



DEPARTMENT OF MECHANICAL ENGINEERING

Haldia, Purba Medinipur, West Bengal
HALDIA INSTITUTE OF TECHNOLOGY

PRACTICAL MANUAL

(Assessment Instrument and Instruction Items)

Course Name	FLUID MECHANICS AND HYDRAULIC MACHINES LABORATORY
Course Code	PC-ME 391
Laboratory Name	FLUID MECHANICS AND HYDRAULIC MACHINES LABORATORY
Program	B. Tech in Mechanical Engineering
Semester / Year	[3 rd / 2 nd]
Academic Session	2026–27

Faculty-in-Charge & Technical Staff

Faculty-in-Charge	Dr. Soumyajit Roy
Co-Faculty (if any)	Dr. Prabir Kumar Kar, Dr. Sourav Ganguli
Technical Staffs	Mr. Subhabrata Panda
	Mr. Santanu Maity



Vision

To impart quality, industry-relevant teaching-learning that blends knowledge and skill to produce industry-ready mechanical engineering graduates.

Mission Statements

M1: To create qualified and proficient technocrats having contemporary skills through outcome-based and self-learning strategies.

M2: To encourage innovation-oriented and problem-based research capabilities among young engineers through higher studies, in order to nurture the progress of society.

M3: To instill strong ethical values and good professional behaviour, enabling graduates to adopt and absorb emerging changes in the engineering profession.

Program Educational Objective

Graduates of B. Tech. Mechanical Engineering program, four years after graduation will

PEO1: Specify, design, supervise, test, and evaluate engineering skills to design, develop, and implement innovative solutions, systems, and applications in Mechanical Engineering and allied industries.

PEO2: Utilize Mechanical Engineering knowledge to address real-world and societal challenges while pursuing higher studies, research, and professional development.

PEO3: Demonstrate effective individual and collaborative capabilities in multidisciplinary professional environments, with a commitment to lifelong learning and adaptability to evolving technological, industrial, and societal requirements.

Program Specific Outcomes (PSOs)

PSO1: Design, analyze and evaluate mechanical components and systems such as thermal, fluid, manufacturing, design systems and allied engineering solutions.

PSO2: Utilize and evaluate modern engineering tools, software, and techniques to model, analyze, and solve real-world mechanical engineering problems.

PSO3: Demonstrate professional and ethical responsibility, effective communication, and the ability to work in multidisciplinary teams to address societal, industrial, and environmental challenges through sustainable mechanical engineering solutions.



Course Code : PC-ME 391	Category: Professional Core Courses	PCIE Marks	40
Course Name : Fluid Mechanics and Hydraulic Machines Laboratory	Semester : Third	PSEE Marks	60
L-T-P: 0-0-3	Credit: 1.5	Total Marks	100
Pre-Requisites: Fluid Mechanics from Physics (10+2)			
Examination (PSEE): Theory/ Drawing Assignment/ Practical/ Viva-voce/Team work/ others			

Course Content:

Experiments are to be framed based on the following units:

Unit	Topics	Hours	CO
UNIT I	Applications of Bernoulli's equation: Verification of Bernoulli's equation. Determination of the coefficient of discharge of Venturimeter and Orificemeter. Determination of coefficient of discharge (C_d), coefficient of contraction (C_c) and coefficient of velocity (C_v) of a orifice.	9	CO1
UNIT II	Notch: Determination of the coefficient of discharge of rectangular and V notch.	6	CO2
UNIT III	Major and Minor losses: Determination of Major and Minor losses of head in the pipe fittings.	6	CO3
UNIT IV	Turbine: Determination of impact of jet on vanes. Determination of output power and overall efficiency of Pelton wheel turbine and Francis turbine.	9	CO4
UNIT V	Pump: Determination of overall efficiency and pump efficiency of centrifugal pump. Determination of different parameters of reciprocating pump	6	CO5
UNIT VI	Blower and Compressor: Determination of volume flow rate and volumetric efficiency of centrifugal blower. Determination of volumetric efficiency and compression ratio of centrifugal compressor.	6	CO6
Total		42	

Suggested Reference Books

1. Introduction to Fluid Mechanics and Fluid Machines, S K Som, G Biswas, S Chakraborty, Mc Graw Hill Education
2. Fluid Mechanics & Hydraulic Machines, S. S. Rattan, Khanna Book Publishing Co.
3. Fluid Mechanics and Machinery, R. K. Bansal, Laxmi Publication.
4. A Text book on Fluid Mechanics and Machines, S. Pati, Mc Graw Hill Education.
5. Fluid Mechanics and Machinery, C. S. P. Ojha, R. Berndtsson and P. N. Chadramouli, Oxford University Press.
6. Hydraulics and Fluid Mechanics, P M Modi and, S M Seth, Standard Book House.
7. Chakraborty, S. Introduction to Fluid Mechanics [Video course]. NPTEL, IIT Kharagpur. <https://nptel.ac.in/courses/112105269>
8. Som, S. K. (2013). Fluid Mechanics [Video file]. (NPTEL), IIT Kharagpur. Available from: <https://www.youtube.com/playlist?list=PLbMVogVj5nJTZJHsH6uLCO0I-ffGyBEm>
9. Biswas, G., & Som, S. K. Fluid Mechanics [Web/Video Course]. (NPTEL), IIT Kanpur. <https://nptel.ac.in/courses/112104118>



Course Outcomes:

Upon successful completion of the course, students will be able to:

CO CODES	CO Statement	Knowledge Categories	Cognitive Level
PC-ME 391.1	Determine and analyze the coefficient of discharge (C_d) of each of orificemeter (C_c & C_v) and venturimeter flow-measuring device using actual and theoretical discharge data, with acceptable error margin.	P	An
PC-ME 391.2	Determine coefficient of discharge (C_d) of rectangular and V-notches using discharge data within standard range.	P	Ap
PC-ME 391.3	Determine minor head loss and major friction factor for four different pipe materials accurately.	P	Ap



PC-ME 391.4	Determine output power and overall efficiency of Pelton wheel and Francis turbines accurately.	P, C&S	E
PC-ME 391.5	Determine the efficiency of centrifugal and reciprocating pumps by evaluating relevant performance parameters under specified operating conditions using standard experimental procedures and criteria.	P, C&S	E
PC-ME 391.6	Determine the volumetric efficiency and compression ratio of centrifugal blowers and compressors by measuring relevant parameters under specified operating conditions using standard experimental procedures.	P, C&S	E

ALIGNING OF COS IN [CL × KC] METRIC

Knowledge Categories (KC)								
Cognitive Levels (CL)	Factual	Conceptual	Procedural	Meta-cognitive	Fundamental Design Principles	Criteria & Specifications	Practical Constraints	Design instrumentalities
Remember (R)								
Understand (U)								
Apply (Ap)			CO2, CO3					
Analyze (An)			CO1					
Evaluate (E)			CO4, CO5 & CO6			CO4, CO5 & CO6		
Create (C)								

Assessment Pattern and Assessment Instruments for Continuous Internal Evaluation (PCIE & PSEE)

Marks allotted	PCIE								PSEE (60)	
	PCAI (40)				PCAII (40)					
	10	10	10	10	10	10	10	10	40	20
CO	EX 1	EX 2	EX 3	VIVA I	EX 4	EX 5	EX 6	VIVA II	GR-A	GR-B (Viva)
CO1	10			10/3					40/6	20/6
CO2		10		10/3					40/6	20/6
CO3			10	10/3					40/6	20/6
CO4					10			10/3	40/6	20/6
CO5						10		10/3	40/6	20/6
CO6							10	10/3	40/6	20/6

CO-PO & CO-PSO Articulation Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3
PC-ME 391.1	3	3	1	3	-	-	-	2	1	-	1	3	1	-
PC-ME 391.2	3	2	1	3	-	-	-	2	1	-	1	3	1	-
PC-ME 391.3	3	2	1	3	-	-	-	2	1	-	1	3	1	-
PC-ME 391.4	3	2	2	3	-	1	-	2	1	-	2	3	1	1
PC-ME 391.5	3	2	2	3	-	1	-	2	1	-	2	3	1	1
PC-ME 391.6	3	2	1	3	-	1	-	2	1	-	2	3	1	1
Average	3.0	2.2	1.3	3.0		0.5		2.0	1.0		1.5	3.0	1.0	0.5





FLUID MECHANICS AND HYDRAULIC MACHINES LABORATORY (PC-ME-391)

LIST OF ASSESSMENT ITEMS, INSTRUCTION ITEMS

Experiment No.	Name of the experiment	Instruction Item	CO Congruence
EX1-I	Determination of the coefficient of discharge of Orificemeter.	II1	CO1
EX1-II	Determination of the coefficient of discharge of Venturimeter.		
EX1-III	Determination of C_d , C_c and C_v , of orifice.		
EX2	Determination of the coefficient of discharge of rectangular and V notch.	II2	CO2
EX3-I	Determination of the loss of head in the pipe fittings (Minor losses).	II3	CO3
EX3-II	Determination of friction factor of four different materials (Major losses).		
EX4-I	Determination of impact of jet on vanes.	II4	CO4:
EX4-II	Determination of output power and overall efficiency of Francis turbine.		
EX4-III	Determination of output power and overall efficiency of Pelton wheel turbine.		
EX5-I	Determination of overall efficiency and pump efficiency of centrifugal pump.	II5	CO5:
EX5-II	Determination of different parameters of reciprocating pump.		
EX6-I	Determination of volume flow rate and volumetric efficiency of centrifugal blower.	II6	CO6:
EX6-II	Determination of volumetric efficiency and compression ratio of centrifugal compressor.		



