MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY

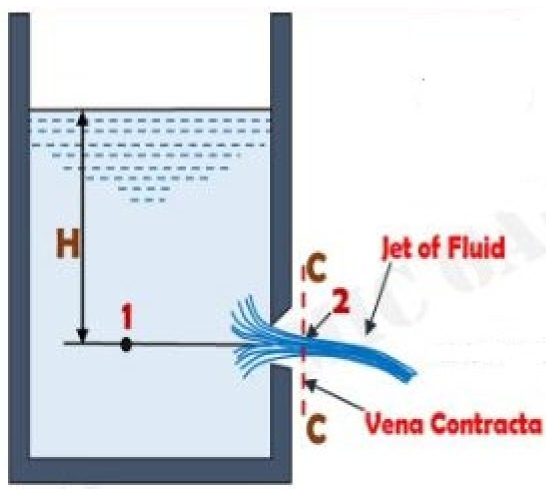
CIVIL ENGINEERING DEPARTMENT
Fluid Mechanics Laboratory

STUDY OF EFFLUX FROM SMALL ORIFICES
DETERMINATION OF HYDRAULIC COEFFICIENTS (C_C, C_V, C_D)

AIM:- To determine the coefficient of discharge C_d, coefficient of velocity C_v, and coefficient of contraction C_c of small circular orifice.

APPARATUS:- An inlet pipe with a valve, balancing tank fitted with an orifice, horizontal scale and a sliding hook gauge fitted to the balancing tank for measuring the X and Y coordinates of the jet of water, micrometer screw gauge, collecting tank and a stop watch.

THEORY AND SIGNIFICANCE:- An orifice is an opening in the wall of a tank, or in a plate normal to the axis of a pipe, the plate being either at the end of the pipe or in some intermediate location. It is characterized by the fact that the thickness of the wall or plate is very small relative to the size of the opening.

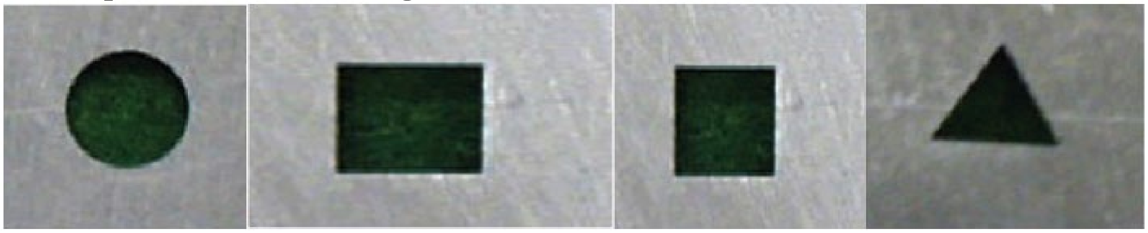


Classification of Orifices

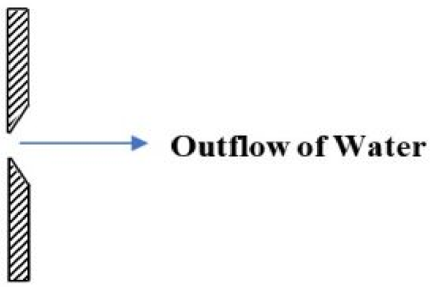
Orifices may be classified based on a number of factors, some of which are related to geometry and the others related to out flowing conditions.

1. Based on size, the orifices are classified as (i) **small orifice** and (ii) **large orifice**. If the opening size of the orifice is small relative to the available head that triggers flow through it, the orifice is termed as small. A mathematical limit on the size of small orifice is D<H/5 , where D is the diameter or opening size of the orifice and H is the head.
On the other hand, large orifices have the opening (D) greater than H/5.

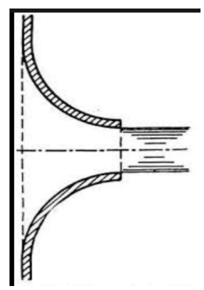
2. Based on shape, the orifices are classified as **(i) Circular (ii) Rectangular (iii)Square and (iv)Triangular**



3. Based on shape of entrance or upstream edge the orifices are classified as (i) **sharp-edged orifice** and (ii**) bell mouthed orifice**. A sharp-edged orifice provides a sharp entry of water through it. This may lead to some local turbulence around or near the orifice. A bell-mouthed orifice, as the name indicates, provides a smooth transition for water to flow out and therefore, losses due to friction are likely to minimize.

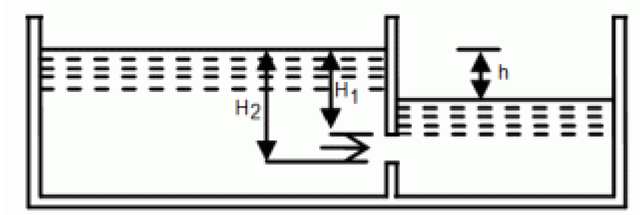


Sharp edged orifice



Bell mouthed orifice

4. Based on discharge condition the orifices are classified as (i) **free discharge orifice** and (ii) **submerged orifice**. Free discharge orifice outflows water into the atmosphere and once the jet escapes, the entire pressure energy of water is converted into kinetic energy. Therefore, the jet is subjected to atmospheric pressure (i.e., zero absolute pressure) the instant it leaves the orifice. In case of a submerged orifice, the water that is discharged from one container goes to another and therefore, it still possesses some pressure energy depending upon the available head in the latter container.



Submerged orifice

An orifice may be fixed either in the walls or in the bottom of a tank. The area of the orifice is the area of the opening. When a liquid flows through an orifice, it comes out in the form of a free jet. As the jet issues out into the atmosphere, it contracts at a certain point because the portion of flow that approaches along the wall cannot make a right angled turn at the opening, and therefore maintains a radial velocity component that reduces the jet area. The cross section where the contraction is greatest is called the VENA CONTRACTA. The pressure at this point is atmospheric

$$C_c = \frac{\text{Area of the jet at vena contracta}}{\text{Area of the orifice}}$$

$$C_c = a_c/a_o = d_c^2/d_o^2$$

Application of the Bernoulli's equation between points 1 and 2 shown in the figure yields the required expression for computing the theoretical velocity V_t .

$$V_t = \sqrt{2gh}$$

Then, the theoretical discharge Q_t is given by $Q_t = a_o\sqrt{2gh}$

The coefficient of discharge C_d is given by $C_d = Q_a/Q_t$

Where, Q_a is the actual discharge. The coefficient of velocity C_v is found by measuring the X and Y coordinates of any point on the trajectory of the jet. The origin is taken as the lowest point of the jet at vena contracta and the coordinates are measures positive downwards.

