c	m_b	h(cm)	h_b(cm)	OG(cm)	GM(cm)
Result								

1. **Experiment No.: ESC-205/07**
2. **Experiment Name:** Flow through pipes: Pipe friction in laminar and turbulent flow regimes
3. **Objectives:** To Determine the Darcy friction co-efficient
4. **Principle:**

Due to the viscous resistance between the layers of flowing fluid and the layer and boundary, friction is developed, which opposes the motion. This co-efficient of friction can be obtained from Darcy– Weisbach equation.

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

Where,

h_f = Head loss due to friction = $x\left(\frac{s_m}{s} - 1\right)$

m = Specific gravity of manometric fluid, i.e. water = 13.60

s = Specific gravity of flowing fluid, i.e. water = 1.00

x = Difference in levels of the manometric fluid in the two limbs of manometer

f = Coefficient of friction.

l = Length of the pipe; d = Diameter of the pipe.

V = velocity of water in the pipe = $\frac{Q_a}{a}$

Q_a= Actual discharge

a = Cross section area of the pipe

g = Acceleration due to gravity = 9.81m/s^2

Actual discharge, $Q_a = \frac{A \times r}{t}$

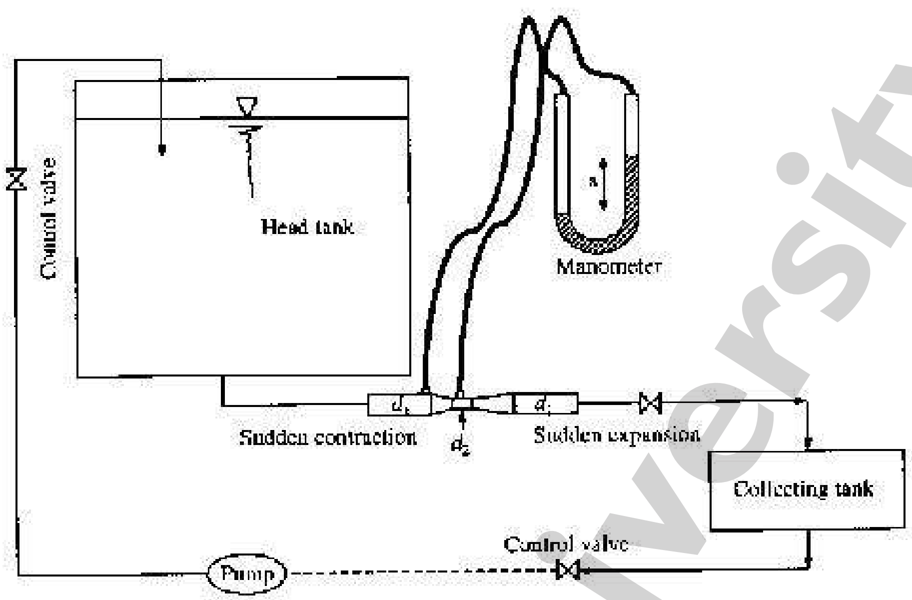
A = Area of measuring tank

r = Rise of water level in the measuring tank

t = Time for r cm rise in measuring

5. **Apparatus:**

1. A small diameter pipe line
2. U-tube manometer to measure the difference across the tapings
3. A constant steady supply of water with a means of varying discharge
4. Measuring tank and stop watch to measure the actual discharge



6. Procedure:

1. Note down diameter of the pipe.
2. Connect the two limbs of manometer to the two gauge pints.
3. Allow the water to flow into the pipe by opening the gate valve.
4. Vent the manometer by removing the air bubbles in the tube.
5. Note down the difference in the level of manometric fluid in the left and right limb.
6. Note down the time required to fill particular height of water in the collecting tank.
7. Repeat Steps 3 to 5 for various discharges by varying the gate valve for four more trials.

7. Tabular Column:

S. No.	Manometer reading $x = (x_1 - x_2)$	Equivalent water head h=12.6x	Time for ------mm Rise in tank (t)	$Q_a = \frac{A \times r}{t}$	Velocity of Water $V = \frac{Q_a}{a}$	F	R_e
	M	M	S	m^3/s	m/s		
1							
2							
3							
4							
5							

8. Calculation

$Q_a = \frac{A \times r}{t} =$ ………; A = ………. × ……….. = ……….. m^2;

$Q_a = \frac{(\quad \times \quad)}{(\quad)} =$ …………… m^3/s

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

$h = x\left[\frac{s_m}{s} - 1\right] = 12.6x =$……………m

$g = 9.81\ m/s^2$

$V = \frac{Q_a}{a} =$ ………………… $a = \frac{\pi d^2}{4} =$ ……………… m^2; d = diameter of the pipe

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

$R_e = \frac{16}{f}$ for $R_e < 2000$

$f = \frac{0.079}{(R_e)^{1/4}}$ for $2000 < R_e < 10^6$

$R_e = \frac{3.895 \times 10^{-5}}{f^4}$

GRAPH: Draw *vs f* graph

9. Results

Normal Graph

10. Possible Errors:

1. The manometric reading (head) for the flow through the pipe before and after taking readings of volumetric measurements (actual discharge) should be the same. If not, take the average of the two readings for volumetric readings.
2. Reading errors at manometer and volumetric piezometer scale may occur by not recording the readings at the eye level.
3. Synchronize the stopwatch operations for volumetric measurements.
4. U-tube mercury manometer records very low head difference by showing small readings. Using inverted U-tube manometer will have better sensitivity.

PRE-LAB QUESTIONS

1. List out the various types of pipe fittings?
2. What do you meant by minor losses?
3. What are the types of losses in pipe flow?
4. What do you meant by entry loss?
5. What do you meant by exit loss?