INSTRUCTION ITEM-1 (II-1)		
Experiment No.	Name of the experiment	CO Congruence
EX1-I	Determination of the coefficient of discharge of Orificemeter.	[CO1]
EX1-II	Determination of the coefficient of discharge of Venturimeter.	
EX1-III	Determination of C_d , C_c and C_v of orifice.	

EX1-I

Title: DETERMINATION OF THE COEFFICIENT OF DISCHARGE OF ORIFICEMETER.

Theory

Orifice:

An orifice is an aperture through which fluid passes and its thickness (in the direction of flow) is very small in comparison with its other dimension. An orifice used for measuring purpose has a sharp edge, beveled side facing downstream, so that there is minimum contact with fluid and consequently minimum frictional effects. If a sharp edge is not provided, the flow would depend on the thickness of the orifice and the roughness of its boundary. Fluid approaching an orifice converges towards it. Because an instantaneous change in direction is impossible, the streamlines continue to converge beyond the orifice until they become parallel at a section (which is also the section for minimum cross-sectional area) called vent contracta.

Orifice Co-efficient:

It is the ratio of the actual discharge through an orifice-meter to the theoretical discharge

$$Q = C_d A_0 (2\Delta P / \rho_w)^{1/2} / (1 - r^4)^{1/2}$$

Q = actual discharge, m^3/s

C_d = Orifice Co-efficient

A_0 = cross-sectional area at orifice, m^2

ΔP = difference of piezometric pressure between upstream and downstream section of the orifice-meter N/m^2

$$= \Delta h (\rho_m - \rho_w) g$$

Δh = manometer reading, m

ρ_w = density of working fluid, kg/m^3

ρ_m = density of manometric fluid, kg/m^3

r = ratio of diameter of throat to that of pipe

g = acceleration due to gravity, m/s^2

Procedure:

1. Fill Sump tank $\frac{1}{4}$ with clean water.
2. Collect data on water density, viscosity and experiment temperature.
3. Send water through the orifice-meter at moderate flow rate to drive out entrapped air.
4. Start operating the orifice meter at a low flow rate
5. Record manometer reading
6. Measure the actual discharge (flow) rate with the help of volumetric measuring tank and stopwatch.
7. Increase the flow rate by increasing the opening of the inlet valve to the orifice meter and repeat measurements.

Physical Dimensions:

Dia. Of the pipe = 0.028 m, orifice diameter = 0.014 m,

Manometer fluid: Mercury



Density of manometer fluid $\rho_m = 13600 \text{ kg/m}^3$

Plan area of the volumetric measuring tank = _____ m^2

Water temperature = _____ $^\circ\text{C}$

Density of water $\rho_w = \text{kg/m}^3$

Kinematic viscosity of water = _____ m^2/s

OBSERVATION DATA TABLE:

SL.No.	Manometer reading. Δh (cm)	Volume of water collected in the measuring tank, V. (lit.)	Time for water collection, t (sec)

ANALYSIS DATA TABLE:

SL. No.	$(2\Delta P / \rho_w)^{1/2}$	V (m^3)	Q (m^3/s)	C_d

FAQ & A on Orifice meter:

1. Why C_d is higher in Venturi meter than Orifice meter:

Ans: Venturi meter has a gradually converging-diverging shape, which minimizes flow separation and turbulence, resulting in lower energy losses. Hence its coefficient of discharge ($C_d \approx 0.95\text{--}0.98$) is higher than that of an orifice meter ($C_d \approx 0.6\text{--}0.65$), which has sudden contraction causing more losses.

2. Why Orifice meter is cheaper than Venturi meter:

Ans: Orifice meter has a simple construction (just a plate with a hole) that's easy to manufacture and install, requiring less material and machining precision, whereas a Venturi meter needs a precisely shaped converging-diverging nozzle, making it costlier to fabricate.

3. Vena Contracta:

Ans: It is the point downstream of an orifice/restriction where the fluid jet has the minimum cross-sectional area (less than the orifice area itself). It forms because fluid streamlines cannot turn the sharp corner of the orifice instantly, causing the jet to converge before it stabilizes and gradually expands again.



EX1-II

Title : Determination of the coefficient of discharge of Venturimeter.

Venturimeter:

The device consists of a convergence in a pipeline, followed by a short parallel sided hooor and then a divergence. Continuity requires a greater velocity at the throat than at the inlet, there is consequently a difference of pressure between the inter and the throat, Measurement of this pressure difference enables the rate of flow through the ventutimeter to be calculated The present experiment is to be conducted with water as the fluid.

Co-efficient of Discharge:

It is the ratio of the actual discharge through a venturimeter to the theoretical discharge

$$Q = C_d A_t (2\Delta P / \rho_w)^{1/2} / (1 - r^4)^{1/2}$$

Q = actual discharge, m³/s

C_d = Orifice Co-efficient

A_t = cross-sectional area at orifice, m²

ΔP = difference of piezometric pressure between upstream and downstream section of the orifice-meter, N/m² = Δh(ρ_m - ρ_w)g

Δh = manometer reading, m

ρ_w = density of working fluid, kg/m³

ρ_m = density of manometric fluid, kg/m³

r = ratio of diameter of throat to that of pipe

Procedure:

1. Fill Sump tank % with clean water,
2. Collect data on water density, viscosity and experiment temperature.
3. Close all flow control valves given on the wafer line and open by-pass valve.
4. Check the level of Hg in manometer tube.
5. Close all pressure taps of manometer connected to venturimeter.
6. Send water through the venturimeter at moderate flow rate to drive out entrapped air.
7. Start operating at a low flow rate
8. Record manometer reading.
9. Measure the actual discharge (flow) rate with the help of volumetric measuring tank and stop watch.
10. Increase the flow rate by increasing the opening of the inlet valve to the orificemeter and repeat measurements.
11. When experiment is over, open the by-pass valve fully and then close the flow control valve. After that close all manometers pressure taps

Physical Dimensions:

Dia, at the inlet of the venturimeter = 0.028 m

Dia, at the throat of the venturimeter = 0.014 m

Manometer fluid: Mercury

Density of manometer fluid ρ_m = 13600 kg/m³

Plan area of the volumetric measuring tank = _____ m²

Water temperature = _____ °C

Kinematic viscosity of water = _____ m²/s



OBSERVATION DATA TABLE:

SL.No.	Manometer reading. Δh (cm)	Rise of water level in measuring tank R (cm)	Time for water collection, t (sec)

ANALYSIS DATA TABLE:

SL. No.	$(2\Delta P / \rho_w)^{1/2}$	Theoretical discharge Q_t (m ³ /s)	V (m ³)	Actual discharge Q (m ³ /s)	C_d

FAQ & A on Venturimeter:

1. Why the divergent cone is longer than convergent cone in venturi meter?

Ans : The divergent cone is kept longer (typically 5-7° angle) to allow gradual expansion of flow area, preventing flow separation and boundary layer detachment from the walls. This minimizes energy losses due to turbulence/eddies that would occur with abrupt expansion, ensuring smooth pressure recovery.

2. Compare the merits and demerits of venturi meter with orifice meter.

Ans : Venturi meter has higher accuracy, lower head loss (better pressure recovery), and doesn't cause flow disturbance downstream, but is bulkier, more expensive, and harder to install/maintain. Orifice meter is compact, cheap, and easy to install/replace, but causes higher permanent head loss and lower accuracy due to sudden contraction and turbulence.

3. Why the divergent angle is kept small in venturi meter?

Ans : A small divergent angle (5-7°) ensures gradual pressure recovery and prevents flow separation from the diverging walls. A larger angle would cause the boundary layer to separate, creating turbulence and eddies, resulting in higher energy losses and reduced accuracy.

4. What will be the value of C_d if losses are taken?

Ans : When losses (friction, turbulence) are considered, the actual discharge is less than the theoretical discharge, so C_d (coefficient of discharge) is less than 1, typically ranging between 0.95-0.99 for venturi meters. $C_d = \text{Actual discharge} / \text{Theoretical discharge}$, accounting for these real losses.

5. If the flow is compressible how can you measure C_d ?

Ans : For compressible flow, a compressibility correction factor (expansion factor, Y) is introduced along with C_d , since density changes with pressure. The discharge equation includes this factor: $Q = C_d \times Y \times A \times \sqrt{(2\Delta P / \rho)}$, where Y accounts for the density/pressure variation, and $Y=1$ for incompressible flow.



