A Laboratory Manual for

Fluid Mechanics
(Basic Science Courses)
(BE04006051)

B.E. Semester 4 (Civil Engineering)

Institute logo

Directorate of Technical Education
Gandhinagar, Gujarat

GOVERNMENT ENGINEERING COLLEGE DAHOD
[Directorate of Technical Education, Gandhinagar]

Certificate

This is to certify that Mr./Ms. ____________________________________ ________ Enrollment No. _______________ of B.E. Semester 4 Civil Engineering of this Institute (GTU Code: _____) has satisfactorily completed the Practical / Tutorial work for the subject Fluid Mechanics (BE04006051) for the even term in academic year 2025-26.

Place: __________
Date: __________

Name and Sign of Faculty member

Head of the Department

Preface

The basic aim of laboratory/practical/field work is to enhance the required skills as well as creating ability amongst students to solve real time problem by developing relevant competencies in psychomotor domain. By keeping this in view, GTU has designed competency focused outcome-based curriculum for engineering degree programs where sufficient focus is given to the practical work. It shows importance of enhancement of skills amongst the students and pays attention to utilize every second of time allotted for practical amongst students, instructors and faculty members to achieve relevant outcomes by performing the experiments rather than having merely study type experiments. It is must for effective implementation of competency focused outcome-based curriculum that every practical is keenly designed to serve as a tool to develop and enhance relevant competency required by the various industry among every student. These psychomotor skills are very difficult to develop through traditional chalk and board content delivery method in the classroom. Accordingly, this lab manual is designed to focus on the industry defined relevant outcomes, rather than old practice of conducting practical to prove concept and theory.

By using this lab manual students can go through the relevant theory and procedure in advance before the actual performance which creates interest and students can have basic idea prior to performance. This in turn enhances pre-determined outcomes amongst students. Each experiment in this manual begins with industry relevant skills, course outcomes as well as practical outcomes (objectives). The students will also achieve safety and necessary precautions to be taken while performing practical.

This manual also provides guidelines to faculty members to facilitate student centric lab activities through each experiment by arranging and managing necessary resources in order that the students follow the procedures with required safety and necessary precautions to achieve the outcomes. It also gives an idea that how students will be assessed by providing rubrics.

Fluid Mechanics is the subject of professional core course which deals to develop a basic understanding about the properties of fluids, their behavior under static and dynamic conditions. Also Fluid mechanics & Hydraulics enables the students to apply the basic principles of Fluid Mechanics to solve real life problems. Students also studies about the flow measuring devices, drag and lift application in Fluids/ bodies, Model studies, dynamics and kinematics.

Utmost care has been taken while preparing this lab manual however always there are chances of improvement. Therefore, we welcome constructive suggestions and comments for improvement and removal of errors if any from those who use it.

:: VISION STATEMENT OF THE INSTITUTE ::

To be a value-based engineering institute to disseminate globally acceptable educationand nurturing research, innovation and entrepreneurship.

:: MISSION STATEMENTS OF THE INSTITUTE ::

1. To provide quality education in the engineering disciplines through creative balance ofacademics and extracurricular programs.

2. To provide learning environment for innovation and entrepreneurship.

3. To disseminate ethical values, social values and sensitivity towardsenvironmental issues.

:: VISION STATEMENT OF THE CIVIL ENGINEERING DEPARTMENT::

To be a recognized department in the field of civil engineering education to produce professional civil engineers, innovators and entrepreneurs for the development of the society.

:: MISSION STATEMENTS OF THE CIVIL ENGINEERING DEPARTMENT::

1. To provide quality education to civil engineering undergraduates through creative balance of academic, professional and extra-curricular activities.

2. To impart knowledge in the field of civil engineering for the development of infrastructure facilities with environmental concern for betterment of the society.

3. To contribute in the nation's development through innovative ideas in the field of civil engineering.

Knowledge and Attitude Profile (WK)

WK Code	Description
WK1	A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences.
WK2	Conceptually-based mathematics, numerical analysis, data analysis, statistics, and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.
WK3	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
WK4	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
WK5	Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.
WK6	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.
WK7	Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.
WK8	Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.
WK9	Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability etc. with mutual understanding and respect, and of inclusive attitudes.

:: PROGRAM OUTCOMES (POs)::

Program Outcomes (POs) as identified by National Board of Accreditation (NBA), India are the attributes that the students are expected to attain at the point of graduation. Following are the POs of B.E Civil Engineering program:

1. Engineering Knowledge: Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problems.
2. Problem Analysis: Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)
3. Design/Development of Solutions: Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5)
4. Conduct Investigations of Complex Problems: Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8).
5. Engineering Tool Usage: Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 and WK6)
6. The Engineer and The World: Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).
7. Ethics: Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)
8. Individual and Collaborative Team work: Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.
9. Communication: Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences

10. Project Management and Finance: Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments.
11. Life-Long Learning: Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8)

:: PROGRAM SPECIFIC OUTCOMES (PSOs) ::

Program Specific Outcomes (PSOs) are what the graduates of a specific undergraduate engineering program should be able to do at the time of graduation.

Civil Engineering Graduates shall have

PSO 1: Ability to analyze, design and rehabilitate the infrastructural projects of civil engineering.

PSO 2: Ability to use advanced civil equipment, software, techniques and work seamlessly in teams.

PSO 3: Ability to apply gained knowledge to choose from the innovative career paths, to be an entrepreneur, and a zest for higher studies.

Practical – Course Outcome matrix

Course Outcomes (COs):

CO.1: Analyze and apply the fundamental concepts of fluid properties and fluid statics, including pressure distribution, buoyancy, and hydrostatic forces on submerged surfaces.

CO.2: Apply the principles of conservation of mass and energy (Bernoulli's equation), and use the momentum equation to solve problems in fluid dynamics

CO.3: Identify various flow measuring devices, such as Venturimeter and Pitot tube, and calculate discharge through orifices, notches, and weirs.

CO.4: Solve problems related to drag and lift in applications like wind tunnels.

CO.5: Perform dimensional analysis using Buckingham's π theorem on the different applications of fluid mechanics (Design and carry out model studies for fluid flow problems).

Sr. No.	Objective(s) of Experiment	CO 1	CO 2	CO 3	CO 4	CO 5
1.	To Determine the Value of Viscosity of a Given Fluid at Different Temperature by Redwood Viscometer/ Other viscometer	√				
2.	To perform experimentation for pressure measurement devices (Manometer/ Pitot tube).	√				
3.	To measure hydrostatic force and center of pressure on flat/curved surfaces.	√				
4.	To determine stability of floating body (Metacentric Height Experiment).	√				√
5.	To determine characteristics of Laminar and Turbulent flows (To perform Reynolds experiment)	√		√		
6.	To verify and prove Bernoulli's theorum.		√	√		
7.	To determine hydraulic coefficients of a small circular orifice		√	√		
8.	To Calibrate flow measuring devices (Venturimeter, Orificemeter, Rectangular and V-notch)			√		
9.	To measure drag and lift in Wind Tunnel (To prepare a Drag/ Lift Model if Wind Tunnel is not available)				√	√
10.	To perform model studies, similitude and develop a model/sketch for fluid flow in pipes, open channel and dimensional analysis.					√

Industry Relevant Skills

The following industry relevant competencies are expected to be developed in the student by undertaking the practical work of this laboratory.

1. Collection of important data and specific information required to complete a construction project in a best way.
2. Analysis of the data and preparing reports about the geotechnical conditions of a location.

Guidelines for the Faculty members

1. Professor should provide the guideline with demonstration of practical to the students with all features.
2. Professor shall explain basic concepts/theory related to the experiment to the students before starting of each practical.
3. Involve all the students in performance of each experiment.
4. Professor is expected to share the skills and competencies to be developed in the students and ensure that the respective skills and competencies are developed in the students after the completion of the experimentation.
5. Professors should give opportunity to students for hands-on experience after the demonstration.
6. Professor may provide additional knowledge and skills to the students even though not covered in the manual but are expected from the students by concerned industry.
7. Give practical assignment and assess the performance of students based on task assigned to check whether it is as per the instructions or not.
8. Professor is expected to refer complete curriculum of the course and follow the guidelines for implementation.

Instructions for Students

1. Students are expected to carefully listen to all the theory classes delivered by the faculty members and understand the COs, content of the course, teaching and examination scheme, skill set to be developed etc.
2. Students shall organize the work in the group and make record of all observations.
3. Students shall develop maintenance skill as expected by industries.
4. Student shall attempt to develop related hand-on skills and build confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. apart from those included in scope of manual.
6. Student shall refer research papers, technical magazines and data books.
7. Student should develop a habit of submitting the experimentation work as per the schedule and s/he should be well prepared for the same.

Common Safety Instructions

Follow the safety instructions displayed in the laboratory.

FLUID MECHANICS LABORATORY

RATIONALE: Fluid Mechanics is a basic engineering subject which helps in solving fluid flow problems in the field of Civil Engineering. Subject deals with basic concepts and principles in hydrostatics, hydro kinematics and hydrodynamics and their application in solving fluid mechanics problems. The students will be able to apply the basic principles of fluid mechanics to solve real life problems also.

OBJECTIVE: The objective of this lab is to teach students, the knowledge of various flow meters and the concept of fluid mechanics and hydraulics. This lab helps to gain knowledge on characteristics of fluids, pressure measurement devices, model studies and open channel flow. Students will compare the performance of various fluid based equipment's and machines at different operating points. This course will provide a basic understanding of flow measurements using various types of flow measuring devices, calibration and losses associated with these devices. Knowledge of Energy conversion principles, analysis and understanding will be discussed.

OUTCOMES:

After completing this course the student must demonstrate the knowledge and ability to:

1. Determine how properties of fluids change with temperature & their effect on pressure & fluid flow.
2. Understanding the relationship between pressure & elevation as it relates to manometers & other pressure measuring devices.
3. Apply Newton's law of viscosity and explain the mechanics of fluids at rest and in motion by observing the fluid phenomena.
4. Analyze force of buoyancy on a partially or fully submerged body and analyze the stability of a floating body.
5. Apply the principles of Euler's equation, Bernoulli's equation in measurement of discharge in pipes, and in other pipe flow problems.
6. To measure drag and lift in Wind Tunnel (Also, To prepare a Drag/ Lift Model if Wind Tunnel is not available)
7. To design the models of Pipe flow and Open channel flow.

Index
(Progressive Assessment Sheet)

Sr. No.	Objective(s) of Experiment	Page No.	Date of performance	Date of submission	Assessment Marks	Sign. of Professor with date	Remarks
1.	To Determine the Value of Viscosity of a Given Fluid at Different Temperature by Redwood Viscometer/ any other viscometer						
2.	To perform experimentation for pressure measurement devices.						
3.	To measure hydrostatic force and center of pressure on flat/curved surfaces.						
4.	To establish stability of floating body. (Metacentric height experiment)						
5.	To determine characteristics of Laminar and Turbulent flows (To perform Reynolds experiment)						
6.	To verify and prove Bernoulli's theorum.						
7.	To determine hydraulic coefficients of a small circular orifice						
8.	To Calibrate flow measuring devices (Venturimeter, Orificemeter, Rectangular and V-notch)						
9.	To measure drag and lift in Wind Tunnel (Also, To prepare a Drag/ Lift Model if Wind Tunnel is not available)						
10.	To perform model studies, similitude and develop a model/sketch for fluid flow in pipes, open channel and dimensional analysis.						
Total							

Experiment No: 1

Fluid Viscosity Measurement using Viscometer

Date:

Relevant CO:

CO-1: Analyze and apply the fundamental concepts of fluid properties and fluid statics, including pressure distribution, buoyancy, and hydrostatic forces on submerged surfaces.

Objectives: To Determine the Value of Viscosity of a Given Fluid at Different Temperature by Redwood Viscometer/ any other viscometer.

Equipment/Instruments: Redwood Viscometer, Thermometer, Measuring Cylinder,Stop Watch etc.

Theory:

Viscosity

Viscosity is a measure of a fluid's resistance to flow. The SI unit of viscosity is poiseiulle (PI) and other units are newton-second per square metre (N s m-2). An *ideal fluid has no viscosity.* In reality there is no fluid which can be classified as perfectly ideal fluid. However, the fluids with very little viscosity are sometimes considered as ideal fluids. Viscosity of fluids is due to cohesion and interaction between particles.

