

Vision of the Institute

"To become a leading institute of providing professionally competent and socially responsive technocrats with high moral values."

Mission of the Institute

- ⇒ To create an eco-system for the dissemination of technical knowledge, to achieve academic excellence.
- ⇒ To develop technocrats with creative skills and leadership qualities, to solve local and global challenges.
- ⇒ To impart human values and ethics in students, to make them socially and Eco-friendly responsible.

LAB MANUAL OF HHM LAB [BCE 453]

B.TECH, 2nd Year, Semester -4th



**Dr. A.P.J. Abdul Kalam Tech. University
Uttar Pradesh**

2025-26

Department of Civil Engineering

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(Assistant Professor)

Approved by: (Head of the Department)

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MANUAL CONTENTS

This manual is intended for the 2nd year students of Civil Engineering in the subject of **Hydraulics and Hydraulic Machine Lab**. This manual typically contains practical/lab sessions related to hydraulics and hydraulic machines, covering various aspects of fluid flow behavior, open channel flow, and performance analysis of hydraulic devices such as pumps and turbines for enhanced understanding of the subject.

Students are advised to thoroughly go through this manual rather than only focusing on topics mentioned in the syllabus, as practical exposure is essential for understanding and visualizing the theoretical concepts of fluid mechanics and hydraulic machinery covered in textbooks.

The laboratory sessions are designed to help students gain hands-on experience, develop analytical skills, and understand the real-life applications of hydraulic principles.

Good Luck for your Enjoyable Laboratory Sessions.

PREFACE

This practical manual will be helpful for students of Civil Engineering for understanding the course from the point of view of applied aspects. Though all the efforts have been made to make this manual error free, yet some errors might have crept in inadvertently. Suggestions from the readers for the improvement of the manual are most welcomed.



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VISION OF THE DEPARTMENT

To impart academic excellence in civil engineering field with emphasis on holistic development of the professional, while inculcating ethics, socially and professionally responsive technocrats.

MISSION OF THE DEPARTMENT

- **M1** – To provide a comprehensive platform for academic expertise and proficiency.
- **M2** – To develop civil engineering professionals with creative skills and leadership qualities in order to face regional and global challenges.
- **M3** – To develop ethics in students in order to promote socially responsible environmental awareness with innovative thinking.



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Program Educational Objectives(PEOs) of Department

PEO 1: To develop capacities and proficiency in the field of Civil engineering field towards improving employability attitude.

PEO 2: To develop multidisciplinary approach through sophisticated tools/information system, construction projects and data bases to meet the social requirements.

PEO 3: To utilize basic knowledge in the actual working conditions as a contribution towards safe and sustainable society.

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Program Outcomes:(PO)

Graduates will be able to achieve

• **PO1: Engineering Knowledge**

Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

• **PO2: Problem Analysis**

Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

• **PO3: Design/Development of Solutions**

Design solutions for complex engineering problems and design system components or processes that meet specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.

• **PO4: Conduct Investigations of Complex Problems**

Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

• **PO5: Modern Tool Usage**

Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

• **PO6: The Engineer and Society**

Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to professional engineering practice.

• **PO7: Environment and Sustainability**

Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate the knowledge of, and need for sustainable development.

• **PO8: Ethics**

Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.

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- **PO9: Individual and Team Work**

Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

- **PO10: Communication**

Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

- **PO11: Project Management and Finance**

Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

Program Specific Outcomes(PSOs) of the Department

- **PSO 1:** Graduates shall be able to apply critical thinking in research, design, analysis and implementation of Civil Engineering problems.
- **PSO2:** Graduate shall be able to inculcate the idea of sustainability in engineering solution to meet real world Challenges.

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Course Evaluation Scheme

| Sr No | Subject Code | Subject Name | Periods | | | Evaluation Scheme | | | | Total | Credit |
|-------|--------------|------------------------------------|---------|---|---|----------------------|----|----|----|-------|--------|
| | | | L | T | P | Sessional Assessment | | | PE | | |
| | | | | | | CT | TA | PS | | | |
| 1. | BCE453 | Hydraulics & Hydraulic Machine Lab | 0 | 0 | 2 | - | 50 | - | 50 | 100 | 1 |

Course Objectives:

The teacher will explain:

| | |
|----|---|
| 1. | To understand and analyze the behavior of open channel flow under different conditions and to determine related parameters such as velocity distribution, energy, and momentum. |
| 2. | To study and evaluate the performance of hydraulic structures like weirs, notches, and flow measuring devices. |
| 3. | To understand the working principles and performance characteristics of hydraulic machines including pumps and turbines. |

Pre-requisite: Fundamentals of Fluid Mechanics, Engineering Mechanics, Basic Hydraulics, Open Channel Flow, and Hydraulic Machines.

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Course Outcomes (COs)

| Course Outcomes: The students should be able to: | | Bloom's Level |
|--|--|---------------|
| CO1 | Perform open channel flow experiments to determine velocity, discharge, energy, and roughness parameters. | L3 |
| CO2 | Examine flow behavior in open channels including contractions, humps, hydraulic jumps, and free over-fall. | L4 |
| CO3 | Compute work done and efficiency of water jets on different types of blades/vanes (stationary and moving) using impulse–momentum principles. | L5 |
| CO4 | Determine performance characteristics of hydraulic machines including pumps and turbines. | L2 |
| CO5 | Integrate experimental results to relate flow phenomena and machine performance with theoretical principles. | L4 |

CO-PO-PSO Mapping

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PSO1 | PSO2 |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|
| CO1 | 2 | 2 | – | 2 | 1 | 1 | – | 2 | 2 | – | – | 2 | – |
| CO2 | 2 | 2 | – | 1 | – | 1 | – | 2 | 2 | – | – | 1 | - |
| CO3 | 3 | 2 | – | 2 | 1 | – | – | 2 | 2 | – | – | 1 | – |
| CO4 | 3 | 2 | – | 2 | 1 | 1 | – | 2 | 2 | – | – | 2 | - |
| CO5 | 2 | 1 | – | 1 | – | 1 | – | 2 | 2 | – | – | 2 | - |
| Avg. | 2.4 | 1.8 | - | 1.6 | 1 | 1 | - | 2 | 2 | - | - | 1.6 | - |

The extent of mapping is as follows: 1 for low, 2 for moderate, 3 for high & "–" for No correlation between CO & PO.