EX1-III

Title: DETERMINATION OF C_d , C_c and C_v , OF ORIFICE

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

Formula Used:

$$C_d = \frac{Q_{act}}{Q_{th}}$$

$$Q_{th} = \text{Theoretical velocity} \times \text{Theoretical area} = \sqrt{2gh} a$$

$$C_v = \frac{\text{Actual velocity of jet at vena contracta}}{\text{Theoretical velocity}}$$

$$C_v = \frac{V}{V_{th}}$$

$$C_c = \frac{\text{Area of jet at vena contracta}}{\text{Theoretical area}}$$

Theory:

Orifice is a small opening of any cross section such as circular, triangular, rectangular, on a side or on the bottom of the tank, through which a fluid flows. Orifices are used for measuring the rate of flowing fluid. The water is allowed to flow through an orifice fitted to tank and a constant head. The water is collected in measuring tank for known time. The height of water in the measuring tank is noted.

Horizontal distance $x = Vt$

Vertical distance $y = 1/2gt^2$

Eliminating t from the two equations we will get

$$V = \sqrt{\frac{gx^2}{2y}}$$

But the theoretical velocity $V = \sqrt{2gh}$

$$\text{Coefficient of velocity } C_v = \frac{V}{V_{th}}$$

$$\text{Coefficient of contraction } C_c = \frac{C_d}{C_v}$$

Vena- Contracta: The fluid out is in form of jet goes on contracting from orifice up to a distance of about the orifice dia. After the expenditure this least relation

Procedure

1. Set the mouthpiece of orifice of which the C_c , C_v , C_d 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 remain 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 X or Y for mouthpiece.
6. Take three readings using hook gauge for one particular orifice.
7. Using the formula get value of C_c , C_v , C_d for a particular orifice and mouthpiece.



Observation

Sl. No.	ΔH (cm)	Δt (cm)	Q_{act}	H (cm)	$Q_{th} = \sqrt{2gh} a$	X (cm)	Y (cm)	C_d	Mean C_d

Sl. No.	C_v	Mean C_v	$C_c = \frac{C_d}{C_v}$	Mean C_c

Result:

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.

FAQ & A on Orifice:

1. Define Orifice?

Ans : An orifice is a small opening or aperture made in the side or bottom of a tank/vessel through which fluid flows out. It is used to measure the rate of flow or discharge of liquid from the vessel, based on the head of liquid above it.

2. Define Mouth piece?

Ans : A mouthpiece is a short pipe or tube (length typically 2-3 times its diameter) attached to an orifice, through which liquid flows. It is used to increase the discharge rate compared to a plain orifice by guiding and streamlining the flow.

3. Define vena contracta?

Ans : Vena contracta is the point downstream of the orifice where the jet of liquid attains its minimum cross-sectional area, due to convergence of streamlines. It occurs because fluid particles cannot make a sharp turn at the orifice edge, causing the jet to contract.

4. Define coefficient of velocity?

Ans : Coefficient of velocity (C_v) is the ratio of the actual velocity of the jet at vena contracta to the theoretical velocity of the jet. $C_v = \text{Actual velocity} / \text{Theoretical velocity}$, and it accounts for losses due to friction as fluid passes through the orifice.

5. What is the relation between C_c , C_v and C_d ?

Ans : The coefficient of discharge (C_d) is the product of coefficient of contraction (C_c) and coefficient of velocity (C_v): $C_d = C_c \times C_v$. This relation shows that discharge losses arise from both the reduction in jet area and the reduction in jet velocity.

6. How can you measure the coordinate i.e. x and y ?

Ans : The horizontal (x) and vertical (y) coordinates of the jet trajectory are measured using a scale or graph sheet placed behind the jet, or using a hook gauge/pointer setup, by tracking the path of the jet at different points as it falls under gravity.



7. How can you apply Projectile motion to this experiment?

Ans : Since the jet leaves the orifice horizontally and falls under gravity, its path follows projectile motion. By measuring the horizontal distance (x) and vertical drop (y) at a point, actual velocity is calculated using $v = x\sqrt{g/2y}$, based on equations of motion.

8. If the losses are taken then what will be the value of theoretical velocity?

Ans : Theoretical velocity itself ($V_{th} = \sqrt{2gH}$) is derived from Bernoulli's equation assuming no losses, so it remains unchanged regardless of actual losses. Losses instead reduce the actual velocity, which is accounted for by multiplying theoretical velocity with coefficient of velocity (C_v).

9. Define the term vena contracta?

Ans : Vena contracta is the section of the jet, located slightly downstream of the orifice, where the flow area is minimum due to the convergence of streamlines from all directions. Beyond this point, the jet gradually expands and does not fully return to the orifice area.



INSTRUCTION ITEM-2 (II-2)		
Experiment No.	Name of the experiment	CO Congruence
EX2-I	Determination of the coefficient of discharge of rectangular and V notch.	[CO2]

EX2-I

Title: DETERMINATION OF THE COEFFICIENT OF DISCHARGE FOR RECTANGULAR AND V NOTCHES

Theory

Notches:

A notch is a device used for measuring the rate of flow of a liquid through a channel. It is an opening on the side of a tank or channel; placed in such a way that the liquid surface in the tank or channel is below the top edge of the opening. It is formed in a smooth plane vertical plate and its edges are bevelled on the downstream side so as to give minimum contact with the fluid. The sheet of water flowing through the notch is called nappe. The bottom edge of the notch over which the water flows, is known as the sill or the crest.

A depth of flow above the crest is related to the discharge, the notch forms a useful measuring device. Depending on its shape of the notch, it is termed as a V notch or a rectangular notch.

Coefficient of discharge:

It is the ratio of the actual discharge over the notch to the theoretical discharge.

For a rectangular notch,

$$Q = \frac{2}{3} C_d L (2g)^{\frac{1}{2}} (H)^{\frac{3}{2}}$$

For a V shaped notch,

$$Q = \frac{8}{15} C_d \tan\left(\frac{\theta}{2}\right) (2g)^{\frac{1}{2}} (H)^{\frac{5}{2}}$$

Where, Q = actual discharge, m³/sec

C_d = coefficient of discharge

L = width of the rectangular notch in m

θ = angle of notch (in case of V shaped notch)

R = height of water in the volumetric measuring tank

H = water height over crest in m g acceleration due to gravity, m/s²

Procedure:

Starting procedure.

1. Clean the apparatus and make all tanks free from dust
2. Close the drain valves.
3. Close the control valves on the discharge line.
4. Open bypass valve.
5. Fix desired notch (rectangular or V shaped) on the flow channel.
6. Fill the storage sump up to 75% of its capacity.
7. Ensure that all on off switches on the panel are at off positions.
8. Switch on the main power supply, switch on the pump
9. Regulate flow through the channel by the flow control valve.
10. Record the height of water in the channel with the help of pointer gauge.
11. Measure discharge rate using volumetric measuring tank and stop watch



Closing procedure

1. when the experiment is over switch off the pump
2. Switch off power supply to panel.
3. Drain water from all tanks to keep the tanks dry.

Physical dimensions:

Rectangular notch Width (L) = 65mm

Depth = 105mm

V notch: depth = 105mm

Angle = 60 and 45°

Plan area of the volumetric measuring tank = _____ m²

OBSERVATION DATA TABLE: RECTANGULAR NOTCH:

SL NO.	Water head over crest H (cm)	Rise of water level in measuring tank, R(cm)	Time taken for R, t(sec)

ANALYSIS DATA TABLE (RECTANGULAR NOTCH):

SL NO.	Water head over crest H (cm)	Volume, V(m ³)	Q(m ³ /sec)	C _d

OBSERVATION DATA TABLE (V SHAPED NOTCH) (Angle = ...):

SL NO.	Water head over crest H (cm)	Rise of water level in measuring tank, R(cm)	Time taken for R, t(sec)

ANALYSIS DATA TABLE (V SHAPED NOTCH) (Angle=.....):

SL NO.	Water head over crest H (cm)	Volume, V(m ³)	Q(m ³ /sec)	C _d

FAQ & A on Notch

1. What is the difference between notch and venturimeter?

Ans : A **notch** measures flow in **open channels** based on the **head of liquid** above it (e.g., rectangular, V-notch).

A **venturimeter** measures flow in **closed pipes** based on the **pressure difference** between inlet and throat (using Bernoulli's equation).

Key difference: Notch → open-channel, liquid head; Venturimeter → closed pipe, pressure difference.

2. Which will have more value of C_d rectangular or triangular notch?

Ans : The coefficient of discharge (C_d) for rectangular and triangular (V) notches depends on the notch geometry, head of water, edge condition, and experimental conditions. Generally, both have C_d values in a similar range of about 0.60–0.65.

3. State one application of notch.

Ans : One important application of a notch is to measure the discharge or flow rate of water in open channels, such as irrigation canals, laboratory channels, and small streams, by measuring the head of water flowing over the notch.



INSTRUCTION ITEM-3 (II-3)		
Experiment No.	Name of the experiment	CO Congruence
EX3-I	Determination of the loss of head in the pipe fittings (Minor losses).	[CO3]
EX3-II	Determination of friction factor of four different materials (Major losses).	

EX3-I

Title: DETERMINATION OF FRICTION FACTOR FOR FLOW THROUGH PIPES.

Theory

Darcy-Weisbach Equation:

The loss of head in a pipe due to friction, as calculated from Darcy- Weisbach Equation, is given by.