Newton's Law of Viscosity

$$\tau = \mu \frac{dv}{dy}$$

The above Equation is known as Newton's Law of viscosity. The ratio dv/dy is known as the velocity gradient. The constant μ (mu) is called the co-efficient of dynamic viscosity. The fluid which obeys this law is called a Newtonian Fluid and the fluid which does not obey this law is called non Newtonian Fluids.

Dynamic Viscosity

The co-efficient of viscosity may be defined as the amount of tangential stress required to maintain unit relative velocity between two parallel layers of fluid at unit distance apart.

In SI units, the unit of dynamic viscosity is N-s/m^2 or kg/(m-s) or (kg m^{-1} s^{-1}). The unit N-s/m^2 is also called Pascal- second (pa-s).

In CGS (Centimeter – gram – Second) units, viscosity is measured in poise which is equal to one dyne-sec/cm^2 or one (mass)/cm-sec.

Kinematic Viscosity

In fluid problems the coefficient of dynamic viscosity μ usually occurs together with mass density ρ in form μ / ρ. In such problems, it is convenient to use another coefficient called the coefficient of kinematic viscosity ν (nu). It is the ratio of the dynamic viscosity to mass density. Thus $\nu = \frac{\mu}{\rho}$

The dimension of ν can obtained from equation, $[\nu] = \left[\frac{M}{LT}\right]\left[\frac{L^3}{M}\right] = \left[\frac{L^2}{T}\right]$ Thus ν is a kinematic terms as it does not involve forces. In CGS units are measured in stoke, which is equal to one cm^2/ sec. The unit is named after Stoke. A smaller unit centistokes which is one hundredth of stoke is sometimes used. In SI units, the unit is one m^2/sec. obviously, 1 stoke = 10^{-4} m^2/sec.

Determination of Viscosity Using Redwood Viscometer

It consists of a vertical cylinder provided with an orifice at the centre of its base. The cylinder is surrounded by a water bath which can maintain the liquid whose viscosity is to be determined at constant temperature. The cylinder is 88.90 mm deep and has 47.625 mm diameter. The orifice is 1.70 mm diameter and 12 mm length. The Cylinder is filled up to fixed height with the liquid as shown in Figure.

The orifice is opened and the time taken for 50 ml of the liquid to flow out is observed. The viscosity is proportional to the time taken. This viscometer is frequently used to measure kinematic viscosity (v) thus, $v = \frac{\mu}{\rho} = \frac{tagD^2}{32AL\left[\log_e\left(h_1/h_2\right)\right]}$

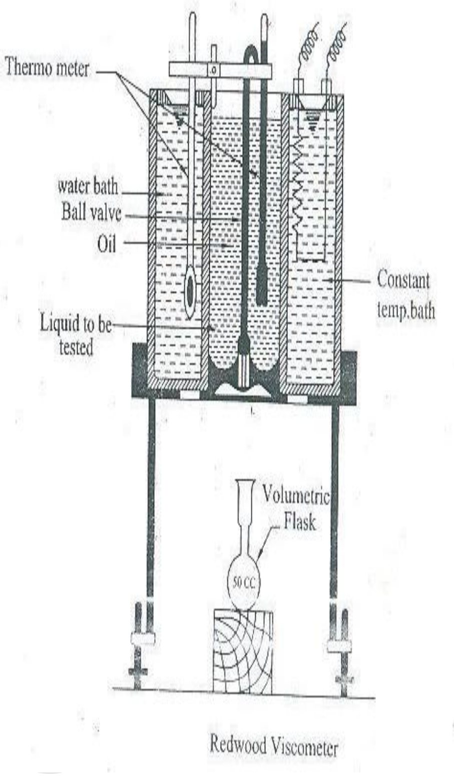


Figure Courtesy: IITGN- Geotechnical Lab. Manual

In this Expression, although the head varies from h_1 to h_2, its variation is the same for all the liquid for a known volume of the liquid (i.e. 50 ml). As such all the terms on the right- hand side expect t may be considered as constants (say equal to C). Thus,

$$v = Ct \quad \text{……………………………………………………………………….. (1)}$$

Equation (1) shows that the kinematic viscosity varies linearly with time t. However, in this case as the capillary tube is quite short, steady conditions do not exist in the tube Thus the Hagen –

Poiseuille equation is not strictly applicable. A correction factor is usually incorporated in Eq. (1) to account for this error. The equation is modified as, $v = Ct + C_1 / T$

For a Redwood Viscometer, the value of C and C_1 are, respectively 0.26 and -172 thus

$$v = 0.26t - \frac{172}{t}$$

PROCEDURE : -

1. Fill the cylindrical container of the viscometer up to the mark with the given sample of liquid – SAE 30 oil.
2. Maintain constant temperature of the test liquid by means of surrounding constant temperature bath.
3. Note the temperature.
4. Measure the time required to collect 50ml volume of the test liquid in the measuring cylinder flask.
5. Repeat the procedure (1) to (4) by raising the temperature up to desired value by means of attached electric heater.

OBSERVATION DATA : -

1) Depth of the cylindrical container = H = mm
2) Diameter of the cylindrical container = d = mm
3) Diameter of the orifice = D = mm
4) Length (thickness) of the orifice plate= L = mm
5) Volume of liquid collected = V = ml
6) Value of the Redwood Constants = C = & C_1=

OBSERVATION TABLE : -

Observation No	Temperature T (^{0} C)	Time t (Sec)	Kinematic Viscosity $v = Ct + C_1 / T$			Remarks
			Centistokes	Stokes 10^{-2}	m^2/Sec 10^{-6}	

SAMPLE CALCULATION :-

Observation No =

C =

C_1 =

Temperature T = ^{0} C

Time of collection t = sec

$\nu = Ct + C_2 / T$ = Centistokes

$= 10^{-2}\ \nu$ = Stokes.

$= 10^{-6}\ \nu$ = m^2 / s

Graph :-Temperature Vs Viscosity

Scope of Application: - Redwood and other types of Efflux viscometer are widely employed in the petroleum and applied industries to determine the viscometer. Those Efflux viscometers cannot give the viscosity in absolute units. However, they may be calibrated with some standard liquids and the viscosity may be expressed in terms of the ratio of times taken with respects to the standards liquid.

Result:

Conclusion:

Quiz/Assignment:

1. What is dynamic viscosity?

2. In which unit does the viscosity is measured.?

3. Differentiate between Dynamic and Kinematic viscosity?

Suggested Reference:

- Bansal, R.K. (2014), A TextBook of Fluid Mechanics and Hydraulic Machines: (In S.I. Units, Revised Ninth Edition). Laxmi Publications, Telangana.
- Engineering Fluid mechanics, K.L. Kumar, 8th Edition S. Chand & Company Ltd.
- Hydraulics and Fluid Mechanics, P.M. Modi and S.M. Seth, Standard Book House
- Theory and Applications of Fluid Mechanics, K. Subramanya, Tata McGraw Hill.
- Fluid Mechanics, A.K. Jain, 4th edition, Khanna Publishers.
- Theory and Applications of Fluid Mechanics by K Subramanya, McGraw Hill Publication

References used by the students:

Rubric wise marks obtained:

Rubrics	1	2	3	4	5	Total
Marks						

Experiment No: 2

Fluid Measurement through Devices

Date:

Relevant CO:

CO-1: Analyze and apply the fundamental concepts of fluid properties and fluid statics, including pressure distribution, buoyancy, and hydrostatic forces on submerged surfaces.

Objectives: To perform experimentation for pressure measurement devices (Using Manometer/ Pitot tube).

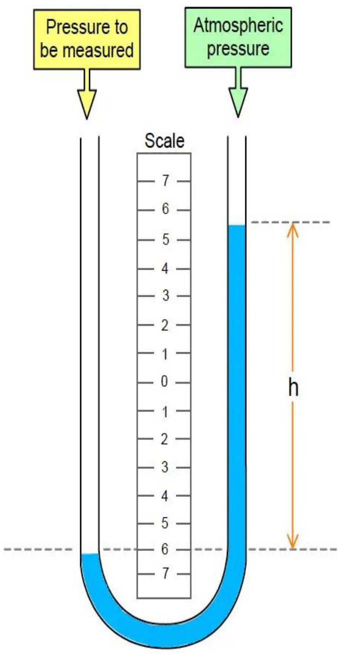
Equipment/Instruments: Pitot tube, Manometer (U-tube or digital), Fluid source (water, air, etc.), Tubing and fittings, Leveling device, Vernier calipers or ruler, Stopwatch or timer, Safety equipment (lab coat, safety goggles)

Theory: Pressure measurement devices in fluid mechanics are essential tools for quantifying the force exerted by a fluid on a surface or within a closed system. These devices play a crucial role in various applications, including engineering, meteorology, and scientific research. Here are some common pressure measurement devices used in fluid mechanics:

- *Manometers:* Manometers are simple and versatile instruments used to measure fluid pressure. They typically consist of a U-shaped tube filled with a liquid (e.g., mercury or water) and are connected to the fluid whose pressure is being measured. The height difference between the two liquid columns in the U-tube corresponds to the pressure difference between the fluid and the atmosphere.
- *Pitot Tubes:* Pitot tubes are specialized instruments used to measure fluid velocity by comparing the static pressure and the total pressure of the fluid. They are commonly employed in aerodynamics to determine airspeed in aircraft and airflow in wind tunnels.
- Pressure Gauges: Pressure gauges are among the most common pressure measurement devices. They provide a direct readout of pressure on a dial or digital display. Various types of pressure gauges, including Bourdon tube gauges and diaphragm gauges, are available for different pressure ranges and applications.
- *Bourdon Tubes:* Bourdon tubes are mechanical pressure sensors often found in industrial applications. They consist of a curved, flattened tube that straightens when pressure is applied. This straightening is converted into mechanical motion, which can be measured and correlated to pressure.
- *Piezoelectric Sensors:* Piezoelectric sensors utilize the piezoelectric effect, where certain materials generate an electric charge when subjected to mechanical stress. These sensors are highly sensitive and can measure rapid pressure changes. They are commonly used in dynamic pressure measurements, such as in aerodynamics and automotive applications.

- *Strain Gauge Pressure Transducers:* Strain gauges are electrical resistance-based sensors that change their resistance when subjected to mechanical deformation. When attached to a diaphragm or membrane exposed to fluid pressure, they can measure pressure changes. These transducers are used in various industrial and laboratory settings.
- *Capacitive Pressure Sensors:* Capacitive pressure sensors work by measuring the change in capacitance between two conductive plates as the distance between them varies due to pressure-induced deflection of a diaphragm. They are known for their high accuracy and are used in applications like medical devices and HVAC systems.
- *Pressure Transmitters:* Pressure transmitters are devices that convert pressure readings into electrical signals, often using various sensing technologies mentioned above. These electrical signals can be easily transmitted and processed by control systems, making them ideal for industrial automation and control.

In fluid mechanics, selecting the appropriate pressure measurement device depends on factors such as the type of fluid, pressure range, accuracy requirements, and environmental conditions. These devices are indispensable for understanding and optimizing fluid flow, ensuring safety in various industrial processes, and conducting research in fields ranging from aerospace engineering to hydraulics.



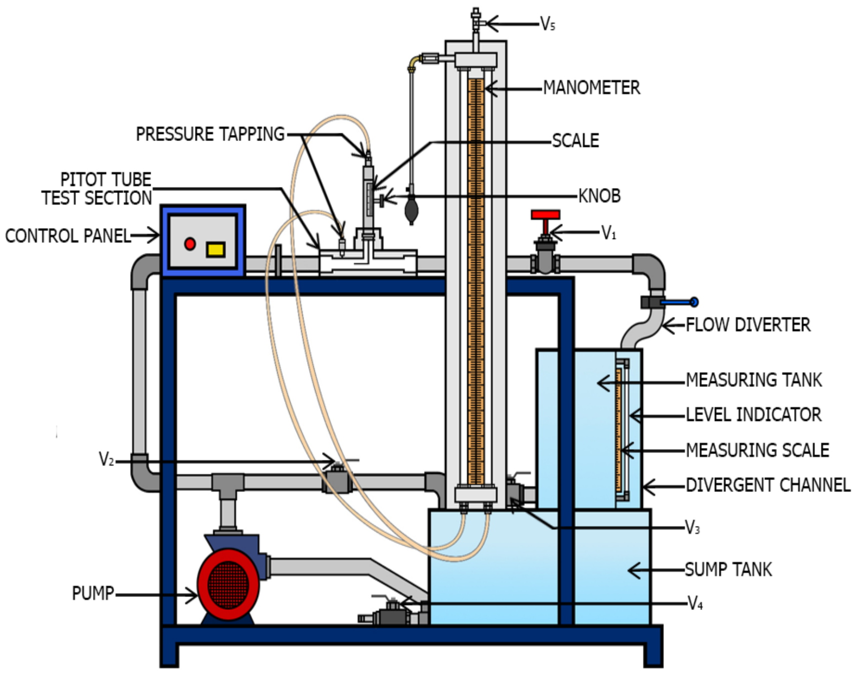


Figure Courtesy: intrumentstool.com , https://me.iitp.ac.in

A Pitot Tube is a simple device used for measuring the velocity of flow. The basic principle used in this device is that if the velocity of flow at a particular point is reduced to zero, which is known as stagnation point, the pressure there is increased due to the conversion of the kinetic energy into the pressure energy, and by measuring the increase in the pressure energy at this point the velocity of flow may be determined. This principle is adopted for measuring the velocity in the River. The " DYNAMIC " equipment enables to determine the co-efficient of velocity of Pitot Tube.

