FLOW THROUGH SHARP EDGED ORIFICE

OBJECTIVES:

(a) To determine the coefficient of discharge of the sharp edged orifice.

(b) To measure the trajectory of a jet emerging from the orifice and determine coefficient of velocity and coefficient of contraction for the orifice.

(c) To measure time to lower the water level in the tank drained by the orifice and compare the value with that obtained from theory.

SCOPE :

An orifice is used to discharge liquid into the atmosphere from reservoirs, tanks and conduits. Orifices provided in dams to supply water to canals. Orifice are fitted into storage tanks also. In such example, it is essential to know the actual discharge flowing through the orifice and the time require to empty the tanks when flow takes place through. They are determined by knowing the jet characteristic and the hydraulic constants of the orifice. Coefficient of discharge c_d, coefficient of velocity c_v and coefficient of contraction c_c are the three orifice constants. Coefficient of discharge enables us to calculate actual flow rate through the orifice. Coefficient of velocity enables us to calculate the actual velocity of flow. Coefficient of contraction and coefficient of velocity also enable indirect calculation of the coefficient of discharge. This experiment illustrates the technique of determining these coefficients and the valves obtained thus can be compare

APPARATUS :

(a) Hydraulic bench

(b) Orifice tank

(c) Stop watch.

THEORY :

(a) Theoretical discharge through the orifice

$$Q_{th} = A_T\sqrt{2g\,H}$$

Where, A_T = Area of the orifice

H = Height of the orifice

g = Acceleration due to gravity

(b) Actual discharge $(Q_a) = w/T$.

(c) Coefficient of discharge $(C_d) = Q_a/Q_{th}$

(d) Coefficient of velocity $(C_v) = \frac{X}{2}\sqrt{\frac{1}{YH}}$

Where, X = Distance from the orifice to a point in the jet trajectory

Y = Drop from the orifice at the point where X is measured.

(e) Coefficient of contraction $(C_c) = C_d / C_v$.

(f) Time required lower the water level from H_1 to H_2 in the tank.

(g) Show the figure of apparatus

$$T = T = \frac{2 A_T}{C_d A_1 \sqrt{2g}} \left(\sqrt{H_1} - \sqrt{H_2}\right)$$

Where, A_T = Area of the tank.

EXPERIMENTAL PROCEDURE :

(a) Connect the hydraulic bench supply to the orifice tank.

(b) Close the main delivery valve and start the pump.

(c) Open the valve and allow water level in the cylinder to settle at around 500mm above the orifice. Check that the level is constant at this level. Allow conditions to settle.

(d) Determine the discharge by timing the mass of water collected in the measuring tank.

(e) Note H and continue to do so during the discharge measurement process and determine an average H.

(f) Repeat the procedure five more times by reducing flow and at each stage measure the flow rate and head.

(g) At three of the values of H, measure the trajectory of the jet by taking reading of horizontal distance from the orifice (X) against the vertical drop Y. At orifice X = 0, Y = 0

(h) Restore the head to a convenient value in the cylinder and close the supply valve. Note the time taken for the level to drop from say 450mm to 200mm above the orifice. Repeat two further times and calculate average time to lower the water level.

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Observation table

Number of observations	Head H mm	Mass of water collected kg.	Time
1	230	5kg	1: 2328
2	314	5kg	1: 12.93
3	350	5kg	1:04.48
4	373	5kg	1:03.20
5	490	5kg	0 ; 59.59
6			

Observation table

Number of observations	X mm	0	5	10	15	20	25	30	35	40
1	Y mm		36	56	82	117	157			
2	Y mm		34	39	69	95	126	163		
3	Y mm		32	44	62	83	110	142		

Observation table

Number of observations	Head mm		Time in Sec.	Average time in Sec.
	H_1	H_2		
1	50	20	0:21.73	
2			21.99	
3			21.65	

97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108

CALCULATION :

a) Actual discharge Q_a.

b) Theoretical discharger Q_{th}.

c) C_d for each test conducted and compute average value of C_d.

d) Determine C_v and C_c.

e) Compare the time taken to lower the level to that calculated by theory.

f) Coefficient of discharge C_d.

g) Coefficient of velocity C_v.

h) Coefficient of contraction C_c.

i) Plot actual discharge Q versus H and actual discharge Q versus $H^{1/2}$

PRESENTATION :

a) Show a sample calculation

b) Present the result in a tabular form

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Calculation table

Number of observation	Water level H m	$\sqrt{H}$	Theoretical discharge Q_{th} m^3/s	Actual discharge Q_a m^3/s	Coefficient discharge C_d	Coefficient of velocity C_v	Coefficient of contraction C_c	Actual taken to empty tank Sec.	Calculated time to empty tank sec.
1									
2									
3									
4									
5									
6									

COMMENTS :

Comment on your results. Also comment on the accurancy of the results.