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List of Experiments

| S. No. | Experiment |
|--------|---|
| 1. | To determine the Manning’s coefficient of roughness ‘n’ for the bed of a given flume. |
| 2. | To study the flow characteristics over a hump placed in an open channel. |
| 3. | To study the flow through a horizontal contraction in a rectangular channel. |
| 4. | To calibrate a broad-crested weir. |
| 5. | To study the characteristics of free hydraulic jump. |
| 6. | To study centrifugal pump and their characteristics. |
| 7. | To study characteristics of Pelton Turbine. |
| 8. | To study characteristics Francis Turbine. |
| 9. | To study characteristics of Kaplan Turbine. |
| 10. | To determine coefficient of discharge for given rectangular notch. |

Beyond Syllabus:

| S. No. | Experiment |
|--------|--|
| 1. | To calculate Manning’s Coefficient (or depth) from cross-section data for trapezoidal or rectangular channels by using Manning’s calculator. |
| 2. | Field visit to the Indira Canal Aqueduct for practical observation and analysis of hydraulic jump phenomena. |

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INDEX

| S. No. | Name of the Experiment | CO | BTL | Lab Conduction Date | Remark/ Grade/ Marks | Faculty Signature with Date |
|--------|--------------------------------|-----|-----|---------------------|----------------------|-----------------------------|
| 1. | Manning’s coefficient | CO1 | L3 | | | |
| 2. | Flow over hump | CO2 | L4 | | | |
| 3. | Flow through contraction | CO2 | L4 | | | |
| 4. | Broad-crested weir calibration | CO3 | L5 | | | |
| 5. | Hydraulic jump | CO2 | L4 | | | |
| 6. | Centrifugal pump | CO4 | L3 | | | |
| 7. | Pelton turbine | CO5 | L4 | | | |
| 8. | Francis turbine | CO5 | L4 | | | |
| 9. | Kaplan turbine | CO5 | L4 | | | |
| 10. | Rectangular notch (Cd) | CO3 | L3 | | | |



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Software's required:

Manning's Equation Calculator

Hardware's required:

Open channel flume, measuring tank, point gauge, hook gauge, current meter, broad-crested weir, rectangular notch, hump and contraction models, hydraulic jump apparatus, centrifugal pump test rig, Pelton turbine setup, Francis turbine setup, Kaplan turbine setup, pressure gauges, flow measuring devices, stop watch, and measuring scale.

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Do's

1. Ensure all apparatus are clean and properly set before starting the experiment.
2. Take all readings carefully and accurately with proper observation.
3. Maintain steady flow conditions before recording readings.
4. Check all connections, valves, and measuring devices before operation.
5. Follow the instructions of the lab instructor strictly.
6. Record observations systematically in the observation table.
7. Switch off the equipment properly after completion of the experiment.

Don'ts

1. Do not start the equipment without proper guidance or permission.
2. Do not take readings under unsteady or fluctuating flow conditions.
3. Do not mishandle instruments like point gauge, pressure gauge, etc.
4. Do not allow water spillage near electrical components.
5. Do not change valve settings abruptly.
6. Do not ignore safety precautions during operation.
7. Do not leave the apparatus running unattended.

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EXPERIMENT NO: 01

OBJECTIVE: To determine the Manning's coefficient of roughness 'n' for the bed of a given flume.

EXPERIMENTAL SETUP:

For conducting this experiment long hollow rectangular channel is used with bed slope adjustments, point gauge is kept on upstream side of channel to measure the depth of water. Inlet pipe is provided with flow regulating arrangement. Outlet of channel is directly taken to the measuring tank which is provided with piezometer tube arrangement outlet is provided with measuring tank.

THEORY:

In open channel water flows under atmospheric pressure, when water flows in an open channel, resistance is offered to it, which causes loss of energy. A uniform flow will be developed if the resistance is balanced by the gravity forces. The magnitude of the resistance when other physical factors of the channel are kept unchanged depends on the velocity of the flow. The following formulae are used to measure the velocity are

Manning's formula is $V=(1/N)R^{2/3} S_0^{(1/2)}$

Where N is manning's roughness

coefficient R is hydraulic mean radius

S_0 is channel bottom slope

The relation between chezy and manning's

formula is $C = (1/N)R^{1/6}$

PROCEDURE:

1. Remove all the obstructions in the channel
2. Prepare the unit for open channel experiment by lifting both the gates so that there is no obstruction to the flow of water.
3. By screwing up the wheel of the tilting arrangement the required slope for the channel can be attained. Note the readings in the vertical scale as shown.
4. Allow the water in the channel, so that the water flows along the open channel at the steady condition.
5. With the help of the point gauge, find the head of water in the channel. Let it be $y=----m$

| | |
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|--|---|

6. Take manometer reading L.

Calculate the discharge by using formula, $Q_{act} = Cd.a \sqrt{2gh}$.

7. Repeat Steps 1 to 6 for different readings. i.e. head of water and for different channel slope.

OBSERVATIONS:

- Width of channel “ B ”= 30 cm
- Diameter of orifice “d”= 4.8 cm
- Area of orifice “a” = 18.09 cm²
- 3. Length of channel= 6 m = 6000 mm

OBSERVATION TABLE: SAMPLE CALCULATIONS:

1. $Y = W.S. - C.B$
2. $h = h' *(13.6-1)$
3. $Q_{act} = Cd.a \sqrt{2gh}$
Where $Cd= 0.611$; $g= 981 \text{ cm/s}^2$
4. $R= \text{Area} / \text{Wetted Perimeter} = B*Y/ B+2Y$
5. $\text{Velocity} = Q_{act}/\text{Area}$
6. $V=C \sqrt{(RS_o)}$
7. $V= (1/N)*R^{2/3}S_o^{1/2}$

RESULTS:

1. Average value of manning’s constant =N=

| S. No | Bed Slope | C. B. | W.S. Reading | Dif f. (h') cm | Manometer Reading (h) cm | Depth (Y) | Area (a) | Qact | Hydraulic Radius (R) | Velocity V = Q/a | Chez y’s C | 1/ N | N | Slope (So) |
|-------|-----------|-------|--------------|----------------|--------------------------|-----------|----------|------|----------------------|------------------|------------|------|---|------------|
| 1 | 5/6000 | | | | | | | | | | | | | |



**BABU BANARASI DAS
INSTITUTE OF TECHNOLOGY & MANAGEMENT**

Affiliated to Dr A P J Abdul Kalam Technical University (AKTU College Code- 054)

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| | | | | | | | | | | | | | | | | | | | |
|---|-------------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| 2 | 10/60 00 | | | | | | | | | | | | | | | | | | |
| 3 | 15/60 00 | | | | | | | | | | | | | | | | | | |
| 4 | 20/60 00 | | | | | | | | | | | | | | | | | | |
| 5 | 25/60 00 | | | | | | | | | | | | | | | | | | |
| 6 | 30/60 00 | | | | | | | | | | | | | | | | | | |

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EXPERIMENT NO. 02

Objective

To study the flow characteristics over a hump placed in an open channel.