Then $C_v = \sqrt{X^2/4yh}$

PROCEDURE:-

1. Make the water level constant in the balancing tank at the highest possible head (h) by regulating the inlet valve. Note down the valve of head h in m.
2. Collect H (m) of water in the collecting tank and note down time of collection t (s)
3. Note down the X and Y coordinates of the lower most point of the jet by sliding hook gauge on the horizontal scale.
4. Drop the head by about 10 cm and repeat steps 1 to 4 about 8 different discharges.

SPECIMEN CALCULATIONS:-

Data:
Diameter of the orifice = 20 mm
Area of the orifice = 3.14 x 10-4 m^2
Area of the collecting tank = 0.25 m^2
Height of collection = 0.10 m
g = 9.81 m/s^2
(i) Head over the orifice = (h) m

(ii) $Qt = a_o \sqrt{2gh}$
where

ao = area of the orifice in $m^2 = \pi d_o^2/4$
d_o = diameter of the orifice in m
g = 9.81 m/s^2

(iii) Volume of water collected = (0.25 X H) m^3

(iv) Time of collection = (t) s

(v) Qa = (0.25 X H)/t m^3/s

(vi) Compute $C_d = Q_a/Q_t$

(vii) Compute C_v by inserting the values of X and Y coordinates in the formula
$C_v = \sqrt{X^2/4yh}$

(viii) Compute C_c using the formula $C_d = C_c C_v$.

PRECAUTIONS:-

1. Head of the water must be maintained constant, till one complete set of observations are taken.
2. The position of the vena contracta should be found out accurately.
3. Collecting tank observations should not be taken when the water level in the Piezometer fluctuates.

GRAPHS:- Plot the following graphs.

(i) Qa vs $\sqrt{h}$ for steady flow
(ii) Qa vs h for steady flow
(iii) Log Qa vs Log h for steady flow
(iv) t vs ($\sqrt{h_1} - \sqrt{h_2}$) for unsteady flow.

RESULTS:-

The average value of coefficient of discharge (C_d) of the circular orifice is ----
The average value of coefficient of velocity (C_v) of the jet of water through a circular orifice is ----
The average value of coefficient of contraction (C_c) of the jet of water through a circular orifice is ----

S.No	Head over the orifice H (m)	Theoretical discharge Q_t (m^3/s)	Volume of water collected (m^3)	Time of collection t (s)	Actual Discharge Q_a (m^3/s)	Coefficient of discharge $C_d = Q_a/Q_t$	X – coordinate	Y – coordinate	$C_v = \sqrt{X^2/4yh}$	$C_c = C_d/C_v$

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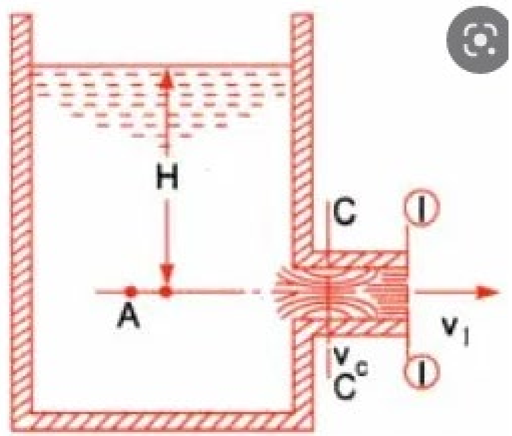
STUDY OF EFFLUX FROM MOUTH PIECES
(DETERMINATION OF COEFFICIENT OF DISCHARGE C_d)

AIM:- To determine the coefficient of discharge C_d of a mouth piece, by the following two methods.

i) Constant head method and
ii) Falling head method.

APPARATUS:- An inlet pipe with a valve, a balancing tank with provision for fixing interchangeable mouth pieces, collecting tank and a stop watch.

THEORY AND SIGNIFICANCE:- A mouth piece is one of the many flow rate meters available for determining the discharge through tanks or reservoirs. It is a short pipe whose length is not more than two or three times the diameter of the pipe. It may be internal or external, and have a uniform or varying cross section.



Flow through mouth piece

(i) C_d under constant head:

As the head 'H' on the mouth piece held constant, application of the Bernoulli's equation between points 1 and 2 yields:

$$V_t = \sqrt{2gH}$$

If a is the area of cross section of the mouth piece, the discharge Q_t is given by

$$Q_t = a\sqrt{2gH}$$

The actual discharge Q a, is obtained from collecting tank observation

Hence, $C_d = Q_a/Q_t = Q_a/a\sqrt{2gH}$

(ii) C_d under falling head:- as the name implies, the head is not held constant, but is allowed to fall from H_1 to H_2 m. Under these conditions, the coefficient of discharge Cd is given by:

$$C_d = \frac{2A\,(\sqrt{H_1} - \sqrt{H_2})}{t\,a\,\sqrt{2g}}$$

Where A = area of the mouth piece tank.

A mouth piece usually employed for measuring the discharge from a tank or a reservoir. It gives a higher value of C_d, as compared to an orifice, and hence is used in a number of situations required accurate flow measurements.

PROCEDURE:-

A. For constant head method:-

1. Operate the inlet and outlet valves in such a manner that the head on the mouth piece remains constant.
2. Collect h m of water in the collecting tank and note down the time of collection t (s).
3. Repeat the experiment 5 times, with different heads, to get an average value of Cd.

B. For falling head method:-

1. Open the inlet valve and allow sufficient head to build up, before closing it.
2. Decide suitable the values of H1 and H2 and using the stop watch determine the time t required in bringing down water level in the tank from H_1 and H_2.
3. Repeat steps 1 and 2 for 6 suitable combinations of H_1 and H_2.

NOTE:- The recommended combinations of H_1 and H_2 are as follows.

(i) 0.90 m to 0.60 m
(ii) 0.80 m to 0.50 m
(iii) 0.75 m to 0.45 m
(iv) 0.70 m to 0.40 m
(v) 0.60 m to 0.30 m

SPECIMEN CALCULATIONS:-

(i) FOR CONSTANT HEAD METHOD:-

a = area of the mouth piece in m^2 = $7.068 \times 10^{-4}\ m^2$
Area of collection tank = $0.25\ m^2$
g = $9.81\ m/s^2$
h = head in m

$Q_t = a\sqrt{2gH}$

Volume of water collected = 0.25 h m^3
Time of collection = t s

$$Q_a = \frac{0.25\ h}{T}\ m^3/s$$

$$C_d = \frac{Q_a}{Q_t}$$

(ii) **FOR FALLING HEAD METHOD**:-

a = area of the mouth piece in m^2 = $7.068 \times 10^{-4}\ m^2$
A = Area of collection tank = 0.25 m^2
g = 9.81 m/s^2
H_1 = initial head in m
H_2 = final head in m
t = time for falling

$$C_d = \frac{2A(\sqrt{H_1} - \sqrt{H_2})}{t\ a\ \sqrt{2g}}$$

PRECAUTIONS:-

1. In constant head method, the head should be maintained constant till one complete set of readings is taken.
2. Piezometer readings should not be taken when the water level fluctuates.