Dhagyan Shrestha
074BCE104

VERIFICATION OF BERNOULLIS THEOREM

OBJECTIVE :

To compute total heads at different point in a venturimeter and verify Bernoullis' theorem.

SCOPE :

Bernoulli's theorem is one the fundamental principles of fluid flow. Its verification leads to better understanding of fluid flow circumstances through various devices.

APPARATUS :

(a) Hydraulic bench

(b) Orifice tank

(c) Stop watch.

THEORY :

(a) For a horizontal pipe the total head

$$H = P_1 / r + V_1^2 /2g = P_2 / r + V_2^2 / 2g$$

Where, p_1/r, p_2/r = Pressure head

V_1, V_2 = Velocity of flow

(b) Actual discharge (Q_a) = V/T.

EXPERIMENTAL PROCEDURE :

(a) Connect the venturimeter with the hydraulics bench

(b) Close the main delivery valve and start the pump.

(c) Allow sufficient flow to pass through the venturimeter by gradually operating the valve so that a head different of about 200mm is obtained. Allow the condition to settle.

(d) Note the piezometer reading Ha, Hb, Hc and Hd.

(e) Determine the actual flow rate by timing the mass of water collected in the measuring tank.

(f) Repeat for five more observations.

(g) Show figure of apparatus

Pradyan Shrestha
074BCE104

20 20 10 20

OBSERVATION :

Inlet diameter = 20

Pipe diameter = 10

Throat diameter = 20

Observation table

Number of observations	Peizometric reading mm				Mass of water collected kg	Time s.
	Ha	Hb	Hc	Hd		
1	23.3	23.2	12.8	20.5	5kg	39.3
2	27.3	26.8	14.4	23.3	5kg	34.9
3	30.9	30.6	16.0	26.4	5kg	32.6
4	36.3	36.2	20.5	32.0	5kg	31.38
5	39.3	39.2	22.2	34.3	5kg	29.6
6	45.2	45.0	25.5	39.8	5kg	28.3

CALCULATION :

a) Actual discharge Q_a.

b) Velocity at points a, b, c, d .

c) Velocity head $V^2/2g$ at each points.

PRESENTATION :

a) Present one sample calculation

b) Present your result in the tabular form.

97, 98, 99, 100, 101, 102, 103, 104, 103, 106, 107, 108

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Pragyan Shrestha 074BCE124

Observation table

Number of observations	Points	Pressure head m	Discharge Q_a m^3/s	Area A m^3	Velocity m/s	Velocity Head m	Total Head m
1	a b c d						
2	a b c d						
3	a b c d						
4	a b c d						
5	a b c d						
6	a b c d						

(c) Plot the pressure head and velocity head along the duct graphically.

(d) Join the point indicating the velocity and pressure heads.

Comments :

Comment on the results. What inference do you get from the line joining pressure head points.

Pragyan Shrestha 074BCE104

STABILITY OF A FLOATING BODY

OBJECTIVE :

To determine the metacentric height of a simple floating body and to investigate how the metacentric height varies with changes in the position of the centre of gravity.

SCOPE :

Metacentric height of a floating object determine its stability. The study of variation of metacentric height with position of centre of gravity enables us to analyse the stability of floating bodies.

APPARATUS :

(a) Pontoon

(b) Trough

THEORY :

(a) $BM = \frac{I}{V}$

Where, BM = Distance between centre of buoyancy and metacentre

I = Moment of Inertia

V = Displaced Volume

(b) $OB = \frac{V}{2\,LB}$

Where, OB = Distance between base of the pontoon and the centre of buoyancy

V = Displaced volume

L = Length of pontoon

B = Breadth of pontoon

(c) $GM = \frac{W}{W}\left(\frac{dx}{d\theta}\right)$

Where, GM = Metacentric height

W = Total weight of the pontoon

dx = Lateral displacement

dθ = Angle of tilt for the displacement [illegible]

(d) OG = OB + BM − GM (refer figure 1)

Prajyal Shrestha
07ABCE104

EXPERIMENTAL PROCEDURE :

(a) Place the water through on a table and fill it three fourth with water.

(b) Place the pontoon on the trough.

(c) Place the lateral weight on the centre of the horizontal bar and adjust the plumb to give zero reading on the scale.

(d) Place the mast weight at its lowest position and note its height above the base of the pontoon.

(e) Move the lateral weight a distance of x along the cross horizontal bar to give a tilt to the right.

(f) At this position of the lateral weight, note x and θ.

(g) Repeat step (e) to get a tilt to the left and note x and θ.

(h) Repeat steps (e), (f) and (g) for five more positions of the mast above the base of the pontoon.