APPARATUS REQUIRED

Tilting flume, hump (different heights), point gauge/hook gauge, measuring tank, scale.

THEORY

A hump is a raised obstruction in the bed of an open channel. When water flows over a hump, the flow characteristics change depending on the height of the hump and discharge.

Flow types:

- **Subcritical Flow** ($y > y_c$) → Velocity low, depth high
- **Critical Flow** ($y = y_c$) → Minimum specific energy
- **Supercritical Flow** ($y < y_c$) → Velocity high, depth low

Effect of Hump Height

- If hump height is **less than critical height** → Flow remains subcritical
- If hump height = **critical height** → Flow becomes critical over hump
- If hump height > **critical height** → Flow becomes supercritical downstream

FORMULAE

Discharge:

$$Q = A \times V$$

Specific Energy:

$$E = y + (V^2 / 2g)$$

Critical Depth:

$$y_c = (Q^2 / gB^2)^{1/3}$$

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Velocity:

$$V = Q / (B \times y)$$

PROCEDURE

1. Set the flume at required slope
2. Allow water to flow and achieve steady condition
3. Measure initial depth (upstream)
4. Place hump in the channel
5. Measure depth:
 - Upstream of hump
 - Over the hump
6. Repeat for different discharges
7. Repeat for different hump heights
8. Identify type of flow at each section

OBSERVATIONS

Given Data:

Width of channel (B) = _____ m

Discharge (Q) = _____ m³/s

Acceleration due to gravity (g) = 9.81 m/s²

OBSERVATION TABLE

| S. No. | Discharge Q (m ³ /s) | Hump Height (m) | Depth Upstream y ₁ (m) | Depth over Hump y ₂ (m) | Depth Downstream y ₃ (m) | Flow Type |
|-----------|---------------------------------|-----------------|-----------------------------------|------------------------------------|-------------------------------------|-----------|
| 1. | | | | | | |
| 2. | | | | | | |
| 3. | | | | | | |
| 4. | | | | | | |

CALCULATIONS

Area:

$$A = B \times y$$

Velocity:

$$V = Q / A$$

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Specific Energy:

$$E = y + (V^2 / 2g)$$

Critical Depth:

$$y_c = (Q^2 / gB^2)^{1/3}$$

GRAPH

Plot:

- Depth (y) vs Distance along channel
(Flow profile curve)

RESULT

Flow characteristics over the hump were studied.

Observed:

- Upstream flow = _____
- Over hump flow = _____
- Downstream flow = _____

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EXPERIMENT NO. 03

OBJECTIVE

To study the flow through a horizontal contraction in a rectangular channel.

APPARATUS REQUIRED

Hydraulic bench, rectangular flume, contraction model, hook/point gauge, measuring tank, stopwatch, scale.

THEORY

In open channel flow, when the width of the channel is reduced (horizontal contraction), the flow characteristics change due to the principles of continuity and energy conservation.

According to the continuity equation:

$$Q = A_1 V_1 = A_2 V_2$$

When the channel width decreases:

- Cross-sectional area decreases
- Velocity increases
- Depth of flow decreases

Detailed Flow Behavior

When water flows through a contracted section:

- Velocity increases due to reduced area
- Flow depth decreases due to acceleration
- Pressure head reduces at contraction
- Flow may reach critical condition depending on discharge

If contraction is significant:

- Flow becomes **critical at contraction**
- Downstream flow may become **supercritical**

Specific Energy Concept

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Specific energy is defined as:

$$E = y + (V^2 / 2g)$$

During contraction:

- Velocity head increases
- Depth decreases
- Total energy remains approximately constant (neglecting losses)

Froude Number & Flow Type

Froude Number:

$$Fr = V / \sqrt{(gy)}$$

Flow classification:

- $Fr < 1 \rightarrow$ Subcritical flow
- $Fr = 1 \rightarrow$ Critical flow
- $Fr > 1 \rightarrow$ Supercritical flow

FORMULAE

Discharge:

$$Q = A \times V$$

Area:

$$A = B \times y$$

Velocity:

$$V = Q / A$$

Specific Energy:

$$E = y + (V^2 / 2g)$$

Froude Number:

$$Fr = V / \sqrt{(gy)}$$

PROCEDURE

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1. Measure initial width of channel (B_1)
2. Measure contracted width (B_2)
3. Start water flow and maintain steady condition
4. Measure depth:
 - Before contraction (y_1)
 - At contraction (y_2)
 - After contraction (y_3)
5. Measure discharge using collecting tank
6. Repeat for different discharges
7. Calculate velocity, energy and Froude number

OBSERVATIONS

Given Data:

Width before contraction (B_1) = _____ m

Width after contraction (B_2) = _____ m

Acceleration due to gravity (g) = 9.81 m/s²

OBSERVATION TABLE

| S.No | Discharge Q (m ³ /s) | Depth y_1 (m) | Depth y_2 (m) | Depth y_3 (m) | Velocity V_1 (m/s) | Velocity V_2 (m/s) | Froude No. (Fr) | Flow Type |
|------|---------------------------------|-----------------|-----------------|-----------------|----------------------|----------------------|-----------------|-----------|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |

CALCULATIONS

Area:

$$A = B \times y$$

Velocity:

$$V = Q / A$$

Specific Energy:

$$E = y + (V^2 / 2g)$$



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Froude Number:

$$Fr = V / \sqrt{gy}$$

GRAPH

- Plot Depth (y) vs Distance
- Plot Specific Energy vs Depth

RESULT

The flow through horizontal contraction was studied.

Observed:

Increase in velocity at contraction

Decrease in depth at contraction

Flow type at contraction = _____

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EXPERIMENT NO. 04

OBJECTIVE

To calibrate a broad-crested weir.

APPARATUS REQUIRED

Open channel (flume), broad-crested weir, hook/point gauge, measuring tank, stopwatch, scale.

THEORY

A weir is a structure used to measure or control the flow of water in an open channel. A broad-crested weir has a long crest in the direction of flow which allows water to flow smoothly over it.

When water flows over the crest:

- Velocity increases
- Depth decreases
- Pressure distribution becomes nearly hydrostatic

At the crest, the flow may become **critical**, where discharge is maximum and specific energy is minimum.

