LAB MANUAL FOR
FLUID MECHANICS LAB

Prepared by:
STATE INSTITUTE OF TECHNICAL TEACHERS
TRAINING & RESEARCH, KALAMASSERY
GENERAL INSTRUCTIONS

Rough record and Fair record are needed to record the experiments conducted in the laboratory. Rough records are needed to be certified immediately on completion of the experiment. Fair records are due at the beginning of the next lab period. Fair records must be submitted as neat, legible, and complete.

INSTRUCTIONS TO STUDENTS FOR WRITING THE FAIR RECORD

In the fair record, the index page should be filled properly by writing the corresponding experiment number, experiment name, date on which it was done and the page number.

On the right side page of the record following has to be written:

1. **Title**: The title of the experiment should be written in the page in capital letters.
2. In the left top margin, experiment number and date should be written.
3. **Aim**: The purpose of the experiment should be written clearly.
4. **Apparatus/Tools/Equipments/Components used**: A list of the Apparatus/Tools/ Equipments/Components used for doing the experiment should be entered.
5. **Principle**: Simple working of the circuit/experimental set up/algorithm should be written.
6. **Procedure**: steps for doing the experiment and recording the readings should be briefly described(flow chart/programs in the case of computer/processor related experiments)
7. **Results**: The results of the experiment must be summarized in writing and should be fulfilling the aim.
8. **Inference**: Inference from the results is to be mentioned.

On the left side page of the record following has to be recorded:

1. **Circuit/Program**: Neatly drawn circuit diagrams/experimental set up.
2. **Design**: The design of the circuit/experimental set up for selecting the components should be clearly shown if necessary.
3. **Observations:**

   i) Data should be clearly recorded using Tabular Columns.

   ii) Unit of the observed data should be clearly mentioned.

   iii) Relevant calculations should be shown. If repetitive calculations are needed, only show a sample calculation and summarize the others in a table.

4. **Graphs:** Graphs can be used to present data in a form that shows the results obtained, as one or more of the parameters are varied. A graph has the advantage of presenting large amounts of data in a concise visual form. Graphs should be in a square format.

**GENERAL RULES FOR PERSONAL SAFETY**

1. Always wear tight shirt/lab coat, pants and shoes inside workshops.

2. REMOVE ALL METAL JEWELLERY since rings, wrist watches or bands, necklaces, etc. make excellent electrodes in the event of accidental contact with electric power sources.

3. DO NOT MAKE CIRCUIT CHANGES without turning off the power.

4. Make sure that equipment working on electrical power are grounded properly.

5. Avoid standing on metal surfaces or wet concrete. Keep your shoes dry.

6. Never handle electrical equipment with wet skin.

7. Hot soldering irons should be rested in its holder. Never leave a hot iron unattended.

8. Avoid use of loose clothing and hair near machines and avoid running around inside lab.

**TO PROTECT EQUIPMENT AND MINIMIZE MAINTENANCE:**

**DO:** 1. SET MULTIRANGE METERS to highest range before connecting to an unknown source.

   2. INFORM YOUR INSTRUCTOR about faulty equipment so that it can be sent for repair.

**DO NOT:** 1. Do not MOVE EQUIPMENT around the room except under the supervision of an instructor.
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INTRODUCTION & SCOPE

Matter exists in either the solid state or the fluid state. The fluid state is further divided into the liquid and the gaseous states.

A fluid is a substance which is capable of flowing. A liquid is a fluid, which possesses definite volume which varies slightly with temperature and pressure. Under ordinary conditions, liquids are considered as incompressible fluid.

Fluid mechanics is that the branch of Engg. science which deals with the behavior of the fluids at rest as well as in motion. In general the scope of fluid mechanics is very wide which includes the study of all gases and liquids.

Fluid mechanics deals with the analysis and methods to solve many engineering problems involving liquid flow, such as flow through pipes or channels, storage dams, pumps and water turbines, hydraulically operated machines such as lift, crane, press etc. Hence it is essential for the engineering students of Civil, Mechanical, and allied branches of engineering to understand the theoretical and practical aspects of fluid mechanics.
PROPERTIES OF FLUIDS

1. **Density**
   The density or mass density of a fluid may be defined as the mass per unit volume at a standard temperature and pressure. It is usually denoted by \( \rho \).

   Mathematically \( \rho = \frac{\text{Mass}}{\text{Volume}} \)

   It is expressed in kg/m\(^3\). Density of water at 4\(^0\)C = 1000 kg/m\(^3\).

2. **Specific weight of water**
   The specific weight or weight density of a fluid may be defined as the weight per unit volume at standard temperature and pressure and is usually denoted by

   \[
   \frac{\text{Weight}}{\text{volume}}
   \]

   It is expressed in N/m\(^3\).
   Specific weight of water = 9.81 KN/m\(^3\).

3. **Specific gravity**
   Specific gravity of a fluid may be defined as the ratio of its specific weight to that of a standard substance at a standard temperature. It is generally denoted by ‘S’ and it is a unitless quantity.

   \[
   S = \frac{\text{Specific weight of the fluid}}{\text{Specific weight of standard fluid}}
   \]

   In the case of liquids the standard fluid chosen is water and for gases it is air.

4. **Compressibility**
   Compressibility of a fluid may be defined as the variation in its volume with the variation of pressure. Normally liquid is considered to be an incompressible fluid.

5. **Surface tension**
   Surface tension of a fluid is its property, which enables it to resist tensile stress. It is due to cohesion between the molecules at the surface of a liquid. It’s unit is N/m.
6. **Capillarity**

   Capillarity may be defined as rise or fall of a liquid in a tube. The phenomenon of rising water in a tube of smaller diameter is called capillary rise.

7. **Viscosity**

   Viscosity is defined as the resistance offered by one layer of fluid against the adjacent layer of that fluid or it is a property of a fluid which opposes the flow. It’s unit is $\text{NS/m}^2$.