The apparatus consists of sump tank with centrifugal pump. A pitot tube made of copper provided in the test section made of acrylic connected to pipeline with flow control valve. The pointer gauge is provided to measure the vertical position of pitot tube in the given test section. A manometer is provided to determine the pressure difference. we need to calculate the discharge using the measuring tank and a stopwatch. The flow of water is regulated with the help of Control and by pass valve. The following precautions have to be followed:

Check electric supply matches with the requirement of the experimental setup. Here, we need single phase, 220 V AC, 50 Hz, 5-15 Amp. combined socket with earth connection. The earth voltage should always be less than 5 volts.

- Always use clean water.
- Keep apparatus free from dust.
- To avoid unnecessary clogging of components run the pump at least once in fortnight.
- While performing experiment always maintain the water in overhead tank.
- After experiment is complete drain the apparatus and Switch Off the power supply
- Avoid parallax error while noting down the reading from tubes.

Procedure : -

1. **Setup and Safety Precautions:**
    - Ensure you are wearing appropriate safety gear, including a lab coat and safety goggles.
    - Set up the Pitot tube apparatus on a stable, level surface.
    - Connect the Pitot tube to the fluid source using tubing and fittings. Ensure there are no leaks.
    - Position the manometer at the same level as the Pitot tube inlet.
    - Ensure that the Pitot tube and manometer are properly zeroed or calibrated.
2. **Measurement of Static Pressure (P1):**
    - Carefully insert the Pitot tube into the fluid flow, ensuring it faces directly into the flow direction.
    - Allow the fluid to flow steadily for a few seconds to ensure accurate pressure measurements.
    - Read and record the static pressure (P1) from the manometer. This represents the pressure of the fluid at rest.
3. **Measurement of Total Pressure (P2):**
    - With the Pitot tube still in the same position, record the total pressure (P2) from the manometer. This represents the pressure at the Pitot tube tip when it's in the moving fluid.

4. **Calculate Dynamic Pressure (q):**
    - Calculate the dynamic pressure (q) using the formula: $q = P2 - P1$.
    - This dynamic pressure represents the energy associated with the fluid's velocity.
5. **Measurement of Velocity (V):**
    - Use Bernoulli's equation to find the velocity (V) of the fluid: $V = \sqrt{(2 * q / \rho)}$ where ρ is the fluid density.
6. **Repeat Measurements:**
    - For accuracy, repeat the procedure at different points in the fluid flow, or at different fluid flow rates, if necessary.
7. **Data Analysis:**
    - Collect and record all data, including static and total pressures, fluid density, and calculated velocities.
    - Calculate the average velocity if you performed multiple measurements.
8. **Conclusion:**
    - Summarize your findings and compare them to expected values or theoretical predictions.
    - Discuss any sources of error and suggest improvements for future experiments.
9. **Cleanup:**
    - Turn off the fluid source and disconnect all equipment safely.
    - Properly dispose of any fluids used during the experiment.
    - Clean and store the equipment appropriately.
10. **Safety:** Ensure that all equipment is stored safely, and the lab area is clean and tidy. Dispose of any chemicals or fluids according to lab safety protocols.

Observation Data : -

SR. NO.	MANOMETER DIFFERENCE h (mtrs.) (AT PITOT TUBE POSITIONS)									TIME FOR 10 LITRES WATER DISCHARGE t (sec.)
	1	2	3	4	5	6	7	8	9	
1										
2										
3										
4										
5										

Calculation :-

1. Actual discharge , Q= 0.01/t ________________m^3/sec (Cumecs)

2. Actual Velocity , V_actual= Q_a/A ______________m/sec

Where,

A = c/s area of pipe = $3.14d^2/4 = 3.14\frac{d^2}{4}$

A = $3.14\,\frac{d^2}{4}$

A = _________________m2

V(actual)= $\frac{Q(actual)}{A}$ = ________________m/s

3. Let 'H' be the water head across manometer in, mtrs

H = Manometer difference x (sp. Gravity of Hg - sp. Gravity of water)

= h x (13.6-1)

H = h x 12.6_______ m of water.

4) Theoretical Velocity -

V= √(2 g H) m/sec.

Where,

V = Theo. Velocity of flow, m/sec.

g = gravitational acceleration = 9.81 m/sec2

V1= √(2 g H_1)

V2= √(2 g H_2)

Vg= √(2 g H_g)

Where, V1, V2, are the velocities at corresponding points in the test pipe along the diameter

Average theoretical velocity -

Vtheo = (V1 + V2 + ………+ Vg)/g ___________________ m/sec.

Co-efficient of velocity

Cv = Vactual/Vtheo

Plot the graph of velocity distribution along the diameter.

Result:

Conclusion:

Quiz/Assignment:

1. What is Manometer?

2. In which unit does the pressure is measured?

3. Differentiate between pitot tube, manometer and pressure gauge?

Suggested Reference:

- Bansal, R.K. (2014), A TextBook of Fluid Mechanics and Hydraulic Machines: (In S.I. Units, Revised Ninth Edition). Laxmi Publications, Telangana.
- Engineering Fluid mechanics, K.L. Kumar, 8th Edition S. Chand & Company Ltd.
- Hydraulics and Fluid Mechanics, P.M. Modi and S.M. Seth, Standard Book House
- Theory and Applications of Fluid Mechanics, K. Subramanya, Tata McGraw Hill.
- Fluid Mechanics, A.K. Jain, 4th edition, Khanna Publishers.
- Theory and Applications of Fluid Mechanics by K Subramanya, McGraw Hill Publication

References used by the students:

Rubric wise marks obtained:

Rubrics	1	2	3	4	5	Total
Marks						

Experiment No: 3

Hydrostatic force and center of pressure Measurement on surfaces.

Date:

Relevant CO:

CO-1: Analyze and apply the fundamental concepts of fluid properties and fluid statics, including pressure distribution, buoyancy, and hydrostatic forces on submerged surfaces.

Objectives: To measure hydrostatic force and center of pressure on flat/curved surfaces.

Equipment/Instruments: Armfield F1-12 Hydrostatic Pressure Apparatus, Flat or curved surface (e.g., a plate, a wing section, or a curved body), Water tank or a large container for submerging the surface, Fluid (usually water)Weighing scale or load cell, Ruler or calipers, Plumb line, Protractor, Vernier calipers, Spirit level, Measuring tape, Support structure or frame, Leveling device,

Theory: Measuring hydrostatic force and center of pressure on flat or curved surfaces is crucial in fluid mechanics and engineering applications, especially for designing objects like dams, boats, and submerged structures. The hydrostatic force is the force exerted by a fluid on a submerged surface due to the pressure distribution, and the center of pressure is the point where this force effectively acts. Hydrostatic forces are the resultant force caused by the pressure loading of a liquid acting on submerged surfaces.

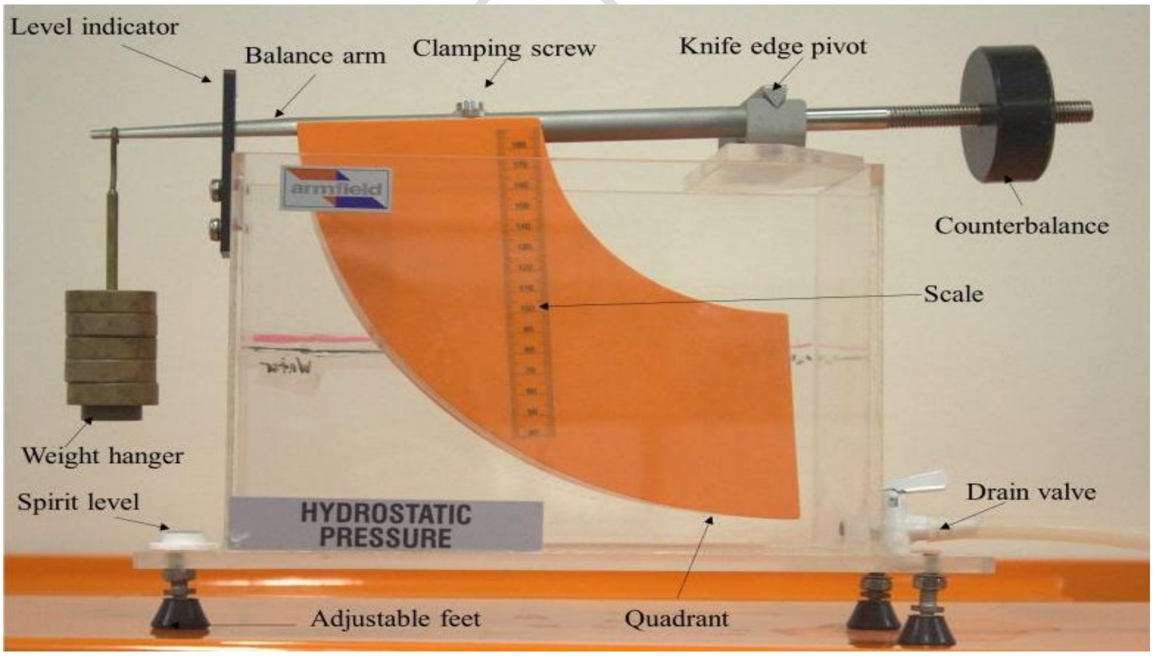


Figure Courtesy: Armfield F1-12 Hydrostatic Pressure Apparatus (uta.pressbooks.pub)

Calculation of the hydrostatic force and the location of the center of pressure are fundamental subjects in fluid mechanics. The center of pressure is a point on the immersed surface at which the resultant hydrostatic pressure force acts. The location and magnitude of water pressure force acting on water-control structures, such as dams, levees, and gates, are very important to their structural design. Hydrostatic force and its line of action is also required for the design of many parts of hydraulic equipment.

Procedure : -

1. **Setup:**
    - Set up the water tank or container on a level surface.
    - Construct a support structure or frame to hold the flat or curved surface in the desired position within the tank.
    - Ensure the surface is clean and free of debris.
2. **Measuring the Surface Dimensions:**
    - Measure and record the dimensions (length, width, and height) of the surface using a ruler or calipers.
3. **Submerging the Surface:**
    - Submerge the surface in the fluid (water) within the tank, ensuring it is fully immersed. The surface should be in a horizontal position if possible.
4. **Measuring Depth and Angle:**
    - Measure the depth of the surface's leading edge (the point where it enters the fluid) from the water surface using a measuring tape or ruler.
    - Measure the angle of inclination (if any) of the surface using a protractor.
5. **Steady State:**
    - Allow the fluid to come to a steady state with no visible motion or turbulence around the submerged surface.
6. **Measuring Hydrostatic Force:**
    - Attach a weighing scale or load cell to the submerged surface in such a way that it measures the vertical force exerted by the fluid.
    - Record the weight or force reading.
7. **Calculating Hydrostatic Force:**
    - Calculate the hydrostatic force (F) using the formula: $F = \rho.g.A.h$, where:
        - ρ is the fluid density.
        - g is the acceleration due to gravity.
        - A is the submerged surface area.
        - h is the depth of the leading edge.
8. **Determining the Center of Pressure:**
    - Use the plumb line to locate the center of pressure on the submerged surface. The center of pressure is the point where the resultant hydrostatic force acts vertically.

- Measure the horizontal distance from the leading edge of the surface to the point where the plumb line crosses the surface. This distance represents the position of the center of pressure.

9. **Data Analysis:**
   - Calculate the center of pressure in terms of the distance from the leading edge and any angles if the surface is inclined.