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

Where, h_f = loss of head due to friction = $\Delta h \left(\frac{\rho_m}{\rho_w} - 1 \right)$

ρ_m = density of working fluid, Kg/m³

ρ_w = density of manometric fluid, Kg/m³

f = friction factor,

L = length of pipe

V = mean velocity of fluid,

D = diameter of pipe

TEST APPARATUS:

The apparatus consist of four parallel pipes of different materials of construction, for which a common inlet connection is provided with control valve to regulate the flow. Each pipeline can be isolated and tested separately by suitable isolation valves. Pressure tapings are taken at the two ends of each test section, and a manometer is provided to study the pressure loss due to the friction. Volumetric discharge is measured with the help of a measuring tank and stopwatch.

Starting Procedure:

1. Clean the apparatus and make all tanks free from dust.
2. Close the drain valves provided.
3. Fill the storage sump upto 75% of its capacity with clean water and ensure that no foreign particles are there.
4. Close valve given on the lines and open by-pass valve.
5. Check the level of mercury in manometer tube
6. Close all pressure taps of manometer.
7. Ensure that all on-off switches on the panel are off position
8. Switch on the main power supply (220 Volt AC,50 Hz)
9. Switch on the pump
10. Operate the by-pass valve to regulate the flow of water in the desired test section.
11. Open the pressure taps of manometer of related test section, very slowly to avoid the blow of water on the manometer fluid.
12. Now open the air release valve provided on the manometer, slowly to release the air in manometer
13. When there is no air in the manometer, close the air release valves
- 14 Adjust water flow rate in desired section with the help of control valve.
- 15 Record the manometer reading.
- 16 Measure the flow rate, discharge through desired test section, using stop watch and measuring tank.
- 17 Repeat above for different flow rates, operating the by-pass valve.



18 When experiment is over for one desired test section, open the by-pass valve fully. Then close the flow control valve of running test section and open the control valve of the next test section.

19. Repeat steps 10 to 18 for selected test section.

Closing procedure:

1. When experiment is over, close all manometers pressure taps first.
- 2 Switch off pump.
- 3 Switch off power supply to panel

APPARATUS DATA:

A = Area of measuring tank = $0.252\text{m} \cdot 0.397\text{m}$

S= Specific gravity of Hg = 13.6

d= diameter of pipe

For GI pipe = 16 mm

For Copper pipe = 15.5 mm

For Aluminium pipe = 15.5 mm

For SS pipe = 16 mm

L= Length of section = 800 mm

R = Rise of water level in measuring tank (m)

T = Time taken for R (sec)

V= Volume of water collected in measuring tank (m^3)

Δh = head difference (cm of Hg)

OBSERVATION DATA TABLE:

SL NO.	Manometer reading. Δh (cm of Hg)	Rise of water level in measuring tank, R(cm)	Time taken for R, t(sec)

ANALYSIS DATA TABLE:

SL No.	Loss of head due to friction, $h_f(\text{m})$	Volume of the water collected in the measuring tank, (m^3)	Mean velocity of fluid, V(m/s)	Reynolds number, Re	Friction factor (f)

FAQ & A on Major Losses:

1. What is the difference between friction factor and coefficient of friction?

Ans : The friction factor is a dimensionless factor used in pipe-flow calculations to determine the head loss due to friction, as in the Darcy–Weisbach equation. The coefficient of friction represents the ratio of frictional force to normal force between two contacting surfaces. Thus, they apply to different physical situations.

2. What do you mean by major energy loss?

Ans : Major energy loss is the loss of mechanical energy or head that occurs due to friction between the flowing fluid and the inner surface of a pipe along its length. It is also called frictional head loss and is calculated using the Darcy–Weisbach equation.

3. If the flow is laminar can you calculate friction factor without performing the experiment? If yes, explain how?

Ans : Yes. For laminar flow, the friction factor can be calculated theoretically without performing an experiment. First, calculate the Reynolds number. For laminar flow, $Re < 2000$, the Darcy friction factor is then obtained directly from: $f = 64/Re$

Thus, by knowing the fluid properties, pipe diameter, and flow velocity, the friction factor can be determined without experimental measurement.



EX3-II

Title: DETERMINATION OF THE LOSS OF HEAD IN THE FITTINGS AT THE VARIOUS WATER FLOW RATES

Introduction:

Loss of head due to changes in the cross section, bends, elbows, valves and fittings of all types fall into the category of minor losses in pipelines. In long pipelines the friction losses are much larger than these minor losses and hence the latter are often neglected. But, in shorter pipelines their consideration is necessary for the correct estimate of losses.

Theory

When there is any type of bend in pipe, the velocity of flow changes, due to which the separation of flow from the boundary and also formation of eddies, takes place. Thus, the energy is lost. The losses of head due to bend in pipe:

$$h_L = K_L \frac{V^2}{2g}$$

The minor losses in contraction can be expressed as

$$h_L = K_L \frac{V_1^2}{2g}$$

The minor losses in enlargement can be expressed as:

$$h_L = K_L \frac{(V_1 - V_2)^2}{2g}$$

Where,

h_L = minor loss or head loss

K_L = Loss coefficient

V = velocity of fluid

V_1 = velocity of fluid in pipe of small Diameter

V_2 = velocity of fluid in pipe of large Diameter

Procedure:

Starting procedure;

1. Clean the apparatus and make all tanks free from dust.
2. Close the drain valves.
3. Fill the storage sump up to 75% of its capacity.
4. Close the flow control valves on the discharge line.
5. Open bypass valve.
6. Check the level of Hg in the manometer tube. It should be up to half. If it is less, then fill it.
7. Close all pressure taps of manometer connected to different pipe fittings.
8. Ensure that all on/off switches on the panel are at off positions.
9. Switch on the main power supply, switch on the pump.
10. Operate the flow control valve to regulate the flow of water in the desired test section.
11. Open the pressure taps of the manometer of related test section, very slowly to avoid the blow of water on manometer fluid.
12. Now open the air release valve provided on the manometer, slowly to release the air in manometer.
13. When there is no air in the manometer, close the air release valves.
14. Adjust water flow rate in desired section with the help of control valve.
15. Record the manometer reading.
16. Measure discharge rate using volumetric measuring tank and stop watch.

Closing procedure:

1. When the experiment is over, close all manometers pressure taps first.
2. Switch off the pump.



3. Switch off power supply to panel.
4. Drain water from all tanks to keep the tanks dry.

Physical dimensions:

Dia of the smaller pipe = 0.016m

Dia of the larger pipe = 0.028m

OBSERVATION DATA TABLE:

Sl No.	Manometer reading, (cm of Hg)	Rise of water level in measuring tank, R(cm)	Time taken for R, t(sec)

ANALYSIS DATA TABLE:

Sl. No.	Volume (V)	Discharge (Q)	Velocity (V ₁)	Velocity (V ₂)	Loss of head	Changes in kinetic energy (C)

Sl. No.	Loss of head (h _L)	Loss coefficient (K _L)

FAQ & A on Minor Losses:

1. List down the type of minor energy losses.

Ans : Minor losses include: loss due to sudden expansion, sudden contraction, entry (into pipe from reservoir), exit (from pipe into reservoir), bends, elbows, fittings (valves, tees), and gradual expansion/contraction. These occur due to change in flow area, direction, or obstruction in the pipe.

2. Explain sudden expansion and sudden contraction. Which one should have more value of K?

Ans : Sudden expansion occurs when flow area abruptly increases, causing flow separation and eddy formation, leading to energy loss. Sudden contraction occurs when flow area abruptly decreases, causing the jet to contract (vena contracta) before expanding again. Sudden expansion generally has a higher loss coefficient K, as it involves greater turbulence and eddy formation than sudden contraction.

3. Why the eddies are formed in sudden expansion?

Ans : When flow area suddenly increases, the fluid stream cannot follow the abrupt boundary change and separates from the walls, creating a region of stagnant/re-circulating flow near the corners. This flow separation generates turbulent eddies, dissipating kinetic energy as heat.

4. Define the term entry and exit losses.

Ans : Entry loss occurs when fluid enters a pipe from a large reservoir, due to sudden contraction of streamlines at the pipe inlet (typically $0.5 V^2/2g$). Exit loss occurs when fluid leaves the pipe and enters a large reservoir/tank, where the entire kinetic energy of the fluid is dissipated ($V^2/2g$).

5. There are two bends say 90° and 120°, which will have the maximum minor losses?

Ans: The 90° bend will have maximum minor losses compared to the 120° bend, because a sharper bend causes greater flow separation, secondary flows, and turbulence. As the bend angle increases towards 180° (or decreases towards a gentler turn), the loss coefficient generally decreases for angles beyond 90°.



INSTRUCTION ITEM-4(II-4)		
Experiment No.	Name of the experiment	CO Congruence
EX4-I	Determination of impact of jet on vanes.	[C04]
EX4-II	Determination of output power and overall efficiency of Francis turbine.	
EX4-III	Determination of output power and overall efficiency of Pelton wheel turbine.	

EX4-I

Title: DETERMINATION OF IMPACT OF JET ON VANES.

Introduction

When a plate is placed in the path of a jet, the jet exerts a force on the plate. This force can be calculated from the impulse-momentum equation. Momentum equation is based on Newton's second law of Motion, which states that "The algebraic sum of external forces applied to control volume of fluid in any direction is equal to the rate of change of momentum in that direction". The external forces include the components of the weight of the fluid and of the forces exerted externally upon the boundary surface of the control volume.

