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Section : "B"

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Question no: 01

Part (A): Lets suppose a rectangular channel, discharge 7867 liter/sec of water into a 8m wide apron with zero slope. Mean velocity is 7867-220 ft/sec

Calculate:

(1) Height of Hydraulic jump (In unit of meter).

(2) Power absorbed due to hydraulic jump (In unit of KW).

Given Data: Channel width $= b = 8m$

Discharge $= Q = 7867$ liter/sec

$Q = 7.867 \ m^3/sec$

Mean velocity $= U_1 = 7867 - 220$

$U_1 = 7647$ ft/sec

$$U_1 = \frac{7647}{3.28} = 2331.4 \ m/sec$$

Solution:-

(1): Height of Hydraulic jump:-

*** Discharge per Unit width (q):**

$$Q = q \cdot b$$

$$q = \frac{Q}{b} = \frac{7.867}{8}$$

$$\boxed{q = 0.98 \ m^2/sec}$$

* Critical Depth (y_c):-

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

$$y_c = \left(\frac{(0.98)^2}{9.81}\right)^{1/3}$$

$$\boxed{y_c = 0.46m}$$

* Critical Velocity (V_c):-

$$q = y.V$$

$$V_c = \frac{q}{y_c}$$

$$V_c = \frac{0.98}{0.46}$$

$$\boxed{V_c = 2.13 m/sec}$$

$\boxed{V1 > V_c}$ ⇒ hence Super Critical Flow

* Depth of water on upstream side:-

$Q = AV \Rightarrow Q = b.y.V$

$y = \frac{Q}{V.b} \Rightarrow y_1 = \frac{Q}{V_c.b}$

$y_1 = \frac{7.867}{(2.13)(8)}$

$\boxed{y_1 = 0.462m}$

$y_2 = \frac{-y_1}{2} + \sqrt{\frac{y_1^2}{4} + \frac{2y_1.V_c^2}{g}}$

$y_2 = \frac{-0.462}{2} + \sqrt{\frac{0.462^2}{4} + \frac{2(0.462)(2.13)^2}{9.81}}$

$\boxed{y_2 = 0.462m}$

*** Depth Difference (Δy):-**

$$\Delta y = y_2 - y_1$$

$$\Delta y = 0.462 - 0.462$$

$$\boxed{\Delta y = 0\,m}$$

*** Now finding U_2:-**

As we know that

$$\Delta E = E_1 - E_2$$

$$Q_1 = Q_2$$

$$A_1 U_1 = A_2 U_2$$

$$\cancel{b} \cdot y_1 \cdot U_1 = \cancel{b} \cdot y_2 \cdot U_2$$

$$U_2 = \frac{y_1 \cdot U_1}{y_2}$$

$$U_2 = \frac{(0.462)(2331.4)}{(0.462)}$$

$$\boxed{U_2 = 2331.4\ m/sec}$$

*** Difference in Specific Energy (ΔE):-**

$$\Delta E = E_1 - E_2 = \left(y_1 + \frac{U_1^2}{2g}\right) - \left(y_2 + \frac{U_2^2}{2g}\right)$$

$$E_1 - E_2 = \left(0.462 + \frac{2331.4^2}{2 * 9.81}\right) - \left(0.462 + \frac{2331.4^2}{2 * 9.81}\right)$$

$$\boxed{E_1 - E_2 = 0\,m}$$

(2): Power Dissipated in hydraulic jump:-

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

$$\Delta P = (1000)(9.81)(7.867)(277013.39)$$

$$\Delta P = 2.138 * 10^{10}\ W$$

$$\boxed{\Delta P = 21378583.17\ KW}$$

Question no:01

Part (B): A Sluice gate controls the flow in channel of width 4m. If the discharge is 7867 ft^3/sec and the upstream and downstream water depth is 2.9m and 1.1m respectively, calculate the down-stream velocity.

Also State the type of flow at upstream and downstream side using any equation.