GRAPHS:- Plot the following graphs.

(i) H vs Q_a
(ii) Log H vs Log Q_a
(iii) $(\sqrt{H_1} - \sqrt{H_2})$ vs t

RESULTS:-

The Average value of C_d by constant head method is --------
The Average value of C_d by falling head method is ----------

CONSTANT HEAD METHOD

S.No	Head over the mouth piece H (m)	Theoretical discharge Q_t (m^3/s) $Q_t = a\sqrt{2gH}$	Volume of water collected (m^3)	Time of collection t (s)	Actual discharge $Q_a = \frac{(0.25)\,h}{t}$ m^3/s	Coefficient of discharge $C_d = \frac{Q_a}{Q_t}$
1						
2						
3						
4						
5						
6						

FALLING HEAD METHOD

S. No	Initial head over the mouth piece H_1 (m)	Final head over the mouth piece H_2 (m)	Time of the emptying from H_1 to H_2 (s)	$\sqrt{H_1} - \sqrt{H_2}$	Coefficient of discharge $C_d = \frac{2A(\sqrt{H_1} - \sqrt{H_2})}{t\,a\,\sqrt{2g}}$
1					
2					
3					
4					
5					
6					
7					
8					

STUDY OF FLOW CHARACTERISTICS OF TRIANGULAR NOTCHES
(DISCHARGE MEASURING DEVICE INFREE SURFACE FLOWS)

AIM:- To determine the coefficient of discharge for a triangular or "V" notch.

APPARATUS:- Inlet pipe with a valve, on open channel fitted with a triangular notch, hook gauge, collecting tank and a stop watch.

THEORY AND SIGNIFICANCE:- A notch is an opening made in a plate and fixed at the end of an open channel. It causes the water to back up behind it, and the flow occurs under this head.

Notches and weir have long been standard devices for measurement of water discharge in an open channel. Their simplicity lies in the fact that only one measurement, i.e., the head 'H' is sufficient to determine the discharge. The opening in the plate can be of any standard geometrical shape. The advantage of a "V" notch is that it can function for a very small flows and also measure reasonably large discharges. Incase of a rectangular weir, if the head is small, the nappe will not spring clear but will cling to the plate.

The vertex angle of a triangular notch is lies between 10^0 and 90^0. If H is the head causing the flow, the theoretical discharge is given by

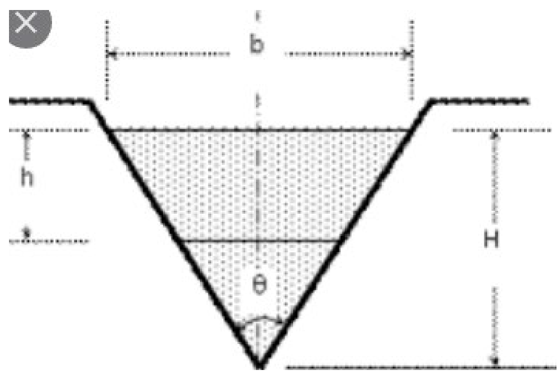
$$Q_t = \frac{8}{15} \sqrt{(2g)} \tan(\theta/2) H^{5/2}$$

Where θ = vertex angle

The actual discharge is obtained from the collecting tank observations

Coefficient of discharge C_d is defined as the ratio of the actual discharge to the theoretical discharge.

$$C_d = Q_a/Q_t$$



Triangular Notch

θ = vertex angle
H = head over the notch

The study of flow over a particular notch and its calibration is essential before it can be installed in the field. Notches are exclusively installed in an open channel of stream for the purpose of discharge measurement. Weirs can be used for harnessing the flow and also for flow measurements

PROCEDURE:-

1. Open the inlet valve and allow water to flow. Regulate the valve to obtain a steady flow condition.
2. When the water just touches the crest of the notch, take the initial hook gauge reading H_1. For this purpose bring the pointer just in contact with the water surface.
3. Allow more discharge into the channel and once again maintain a steady flow condition. Take the final hook gauge reading H_2 by bringing the pointer just in contact with the water surface.
4. Collect h(m) of water in the collecting tank and note down the time of collection t (s).
5. Repeat the experiment 6 times for six different heads.

SPECIMEN CALCULATIONS:-

1. Head 'H' over the notch = final hook gauge reading - initial hook gauge reading.
   Vertex angle $\theta = 90^0$
   $g = 9.81\ m/s^2$
   Compute the theoretical discharge
   $Q_t = K H^{5/2}$ where K is a constant and is given by $K = \frac{8}{15} \sqrt{(2g)} \tan(\theta/2) H^{5/2}$
2. Height of water collected = h m
   Area of collecting tank = $0.64\ m^2$
   Volume of water collected = $(0.64\ h)\ m^3$
   Time of collection = t s
   Discharge Qa = (0.64h) / t

3. $C_d = Q_a/Q_t$

PRECAUTIONS:-

1. Head of water must be maintained constant for one complete set of readings.
2. Initial reading H_1 should be taken when the water just reaches the crest level, but does not over flow.

3. Collecting tank observations must not be taken when the water level in the piezometer tube fluctuates.

GRAPHS:- Plot the following graph for Q_a vs H

RESULTS:- The experimental value of coefficient of discharge C_d for the triangular notch is

S.No	Initial point gauge reading (mm)	Final point gauge reading (mm)	Head over the notch H (m)	Theoretical discharge $Q_t(m^2/s)$	Height of the collection (m)	Volume of the water collected (m^3)	Time of the water collected t (s)	Actual discharge $Q_a(m^3/s)$	Coefficient of discharge $C_d = Q_a/Q_t$
1									
2									
3									
4									
5									
6									

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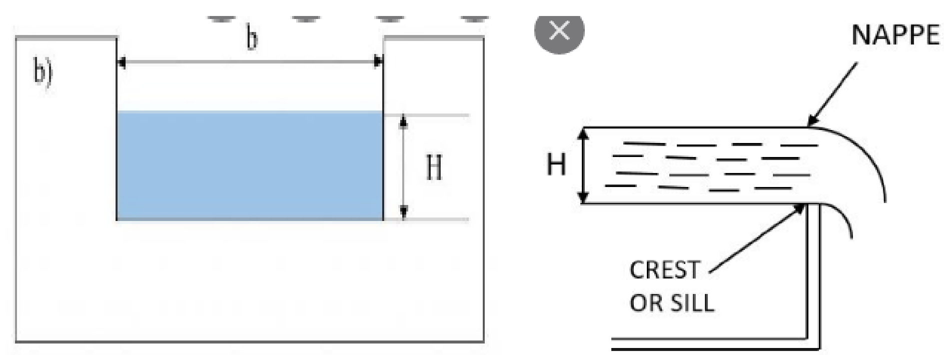
STUDY OF FLOW CHARACTERISTICS OF RECTANGULAR WEIRS

AIM:- To study the flow characteristics of a rectangular weir and to determine the coefficient of discharge in a free surface flow.