Theory:

If a vertical water jet moving with a velocity 'v' is made to strike a target, which is free to move in the direction, then a force will be exerted on the jet by the impact of jet. Due to impact of the jet on the first stationary plate, the entire velocity of the jet is destroyed and due to the rate of change of momentum, force acts on the plate. The jet after striking will move along the plate. But the plate is at right angles to the jet. Hence the components the velocity of the jet in the direction of the jet after striking it will be zero. The force exerted by the jet on the flat plate in the direction of the jet,

$F_x = \text{Rate of change of momentum in the direction of force}$

$$= (\text{Final momentum} - \text{Initial momentum})$$

$$= (\text{Mass/time}) \cdot (\text{Final velocity} - \text{Initial velocity})$$

$$= \rho A v [v - 0] = \rho A v^2$$

For Flat plate vane: $F_x = \rho Q^2/A$

For hemisphere, $F_x = 2\rho Q^2/A$

Procedure:

Starting Procedure:

1. Clean the apparatus and make all tanks free from dust.
2. Close the drain valves provided.
3. Fill the storage sump up to 75% of its capacity with clean water and ensure that no foreign particles are there.
4. Fixed desired vane on the apparatus.
5. Ensure that all on-off switches on the panel are off position.
6. Switch on the main power supply.
7. Switch on the pump
8. Regulate flow through the channel by the flow control valve.
9. Note the initial reading of the plate provided at the top and then put known value of weight.
10. Now control the valve so that the applied weight on the top is counter balanced by the impact of jet.
11. Measure flow rate using measuring tank and stop watch



12. Repeat the experiment with different weights.

Closing Procedure:

1. When experiment is over, switch off the pump.
2. Switch off power supply to panel
3. Drain water from all tanks with the help of given drain valve to keep the tanks dry

Physical Dimensions:

Diameter of nozzle = 0.010m

Weight of Aluminium disc = 152.17 gm

Weight of SS rod = 190.189gm

Weight of Flat plate vane = 0.229 kg

Weight of hemispherical vane = 187.82 gm

Sample weights = 100, 200, 300, 500 gms

OBSERVATION DATA TABLE:

SL.No.	Weight applied (Kg)	Rise of level in measuring tank R (cm)	Time for water collection (sec)

ANALYSIS DATA TABLE:

SL.No.	W(Kg)	Actual Force (Fa)	Q(m ³ /s)	Theoretical force (Ft)	Error (%)

FAQ & A on Force on a plate by jet

1. Explain the momentum analysis in fluid mechanics.

Ans: It applies Newton's second law to a fluid stream, stating that the force exerted equals the rate of change of momentum ($\dot{m}\Delta V$). For a jet striking a surface, the force is calculated from the mass flow rate and change in velocity direction/magnitude, using the momentum equation $F = \rho Q(V_1 - V_2)$.

2. How can you check that the measured force by jet on the plate is correct or not?

Ans: Compare the experimentally measured force (from weights/balance) with the theoretically calculated force ($F = \rho AV^2$) using measured flow rate and velocity. Plot force vs. velocity² (or Q^2) — a straight line through the origin confirms accuracy. Small deviations are attributed to friction and energy losses.

3. What is the effect of the friction for this experiment?

Ans: Friction (in the nozzle, pipe, and at the vane/plate support) causes energy losses, reducing the actual jet velocity and force compared to theoretical values. This makes the experimental force slightly lower than the calculated force, and is accounted for using a coefficient of discharge/velocity.

4. Calculate the force exerted by jet on a hemispherical vane.

Ans: For a jet deflected by 180° (hemispherical vane), the force is $F = \rho AV^2(1 - \cos\theta)$, where $\theta = 180^\circ$, giving $F = 2\rho AV^2$ (maximum possible force since the jet reverses direction completely).

5. If the plane is moving how can you calculate the force?

Ans: Use the relative velocity ($V - u$) instead of jet velocity V , where u is the plate's velocity. The force becomes $F = \rho A(V - u)^2(1 - \cos\theta)$, since only the relative velocity contributes to momentum change on the moving surface.



EX4-II

Title: DETERMINATION OF THE OUTPUT POWER AND EFFICIENCY OF A FRANCIS TURBINE.

Theory

TEST APPARATUS:

The test rig consists of the turbine spiral casing, the runner assembly with brake drum and an outer bearing pedestal. A conical draft tube is provided at the discharge. A transparent hollow cylinder is provided in between the discharge bend and the casing outlet nozzle for observation of the flow at the exit of the runner. The turbine is loaded by a rope brake type dynamometer. The output of the turbine is controlled by adjusting the guide vanes, for which a suitable hand wheel and a link mechanism are provided. The net head on the turbine is measured by a pressure and a vacuum gauge.

Guiding Relations:

$$H = 10\{P_1 + (P_2 / 760)\}$$

m of H₂O

$$Q = A.V$$

m³/s

$$V = C [2g\Delta h (\rho_m - \rho_w) / \rho_w]^{0.5}$$

m/s

$$P_{output} = \frac{1}{60} \left[2\pi N (W_1 - W_2) \left\{ \frac{D + d}{2} \right\} \right]$$

$$P_{input} = \rho Q g H$$

$$\eta = \frac{P_{output}}{P_{input}}$$

Where

Q = discharge, m³/s

H = Net head on the turbine, m

V = velocity of water in pipe, in m/s

A = cross sectional area of pipe at the location of pitot tube, m²

C = Pitot tube Coefficient = 0.9

P₁ = turbine inlet pressure gauge reading, kg/cm²

P₂ = turbine outlet Vacuum gauge reading, mm Hg

Δh = manometer reading, m

W₁ = dead weight in dynamometer, N

W₂ = Spring balance reading in N

D = Brake drum diameter

d = Rope diameter

ρ_w = density of working fluid, kg/m³

ρ_m = density of manometric fluid, kg/m³

N = rotational speed of runner, rpm

g = acceleration due to gravity, m/s²

Procedure:

1. Clean the apparatus and make all tanks free from dust.
2. Close the drain valves provided.
3. Fill the storage sump upto 75% of its capacity with clean water and ensure that no foreign particles are there.
4. Check the manometric fluid is present in manometer
5. Switch on the main power supply (220 Volt AC, 50 Hz)
6. Switch on the pump.



7. Open the air release valve carefully to release any air from manometer.
8. When there is no air in the manometer, close the air release valves.
9. Regulate the guide vane position with the help of the hand wheel.
10. Now turbine is in operation.
11. Regulate the discharge by regulating the guide vane position.
12. Load the turbine with the help of hand wheel attached to the spring balance.
13. Record the pressure gauge and vacuum gauge readings.
14. Record the rotational speed of the turbine.
15. Record the dead weight and spring balance reading.
16. Record the manometer reading

APPARATUS DATA:

Cross-sectional area of the pipe	= 0.00916 m ²
Density of manometric fluid	= 13600 kg/m ³
Diameter of brake drum	= 0.3 m
Diameter of rope	= 0.012 m
Co-efficient of pitot tube	= 0.9
Energy meter constant	= 320 Pulses/kWh

OBSERVATION DATA TABLE:

Sl. No.	Turbine Speed (rpm)	Pressure Gauge reading			Dead weight, W ₁ . (Kg)	Spring balance reading, W ₂ (Kg)
		P (Kg/cm ³)	Vacuum gauge P (mm Hg)	Δh (m)		

FORMAT OF ANALYSIS DATA TABLE:

SL. No	Turbine Speed (rpm)	Head, H (m)	Flow rate, Q (m ³ /s)	Input power (KW)	Output power (KW)	Turbine efficiency (η)

FAQ & A on Reaction Turbine:

1. Why the area of the spiral casing is continuously decreasing towards the runner of the turbine?

Ans : The decreasing cross-sectional area compensates for the reduction in water volume as it is progressively distributed to the guide vanes around the runner. This maintains a constant velocity of flow throughout the casing, ensuring uniform and efficient water distribution to the runner.

2. What is the significance of the term "Reaction"?

Ans : It indicates that the turbine runner is fully immersed in water and both pressure and velocity change as water flows through it. The work is done partly by pressure energy conversion and partly by kinetic energy conversion, unlike impulse turbines.

3. Differentiate between impulse and reaction turbine.

Ans : In an impulse turbine (e.g., Pelton), all pressure energy is converted to kinetic energy before the water hits the runner, which operates at atmospheric pressure. In a reaction turbine (e.g., Francis/Kaplan), only part of the pressure energy converts to kinetic energy in the guide vanes; the rest converts inside the runner, which operates under pressure and requires a draft tube.

4. What do you mean by cavitation? What is the function of draft tube?



Ans : Cavitation is the formation and collapse of vapor bubbles when local pressure falls below vapor pressure, causing pitting and damage to turbine blades. The draft tube reduces the runner outlet velocity and recovers kinetic energy as pressure head, allowing the runner to be set above tailrace level while minimizing cavitation risk.

5. What do you mean by degree of reaction?

Ans : It is the ratio of pressure energy change in the runner to the total energy change (pressure + kinetic) across the turbine. It indicates how much of the total head conversion occurs within the runner itself.

6. What is the function of casing in reaction turbine?

Ans : The casing (spiral/volute casing) guides water smoothly and uniformly around the guide vanes into the runner, maintaining constant velocity and even pressure distribution, minimizing losses and shock at entry.