POST-LAB QUESTIONS

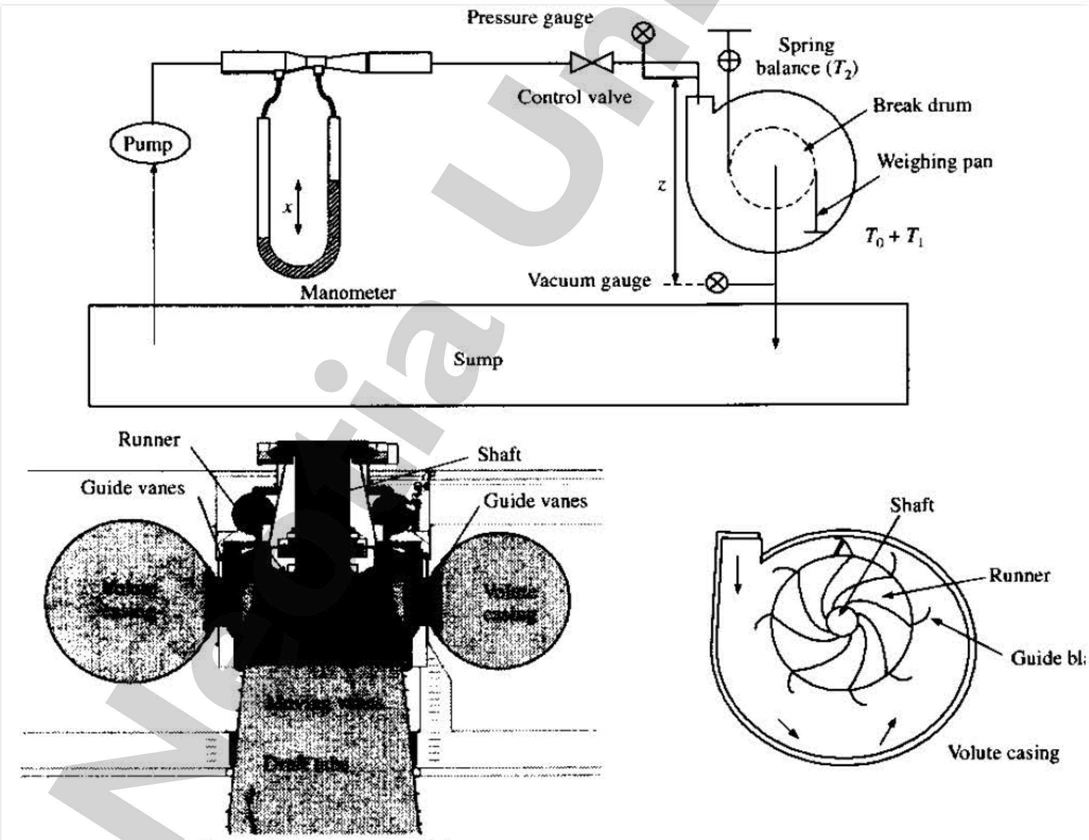
1. What is the equation for head loss due to sudden enlargement?
2. What is the equation for head loss due to sudden contraction?
3. What is the equation for head loss due to bend?
4. What is the equation for head loss at entry of pipe?
5. What is the equation for head loss at exit of pipe?
6. Which Newton's law is applicable to impulse turbine?

1. **Experiment No.: ESC-205/08A**
2. **Experiment Name: Experiments on Hydro-Turbines: Francis and Pelton turbines**
3. **Objectives:** Performance test on Francis Turbine (a) at head (b) at constant speed
4. **Principle:**

Francis turbine is a hydraulic machine used to convert hydraulic energy into mechanical energy which in turn is converted to electrical by coupling a generator to turbine.

Francis turbine is medium head, medium discharge, radially inward flow reaction turbine.

A Venturimeter with the manometer is provided to calculate the amount of water (discharge) supplied to the turbine. Pressure gauge is fixed to measure the head of water. Using the tachometer, measure the speed of the turbine.



Francis turbine cross-section

$Q_a = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$

Where, $a_1 = \frac{\pi d_1^2}{4}$ and $a_2 = \frac{\pi d_2^2}{4} =$ …………… m^2

d_1 = Diameter of the inlet of Venturimeter and d_2 = diameter of the throat of Venturimeter

h = x $\left[\frac{S_m}{S} - 1\right]$ = ……………………… x = $x_1 - x_2$ m g = 9.81 m/ sec^2

h = Equivalent water head

s_m = Specific gravity of manometric fluid, i.e. mercury = 13.60

S = Specific gravity of flowing fluid, i.e. water = 1.00

X = Difference in levels of the manometric fluid in the two limbs of manometer

Input to the turbine = γQH kW

γ = Specific weight of water 9.81 kN/m^3

Q = Discharge

H = Head (G + V) × 10

Z = Vertical difference between pressure gauges

Output of the turbine = O.P. = $\frac{\pi DNT}{60}$ = ………………………..kW

D = Equivalent brake drum diameter …………………………… m

N = Speed of the turbine = …………………………..rpm

T = $(T_1 - T_2 + T_0) \times 9.81N$

T_1 = Load on brake drum in kg

T_2 = Spring balance reading in kg

T_0 = Weight of the hanger in kg

Efficiency of the turbine = η = $\frac{Output}{Input}$ × 100%

5. Apparatus:

1. Centrifugal pump to supply water at required head
2. Francis Turbine
3. Pipe network system with necessary control valves
4. Pressure Gauge and Vacuum Gauge
5. Tachometer to measure the speed of the shaft
6. Venturimeter along with manometer to measure the discharge
7. Rope brake with spring balance and weighing pan to measure torque

6. Procedure:

1. Prime the pump with water.
2. Keeps the gate opening to the required position.
3. Open the gate valve 1 or 2 rotations.
4. Start the motor.
5. Allow the water into the turbine and the turbine starts to rotate.
6. Fix the weight hanger to the rope of the brake drum with no load on weight hanger.
7. By varying the gate valve, keep the head constant using the tachometer to the required speed in case of experiment on constant speed.

8. Note down the following readings :
   (a) Pressure gauge reading, G
   (b) Vacuum gauge reading, V
   (c) Speed of the turbine, N
   (d) Manometer readings,
   (e) Load on weight hanger,
   (f) Spring balance reading indicate the frictional loss between the brake drum and rope,
9. Repeat the step 8 for different load conditions by varying the load on the weight hanger either to constant head or for constant speed.
10. Note down the above readings G, V, N,
11. Take at least 5 sets of readings by varying the load.
12. Calculate the efficiency of the turbine.

7. Tabulation

S. No.	Pressure Gauge Read (G)	Vacuum gauge reading (V)	Total head (H)	Mano-meter reading	Equivalent water head	Actual discharge Q_a	Speed (N)	Load $T = T_0 + T_1 - T_2$			Input	Output	Efficiency (η)
				x	H = 12.6x			T_1	T_2	T			
	Kg/cm^2	M	m		M	m^3/s	rpm	kg	kg	N	kW	kW	%
1													
2													
3													
4													
5													

8. Calculation

$$Q_a = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh} = \ldots\ldots\ldots\ldots\ldots\ldots\ m^3/S$$

$$I.P. = \gamma Q H = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots kW$$

$$O.P. = \frac{\pi DNT}{60} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots kW$$

$$\text{Efficiency of the turbine} = \eta = \frac{Output}{Input} \times 100\%$$

9. Results

10. Precautions

1. Check for priming of the pump so that air bubbles are not developed.
2. Check for the possible leakages at delivery and suction pipes.
3. Sufficient time should be given for the flow to become steady – uniform.
4. Voltage and current input to the pump – motor should be maintained near constant during values are to be considered.
5. Gauge readings should be maintained constant, and if varying during the readings, average values are to be considered. Tachometer used to measure speed of the shaft should be periodically calibrated and for constant speed characteristics, the speed should be checked both at the beginning and in the end of the trial, and if found to be different, average should be considered.
6. The air bubbles should be completely removed in the pipe connecting the manometer. This should be achieved only by opening the valves provided at the top of the manometers simultaneously. If they are opened separately, the manometeric fluid (usually mercury, which is very costly) will spill out of manometer.
7. Diameter of the break drum and the rope should be properly measured and recorded.
8. Weights and spring balance used should be periodically calibrated.