10. **State Conclusions:**
    - Summarize your findings, including the hydrostatic force and the center of pressure.
    - Discuss the significance of these measurements in the context of your experiment or application.

11. **Cleanup:** Ensure proper disposal of the fluid and cleanup of the equipment and lab area.

By following this procedure, you can measure the hydrostatic force and determine the center of pressure on flat or curved surfaces submerged in a fluid. These measurements are critical for understanding the behavior of submerged objects and designing them to withstand hydrostatic forces.

Observation Data : -

Record the following dimensions:

Height of quadrant endface, D (m) =

Width of submerged, B (m)=

Length of balance arm, L (m)=

Distance from base of quadrant to pivot, H (m)=

All mass and water depth readings should be recorded in the table.

Observation Table : -

Test No.	Mass m(kg)	Density Calculation (ρ)	Area (m^2)	Height/Depth observance H(m)	Hydrostatic force Calculations (F in N)
1					
2					
3					
4					
5					
6					
7					
8					

9					
10					

Sample Calculation :-

Result:

Conclusion:

Quiz/Assignment:

1. Differentiate between force, stress, pressure?

Sr. No.	Parameter	Force	Stress	Pressure
1	Definition			
2	Formulae			
3	Notation			
4	SI Unit			
5	CGS Unit			
6	FPS Unit			

2. What is Hydrostatic force, Write formulae.?

Suggested Reference:

- Engineering Fluid mechanics, K.L. Kumar, 8th Edition S. Chand & Company Ltd.
- Hydraulics and Fluid Mechanics, P.M. Modi and S.M. Seth, Standard Book House
- Theory and Applications of Fluid Mechanics, K. Subramanya, Tata McGraw Hill.
- Fluid Mechanics, A.K. Jain, 4th edition, Khanna Publishers.
- Theory and Applications of Fluid Mechanics by K Subramanya, McGraw Hill Publication

References used by the students:

Rubric wise marks obtained:

Rubrics	1	2	3	4	5	Total
Marks						

Experiment No: 4

To determine stability of floating body (Metacentric Height Experiment).

Date:

Relevant CO:

CO-1: Analyze and apply the fundamental concepts of fluid properties and fluid statics, including pressure distribution, buoyancy, and hydrostatic forces on submerged surfaces.
CO-5: Perform dimensional analysis using Buckingham's π theorem on the different applications of fluid mechanics (Design and carry out model studies for fluid flow problems.)

Objectives: To establish stability of floating body (Metacentric Height Experiment).

Equipment/Instruments: A stable tank or water-filled container with a still water surface.

Metacentric height apparatus setup: A model ship or body (scaled down representation of a ship) with a known geometric shape and dimensions, A scale to measure the dimensions of the model ship, A pendulum or pendulum-like apparatus with a graduated scale, A protractor or angle measuring device, A depth gauge or ruler, Weights and pulleys for heeling the model ship, A stopwatch or timer, Safety equipment (lab coat, safety goggles).

Theory: When a body is immersed in fluid, it is subjected to an upwards force which tends to lift up the body. This is called buoyancy and the upward force is called buoyant force. Archimede's principle states that when a body is immersed in a fluid, wholly or partially, it is buoyed or lifted up by a force which is equal to the weight of the fluid displaced by the body. When a body is floating in liquid, it is acted upon by two forces, viz. Weight of body acting downwards through center of gravity and upward buoyant force acting through center of -buoyancy. Both these forces are equal and opposite in direction and the body is in equilibrium. Center of buoyancy of a body is centroid of the volume of liquid displaced. If the body is tilted slightly, then position of center of gravity remains the same but center of buoyancy occupies the new position, as geometry volume changes. If a vertical line is drawn through the new center of buoyancy, it intersects the line joining initial center of buoyancy and center of gravity at a point, known as metacenter. The distance between metacenter and center of gravity is called metacentric height.

Stability of a floating body depends upon the metacentric height .If metacenter lies above the center of gravity, the slight angular displacement of body causes to form a restoring couple, which tends to bring the body to it's original position. This is called stable equilibrium. When metacenter lies below the center of gravity, then slight angular displacement of body causes to form a couple which tends to increase the angular displacement further. This is called unstable equilibrium. When metacenter lies exactly on center of gravity then slight angular displacement does not create any couple, hence body remains in it's new position. This is called neutral equilibrium. Hence, in design of ship, care has to be taken to keep the metacenter well above the center of gravity, so that ship is in stable equilibrium.

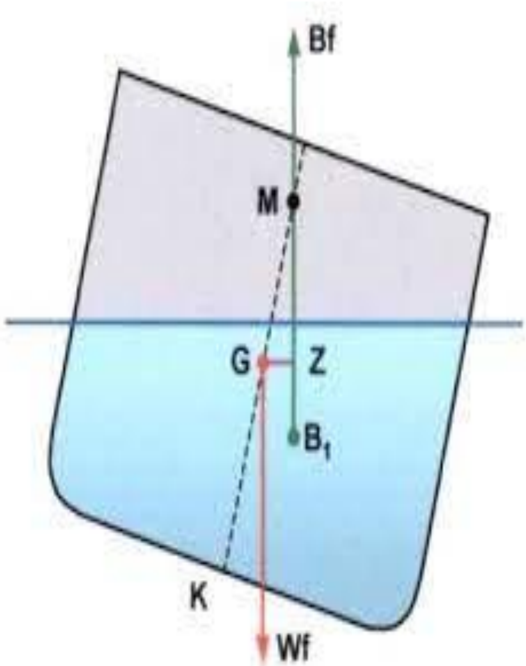


Figure Courtesy: Internet

The 'DYNAMIC' apparatus consist of a ship model, which is made of half round shape. A movable weight slides in a guide bar at the deck. When the weight is shifted from the center position, the ship tilts slightly. The angle of tilt (or angle of heel) is measured with the help of angular scale fitted on upside. The position of metacenter is then determine by displacement of weight and angle of heel.

Procedure : -

1. Setup: Fill the tank or container with water until the water surface is calm and still.
2. Place the model ship gently onto the water's surface. Ensure it is free to move without any external forces acting on it. Fill up water in the floating tank.
3. Keeps the ship floating over the water.
4. See that plumb indicates zero reading.
5. Displace the weight on the deck.
6. Measurement of Initial Parameters: Measure and record the length (L) and breadth (B) of the model ship. Measure and record the initial draft (d), which is the vertical distance from the waterline to the keel of the ship.
7. Measure the displacement of weight and distance indicated by plumb.
8. Repeat the procedure for different displacement of weight.

Determining the Initial Metacentric Height (GM_initial):

- Using the pendulum or pendulum-like apparatus, suspend a weight or mass below the model ship. This will heel the ship to one side.
- Measure and record the angle of heel (θ) at which the ship starts to heel.
- Record the time (t) it takes for the ship to reach this angle.
- Calculate the initial metacentric height using the formula: GM_initial = (t^2 * g) / (8 * sin(θ)) where: g is the acceleration due to gravity.

Observation Data and Table: -

Sr. No.	Weight displacement x cm	Angle of heel θ	Metacentric Height (GM)

Calculation :- 1. Weight of the ship, W = ____kg

2. Sliding weight on the deck, w=______kg.

3. Let distance moved by the weight w at the deck be x.

Let angle of heel [through which the slip is tilted] be θ.

Then metacentric height,

GM=w.x/W.tanθ

Result:

Conclusion:

Quiz/Assignment:

1. What is buoyancy and buoyant force?

2. What is meant by Metacentric Height.?

3. Write down the formulae for theoretical and experimental metacentric height?

Suggested Reference:

- Bansal, R.K. (2014), A TextBook of Fluid Mechanics and Hydraulic Machines: (In S.I. Units, Revised Ninth Edition). Laxmi Publications, Telangana.
- Engineering Fluid mechanics, K.L. Kumar, 8th Edition S. Chand & Company Ltd.
- Hydraulics and Fluid Mechanics, P.M. Modi and S.M. Seth, Standard Book House
- Theory and Applications of Fluid Mechanics, K. Subramanya, Tata McGraw Hill.
- Fluid Mechanics, A.K. Jain, 4th edition, Khanna Publishers.
- Theory and Applications of Fluid Mechanics by K Subramanya, McGraw Hill Publication

References used by the students:

Rubric wise marks obtained:

Rubrics	1	2	3	4	5	Total
Marks						

Experiment No: 5
Reynold's Experiment

Date:

Relevant CO:

CO.1: Analyze and apply the fundamental concepts of fluid properties and fluid statics, including pressure distribution, buoyancy, and hydrostatic forces on submerged surfaces.

CO.3: Identify various flow measuring devices, such as Venturimeter and Pitot tube, and calculate discharge through orifices, notches, and weirs.

Objectives: To determine characteristics of Laminar and Turbulent flows (To perform Reynolds experiment)

Equipment/Instruments: Reynold's Apparatus, Dye, Water, Water tank.

Theory: Whenever a fluid is flowing through a pipe, the flow is either laminar or turbulent. When fluid is flowing in parallel layers or laminate, sliding past adjacent laminar, is called laminar flow. When fluid does not flow in parallel layers and there is intermingling of fluid particles then the flow is said to be turbulent. Existence of these two types was first demonstrated by 'OSBORN REYNOLDS' in 1883. The apparatus consists of a constant head supply tank supplied with water. Tank is provided with a bell mouth outlet to which a transparent tube is fitted. At outlet of the tube a regulating valve is provided. A dye tank containing colored dye is fitted above the supply tank. The water flow through pipe and dye is injected at the center of the pipe.

Figure Courtesy: Reynolds Experiment set-up

When velocity of flow is low, (i.e. flow is laminar) then dye remains in the form of straight filament. As the velocity of water is increased, a state is reached when the dye filament becomes irregular in flowing water. With further increases of water through the tube, dye filament becomes more and more irregular and ultimately the dye diffuses over the entire cross section of the tube. The velocity at which the flow changes from laminar to turbulent for the case of given fluid at given temperature and in a given pipe is known as critical velocity. The state of flow between these two types of flow is known as 'transition state' or flow in transition. The occurrence of laminar and turbulent flow is governed by relative magnitude of inertia and viscous forces. Reynolds related the inertia forces to viscous forces and arrived at a dimensionless parameter now called 'Reynolds number'.

Procedure : -

- Setup: Ready the setup do necessary connections and Fill up water up to the mark.
- Fill up sufficient water in dye tank and add a small amount of potassium permanganate in to the water.
- Prime pump (remove the end plug & fill up water, remove all the air. Then tight the plug, fitted near the flow control valve.) Connect the electric supply and start pump. Adjust the water flow to about 2 lpm. Start the dye injection.
- Wait for some time. A steady line of dye will be observed. Adjust the dye flow if required.
- Slowly increase the water flow & see that water level in supply tank remains constant. At particular flow rate, dye line will be disturbed. Note down this flow rate by using 1 litre measuring flask and stop watch.
- Further increase the flow. This disturbance of dye line will go on increasing and at certain flow; the dye line diffuses over the entire cross section. Note down this flow.
- Slightly slowly reduce the flow. Note down the flow at which diffused dye tends to become steady, (beginning of transition zone while reducing velocity.)
- Further reduce the flow and note the flow at which dye line becomes straight and steady.
- After completion of experiment drain all of water and the tight the drain plug. Also clean the dye container.

Observation Data : -

1. Increasing velocity

a) Flow at beginning of transition:

b) Flow at beginning of turbulence:

2. Decreasing velocity

a) Flow at beginning of transition:

b) Flow at beginning of turbulence:

Observation Table : -

Sr. No.	Flow type	Reynold's Number	Discharge

Sample Calculation :-

Assume I.D. of pipe = 20 mm (Write as per apparatus reading),

Therefore cross sectional area of pipe, A = 3.14 x 10^{-4} m^2
Let, time required for 1liter in measuring flask be't' sec.

Then flow, $Q = \frac{0.005}{t}$

Velocity, V = Q/A

Then Reynold's number $R_e = \frac{\rho \quad V \quad D}{\mu}$

$$R_e = \frac{V \quad D}{\vartheta}$$

ρ = Density of fluid = 1000 Kg/m^3

V = velocity m/sec.

D = Diameter of the pipe = 0.02 m (Write as per apparatus reading).

ϑ = Kinetic energy of fluid = 0.805 x 10^{-6} m^2/s

μ = 801.2 x 10^{-6} N-s/m^2

While increasing the velocity, laminar flow is disturbed at slightly higher velocity. But at the reducing the velocity the flow does not turn to laminar at this velocity, but becomes laminar at still lower velocity is called lower critical velocity.