7. Define NPSH and cavitation factor.

Ans : NPSH (Net Positive Suction Head) is the head available at the pump/turbine inlet above vapor pressure, ensuring no cavitation occurs. Cavitation factor (Thoma's factor, σ) is the ratio of (available NPSH) to the net head, used to predict the onset of cavitation.

8. How can you measure the output power of the turbine?

Ans : Output power is measured using a dynamometer (brake, prony brake, or electrical generator) coupled to the turbine shaft, which measures torque and speed. $\text{Power} = 2\pi NT/60$, where N is speed (rpm) and T is torque.

9. How can you measure the inlet pressure head to the turbine?

Ans : A pressure gauge or manometer is connected at the turbine inlet (penstock) to directly measure the pressure head. This, combined with the velocity head (from flow rate and pipe area), gives the total head available at inlet.



EX4-III

Title: DETERMINATION OF THE OUTPUT POWER AND EFFICIENCY OF A PELTON TURBINE.

Test Apparatus:

The unit essentially consists of casing, with a large circular transparent window kept at the front for the visual inspection of the impact of the jet on buckets, a bearing pedestal, a rotor assembly of shaft, runner and brake drum, all mounted on a suitable sturdy cast iron base plate. A rope brake arrangement is provided to load the turbine. The input to the turbine is controlled by adjusting the spear position by means of a hand wheel fitted with indicator arrangement. The water inlet pressure is measured by a pressure gauge and for the measurement of speed, a hand tachometer is to be used.

Guiding Relations:

$$Q = k\sqrt{\Delta h}$$

Q = flow rate in LPM

Δh = mm of Hg

$$P_{output} = \frac{1}{60} \left[2\pi N (W_1 - W_2) \left\{ \frac{D + d}{2} \right\} \right]$$

$$P_{input} = \rho Q g H$$

$$\eta = \frac{P_{output}}{P_{input}}$$

W_1 = Load on brake pan + self-weight of pan (1 Kgf)

W_2 = Spring balance reading in Kgf

D = Brake drum diameter

d = Rope diameter

H = Net head m of water

Procedure:

1. Clean the apparatus and make all tanks free from dust.
2. Close the drain valves provided.
3. Fill the storage sump upto 75% of its capacity with clean water and ensure that no foreign particles are there
4. Switch on the main power supply (220 Volt AC, 50 Hz)
5. Switch on the pump.
6. Regulate the spear with the help of hand wheel.
7. Regulate the discharge by regulating the spear position.
8. Load the turbine with the help of hand wheel attached to the spring balance.
9. Record the pressure gauge and differential manometer reading.
10. Record the rotational speed of the turbine
11. Record the dead weight and spring balance reading.

APPARATUS DATA:

Brake drum diameter	= 450 mm
Rope diameter	= 16 mm
Venturimeter inlet pipe dia.	= 65 mm
Arca ratio	= 0.35
Venturimeter constant k	= 35.7

OBSERVATION DATA TABLE:

Sl.	Setting of	Speed	Net Head.	Pressure Gauge reading	W_1	W_2
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No.	Spear (%)	(rpm)	(Kg/cm ²)	P ₁ (Kg/cm ²)	P ₂ (Kg/cm ²)	Δh(Kg/cm ²)	(kg)	(kg)

ANALYSIS DATA TABLE:

Sl. No	Speed (rpm)	Net Head. H (m)	Flow rate, Q(m ³ /s)	Input power (KW)	Output power (KW)	Turbine efficiency (η)

FAQ & A on Pelton Wheel:

1. What are the main parameters in designing a Pelton wheel turbine?

Ans: Key parameters include jet velocity, bucket velocity (speed ratio), number of buckets, jet diameter, and head available. These determine the wheel diameter, number of jets, and overall efficiency of the turbine.

2. What is breaking jet in Pelton wheel turbine?

Ans: A breaking jet is a small jet directed at the back of the Pelton wheel buckets to quickly stop the wheel when the flow to the main nozzle is shut off. It prevents the runner from rotating freely for a long time due to inertia after load removal.

3. How the inlet discharge is controlled in Pelton turbine?

Ans: Discharge is controlled using a spear/needle valve inside the nozzle, which regulates the jet's cross-sectional area without significantly changing jet velocity, thus maintaining efficiency across varying loads.

4. Why draft tube is not required in impulse turbine?

Ans: Since the impulse turbine operates at atmospheric pressure and the jet has already converted all pressure energy to kinetic energy before striking the buckets, there is no pressure drop to recover, making a draft tube unnecessary.

5. What do you mean by bucket friction?

Ans: Bucket friction refers to the frictional resistance the water experiences while flowing over the bucket surface, causing a slight reduction in the relative velocity of water at the bucket exit compared to inlet, reducing efficiency slightly.

6. Why the inlet velocity triangle is linear in case of Pelton wheel?

Ans: Since the jet strikes the bucket tangentially and the direction of jet velocity coincides with the direction of bucket velocity at inlet, the relative velocity is also along the same line, making the inlet velocity triangle degenerate into a straight line.



INSTRUCTION ITEM-5 (II-5)		
Experiment No.	Name of the experiment	CO Congruence
EX5-I	Determination of overall efficiency and pump efficiency of centrifugal pump.	[CO5]
EX5-II	Determination of different parameters of reciprocating pump	

EX5-I

Title: DETERMINATION OF THE PERFORMANCE CHARACTERISTICS OF A CENTRIFUGAL PUMP.

TEST APPARATUS:

The centrifugal pump test rig consists of a sump, a centrifugal pump, a variable speed drive motor, volumetric measuring tank and a swinging field dynamometer. To measure the head, pressure and vacuum, gauges are provided. Pump discharge is measured with the help of the measuring tank. A flow diversion system is provided to divert the flow from the sump to the measuring tank and from the measuring tank back to the sump. To find the power, a swinging field dynamometer is provided. A valve is provided in the pipeline to vary the rate of flow.

Guiding Relations:

Shaft power as indicated by swinging field dynamometer,

$$\text{Shaft power} = 2 \pi \cdot N \cdot T / 60$$

$$\text{Torque} = F \cdot r$$

Where,

T = torque, Nm

N = shaft speed, rpm

F = force in spring balance

R = radius of swinging arm, m

Discharge as indicated by measuring tank:

$$\text{Discharge } Q = (AH)/t$$

Where,

A = area of base of measuring tank, m²

R = of collecting tank, m

T = time, sec

Head as indicated by pressure and vacuum gauges:

$$\text{Total head, m} = 10 \times [\text{discharge gauge reading} + (\text{Suction (Vacuum) gauge reading})/760] + 1 \text{ m of Water}$$

Calculation of power and Efficiency:

$$\text{Hydraulic power} = \rho Q g H$$

Where,

ρ = density of the working fluid, kg/m³

Q = discharge, m³/s

H = total head, m

APPARATUS DATA:

Area of measuring tank = 0.125849 m²

Energy meter constant = 3200 pulses/KWh

Radius of swinging field dynamometer = 0.127 m

PROCEDURE:

1. Fill the sump with clean water.
2. Open the delivery valve of the pump.
3. Start the pump and increase its speed.
4. Set the pump speed to the desired value.
5. Measure the discharge with the help of measuring tank and stop watch.
6. Record the pressure gauge and vacuum gauge readings.
7. Record the reading of spring balance to calculate torque



8. Alter the discharge by valve provided in pipeline.
9. Repeat the measurements in steps 5 to 7 and record all the readings.
10. Repeat this process 5 times for different flow rates.
11. Repeat the steps 4 to 10 for 3 different speeds.
12. Calculate the head, discharge, power and hydraulic efficiency and plot the graphs.

OBSERVATION DATA TABLE:

Sl. No.	Discharge gauge pressure (kg/cm ²)	Suction vacuum gauge pressure (mm of Hg)	Time for R (sec)	Spring balance reading (kg)	Force (N)	Speed N (rpm)	Height of water in tank, (cm) R

ANALYSIS DATA TABLE:

Sl. No.	Mean speed (rpm)	Discharge (m ³ /s)	Head, H (m of water)	Input power (W)	Torque (N-m)	Output power (W)	Efficiency (η)

FAQ & A on Centrifugal Pump:

1. Why backward curved vane is preferred in centrifugal pump?

Ans: They give higher hydraulic efficiency, stable operation and lower losses. The outlet velocity is lower, so less kinetic energy has to be converted into pressure in the casing. The power curve is also non-overloading.

2. Explain priming.

Ans: Filling the suction pipe and casing with liquid before starting. A pump running full of air develops almost no pressure because air is so light, so it cannot lift liquid. Priming removes this air.

3. Why the suction and delivery pipe diameter are not equal?

Ans: The suction pipe is larger, so velocity is low and the pressure drop stays small. This keeps the pressure above the vapour pressure and avoids cavitation. The delivery pipe is smaller, which is more economical and suits the higher pressure.

4. What kind of losses occur inside the impeller of centrifugal pump?

Ans: (i) Friction losses between the liquid and the vane surfaces.

(ii) Shock (incidence) losses at the inlet when the flow angle does not match the vane angle.

(iii) Eddy or separation losses caused by flow separation and turbulence.