11. Possible Errors

1. Sensitivity of the pressure gauge may affect the computation of the efficiency and analysis of performance of the pump.
2. The manometeric reading (head) for the flow through the pipe before and after taking readings should be the same. If not, take the average of the two readings.
3. Reading errors at manometer and spring balance by not recordings at the eye level.

Pre Lab Questions:

1. What is a reaction turbine**?**
2. What is difference between impulse and reaction turbine?
4. Specify the flow of the Francis turbine.
5. What head Francis turbine used?
6. What is purpose of draft tube in reaction turbine?
7. What is cavitation?

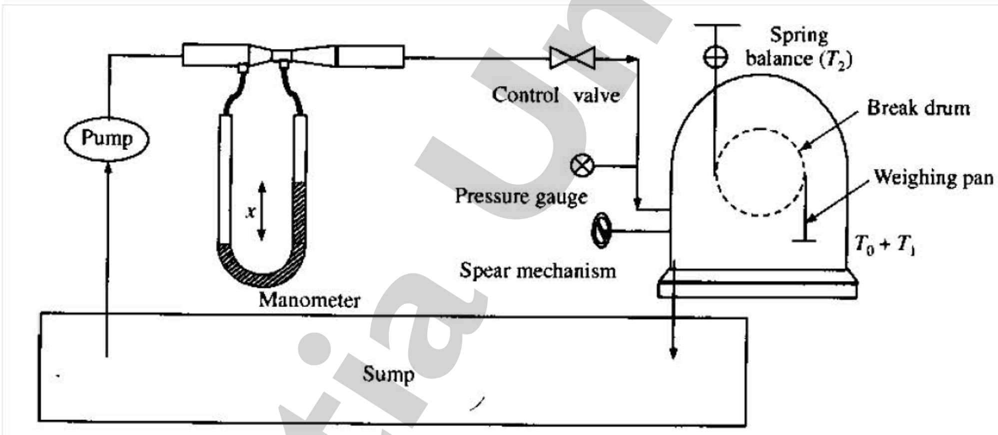
POST LAB QUESTIONS:

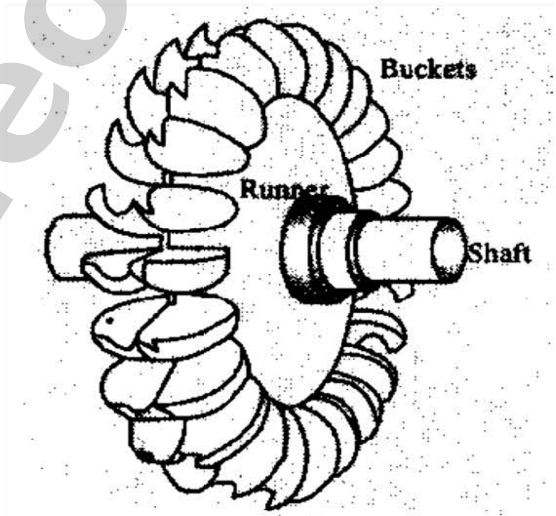
1. How do you Francis wheel is which type of turbine
2. How do you differentiate between impulse and reaction turbine?
3. What is the use of draft tube?
4. What is the use of draft tube?

1. **Experiment No.: ESC-205/08B**
2. **Experiment Name: Experiments on Hydro-Turbines: Francis and Pelton turbines**
3. **Objectives:** Performance test on Pelton Wheel (Turbine) (a) at constant head and (b) at constant Speed
4. **Principle:**

Peloton turbine is a high head, impulse turbine, which is used to generate electricity at high heads of water. All the available head is converted into velocity head by means a nozzle which is controlled by spear and nozzle arrangement.

A Venturimeter with a U-tube manometer is provided to calculate the amount of water (discharge) supplied to the turbine. Pressure gauge is fixed to measure the head of water. Using the tachometer the speed of the turbine is measured.





$$Q_a = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

Where, $a_1 = \frac{\pi d_1^2}{4}$ and $a_2 = \frac{\pi d_2^2}{4} m^2$

d_1 = Diameter of the inlet of Venturimeter and d_2 = diameter of the throat of Venturimeter

$h = x\left[\frac{S_m}{S} - 1\right] =$ …………………… $x = x_1 - x_2$ m $g = 9.81\ m/sec^2$

h = Equivalent water head

s_m = Specific gravity of manometric fluid, i.e. mercury = 13.60

S = Specific gravity of flowing fluid, i.e. water = 1.00

x = Difference in levels of the manometric fluid in the two limbs of manometer

Input to the turbine = γQH kW

γ = Specific weight of water 9.81 kN/m^3

Q = Discharge

H = Head (G × 10) m(pressure gauge reading)

Output of the turbine = O.P = $\frac{\pi DNT}{60}$ = ……………. kW

D = Equivalent brake drum diameter …………………m

N = Speed of the turbine = ………………………rpm

T = Resultant load = ………………………N

$T = (T_1 - T_2 + T_0) \times 9.81\ N$

T_1 = Load on brake drum in kg

T_2 = Spring balance reading in kg

T_o = Weight of the hanger in kg

Efficiency of the turbine = η = $\frac{Output}{Input} \times 100\ \%$

5. Apparatus:

1. Centrifugal pump to supply water at required head
2. Peloton Wheel
3. Pipe network system with necessary control valves
4. Pressure gauge
5. Tachometer to measure the speed of the shaft.
6. Venturimeter along with manometer to measure the discharge
7. Rope brake with spring balance and weighing pan to measure torque

6. Procedure:

1. Prime the pump with water.
2. Keep the nozzle – opening to the required position.

   Open the gate valve 1 or 2 rotations.
3. Start the motor
4. Allow the water into the turbine and the turbine will start rotating.
5. Fix the weight hanger to the rope of the brake drum with no load on weight hanger.

6. By varying the gate valve, keep the head constant using the pressure gauge to the required head in case of experiment on constant head or keeps the speed constant using the tachometer to the required speed in case of experiment on constant speed.
7. Note down the following readings :

   (a) Pressure gauge reading, G

   (b) Vacuum gauge reading, V

   (c) Speed of the turbine, N

   (d) Manometer readings, h_1 and h_2

   (e) Load on weight hanger, T_1

   (f) Spring balance reading indicating the frictional loss between the brake drum and rope, T_2

   (g) Repeat step 8 for different load conditions by varying the load on the weight hanger either to constant head or for constant speed.

   (h) Note down the above readings G, V, N, h_1, h_2, T_1, and T_2

   (i) Take at least 5 sets of readings by varying the load.