Working Principle

As water approaches the weir:

- Flow accelerates
- Depth reduces
- At crest → flow becomes critical ($Fr = 1$)

Discharge Equation

Theoretical discharge:

$$Q_t = 1.705 \times L \times H^{3/2}$$

Where:

$$Q_t = \text{Theoretical discharge (m}^3\text{/s)}$$

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L = Length of weir (m)

H = Head over crest (m)

Actual Discharge

$$Q_a = (A \times h) / t$$

Where:

A = Area of collecting tank

h = Rise in water level

t = Time taken

Coefficient of Discharge

$$C_d = Q_a / Q_t$$

FORMULAE

Theoretical discharge:

$$Q_t = 1.705 \times L \times H^{(3/2)}$$

Actual discharge:

$$Q_a = (A \times h) / t$$

Coefficient of discharge:

$$C_d = Q_a / Q_t$$

PROCEDURE

1. Start water flow in the channel
2. Allow water level to reach crest level
3. Measure initial reading (h_1) using hook gauge
4. Allow water to flow over the weir
5. Measure final reading (h_2)
6. Calculate head: $H = h_2 - h_1$
7. Measure discharge using collecting tank
8. Record time for rise in water level

| | |
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|---|---|

9. Repeat for different discharges

OBSERVATIONS

Given Data:

Length of weir (L) = _____ m

Area of collecting tank (A) = _____ m²

OBSERVATION TABLE

| S.No | Initial Reading h ₁ (m) | Final Reading h ₂ (m) | Head H (m) | Time t (sec) | Rise h (m) | Q _a (m ³ /s) | Q _t (m ³ /s) | Cd |
|------|------------------------------------|----------------------------------|------------|--------------|------------|------------------------------------|------------------------------------|----|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |

CALCULATIONS

Head:

$$H = h_2 - h_1$$

Theoretical discharge:

$$Q_t = 1.705 \times L \times H^{(3/2)}$$

Actual discharge:

$$Q_a = (A \times h) / t$$

Coefficient of discharge:

$$Cd = Q_a / Q_t$$



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GRAPH

- Plot H vs Q_a
- Plot $H^{(3/2)}$ vs Q_a

RESULT

The broad-crested weir was calibrated successfully.

Average coefficient of discharge:

$C_d =$ _____

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EXPERIMENT NO. 05

OBJECTIVE

To study the characteristics of free hydraulic jump in an open channel.

APPARATUS REQUIRED

Hydraulic flume, sluice gate, point gauge/hook gauge, measuring tank, stopwatch, scale.

THEORY

A **hydraulic jump** is a phenomenon in open channel flow in which water flowing at **supercritical velocity (high velocity, low depth)** suddenly changes to **subcritical flow (low velocity, high depth)**. This transition is accompanied by a sudden rise in water surface level and formation of turbulent rollers.

Hydraulic jump is an example of **rapidly varied flow** and is commonly used in engineering applications for **energy dissipation**.

Detailed Explanation of Hydraulic Jump

When water flows under a sluice gate, it attains high velocity and becomes **supercritical**. As this high-energy flow moves downstream, it interacts with slower moving water, causing:

- Sudden increase in depth
- Formation of eddies and turbulence
- Loss of kinetic energy
- Conversion of kinetic energy into heat and sound

This transition from supercritical to subcritical flow is called a **hydraulic jump**.

Flow Regions in Hydraulic Jump

1. **Before Jump (Upstream)**
 - Supercritical flow
 - Low depth (y_1)
 - High velocity

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2. **At Jump**

- Highly turbulent region
- Energy dissipation maximum

3. **After Jump (Downstream)**

- Subcritical flow
- High depth (y_2)
- Low velocity

Types of Hydraulic Jump (Based on Froude Number)

| Froude Number (Fr_1) | Type of Jump |
|--------------------------|------------------|
| 1 – 2 | Undular Jump |
| 2 – 4 | Weak Jump |
| 4 – 9 | Oscillating Jump |
| 9 – 18 | Steady Jump |
| > 18 | Strong Jump |

Energy Loss in Hydraulic Jump

A large amount of energy is dissipated in the jump due to turbulence.

Energy loss:

$$\Delta E = \left(\frac{y_2 - y_1}{4} \right)^3 \left(\frac{1}{y_1} + \frac{1}{y_2} \right)$$

Importance of Hydraulic Jump

- Used in **stilling basins** to reduce erosion
- Protects downstream structures
- Converts high energy flow into stable flow
- Used in canal regulation

FORMULAE

Froude Number:

$$Fr = V / \sqrt{g y}$$

Velocity:

$$V = Q / (B \times y)$$

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Continuity:

$$Q = A \times V$$

Sequent Depth Relation:

$$y_2 / y_1 = (1/2) [\sqrt{(1 + 8Fr_1^2)} - 1]$$

Energy Loss:

$$\Delta E = ((y_2 - y_1)^3) / (4 y_1 y_2)$$

PROCEDURE

1. Start the water flow in the flume
2. Adjust sluice gate to produce supercritical flow
3. Observe formation of hydraulic jump
4. Measure:
 - Upstream depth (y_1)
 - Downstream depth (y_2)
 - Length of jump (L)
5. Measure discharge using collecting tank
6. Repeat for different discharges
7. Record all readings

OBSERVATIONS

Given Data:

Width of channel (B) = _____ m

Acceleration due to gravity (g) = 9.81 m/s²

OBSERVATION TABLE

| S.No | Discharge Q (m ³ /s) | Upstream Depth y_1 (m) | Downstream Depth y_2 (m) | Length of Jump L (m) | Velocity V_1 (m/s) | Froude No. Fr_1 | Energy Loss ΔE (m) |
|------|---------------------------------|--------------------------|----------------------------|----------------------|----------------------|-------------------|----------------------------|
| 1 | | | | | | | |
| 2 | | | | | | | |

| | | | | | | | |
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CALCULATIONS

Area:

$$A = B \times y$$

Velocity:

$$V = Q / A$$

Froude Number:

$$Fr = V / \sqrt{(g y)}$$

Sequent Depth:

$$y_2 / y_1 = (1/2) [\sqrt{(1 + 8Fr_1^2)} - 1]$$

Energy Loss:

$$\Delta E = ((y_2 - y_1)^3) / (4 y_1 y_2)$$

GRAPH

- Plot y_2/y_1 vs Fr_1
- Plot Energy Loss vs Discharge

RESULT

The characteristics of free hydraulic jump were studied.