APPARATUS:- An inlet pipe with a valve, a channel with a rectangular weir attached to it. Pointer or hook gauge, collecting tank and a stopwatch.

THEORY AND SIGNIFICANCE:- A weir is an obstruction in the channel that causes the liquid to backup behind it and flow over it or through it. Although, theoretically the top edge is of zero thickness, in actual practice the top of the place is 1 to 2 mm long in the flow direction and the downstream edge is beveled at an angle of 45 to 60^0. This has the effect of making the nappe spring clear, making a line contact for all but the very lowest heads.

The discharge passing through a weir can be determined by measuring the head H, on the weir.



Rectangular Notch

The weir is classified as sharp crested or broad crested depending upon the shape of the crest. When the length of the weir is the same as the width of the approach channel, it is termed as a suppressed weir as the end contraction are suppressed. The discharge formula for suppressed weir is given by

$$Qt = 2/3 \sqrt{2g}\, L\, H^{3/2}$$

Where L = length of the weir crest. However, when the length L of the crest of a rectangular weir is less than the width of the channel, there will be lateral contraction of the nappe so that its width is less than L. the contracted width, denoted as L^e can be obtained from

$$L_e = (L - 0.1\, n\, H)$$

Where n = no. of end contrations, the end contration.
Coefficient being 0.1
(n = 2 for the given rectangular weir)
The actual discharge Q_a can be obtained from collecting tank observations

$$\text{Thus } C_d = Q_a/Q_t$$

Weirs and notches constitute the most commonly employed channel control devices in irrigation system. They are sometimes installed for purely discharge measurement purpose, but, in the form of a dam or barrage, they are excellent flow harnessing devices also.

PROCEDURE:-

1. Open the inlet valve and allow the water to backup behind the notch just up to the crest level. Close the valve and allow water to stabilize. Take the initial hook gauge reading h_1, corresponding to the notch crest level.
2. Open the inlet valve once again and allow the maximum discharge as far as possible.
3. Wait for about 3 to 5 minutes for the flow to become steady. Take the final point gauge reading h_2.
4. Collect h (m) of water in the collecting tank and note down the time of collection t (s).
5. Reduce the discharge and repeat steps 2 to 4 for 8 different discharge. The final observation should correspond to the least possible discharge.

SPECIMEN CALCULATIONS:-

Area of the collecting tank = $0.64\ m^2$
Height of collection = 0.10 m
Length of weir L = 0.20 m
g = $9.81\ m/s^2$

1. From the initial and final point gauge readings compute the head over the notch
$H = (h_1 - h_2)$ mm
2. For the notch with end contraction find effective length $Le = (L - 0.2H)$ where L = length of the notch.
3. With $g = 9.81\ m/s^2$, compute theoretical discharge using the formulae
$Q_t = 2/3\ Le \sqrt{2g}\ H^{3/2}$ for notch with end contrations.
4. Volume of water collected = (0.64 h) m^3.
Time of collection = (t) s.
Actual discharge, $Q_a = \frac{(0.64h)}{t}\ m^3/s$
5. Compute Cd from, $C_d = Q_a/Q_t$.

PRECAUTIONS:-

1) Head of water must be maintained constant till one complete sot of observation are taken.
2) Initial reading H_1 must be taken when the water just reaches the crest level. But does not overflow.

GRAPH:- Plot the following graphs for both the notches.

1. Q_a vs H
2. Q vs $H^{3/2}$
3. Log Q_a vs Log H

RESULTS:-
The experimental coefficient of discharge for a rectangular notch is

S.No	Initial point gauge reading h_1(mm)	Final point gauge reading h_2(mm)	Head over the notch H(mm)	Eff. length = (L-0.2H)	Theoretical discharge $Q_t = 2/3\ Le\ \sqrt{2g}\ H^{3/2}$	Volume of the water collected (m^3)	Time of the water collected t (s)	Actual discharge Q_a (m^3/s)	Coeff. of discharge C_d= Qa/Qt

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VENTURIMETER
(A DISCHARGE MEASURING DEVICEIN PRESSURE CONDUITS)

AIM:- To calibrate a venturimeter and to study the variation of coefficient of discharge with the Reynolds number.

APPARATUS:- Venturimeter setup, collecting tank and a stop watch.

THEORY AND SIGNIFICANCE:- Venturimeter is a flow-measuring device, which falls under the class of meters called obstruction meters. Having a converging, diverging duct as shown in the figure provided the required obstruction. The converging tube is an effective device for converting pressure head to velocity head, while the diverging tube converts back velocity head to pressure head. The overall loss is low, due to a gradually expanding conical section. A differential manometer is provided to measure the pressure at the beginning and end of the constriction. As there is a definite Q, application of the continuity equation and the Bernoulli's
Equation between sections 1 and 2 corresponding to inlet and throat yields.

a = inlet section: b = throat section

$$Q = \frac{A_1 A_2 \sqrt{2g}}{\sqrt{A_1^2 - A_2^2}} \sqrt{H}$$

Where A_1 = area of cross section at the point of entry
A_2 = area of cross section at the constriction
h = differential pressure head in m of water.
Flowing through the system if hm is the differential head in m of mercury than

$$h = h_m \left(\frac{S_m}{S} - 1\right)$$

Where
S_m = specific gravity of manometric fluid (mercury)
S = specific gravity of the fluid flowing in the pipe.

Venturimeter is used to measure the flow in a pipe. It is used in the laboratories to measure discharge to a pump or a turbine. The obstruction meters are also used in chemical processing plants, water distribution system and boiler plants.

The coefficient Cd accounts for viscous effects of the flow and depends on Re and the ratio D_2/D_1. As the later is fixed. It depends on only Re generally, for $Re>10^5$, Cg varies between 0.96 and 0.99.

PROCEDURE:- The experiment is done to calibrate two venturimeters (25/15 and 50/30) select one of these and proceed sequentially as follows.

1. Complete the manometer connections for the venturimeter selected and open the valve to set the discharge to the maximum practical value.
2. Allow flow to stabilize. Note down the manometer readings h_1 and h_2 in mm of mercury, in the two manometer limbs.
3. Collect H (m) of water in the collecting tank and note down the time of collection t (s).
4. Decrease the discharge such that the mercury level in the manometer limb drops by about 50 to 70 mm.
5. Repeat steps 2 to 4 for about 8 different discharges.
6. Select the next venturimeter and repeat the experiment.