(iv) Leakage (recirculation) losses through the clearance between the impeller and casing.

5. How can you measure the pressure developed by the pump?

Ans: Use a pressure gauge on the delivery side and a vacuum gauge on the suction side. Then add the two readings, plus any correction for the height between the gauges. The total head is

$$H = (P_d - P_s)/\rho g + (V_d^2 - V_s^2)/2g + Z.$$



EX5-II

Title: DETERMINATION OF DIFFERENT PARAMETERS OF RECIPROCATING PUMP

Theory

RECIPROCATING PUMP TEST RIG (constant speed type)

Reciprocating pump is a positive displacement plunger pump. It is often used where relatively small quantity of water is to be handled and delivery pressure is quite large. Reciprocating pumps are widely used at Automobile Service Stations, Chemical Industries and as metering pumps.

The apparatus consists of a single cylinder, single acting reciprocating pump mounted over the sump tank. The pump is driven by 1 ph. D.C. motor. An energy meter to measures electrical input to motor. Measuring tank is provided to measure discharge of the pump. The pressure and vacuum gauges provided to measure the delivery pressure and suction vacuum respectively.

SPECIFICATIONS:

1. Reciprocating pump - Single cylinder, single acting with air vessel on discharge side. Piston 55 mm & Stroke length 40 mm. Suction pipe 1 inch. & discharge pipe 1 inch.
2. Motor 1 P.H., 1 H.P. capacity DC motor.
3. Measuring tank- (L) mm x (W) mm x (H) mm height provided with piezometer tube.
4. Measurements -
 - a) Pressure gauge for discharge pressure.
 - b) Vacuum gauge 0-760 mm Hg for suction vacuum.
 - c) 1 PH energy meter for motor input measurement.

EXPERIMENTAL PROCEDURE:

- 1) Fill up clean water in sump tank.
 - 2) Open the gate valve of the discharge pipe and drain valve of the measuring tank fully.
 - 3) Start the pump. Let some water flow in the measuring tank.
- *(Note: The pressure gauge & vacuum gauges are provided with damping valves. These valves are just opened slightly to read the gauge and avoid fluctuations of the pointer.)
- 4) Slightly close the discharge valve till the pressure rises by about 1 kg/cm².
 - 5) Close the drain valve of the measuring tank. Note down the time required for X cm rise of water in the measuring tank.
 - 6) Fill up various readings in the observations table.
 - 7) Repeat the procedure for different gate valve openings.

Take care that discharge pressure does not rise above 4 Kg/cm².

OBSERVATIONS:

Measuring tank length (L) = _____ m

Measuring tank width (W) = _____ m.

Sr. No.	Pump speed rpm	Discharge P (Kg/cm ²)	Suction Vacuum mm of Hg	Time for H m water collection, t sec.	Q = L·B·H/T m ³ /s	Time for N blinks of Energy meter t _e sec

Note- Pump speed is to be measured with laboratory tachometer and it is not the part of the equipment.



CALCULATIONS:

1) Volume per stroke,

$$V_s = \frac{\pi}{4} D^2 L \quad (\text{Total swept volume})$$

$$= \frac{\pi}{4} (0.055)^2 (0.04) \text{ m}^3/\text{stroke}$$

2) Theoretical discharge,

$$Q_t = \frac{V_s \times N_p}{60} \quad \text{m}^3/\text{sec}$$

3) Suction head

$$H_s = \text{Suction Vacuum of Hg} \times \left(\frac{\rho_{Hg}}{\rho_w} - 1 \right)$$

Where,

ρ_{Hg} = Sp. gravity of mercury = 13.6

H_s = 12.6 x suction vacuum (m) .

4) Delivery head -

H_d = Discharge pressure $\text{kg/cm}^2 \times 10$ (as 10m of water = 1 kg/cm^2)

5) Total head

$$H_T = H_s + H_d + 3 \text{ mtr.}$$

Where, loss of head of piping and fitting is assumed to be 3 mtrs.

6) Actual discharge (for 10 cm rise)

Actual discharge. $Q_a = L \times W \times 0.10 / t \text{ m}^3/\text{sec}$,

7) Output power of pump

$$P_w = W \cdot Q_a \cdot H_r / 1000 \text{ kw}$$

Where,

W = Specific weight of water = 9810 n/m^3

Q_a = Discharge m^3/sec

H_T = Total head, m

8) Input power to pump

Let time required for 10 imp of energy meter be sec. Then.

$$IP = \frac{10}{t_c} \times \frac{3600}{3200} \text{ Kw}$$

Where, Energy meter constant is 3200 imp/ kw h.

Taking motor efficiency 75% we have input shaft power

Taking belt transmission efficiency 80%

$$S.P. = I.P. \times 0.75 \times 0.80$$

9) Overall efficiency of pump

$$\eta_0 = \frac{P_w}{SP} \times 100\%$$

Graphs - Plot the graph of head Vs. discharge, input power and efficiency of the pump. (at constant speed).



FAQ & A on Reciprocating pump

1. How does a reciprocating pump differ from other types of pumps, such as centrifugal pumps, in terms of its operating principle?

Ans: A reciprocating pump moves fluid using the back-and-forth motion of a piston/plunger in a cylinder (positive displacement), whereas a centrifugal pump uses a rotating impeller to impart kinetic energy to the fluid, converting it to pressure. Reciprocating pumps give constant flow regardless of pressure; centrifugal pump flow varies with pressure head.

2. What are the key components of a reciprocating pump, and how do they contribute to its functionality?

Ans: (i) **Cylinder** – chamber where fluid is trapped and displaced
(ii) **Piston/Plunger** – moves back and forth to draw in and push out fluid
(iii) **Suction & Delivery valves** – one-way valves controlling fluid direction
(iv) **Crankshaft & Connecting rod** – convert rotary motor motion into reciprocating motion
(v) **Suction & Delivery pipes** – carry fluid to/from the pump

3. What factors influence the efficiency of a reciprocating pump, and how can they be optimized for better performance?

Ans: (i) Slip (leakage past valves/piston) – minimize with proper valve seating
(ii) Friction losses in pipes/valves – reduce pipe length, use smooth bores
(iii) Speed of operation – optimum speed avoids excessive inertia effects
(iv) Valve design and inertia – lighter, faster-responding valves
(v) Air vessels – used to smooth flow and reduce acceleration losses

4. Can you explain the working principle of a double-acting reciprocating pump and how it differs from a single-acting pump?

Ans: **Single-acting:** Fluid is drawn and delivered on only one side of the piston, one suction & one delivery stroke per crank revolution.

Double-acting: Fluid is drawn and delivered on both sides of the piston, giving two suction and two delivery strokes per revolution, nearly doubling output for the same size.

5. What are some common applications of reciprocating pumps, and why are they preferred in certain industries or scenarios over other types of pumps?

Ans: (i) Oil drilling & well pumps (high pressure, low flow needs)
(ii) Boiler feed water pumps
(iii) Hydraulic systems/presses
(iv) Metering and dosing (chemical industry) due to precise, constant flow
Preferred where **high pressure at low/moderate flow rate** or **precise dosing** is needed—something centrifugal pumps handle poorly.



INSTRUCTION ITEM-6 (II-6)		
Experiment No.	Name of the experiment	CO Congruence
EX6-I	Determination of volume flow rate and volumetric efficiency of centrifugal blower.	[CO6]
EX6-II	Determination of volumetric efficiency and compression ratio of centrifugal compressor.	

EX6-I

Title: DETERMINATION OF THE DISCHARGE, HEAD AND EFFICIENCY OF THE CENTRIFUGAL BLOWER.

THEORY:

Blowers are used to discharge higher volume of air at low pressure. They consist of impeller and spiral casing. They are used in furnaces, cupolas, mine and air-conditioning plants etc

There can be three different types of impellers namely Radial Curved Vane, Forward Curve Vane, and Backward Curve Vane. Impellers may be made of sheets and can be casted. Motor rotates the impeller and impeller sucks the air through the center and delivers the air through its periphery. Velocity, discharge and head depend upon the outlet, inlet angles and peripheral speed.

Guiding Relations

$$H. P. Elect = P / \eta \times 3600 / EMC \times 1000 / 746$$

$$H. P. Shaft = H. P. Elect \times \eta \text{ motor}$$

$$\eta \text{ Motor} = \text{Efficiency of motor} = 0.8 \text{ (assumed)}$$

$$H = (h_1 + h_2) (\rho_w / \rho_a - 1)$$

$$V = C_{pitot} \sqrt{2gh}$$

$$h = R(\rho_w / \rho_a - 1) \text{ meter of air}$$

$$Q = A.V$$

$$H. P. Blower = \rho_a QH / 75$$

$$\text{Blower Efficiency} = H.P \text{ Blower} / H. P. Shaft \times 100$$

$$\text{Overall Efficiency} = H.P \text{ Blower} / H. P. Electrical \times 100$$

Procedure:

STARTING PROCEDURE:

1. Clean the apparatus and make it free from dust.
2. Fill manometer fluid in manometer tube i.e. water..
3. Fix the impeller on the desired one(Radial, backward or forward curve vane).
4. Switch on the main power supply.
5. Switch on the blower.
6. Fix the RPM of motor with the help of DC drive and read the RPM of motor with the help of RPM indicator provided on the panel.
7. Control the flow of air with the help of control valve provided in the discharge pipe.
8. Measure the pressure difference, static head and dynamic head with the help of manometer.
9. Record the power consumption by means of energy meter, provided in panel using stop watcg.
10. Repeat the same experiment for constant RPM but change the flow of air with the help of control valve and then for different RPM.
11. When experiment on first particular impeller is over, fix other desired impeller on blower and start experiment.