   (j) Calculate the efficiency of the turbine.

7. Tabulation

S.No.	Pressure gauge read (G)	Total Head (H)	Mano Meter reading	Equivalent water head	Actual discharge Q_a	Speed (N)	Load $T = T_0 + T_1 - T_2$			In put	Out put	Efficiency (η)
			X	h = 12.6x			T_1	T_2	T			
	Kg / cm^2	m	M	m	m^3/s	rpm	Kg	Kg	N	kW	kW	%
1												
2												
3												
4												
5												

8. Calculation

$$Q_a = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh} = \ldots\ldots\ldots\ldots\ldots \; m^3/s$$

I.P. = γQH = ………………………….kW

O.P. = $\frac{\pi DNT}{60}$ =………………………….kW

Efficiency of the turbine = $\eta = \frac{Output}{Input} \times 100\%$

9. Results

10. Precautions

1. Check for priming of the pump so that air bubbles are not developed.
2. Check for the possible leakages at delivery and suction pipes.
3. Sufficient time should be given for the flow to become steady – uniform.
4. Voltage and current input to the pump – motor should be maintained near constant during values are to be considered.
5. Gauge readings should be maintained constant, and if varying during the readings, average values are to be considered. Tachometer used to measure speed of the shaft should be periodically calibrated and for constant speed characteristics, the speed should be checked both at the beginning and in the end of the trial, and if found to be different, average should be considered.
6. The air bubbles should be completely removed in the pipe connecting the manometer. This should be achieved only by opening the valves provided at the top of the manometers simultaneously. If they are opened separately, the manometeric fluid (usually mercury, which is very costly) will spill out of manometer.
7. Diameter of the break drum and the rope should be properly measured and recorded.
8. Weights and spring balance used should be periodically calibrated.

11. Possible Errors

1. Sensitivity of the pressure gauge may affect the computation of the efficiency and analysis of performance of the pump.
2. The manometeric reading (head) for the flow through the pipe before and after taking readings should be the same. If not, take the average of the two readings.
3. Reading errors at manometer and spring balance by not recordings at the eye level.

Pre Lab Questions:

1. What is a reaction turbine?
2. What is difference between impulse and reaction turbine?
4. Specify the flow of the Francis turbine.
5. What head Francis turbine used?
6. What is purpose of draft tube in reaction turbine?

7. What is cavitation?

POST LAB QUESTIONS:

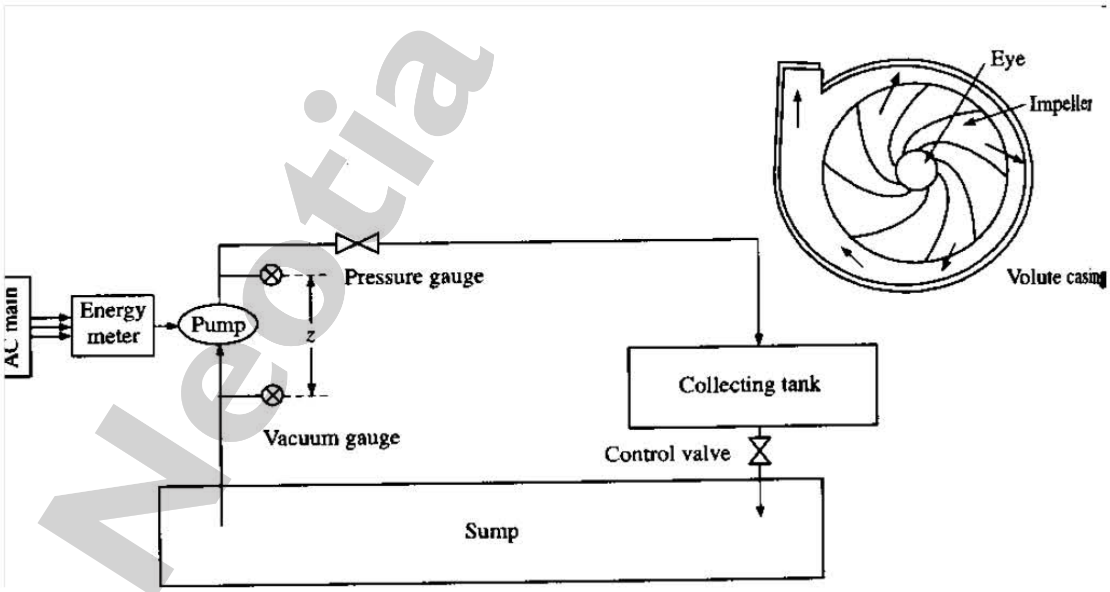
1. How do you Francis wheel is which type of turbine
2. How do you differentiate between impulse and reaction turbine?
3. What is the use of draft tube?
4. What is the use of draft tube?

1. **Experiment No.: ESC-205/09A**
2. **Experiment Name: Experiments on Fluid Machinery: Pumps, jet pumps**
3. **Objectives:** To conduct the performance test on single stage centrifugal pump.
4. **Principle:**

A centrifugal pump is a Hydraulic machine which converts mechanical energy to hydraulic energy, used to lift water from lower level to higher level. A centrifugal pump consists of essentially an impeller rotating inside a casing. The impeller has a number of curved vanes. Due to centrifugal head impressed by the rotation of the impeller, the water enters at the centre and flows outwards to the periphery. There, it is collected in a gradually increasing passage in the casing, known as volute chamber, which serves to convert a part of the velocity head into pressure head. For higher heads, multi stage centrifugal pumps having two or more impellers in series will have to be used.

A single/multistage centrifugal pump is coupled to a motor. In this experiment, the efficiency of the centrifugal pump at constant speed is computed.

An energy meter is provided to measure the input to the motor and a collecting tank is provided to calculate the discharge from the pump. Pressure and vacuum gauges are provided in the delivery and suction sides of the pump to measure the heads, respectively.



$$Q_a = \frac{A \times r}{t} \; m^3/s$$

$$H = G + V + z + \frac{V_d^2 - V_s^2}{2g} \; m$$

G = Pressure head, V = Vacuum head

z = Vertical difference in level between pressure and vacuum gauges

V_d = Velocity of water in delivery pipe

V_s = Velocity of water in suction pipe

g = Specific gravity = 9.81 m/sec^2

Output from the pump = γQHkW

where, γ is the specific weight of water = 9.81 kN/m^3; Q is the discharge through the pump in m^3/s, and H is the total head in m

Input to the pump = I.P = $\eta_{motor} \times \frac{3600 \times 10}{NT}$ kW

η_{motor} = Efficiency of the motor = 85% (assumed)

N = Energy meter constant revolutions / kWh

T = Time for 10 revolutions of the disk in energy meter Efficiency = $\eta = \frac{output}{input}$

5. Apparatus

1. Single stage Centrifugal pump with an electric motor device (constant speed)
2. Pipe network system with necessary control valves
3. Vacuum and pressure gauges
4. An energy meter to measure the input power to the motor
5. Measuring tank and stop watch to measure the actual discharge

6. Procedure

1. Prime the pump with water
2. Open the gate valve 1 or 2 rotations
3. Start the motor and set the vacuum gauge reading to the required head.
4. Note down the following reading:
   (i) Pressure gauge reading, G
   (ii) Vacuum gauge reading , V
   (iii) Time taken for 10 revolutions in the energy meter, T
   (iv) Time taken to fill up 200 cm rise in the collecting tank, t
   (v) The difference in the levels of the pressure and vacuum gauges, x
5. And then set the vacuum gauge reading to the other heads.
6. Note down the above readings G, V, T and t
7. Take at least 5 sets of readings by varying the head through delivery valve and note down the readings.

