Module 2(b)

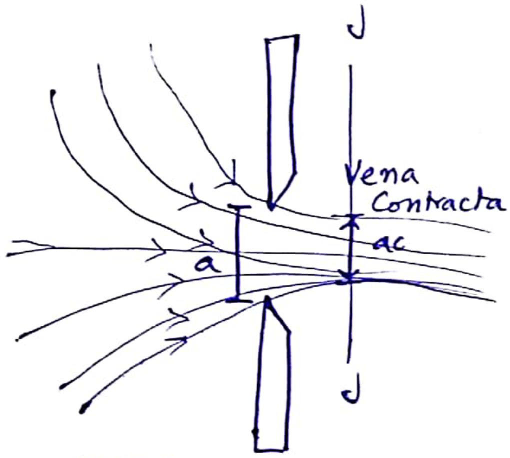
Orifice:-

The orifice is a small opening in the wall or base of vessel through which the fluid flows.

While mouthpiece is an attachment in the form of a small tube or pipe fixed to the orifice. Its length is usually two to three time the diameter of orifice.

Hydraulic Coefficients:-

The following are the hydraulic coefficients:



1- **Coefficient of Contraction (C_c)**

It is defined as the ratio of area of jet at Vena Contracta "a_c" to the area of orifice (a)

$$C_c = \frac{a_c}{a}.$$

$C_c = 0.61 - 0.69$

2 - **Coefficient of Velocity (C_v)**

It is defined as the ratio of actual velocity of the jet at vena Contracta "V_c" to the theoretical velocity "V_{th}"

$$C_v = \frac{V_c}{V_{th}} = \frac{V}{\sqrt{2gh}}$$

$C_v = 0.95 - 0.99$

The Section cc is approximately at a distance of half of dia of the orifice, At this Section the Stream line are straight and Perpendicular to plane of orifice (2)

Note:- The point at which the stream lines first become parallel is called Vena Contracta.

The cross Sectional area of the jet at vena Contracta is less than that of the orifice.

The theoretical velocity of jet at vena Contracta "V_{th}" is given by:

$$V_{th} = \sqrt{2gH}$$

This expression is called Torricelli's theorm.

3— <u>Coefficient of discharge</u> "Cd"

It is defined as the ratio of the actual discharge the orifice Q to the theoretical discharge Q_{th} - The Coefficient of discharge is equal to the product of Cc and Cv.

$$C_d = C_c \times C_v \quad \text{or} \quad C_d = \frac{Q}{Q_{th}} = \frac{\text{Actual area} \times \text{Actual velocity}}{\text{Th(area)} \times \text{Th (velocity)}}$$

4- <u>Coefficient of Resistance</u> "Cr"

It is defined as the ratio of loss of head in the orifice to the head of water available at the exit of the orifice.

$$C_r = \frac{\Delta H}{H_e}$$

Classification:-

1. Small orifice — head of liquid > 5d (d = depth of Orifice)
2. Large orifice — head of liquid < 5d (d = depth of orifice)

The Coefficient of velocity is determined experimentally by using the following relation (i.e)

$$C_v = \sqrt{\frac{x^2}{4yH}}$$

x = horizontal distance.
y = vertical distance.
H = Constant water head.

Discharge through Rectangular Orifice:-

(1) Discharge through a Small Rectangular Orifice:

An orifice is considered to be small, if the head of water above the orifice if over 5 time the height of the orifice.

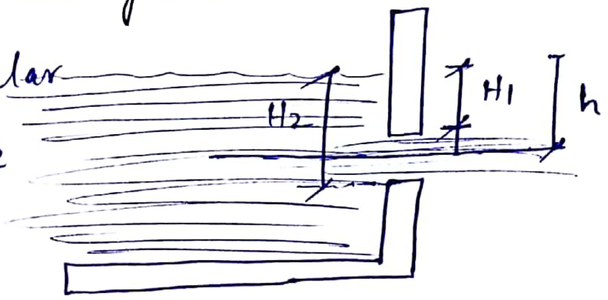
In a small rectangular orifice, the velocity of water in the entire cross section of the jet is approximately constant, so the discharge can be calculated by derived relation.

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

$$Q = cd . b \times d . \sqrt{2gh}$$

Cd = Coefficient of discharge for the orifice.
a = Cross sectional area of the orifice.
h = Height of the liquid above the centre of the orifice.
b = width of the orifice.
d = depth of the orifice.

(2) Discharge through a large Rectangular Orifice



With the large rectangular orifice, the velocity of the liquid particles is not constant, because there is a considerable variation of effective pressure head over the height of an orifice.

