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Subject Hydraulic Engineering
(2 credit hours)

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Q1 (A)

Let suppose a rectangular channel, discharges R Lit/sec of water into a 8m wide open with zero slope.

Calculate:-

=> Height of Hydraulic Jump

=> Power absorbed due to Hydraulic Jump

Given:-

Discharge $Q = 7480$ Lit/sec

$= \frac{7480}{1000} = 7.48 \text{ m}^3/\text{sec}$

Breadth $= 8\text{m}$

Mean Velocity $V = 7480 - 220$

$= 7260 \text{ ft/sec}$

$= \frac{7260}{3.28} = 2213.41 \text{ m/sec}$

=> Height of Hydraulic Jump:-

As we know that "q" → discharge per unit breadth

$q = \frac{Q}{b} = \frac{7.48}{8} = \boxed{0.935 \text{ m}^2/\text{sec}}$

Critical depth:-

$y_c = \left(\frac{(q)^2}{g}\right)^{1/3} = \left(\frac{(0.935)^2}{9.81}\right)^{1/3}$

$\boxed{y_c = 0.446}$

Critical Velocity:-

As we know

$$q = vy \Rightarrow v = q/y$$

$$V_c = q/y_c$$

$$V_c = \frac{0.935}{0.44}$$

$$\boxed{V_c = 2.125}$$

Depth of water on upstream side:-

Using discharge formula

$$Q = AV$$

$$Q = (b \times y) \cdot v$$

$$y = \frac{Q}{v \cdot b} \Rightarrow y_1 = \frac{Q}{V_1 \cdot b}$$

$$\Rightarrow y_1 = \frac{7.48}{2213.4 \times 8} = \boxed{y_1 = 0.000422\,m}$$

Also,

By using formula we can find water depth on downstream side

$$\Rightarrow y_2 = \frac{-y_1}{2} + \sqrt{\frac{v_1^2}{4} + \frac{2 y_1 V_1^2}{g}}$$

$$= -\frac{0.000422}{2} + \sqrt{\frac{(0.000422)^2}{4} + \frac{2(0.000422)(2213.4)^2}{9.81}}$$

$$y_2 = 20.53 \, m$$

Difference in Depth :-

$$\Delta y = y_2 - y_1$$

$$= 20.53 - 0.000422$$

$$\Delta y = 20.53$$

By discharge formula

$$Q_1 = Q_2$$

$$A_1 V_1 = A_2 V_2$$

$$(b_1 . y_1) V_1 = (b_2 . y_2) V_2$$

$$b . y_1 . v_1 = b . y_2 . v_2 \qquad (\because b = b_1 = b_2)$$

$$y_1 V_1 = y_2 V_2$$

$$\Rightarrow V_2 = \frac{y_1 V_1}{y_2} = \frac{(0.000422)(2213.4)}{20.53}$$

$$V_2 = 0.045 \, m/sec$$

As we know that

$$\Delta E = E_1 - E_2$$

$$E_1 - E_2 = \left(y_1 + \frac{V_1^2}{2g}\right) - \left(y_2 + \frac{V_2^2}{2g}\right)$$

$$= \left(0.000422 + \frac{(2213.4)^2}{2(9.81)}\right) - \left(20.53 + \frac{(0.045)^2}{2(9.81)}\right)$$

$$= 249701.30 - 20.53$$

$$E_1 - E_2 = 249680.77$$

Power Dissipation In Hydraulic Jump:-

By using formula

$$\Delta p = \rho g Q (E_1 - E_2)$$

$$= (1000)(9.81)(7.48)(249680.77)$$

$$\Delta p = 1.832 \times 10^{10} \text{ W}$$

$$\Delta p = 18321275.29 \text{ KW}$$

Q1 (B)