CLOSING PROCEDURE:



1. When experiment is over, adjust DC drive knob at zero.
2. Switch off the blower.
3. Switch off power supply to panel.

APPARATUS DATA:

$$D = 69 \text{ mm} = 0.069 \text{ m}$$

$$\rho_a = 1.19 \text{ kg/m}^3$$

$$\rho_w = 1000 \text{ kg/m}^3$$

$$C_{\text{Pitot}} = 0.98$$

OBSERVATION DATA TABLE:

RPM	Opening	Static Pressure(cm), h	Dynamic Pressure(cm), h	Differential Pressure(cm), R	Time taken for 10 Pulses (Sec)
	Full open				
	3/4 open				
	1/2 open				
	1/4 open				

ANALYSIS DATA TABLE:

Input power (Electrical)	Shaft power	Velocity of air m/scc	Total head (m)	Discharge, m ³ /sec	Output power (Blower)	Blower efficiency (%)	Overall efficiency. (%)

FAQ & A on Blower:

1. Difference between compressor, fan and blower.
2. How can you measure the flow rate?
3. How can you control the flow rate in blower?
4. How can you measure the power consumed by blower?
5. What is the overall efficiency of blower? How can you calculate?



EX6-II

Title: DETERMINATION OF VOLUMETRIC EFFICIENCY AND COMPRESSION RATIO OF CENTRIFUGAL COMPRESSOR.

THEORY

A centrifugal compressor is a rotary, continuous-flow machine. Air enters axially at the eye of the impeller and is thrown radially outward by centrifugal force. The impeller raises the air's velocity (kinetic energy). The diffuser and volute casing then convert this velocity into pressure.

Compression ratio (r): the ratio of absolute delivery pressure to absolute suction pressure.

$$r = P_2 / P_1$$

where P_1 = absolute suction pressure ($\approx$ atmospheric) and P_2 = absolute delivery pressure (gauge reading + atmospheric).

Volumetric efficiency (η_v): the ratio of the actual volume of air delivered (measured at suction conditions) to the theoretical volume the compressor can handle (rated capacity at the same speed).

Actual air flow is measured with an orifice meter connected to an air tank and a water U-tube manometer:

- Head of air: $h_a = h_w \times (\rho_w / \rho_a)$
- Actual volume flow: $Q_a = C_d \times a_o \times \sqrt{2 g h_a}$ (m^3/s)
- Air density: $\rho_a = P_{\text{atm}} / (R \times T_1)$, with $R = 287 \text{ J/kg}\cdot\text{K}$

Here C_d is the coefficient of discharge of the orifice, a_o is the orifice area, and h_w is the manometer difference in metres of water. Q_{th} is taken from the manufacturer's rated capacity at the test speed (or from the impeller geometry if the rig provides it). A centrifugal compressor is not a positive-displacement machine, so flow and pressure ratio vary with speed and delivery valve setting; several readings are therefore taken.

APPARATUS DATA

(Fill in from the nameplate / rig specification.)

Parameter	Symbol	Value	Unit
Type of compressor	-	Centrifugal, single stage	-
Rated speed	N	_____	rpm
Motor power rating	P	_____	kW
Impeller diameter	D	_____	m
Orifice diameter	d_o	_____	m
Orifice area ($\pi d_o^2/4$)	a_o	_____	m^2
Coefficient of discharge of orifice	C_d	_____ (typ. 0.62)	-
Density of water	ρ_w	1000	kg/m^3
Gas constant for air	R	287	$\text{J}/\text{kg}\cdot\text{K}$
Atmospheric pressure	P_{atm}	_____	bar
Atmospheric (suction) temperature	T_1	_____	K
Rated (theoretical) volume flow	Q_{th}	_____	m^3/s



Parameter	Symbol	Value	Unit
Pressure gauge range / least count	-	_____	bar
Manometer fluid	-	Water	-

PROCEDURE

STARTING PROCEDURE

1. Check that the compressor, motor and pipe connections are properly assembled and free of leaks.
2. Check the lubricating oil level and the coolant (water) supply, if provided.
3. Ensure the water manometer is filled and both limbs read the same level (zero error).
4. Fully open the delivery (throttle) valve so that the compressor starts at minimum load.
5. Ensure the pressure gauge and the speed measuring device (tachometer) are working.
6. Note down the atmospheric pressure and temperature.
7. Switch on the main supply and start the motor using the starter. Allow the compressor to reach its steady speed.

EXPERIMENTAL PROCEDURE

1. With the delivery valve fully open, allow the machine to run for a few minutes to reach steady state.
2. Record the speed (N), delivery pressure gauge reading (P_g), manometer readings (h_1 and h_2), suction temperature (T_1) and delivery temperature (T_2).
3. Gradually close the delivery valve to raise the delivery pressure in steps (e.g. 0.1 bar, or as advised by the instructor).
4. At each valve setting, wait for the readings to stabilise, then record all the above observations.
5. Repeat for at least 5–6 readings, without exceeding the maximum permissible delivery pressure.
6. If the rig has variable speed, repeat the test at one or two other speeds.
7. Use the observations to calculate the compression ratio and volumetric efficiency.

CLOSING PROCEDURE

1. Gradually open the delivery valve fully to unload the compressor.
2. Switch off the motor and the main power supply.
3. Let the compressor come to rest; do not touch hot parts.
4. Turn off the cooling water supply (if used).
5. Clean the apparatus and leave the workstation tidy.

Precautions: Never start the compressor with the delivery valve closed. Do not exceed the maximum delivery pressure. Keep clear of rotating parts. Take readings only after the flow is steady.

OBSERVATION DATA TABLE

Atmospheric pressure, P_{atm} = _____ bar Atmospheric temperature, T_1 = _____ K

S. No.	Speed N (rpm)	Delivery gauge pressure P_g (bar)	Manometer left limb h_1 (cm)	Manometer right limb h_2 (cm)	$h_w = h_1 - h_2$ (cm)	Suction temp. T_1 ($^{\circ}\text{C}$)	Delivery temp. T_2 ($^{\circ}\text{C}$)



6. ANALYSIS (CALCULATION) DATA TABLE

Formulae used:

1. Absolute delivery pressure: $P_2 = P_g + P_{atm}$ (bar)
2. Compression ratio: $r = P_2 / P_1$, where $P_1 = P_{atm}$
3. Air density: $\rho_a = (P_{atm} \times 10^5) / (287 \times T_1)$ (kg/m^3)
4. Head of air: $h_a = h_w \times (\rho_w / \rho_a)$ (m of air), with h_w in metres
5. Actual volume flow rate: $Q_a = C_d \times a_o \times \sqrt{2 g h_a}$ (m^3/s)
6. Volumetric efficiency: $\eta_v = (Q_a / Q_{th}) \times 100$ (%)

S. No.	$P_2 = P_g + P_{atm}$ (bar)	Compression ratio $r = P_2/P_1$	h_w (m)	ρ_a (kg/m^3)	h_a (m of air)	Q_a (m^3/s)	Q_{th} (m^3/s)	η_v (%)

7. GRAPHS TO BE PLOTTED

1. Compression ratio (r) vs. actual flow rate (Q_a)
2. Volumetric efficiency (η_v) vs. compression ratio (r)

8. RESULT

The compression ratio of the centrifugal compressor varied from _____ to _____, and the volumetric efficiency varied from _____ % to _____ % over the range tested.

9. VIVA QUESTIONS

1. How does a centrifugal compressor differ from a reciprocating compressor?

Ans: Centrifugal compressor uses a rotating impeller to accelerate gas and convert kinetic energy to pressure (continuous flow, dynamic type). Reciprocating compressor uses a piston moving in a cylinder to compress gas by reducing volume (positive displacement, pulsating flow).

2. Why should the delivery valve be open at start-up?

Ans: It should be open (in centrifugal compressors) so the compressor starts against **low/no load**, reducing starting torque and current draw, and preventing surge/damage until proper speed and pressure are built up.

3. What is surging in a centrifugal compressor?

Ans: Surging is a condition of **flow instability** where flow reverses intermittently due to operation below the minimum flow rate, causing pressure and flow to fluctuate rapidly—leading to vibration, noise, and possible mechanical damage.

4. Why is an orifice meter used to measure air flow?

Ans: It's used because it's **simple, inexpensive, and reliable** for measuring flow rate by relating the pressure drop across the orifice plate to flow velocity, suitable for compressible fluids like air.

5. What factors affect the volumetric efficiency and pressure ratio?

Ans: The following factors affect the volumetric efficiency and pressure ratio

- Clearance volume in cylinder
- Pressure ratio itself (higher ratio $\rightarrow$ lower volumetric efficiency)
- Valve leakage/losses
- Temperature of intake air
- Speed of compressor
- Type of gas (specific heat ratio)