SPECIMEN CALCULATIONS:-

1. Calculate the differential head hm = $(h_1 – h_2)$ mm of mercury.
2. Convert the head from mm of mercury to m of water head by plugging in the appropriate values in

$$h = \frac{h_m}{1000}\left(\frac{S_m}{S} - 1\right)$$

With $S_m = 13.56$ and $S = 1.00$

3. Calculate the cross-section areas and hence the theoretical discharge.

A_1 = area of inlet = $D_1^2/4$
A_2 = are of throat = $D_2^2/4$
$g = 9.81\ m/s^2$

$$Q = \frac{A_1 A_2 \sqrt{(2g)}}{(A_1^2 - A_2^2)1/2} \sqrt{h}$$

Note:- The inlet and throat diameters of the three venturimeter in the setup are as follows.

D_1 = inlet diameters in mm = 75.50 and 25
D_2 = throat diameters in mm = 45.30 and 15

In the equations $Q = \frac{A_1 A_2 \sqrt{(2g)}}{(A_1^2 - A_2^2)^{1/2}} \sqrt{h}$ the quantity in

Parenthesis is a constant and its vale depends on the ratio of D_2/D_1

4. Volume of water collected = (0.64 H) m^3/s
5. Time of collection = t (s). Hence actual discharge Qa = $\frac{(0.64\ H)}{t}$ m^3/s
6. Finally compute $C_d = Q_a/Q_t$
7. To fine the Reynolds number at the throat, first compute the throat velocity

   $Vs = Qa/A_2$

   Reynolds number $Re = V_2D_2/v$, where v = kinetic viscosity of water
   $= 1.00 \times 10^{-6}\ m^2/s$

PRECAUTIONS:-

1. While taking manometer readings, the upper meniscus of mercury should be considered.
2. Piezometer readings should not be taken when the water level fluctuates.
3. The flow through the venturimeter should be steady.

GRAPHS:- Plot the following graphs.

i) Qa vs H
ii) Qa vs √h
iii) Log Qa vs Log h
iv).Cd vs Re

RESULTS:- Report the following average values.
50/3 25/15

1. Cd (experimental average)
2. K from Qa vs H graph
3. N from log – log graph
4. K from log – log graph

Area of collecting tank = 0.64 m^2
Pipe diameter 'D' in mm = 75, 50 and 25
Orifice diameter'd' in mm = 45, 30 and 15
d/D = 0.6
Kinetic viscosity = $1.00 \times 10^{-6}\ m^2/s$

S.no,	Left limb reading (mm)	Right limb reading (mm)	Hm (mm) of Hg	h, in m of water head	$A_1 = D_1^2/2$	$A_2 = D_2^2/2$	$K = \frac{A_1 A_2 \sqrt{2g}}{(A_1^2 - A_2^2)^{1/2}}$	Qt	Ht. of col. m	Vol. of water coll. m^3	T (s)	Qa	Cd =Qa/Qt	$V_2 =$ Qa/A_2 (m/s)	Re

<u>SPECIMEN CALCULATION</u>:-

1. $d1 = (x - x_1)/1000$ and $d_2 = (y - y_1)/1000$
   Calculate the areas A_1 and b_1d_1 and $A_2 = b_2d_2$
   Calculate $h = (d_1 - d_2)$ m

2. Area of the collecting tank = 0.64 m^3.
   Time of collecting = t s.

3. Calculate the theoretical discharge Q_t.
4. Coefficient of discharge $C_d = Q_a/Q_t$.

GRAPH:- Plot the following graphs:

1. Q vs Es

RESULT:- Coefficient of discharge Cd =

NOTE:- Your record should also include (i) A neat dimensional sketch of the experimental set up (ii) comments on your results

Width of the channel b_1 = 0.25 m
Width of contraction b_2 = 0.10 m
Area of collection tank = 0.64 m^2
Height of collection = m
g = 9.81 m/s^2

Time of collectio	Actual discharg	A_1 (m_2)	A_2 (m^2)	Theoretical	Cd	Hydraulic jump	Velocity V vs (s)	$V^2/2g$	Specific energy	Theoretical	Cd

S.no	u/s point guage	u/s depth x_1 (mm)	Throat point	Throat depth y_1	Head h (m) d_1 –	Volume of water

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CIVIL ENGINEERING DEPARTMENT
Fluid Mechanics Laboratory

STUDY OF FREE VORTEX FLOW
(DETERMINATION OF Cd OF THE ORIFICE FOR UNSTEDADY FLOW)

AIM:-

a) To visualize the free vortex flow pattern and establish that it is an irrotational flow
b) To determine the coefficient of discharge of the sharp edged orifice under unsteady flow conditions.

APPARATUS:- Hemispherical vessel set up, hook gauge, dye injection system and a stop watch.

THEORY AND SIGNIFICANCE:- When flow takes place in a curved path of radius r, the variation for pressure over a thickness dr, is given by

$$Dp = \rho \frac{V^2}{R} dR.$$

The two different type of variations of V with r given rise to two different type if flows
i) ROTATIONAL FLOW FORCED VORTEX – V α r i.e V = Cr
ii) IRROTATIONAL FLOW FREE VORTEX – V α 1/r i.e V = C/r

In the free vortex there is no expenditure of energy from on external source and the fluid rotated by virtue of some rotation previously imparted to it or because of some internal action. Examples of a free vortex flow are whirlpool in a river that rotary flow that often arises in a shallow vessel when liquid flows out through a hole in the bottom.

Theoretically, free vortex flow in an irrotational flow but for this type of flow to exist, the velocity at r = O should become infinity.

In practice (due to viscosity fluids) the velocity never become infinity because as the high velocity are attained as the axis is approached, the friction losses which vary as square of the velocity also increases substantially and become so large that they can no longer be neglected. As a result the cone of the vortex tends to rotate as solid body as in the central part of the figure 11.1 figure 11.2 shows the velocity variation for free vortex.

In order to find the coefficient of discharge of the orifice under unsteady flow conditions, the following relation ship is utilized.

$$Cd = 2\pi \left[\frac{2}{3} R \left(H_1^{3/2} - H_2^{3/2}\right) - \frac{1}{5} \left(H_1^{5/2} - H_2^{5/2}\right)\right] / \left(Ta \sqrt{2g}\right)$$

Where
H_1 = initial head in m
H_2 = final head in m
R = radius of the hemispherical vessel
A = area of the orifice
Cd = coefficient of discharge of the orifice
T = time taken for the level to fall from H1 to H2

PROCEDURE:-

1. Open the inlet valve and allow the water to collect in the vessel
2. After a sufficient head has been obtained close the inlet valve. Start the stopwatch when the water level touches the hook gauge fixed at a particular position. The point gauge readings give H_1.
3. When the water level falls by about 20 to 25 cm stop the stop watch and note down the time.
4. Refill the vessel and take the above observations for different set of H_1 and H_2 repeat 5 times stops 1 to 3.