Given Data: Channel width = 4m = b

Discharge = Q = 7867 ft^3/sec

Height of upstream = y_1 = 2.9m

Height at downstream = y_2 = 1.1m

Required Data: (*) Downstream Velocity

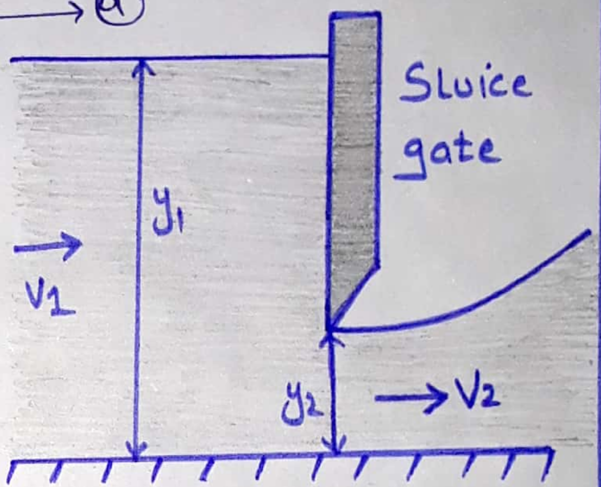
(*) Flow type at upstream and downstream

Solution:-

(*) Downstream velocity (U_2):-

As we assumed $E_1 = E_2$

$$y_1 + \frac{U_1^2}{2g} = y_2 + \frac{U_2^2}{2g} \longrightarrow (a)$$



$$Q_1 = Q_2$$

$$A_1 \cdot U_1 = A_2 \cdot U_2$$

$$\cancel{b} \cdot y_1 \cdot U_1 = \cancel{b} \cdot y_2 \cdot U_2$$

$$U_2 = \frac{y_1 \cdot U_1}{y_2}$$

$$U_2 = \frac{(2.9)(U_1)}{(1.1)}$$

$$\boxed{U_2 = 2.64 U_1} \longrightarrow \text{equation } (x)$$

Substituting values in (a)

$$y_1 + \frac{U_1^2}{2g} = y_2 + \frac{U_2^2}{2g}$$

$$(2.9) + \frac{U_1^2}{2g} = (1.1) + \frac{(2.64U_1)^2}{2g}$$

$$\frac{U_1^2}{2g} - \frac{6.97U_1^2}{2g} = 1.1 - 2.9$$

$$-5.97 \cdot \frac{U_1^2}{2g} = -1.8$$

$$U_1 = \sqrt{\frac{1.8 * 2 * 9.81}{5.97}}$$

$$\boxed{U_1 = 2.432 \text{ m/sec}}$$

Putting U_1 in equation ⓧ

$$U_2 = 2.64(2.432)$$

$$\boxed{U_2 = 6.420 \text{ m/sec}}$$

(*) Type of Flow:-

By Froud number (fr):-

⇒ At upstream side:

$$Fr_1 = \frac{U_1}{\sqrt{g \cdot y_1}}$$

$$Fr_1 = \frac{2.432}{\sqrt{(9.81)(2.9)}}$$

$$\boxed{Fr_1 = 0.456} < 1$$ ⇒ hence Subcritical flow ($Fr<1$)

⇒ At downstream side:

$$Fr_2 = \frac{U_2}{\sqrt{g \cdot y_2}}$$

$$Fr_2 = \frac{6.420}{\sqrt{(9.81)(1.1)}}$$

$$\boxed{Fr_2 = 1.95} > 1$$ ⇒ hence Supercritical flow ($Fr>1$)

Question no:02

Part (A): What is the minimum height (in Unit of meter) of broad chested weir if it is to function critical depth on the crest.

If water flows along a rectangular channel at a depth of 1.8m with a discharge of 7867 ft^3/sec. the channel width is 66ft.