Observed:

- Upstream flow = Supercritical
- Downstream flow = Subcritical
- Energy loss = _____

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EXPERIMENT NO. 06

OBJECTIVE

To study the centrifugal pump and determine its characteristics.

APPARATUS REQUIRED

Centrifugal pump test rig, pressure gauge, vacuum gauge, measuring tank, stopwatch, tachometer, control valves, pipes and fittings.

THEORY

A **centrifugal pump** is a hydraulic machine used to convert mechanical energy into hydraulic energy by means of centrifugal force. It is widely used for lifting water and other fluids.

The pump consists of an **impeller** rotating inside a casing. When the impeller rotates, it imparts velocity to the fluid, which is then converted into pressure energy.

Working Principle

When the pump is started:

- Water enters through the suction pipe
- Impeller rotates and throws water outward due to centrifugal force
- Velocity of water increases
- Kinetic energy is converted into pressure energy in casing
- Water is discharged through delivery pipe

Important Heads in Centrifugal Pump

1. **Suction Head (H_s)**
Vertical distance between water surface in sump and pump center
2. **Delivery Head (H_d)**
Vertical distance between pump center and delivery tank
3. **Total Head (H)**
 $H = H_d + H_s$

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Manometric Head

$$H_m = (P_d / \gamma) - (P_s / \gamma)$$

Where:

P_d = Delivery pressure

P_s = Suction pressure

γ = Specific weight of water

Pump Performance Characteristics

The following curves are plotted:

- Discharge (Q) vs Head (H)
- Discharge (Q) vs Efficiency (η)
- Discharge (Q) vs Power

FORMULAE

Discharge:

$$Q = \text{Volume} / \text{Time}$$

Total Head:

$$H = H_d + H_s$$

Manometric Head:

$$H_m = (P_d / \gamma) - (P_s / \gamma)$$

Input Power:

$$P_i = (\text{Voltage} \times \text{Current} \times \text{Power Factor})$$

Output Power:

$$P_o = \rho g Q H$$

Efficiency:

$$\eta = (\text{Output Power} / \text{Input Power}) \times 100$$

PROCEDURE

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1. Prime the pump before starting
2. Start the pump
3. Open delivery valve gradually
4. Note readings:
 - Pressure gauge (delivery side)
 - Vacuum gauge (suction side)
 - Discharge
 - Time taken
5. Measure speed using tachometer
6. Repeat for different valve openings
7. Record all readings

OBSERVATIONS

Given Data:

Density of water (ρ) = 1000 kg/m³

Acceleration due to gravity (g) = 9.81 m/s²

OBSERVATION TABLE

| S.No | Pressure Gauge (Pd) | Vacuum Gauge (Ps) | Time (sec) | Volume (m ³) | Discharge Q (m ³ /s) | Head H (m) | Input Power (kW) | Output Power (kW) | Efficiency (%) |
|------|---------------------|-------------------|------------|--------------------------|---------------------------------|------------|------------------|-------------------|----------------|
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |

CALCULATIONS

Discharge:

$$Q = \text{Volume} / \text{Time}$$

Head:

$$H = H_d + H_s$$

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Manometric Head:

$$H_m = (P_d / \gamma) - (P_s / \gamma)$$

Output Power:

$$P_o = \rho g Q H$$

Efficiency:

$$\eta = (P_o / P_i) \times 100$$

GRAPH

- Plot Q vs H
- Plot Q vs Efficiency
- Plot Q vs Power

RESULT

The centrifugal pump characteristics were studied.

Observed:

- Maximum efficiency = _____
- Discharge = _____
- Head developed = _____

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EXPERIMENT NO. 07

OBJECTIVE

To study the characteristics of a Pelton turbine.

APPARATUS REQUIRED

Pelton turbine test rig, nozzle with spear arrangement, pressure gauge, tachometer, brake drum with rope and weights, measuring tank, stopwatch.

THEORY

A **Pelton turbine** is an **impulse turbine** used for high head and low discharge conditions. In this turbine, the entire hydraulic energy of water is first converted into kinetic energy by means of a nozzle, and this high-velocity jet strikes the buckets mounted on the runner.

The turbine works on the principle of **impulse**, where pressure energy is converted into kinetic energy before striking the runner.

Working Principle

- Water from high head is directed through a nozzle
- The nozzle converts pressure energy into high velocity jet
- The jet strikes the buckets of the runner
- Force exerted by jet causes rotation of runner
- Water leaves the buckets with reduced velocity

Components of Pelton Turbine

- Nozzle and spear
- Runner with buckets
- Casing
- Brake drum arrangement

Velocity Triangles (Concept)

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At inlet:

- Velocity of jet = V
- Bucket speed = u

Relative velocity at inlet:

$$V_r = V - u$$

At outlet:

Water leaves with reduced velocity, ideally opposite direction to maximize energy transfer.

Power Developed

Hydraulic Power (Input):

$$P_i = \rho g Q H$$

Brake Power (Output):

$$P_o = (2\pi N T) / 60$$

Where:

N = Speed (rpm)

T = Torque (Nm)

Efficiency

$$\eta = (P_o / P_i) \times 100$$

Characteristic Curves

The following graphs are plotted:

- Speed vs Efficiency
- Load vs Speed
- Load vs Efficiency

FORMULAE

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Discharge:

$$Q = \text{Volume} / \text{Time}$$

Hydraulic Power:

$$P_i = \rho g Q H$$

Brake Power:

$$P_o = (2\pi N T) / 60$$

Torque:

$$T = W \times R$$

Where:

W = Net load

R = Radius of brake drum

Efficiency:

$$\eta = (P_o / P_i) \times 100$$

PROCEDURE

1. Start the pump and allow water to flow
2. Adjust nozzle opening using spear
3. Allow turbine to run at no load
4. Measure initial readings
5. Apply load gradually using weights
6. Measure:
 - Speed (N)
 - Load (W)
 - Discharge
 - Pressure head
7. Repeat for different loads
8. Record all readings

OBSERVATIONS

Given Data:

Density of water (ρ) = 1000 kg/m³

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Acceleration due to gravity (g) = 9.81 m/s²

Radius of brake drum (R) = _____ m

OBSERVATION TABLE

| S.No | Load W (kg) | Speed N (rpm) | Time (sec) | Volume (m ³) | Discharge Q (m ³ /s) | Head H (m) | Torque T (Nm) | Output Power (kW) | Input Power (kW) | Efficiency (%) |
|------|-------------|---------------|------------|--------------------------|---------------------------------|------------|---------------|-------------------|------------------|----------------|
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |

CALCULATIONS

Discharge:

$$Q = \text{Volume} / \text{Time}$$

Torque:

$$T = W \times R$$

Output Power:

$$P_o = (2\pi N T) / 60$$

Input Power:

$$P_i = \rho g Q H$$

Efficiency:

$$\eta = (P_o / P_i) \times 100$$

GRAPH



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- Plot Load vs Speed
- Plot Load vs Efficiency
- Plot Speed vs Efficiency

RESULT

The characteristics of Pelton turbine were studied.