Velocity of liquid varies with the available pressure head of the liquid.

$$Q = \frac{2}{3} C_d . b \sqrt{2g} \left[H_2^{3/2} - H_1^{3/2} \right]$$

C_d = Coefficient of discharge.
b = breath of the orifice.
H_1 = Height of the liquid above the top of the orifice.
H_2 = Height of the liquid above the bottom of the orifice.

Problem:- A Large rectangular orifice of 1.5m wide and 0.5m deep is discharging water from a tank. If the water level in the tank is 3m above the top edge of the orifice, find the discharge through the orifice. Take coefficient of discharge for the orifice as 0.6

Given data:-

$b = 1.5m$
$d = 0.5m$
$H_1 = 3m$
$Cd = 0.6$

Required data:-

Discharge through orifice = $Q = ?$

Solution:-

Height of water above the bottom of the orifice, $H_2 = H_1 + d = 3 + 0.5$

$H_2 = 3.5m.$

As
$$Q = \frac{2}{3} Cd \cdot b\sqrt{2g}\left(H_2^{\frac{3}{2}} - H_1^{\frac{3}{2}}\right)$$

$$Q = \frac{2}{3} \times 0.6 \times 1.5 \times \sqrt{2 \times 9.81}\left((3.5)^{\frac{3}{2}} - (3)^{\frac{3}{2}}\right)$$

$$Q = \frac{2}{3} \times 0.6 \times 1.5 \times \sqrt{2\times9.81}\,(6.548 - 5.196)$$

$$Q = 0.6 \times 4.429 \times (6.548 - 5.196)$$

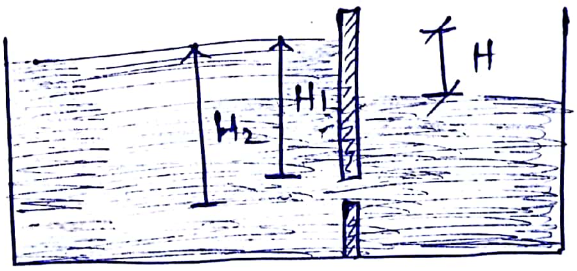
$$\boxed{Q = 3.59\ m^3/sec}$$

Discharge through the orifice, $Q = 3.59\ m^3/sec$

Discharge through a drowned Orifice:-

(1) Discharge through fully Sub-merged Orifice:-

It is one which has it whole of the outlet side submerged under liquid.



The coefficient of Contraction is equal to one $C_c = 1$

Discharge = Cd × Area × Velocity

$$Q = Cd \times b(H_2 - H_1) \times \sqrt{2gh}$$

H_1 = Height of water above the top of the orifice on the u/s side.

H_2 = Height of water above bottom of the orifice.

H = difference in water level.

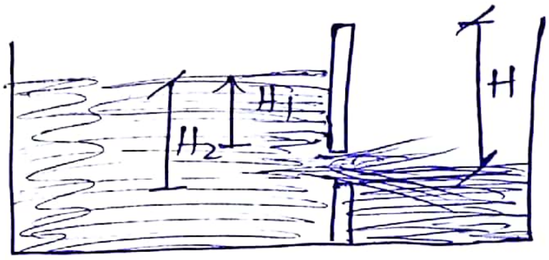
b = width of orifice.

Cd = Coefficient of discharge.

② Discharge through partially Submerged Orifice :-

It is one which has its outlet side partially Submerged under liquid

The upper portion behaves as orifice discharging free and Lower portion behaves as partially Sub-merged Orifice.



- Only Large orifice behaves as a partially Submerged orifice.

Discharge through Submerged Portion

$$Q_1 = Cd \times b(H_2 - H) \times \sqrt{2gH}$$

Discharge through Free portion.

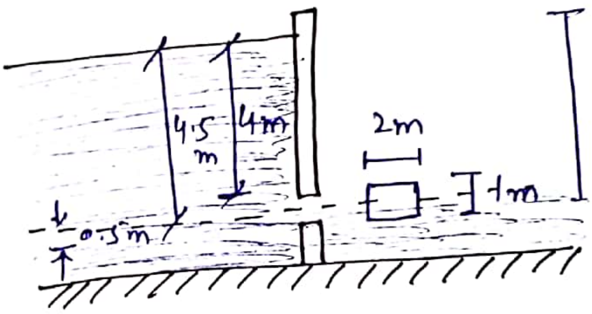
$$Q_2 = \frac{2}{3} Cd \times b\sqrt{2g}\left[H^{\frac{3}{2}} - H_1^{\frac{3}{2}}\right]$$

Total discharge $= Q = Q_1 + Q_2$

Problem:-

An orifice in one side of large tank is rectangular in shape, 2 meter broad and 1 meter deep. The water level on one side of the orifice is 4 meters above its top edge. The water level on the other side of the orifice is 0.5 meter below its top edge as shown in figure.