A sluice gate controls - - - - -
- - - - downstream velocity

Given Data:-

Channel width $(b) = 4m$

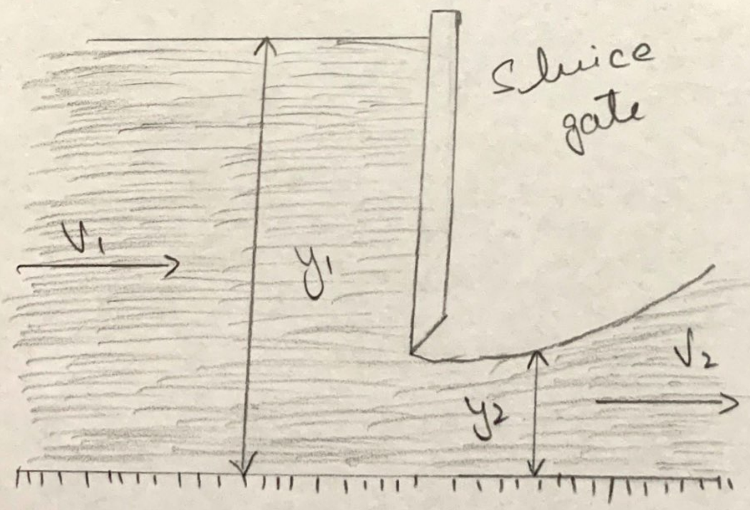
Discharge $= 7480\ ft^3/sec$

$= \frac{7480}{(3.28m)^3}$

$= 211.97\ m^3/sec$

Depth on upsteam side $= 2.9m$

Depth on downstream side $= 1.1m$



Solution :-

First we have to find downstream velocity

1) Downstream velocity :-

As from specific energy equation

Specific energy remains same on both streams

So,

$$E_1 = E_2$$

$$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g} \quad \text{---} (1)$$

from Discharge equation

$$Q = AV$$

$$Q = A_1 V_1 = A_2 V_2$$

$$(b_1 y_1) . V_1 = (b_2 y_2) V_2$$

As $b = b_1 = b_2$

$$\cancel{b} . y_1 . V_1 = \cancel{b} . y_2 . V_2$$

$$y_1 V_1 = y_2 V_2$$

$$\Longrightarrow V_2 = \frac{y_1 V_1}{y_2}$$

$$V_2 = \frac{2.9}{1.1} V_1 = \boxed{V_2 = 2.63 V_1}$$

Put the V_2 value in eq (1)

$$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g}$$

$$2.9 + \frac{V_1^2}{2g} = 1.1 + \frac{(2.63 V_1)^2}{2g}$$

$$\frac{V_1^2}{2(9.81)} - \frac{6.91 V^2}{2(9.81)} = 1.1 - 2.9$$

$$-\frac{5.91 V_1^2}{19.62} = -1.8$$

$$5.91 V_1^2 = 1.8$$

$$V_1 = \sqrt{\frac{1.8 \times 19.62}{5.91}}$$

$$\boxed{V_1 = 2.44 \text{ m/sec}}$$

Put this value in "V_2"

$$V_2 = 2.44(2.63)$$

$$\boxed{V_2 = 6.41 \text{ m/sec}}$$

Types of Flow determination:-

ON upstream Side:-

By using Froud Number

$$Fr_1 = \frac{V_1}{\sqrt{gy_1}} = \frac{2.44}{\sqrt{9.81 \times 2.9}} = 0.45$$

$0.45 < 1$

↓

Sub-critical flow

($Fr < 1$)

ON Downstream Side:-

Using Froud Number

$$Fr_2 = \frac{V_2}{\sqrt{gy_2}} = \frac{6.41}{\sqrt{9.81 \times 1.1}} = 1.95$$

$1.95 > 1$

↓

Super critical Flow

($Fr > 1$)

Q 2 (A)