Lower critical Reynold's number flow is always laminar and above upper critical Reynold's number flow is always turbulent. Practically, upper critical Reynold's number lies between 2000 & 4000 and lower critical Reynolds number is approximately 2000. Between Reynold's numbers 2000 to 4000 the transition region exists.

Result:

Conclusion:

Quiz/Assignment:

1. What is the significance of Reynold's experiment?

2. Differentiate the category of classifying laminar, transition and turbulent flow.?

3. Write down the formulae of Reynolds Number?

Suggested Reference:

- Bansal, R.K. (2014), A TextBook of Fluid Mechanics and Hydraulic Machines: (In S.I. Units, Revised Ninth Edition). Laxmi Publications, Telangana.
- Engineering Fluid mechanics, K.L. Kumar, 8th Edition S. Chand & Company Ltd.
- Hydraulics and Fluid Mechanics, P.M. Modi and S.M. Seth, Standard Book House
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- Fluid Mechanics, A.K. Jain, 4th edition, Khanna Publishers.
- Theory and Applications of Fluid Mechanics by K Subramanya, McGraw Hill Publication

References used by the students:

Rubric wise marks obtained:

Rubrics	1	2	3	4	5	Total
Marks						

Experiment No: 6

Bernoulli’s Theorem Experiment

Date:

Relevant CO:

CO.2: Apply the principles of conservation of mass and energy (Bernoulli's equation), and use the momentum equation to solve problems in fluid dynamics.

CO.3: Identify various flow measuring devices, such as Venturimeter and Pitot tube, and calculate discharge through orifices, notches, and weirs.

Objectives: To verify and prove Bernoulli’s theorem.

Equipment/Instruments: Bernoulli’s theorem apparatus with embedded manometer system, pipe system, manometers, pump, measuring instruments, sump tank. Water reservoir, Tubing and connectors, Stopwatch or timer, Ruler or measuring tape, Thermometer (optional, for temperature measurements).

Theory:

Bernoulli's theorem is a fundamental principle in fluid dynamics that describes the behavior of an ideal fluid as it moves along a streamline. It is named after the Swiss mathematician Daniel Bernoulli. In brief, Bernoulli's theorem states: "When the velocity of a fluid (liquid or gas) increases, its pressure decreases, and vice versa, provided that no energy is added to or taken away from the fluid, and there is no change in height (gravitational potential energy) along the streamline." It states that *the sum of potential energy, kinetic energy and pressure energy is constant for a fluid flow.* As fluid flows along a streamline, if its velocity increases at a certain point, the pressure at that point decreases. Conversely, if the velocity decreases, the pressure increases. This relationship is a result of the conservation of energy.

In other words, if velocity energy of fluid is raised, its pressure will drop, i.e. total energy of fluid is constant at any two points in the path of flow. The theorem is known as Bernoulli's theorem. Hence, when applied to steady irrotational flow of incompressible fluids,

$$\frac{P}{\omega} + \frac{V^2}{2g} + z = c$$

where,

P = pressure
V = velocity at the point
z = potential head from datum
ω = Specific weight = ρ.g

In summary, Bernoulli's theorem describes the relationship between the velocity and pressure of an ideal fluid along a streamline, based on the conservation of energy principle. It is a useful tool for analyzing and predicting fluid behavior in various applications but should be applied with caution when real-world factors deviate from ideal conditions.

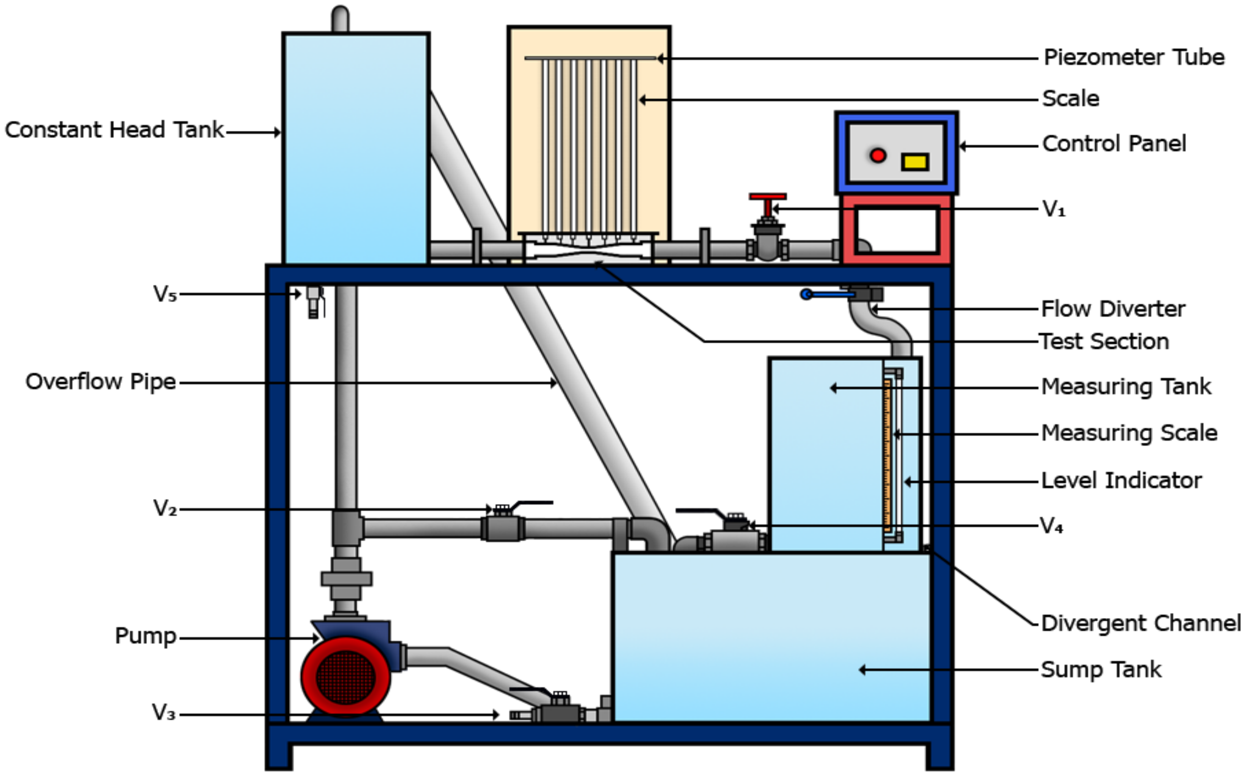


Figure Courtesy: Bernoulli's Theorum Apparatus (Source: me.iitp.ac.in)

The experimental set-up for Bernoulli's Theorem constitutes with self-contained re circulating unit. It passes this through the use of sump tank, constant head tank and a centrifugal pump for water circulation and maintaining discharge. The test section within apparatus, made up of material Perspex, having a varying cross-section with converging and diverging portions is provided in the set up. The flow of water in the test section is regulated through the use of control and bypass valves. Piezometer tubes/ manometer tubes are fitted on this test tubes at various test points. The inlet of the test-section is connected to the overhead tank. The discharge through the test-section can be measured with the help of the measuring tank and a stop-watch. Actual set up is shown in the figure above.

To perform experiments or demonstrations related to Bernoulli's theorem in fluid dynamics and to measure fluid flow and pressure following apparatus is used for experiments involving:

- Flow Tube or Pipe: A tube or pipe through which the fluid (liquid or gas) flows. This is often a key component to create a controlled flow of the fluid.
- Pump: A pump is used to provide a controlled and consistent flow of the fluid through the system. It helps maintain a steady flow rate.
- Pressure Gauge or Manometer: Pressure measuring instruments like gauges or manometers are used to measure the pressure at different points within the fluid flow. These instruments help confirm the pressure changes predicted by Bernoulli's theorem.

- Bernoulli's theorem apparatus with embedded manometer system.

Procedure : -

(1) Setup:

a. Set up the Venturi tube apparatus on a stable surface. Ensure that it is level and secure.

b. Connect the Venturi tube to the pump using tubing and connectors. Make sure there are no leaks in the system.

c. Connect the manometer to the Venturi tube at appropriate pressure measurement points. The manometer should be at the wider and narrower sections of the tube.

d. Fill the water reservoir and connect it to the pump.

(2) Calibration:

a. Before starting the experiment, calibrate the manometer to ensure accurate pressure readings. Zero the manometer by aligning the liquid levels in both sides of the U-shaped tube.

(3) Flow Rate Control:

a. set up flow rate/ discharge in the set up. Maintain the flow rate for experiment.

b. Measure and record the flow rate by collecting water in a container for a known duration and measuring the volume.

(4) Pressure Measurements:

a. Measure and record the pressure at the wider section (P1) and the narrower section (P2) of the Venturi tube using the manometer.

b. Ensure that the pressure measurements are taken simultaneously, or record the time difference if measurements are not simultaneous.

(5) Data Collection:

a. Record the observations in the manometer tubes. There may be aroud 14 junctions in 1 m pipe at which height may be recorded. Temperature of water can also be recorded. Temperature can affect the density of the fluid.

b. Measure the cross-sectional areas of both the wider and narrower sections of the Venturi tube (if necessary).

(6) Calculations:

Maintain the uniform discharge throughout the experiment.

a. Calculate the velocity of the fluid at the wider section (V1) using the flow rate and cross-sectional area (A1).

b. Calculate the velocity of the fluid at the narrower section (V2) using the flow rate and cross-sectional area (A2).

c. Calculate the kinetic energy per unit volume ($\frac{1}{2}\rho V^2$) at both sections.

d. Calculate the potential energy per unit volume (ρgh) at both sections, where ρ is the density of water, g is the acceleration due to gravity, and h is the height difference between the pressure measurement points and a reference point (usually the bottom of the manometer).

(7) Analysis:

a. Compare the kinetic energy and potential energy per unit volume at the wider and narrower sections of the Venturi tube.

b. Observe how the pressure difference (P1 - P2) corresponds to the change in kinetic and potential energy, as predicted by Bernoulli's theorem.

(8) Repeat and Variations:

a. Repeat the experiment with different flow rates or by altering the geometry of the Venturi tube to observe how it affects the pressure and velocity distributions.

b. Record and analyze the data to reinforce the principles of Bernoulli's theorem.

(9) Turn off the pump, drain the system, and properly clean and store all equipment.

This procedure provides a basic outline for conducting an experiment to demonstrate Bernoulli's theorem using a Venturi tube apparatus. Depending on your specific goals and available equipment, you may need to make adjustments and conduct additional measurements or variations.

Observation Data : -

Pressure head (z or H) for different observations, Discharge/ Flow rate, Velocity.

Observation Table : -

Sr. No.	Head Values (in cm or mm)														Time in stop watch for 10 liters flow	Constant Discharge
	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
1																
2																
3																
4																
5																

Calculation :-

(Consider section at 1st tapping)

Area of flow channel, A = ___________ m^2 -----------

(1) Discharge, $Q = \frac{0.01}{t}$ m^3/sec

(2) Velocity of water, $V = \frac{Q}{A}\ m/sec$

Hence,

Velocity energy or head = $\frac{V^2}{2g}$

(3) Pressure head,

$$H = \frac{P}{\omega}$$

or $\quad H = h + hi$

Where, h = Water rise from top channel, m

hi = Distance from top of channel to its center

(5) Now, datum line is same at inlet and outlet.

Hence, $Z_1 = Z_2 = Z_3 = 0$

According to Bernoulli's equation,

$$\frac{P_1}{\omega} + \frac{{V_1}^2}{2g} + Z_1 = \frac{P_2}{\omega} + \frac{{V_2}^2}{2g} + Z_2$$

$$H_1 + \frac{{V_1}^2}{2g} + Z_1 = H_2 + \frac{{V_2}^2}{2g} + Z_2$$

As $Z_1 = Z_2$ for the channel,

$$H_1 + \frac{{V_1}^2}{2g} = H_2 + \frac{{V_2}^2}{2g}$$

Find out the value of C for each section (at same flow rate). It is same for all section

Note- Practically, value of 'C goes on reducing slightly towards outlet, due to various factors which are not considered, e.g. friction, turbulance etc.,

Result: Write the results obtained during experimentation.

Conclusion: Summarize your findings and how they align with Bernoulli's theorem. Discuss any sources of error or limitations in your experiment.