Given Data: width of channel = $b = 66ft = 20.1m$

Discharge = $Q = 7867 ft^3/sec$

$$Q = \frac{7867}{3.28}$$

$$Q = 222.94 m^3/sec$$

Depth of channel = $y_1 = 1.8m$

Required Data: weir Height = $P = ?$

Solution: As by discharge equation

$$Q = A.V$$

$$V_1 = Q/A$$

$$V_1 = Q/b.y$$

$$V_1 = \frac{222.94}{\left(\frac{66}{3.28}\right)(1.8)}$$

$$\boxed{V_1 = 6.162 m/sec}$$

*** Critical depth (y_c):-**

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

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

$$y_c = \left(\frac{222.94^2}{(20.1)^2 \cdot (9.81)}\right)^{1/3}$$

$$\boxed{y_c = 2.323\text{m}}$$

*** Critical Velocity (V_c):-**

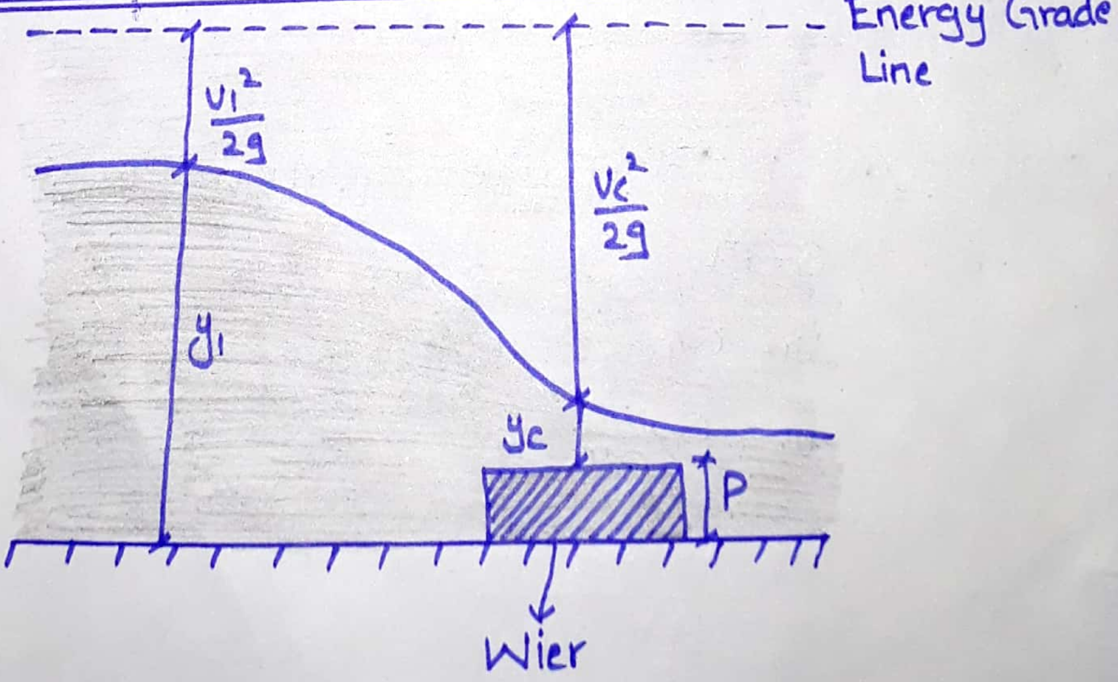
$$V = \sqrt{g \cdot y}$$

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

$$V_c = \sqrt{(9.81) \cdot (2.323)}$$

$$\boxed{V_c = 4.774\text{m/sec}}$$

*** Figure of Broad Crested Weir:-**



$$\boxed{\frac{v_1^2}{2g} + y_1 = \frac{v_c^2}{2g} + y_c + P}$$

$$\frac{(6.162)^2}{2*9.81} + (1.8) = \frac{(4.774)^2}{2*9.81} + (2.323) + P$$

$$P = 3.735 - 3.485$$

$$\boxed{P = 0.25m}$$

⇒ Thus the weir should have a height of 0.25m measured from the bed level.

Question no: 02

Part (B): An orifice in one side of large tank is rectangular in shape. 2.8m broad and 1.5m deep. The water level on one side of the orifice is 5m above its top edge. The water level on the other side of the orifice is 0.6m below its top edge. Calculate the discharge through the orifice if Coefficient of discharge is Cd= 0.7867.

Given Data:-

width = b = 2.8m H = 5+0.6 = 5.6m

Depth = d = 1.5m Cd = 0.7867

H_1 = 5m

H_2 = 5+1.5 = 6.5m

Required Data: Discharge $= Q = ?$

Solution:

(*) Discharge through submerged portion:-

$$Q_1 = Cd * b * (H_2 - H_1) * \sqrt{2gH}$$

$$Q_1 = (0.7867) * (2.8) * (6.5 - 5.6) * (\sqrt{2 * 9.81 * 5.6}$$

$$\boxed{Q_1 = 20.78\ m^3/sec}$$

(*) Discharge through free portion:-

$$Q_2 = \frac{2}{3} cd * b\sqrt{2g} \cdot [H^{3/2} - H_1^{3/2}]$$

$$Q_2 = \left(\frac{2}{3}\right)(0.7867) * (2.8\sqrt{2 * 9.81}) [(5.6)^{3/2} - (5)^{3/2}]$$