What is the maximum - - -

- - - - - width is 66ft

Given:-

Channel depth $(d) = 1.8m$

Discharge $= 7480\ ft^3/sec$

$$= \frac{7480}{(3.28)^3} = 211.97 m^3/sec$$

width of Channel $(b) = 66ft$

$$\frac{66}{3.28} = 20.1m$$

Weir Height $(P) = ?$

Solution:-

By using discharge formula

$$Q = AV$$

$$V = Q/A \rightarrow V_1 = \frac{Q}{A_1} \rightarrow V_1 = Q/b \times y$$

$$V_1 = \frac{211.97}{20.1 \times 1.8} = \boxed{5.858 m/sec}$$

Critical Depth:-

By formula

$$y_c = \left(\frac{(q)^2}{g}\right)^{1/3}$$

where $q = Q/b$

$$= \frac{211.97}{20.1} = 10.54 \ m^2/sec$$

So,

$$y_c = \left(\frac{(10.54)^2}{9.81} \right)^{1/3}$$

$$\boxed{y_c = 2.24 m}$$

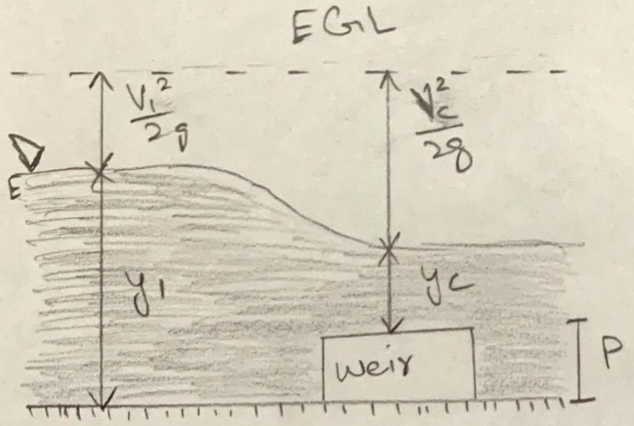
Also

$$V = \sqrt{gy}$$

$$V_c = \sqrt{g y_c}$$

$$V_c = \sqrt{9.81 \times 2.24}$$

$$\boxed{V_c = 4.687 \ m/sec}$$



According to the figure

$$\frac{V_1^2}{2g} + y_1 = \frac{V_c^2}{2g} + y_c + P$$

$$\frac{(5.85)^2}{2 \times 9.81} + 1.8 = \frac{(4.687)^2}{2 \times 9.81} + 2.24 + P$$

$1.744 + 1.8 = 1.1196 + 2.24$

$3.544 = 3.359 + P$

$$\boxed{P = 0.185m}$$

The weir should have height of 0.185m measured from the channel bed.

Q2 (B)

An orifice in one side - - - -

- - - - - - - coefficient of discharge is cd= 0.R

Given:-

Breadth (b) = 2.8m

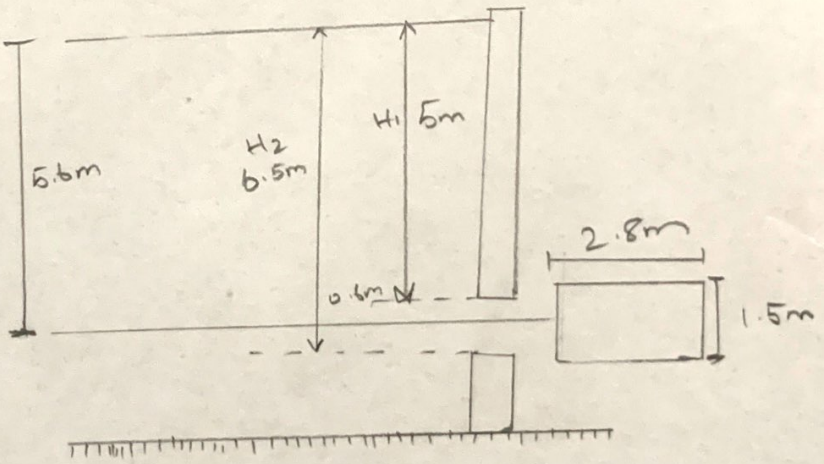
Depth (d) = 1.5m

$H_1 = 5m$

$H_2 = 5m + 1.5m = 6.5m$

$H = 5m + 0.6m = 5.6m$

$cd = 0.7480$



Solution:-

Discharge through Submerged Portion:-

By using formula

$Q_1 = cd \times b \times (H_2 - H_1) \times \sqrt{2gH}$

$= 0.7480 \times 2.8 (6.5 - 5.6)(\sqrt{2(9.81)(5.6)})$

$Q_1 = 19.758 \ m^3/sec$

Discharge through Free Portion:-

By using formula

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

$$= \frac{2}{3}(0.7480) \times (2.8)\sqrt{2\times9.81} \times \left[(5.6)^{3/2} - (5)^{3/2}\right]$$