SPECIMENT CALCULATIONS:-

1. initial readings = H_1 m
   final readings of the point gauge = H_2 m
   time taken for the level to fall from H_1 to H_2 = t s
   radius of the hemispherical vessel = 0.61 m

2. $\frac{2}{3} R \left(H_1^{3/2} - H_2^{3/2}\right) =$

   $\frac{1}{5} \left(H_1^{5/2} - H_2^{5/2}\right) =$

3. diameter of the orifice = d mm
   area of the orifice a =

4. $2\pi \left[\frac{2}{3} R (H_1^{3/2} - H_2^{3/2}) - \frac{1}{5} (H_1^{5/2} - H_2^{5/2}) \right] / (Ta \sqrt{2g})$

PRECAUTIONS:

i) The fall in head should be at least 200 mm.
ii) Since, the point gauge does not reach the orifice, 400 mm has to be added to the point gauge in order to get the correct value of the head.

GRAPH:- None

RESULT:- The value of coefficient of discharge of the orifice is ________

Diameter of the orifice = 30 mm
Area of the orifice =
Radius of the hemispherical vessel = 0.61 m
$H_1 = 0.4$, $H_2 = 0.4 - (\text{final reading})/1000$
g = 9.81 m/s2

S.No	Initial point gauge	Initial head over the	Final point gauge	Final head over the	Time taken for the head	$H_1^{3/2} – H_2^{3/2}$	$H_1^{5/2} – H_2^{5/2}$	Coefficient of discharg

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STUDY OF RESISTANCE CHARACTERISTICS IN PIPES DETERMINATION OF DARCY – WEISBACH COEFFICIENT

AIM:- To study the variation of the Darcy-Weisbach friction factor f, for turbulent flow in closed conduit.

APPARATUS:- Pipeline with an inlet valve, collecting tank and a stop watch.

THEORY AND SIGNIFICANCE:- Closed conduits are employed whenever fluids have to be carried from one point to another under pressures different from the atmospheric pressure. The commonly employed conduit for this purpose is a circular pipe. In compressible fluids, rectangular ducts are normally used.

When a fluid flows steadily through a pipe of constant diameter, the average velocity remains the same at every cross section, because the flow has to satisfy the continuity equation.

$$U = Q/A$$

But, the static pressure drops along the direction of flow due to loss in energy in overcoming friction as the flow occurs. However, the roughness of a pipe cannot be defined easily by any geometrical factors, because of the varying size and shape of th projections and also their distribution or spacing.

The velocity distribution in turbulent flow follows log-log. Where as in case of laminar flow parabolic law

The value of the friction factor ‘f’ is determined experimentally for a pipeline of a given material and the head loss. Due to friction is computed from the Darcy’s equation.

$hf = flu^2/d2g$

Where
hf = head loss between points 1 and 2
f = Darcy’s friction factor
L = length of the pipe
U = average velocity of flow

The flow is said to be turbulent if Re>3000

It can also be shown that the value of ‘f’ is given by

$f = 64/Re$ for laminar flow and

$f = 0.316/Re^{1/4}$ for turbulent flow upto $Re = 10^5$

A plot between f and Re (called MOODY DIAGRAM) is very useful for determining the value of friction factor from the Reynold’s number Re.

Pipelines are used for a variety of purpose, and a few among them are stated below.

They are used to convey water for water distribution networks, oil for oil transportation and gas for industrial and domestic supply. As pen stocks, they are used to carry water under high pressures to the turbines. They also find an application in pneumatic system and for power transmission. They are used to convey air in air conditioners.

PROCEDURE:-

1. Select the required pipeline and open inlet valve. Allow the flow to stabilize.
2. Note down the readings of the mercury level in the two limbs of the manometer.
3. Collect H (m) of water in the collecting tank and note down the time of collection (t).
4. Repeat the experiment for six different discharges.

SPECIMEN CALCULATIONS:-

i) Volume of water collected = 0.64 Hm^3
time of collection discharge Q = 0.64H/t m^3/s

ii) Diameter of the pipe = cm

Area of the pipe $a = \pi d^2/4$ m^2
Velocity of flow $u = Q/a$ m/s

iii) Loss of head in mm of mercury = hm

$$\text{loss of head in m of water } hf = \frac{hm}{1000}\left(\frac{Sm}{S} - 1\right)$$

Where
Sm = specific gravity of mercury = 13.56
S = specific gravity of water = 1

iv) Assuming $g = 9.81 m/s^2$
Computing f from $hf = flu^2/d2g$

v) Computer the Reynold's number from Re = ud/v
where $v = 1x10^{-6}$ m^2/s

PRECAUTIONS:- Piezometer readings should be taken when the water level does not fluctuate.

GRAPHS:- Plot the following graphs

i) hf vs u2 ii) log hf vs log u iii) f vs Re

RESULTS:- The values of 'f' are as follows

i) Experimental average =
ii) From hf vs V^2 graph =
iii) From log hf vs log V graph =

Note: your record should also include (i) A neat dimensioned sketch of the experiment set up (ii) comments on your results.

S. No	Manometer Reading		Head loss in mm of mercury	Head loss in m of water collection	Volume of water collected (m^3)	Time of collection (s)	Discharge Q (m^3/s)	Velocity of flow u(m/s)	U2	2gd	Darcy's friction factor f	Re
	Left limb	Right limb										

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STUDY OF ENERGY PRINCIPLES AND VERIFICATION OF BERNOULLI'S THEORM

AIM:- To verify the Bernoulli's theorem, experimentally and to plot the Hydraulic grade line and the energy grade lines.

APPARATUS:- Bernoulli's apparatus (consisting of a receiving cylinder, a converging – diverging duct with piezeometer, an outlet cylinder), collecting tank and a stopwatch.

THEORY AND SIGNIFICANCE:- Apart from the continuity equation, the other controlling equations in fluid flow studies are the Euler's equation, the Bernoulli's equation, the momentum equations and the energy equation. Bernoulli's equation is founded on the Euler's equation of motion, and can be obtained by integrating it for in viscid incompressible, irrigational and steady flow. In confirmation with the law of conservation of energy (P/γ), the potential (datum) energy (Z), and the kinetic energy ($V^2/2g$).

$$Z + P/\gamma + V^2/2g = \text{constant}$$

Or, when applied between two sections, for frictionless flow it reduces to

$$Z_1 + P_1/\gamma + V_1^2/2g = Z_2 + P_2/\gamma + V_2^2/2g$$

The above equation is valid, provided there is no loss or gain of energy between the sections 1 and 2, due to a hydraulic machine.
However, in case of real fluids, which do possess viscosity, energy losses due to friction are inevitable. Hence, for a true representation of the energy equation, the head loss should also be included.

$$Z_1 + P_1/\gamma + V_1^2/2g = Z_2 + P_2/\gamma + V_2^2/2g + h_L$$

Where
Z = datum head in m
P/γ = pressure head in m
$V^2/2g$ = velocity head in m
h_L = loss of head due to friction

Bernoulli's equation is used in a number of flow situations such as in pumps, compressors, fans, blowers, turbines, pressure conduits and open channels.