7. Tabulation

S. No	Pressure gauge reading (G)	Vacuum gauge reading (V)	Total head (H)	Time for ________ mm rise in tank (t)	Actual discharge (Q)	Time for 10 Revolutions in energy meter (T)	Input	Output	Efficiency
	kg/cm^2	Kg/cm^2	m	S	m^3/s	S	kW	kW	%
1									
2									
3									
4									
5									

8. Calculation

Actual discharge, $Q_a = \frac{A \times r}{t}$

A = Area of measuring tank = ………………. × …………... = ……………. m^2

r = Rise of water level in the measuring tank = …………………

t = Time for r cm rise in measuring tank = ……………………

Total head, $H = G + V + z + \frac{V_d^2 - V_s^2}{2g}$ = ……………………

G = ……………….. kg/cm^2 = …………….. × 10 m of water

V = ……………….. kg/cm^2 = …………….. × 10 m of water

Out from the pump = γQH = ………………… kW

γ = Specific weight of water 9.81 kN/m^3

Q = Discharge from the pump

H = Total head

Input to pump = $\eta_{motor} \times \frac{3600 \times 10}{NT}$ = …………… kW

Efficiency of the pump = $\eta = \frac{Output}{input} \times 100\%$

GRAPHS:

Draw the graph of output vs input. The slope of the straight line fit gives the efficiency

9. Results

10. Precautions

1. Check for the priming of the pump so that air bubbles are not developed.
2. Check for the possible leakages at delivery and suction pipes.
3. Sufficient time should be given for the flow to become steady- uniform.

4. Voltage and current input to the pump-motor should be maintained near constant during the recording of readings.

5. Both delivery and suction gauge readings should be maintained constant, and if varying during the readings, average values are to be considered.

11. Possible Errors:

1. Sensitivity of the pressure gauge may effect the computation of the efficiency and analysis of performance of the pump.
2. Ignoring the vertical difference between the delivery and suction gauges.
3. The head for the flow through the pipe for the jet before and after taking readings of volumetric measurements (actual discharge) should be the same. If not, take the average of the two readings for volumetric readings.
4. Reading errors at volumetric piezometer scale may occur by not recording the readings at the eye level.
5. Synchronize the stopwatch operations for volumetric measurements.

PRELAB QUESTIONS

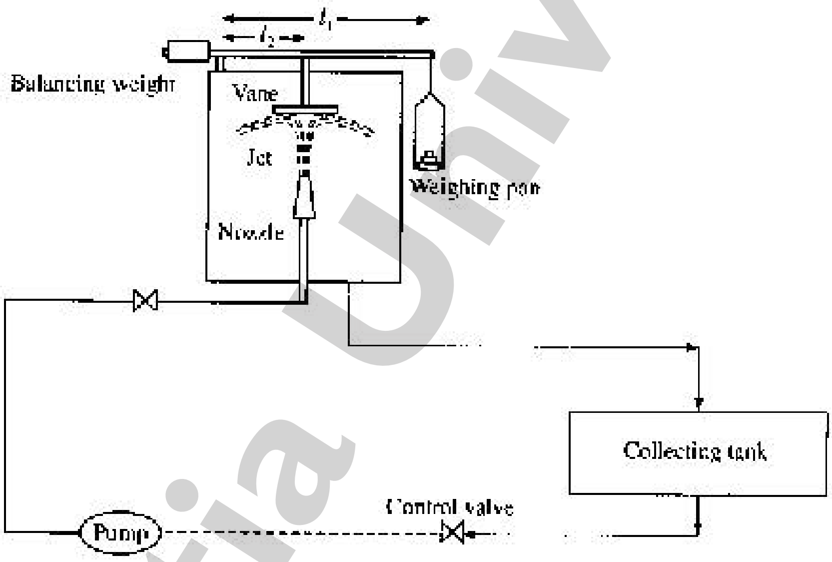
1. What is a pump?
2. What is a centrifugal pump?
3. What are forces involved in impeller?
4. What is priming

POSTLAB QUESTIONS

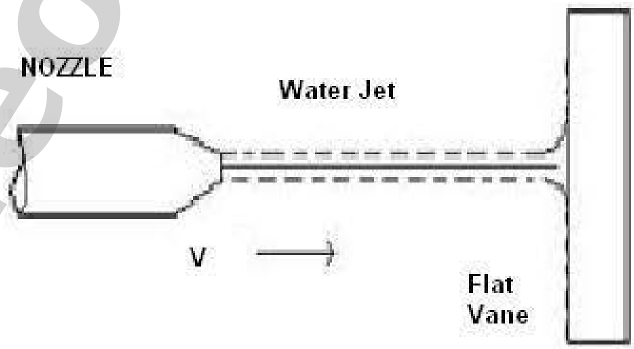
1. How do you classify the pumps?
2. What is the difference between centrifugal pump and reciprocating pump?
3. Which one is delivers maximum discharge
4. What is the use of priming?

1. **Experiment No.: ESC-205/09B**
2. **Experiment Name: Experiments on Fluid Machinery: Pumps, jet pumps**
3. **Objectives:** To determine the coefficient of impact of jet by comparing the momentum in a fluid jet with the force generated when it strikes a fixed surface/vane.
4. **Principle:**

The apparatus consists of a water jet issuing from a nozzle with a high velocity, which is connected to a high head pump main or an over head tank. All the pressure head of water is converted in to velocity head by the nozzle, which discharges the water in to the atmosphere. The jet then strikes the vane. The kinetic energy of the jet is transmitted to the vanes which lifts the vane upwards.



Experimental setup of Impact of jet



5. **Apparatus:**
   1. A nozzle of known diameter
   2. A flat plate/vane of which the water jet can impinge
   3. Weighing pan, weights and lever arm to measure the force of the jet on the flat plate
   4. A constant steady supply of water with a means of varying discharge
   5. Measuring tank and stop watch to measure the actual discharge

6. Procedure:

1. Fit the flat vane into slot and weighing pan to the lever arm.
2. Measure the differential lever arms l_1 and l_2 from pivot to the weighing pan and pivot to the vane, respectively.
3. Note down diameter of the jet/nozzle.
4. Balance the lever arm system by means of counter weight for no load.
5. Open the gate valve by 1 or 2 rotations.
6. Place the weight on the hanger.
7. Start the pump.
8. Adjust the jet so that the weight applied on hanger is balanced.
9. Note down the following readings:
   (i) Weight on the hanger (w)
   (ii) Time for 50 mm rise of water level in the measuring tank (t)
10. Repeat steps 6, 8 and 9 for different weights on hanger for four more trials.