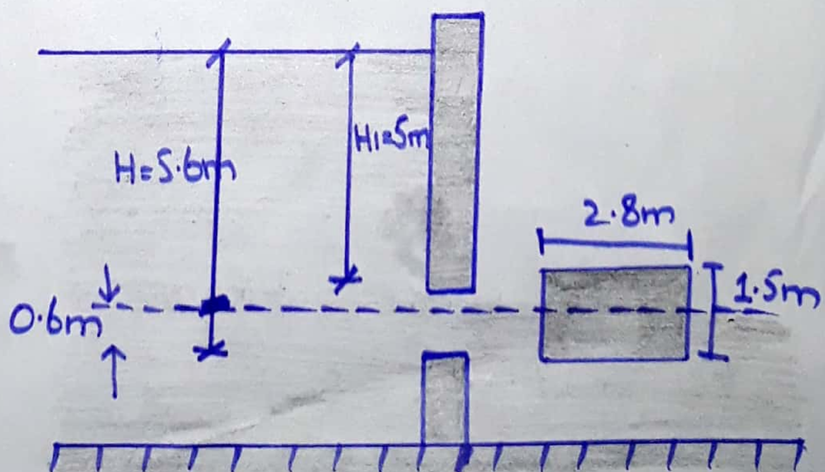
$$\boxed{Q_2 = 13.476\ m^3/sec}$$

(*) Total Discharge:-

$$Q = Q_1 + Q_2$$

$$Q = (20.78) + (13.476)$$

$$\boxed{Q = 34.256\ m^3/sec}$$



Question no:03

Part (A): The diameter of a water pipe is suddenly enlarged from 7867-200mm to 7867+3000mm. The rate of flow through is $0.95 m^3/sec$ and the pressure in the larger pipe is $7867+800 N/m^2$

Calculate:

(1) The Loss of Head due to Sudden Enlargement.

(2) The power Lost due to Sudden Enlargement.

(3) The pressure in the Smaller pipe (if the pipe is horizontal).

Given Data:-

$D_1 = 7867-200 = 7667mm = 7.667m$

$D_2 = 7867+3000 = 10867mm = 10.867m$

Discharge $= Q = 0.95 m^3/sec$

Pressure in larger pipe $= P = R + 800$

$P = 7867 + 800$

$P = 8667 N/m^2$

Area $= A_1 = \frac{\pi}{4} \cdot (D_1)^2 = \frac{3.14}{4} * (7.667)^2 = 46.145 m^2$

Area $= A_2 = \frac{\pi}{4} \cdot (D_2)^2 = \frac{3.14}{4} * (10.867)^2 = 92.702 m^2$

Q = discharge = $0.95\ m^3/sec$

$$Q = AV \Rightarrow V = Q/A \Rightarrow V_1 = \frac{Q}{A_1}$$

$$V_1 = \frac{0.95}{46.145}$$

$$\boxed{V_1 = 0.021\ m/sec}$$

$$V_2 = \frac{Q}{A_2}$$

$$V_2 = \frac{0.95}{92.702}$$

$$\boxed{V_2 = 0.010\ m/sec}$$

(1) Head Loss due to Sudden Enlargement (he):-

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

$$he = \left(1 - \frac{46.145}{92.702}\right)^2 \cdot \frac{(0.021 - 0.010)^2}{2 * 9.81}$$

$$\boxed{he = 1.556 * 10^{-6}\ m}$$

(2) Power loss due to Sudden Enlargement (P):-

$$P = \rho \cdot g \cdot Q \cdot he$$

$$P = (1000) \cdot (9.81) \cdot (0.95) \cdot (1.556 * 10^{-6})$$

$$\boxed{P = 0.0145\ W}$$

(c) The pressure in the smaller pipe (if pipe is horizontal):-

By applying Bernoulli's equation:

$$\frac{P_1}{\rho g} + \frac{U_1^2}{2g} = \frac{P_2}{\rho g} + \frac{U_2^2}{2g} + h_e$$

$$\frac{P_1}{(1000)(9.81)} + \frac{0.021^2}{2*9.81} = \frac{8667}{(1000)(9.81)} + \frac{0.010^2}{(2*9.81)} + (1.556*10^{-6})$$