$$\boxed{Q_2 = 12.81\ m^3/sec}$$

Now Total discharge will b

$$Q = Q_1 + Q_2$$

$$Q = 19.758 + 12.81$$

$$\boxed{Q = 32.568}$$

Q3 (A)

The diameter of a water pipe - - -

- - - - larger pipe is R+800 N/m²

Calculate

1) The loss of Head due to sudden enlargment

2) The power lost due to sudden enlargment

3) The pressure in the smaller pipe (If the pipe is horizontal)

Given:-

$d_1 = R - 200mm$

$d_1 = 7480 - 200 = 7280mm$

$d_2 = R + 3000mm$

$= 7480 + 3000 = 10480$

Flowrate $(Q) = 0.95 m^3/sec$

Pressure in larger Pipe $= R + 800 \, N/m^2$

$= 7480 + 800$

$= 8280 \, N/m^2$

Solution

1) Head loss due to sudden enlargement:-

$d_1 = 7280mm = 7.28m$

$\Rightarrow A_1 = \frac{\pi}{4}(d_1)^2 = \frac{\pi}{4}(7.28)^2$

$$\boxed{A_1 = 43.45m^2}$$

$d_2 = 10480mm = 10.48m$

$A_2 = \frac{\pi}{4}(d_2)^2 = \frac{\pi}{4}(10.480)^2$

$$\boxed{A_2 = 90.06m^2}$$

By discharge formula

$$Q = AV$$

$$V = Q/A$$

$$\Rightarrow V_1 = Q/A_1 = \frac{0.95}{43.45} = \boxed{0.021\ m/sec}$$

Similarly

$$V_2 = \frac{Q}{A_2} = \frac{0.95}{90.06} = \boxed{0.0105\ m/sec}$$

By formula of sudden Enlargement :-

$$h_e = \left(1 - \frac{A_1}{A_2}\right)^2 \times \left(\frac{(V_1 - V_2)^2}{2g}\right)$$

$$= \left(1 - \frac{43.45}{90.06}\right)^2 \times \frac{(0.021 - 0.0105)^2}{2(9.81)}$$

$$= (0.267)(5.6192 \times 10^{-6})$$

$$\boxed{h_e = 1.5003 \times 10^{-6}\ m}$$

2) Power Loss due to sudden enlargment

By formula

$$P = \rho g Q h_e$$

$$= (1000)(9.81)(0.95)(1.5003 \times 10^{-6})$$

$$\boxed{P = 0.013\ W}$$

3) Pressure in Smaller Pipe:-

By using Bernauli's equation

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + h_e$$

$$\frac{P_1}{(1000)(9.81)} + \frac{(0.021)^2}{2(9.81} = \frac{8605}{(1000)(9.81)} + \frac{(0.0105)^2}{2(9.81)} + 1.5003\times10^{-6}$$

$$\frac{P_1}{9810} + 0.0000224 = 0.877 + 0.00000561 + 0.000001500$$

$$\frac{P_1}{9810} = 0.877 + 0.00000561 + 0.000001500 - 0.0000224$$

$$\frac{P_1}{9810} = 0.876$$

$$P_1 = 0.876 \times 9810$$

$$\boxed{P_1 = 8593.56 \ N/m^2}$$

Q3 (B)

Specific Energy:-

Specific energy is a parameter that can be used to clarify the meaning of super critical, sub critical and critical flow in an open channel.