(i) Show figure of apparatus

OBSERVATION :

Length of the pontoon L = 36cm

Breadth of the pontoon B = 20.05 cm

Weight of the pontoon W = 2600gm

Lateral weight W = 500gm

Height = 7.5 cm

97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108,

Observation table

Number of observations	Position of Mast Above Base mm	Lateral Weight Shifted to			
		Left		Right	
		x mm	θ	x mm	θ
1	140-17	102-55	3	102-65	3
2	~~168~~ 182-17	102-40	5	102-65	3.5
3	207-17	102-40	5.5	102-48	5.25
4	241-17	102-55	4.5	102-48	6
5	282-17	102-55	6	102-55	7
6	298-17	102-64	5.5	102-68	5.5

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W = 526gm

V = 0.000526 m³

CALCULATION :

(a) Centre of buoyancy above the base of the pontoon.

(b) BM

(c) Average angle of tilt θ^0

(d) The metacentric height GM

(e) The position of centre of gravity from the base and find OG for each position of the mast weight.

PRESENTATION :

a) Show a sample calculation

b) Present the result in a tabular form.

Observation table

Number of observations	Height of centre of gravity above abase OG	Average tilt θ^0	$\frac{dx}{d\theta}$	Metacentric height Gm	Height of metacentric above base OM
1					
2					
3					
4					
5					
6					

(c) Plot Metacentric height GM versus height of centre of gravity above base OG.

Height above centre of gravity OG versus $\frac{dx}{d\theta}$

Comments :

Comment on the effect of position of centre of gravity on stability. How do the experimental and theoretical calculation of metacentre corroborate.

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HYDROSTATIC FORCE ON A SUBMERGED SURFACE

OBJECTIVE :

To measure the moment, about a knife edge of the hydrostatic force on a fully immersed plane vertical surface and to compare this moment with that derived from theory.

SCOPE :

All surfaces that are in contact with water experience force. All water retaining structures must be designed to withstand water pressure. This experiment helps to determine the hydrostatic force on a plane surface.

APPARATUS :

(a) Centre of pressure apparatus with weights.

THEORY :

(a) The moment about the pivot of the water pressure on the cully immersed plane vertical face is

$$M_{th} = \rho g \overline{y} b d \left(a + \frac{d}{2} + \frac{d^2}{12\overline{y}} \right) \quad \overline{Y} = \left(Y - \frac{d}{2} \right)$$

Where, M = Moment due to the force

b = Breadth of the plane face of a quard

d = Depth of the plane face

a = Distance of edge of plane face from the knife edge

y = Bottom edge of the plane below water surface

(b) The moment is also measured experimentally by putting a mass must a distance 1 from the knife edge.

$$M_E = mgl$$

Equating

$$mgl = \rho g \overline{y} b d \left(a + \frac{d}{2} + \frac{d^2}{12\overline{y}} \right) \quad \overline{Y} = \left(Y - \frac{d}{2} \right)$$

EXPERIMENTAL PROCEDURE :

(a) Place the apparatus on a level table.

(b) Measure l, b, a and d in metre.

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(c) With no water in the apparatus, check that the plane face is vertical and make a preliminary balance by using the empty mass longer and the adjustable screw at the end. In the balanced position the beam just lifts off its underside preset stop.

(d) Add water to the perspex quadrant until the level of water is just above the top edge of th4e plane under test.

(e) At this stage add masses in the mass area until the balance is restored Note y_1 and w_1. It might be essential to add little water to get exact balance.

(f) Put addition mass on the m_1 (to give m_2) and carefully and water to restore the balance. Note y_2.

(g) Repeat the procedure for six more readings.

(h) Show figure of apparatus

OBSERVATION :

Moment arm l = 275 mm

Breadth of the plane face b = 75mm

Depth of plane face d = 100mm

Distance of top edge of the face from knife edge n a = 100

Observation table

Number of observations	Depth of water y mm	Mass added ~~Kg~~
1	107	250g
2	112	270
3	116	290
4	129	340
5	141	390
6	143	400

97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108

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075BCE104

Pragyan
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CALCULATION :

(a) Theoretical moment M_{TE}

(b) Experimental moment M_E

(c) $H = (a - y)(y - d)$

PRESENTATION :

a) Show a sample calculation

b) Present the result in a tabular form.

(c) Plot between experimental moment M and H.

Calculation table

Number of observations	Weight added N	Experimental Moment M_E Nm	Depth of water y m	Depth Hm	Theoretical moment M_{sh} Am	Remarks
1						
2						
3						
4						
5						
6						

Comments :

Comment in the significance of the result and accuracy of the experiment.