   There are two types of Viscosity-dynamic Viscosity or (simply viscosity) and kinematic viscosity. Kinematic viscosity is the ratio between dynamic viscosity to the density of the fluid. It’s unit is square meter per second.
**EXPERIMENT ON PIPE FRICITION APPARATUS**

**Aim:** To determine the co-efficient of friction (Darcy’s constant) ‘f’ for Pipes of different diameters and plot the H.G.L and T.E.L

**Objectives:** Understand the pipe friction apparatus and use it to determine the Darcy’s constant.

**Apparatus:**
1. A differential manometer
2. Different diameter pipes with tappings of manometer at a known distance.
3. Inlet and outlet valves
4. Pressure tappings cocks
5. Stop watch
6. Collecting tank fitted with piezometer tube.

**Principle:** When a fluid flows through a pipe, certain resistance is offered to the flowing fluid, which results in loss of energy. W. Froude conducted a series of experiments to investigate frictional resistance offered to the flowing water by different surfaces. From the results of his experiments Froude derived the following conclusions.

1. The frictional resistance varies approximately with the square of the velocity.
2. The frictional resistance varies with the nature of the surface.

In the study of flow of fluid in pipes, the concept of HGL & TEL are quite useful. HGL is defined as the line which gives the sum of pressure head and datum head of a flowing fluid in a pipe with respect to some reference line. TEL is the line which gives the total head \( Z + \frac{P}{\rho g} + \frac{V^2}{2g} \) of a flowing fluid in a pipe with respect to the reference line. TEL will be parallel to HGL with a vertical distance of \( \frac{V^2}{2g} \).

According to Darcy’s equation,

\[
\frac{h_l}{2gd} = \frac{4f l v^2}{g S_m}
\]

Where

- \( h_l \) = head lost due to friction in m of H₂O
- \( x \) = monometer deflection = \( x_2 - x_1 \) in m of Hg
- \( S_m \) = Sp .gravity of Hg.
- \( S_w \) = Sp .gravity of water.
- \( f \) = co-efficient of friction (Darcy’s constant)
- \( l \) = length of pipe between the pressure tappings in m
- \( v \) = velocity of flow = \( \frac{Q}{a} \) m/s
Where  \( Q = \text{Actual Discharge} \)
\( a = \text{area of the pipe. In m}^2 \)
\( Q = \frac{AR}{t} \text{ m}^3/\text{s} \)

Where  \( A = \text{Area of measuring tank in m}^2 \)
\( R = \text{rise in water level in the collecting tank in m.} \)
\( t = \text{time taken for the rise in sec} \)
\( a = \frac{\pi d^2}{4} \)

Where  \( d = \text{dia of the pipe in m} \)
\[ \therefore f = \frac{2gdh}{4lv^2} \]

**Procedure (Instructional mode)**

(1) Note the pipe diameter (d), length of the pipe (l)
(2) Make sure only required water regulator valves and required valves at tappings connected to manometer are opened
(3) Start the pump and adjust the control valve just enough to make fully developed flow but laminar flow. wait for sometime so that flow is stabilized
(4) Measure the manometer deflection ‘x’ across the pressure tappings
(5) Close the outlet valve of the collecting tank and record the time ‘t’ taken for rise in water level ‘R’ in the collecting tank by using a stop watch.
(6) Change the pressure tappings to pipes of different diameters and repeat the steps 1 to 5.
(7) Tabulate readings and calculate of:

**Result**

1) Darcy’s constant (f) for
   Pipe No.1 =
   Pipe No.2 =
   Pipe No.3 =

**Inference:**
### Observation and Tabulation

#### A. For pipe No.1:

Dia of the pipe (d) = 
Length of the pipe (l) = 
Dimensions of collecting tank: 
\[ L = \text{B} = \]
Rise in water level in the measuring tank (R) = 

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Time ( t ) for ( R_m ) rise in C/T</th>
<th>Manometer readings</th>
<th>( hf )</th>
<th>( Q_a )</th>
<th>velocity ((v))</th>
<th>Co-efficient of friction ( f )</th>
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</table>

#### B. For pipe No.2:

Dia of the pipe (d) = 
Length of the pipe (l) = 
Dimensions of collecting tank: 
\[ L = \text{B} = \]
Rise in water level in the measuring tank (R) = 

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Time ( t ) for ( R_m ) rise in C/T</th>
<th>Manometer readings</th>
<th>( hf )</th>
<th>( Q_a )</th>
<th>velocity ((v))</th>
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</table>
### C. For pipe No.3:

Dia of the pipe (d) =
Length of the pipe (l) =
Coll. tank dim. 
\[ L = \quad B = \]
Rise in water level in the measuring tank (R) =

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Time for Rm rise in C/T</th>
<th>Manometer readings</th>
<th>hf</th>
<th>Qa</th>
<th>velocity (v)</th>
<th>Co-efficient of friction f</th>
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**Sample calculation (Pipe.No..................)**

Dia of the pipe (d) =
Length of the pipe (l) =
Dimensions of collecting tank,
\[ L = \quad B = \]
Area of the measuring tank (A) = LxB
\[ = \]
Rise in water level in the collecting tank (R) =
Time taken for the rise in water (t) =
Actual Discharge (Q) = \( \frac{AR}{t} \)
\[ = \]
Area of the pipe (a) = \( \frac{\pi d^2}{4} \)
Velocity of flow in the pie (v) = \( \frac{Q}{a} \)
\[ = \]
Manometer deflection (x) = \( X_2 - X_1 \)
\[ = \]
head lost due to friction (h) = \( x \left( \frac{sm}{Sw} - 1 \right) \)
\[ = \]
Co-efficient of friction (f) = \( \frac{2gh_x}{4IV^2} \)
STUDY OF ROTAMETER

The rotameter also known as variable-area meter is shown in Fig. It consists of a vertical transparent conical tube in which there is a rotor or float having a sharp circular upper edge. The rotor has grooves on its head which ensure that as liquid flows past; it causes the rotor to rotate about its axis. The rotor is heavier than the liquid and hence it will sink to the bottom of the tube when the liquid is at rest. But as the liquid begins to flow through the meter, it lifts the rotor until it reaches a steady level corresponding to the discharge. This rate of flow of liquid can then be read from graduations engraved on the tube by prior calibration, the sharp edge of the float serving as a pointer. The rotating motion of the float helps to keep it steady. In this condition of equilibrium, the hydrostatic and dynamic thrusts of the liquid on the underside of the rotor will be equal to the hydrostatic thrust on the upper side, plus the apparent weight of the rotor.
STUDY OF WATER METER

Water meters are used to measure the volume of water used by residential and commercial building that are supplied with water by a public water supply system. Water meters can also be used at the water source, well, or throughout a water system to determine flow through a particular portion of the system. In most of the world water meters measure flow in cubic metres(m$^3$) or litres but in the USA and some other countries water meters are calibrated in cubic feet (ft.) or US gallons on a mechanical or electronic register. Some electronic meter registers can display rate-of-flow in addition to total usage.