Observed:

- Maximum efficiency = _____
- Speed at maximum efficiency = _____
- Output power = _____

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EXPERIMENT NO. 08

OBJECTIVE

To study the characteristics of a Francis turbine.

APPARATUS REQUIRED

Francis turbine test rig, pressure gauge, vacuum gauge, tachometer, brake drum with rope and weights, measuring tank, stopwatch.

THEORY

A **Francis turbine** is a **reaction turbine** used for medium head and medium discharge conditions. In this turbine, water enters the runner under pressure and flows radially inward, transferring both **pressure energy and kinetic energy** to the runner.

Unlike impulse turbines, the pressure of water changes as it flows through the runner.

Working Principle

- Water enters the turbine through spiral casing
- It passes through guide vanes which control flow direction
- Water enters runner blades radially
- Energy transfer occurs due to pressure and velocity change
- Water exits axially through draft tube

Main Components

- Spiral casing
- Guide vanes
- Runner
- Draft tube
- Shaft and bearings

Energy Conversion

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- Hydraulic energy → Mechanical energy
- Pressure + velocity energy contribute to power generation

Power Developed

Input Power (Hydraulic Power):

$$P_i = \rho g Q H$$

Output Power (Brake Power):

$$P_o = (2\pi N T) / 60$$

Where:

N = Speed (rpm)

T = Torque (Nm)

Efficiency

$$\eta = (P_o / P_i) \times 100$$

Characteristic Curves

The following curves are plotted:

- Load vs Efficiency
- Load vs Speed
- Speed vs Efficiency

FORMULAE

Discharge:

$$Q = \text{Volume} / \text{Time}$$

Hydraulic Power:

$$P_i = \rho g Q H$$

Brake Power:

$$P_o = (2\pi N T) / 60$$

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Torque:

$$T = W \times R$$

Efficiency:

$$\eta = (P_o / P_i) \times 100$$

PROCEDURE

1. Start the pump and allow water to flow
2. Open guide vanes to required position
3. Allow turbine to run at no load
4. Measure initial readings
5. Apply load gradually using weights
6. Measure:
 - Speed (N)
 - Load (W)
 - Discharge
 - Pressure readings
7. Repeat for different loads
8. Record all readings

OBSERVATIONS

Given Data:

Density of water (ρ) = 1000 kg/m³

Acceleration due to gravity (g) = 9.81 m/s²

Radius of brake drum (R) = _____ m

OBSERVATION TABLE

| S.No | Load W (kg) | Speed N (rpm) | Time (sec) | Volume (m ³) | Discharge Q (m ³ /s) | Head H (m) | Torque T (Nm) | Output Power (kW) | Input Power (kW) | Efficiency (%) |
|------|-------------|---------------|------------|--------------------------|---------------------------------|------------|---------------|-------------------|------------------|----------------|
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |

| | | | | | | | | | | |
|---|--|--|--|--|--|--|--|--|--|--|
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| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |

CALCULATIONS

Discharge:

$$Q = \text{Volume} / \text{Time}$$

Torque:

$$T = W \times R$$

Output Power:

$$P_o = (2\pi N T) / 60$$

Input Power:

$$P_i = \rho g Q H$$

Efficiency:

$$\eta = (P_o / P_i) \times 100$$

GRAPH

- Plot Load vs Efficiency
- Plot Load vs Speed
- Plot Speed vs Efficiency

RESULT

The characteristics of Francis turbine were studied.

Observed:

- Maximum efficiency = _____
- Speed at maximum efficiency = _____
- Output power = _____

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EXPERIMENT-09

OBJECTIVE

To study the characteristics of a Kaplan turbine.

APPARATUS REQUIRED

Kaplan turbine test rig, pressure gauge, vacuum gauge, tachometer, brake drum with rope and weights, measuring tank, stopwatch.

THEORY

A **Kaplan turbine** is a **reaction turbine** used for **low head and high discharge** conditions. It is an axial flow turbine in which water flows parallel to the axis of rotation.

The special feature of Kaplan turbine is that its **runner blades are adjustable**, which allows high efficiency over a wide range of flow conditions.

Working Principle

- Water enters through spiral casing
- It passes through guide vanes which control flow direction
- Water flows axially through runner blades
- Blades adjust automatically according to flow
- Energy is transferred to runner
- Water exits through draft tube

Main Components

- Spiral casing
- Guide vanes
- Runner with adjustable blades
- Draft tube
- Shaft

Energy Conversion

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- Hydraulic energy → Mechanical energy
- Both pressure and kinetic energy are utilized

Power Developed

Input Power (Hydraulic Power):

$$P_i = \rho g Q H$$

Output Power (Brake Power):

$$P_o = (2\pi N T) / 60$$

Efficiency

$$\eta = (P_o / P_i) \times 100$$

Characteristic Curves

The following curves are plotted:

- Load vs Efficiency
- Load vs Speed
- Speed vs Efficiency

FORMULAE

Discharge:

$$Q = \text{Volume} / \text{Time}$$

Hydraulic Power:

$$P_i = \rho g Q H$$

Brake Power:

$$P_o = (2\pi N T) / 60$$

Torque:

$$T = W \times R$$

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Efficiency:

$$\eta = (P_o / P_i) \times 100$$

PROCEDURE

1. Start the pump and allow water to flow
2. Set runner blade angle and guide vane opening
3. Allow turbine to run at no load
4. Measure initial readings
5. Apply load gradually using weights
6. Measure:
 - Speed (N)
 - Load (W)
 - Discharge
 - Pressure readings
7. Repeat for different loads
8. Record all readings

OBSERVATIONS

Given Data:

Density of water (ρ) = 1000 kg/m³

Acceleration due to gravity (g) = 9.81 m/s²

Radius of brake drum (R) = _____ m

OBSERVATION TABLE

| S.No | Load W (kg) | Speed N (rpm) | Time (sec) | Volume (m ³) | Discharge Q (m ³ /s) | Head H (m) | Torque T (Nm) | Output Power (kW) | Input Power (kW) | Efficiency (%) |
|------|-------------|---------------|------------|--------------------------|---------------------------------|------------|---------------|-------------------|------------------|----------------|
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |

CALCULATIONS

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Discharge:

$$Q = \text{Volume} / \text{Time}$$

Torque:

$$T = W \times R$$

Output Power:

$$P_o = (2\pi N T) / 60$$

Input Power:

$$P_i = \rho g Q H$$

Efficiency:

$$\eta = (P_o / P_i) \times 100$$

GRAPH

- Plot Load vs Efficiency
- Plot Load vs Speed
- Plot Speed vs Efficiency

RESULT

The characteristics of Kaplan turbine were studied.