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To determine the coefficient discharge flow over the broad crested weir on long flume

$\theta = A \times V$

Where,

θ = Discharge

A = Area of the orifice

V = Velocity

and

diameter of orifice = 60mm

V determines by the head different when water flows through the orifice the inlet and outlet of the manometer tubes are connected on the manometer. In the manometer shows the head different which is import to note down.

or $H = h_1 - h_2$ (mm)

$\theta_{th} = 170B\ H^{3/2}$

θ_{th} = theoretical discharge

B = Breadth of the flume (300mm)

H = measures by the needle gauge

and

depth of the weir measures by the needle gauge after installed on the flume.

Observation table

Series no. $H_1 - H_2 = V$; (manometer varies reading)

B = 300mm constant flume width

H of above broad creased weir

Depth (d) = broad crested weir

Orifice (ai) = 60mm0

S. No $H - V = (H_1 - H_2 =)$

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(e) Note the depth causing flow (relative to the apron) about 500mm upstream from the weir.

(f) Determine the volume flow rate by timing a known volume through the meter.

(g) Repeat for apron depth, 8, 10, 12, 15, 18 and 20mm.

OBSERVATION :

Number of observations	Head H	Volume m^3	Time Sec.
1	110/89	$0.1m^3$	1:17.10
2	122.3/96.8		0:48.02
3	133.5/101.2		0:37.41
4	139.3/104.6		0:33.98
5	141.4/106.6		0:30.47
6	148.1/110.1		0:27.14

97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108

CALCULATION :

(a) Actual discharge Q_a.

(b) Theoretical discharge Q_{th}.

(c) Coefficient of discharge C_d.

(d) Show the figure of the apparatus and simple description.

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PRESENTATION :

(a) Show a sample calculation.

(b) Present the result in a tabular form.

Number of observations	Actual discharge Q_a m^3/s	Head H m	$H^{3/2}$	Theoretical discharge Q_{th}	Coefficient of discharge C_d
1					
2					
3					
4					
5					
6					

(c) Plot actual discharger Q_a versus depth H.

COMMENTS :

Comment on the variation of C_d accuracy of depth measurement and effect of velocity of approach on the discharge. Discuss its applications to discharge measurement.

Pragyan Shrestha
074BCE104

IMPACT OF JET

OBJECTIVE :

To measure the force exerted by a jet on a fixed vane and compare the magnitude of this force with the force obtained by theory.

SCOPE :

The momentum equation has wide applications in many engineering systems like turbines, pumps and other rotodynamic machines. Study of impact of jet on fixed vanes enables one to calculate the forces essential for the analysis of flow through machines.

APPARATUS :

(a) Hydraulic bench

(b) Jet impact apparatus

(c) Stop watch.

THEORY :

(a) Theoretical force due to jet of water on a vane

$$F_{th} = K \rho A V^2$$

Where, K = Coefficient depending the shape of the vane

F_{th} = Theoretical force on the vane

ρ = Density of water = 1000

A = Area of jet = 8mmϕ

V = Velocity of jet. m/s

The value of K for different shaped vanes are as follows :

K = 0.5 for 45° vane

K = 1.0 for flat vane

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Observation table

Number of observations	Mass of water collected			Time in sec		
	120	flat	Hemi-spherical	Flat	120°	Hemi-spherical
1	100	100	100	~~100~~ 25.81	34.30	35.08
2	120	120	120	24.68	29.17	32.75
3	150	150	140 (150)	22.14	26.14	30.30 (29.35)
4	170	170	160 (170)	20.68	25.23	28.39 (27.46)
5	190	190	190	19.43	23.64	26.98
6	210	210	210	18.47	22.15	25.03

CALCULATIONS:

(a) Actual discharge (Q_a) = v/t

(b) Velocity of flow (V) = Q_a/A

(c) Theoretical force (F^{th}) = $k\rho av^2$

k = coefficient of vane

a = area of vane

v = velocity

~~97~~, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107

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K = 1.5 for 120° vane

K = 2.0 for hemispherical vane

(b) Actual discharge (Q_a) = v/T.

EXPERIMENTAL PROCEDURE :

(a) Connect the jet impact apparatus to the hydraulic bench supply point.

(b) Using the level and balance weight, adjust the apparatus so that the gauge reads zero at level position.

(c) Close the main delivery valve and start the pump.

(d) Raise the flow carefully in stages balancing the level at each stage by turning the screw in the gauge (balancing weight should not be touched once adjusted). Note the maximum force. Reduce the flow to zero adjusting the balancing force at each stage until the balance level in zeroed conditions is restored.

(e) Increase the flow so that one fifth of the maximum force indicated in (d) is exerted on the vane after leveling. Allow condition to settled.

(f) Note the force indicated in the gauge.

(g) Determine the actual flow rate by timing the mass of water collected in the measuring tank.

(h) Repeat five more times until the maximum force is reached.

(i) Show the figure of apparatus

OBSERVATION :

Nozzle diameter

Vane type (K)

Lever arm ratio