PROCEDURE:-

1. Open the inlet valve and allow some water to collect in the supply cylinder.
2. Operate the outlet valve, such that a constant head is maintained in the supply cylinder.
3. Measure and note down the height of water in all the 13 piezometer tubes.
4. Collect h m of water in the collecting tank and note the time of collection, t (s)
5. Repeat the experiment three times, for three different heads of water in the supple cylinder.

SPECIMEN CALCULATIONS:-

Area of collecting tank = 0.09 m^2
Height of collection = (h) m
Volume of water collected = 0.009 h m^3
Time of collection = (t) s
Discharge Q = 0.009 h/t m^3/s

Knowing Q and area of the duct at a point 'a'
Compute the velocity V =Q/a
Thus, velocity head = $V^2/2g$ where g = 9.81 m/s^2
Total head = $P/r + Z + V^2/2g$
Where Z = 0 and P/r = piezometer reading in m

PRECAUTIONS:-

1. Head in the supply cylinder should be maintained constant, for one complete set of readings.
2. Piezometer tube readings should be taken, only when the water level does not fluctuate.

GRAPH:- Plot the following graphs on the same sheet of paper.

1. (P/r + Z) vs the distance of piezometer tubes from some reference point. This plot represents the hydraulic gradient line.
2. ($P/r + Z + V^2/2g$) vs the distance of piezometer tubes from some reference point. This plot represents the total energy line.
3. ($V^2/2g$) vs distance of piezometer tubes.

RESULTS:- Identify whether the total energy line remains the same at different sections. Mention this along with the possible reason for discrepancy, if any.

NOTE:- Your record should also include (i) A neat dimensional sketch of the experimental set up (ii) comments on your results.

Area of the collecting tank = 0.09 m^2
Height of the collection = 0.10 m
Distance between consecutive piezometer tubes = 45 mm
Volume of water collected = m^3
Discharge Q = m^3/s

S.No	c/s area of the duet in mm^2 ($\times 10^{-4}$)	Velocity of V in m/s	Velocity of head $V^2/2g$ (m)	Pressure head P/r (m)	Datum head Z (m)	(P/r + Z) (m)	P/r + Z + $V^2/2g$ (m)	Trail of Collection

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STUDY OF LAMINAR AND TURBULENT FLOWS IN PRESSURE CONDUICTS

AIM:- A) To study the validity of poiseuille's equation in laminar flows in pressure conduits and to verify the Blasius equation.
B) To study the turbulent flow characteristics in pressure conduits and to study the variation of head loss coefficient of a fitting with Reynold's number.

APPARATUS:- A) Experimental set up with a long G.I. pipe with pressure tap points along its length, oil sump, gear pump, collecting tank, SAE 10 oil, thermometer, standard viscosity chart and stop watch.

B) Experimental set up with a long G.I. pipe fixed with piezometer tappings along its length, an orifice meter on the up stream side, collecting tank and stop watch.

THEORY AND SIGNIFICANCE:-

A) **LAMINAR FLOW**:- A flow is defined as laminar when the fluid particles move in thin laminae, relative to one another. It is characterized by a very low Reynold's number (2000) indicating the predominance of viscous forces. To ensure laminar flow, oil (SAE 10) is used to run the experiment and selected pipe diameter is kept low (28 mm).

The velocity profile is laminar flow is governed by the Poiseuille set of equations stated as:

i) $u = 1/(4\mu) \times (-dp/dx) \times (R^2 - r^2)$
ii) $U_{max} = 1/(4\mu) \times (-dp/dx)\ R^2$
iii) $u = U_{max}\ (1 - (r/R)^2)$
iv) $Q = (\pi d^4/128\mu) \times (dp/dx)$
v) Power $P = (p_1 - p_2)\ Q$

Where u = velocity at any radius r.

The velocity profile is parabolic in laminar flows as can be seen from the above equations. The shape of the velocity profile changes with increasing values of Reynolds number.

The head loss through a conduit with laminar flow is given by the Darcy's equation

$h_f = flu^2/) 2gd)$ where the friction factor 'f' as obtained by Blaslus is

$f = 64/Re$ for $Re<2000$

The most beautiful aspect about laminar flow is that the head loss is independent of the pipe roughness.

It is also known through the experiments of Nikuradse and Reynolds that the head loss is proportional to the velocity in case of laminar flow.

$$h_f \infty V$$

B) **TURBULENT FLOW**: The turbulent flow is characterized by the fact that the fluid particles have a random and erratic motion with out any regular pattern as in eddies or a fixed frequency as in wave motion. No two fluid particles may have the same velocity and path.

The head loss in turbulent flow is given by the Darcy's equation stated as

$$h_f = flu^2/(2gd) \text{ where}$$

$f = 0.3164/R0.25$ for $4000<Re<10^5$

$g = 0.0032 + 0.221/Re0.237$ for $Re>10^5$

The head loss in turbulent flow is generally greater than that of laminar flow.

TURBULENT FLOW APPARATUS:

PROCEDURE:-

A) **LAMINAR FLOW**:-

1. Start the pump and open the valve to get a low initial discharge.
2. Note down the pressure readings from the manometer of the six points along the length of the pipe.
3. Collect 5 to 10 liter of oil in the collecting tank and note down the time of collection.
4. Note down the room temperature from the thermometer provided.
5. Repeat the above stops for six different discharges.

B) **TURBULENT FLOW**:-

1. Open the supply valve and select a suitable low initial discharge.
2. Collect 100 mm water in the collecting tank and note down the time of collection.
3. Note down the pressure readings of the eight points along the length of the pipe.
4. Repeat the above steps for sox different discharges.

SPECIMEN CALCULATIONS:-

A) **LAMINAR FLOW**:-

1. Find the discharge from the formula Q = volume collected /Time
2. h_1 = pressure head at section 1 in mm of mercury.
   h_2 = pressure head at the last section in mm of mercury
   Hence compute dp/dx.

3, Compute the viscosity from the relations
   $Q = (\pi d^4/128\mu)x(dp/dx)$ knowing Q, d, dp/dx. Also note down the viscosity from the standard chart at the room temperature.

4. $U_{max} = (1/4\mu)x(dp/dx)\ R^2$ m/s. Where R = pipe diameter = 28 mm.
5. Obtain the values of u at different radii from the equation $u = U_{max}(1 - (r/R^2))$m/s.
6. Power P $(p_1 - p_2)$ x Q W.
7. Reynold's number $Re = U_{mean}\ d / \mu$
8. Find f_{th} = 64/Re. Also compute f from the relation $hf = (f_{exp}\ l\ U^2mean)/(2gd)$
   Where hf is the head loss in the length l of the pipe.