Observed:

- Maximum efficiency = _____
- Speed at maximum efficiency = _____
- Output power = _____

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EXPERIMENT NO. 10

OBJECTIVE

To determine the coefficient of discharge for a given rectangular notch.

APPARATUS REQUIRED

Rectangular notch setup, hook/point gauge, measuring tank, stopwatch, scale.

THEORY

A **rectangular notch** is a device used to measure the flow rate of water in an open channel. It consists of a sharp-edged rectangular opening in a vertical plate through which water flows.

When water flows over the notch:

- A thin sheet of water called **nappe** is formed
- The edges are sharp to ensure accurate measurement
- Flow is mainly dependent on head over the notch

Working Principle

The discharge over a rectangular notch depends on:

- Width of notch (L)
- Head of water above crest (H)
- Acceleration due to gravity (g)

The flow is assumed to be:

- Steady
- Incompressible
- Uniform

Theoretical Discharge

For rectangular notch:

$$Q_t = (2/3) C_d \sqrt{2g} L H^{3/2}$$

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But for ideal case ($C_d = 1$):

$$Q_t = (2/3) \sqrt{(2g)} L H^{(3/2)}$$

Actual Discharge

$$Q_a = (A \times h) / t$$

Where:

A = Area of collecting tank

h = Rise in water level

t = Time taken

Coefficient of Discharge

$$C_d = Q_a / Q_t$$

End Contraction (if present)

Effective length:

$$L_e = L - 0.1 n H$$

Where:

n = Number of end contractions

FORMULAE

Theoretical discharge:

$$Q_t = (2/3) \sqrt{(2g)} L H^{(3/2)}$$

Actual discharge:

$$Q_a = (A \times h) / t$$

Coefficient of discharge:

$$C_d = Q_a / Q_t$$

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Effective length:

$$L_e = L - 0.1 n H$$

PROCEDURE

1. Start the water flow
2. Allow water level to reach steady condition
3. Measure initial head (h_1)
4. Measure final head (h_2)
5. Calculate head: $H = h_2 - h_1$
6. Measure discharge using collecting tank
7. Record time for rise in water level
8. Repeat for different heads
9. Tabulate readings

OBSERVATIONS

Given Data:

Length of notch (L) = _____ m

Area of collecting tank (A) = _____ m^2

Number of contractions (n) = _____

OBSERVATION TABLE

| S.No | Initial Reading h_1 (m) | Final Reading h_2 (m) | Head H (m) | Time t (sec) | Rise h (m) | Q_a (m^3/s) | Q_t (m^3/s) | C_d |
|------|---------------------------|-------------------------|--------------|----------------|--------------|-------------------|-------------------|-------|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |

CALCULATIONS

Head:

$$H = h_2 - h_1$$

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Theoretical discharge:

$$Q_t = (2/3) \sqrt{2g} L H^{3/2}$$

Actual discharge:

$$Q_a = (A \times h) / t$$

Coefficient of discharge:

$$C_d = Q_a / Q_t$$

GRAPH

- Plot H vs Q_a
- Plot $H^{3/2}$ vs Q_a

RESULT

The coefficient of discharge for the rectangular notch was determined.

Average value of $C_d =$ _____

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EXPERIMENT 01 (BEYOND SYLLABUS)

Aim

To determine Manning's roughness coefficient (n) or normal depth of flow for rectangular and trapezoidal open channels using Manning's calculator software.

Objectives

1. To study open channel flow characteristics.
2. To understand the application of Manning's equation.
3. To calculate hydraulic properties of rectangular and trapezoidal channels.
4. To determine Manning's coefficient using software tools.
5. To compare flow parameters for different channel sections.

Apparatus / Software Required

- Computer or Laptop
- Internet Connection
- Calculator
- Observation Notebook

Software Used

- LMNO Engineering Manning Calculator

Introduction

Open channel flow refers to the flow of liquid with a free surface exposed to atmospheric pressure such as canals, rivers, and drainage channels. The velocity and discharge in open channels depend upon the channel geometry, slope, and surface roughness.

Manning's equation is one of the most commonly used empirical equations for analyzing uniform flow in open channels. It helps in calculating discharge, flow depth, velocity, and Manning's roughness coefficient.

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The Manning calculator software simplifies hydraulic computations by automatically calculating required parameters for different channel sections.

Theory

The Manning equation for uniform open channel flow is:

$$Q = AR^{2/3}S_0^{1/2}$$

Where:

| Symbol | Description | Unit |
|--------|---------------------------------|-------------------|
| Q | Discharge | m ³ /s |
| n | Manning's roughness coefficient | — |
| A | Area of flow | m ² |
| R | Hydraulic radius | m |
| S | Bed slope of channel | m/m |

Hydraulic radius is defined as:

$$R = A/P$$

Where:

| Symbol | Description |
|--------|---------------------------|
| A | Cross-sectional flow area |
| P | Wetted perimeter |

Types of Channel Sections

1. Rectangular Channel

A rectangular channel has a flat bottom and vertical sides.

Area of Flow

$$A = b \times y$$

Wetted Perimeter

$$P = b + 2y$$

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Hydraulic Radius

$$R=A/P$$

Where:

- b = width of channel
- y = depth of flow

2. Trapezoidal Channel

A trapezoidal channel has a bottom width with sloping sides.

Area of Flow

$$A=y (b+zy)$$

Wetted Perimeter

$$P = b + 2y\sqrt{1 + Z^2}$$

Where:

- b = bottom width
- z = side slope
- y = depth of flow

Procedure

Part A: Rectangular Channel

1. Open the Manning calculator website:
LMNO Engineering Manning Calculator
2. Select the option "Rectangular Channel".
3. Enter the required input values:
 - Channel width (b)
 - Flow depth (y)
 - Channel bed slope (S)
 - Discharge (Q)
4. Select SI units.
5. Click on the "Calculate" button.
6. Observe the calculated output values:
 - Manning's coefficient (n)
 - Velocity
 - Hydraulic radius

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- Area of flow

7. Record all observations in the observation table.

Part B: Trapezoidal Channel

1. Select “Trapezoidal Channel” in the software.
2. Enter the following parameters:
 - Bottom width (b)
 - Side slope (z)
 - Depth of flow (y)
 - Bed slope (S)
 - Discharge (Q)
3. Click on “Calculate”.
4. Note the calculated values displayed by the software.
5. Record the results properly.