TYPES OF METERING DEVICES

There are two common approaches to flow measurement, displacement and velocity, each making use of a variety of technologies. Common displacement designs include oscillating piston and nutating disc meters. Velocity-based designs include single-and multi-jet meters and turbine meters.

There are also non-mechanical designs, for example electromagnetic and ultrasonic meters, and meters designed for special uses. Most meters in a typical water distribution system are designed to measure cold potable water only. Special hot water meters are designed with materials that can withstand higher temperatures. Meters for reclaimed water have special lavender register covers to signify that the water should not be used for drinking.

Water meters are generally owned, read and maintained by a public water provider such as a city, rural water association or private water company. In some cases an owner of a mobile home park, apartment complex or commercial building may be billed by a utility based on the reading of one meter, with the costs shared among the tenants based on some sort of key (size of flat, number of inhabitants or by separately tracking the water consumption of each unit in what is called submetering).
A venturi meter is a device which is used for measuring the rate of flow of fluid through a pipe. The principle of the venturi meter was first demonstrated in 1797 by an Italian physicist G.B. Venturi (1746-1822), but the principle was first applied, by C. Herschel (1842-1930) in 1887, to develop the device in its present form for measuring the discharge or the rate of flow of fluid through pipes. The basic principle on which a venturi meter works is that by reducing the cross-sectional area of the flow passage, a pressure difference is created and the measurement of the pressure difference enables the determination of the discharge through the pipe.

As shown in Fig. venturi meter consists of (1) an inlet section followed by a convergent cone, (2) a cylindrical throat, and (3) a gradually divergent cone. The inlet section of the venturi meter is of the same diameter as that of the pipe which is followed by a convergent cone. The convergent cone is a short pipe which tapers from the original size of the pipe to that of the throat of the venturi meter. The throat of the venturi meter is a short parallel-sided tube having its cross-sectional area smaller than that of the pipe. The divergent cone of the venturi meter is a gradually diverging pipe with its cross-sectional area increasing area increasing from that of the throat to the original size of the pipe. At the inlet section and the throat i.e., sections 1 and 2 of the venturi meter, pressure taps are provided to connect a differential manometer or pressure gauges.

The convergent cone of a venturi meter has a total included angle of $21^\circ \pm 1^0$ and its length parallel to the axis is approximately equal to $2.7 \ (D-d)$, where D is the diameter of the inlet section and d is the diameter of the throat.

The length of the throat is equal to $d$. The divergent cone has a total included angle lying between $5^0$ to $15^0$, (preferably about $6^0$). This results in the convergent cone of the venturi meter to be of smaller length than its divergent cone. This is so because from the consideration of the continuity equation it is obvious that in the convergent cone the fluid is being accelerated from the inlet section 1 to the throat section 2, but in the divergent cone the fluid is retarded from the throat section 2 to the end section 3 of the venturi meter. The acceleration of the flowing fluid may be allowed to take place rapidly in a relatively small length, without resulting in appreciable loss of energy.
However, if the retardation of flow is allowed to take place rapidly in small length, then the flowing fluid will not remain in contact with the boundary of the diverging flow passage or in other words the flow separates from the walls, and eddies are formed which in turn result in excessive energy loss. Therefore, in order to avoid the possibility of flow separation and the consequent energy loss, the divergent cone of the venturi meter is made longer with a gradual divergence. Since the separation of flow may occur in the divergent cone of the venturi meter, this portion is not used for discharge measurement.

Since the cross-sectional area of the throat is smaller than the cross-sectional area of the inlet section, the velocity of flow at the throat will become greater than that at the inlet section, according to the continuity equation. The increase in the velocity of flow at the throat results in the decrease in the pressure at this section as explained earlier. As such a pressure difference is developed between the inlet section and the throat of the venturi meter. The pressure difference between these sections can be determined either by connecting a differential manometer between the pressure taps provided at these sections or by connecting a separate pressure gauges at each of the pressure taps. The measurement of the pressure difference between these sections enables the rate of flow of fluid to be calculated. For a greater accuracy in the measurement of the pressure difference the cross-sectional area of the throat should be reduced considerably, so that the pressure at the throat is very much reduced. But if the cross-sectional area of the throat of a venturi meter is reduced so much that the pressure at this section drops below the vapour pressure of the flowing liquid, then the following liquid may vapourise and vapour pockets or bubbles may be formed in the liquid at this section.

Further liquids ordinarily contain some dissolved air which is released as the pressure is reduced and it too may form air pockets in the liquid. The formation of the vapour and air pockets in the liquid ultimately results in a phenomenon called cavitation, which is not desirable. Therefore, in order to avoid the phenomenon of cavitation to occur, the diameter of the throat can be reduced only up to a certain limited value which is restricted on account of the above noted factors. In general, the diameter of the throat may vary from 1/3 to 3/4 of the pipe diameter and more commonly the diameter of the throat is kept equal to ½ of the pipe diameter.
EXPERIMENT ON VENTURI METER

Aim: To determine the co-efficient of discharge of the given venturimeter and plot the graph, $Q_a$ vs $h$.

Objectives: To appreciate the venturimeter and its co-efficient of discharge.


Principle:  
Venturimeter is a device based on Bernoulli’s theorem, used to measure discharge of water flowing through a pipe. Co-efficient of discharge of a Venturimeter is the ratio between actual and theoretical discharge.