7. Tabulation:

S. No.	Weight on hanger (w)	$F_a = \frac{l_1}{l_2} \times w \times 10^{-5}$	Time for ------------- mm rise in tank(t)	$Q_a = \frac{A \times r}{t}$	Velocity of water jet $v = \frac{Q_a}{a}$	F_t	Efficiency (η)
	gm	kN	S	m^3/s	m/s	kN	
1							
2							
3							
4							
5							

8. Calculations:

Actual force lifted, $F_a = w \times \frac{l_1}{l_2}\ kN$

Theoretical force lifted, $F_t = \rho a v^2 \sin\theta\ kN$

Efficiency of the vane, $\eta = \frac{F_a}{F_t} \times 100$

Area of measuring tank $A = l \times b$ = …………….. × …………….. = ………………. m^2

Angle of the vane = θ = ………………….

Lever arm lengths, l_1 = …………….. m; l_2 = …………………… m

Diameter of the jet = d = ……………… m

SPECIMEN CALCULATION:

Actual discharge, $Q_a = \frac{A \times r}{t}$ = ……………………………………………………….

Actual force lifted, $F_a = \frac{l_1}{l_2} \times w \times 10^{-5}$ ………………………………… kN

Where

w = Weight on hanger = ………………….. gm

l_1 and l_2 = Lever arm lengths

Theoretical force lifted, $F_t = \rho a V^2 \sin\theta$ = …………………………………… kN

ρ = Specific weight of water 9.81 kN/m^3

a = Cross – section area of the jet

V = Velocity of water

θ = Angle of the vane

Efficiency of the vane, $\eta = \frac{F_{act}}{F_{theo}} \times 100$ =

9. Result:

Graphs:

Draw the graph of vs .The slope of the straight line fit gives the efficiency

10. Precautions:

1. Fix the vane exactly symmetrical with the jet axis except for inclined vane. In the case of inclined vane, the fixed vane angle should match with the angle specified on the vane.
2. Sufficient time should be given for the flow to become steady-uniform.
3. The balancing arm should be made near frictionless by proper oiling at the pivot.
4. The balancing drum should be properly placed such that the balancing arm should be horizontal after fixing the vane and weight hanger in position.
5. The weights are too small and should be properly calibrated periodically.
6. Volumetric measurements can be preferred to pressure gauge readings to avoid errors in the computation of the jet velocity.

11. Possible Errors:

1. Sensitivity of the pressure gauge may affect the computation of velocity of the jet.
2. The horizontal level of the balancing arm should be properly adjusted.

3. The head for the flow through the pipe for the jet before and after taking readings of volumetric measurements (actual discharge) should be the same. If not, take the average of the two readings for volumetric readings.
4. Reading errors at volumetric piezometer scale by not recording the read

PRE-LAB QUESTIONS

1. What is the water jet?
2. What is the effect of water jet on vanes?
3. What do you meant by impact?
5. List out different types of vanes?

POST-LAB QUESTIONS

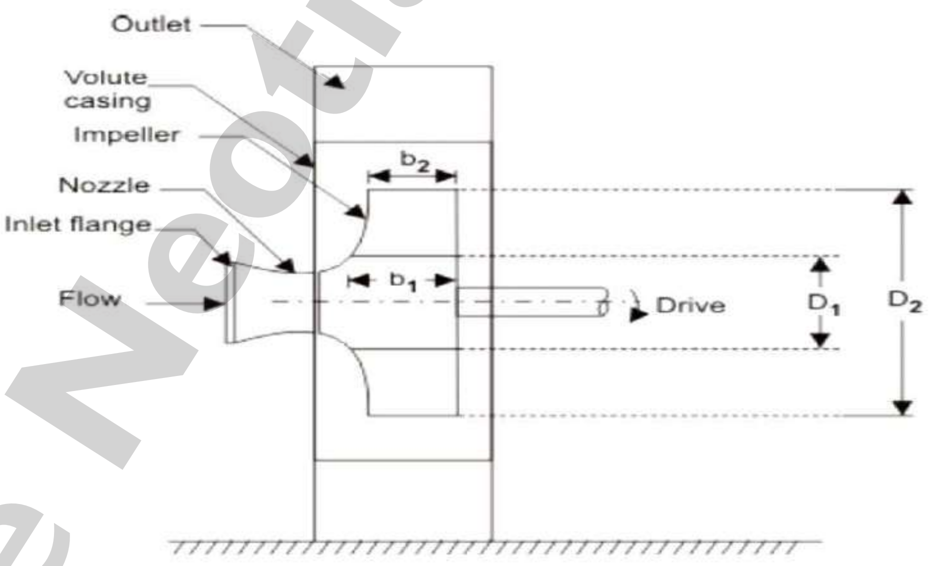
1. How do you compare different vanes?
2. What do you meant by co-efficient of impact?
3. How do you measure the force of the jet?
4. How do you measure actual flow rate?
5. How do you measure theoretical flow rate

1. **Experiment No.: ESC-205/10A**
2. **Experiment Name: Experiments on Fluid Machinery: Blowers, Compressors**
3. **Objectives:** To conduct the performance test on the centrifugal blower & determine the overall efficiency at various gate openings.
4. **Principle:**

Blowers *are turbo machines which deliver air at a desired high velocity (and accordingly at a high mass flow rate) but at a relatively low static pressure.*

The rise in static pressure across a blower is relatively higher and is more than 1000 mm of water gauge that is required to overcome the pressure losses of the gas during its flow through various passages. A blower may be constructed in multi stages for still higher discharge pressure.

A large number of blowers for relatively high pressure applications are of centrifugal type. The main components of a centrifugal blower are shown in Fig. A blower consists of an impeller which has blades fixed between the inner and outer diameters. The impeller can be mounted either directly on the shaft extension of the prime mover or separately on a shaft supported between two additional bearings. Air or gas enters the impeller axially through the inlet nozzle which provides slight acceleration to the air before its entry to the impeller. The action of the impeller swings the gas from a smaller to a larger radius and delivers the gas at a high pressure and velocity to the casing. The flow from the impeller blades is collected by a spiral-shaped casing known as *volute casing* or *spiral casing* . The casing can further increase the static pressure of the air and it finally delivers the air to the exit of the blower.