$$\frac{P_1}{9810} + 0.00002248 = 0.8835$$

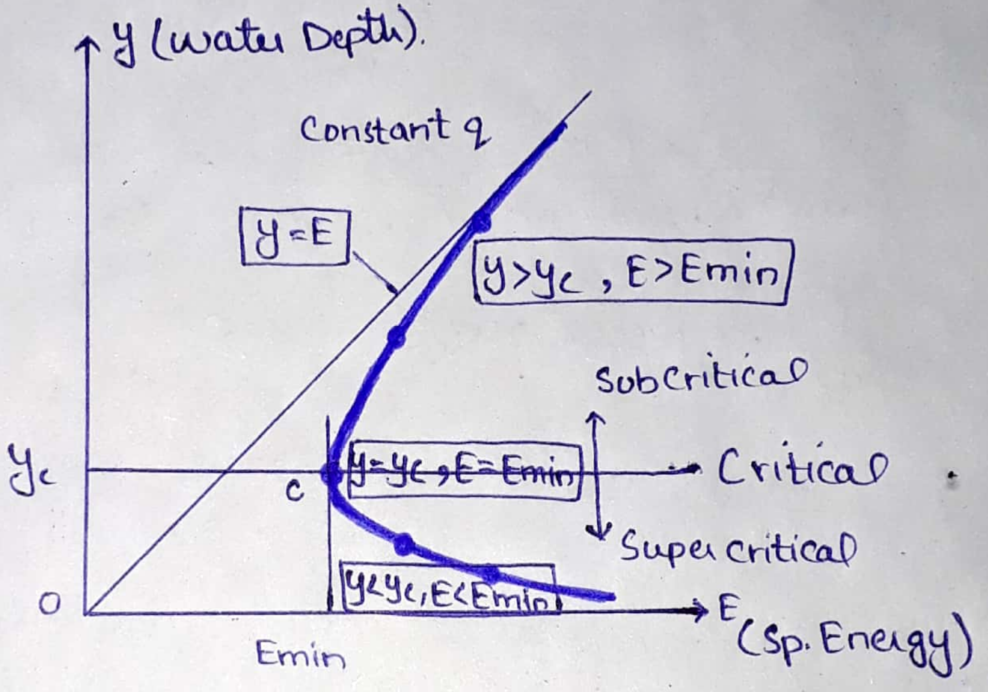
$$\frac{P_1}{9810} = 0.8835 - 0.00002248$$

$$\frac{P_1}{9810} = 0.8835$$

$$\boxed{P_1 = 8667.135\ N/m^2}$$

Question no:03

Part (b): what does the blue curve indicates. How it is obtained. Explain the below figure from each and every point of view.



Blue Curve: It is clear from the above diagram drawn for constant discharge for any given value of E, there would be two possible lengths/depths say y_1, y_2. These two depths are called Alternate depths.

⇒ However for point c corresponding to minimum Specific energy Emin, there would be only one possible depth "y_c". The depth "y_c" is known as critical depth.

$\Rightarrow (E-y)y^2 = \text{Constant} \longrightarrow$ equation ⓐ

In the above equation ⓐ, the q and 2g are constant and the equation is three dimensional polynomial equation. It can be used to prepare a plot at Specific energy "E", and depth of water "y".

⇒ How it is obtained?

Total energy = Potential Energy + Kinetic Energy

$$T.E = P.E + K.E \qquad \boxed{w = mg \Rightarrow m = \frac{w}{g}}$$

$$T.E = mgh + \tfrac{1}{2} mu^2$$

$$T.E = w.h + \frac{1}{2}\frac{w}{g}u^2 \quad \text{(w is ignored)}$$

$$T.E = h + \frac{1}{2g}.u^2$$

$$\boxed{TE = y + \frac{u^2}{2g}} \qquad \boxed{E = y + \frac{u^2}{2g}} \longrightarrow (i)$$

* As we know that

$$Q = AU \Rightarrow U = Q/A \Rightarrow U^2 = \frac{Q^2}{A^2}$$

* So equation (i) will be

$$\boxed{E = y + \frac{Q^2}{A^2 . 2g}} \longrightarrow (ii)$$

* For rectangular channel

$$A = y * b \longrightarrow (x)$$

$$q = Q/b \longrightarrow (y)$$

Putting (X) and (Y) in equation (ii)

$$E = y + \frac{Q^2}{A^2 \cdot 2g} \Rightarrow E = y + \frac{Q^2}{(y^2 * b^2) \cdot 2g} \longrightarrow \text{"X" is putted}$$

$$E = y + \frac{q^2}{y^2 \cdot 2g} \longrightarrow \text{"Y" is putted.}$$

$$E - y = \frac{q^2}{y^2 \cdot 2g}$$

$$(E-y) y^2 = \frac{q^2}{2g}$$

$$\boxed{(E-y) y^2 = \text{Constant}} \longrightarrow \text{Three dimensional equation. (Polynomial).}$$

Critical Depth (y_c): It is the depth corresponding to minimum specific energy.

$y > y_c$, $E > E_{min}$ (Subcritical Flow).

$y = y_c$, $E = E_{min}$ (Critical Flow).

$y < y_c$, $E < E_{min}$ (Super Critical Flow).