- As value of 'C' is fairly constant, total energy of flow Is same over the entire length.
- As velocity of flow increases, pressure head drops.
- Bernoulli's equation, i.e. $\frac{P}{\rho g} + \frac{V^2}{2g} + z = c$ OR $\frac{P}{\omega} + \frac{V^2}{2g} + z = c$ is thus verified.

Quiz/Assignment:

1. Write the Euler's equation and Bernoulli's equation?

Euler's Equation:

Bernoulli's Equation:

2. What forces are considered in analyzing Euler's equation and Bernoulli's equation?

3. Differentiate between Fluid kinematics and Fluid Dynamics?

Suggested Reference:

- Bansal, R.K. (2014), A TextBook of Fluid Mechanics and Hydraulic Machines: (In S.I. Units, Revised Ninth Edition). Laxmi Publications, Telangana.
- Engineering Fluid mechanics, K.L. Kumar, 8th Edition S. Chand & Company Ltd.
- Hydraulics and Fluid Mechanics, P.M. Modi and S.M. Seth, Standard Book House
- Theory and Applications of Fluid Mechanics, K. Subramanya, Tata McGraw Hill.
- Fluid Mechanics, A.K. Jain, 4th edition, Khanna Publishers.
- Theory and Applications of Fluid Mechanics by K Subramanya, McGraw Hill Publication

References used by the students:

Rubric wise marks obtained:

Rubrics	1	2	3	4	5	Total
Marks						

Experiment No: 7

To determine hydraulic coefficients of orifice

Date:

Relevant CO:

CO-2: Calibrate and demonstrate fluid flow measuring devices like venturimeter, orificemeter, notches, orifice, mouthpieces.

CO-3: Compute and Analyze fluid flow through pipes in series, parallel and pipe networks under laminar and turbulent flow conditions**:**.

Objectives: To determine hydraulic coefficients of a small circular orifice.

Equipment/Instruments: A supply tank with circular orifice, scales and sliding apparatus, A Measuring tank, A stopwatch, Micrometer contraction gauge.

Theory:

When flow takes place through an orifice from the supply tank, the water jet leaving the orifice gets contracted at the downstream of the orifice and the point where it gets the maximum contraction is called as **vena-contracta**. Following are three hydraulic coefficients of orifice:

Coefficient of Contraction (C_c): It is the ratio of area of water jet at vena-contracta to the area of the orifice.

Cc= a_c / a

Where,

a_c = Area of jet at vena-contracta

a = Area of the orifice

Coefficient of Velocity (C_v): It is the ratio of velocity of water jet at vena-contracta to the theoretical velocity.

$$\sqrt{\frac{x^2}{4yh}}$$

Where,

x = Horizontal ordinate

y = Vertical ordinate

h = Head

Coefficient of discharge (C_d): It is the ratio of actual discharge to the theoretical discharge.

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

Where,

Q = Actual discharge

a = Area of the orifice

g = acceleration due to gravity

The relation between the coefficient of contraction, coefficient of velocity and coefficient of discharge can be expressed as :

Coefficient of discharge = coefficient of contraction X coefficient of velocity

$\mathbf{C_d = C_c \cdot C_v}$

Figure Courtesy from Lab: Orifice Apparatus

Procedure : -

The Procedure to determine hydraulic coefficients of an orifice is as follows:

- Fill the supply tank with water and allow the water to flow through the orifice.
- Maintain a constant head in the supply tank by adjusting the water supply valve provided.
- After attaining constant head, now observe the water jet coming from the orifice and note the point where maximum contraction occurs which is nothing but vena-contracta.
- At vena-contracta, measure the diameter of jet using micrometer contraction gauge.
- Adjust the vertical scale to the position of vena-contracta such that the hook provided at the bottom of the vertical scale should touch the center of the water jet. Note down the initial coordinates (x_1, y_1) at this point.
- After recording initial coordinates, slide the vertical scale through the horizontal scale up to a certain distance and adjust the vertical scale with its hook touching the water jet and record the final coordinates (x_2, y_2).
- Take the stopwatch and note down the time taken for the rise of water up to a certain height in the measuring tank and calculate the discharge.

- Repeat the above procedure for various constant heads and calcite the average values of hydraulic coefficients of an orifice.

Observation Data : -

Diameter of the orifice, d =

Dimensions of the measuring tank =

Observation Table : -

N.	Head (h)	Diameter of Jet at vena-contracta (d_c)	Area of Jet at vena-contracta (a_c)	Coefficient of Contraction (C_c)	x	y	Coefficient of Velocity (C_v)	Discharge in measuring tank (Q)	Coefficient of discharge (C_d)
1									
2									
3									
4									
5									

Sample Calculation :-

- Volume of water collected in tank in t seconds,
  V = area of tank X Rise of water level in t seconds

- Discharge in measuring tank, Q = volume/time

- Horizontal co-ordinate, $x = x_2 - x_1$

- Vertical co-ordinate, $y = y_2 - y_1$

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

- Area of jet at Vena Contracta = $\frac{\pi}{4} d_c^2$

- Coefficient of contraction of orifice, $C_c = a_c / a$ = ________________

- Coefficient of velocity of orifice, $C_v = \sqrt{\frac{x^2}{4yh}}$ = __________________

- Coefficient of discharge of orifice, $C_d = \frac{Q}{a.\sqrt{2gh}}$ = _________________

Result:

Coefficient of contraction of orifice, C_c =

Coefficient of velocity of orifice, C_v =

Coefficient of discharge of orifice, C_d =

Conclusion:

Quiz/Assignment:

1. What is C_c, C_v and C_d?

C_c:

C_v :

C_d :

2. What is the formulae correlating different coefficients **C_c, C_v and C_d.**

3. Differentiate between orifice and mouthpiece?

Suggested Reference:

- Bansal, R.K. (2014), A TextBook of Fluid Mechanics and Hydraulic Machines: (In S.I. Units, Revised Ninth Edition). Laxmi Publications, Telangana.
- Engineering Fluid mechanics, K.L. Kumar, 8th Edition S. Chand & Company Ltd.
- Hydraulics and Fluid Mechanics, P.M. Modi and S.M. Seth, Standard Book House
- Theory and Applications of Fluid Mechanics, K. Subramanya, Tata McGraw Hill.
- Fluid Mechanics, A.K. Jain, 4th edition, Khanna Publishers.
- Theory and Applications of Fluid Mechanics by K Subramanya, McGraw Hill Publication

References used by the students:

Rubric wise marks obtained:

Rubrics	1	2	3	4	5	Total
Marks						

Experiment No: 8

To Calibrate flow measuring devices (Venturimeter, Orificemeter, Rectangular and V-notch, Weir)

Date:

Relevant CO:

CO.3: Identify various flow measuring devices, such as Venturimeter and Pitot tube, and calculate discharge through orifices, notches, and weirs.

Objectives: To Calibrate flow measuring devices (Venturimeter, Orificemeter, Rectangular and V-notch, weir).

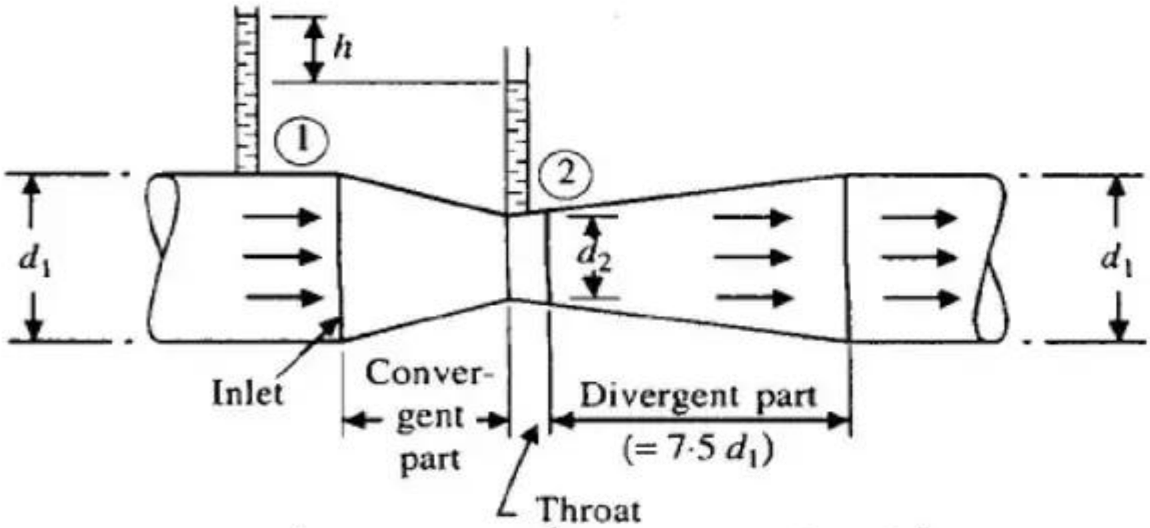
***Note:** At least one experiment from above mentioned device/ apparatus must be performed to calibrate flow measurement.

Equipment/Instruments: Venturimeter device, Orificemeter apparatus, Rectangular- V Notch apparatus, Pump, Sump, Tank, Pipes, Stop Watch.

Theory:

Venturimeter and orifice meter are two common devices used in fluid mechanics to measure the flow rate of fluids (liquids or gases) through pipes or conduits. They work on the principle of Bernoulli's theorem, which relates the velocity and pressure of a fluid in a streamlined flow.

Here's an overview of each device:



$\left(\text{Throat ratio } \frac{d_2}{d_1} \text{ varies from } \frac{1}{4} \text{ to } \frac{3}{4}\right)$

Figure Courtesy Internet: Venturimeter

Venturimeter: A Venturimeter is a device used to measure the flow rate of a fluid in a pipe. It consists of three main components:

Converging Section: This is the part of the Venturimeter where the pipe narrows, causing the fluid velocity to increase. According to Bernoulli's theorem, as the velocity increases, the pressure decreases.

Throat: The throat is the narrowest part of the Venturimeter, where the fluid reaches its maximum velocity. Pressure is typically lowest at this point.

Diverging Section: After passing through the throat, the pipe expands, causing the fluid velocity to decrease, and the pressure to increase to some extent, although it remains lower than in the converging section.

The key principle behind a Venturimeter is that the pressure difference between the converging and throat sections is directly related to the flow rate of the fluid. By measuring this pressure difference using a manometer or pressure gauge, one can calculate the flow rate. Venturimeters are commonly used in industries where precise flow rate measurements are necessary, such as in water supply systems.

Orifice Meter: An orifice meter is another device used to measure the flow rate of fluids through pipes. It consists of a simple orifice plate, which is a flat, circular plate with a hole (or orifice) in the center. The orifice plate is placed in the pipe through which the fluid is flowing. The key components and principles of an orifice meter include:

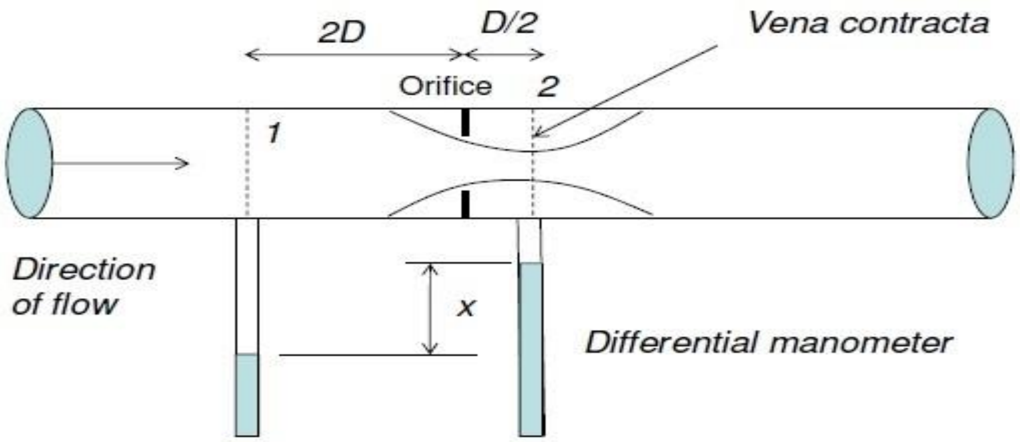


Figure: Orifice Meter

Orifice Plate: This plate creates a restriction in the pipe, causing the fluid to accelerate as it passes through the hole. This increase in velocity is associated with a decrease in pressure, according to Bernoulli's theorem.

Pressure Taps: Two pressure taps, typically located upstream and downstream of the orifice plate, are used to measure the pressure difference across the plate. Pressure taps are connected to a manometer or pressure gauge.