Observation Table

Observation Table for Rectangular Channel

| S.No. | Width b (m) | Depth y (m) | Slope S | Discharge Q (m ³ /s) | Area A (m ²) | Hydraulic Radius R (m) | Manning’s n |
|-------|-------------|-------------|---------|---------------------------------|--------------------------|------------------------|-------------|
| 1 | 2 | 1 | 0.001 | 3 | | | |
| 2 | 2.5 | 1.2 | 0.0015 | 4 | | | |

Observation Table for Trapezoidal Channel

| S.No. | Bottom Width b (m) | Side Slope z | Depth y (m) | Slope S | Discharge Q (m ³ /s) | Area A (m ²) | Hydraulic Radius R (m) | Manning’s n |
|-------|--------------------|--------------|-------------|---------|---------------------------------|--------------------------|------------------------|-------------|
| 1 | 2 | 1 | 1 | 0.001 | 4 | | | |
| 2 | 2.5 | 1 | 1.2 | 0.0015 | 5 | | | |

**Sample Calculation
For Rectangular Channel**

Given Data

- Width of channel, b=2m
- Depth of flow, y=1 m
- Bed slope, S=0.001

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- Discharge, $Q=3 \text{ m}^3/\text{s}$

Step 1: Area of Flow

$A=b \times y, A=2 \times 1, A=2 \text{ m}^2$

Step 2: Wetted Perimeter

$P=b+2y, P=2+2(1), P=4 \text{ m}$

Step 3: Hydraulic Radius

$R=A/P=0.5\text{m}$

Step 4: Manning's Equation

$Q = AR^{2/3}S_0^{1/2}$

Using the software calculator, the value of Manning's coefficient is obtained.

Result

The Manning's roughness coefficient (n) and hydraulic parameters for rectangular and trapezoidal channels were calculated successfully using Manning's calculator software.

Applications

1. Design of irrigation canals.
2. Analysis of drainage channels.
3. River engineering studies.
4. Storm water management.
5. Hydraulic structure design.

Advantages of Using Software

1. Reduces manual calculation errors.
2. Provides quick and accurate results.
3. Easy to analyze different channel sections.
4. Saves time during hydraulic computations.



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Precautions

1. Use SI units throughout the experiment.
2. Enter correct channel dimensions.
3. Check the slope values carefully.
4. Ensure accurate discharge input.
5. Avoid rounding errors while recording values.
6. Verify software settings before calculation.

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EXPERIMENT 02 (BEYOND SYLLABUS)

Aim

To study and observe the hydraulic jump phenomenon at the Indira Canal Aqueduct and analyze its hydraulic characteristics in open channel flow.

Objectives

1. To observe the formation of hydraulic jump in an open channel.
2. To study different flow conditions before and after the jump.
3. To understand energy dissipation due to hydraulic jump.
4. To identify practical applications of hydraulic jump in canal engineering.
5. To analyze flow behavior at an aqueduct structure.

Apparatus / Materials Required

- Measuring tape
- Staff gauge / scale
- Field notebook
- Calculator
- Camera / Mobile phone
- PPE kit (if required)

Introduction

A hydraulic jump is a sudden rise in the water surface occurring in open channel flow when supercritical flow changes into subcritical flow. During this process, a considerable amount of energy is dissipated due to turbulence and mixing.

Hydraulic jumps are commonly observed downstream of spillways, sluice gates, and canal structures. They are used in hydraulic engineering to reduce flow velocity and prevent erosion of the channel bed.

The field visit to the Indira Canal Aqueduct provides practical exposure to hydraulic jump formation and its importance in energy dissipation and flow control.

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Theory

Hydraulic jump occurs when:

$$Fr > 1$$

Where:

| Symbol | Description |
|--------|---------------|
| Fr | Froude Number |

Froude Number Equation

$$Fr = \frac{V}{\sqrt{gD}}$$

Where:

| Symbol | Description | Unit |
|--------|-----------------------------|------------------|
| V | Velocity of flow | m/s |
| g | Acceleration due to gravity | m/s ² |
| D | Hydraulic depth | m |

Types of Flow

| Flow Type | Froude Number |
|--------------------|---------------|
| Subcritical Flow | Fr < 1 |
| Critical Flow | Fr = 1 |
| Supercritical Flow | Fr > 1 |

Characteristics of Hydraulic Jump

1. Sudden rise in water depth.
2. High turbulence and eddies.
3. Loss of kinetic energy.
4. Increase in pressure and water depth.
5. Conversion of supercritical flow into subcritical flow.

| | |
|--|---|
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|--|---|

Procedure

1. Visit the Indira Canal Aqueduct site.
2. Observe the canal flow conditions carefully.
3. Identify the location where hydraulic jump occurs.
4. Observe:
 - Water depth before jump
 - Water depth after jump
 - Turbulence intensity
 - Flow velocity condition
5. Record all observations in the field notebook.
6. Measure approximate dimensions if possible.
7. Take photographs for documentation.
8. Analyze the hydraulic behavior of the flow.

Observation Table

| S.No. | Parameter Observed | Observation |
|-------|-------------------------------|-------------|
| 1 | Type of channel | |
| 2 | Flow condition before jump | |
| 3 | Flow condition after jump | |
| 4 | Approximate depth before jump | |
| 5 | Approximate depth after jump | |
| 6 | Turbulence observed | |
| 7 | Energy dissipation | |
| 8 | Channel condition | |

Applications of Hydraulic Jump

1. Energy dissipation below spillways.
2. Prevention of soil erosion.
3. Mixing of chemicals in water treatment plants.
4. Flow regulation in canals.
5. Protection of hydraulic structures.

Advantages of Hydraulic Jump

1. Reduces excessive flow velocity.
2. Prevents channel bed erosion.

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3. Improves flow stability.
4. Dissipates excess energy efficiently.

Result

The hydraulic jump phenomenon at the Indira Canal Aqueduct was observed successfully, and the flow characteristics before and after the jump were analyzed.

Precautions

1. Follow all field safety instructions.
2. Maintain safe distance from flowing water.
3. Avoid slippery surfaces near the canal.
4. Record observations carefully.
5. Use measuring instruments properly.

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