Theoretical discharge $Q_{th} = \frac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$

where $a_1$ = area at inlet  
$a_2$ = area at throat  
g = acceleration due to gravity  
h = venturi head (ie, difference of pressure heads between inlet and throat)  
$= x \left( \frac{s_2}{s_1} - 1 \right)$ where $x$ = deflection of mercury in the limbs of the manometer, $h_1 - h_2$  
s_2 and s_1 = specific gravities of mercury and water  
Actual discharge ‘$Q_a’ = \frac{AR}{t}$ $m^3/5$  
A = Area of c/T in m^2  
R = Level rise in c/T m  
t = time for Rm level rise in c/T

$\therefore C_d = \frac{Q_a}{Q_{th}}$
**Procedure**

1. Note the dimensions of the venturimeter. (inlet dia & throat dia).
2. Open the bypass valve and outlet valve fully and start the pump.
3. Close the bypass valve such that some water is flowing through the venturimeter.
4. Note the manometer deflection \( x \) and \( t \) time (t) taken to \( R_m \) level rise in C/T.
5. Repeat the steps 3 to 4 for different rates of flow of water through the venturimeter.
6. Tabulate the readings (x and t) and calculate the co-efficient of discharge.

**Result**

\[ \text{Co – efficient of discharge of the given venturimeter} = \]

**Inference**
## OBSERVATION AND TABULATION

Dia at the inlet \( (d_1) = \)
Dia at the throat \( (d_2) = \)
Dimensions of collecting tank: \( L = \quad B = \)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Manometer Readings</th>
<th>Venturi head</th>
<th>Time taken for ( x ) m rise in coll. tank</th>
<th>Actual discharge ( Q_a )</th>
<th>Theor. Discharge ( Q_t )</th>
<th>Coeff. Discharge ( cd )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( L )</td>
<td>( R )</td>
<td>( \text{Deflection } h_1 - h_2 )</td>
<td>( x \left( \frac{d_2}{d_1} - 1 \right) )</td>
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<tr>
<td></td>
<td>( h_1 )</td>
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**Sample calculation (Reading No….)**

Dia at inlet \( (d_1) = \)
Area at inlet \( (a_1) = \frac{\pi d_1^2}{4} \)

Dia at throat \( (d_2) = \)
Area at throat \( (a_2) = \frac{\pi d_2^2}{4} \)
Manometer readings, \( h_1 = h_2 \)
Manometer deflection \( (x) = h_1 - h_2 \)
Venturi head \( (h) = x \left( \frac{d_2}{d_1} - 1 \right) \)

Taking \( g = 9.81 \text{ m/s}^2 \)

Theoretical discharge \( Q_t = \frac{a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}} \text{ m}^3/\text{s} \)

Area of Coll. Tank \( A = L \times B = \)
Rise of water level in the coll. tank \( x = \)
Time Taken for \( x \) m level rise in C/T, \( t = \)

Actual discharge ‘\( Q_a \)' = \( \frac{A x}{t} \frac{m^3}{s} \)

\( C_d = \frac{Q_a}{Q_{th}} = \)


**STUDY OF ORIFICE**

**Orifice**: An orifice is an opening having a closed perimeter, made in the walls or the bottom of a tank or a vessel containing fluid through which the fluid may be discharged.

**Types of Orifices**
Orifices may be classified on the basis of their size, shape, shape of the upstream edge and the discharged conditions.

1. According to the size
   (a) Large orifice
   (b) Small orifice
2. According to the Shape
   (a) Circular orifice
   (b) Rectangular orifice
   (c) Triangular orifice
   (d) Square orifice
3. According to the shape of the upstream edges
   (a) Sharp edged orifice
   (b) Bell-mouthed orifice
4. According to the discharge condition
   (a) Orifice discharged free
   (b) Submerged orifices

The $C_d$ of a sharp edged standard orifice normally varies from 0.61 to 0.65

Velocity of the jet = $\sqrt{2gh}$

Discharge $Q = a . \sqrt{2gh}$

where $a$ = area of c.s of orifice

$h$ = head over the orifice
**EXPERIMENT ON ORIFICE**

**Aim**
To determine the co-efficient of discharge of the given orifice by constant head method and plot the graph, \( Cd \) Vs \( h \)

**Objective**
Understand the orifice apparatus and appreciate the co-efficient of discharge of the orifice.

**Apparatus**
1. Orifice and an orifice tank with piezometer.
2. Collecting tank with piezometer tube.
3. Stop watch

**Principle**
Water enters the supply tank through a perforated diffuser placed below the water surface. The flow passes into the tank and leaves through a sharp edged orifice set at the side of the tank. Water comes of the supply tank in the form of a jet which is directed to the collecting tank. The flow rate is measured by recording the time taken to collect a known volume of water in the tank. Co-efficient of discharge is the ratio between actual and theoretical discharge of water flowing through the orifice. \( C_d \) of a standard orifices varies from 0.61 to 0.67

Actual Discharge \( 'Q_a' = \frac{AR}{t} \) \( m^3/s \)

Where  
- \( A \) = area of the measuring tank in \( m^2 \)
- \( R \) = rise in water level in the measuring tank in m
- \( t \) = time taken for the rise in water level

Theoretical Discharge \( Q_{th} = a\sqrt{2gh} \) \( m^3/s \)

Where  
- \( a \) = area of the orifice in \( m^2 \)
- \( g \) = acceleration due to gravity \( m/s^2 \)
- \( h \) = head over the orifice in m

\[ Cd = \frac{Q_a}{Q_{th}} \]

**Procedure**
1. Note the diameter of the orifice and dimensions of the coll. tank.
2. Open the supply valve and maintain a steady head over the orifice.
3. Note the head over the orifice (\( h \)) from the piezometer.
4. Close the outlet valve of the measuring tank firmly and note the time required for the rise in water level (\( R \)) by using a stop watch.
5. After observing the time, open the outlet valve.
6. Open the supply valve little more and repeat the steps 2 to 5 for different values of ‘\( h \)’.
7. Tabulate the readings (\( h \) and \( t \)) and calculate co-efficient of discharge.
Result:

Inference
Dia. of the orifice (d) =

Dimensions of the Collecting tank,

<table>
<thead>
<tr>
<th>SI No</th>
<th>Head (h)</th>
<th>Time (t)</th>
<th>Qa</th>
<th>Qth</th>
<th>Cd</th>
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</table>

Sample calculation (Reading No......)