Main components of a centrifugal blower

1. Flow across Pitot tube $= h_a = \dfrac{h \times \rho_{water}}{\rho_{air}}$ m

Where h = Flow Head in m of water

$$\rho_{water} = 1000 \, kg/m^3$$

$$\rho_{air} = 1.293 \, kg/m^3$$

2. Static Head $h_{sh} = \dfrac{h_w \times \rho_{water}}{\rho_{air}}$ m

Where h_w = flow head in meter of water.

3. Velocity of Air $= v = \sqrt{2gh_a} \; m/s$

4. Actual Volume of Air Discharged $Q_a = A \times v \; m^3/s$

Where A = Area of duct in m^2

5. Input Power $IP = \dfrac{3600 \times n \times \eta_m}{K \times T}$ KW

Where n = No of Revolution of energy meter

K = Energy meter Constant

T = Time For n revolution of energy meter

η_m = Efficiency of belt Transmission = 0.7

6. Output power $OP = \dfrac{\rho_a \times g \times Q_a \times h_{sh}}{1000}$ kW

7. Efficiency of the blower

$$\eta = \frac{OP}{IP} \times 100 \quad \%$$

5. Apparatus

Centrifugal blower test rig with three types of interchangeable impellers, Stop watch

6. Procedure

1. Check the necessary electrical connection
2. Set the pitot tube to Zero position
3. Check the manometer for Zero position
4. Adjust the speed to the required range
5. Adjust the gate openings for various stages ($1/2$, $1/4$, $3/4$)

6. Start the blower & note down the readings (speed of the blower, manometer, Pitot tube & energy meter)
7. Repeat the experiment for different gate opening

7. Tabulation

1. Length of duct = --------mm
2. Width of duct = ----------mm
3. Breadth of duct = ---------mm
4. Cross sectional area of the duct = --------m^2
5. Number of revolutions of energy meter = n = ----------
6.. Mechanical efficiency, η_m = -----------

8. Calculation

Gate Opening Position	Manometer reading			Pitot tube reading			Time taken for n revolution in (sec)	Static head of air h_{sh} (m)	Q_a, m^3/s	IP in KW	OP in KW	η mech %
	H_1 (cm)	H_2 (cm)	Hw (m)	IR (cm)	FR (cm)	Difference (m)						

9. Results

Performance Curves/GRAPHS:

1. Discharge Vs Efficiency

PRE-LAB QUESTIONS

1. Basics of fan Vs blowers.
2. Concept of centrifugal blowers.
3. Self Reading before Coming to The Laboratory:

POST-LAB QUESTIONS

6. What are Fan Laws?
7. How to organize the experiments to verify Fan Laws?
8. Prepare Brief Planning and show to the instructor, before start the experiments.

1. **Experiment No.: ESC-205/10B**
2. **Experiment Name: Experiments on Fluid Machinery: Blowers, Compressors**
3. **Objectives:** The experiment is conducted at various pressures to
   a. Determine the Volumetric efficiency.
   b. Determine the Isothermal efficiency.
4. **Principle:**
   A COMPRESSOR is a device, which sucks in air at atmospheric pressure & increases its pressure by compressing it. If the air is compressed in a single cylinder it is called as a Single Stage Compressor. If the air is compressed in two or more cylinders it is called as a Multi Stage Compressor. In a Two Stage Compressor the air is sucked from atmosphere & compressed in the first cylinder called the low-pressure cylinder. The compressed air then passes through an inter cooler where its temperature is reduced. The air is then passed into the second cylinder where it is further compressed. The air further goes to the air reservoir where it is stored.
5. **Apparatus:**
   1. Consists of Two Stage Reciprocating air compressor of 3hp capacity. The compressor is fitted with similar capacity Motor as a driver and 160lt capacity reservoir tank.
   2. Air tank with orifice plate assembly is provided to measure the volume of air taken and is done using the Manometer provided.
   3. Compressed air is stored in an air reservoir, which is provided with a pressure gauge and automatic cut-off.
   4. Necessary Pressure and Temperature tapings are made on the compressor for making different measurements
   5. Temperature is read using the Digital temperature indicator and speed by Digital RPM indicator.

6. Procedure

1. Check the necessary electrical connections and also for the direction of the motor.
2. Check the lubricating oil level in the compressor.
3. Start the compressor by switching on the motor.
4. The slow increase of the pressure inside the air reservoir in observed.
5. Maintain the required pressure by slowly operating the discharge valve (open/close). (Note there may be slight variations in the pressure readings since it is a dynamic process and the reservoir will be filled continuously till the cut-off.)
6. Now note down the following readings in the respective units: Speed of the compressor. Manometer readings. Delivery pressure. Temperatures. Energy meter reading.
7. Repeat the experiment for different delivery pressures.
8. Once the set of readings are taken switch of the compressor.
9. The air stored in the tank is discharged. Be careful while doing so, because the compressed air passing through the small area also acts as a air jet which may damage you or your surroundings.
10. Repeat the above two steps after every experiment.

7. Tabulation

Sl. No.	Compressor Speed, rpm	Delivery Pressure, 'P' kg/cm^2	Manometer Reading			Time for 'n' revolutions of energy meter, 'T' sec
			h_1 cm	h_2 cm	h_w = (h1~h2)	

8. Calculation

1. Air head causing flow,ha

Manometer Head Ha =(h_1-h_2) x $\frac{\rho w}{\rho a}$ m

ρ_w=1000kg/m^3

ρ_a=1.293 kg/m^3, h_1 and h_2 in m

2. Actual vol. of air compressed at RTP,

Where,

h_a is air head causing the flow in **m** of air.

C_d = coefficient of discharge of orifice = 0.62

a = Area of orifice = $\frac{\pi}{4}$ d ^{2}

Where,

d = diameter of orifice = 0.02m

3. Theoretical volume of air compressed Q_{th},

Where,

D is the diameter of the LP cylinder = 0.07m.

L is Stroke Length = 0.085m

Is speed of the compressor in rpm

4. Input Power, **IP**

3600*n*η_m /(KxT)..........kW

Where,

n = No. of revolutions of energy meter (Say 5)

K = Energy meter constant revs/kW-hr

T = time for 5 rev. of energy meter in seconds

η_m = efficiency of belt transmission = 75%

5. Isothermal Work done, **WD**

WD = ρa x QalnrkW

Where,

ρ_a= is the density of the air = 1.293 kg/m^3 Q_a = Actual volume of air compressed.

r = Compression ratio

r = Delivery gauge pressure + Atmospheric pressure Atmospheric pressure

Where Atmospheric pressure = 101.325 kPa

NOTE: To convert delivery pressure fromkg/cm[to kPa multiply by 98.1

6. Volumetric efficiency, ηvol

$$\eta_{vol} = Qa/Qth \times 100$$

7. Isothermal efficiency, ηiso

$$\eta_{iso} = \frac{Isothermal\ work\ done}{IP} \times 100$$

S. No	Head of Air h_a, m	Actual volume of air compressed Q_a, m^3/s	Theoretical vol of air compressed Q_{th}, m^3/s	Isothermal work done Kw	Iso thermal efficiency η_{iso}, %	Volumetric Efficiency η_{vol},%

9. **Results**

Graphs to be plotted:

Delivery Pressure vs. η_{vol}

Delivery Pressure vs. η_{iso}

10. Precautions:

1. Do not run the blower if supply voltage is less than 380V
2. Check the direction of the motor, if the motor runs in opposite direction change the phase line of the motor to run in appropriate direction.
3. Do not forget to give electrical earth and neutral connections correctly.