Calculate the discharge through the orifice if $Cd = 0.63$.



Given data:-

$b = 2m$

$d = 1m$

$H_1 = 4m$

$H_2 = 4 + 1 = 5m$.

$H = 4 + 0.5 = 4.5m$.

$Cd = 0.63$.

Required:- $Q = ?$

Solution:- Discharge through Submerged Portion

$$Q_1 = cd \times b \times (H_2 - H) \times \sqrt{2gH}$$

$$Q_1 = 0.63 \times 2(5 - 4.5) \times \sqrt{2 \times 9.81 \times 4.5}$$

$$Q_1 = 5.92 \ m^3/sec.$$

Discharge through free portion.

$$Q_2 = \frac{2}{3} Cd \times b\sqrt{2g}\left[H^{\frac{3}{2}} - H_1^{\frac{3}{2}}\right]$$

$$Q_2 = \frac{2}{3} \times 0.63 \times 2\sqrt{2\times9.81}\left[(4.5)^{\frac{3}{2}} - (4)^{\frac{3}{2}}\right]$$

$$Q_2 = 2.88\ m^3/sec.$$

Total discharge $= Q = Q_1 + Q_2$.

$$Q = 5.92 + 2.88$$

$$\boxed{Q = 8.8\ m^3/sec}$$

Problem:- A drowned orifice 1.5m wide and 0.5m deep is provided in one side of the tank. Find the discharge in Liters/sec through the orifice. if the difference of water level on the both side of the orifice be 4m. Take $Cd = 0.64$.

Given:-

$b = 1.5m$

$d = 0.5m$

$h = 4m$

$Cd = 0.64$

Required:-

$Q = ?$

Solution:-

$$Q = cd \times b(H_2 - H_1) \times \sqrt{2gh}$$

$$Q = 0.64 \times 1.5\,(0.5) \times \sqrt{2\times9.81\times4}$$

$$Q = 4.25\ m^3/sec \Rightarrow \boxed{Q = 4250\ liters/sec}$$

Water Hammer:-

When a liquid flowing through a long pipe is suddenly brought to rest by closing the value at the end of pipe, then a pressure wave of high intensity is produced behind the value. This pressure wave of high intensity has the effect of hammering action on the walls of the pipe. This phenomenon is known as water hammer or hammer blow.

The Magnitude of water hammer depends upon.

(a) The Length of pipe line.

(b) The elastic properties of pipe Material.

(c) The elastic properties of the liquid flowing through the pipe.

(d) The speed at which the value is closed.

Discharge Over different types of weirs:-

① Rectangular Weir:-

$$Q = \frac{2}{3} Cd . L \sqrt{2g} \, H^{\frac{3}{2}}$$

L = Length of wier.

Cd = Coefficient of discharge.

H = Height of water above the crest of the wier.

Problem:- A wier of 8m Long is to be built across a rectangular channel to discharge a flow of $9 m^3/sec$ - if the maximum depth of water on the upstream side of weir is to be 2m, what should be the height of the weir? Adopt Cd = 0.62.

Given data:-

L = 8m

$Q = 9 m^3/sec$

Depth of water on upstream side = 2m

Cd = 0.62

Required:- Height of wier = ?

Solution:-

As

$$Q = \frac{2}{3} Cd. L \sqrt{2g} \; H^{\frac{3}{2}}$$

H = Height of water above crest.

$$q = \frac{2}{3} \times 0.62 \times 8 \sqrt{2 \times 9.81} \times H^{\frac{3}{2}}$$

$$q = 14.65 \, H^{\frac{3}{2}}$$

$$H^{\frac{3}{2}} = \frac{9}{14.65}$$

$$\boxed{H = 0.72m}$$

Therefore Height of wier should be = 2 − 0.72

= 1.28m

Answer.

② **Cippoletti Wier:-**

Problem:- water is flowing over a Cippoletti weir of 4meters long under a head of 1meter Compute the discharge, if the coefficient of discharge for the weir is 0.62.

Given data:-

L = 4m

H = 1 m

Cd = 0.62.

Required:- Q = ?

Solution:- As .

$$Q = \frac{2}{3} \times C_d . L\sqrt{2g} \times H^{\frac{3}{2}}$$

$$Q = \frac{2}{3} \times 0.62 \times 4 \times \sqrt{2 \times 9.81} \times 1^{\frac{3}{2}}$$

$$Q = 7.32 \times 1$$

$$\boxed{Q = 7.32\ m^3/sec}$$