Dia of the orifice (d) =

Area of the orifice (a) = \( \frac{\pi d^2}{4} \)

Head over the orifice (h) =

Taking \( g \) = 9.81 m/s\(^2\)

Theoretical Discharge ‘Qth’ = \( a \times \sqrt{2gh} \)

Dimensions of the measuring tank,

<table>
<thead>
<tr>
<th>L</th>
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</table>

Area of the measuring tank (A) = L x B

Rise in water level

in the measuring tank (R) =

Time taken for the water rise (t) =

Actual Discharge \( Q_a \) = \( \frac{A \times R}{t} \)

Co-efficient of discharge ‘Cd’ = \( \frac{Q_a}{Q_{th}} \)
METACENTRIC HEIGHT APPARATUS

INTRODUCTION:

Whenever a body, floating in a liquid is given a small angular displacement, it starts oscillating about the same point, this point about which the body starts oscillating is called metacentre.

The distance between the center of gravity of a floating body and the metacentre is called metacentre height. As a matter of fact the metacentre height of a floating body is a direct measure of its stability or in otherwards more the metacentric height of a floating body more it will be stable.

A body is said to be in equilibrium when it remains in a steady state, while floating in a liquid. Following are the three conditions of equilibrium of a floating body,

1. Stable equilibrium
2. Unstable equilibrium and
3. Neutral equilibrium

STABLE EQUILIBRIUM:

A body is said to be in a stable equilibrium if it returns back to its original position when given a small angular displacement. This happens when the metacentre is higher than the center of gravity of the floating body.

UNSTABLE EQUILIBRIUM:

A body is said to be in an unstable equilibrium if it does not return back to its original position and heels further away when given a small angular displacement. This happens when the metacentre is lower than the center of gravity of the floating body.

NEUTRAL EQUILIBRIUM

A body is said to be in a Neutral Equilibrium if it occupies a new position and remains rest in this new position when given a small angular displacement. This happens when the metacentre coincides with the centre of gravity of the floating body.

In the experimental set up the variation of metacentric height for different types of loading of a floating vessels can be determined.
DESCRIPTION:

The experimental set up consists of semicylindrical vessel with semi-circular ends, which float in a rectangular tank. The vessel at its top carries a bar along its diameter at the mid section of its length, a circular scale is provided and weight hangers for movable weights. On either side of the bar weights are provided on screws with help of which zero setting on the circular scale can be achieved.

The set up is provided with two small weights, which can be suspended from the weights hangers. In addition dead weights are provided for loading the vessel either at the top or at bottom. Pins are provided to fix the dead weights.
METACENTRIC HEIGHT OF A FLOATING BODY

AIM

To determine metacentric height of floating body

OBJECTIVES:

To comprehend the metacentric height and to use the apparatus to determine the metacentric height.

THEORY

When a floating body is tilted through a small angle its centre of buoyancy will be shifted to a new position the point of intersection of the vertical line drawn through the new centre of buoyancy and centre of buoyancy is called metacentric height.

The metacentric height GM can be determined as

\[ GM = \frac{w \cdot d}{(W+w) \tan \theta} \]

Where,

- \( W \) = Weight of the floating body
- \( w \) = weight of the added body
- \( \theta \) = tilt given to the floating body
- \( d \) = distance of hanger from the body

The metacentric value for ships range as follows:

- Merchant ship - 0.3 to 1 m
- Sailing ship - 0.45 to 1.25 m
- Battle ship - 1 to 1.5 m
- River crafte - up to 3.5 m
PROCEDURE

1. Note the level of water in the vessel without the floating body
2. Put the floating body in the vessel and note the level of water
3. Calculate the weight of the floating body from the principle, weight of the body equal to weight of the displaced liquid
4. Adjust the pointer on zero in the protractor
5. Put a small weights in the grams on the hanger provided on any one side [left or right]
6. Note the distance of hanger from the centre
7. Note that always both the hanger should be in equal distance from the centre to avoid the movement produced by hanger
8. Note also the tilt shown by the pointer in the protractor
9. Repeat the experiment about ten time’s on same side by changing the distance from the centre.

RESULT

The metacentric height of a body is determined.

The metacentric height without dead weight is  

Inference
**OBSERVATION & TABULATION**

Length of the vessel =

Breadth of the vessel =

Initial level of water without floating body =

Weight of floating body =

Additional weight added =

<table>
<thead>
<tr>
<th>SL No</th>
<th>Distance of hanger from centre (d) cm</th>
<th>Angle of tilt $\theta$ degree</th>
<th>tan $\theta$</th>
<th>GM cm</th>
<th>Distance of hanger from centre (d) cm</th>
<th>Angle of tilt $\theta$ degree</th>
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**SAMPLE CALCULATION**

Area of vessel =

Initial level of water without floating body =

Final level of water with floating body =

Weight of floating body = Volume of water displaced $\times$ density of water

Distance of hanger from center =

Angle of tilt $\theta$ =

Tan $\theta$ =

Weight of added weight =

Metacentric height $GM = \frac{w.d}{(W+w)\tan \theta}$
STUDY OF NOTCHES

A notch may be defined as an opening provided in a small channel or a tank to measure the rate of flow of liquid flowing through the channel. A notch is provided in the channel in such a way that the liquid surface in the tank or channel is below the top edge of the opening.

Classification of Notches

1. According to the shape of the opening
   (a) Rectangular notches
   (b) Triangular notches
   (c) Trapezoidal notches
   (d) Stepped notches

2. According to the effect of the sides on the nappe
   (a) Notch with end contraction
   (b) Notch without end contraction or suppressed notch.

Rectangular Notch

Discharge \( Q_{th} = \frac{2}{3} x C_d x \sqrt{2g} \cdot b \cdot h^{3/2} \)
Where \( C_d = \) Coefficient of discharge of the rectangular notch
\( b = \) breadth of the notch
\( h = \) Head over the notch

Triangular Notch

Discharge \( Q_{th} = \frac{8}{15} x C_d x \sqrt{2g} \cdot \tan \frac{\theta}{2} \cdot h^5 \)
Where \( C_d = \) Coefficient of discharge of the Triangular notch
\( \theta = \) angle of the notch
\( h = \) Head over the notch
**Trapezoidal notch**

Discharge $Q_{th} = \frac{8}{15} C_d \times \sqrt{2g} \tan \frac{\theta}{2} \cdot \frac{h^5}{2} + \frac{2}{3} C_d \times \sqrt{2g} \cdot b \cdot h^{3/2}$
EXPERIMENT ON RECTANGULAR NOTCH

Aim: To determine the co-efficient of discharge of the given rectangular notch and plot the graph, \( C_d \) Vs \( Q_a \)

Objectives: Appreciate the rectangular notch and its co-efficient of discharge

Apparatus:
1. Rectangular notch and the notch tank with hook gauge/pointer
2. Stop watch
3. Measuring tank with glass tube and scale.