PRE LAB QUESTIONS:

1. What is the principle of compressor?
2. Differentiate various types of compressors?
3. Explain concept of multi staging?

POST LAB QUESTIONS?

1. Differentiate single stage and multistage compressor?
2. Define isothermal work done?
3. What is isothermal efficiency?

1. **Experiment No.: ESC-205/11**
2. **Experiment Name: Flow through pipes: Reynold's experiments**
3. **Objectives:** To illustrate laminar, transitional, and fully turbulent flows in a pipe, and to determine under which conditions each flow regime occurs.
4. **Principle:**
The Reynolds number (Re) is a dimensionless ratio of inertia forces to viscous forces and is used in determining the type of flow occurring: laminar or turbulent. In most engineering text books, a Reynolds number of 2300 is usually accepted as the value at transition; that is, the value of the Reynolds number between laminar and turbulent flow regimes. The Reynolds number that exists anywhere in the transition region is called the critical Reynolds number. The objective of this experiment is to determine the range of Reynolds numbers by Reynolds apparatus over which transition occurs. Given the tube size (12 mm), the Reynolds number can be calculated as:

$$Re = \frac{V D_h}{\nu}$$

where,

Re = Reynolds number

V = velocity of fluid (m/s)

D_h = hydraulic diameter (m)

μ (mu) = dynamic viscosity of fluid ($N.s/m^2$)

ν (nu) = kinematic viscosity of fluid (m^2/s)

ρ (rho) = density (kg/m^3)

The hydraulic diameter (different than hydraulic radius) is calculated as:

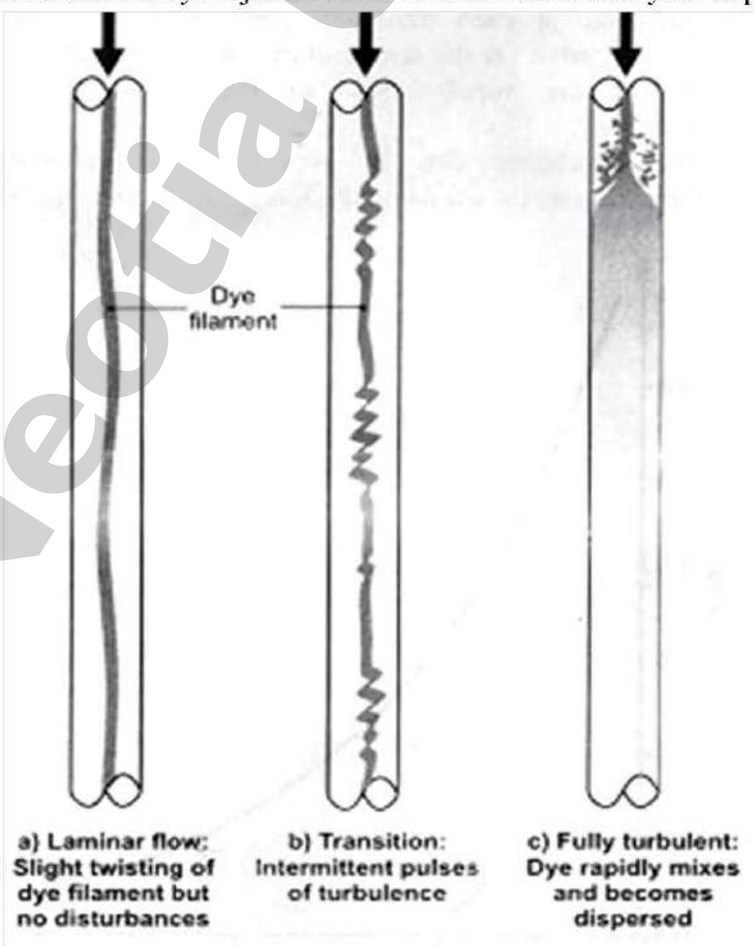
$$D_h = \frac{4 * \text{Area}}{\text{Wetted Perimeter}} = \frac{4 * A}{P_w}$$

5. **Apparatus:**
   1. Reynolds demonstration apparatus,
   2. Cylinder for measuring flow,
   3. Stopwatch for timing the flow measurement
   4. Dye
   5. Thermometer

6. **Procedure:**
   1. Turn on the water, and partially open the discharge valve at the base of the apparatus.
   2. Open and adjust the dye injector valve to obtain a fine filament of dye in the flow down the glass tube. If the dye is dispersed in the tube reduced to water flow rate by closing the discharge valve and adjusting the supply as necessary to maintain the

constant head. **A laminar flow condition** should be achieved in which the filament of dye passes down the complete length of the tube without disturbance (Figure).

3. Record the temperature of the water using the thermometer, find the corresponding kinematic viscosity from a table.
4. Then **measure the flow rate** by timing the collection of a known quantity (volume) of water from discharge pipe. This will help you to determine the velocity of the water in the pipe.
5. Slowly increase the flow rate by opening the discharge valve until disturbances of the dye filament are noted (Figure). **This can be regarded as the starting point of transition to turbulent flow**. Increase the discharge as required to maintain constant head conditions. Do not miss to sketch the dye condition and measure the flow rate for each of your trials.
6. If necessary, 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 the dye filament completely breaks down. This can be regarded as the onset of **fully turbulent flow** (Figure).
7. Now you should **close** the dye injector valve in order to finalize your experiment.



Dye sketchs (Laminar through Turbulent)

7. Tabulation:

Temperature of water = ________ °C

Kinematic viscosity of water = __________ m^2/s

Condition	Visual Dye Condition (Sketch)	Time for 300ml (s)	Flowrate (m^3/s)	Velocity (m/s)	Re	Classification of Flow by Re
Laminar						
Laminar						
Transition						
Transition						
Turbulent						
Turbulent						

PRE-LAB QUESTIONS:

1. Why do we use Reynolds number?
2. Compare the results obtained through calculations and observations. State whether or not the results are reasonable. If not, explain the reasons?
3. Is the Reynolds number obtained dependent on tube size or shape?

POST-LAB QUESTIONS

1. Draw a fully developed laminar and turbulent velocity profile (pipe flow). Explain why they are different.
2. How is Reynolds number designed for:
    a) Flow in a circular pipe of diameter, D?
    b) Flow in a rectangular duct of cross section a x b?