Flow Rate Calculation: The flow rate is determined by measuring the pressure difference between the taps and using a formula that relates this pressure difference to the flow rate. The formula used depends on the fluid properties, orifice plate geometry, and other factors.

Orifice meters are widely used for flow rate measurement in industries such as oil and gas, chemical processing, and water treatment. They are relatively simple and cost-effective but may have limitations when dealing with highly viscous or non-Newtonian fluids.

In summary, both Venturimeters and orifice meters are devices used to measure fluid flow rates based on the principles of Bernoulli's theorem. They are essential tools in various industries for monitoring and controlling fluid flow.

Notches: Notches are openings or notches cut into a plate or structure that are placed in the path of flowing water to measure its flow rate. Notches are often used in laboratories and small-scale flow measurement applications. The shape of the notch, such as V-notch or rectangular notch, determines how flow is measured. The water level in the notch is used to calculate the flow rate based on established equations. Notches are useful for precise flow measurements, especially in research and experimental settings.

Weir: Weirs are structures typically installed in open channels or rivers to measure and control the flow of water. They consist of a barrier or obstruction over which water flows. Weirs are commonly used for flow measurement, flood control, water level control, and diversion of water for various purposes. They can have different shapes, including rectangular, V-notch, and sharp-crested, depending on their specific application and the desired accuracy of flow measurement.

Rectangular weirs, V-notch weirs, and sharp-crested weirs and Notches are all types of flow measurement devices used in hydraulics and fluid mechanics. They are used to measure the flow rate of liquids (usually water) in open channels or channels with free surfaces. Each type of weir has its own distinct shape and characteristics. Here's a differentiation between these three types of weirs:

Rectangular Weir:

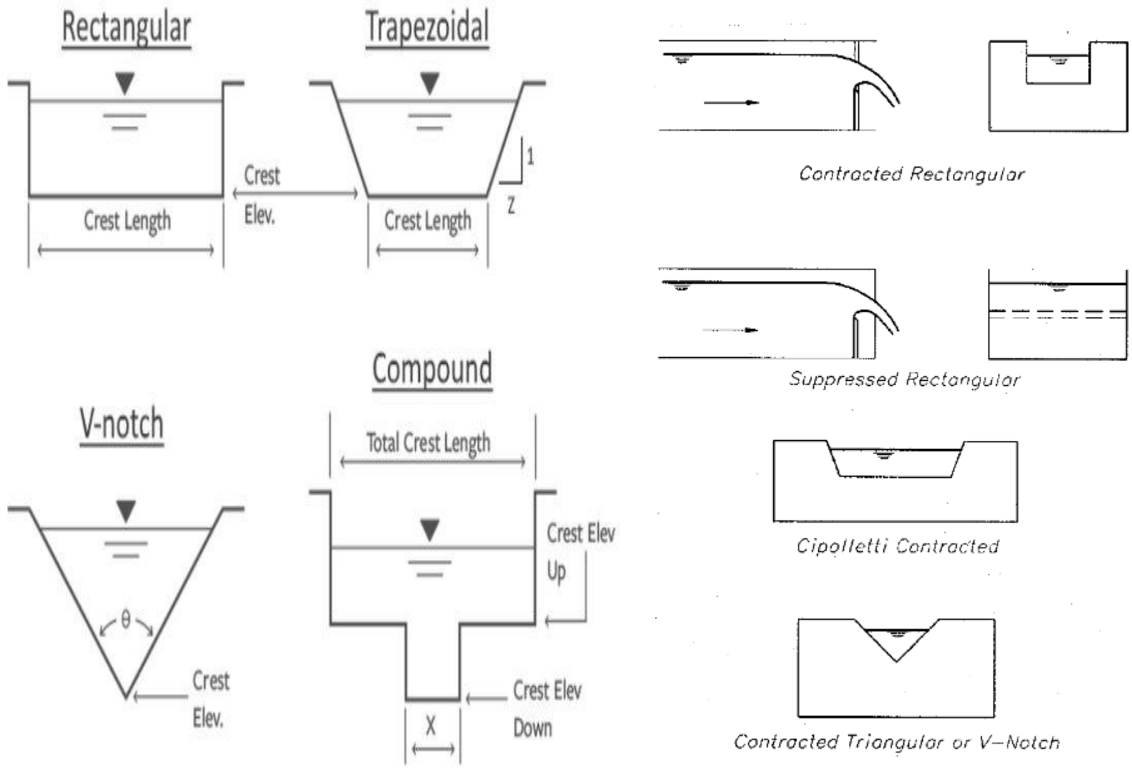
Shape: A rectangular weir has a rectangular shape, and the flow passes over the top edge of the rectangular structure.

Crest Shape: The crest (top edge) of a rectangular weir is flat and horizontal.

Applications: Rectangular weirs are commonly used for flow measurement in various applications, including wastewater treatment plants, irrigation systems, and water monitoring in open channels.

Flow Formula: The flow rate over a rectangular weir can be calculated using various empirical formulas, with the most common one being Francis' formula.

Width: The width of the weir (distance from one end to the other) is one of the key parameters in flow calculation.



Types of Notches and Weir (Figure courtesy: Internet, Google Images)

V-Notch Weir:

Shape: A V-notch weir has a V-shaped notch or opening at the top, and the flow passes through this V-notch.

Crest Shape: The crest of a V-notch weir forms a V-shape, with the apex of the V pointing downstream.

Applications: V-notch weirs are often used for precise flow measurement in research and laboratory settings. They are commonly used to measure small flow rates and are not as suitable for large flows as rectangular weirs.

Flow Formula: The flow rate over a V-notch weir can be calculated using specialized formulas based on the angle of the V-notch and the water level in the notch.

Angle: The angle of the V-notch (often expressed in degrees) is a critical parameter for flow calculation.

Sharp-Crested Weir:

Shape: A sharp-crested weir has a sharp-edged crest, which can be either rectangular or triangular in shape, depending on the design.

Crest Shape: The crest is characterized by its sharp-edged profile.

Applications: Sharp-crested weirs are used in a variety of flow measurement applications, including monitoring water levels in rivers, streams, and industrial processes.

Flow Formula: Flow over a sharp-crested weir can be calculated using established equations, with the most common one being the Francis or standard weir formula. The specific formula used depends on the shape of the crest.

Crest Shape: The crest shape can vary, and it may be rectangular, triangular, or custom-designed based on the flow conditions and requirements.

In summary, the key differences among rectangular weirs, V-notch weirs, and sharp-crested weirs lie in their shapes, crest profiles, applications, and the formulas used to calculate flow rates. The choice of which type of weir to use depends on factors such as the flow rate to be measured, the accuracy required, and the specific application.

Specifications of the Device/ Apparatus used for Practical

Kindly tick mark the apparatus available for experiment. Atleast one apparatus must be used to conduct the practical.

Parameter of specifications	Venturimeter	Orificemeter	Rectangular/ V-Notch	Other Apparatus
Supply pipe				
Motor Capacity				
Sump size				
Tank size				
Diameter/ Width				
Throat Size				
Length of Pipe section/ test section				
Manometer tappings size/ height				
Dimensions of notch etc.				

Procedure for Venturimeter and Orificemeter: -

1. Check all the clamps for tightness
2. Open the gate valve and start the flow.
3. Open the outlet valve of the venturimeter and close the valve of orificemeter.
4. First open air cocks then open the venturimeter cocks, remove all the air bubbles and close the air cocks slowly and simultaneously so that mercury does not run away into water.
5. Close the gate valve of measuring tank and measure the time for 10 litres water discharge and also the manometer difference.
6. Repeat the procedure by changing the discharge and also for orificemeter.

Precautions:

- Operate manometer valve gently while removal of air bubble so that mercury in manometer does not run away with water.
- Do not close the outlet valve completely.
- Drain all the water after completion of experiment.

OBSERVATION TABLE FOR VENTURIMETER :

Sr. No.	Manometer diff. h (m)	Time for 10 liter water discharge t (Sec.)

CALCULATIONS FOR VENTURIMETER : -

1. Actual discharge , $Q = \frac{0.01}{t}$

2. Let 'H' be the water head across manometer in , m.

∴ H = Manometer difference (Sp. gravity of Mercury - Sp. gravity of water)

or H = Manometer difference x (13.6 -1)

A = cross sectional area at inlet to venturimeter = _______________ m^2

a = Cross - sectional area at throat to venturimeter = _______________ ^{4} m^2

Theoretical Discharge,

$Q_{th} = \frac{A\,a\,\sqrt{2gh}}{\sqrt{A^2-a^2}}$ m^3/s

$Q_{th} =$ __________ m^3/s = ___________ (h in meter)

3. Co-efficient of discharge $C_d = \frac{Q_a}{Q_{th}}$

OBSERVATION TABLE FOR ORIFICEMETER

Sr. No.	Manometer diff. h (m)	Time for 10 liter water discharge t (Sec.)

CALCULATIONS FOR ORIFICEMETER: -

1. Actual discharge , $Q = \frac{0.01}{t}$ m^3/sec
2. Let 'H' be the water head across manometer in , m.

∴ H = Manometer difference (Sp. gravity of Mercury - Sp. gravity of water)

or H = Manometer difference x (13.6 -1)

H = Manometer difference x (13.6 -1)

or H = h x 12.6 m

A = cross sectional area at inlet to Orificemeter = ___________ m^2

a = Cross - sectional area to Orificemeter= _______________ m^2

Theoretical Discharge,

$Q_{th} = \frac{A\,a\,\sqrt{2gh}}{\sqrt{A^2-a^2}}$ m^3/s

$Q_{th} =$ ____________ m^3/s = __________ (h in meter)

Co-efficient of discharge $C_d = \frac{Q_a}{Q_{th}}$

EXPERIMENTAL PROCEDURE FOR NOTCHES/ WEIR:-

1. Fit the required notch in the flow channel.
2. Fill up the water in the sump tank.
3. Close the water supply gate valve to the channel and fill up the water in the channel upto sill level.
4. See that water does not leak from the notch.
5. Check the leakage of hose pipes also and keep the collector diverted in the sump tank.
6. Take down the initial reading of crest level (sill level) by piezometer.
7. Now start the pump and open the gate valve slowly so that water starts flowing over the notch.
8. Let the water level become stable and note down the height of water surface at the upstream side by piezometer.

9. Close the drain valve of measuring tank, direct the collector into the measuring tank and measure the discharge.
10. Take the readings for different flow rates.
11. Repeat the same procedure for other notch also.

OBSERVATIONS

Notch type- Triangular / Rectangular/ V-Notch

Sr. No.	Notch Type	Sill level reading 's' mts	Water height on upstream side 'h' mtr.	Discharge time for 10 litres ' t' sec.

CALCULATIONS:-

V-Notch-

1. Head over the notch, H = _______ m.
2. Discharge , $Q_a = \frac{0.01}{t}$ ________________m³/sec
3. Crest length of notch = 0.075 m Now theoretical discharge.
   Q = 8/15 ×Cd ×(2g)1/2 ×tan(θ/2) ×h3/2
   Where, Q = Flow Rate
   Cd = Discharge Constant
   θ = V - Notch Angle
   g = Gravity Constant (9.81 m/s²)
   h = Head on the Weir
4. Co efficient of discharge
   $C_d = Q_a / Q_{the0}$

Rectangular notch -

1. Head over the notch, H = _______ m.
2. Discharge , $Q_a = \frac{0.01}{t}$ ________________m³/sec
3. Crest length of notch = 0.075 m Now theoretical discharge.

Q_{th}= 2/3. $(2.g)^{05}$.L. H 4. Co efficient of discharge.

4. Co efficient of discharge
   $C_d = Q_a / Q_{the0}$

Triangular notch –

1. Head over the notch, H = _______ m .
2. Discharge , $Q_a = \frac{0.01}{t}$ ________________m³/sec
3. Now theoretical discharge,
   $Q_{th} = (8/15)\ (2\ .\ g)^{\circ\ 5} \tan(60\ /\ 2)\ (H)^{5/2}$
4. coefficient of discharge , $C_d = Q_a / Q_{the0}$

Result:

- Calibrated values of co-efficient of discharge for Venturimeter is_________________
- Calibrated values of co- efficient of discharge for Orificemeter is__________________
- Average co-efficient of discharge of V-notch is_____________
- Average co-efficient of discharge of Triangular notch is_____________
- Average co-efficient of discharge of Rectangular notch is_______________

Conclusion: Summarize the findings of experiments performed for flow rate measurements.