Principle: The co-efficient of discharge is the ratio between actual and theoretical discharge of water flowing through the notch.

Actual Discharge \( Q_a = \frac{A R}{t} \)

Where
- \( A \) = area of the measuring tank
- \( R \) = rise of water level in the measuring tank
- \( t \) = time taken for the water rise (x) in the tank.

Theoretical Discharge \( Q_{th} = \frac{2}{3} \sqrt{g b h^{3/2}} \)

Where
- \( g \) = acceleration due to gravity
- \( b \) = breadth of the notch
- \( h \) = head over the notch
  - \( = (H_2 - H_1) \)
- \( h_1 \) = Sill level (initial head)
- \( h_2 \) = final head

\( \therefore C_d = \frac{Q_a}{Q_{th}} \)

Procedure:
1. Note the breadth of the notch and dimensions of the measuring tank.
2. Open the supply valve and allow water to enter the notch tank upto the sill of the notch tank. Then close the supply valve.
3. Note the sill level (h1) using the hook gauge.
4. Open the supply valve and allow water to flow through the notch and a steady head is maintained. Note this constant head over the notch by using the hook gauge(h2).
5. Close the outlet valve of the measuring tank firmly and note the time taken for a particular water rise (R) in the measuring tank by using a stop watch.

6. After taking the time, open the outlet valve of the measuring tank.

7. Repeat the steps 4 to 6 are for the different values of h2.

8. Tabulate the readings (h2 and t) are and calculate the co-efficient of discharge.

Result:

Co-efficient of discharge of the given rectangular notch =

Inference:
Observation and Tabulation

Breadth of the notch (b) =

Dimensions of the measuring tank

\[ L = \quad B = \]

Still level \( (h_1) = \)

<table>
<thead>
<tr>
<th>SI No</th>
<th>Final Head ( h_2 )</th>
<th>Head ( h )</th>
<th>Time ( t )</th>
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Sample calculation (Reading No...........)

Breadth of the notch \( (b) = \)

Still level \( (h_1) = \)

Final head \( (h_2) = \)

Head over the notch \( (h) = \)

\[ h_2 - h_1 \]

Taking \( g \) = 9.81 m/s\(^2\)

\[ Q_{th} = \frac{2}{3} \cdot \sqrt{2g \cdot b \cdot h^{3/2}} \]

Dimensions of measuring tank,

\[ L = \quad B = \]

Area of measuring tank \( (A) = \)

Level of water rise in the measuring tank \( (R) = \)

Time taken for the water rise \( (t) = \)

\[ Q_a = \frac{A \times R}{t} \]

\[ \quad = \]

\[ Cd = \frac{Q_a}{Q_{th}} = \]
EXPERIMENT ON TRIANGULAR NOTCH

Aim: To determine the co-efficient of discharge of the given triangular notch and plot the graph, $C_d$ Vs $Q_a$

Objectives: Appreciate the triangular notch and its co-efficient of discharge

Apparatus:
1. Triangular notch and the notch tank with hook gauge/pointer gauge.
2. Stop watch
3. Measuring tank with glass tube and scale.

Principle: The co-efficient of discharge is the ratio between actual and theoretical discharge of water flowing through the notch.

Actual Discharge $Q_a = \frac{AR}{t}$

Where
- $A$ = area of the measuring tank
- $R$ = rise of water level in the measuring tank
- $t$ = time taken for the water rise ($x$) in the tank.

Theoretical Discharge $Q_{th} = \frac{g}{15} x C_d x \sqrt{2g \cdot \tan \frac{g}{2}} \cdot \frac{x}{h^2}$

Where
- $g$ = acceleration due to gravity
- $\theta$ = angle of the notch
- $h = \text{head over the notch}$
- $h_1 = \text{Sill level (initial head)}$
- $h_2 = \text{final head}$

$\therefore C_d = \frac{Q_a}{Q_{th}}$

Procedure:
1. Note the breadth of the notch and dimensions of the measuring tank.
2. Open the supply valve and allow water to enter the notch tank up to the sill of the notch tank. Then close the supply valve.
3. Note the sill level($h_1$) using the hook gauge.
4. Open the supply valve and allow water to flow through the notch and a steady head is maintained. Note this constant head over the notch by using the hook gauge (h2).

5. Close the outlet valve of the measuring tank firmly and note the time taken for a particular water rise (R) in the measuring tank by using a stop watch.

6. After taking the time, open the outlet valve of the measuring tank.

7. Repeat the steps 4 to 6 for the different values of h2.

8. Tabulate the readings (h2 and t) and calculate the coefficient of discharge.

Result:

Co-efficient of discharge of the given triangular notch =

Inference:
**Observation and Tabulation**

Dimensions of the measuring tank

\[ L = \quad B = \]

Still level \((h_1) = \)

Angle of the notch \(\theta = \)

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<th>Sl No</th>
<th>Final Head (h_2)</th>
<th>Head (h)</th>
<th>Time (t)</th>
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**Sample calculation (Reading No............)**

Angle of the notch \(\theta = \)

Still level \((h_1) = \)

Final head \((h_2) = \)

Head over the notch \((h) = h_2 - h_1\)

\[
\text{Taking } g = 9.81 \text{ m/s}^2
\]

\[
Q_{th} = \frac{8}{15} x C_d x \sqrt{2g \cdot \tan \frac{\theta}{2} \cdot \frac{h^5}{h_1^2}}
\]

Dimensions of measuring tank,

\[ L = \quad B = \]

Area of measuring tank \((A) = L \cdot B\)

Level of water rise in the measuring tank \((R) = \)

Time taken for the water rise \((t) = \)

\[ Q_a = \frac{A \times R}{t} \]

\[ Cd = \frac{Q_a}{Q_{th}} = \]
EXPERIMENT ON TREPEZOIDAL NOTCH

Aim: To determine the co-efficient of discharge of the given trepezoidal notch and plot the graph, $C_d$ Vs $Q_a$

Objectives: Appreciate the trepezoidal notch and its co-efficient of discharge

Apparatus:
1. Trepezoidal notch and the notch tank with hook gauge/pointer
gauge.
2. Stop watch
3. Measuring tank with glass tube and scale.