B) **TURNULENT FLOW**:-

1. Obtain $h_{fitting}$ and $h_{friction}$ from the graph. Compute the discharge from Q = volume collected/Time m^3/s. Hence u = Q/area of the pipe m/s.
2. Find head loss coefficient from $h_{fitting}$ = Ku2/(2g)
3. From hf find the friction factor f using Darcy's equation $hf = flu^2/(2gd)$
4. $Re = Ud^3/\mu$
   Find f from the relations
   f = 0.3164/Re0.25 for $4000<Re<10^5$
   f = 0.0032 + 0.221/Re0.237 for $Re>10^5$

GRAPHS:- Plot the following graphs.

B) **LAMINAR FLOW**:-

3) Velocity profiles for each set of observations.
4) Log fth vs Log fexp vs Log Re on one sheet.
5) Power P vs Q.

C) **TURBULENT FLOW**:-

1. Head vs location of pressure taps.
2. K vs Re.
3. Log f_{th} vs Log Re and Log f_{exp} vs Log Re on one sheet.
4. l/d vs Re.

RESULTS:-

1. Comment on the velocity profile variations with increasing Reynold's number Re.
2. Comment on the discrepancies between the theoretical and experimental values of friction factor f.
3. Average value of head loss coefficient K=

Pipe diameter = 41.5 mm
Area of collecting tank = 890 x 890 mm
Height of collection = _______mm.

S.No.	Volume of water collected	Time of collection (s)	Discharge Q m3/s	Velocity U (m/s)	h fitting (m)	h friction (m)	K	Reynold's no. Re	$F_{experimenta}$	$F_{theorical}$

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ORIFICE METER
(A DISCHARGE MEASURING DEVIVEIN PRESSURE CONDUITS)

AIM:- To calibrate a orifice meter and to study the variation of coefficient of discharge with Reynolds number.

APPARATUS:- Orifice meter setup, collecting tank and a stop watch.

THEORY AND SIGNIFICANCE:- Orifice meter is a flow-measuring device, which falls under the class of meters called obstruction meters. Orifice meter as shown in the figure creates the required obstruction. A differential manometer is provided to measure the pressure difference before and after the orifice. Application of the continuity equation and the Bernoulli's equation between sections 1 and 2 corresponding to inlet and veenacontrata yields.

a: inlet
b: constriction

$$Q = \frac{A_1 A_2 \sqrt{2g}}{\sqrt{A_1^2 - A_2^2}} \sqrt{h} = K\sqrt{h}$$

Where
A_1 = area of cross section at the point inlet
A_2 = area of cross section at the constriction
h = differential pressure head in m of water flowing through the system if h m is the differential head in m of mercury then

$$h = hm \left(\frac{Sm}{S} - 1\right)$$

Where
Sm = specific gravity of manometer fluid (mercury)
S = specific gravity of the fluid flowing in the pipe.

It is used in the laboratories to measure discharge of a pump or a turbine. The obstruction meters are also used in chemical processing plants, water distribution systems and boiler plants.

The coefficient of discharge accounts for viscous effects of the flow and depends on Re and the ratio D_2/D_1. As the later if fixed, it depends on only Re generally for $Re>10^5$, Cd varies between 0.6 and 0.8

PROCEDURE:- The experiment is done to calibrate two orifice meters (25/15 and 50/30 mm). select one of these and proceed sequentially as follows.

1. Complete the manometer connections for the orifice meter selected, open the valve and set the discharge to the maximum practical value.
2. Allow the flow to stabilize. Note down the manometer readings h_1 and h_2 in mm of mercury. Corresponding to the manometer limbs.
3. Collect H (m) of water in the collecting tank and note down the time of collection t (s).
4. Repeat steps 2 to 4 for about 8 different discharge.
5. Select the next orifice meter and repeat the experiment.

SPECIMEN CALCULATIONS:-

i) Calculate the differential head. $hm = (h_1 - h_2)$ mm of mercury.
ii) Convert the head from mm of mercury to m of water head by plugging in the appropriate value in $h = \frac{hm}{1000}\left(\frac{Sm}{S} - 1\right)$
With Sm = 13.56 and S = 1.00

iii) Calculate the cross-section area and hence the theoretical discharge.

A_1 = area of inlet = $\pi D_1^2/4$
A_2 = area of throat = $\pi D_2^2/4$
$g = 9.81\ m/s^2$
$$Q_1 = \frac{A_1 A_2 \sqrt{2g}}{(A_1^2 - A_2^2)^{1/2}} \sqrt{h}$$

NOTE:- The inlet and throat diameters of the three orifices in the setup are as follows.

D_1 = inlet diameter in mm = 75,50 and 25
D_2 = orifice diameter in mm = 45,30 and 15

In the equation $Qt = \frac{A_1 A_2 \sqrt{2g}}{(A_1^2 - A_2^2)^{1/2}} \sqrt{h}$, the quantity in
Parenthesis is a constant and its value depends on the ratio of D_2/D_1.

iv) Volume of water collected = (0.64 H) m^3

v) Time of collection = t (s)
Hence actual discharge $Qa = \left(\frac{0.64\ H}{t}\right) m^3/s$

vi) Finally compute Cd = Qa/Qt

vii) To find the Reynolds number at the throat, first compute the throat velocity
$V_2 = Qa/A_2$

Reynolds number $Re = \frac{V_2 D_2}{v}$

Where v = kinetic viscosity of water
$= 1.00 \times 10^{-6}\ m^2/s$

PRECAUTIONS:-

1. While taking manometer readings, the upper meniscus of mercury should be considered.
2. Piezometer readings should not be taken when the water level fluctuates.
3. The flow through the orifice meter should be steady.

GRAPHS:- Plot the following graphs for both tubes.

i) Qa vs h
ii) Qa vs √h
iii) Log Qa vs Log h
iv).Cd vs Re
RESULTS:- Report the following average values

		50 / 30 Orifice meter	25 / 15 Orifice meter
(i)	Cd (experimental average)		
(ii)	K from Qa vs H graph		
(iii)	N from log – log graph		
(iv)	K from log – log graph		

Area of collecting tank = 0.64 m^2
Pipe diameter 'D' in mm = 75, 50 and 25
Orifice meter'd' in mm = 45, 30 and 15
d/D = 0.6 = 1.00x10-6 m^2/s

$A_1 = \pi D_1^2/4$	$A_2 = \pi D_2^2/4$	$K = \frac{A_1 A_2 \sqrt{2g}}{(A_1^2 - A_2^2)^{1/2}}$	$Qt = K\sqrt{h}$	Ht. of coll. (m)	Vol. of water coll. (m^3)	Time of coll. t (s)	Qa(m^3/s)	Cd=Qa/Qt	V_2= Qa/Qt	Re

S.No	Left limb reading (mm)	Right limb reading (mm)	hm mm of Hg	h, in m of water head