Quiz/Assignment:

1. What is coefficient of discharge?

2. Differentiate between orifice and mouthpiece?

3. Differentiate between notch, weir and orifice?

Suggested Reference:

- Bansal, R.K. (2014), A TextBook of Fluid Mechanics and Hydraulic Machines: (In S.I. Units, Revised Ninth Edition). Laxmi Publications, Telangana.
- Engineering Fluid mechanics, K.L. Kumar, 8th Edition S. Chand & Company Ltd.
- Hydraulics and Fluid Mechanics, P.M. Modi and S.M. Seth, Standard Book House
- Theory and Applications of Fluid Mechanics, K. Subramanya, Tata McGraw Hill.
- Fluid Mechanics, A.K. Jain, 4th edition, Khanna Publishers.
- Theory and Applications of Fluid Mechanics by K Subramanya, McGraw Hill Publication

References used by the students:

Rubric wise marks obtained:

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						

Experiment No: 9

Drag and lift in Wind Tunnel
(Prepare a Drag/ Lift Model, if Wind Tunnel is not available)

Date:

Relevant CO:

CO.4: Solve problems related to drag and lift in applications like wind tunnels

CO.5: Perform dimensional analysis using Buckingham's π theorem on the different applications of fluid mechanics (Design and carry out model studies for fluid flow problems).

CO.5:

Objectives: To measure drag and lift in Wind Tunnel (To prepare a Drag/ Lift Model if Wind Tunnel is not available)

Equipment/Instruments: Wind Tunnel, Drag and Lift Models, Various Shapes and Size of Model sections, Motor.

Theory:

Wind tunnel is one of the most important facilitate for experimental work in aerodynamics and fluid flow. Its purpose is to provide a region of controlled air flow into which models can be inserted. This region is termed as the WORKING SECTION. Wind tunnel is closed working section with bell mouth entry. The tunnel is of simplest tube section open type along which air is propelled. The propulsion is usually provided by a fan downstream of the working section.

DESCRIPTION :

MOUTH AND ENTRY: The entry is shaped to guide the air smoothly into the tunnel. Proper flow separation here would give excessive turbulence and non-uniformity in velocity in the working section. So 2 to 2.5 meter air space is required to entry. Setting chamber and contraction cone to make the flow more parallel and more uniform and to give a little time for turbulence to decay, the mouth is followed by a settling chamber which leads to be contraction to get velocity increase, which is connected with Working section or test section. Contraction is a specially designed carved due to give good results in test section. The setting chamber usually includes a honey comb and nylon mesh screens to filter and stabilize the incoming air flow.

WORKING SECTION/ TEST SECTION: (Transparent): It is also called test section as we can fit the models and use this space for experimentation. 'DATACONE' Tunnel is having 300 mm x 300 mm test section with meter length and two windows to insert the models or Probes.

DIFFUSER SECTION: The working section is followed by a divergent duct. The divergence results in a corresponding reduction in the flow speed. Diffuser reduces in dynamic pressure leads to reduction in power losses at the exit. Leaving the diffuser, the air enters the lab, along which it flows slowly to get this retardation 1.5 to 2 meter air space is to be provided.

FAN AND DRIVE: A six blade fan is fitted to an sturdy frame work and is coupled to a Motor. This motor is controlled with a variable Frequency.

Drive - Digital Display which gives smooth variation of air velocity in test section which can be seen on anemometer and one can set the velocity of Air to desired value. Wind tunnel is a basic equipment and experimentation in this equipment has no limits.

Open return Tunnel is considered to be simple kind of low speed wind tunnel. The room containing the tunnel is in fact part of the tunnel, since it provides the path by which the air returns from the downstream end to upstream end.

EXPERIMENTS:

1. FLOW past Aerofoil model and cylindrical model.

Aim : To study the pressure distribution around (I) Aerofoil and (ii) Cylinder.

Apparatus: Wind Tunnel, Aerofoil and cylindrical model, Multitube manometer.

Procedure: **Part (I) (for Aerofoil model)**

(1) Place the aerofoil model in the respective position.

(2) Set the angle of model at zero.

(3) Connect the piezometric tappings to the multitube manometer.

(4) Set the air speed to the desired value.

(5) Change the angle of the model and take readings for each tube.

(6) Plot the graph of the manometer readings for the fifteen tubes for the various angle.

Part (II) (for cylindrical Model)

(1) Place the Model appropriately.

(2) Set the desired air speed.

(3) Connect the piezometric tapping to the manometer.

(4) Change the angle of inclination and take manometer readings.

(5) Plot the graph of the manometer reading versus angle of inclination.

OBSERVATIONS : PART (I)

ET NO.	ANGLE OF INCLIN-ATION	MANOMETER READINGS (mm of H20)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10 m/sec	90^0															
20 m/sec	90^0															
30 m/sec	90^0															

Model Preparation: Prepare a model of Wind Tunnel/ Drag-Lift if Wind Tunnel is not available in FM Laboratory)

Calculation :-

Result:

Conclusion:

Quiz/Assignment:

1. What is Wind Tunnel

2. Define Drag and Lift?

Suggested Reference:

- Engineering Fluid mechanics, K.L. Kumar, 8th Edition S. Chand & Company Ltd.
- Hydraulics and Fluid Mechanics, P.M. Modi and S.M. Seth, Standard Book House
- Theory and Applications of Fluid Mechanics, K. Subramanya, Tata McGraw Hill.
- Fluid Mechanics, A.K. Jain, 4th edition, Khanna Publishers.
- Theory and Applications of Fluid Mechanics by K Subramanya, McGraw Hill Publication

References used by the students:

Rubric wise marks obtained:

Rubrics	1	2	3	4	5	Total
Marks						

Experiment No: 10

Model studies and Similitude

Date:

Relevant CO:

CO.5: Perform dimensional analysis using Buckingham's π theorem on the different applications of fluid mechanics (Design and carry out model studies for fluid flow problems).

Objectives: To perform model studies, similitude and develop a model/sketch for fluid flow in pipes, open channel and dimensional analysis.

Equipment/Instruments: Ship models, prepared models by previous students.

Theory:

Model studies and similitude play a crucial role in various fields of science and engineering, providing a means to study complex real-world phenomena in a controlled and manageable laboratory environment. These techniques involve creating scaled-down replicas or models that faithfully mimic the behavior of full-scale systems. The concept of similitude ensures that physical properties and behaviors are preserved proportionally between the model and the real system, allowing researchers to draw meaningful conclusions. This short note explores the significance of model studies and similitude in scientific research and engineering applications.

The Principle of Similitude:

At the heart of model studies is the principle of similitude, which states that if the physical properties, geometrical dimensions, and dynamic forces of a model are appropriately scaled down with respect to a real system, the behavior and outcomes observed in the model will accurately represent those of the full-scale system. To achieve similitude, three key types are considered:

Geometric Similitude: Geometric proportions between the model and the real system must be maintained. For example, in fluid dynamics, the relative sizes and shapes of obstacles, such as ships or aircraft, must be preserved.

Kinematic Similitude: This pertains to the similarity of motion between the model and the real system. Velocity, acceleration, and displacement should be scaled correctly.

Dynamic Similitude: Forces and stresses within the model should be proportional to those in the full-scale system. This ensures that the model's behavior under different conditions is representative of the real-world scenario.

Applications of Model Studies and Similitude:

- *Aerospace Engineering:* In the aerospace industry, wind tunnels are used to create scaled models of aircraft to study their aerodynamic properties. By preserving similitude, engineers can evaluate an aircraft's performance and efficiency under different flight conditions without the need for expensive full-scale tests.

- *Civil Engineering:* Model studies are employed to simulate the behavior of structures like bridges and dams subjected to various loads and environmental conditions. This allows engineers to optimize designs and ensure safety.
- *Fluid Dynamics:* Similitude is critical in understanding fluid flow phenomena. Models of ships, submarines, or even entire water distribution systems can help analyze the impact of fluid properties and geometrical variations on performance.
- *Environmental Sciences:* Ecologists use model ecosystems to study the behavior of species and the effects of environmental changes. These models help predict ecological responses to alterations in habitat and climate.
- Model studies and similitude are indispensable tools in scientific research and engineering. They enable researchers and engineers to gain valuable insights, make predictions, and optimize designs without the risks, costs, or complexity associated with full-scale experiments. By faithfully replicating key attributes of the real system, model studies ensure that findings and conclusions derived from the laboratory setting can be confidently applied to the broader world, advancing our understanding and driving innovation across various disciplines.

Practical Task for Similitude and Model studies:

In engineering and science, dimensional analysis is the analysis of the relationships between different physical quantities by identifying their fundamental dimensions (such aslength, mass, time, and electric charge) and units of measure (such as miles vs. kilometers, or pounds vs. kilograms vs. grams) and tracking these dimensions as calculations or comparisons are performed.

Total Similarity = Geometric Similarity + Kinematic Similarity + Dynamic Similarity

- Cost of running full-scale, long-duration experiments is very high
- Incentive to obtain required info using small-scale models and/ or short-duration ("accelerated") tests
- LH Baeckeland (chemist): "Commit your blunders on a small scale, make your profits on a large scale"
- Under what conditions can one quantitatively predict full-scale ("prototype") behavior from small-scale ("model") experiments? Dynamic, thermal, chemical, geometrical similarity: Can all be obtained simultaneously?

Vaschy (1892), Buckingham (1914): (Pi Theorem)

Any dimensional interrelation involving N_v variables can be rewritten in terms of a smaller number, N_p, of independent dimensionless variables

N_v - N_p = number of fundamental dimensions (e.g., 5 in a problem involving length, mass, time, heat, temperature)

e.g., drag relation: $N_v = 5$, $N_p = 2$

Buckingham Pi Theorem:

- Can be used in any branch of science/ technology
- Relevant variables must be listed in their entirety
- Provides relevant similarity criteria for problems beyond geometrical & dynamical similarity
- Relevant dimensionless groups (p's) are the quantities to be kept invariant in model testing

Steady heat flow from isothermal sphere in steady uniform (forced) fluid flow

$$\frac{\dot{q}_w}{A_w} = fct\left(d_w, \mu, \rho, U, k, c_p, (T_w - T_\infty)\right)$$

Interrelation between 8 dimensional quantities can be restated in terms of 3 dimensionless groups:

$$\frac{(\dot{q}_w / A_w)}{\left[k(T_w - T_\infty)/d_w\right]} = \overline{Nu_h}\left(\frac{\rho U d_w}{\mu}, \frac{(\mu/\rho)}{\left[k/(\rho c_p)\right]}\right)$$

OBJECTIVE OF TASK: All the students of batch will be divided into groups of 4 to 7 students per group and they have to design/ sketch/ develop/ solve the model-prototype relationship. Similarity and different symmetricity of the model studies such as Geometric Similarity + Kinematic Similarity + Dynamic Similarity have to be verified, checked and assessed.

POSSIBLE MODEL STUDIES:

Each group in 4 to 7 need to choose an individual model based problem such that each group has separate problem in the batch and they have to analyze the designing/ development of model-prototype relationship. If in any case, two or more groups have the same problem than their case study or dimension patterns may differ.

1. Dam model-prototype study.
2. Structural integrity related model.
3. Spillway model prototype study.
4. Environment and infrastructure project.
5. Machine model prototype study.
6. River channel model-protype study.
7. Urban planning related model study.
8. Canal's similitude study.
9. Port- Harbour model study.
10. Geological or manufacturing processes.
11. Bridge pier destruction model study.
12. Any other Civil Engineering or model related topic allotted by Lab in-charge.

Observation Data : -

Name of the Domain:

Title of Model to be prepared:

Sr. No.	Name of the aspect/ dimensions	Geometrical details	Kinematic Details	Dynamic Details
1				
2				
3				
4				
5				

Result/ Sketch/ Layout of the Model/ 2-D Sketch:

Conclusion:

Quiz/Assignment:

1. What is similitude?

2. What is the importance of model study?

3. State Buckingham's Pi theorem?

Suggested Reference:

- Bansal, R.K. (2014), A TextBook of Fluid Mechanics and Hydraulic Machines: (In S.I. Units, Revised Ninth Edition). Laxmi Publications, Telangana.
- Engineering Fluid mechanics, K.L. Kumar, 8th Edition S. Chand & Company Ltd.
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- Fluid Mechanics, A.K. Jain, 4th edition, Khanna Publishers.
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References used by the students:

Rubric wise marks obtained:

Rubrics	1	2	3	4	5	Total
Marks						

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