Principle: The co-efficient of discharge is the ratio between actual and theoretical discharge of water flowing through the notch.

Actual Discharge $Q_a = \frac{AR}{t}$

Where
- $A$ = area of the measuring tank
- $R$ = rise of water level in the measuring tank
- $t$ = time taken for the water rise ($x$) in the tank.

Theoretical Discharge

$$= \frac{8}{15} x C_d \times \sqrt{2g} \cdot \tan \frac{\theta}{2} \cdot \frac{h^5}{2} + \frac{2}{3} x C_d \times \sqrt{2g} \cdot b \cdot h^{3/2}$$

Where
- $g$ = acceleration due to gravity
- $\theta$ = angle between the side edges
- $b$ = bottom width of the notch
- $h$ = head over the notch
- $h_1 = (h_2 - h_1)$ = water head measured above the crest
- $h_2$ = Sill level (initial head)

$$\therefore C_d = \frac{Q_a}{Q_{th}}$$

Procedure:
1. Note the breadth of the notch and dimensions of the measuring tank.
2. Open the supply valve and allow water to enter the notch tank upto the sill of the notch tank. Then close the supply valve.
3. Note the sill level ($h_1$) using the hook gauge.
4. Open the supply valve and allow water to flow through the notch and a steady head is maintained. Note this constant head over the notch by using the hook gauge ($h_2$).
5. Close the outlet valve of the measuring tank firmly and note the time.
taken for a particular water rise (R) in the measuring tank by using a stop watch.

6. After taking the time, open the outlet valve of the measuring tank.
7. Repeat the steps 4 to 6 are for the different values of $h_2$

8. Tabulate the readings ($h_2$ and $t$) are and calculate the co-efficient of discharge.

**Result:**

Co-efficient of discharge of the given trapezoidal notch =

**Inference:**
Observation and Tabulation

Dimensions of the measuring tank

\[ L = \quad B = \]

Still level \((h_1) = \)

Angle of the notch \(\theta = \)

Bottom width of the notch \(b = \)

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<thead>
<tr>
<th>Sl No</th>
<th>Final Head (h_2)</th>
<th>Head (h)</th>
<th>Time (t)</th>
<th>Qth</th>
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</table>

Sample calculation (Reading No............)

Bottom width of the notch \(b = \)  
Still level \((h_1) = \)
Final head \((h_2) = \)
Head over the notch \((h) = h_2-h_1\)

\[
\text{Taking } g = 9.81 \text{ m/s}^2
\]

\[
Q_{th} = \frac{8}{15} \times C_d \times \sqrt{2g} \times \tan \frac{\theta}{2} \times h_2^\frac{5}{2} + \frac{2}{3} \times C_d \times \sqrt{2g} \times b \times h_2^\frac{3}{2}
\]

Dimensions of measuring tank,

\[ L = \quad B = \]

Area of measuring tank \((A) = \)  
Level of water rise in the measuring tank \((R) = \)
Time taken for the water rise \((t) = \)

\[
Q_a = \frac{A \times R}{t}
\]

\[
Cd = \frac{Q_a}{Q_{th}}
\]
**STUDY OF BERNOULLI’S THEOREM APPARATUS**

The experimental set up consist of a horizontal Perspex duct made up of smooth variable cross section of convergent and divergent in 40x40mm at the entrance and exist and 40x20 mm at middle. The total length of duct in 90 cm. The piezometric pressure $P$ at the locations of pressure tappings is measured by means of piezometers installed along with the length of conduit. The duct is connected with the small tanks. By maintaining suitable amount of steady head difference between these two tanks, there establishes a steady nonuniform flow in the conduit whose dimension at different cross section are known. Knowing the discharge flowing in the conduit, velocity $v$ at different sections are computed. Arrangement to supply the coloured liquid dye in the middle of duct through a dye injector needle is provided to visualize the flow pattern.

Since the conduit is horizontal, the total energy at any section with reference to the centre line of the conduit is the sum of pressure head and velocity head. One can compare the values of the total energy at different sections and comment about the constancy of energy in converging and diverging conduit. The observation and computations can be suitably computed and the result presented in a graphical form by plotting hydraulic gradient line and total energy line.
Verification of Bernoulli’s Theorem

Aim: To verify the Bernoulli’s theorem and plot the graphs.

Length of pipe Vs velocity head \((v^2/2g)\)

Apparatus:
1. Meter Scale
2. Stop watch.

Principle: Bernoulli’s theorem states that “when water is continuously flowing through a conduit, and no extra energy is taken out or added the total energy (or total head) will remain constant at all sections”

\[ H_1 = H_2 = H_3 = H \text{ (Total Head)} \]

Total head \(H\) = Potential head \((Z)_+\)
Pressure head \(\frac{p}{pg}\)_+

Velocity head \((v^2/2g)\)

Where \(Z\) = Potential head, ie the height by which the water particle is situated from a datum.

\(p\) = intensity of pressure
\(S\) = density of water
\(g\) = acceleration due to gravity
\(v\) = velocity of flowing water

The apparatus consists of a duct of varying cross-sectional area and piezometers are installed at various sections. A supply tank and a collecting tank are provided with the apparatus. A centrifugal pump with an electric motor is also provided to circulate the water.

Procedure
1. Observe the area of cross section and the distance of each section from a reference axis.
2. Close the outlet valve of the centrifugal pump and start the pump.
3. Open the outlet valve of the pump gradually and water is allowed to enter the supply tank, and water flows through the duct to the reservoir.
4. Maintain a steady flow through the duct by operating the outlet valves.
5. Consider a datum and measure the vertical height to the level of water in the piezometer from the datum, by using a meter scale ie \((z+p/pg)\).
6. Observe the dimensions of the measuring tank and close the outlet valve of the tank firmly.
7. The water flowing through the duct is collected in the measuring tank and note the time \((t)\) taken for a particular rise in water level \((x)\) in the measuring tank by using a stop watch.
8. After taking the time, open the outlet valve of the measuring tank.
9. Close the outlet valve of the centrifugal pump and switched off. The pump.

Result:
Bernoulli’s theorem is verified and it is found that total head decreases when the flow progresses.

Inference:
Observation and Tabulation

Dimensions of measuring tank,

\[ L = \quad B = \]

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<td>((z + \frac{P}{\rho g}))</td>
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<td>((V^2 / 2g))</td>
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<td>Total Head (H)</td>
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Sample calculation (Section No..................................)

\((z + \frac{P}{\rho g})\) =

Dimensions of measuring tank,

\[ L = \quad B = \]

Area of measuring tank, \((A) = L \times B) =

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

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

Actual Discharge \((Q) = \frac{A \times x}{t}\)

Area of cross section of the duct \((a) =

velocity \((v) = Q/a\)

velocity head \(= V^2 / 2g\) \(g = 9.81 \text{m/s}^2\)

\[ = \]

Total head \((H) = z + \frac{P}{\rho g} + \frac{V^2}{2g} = \]
STUDY OF PIPE FITTINGS

1. **Coupling:** It is a hollow piece of pipe having internal threads. Couplings are used to connect two pipes of same diameter up to 10 cm.

2. **Reducer Coupling:** It is a hollow piece of pipe having internal threads and is used to connect two pipes of different diameter.

3. **Tee:** This is used at a place where branch line of equal diameter is to be taken at right angles to the main line which is continuous. It has equal diameter on three portions and are provided with internal threads.

4. **Reducer Tee:** This is also provided at a place where branch line is to be taken at right angles from a continuous main line. This is provided when the diameter of a branch pipes is less than the diameter of the main pipe.

5. **Elbow:** This is used to change the direction of flow in a pipe line. The change in direction will be at 90°. This provides a sharp change in the direction and has equal diameter on both sides. This will have internal threads and used upto 10cm diameter only.

6. **Reducer Elbow:** If it is intended to change the direction of flow by 90° and the two pipes to be connected are different diameters, the joint used to connect the pipes is called reducer elbow.
7. **Bend** : This is used to change the direction of flow at 90°. The bend is a short gradually bent pipe with outside threads at the ends. This provides a gradual change of direction. The connections to the pipe are made by means of coupling on either side.

8. **Cross** : This is used at a place where main lines and branch lines of the same diameter are connected at right angles. The cross has got inside on all four sides.

9. **Nipple** : This is short piece of pipe with threads outside from end. This is used for connecting two pipes when there is a short gap in (eg: Due to damage of the ends of a pipe)

10. **Union** : Where it becomes necessary to remove and dismantle the connected pipes, a special joint called Union is used. It is used to connect two straight pipes of equal diameters. The union consists of three parts. The two extreme parts (1&2) are provided with threads both inside and outside and can be screwed on to the pipes. The central part consists of nut with inside threads to connect the other two parts together.

11. **Flange** : This is used to connect two pipes of same diameter when the size is more than 10cm. The flange consists of a pair of components and each can be screwed separately to the two pipes. The two flanges are bolted together by means of bolts and nuts with rubber packing in between them.

12. **Plug** : This is used for plugging or blocking the end of the pipe line or to stop the flow of water from a tank. This has outside threads (male plug). If it has internal threads, it is called female plug.
STUDY OF VALVES AND COCKES

1. **Gate valve**: This type of valve is used for opening and closing a fluid passage and consists of a gate or disc which can be moved up and down across the line of flow by, a hand wheel.

2. **Globe valve**: This valve consists of a threaded spindle connected with disc which seats on an opening provided in the middle of the valve. This opening is such that it causes change in the direction of flow.

3. **Check valve**: The check mechanism incorporates a disc, piston or ball which lifts along an axis in-line with the axis of the body seat. There are two types – vertical & horizontal.

4. **Spring loaded safely valve**: It is used as safely valve in reciprocating pump etc. When the pressure in the hydraulic circuit reaches beyond the normal, the valve will be opened and fluid will be discharged.

5. **Foot valve**: It is used at the bottom of the suction line of that centrifugal pump, which requires priming before starting.

6. **Screw down cock**: It is used to deliver water from a pipe line or tank. While rotating the handle the valve will move away from the valve seat.

7. **Push cock**: It is used to deliver water from a tank.

8. **Plug bib cock with lock**: It is used to handle costly fluid like lubricating oil etc.

9. **Air cock**: It is provided in the casing of a centrifugal pump to test the presence of air and to remove the air while priming.

10. **Lift up cock**: It is used to taken water from a tank or a pipe line.

11. **Pressure gauge cock**: It is used to deliver water to the manometers or pressure gauges, while measuring the pressure.
The loss of energy due to change of velocity is called minor losses. The minor loss of energy includes the following:

1. Loss of head due to sudden enlargement
2. Loss of head due to sudden contraction
3. **Loss of head at the entrance to a pipe**

\[ h_e = 0.5 \frac{V^2}{2g} \]

4. **Loss of head at the exit of a pipe**

\[ h_0 = \frac{V^2}{2g} \]

where \( V \) = velocity of flow

5. **Loss of head due to an obstruction in the path of flow**

\[
\text{Head loss due to obstruction} = \frac{(V_e - V^2)}{2g} = \left( \frac{A \times V}{C_c(A-a)} - V \right)^2
\]

where \( V \) = velocity of flow
\( A \) = a/c of the Pipe
\( a \) = a/c of the obstruction, \( C_c \) = Co-efficient of contraction
6. **Loss of head due to Bend in Pipe**

   \[ h_b = \frac{kV^2}{2g} \]

   where \( K \) = Co-efficient of bend
   \( V \) = Velocity of flow

7. **Loss of head in the pipe fittings**

   \[ h_p = \frac{kV^2}{2g} \]

   where \( K \) = Co-efficient of pipe fittings
   \( V \) = Velocity of flow